North Alabama Integrated Poultry and Ethanol Production (IPEP) Feasibility Study

Final Report
for
NRCS Grant Agreement 68-3A75-3-144

Prepared by T.R. Miles Technical Consultants, Inc.
B.R. Bock Consulting, Inc.

September 2006

Feasibility of an Integrated System for Improving the Economic and Environmental Performance of Poultry and Ethanol Production in North Alabama

Final Report
for
NRCS Grant Agreement 68-3A75-3-144

September 2006

Prime Contractor: Thomas R. Miles
T.R. Miles Technical Consultants, Inc
1470 SW Woodward Way
Portland, OR 97225
tmiles@trmiles.com
Phone: 503-292-0107
Fax: 503-292-2919

Subcontractors: B.R. Bock Consulting, Inc
Informa Economics (formerly Sparks Companies)
Energy Products of Idaho
Auburn University Poultry Science Department
Alabama Mountains, Rivers and Valleys RC&D Council (formerly Tennessee Valley RC&D Council

Solicitation Number: USDA-GRANTS-031803-001

Solicitation Title: Biomass Research and Development Initiative 2003 Request for Proposal

CONTENTS

I. Executive Summary 1

II. Introduction 1

A. Background 1

B. Approach 2

III. Summary of Corn Feedstock Resources in Alabama 1

A. AL Long-Run Trends in Corn Production 3

B. Regional Trends in AL Corn Production 6

C. County Trends in AL Corn Production 9

IV. Analysis of Corn Demand in Alabama 1

A. Catfish Demand for Corn 1

B. Dairy Demand for Corn 3

C. Hogs and Pigs Demand for Corn 6

D. Poultry Demand for Corn 8

E. AL Supply/Demand for Corn 12

V. U.S. Corn Market Dynamics and Pricing 1

A. U.S. Corn Production and Consumption 1

B. Corn Pricing 2

1. **The Role of Futures in Corn Pricing and Risk Management** 2
2. **Corn Price Forecast** 4

    a. **Agricultural Policy Foundation to the Forecast** 4

b. The Role of the Ethanol Industry 4
c. Price Forecast 5
d. High and Low Price Scenarios 6
e. North Alabama Basis 8
f. Central Illinois Basis 12
VI. Distillers Grains Market and Pricing 1
A. Background 1
B. United States DDGS Supply and Demand 1
C. Markets Around North Alabama 3
D. DDGS Pricing 7
1. Historical DDGS Prices 7
2. Forecast DDGS Prices 7
VII. Assessment of Dry Mill Fractionation 1
A. The Potential Market for High Protein Distillers Grains 2
B. The Potential Market for Corn Germ 4
C. Conclusion 6
VIII. Ethanol Market Dynamics and Pricing 1
A. Primary Ethanol Market Analysis Report Findings 2
B. History and Background of U.S. Fuel Ethanol 5
1. Ethanol's History as a Motor Fuel 5
2. Understanding Historical U.S. Ethanol Market Prices 7
3. Itemization of Public Policy Support History (from 1978 to present) 10

4. **Enactment of the Federal Renewable Fuel Standard 11**

5. **Definition of Historical Fuel Ethanol Demand Growth 13**

C. Continued Growth Projected in Ethanol Demand, 2005-2015 14

1. **Projecting Future Ethanol Demand: Baseline Forecast Projections 15**

2. **Projecting Future Ethanol Demand: High-Demand Scenarios 16**

3. **Projecting Future Ethanol Demand: Low-Demand Scenario 16**

D. Liability Concerns & MTBE Bans Create New Ethanol Markets..17

E. U.S. Fuel Ethanol Production and Capacity Outlook..........17

F. U.S. Fuel Ethanol Capacity Will Continue Expansion.........19

G. Congress and the President Extended Federal Ethanol Tax Credit..20

H. Future U.S. Ethanol Prices Expected to Remain Strong 20

1. **Defining Ethanol Plant Netback Prices 21**

I. State Incentives for Ethanol Also Available 22

J. Worldwide Growth Market Projected for Renewable Ethanol 23

1. **CBI Imports Remain Below Quota, May Face Legal Challenges 24**

K. Strategic Location in North Alabama Benefits Ethanol Sales..25

IX. Carbon Dioxide Market.. 1

A. Demand **.. 1**

B. Supply 1

C. Price 2

X. Natural Gas Prices.. 1

A. Background 1

B. Price Projections.. 2

XI. Electricity Prices... 1

A. Background 1

B. Historical Prices... 1

XII. Siting Considerations and Transportation Costs 1

A. Siting Considerations 1

B. Transportation Costs.. 8

XIII. Fluidized Bed Combustion of Poultry Litter............. 1

A. Technical Assessment.. *1*

1. Technical Challenges and Solutions.................................. 1

2. Technical Feasibility of the EPI Fluidized Bed Technology for Poultry Litter... 3

3. System Description.. 3

B. Economic Assessment.. *9*

1. Poultry Litter Energy System Costs................................... 9

2. Approach 1: Avoided Natural Gas Costs and First Approximation of Cash Flow.. 14

3. Approach 1: Base Case Economic Projections Based on Avoided Natural Gas Costs.. 16

4. Approach 2: Process Heat Sold to Ethanol Plant at a Cost Savings Relative to Using Natural Gas.................... 19

5. Sensitivity Analyses for Projected Returns vs. Key Variables 24

C. Conclusion *27*

D. References *27*

XIV. Poultry Litter Supplies and Prices for Alternative Uses 1

A. Amount of Poultry Litter Produced in North Alabama 1

B. Environmental Concerns Associated with Current Poultry Litter Practices 2

C. Regulatory Constraints on Land Application of Poultry Litter 5

D. Projected Poultry Litter Prices 9

E. Conclusions 11

F. References 13

Attachment A: Summary of Poultry Grower and Waste Vendor Surveys 15

XV. Fertilizer Nutrient Value of Poultry Litter Ash 1

A. Market Niches for Using Poultry Litter Ash in Fertilizers 1

B. Net Return from Poultry Litter Ash Used in Fertilizers 3

1. Total P_2O_5 and K_2O in Laboratory-Generated Ash 5
2. Expected Reduction in Total P_2O_5 Due to Use of Phytase Enzyme in Poultry Feed 5
3. Nutrient Dilutants in Process Ash 5
4. Percent of Total P_2O_5 and K_2O That can be Claimed on a Fertilizer Label 8

5. Wholesale Price of Fertilizer Nutrients Displaced by Ash 8

6. Discount Relative to Wholesale Price of Fertilizer Nutrients Displaced 9

7. Ash Transportation Costs 9

8. Parametric Estimates of Net Return from Poultry Litter Ash 9

C. Physical Properties of Poultry Litter Ash 12

6. Bulk Density 12

7. Particle Size 13

D. Environmental Considerations for Trace Metals in Poultry Litter Ash 13

E. References 18

XVI. Nutritional Value of Poultry Litter Ash Fed to Broiler Chickens 1

A. Executive Summary 1

B. Objective 2

C. Introduction 2

D. Materials and Methods 2

1. Evaluation of Poultry Litter Ash 2

2. Experiment 1 2

3. Experiment 2 3

4. Experiment 3 3

5. Processing and Yield Determination 4

6. Statistical Analysis 4

7. Facilities 5

E. Results and Discussion 5

F. Economic Evaluation of Poultry Litter Ash 7

Appendix A 17

XVII. Economics of Corn Ethanol: North Alabama IPEP vs. Traditional North Alabama and Central Illinois Scenarios 1

A. Baseline Comparisons 1

1. Economic Tradeoffs 1

2. Financial Projections 3

B. Sensitivity Analyses 16

C. Conclusions 20

XVIII. Fuel-Cycle Fossil Energy Balance and Greenhouse Gas Emissions: IPEP and Traditional Ethanol vs. Gasoline 1

A. Energy Balance 1

B. Greenhouse Gas Emissions 5

C. References 7

XIX. Economic Comparison of IPEP vs. Other Alternatives to Local Land Application of Poultry Litter 1

A. Long-Distance Transport of Unprocessed Litter 1

B. Pelletizing and Transporting Poultry Litter 6

C. Composting 10

D. Electricity Production 13

E. Process Steam for an IPEP Ethanol Plant 19

F. Summary and Conclusions 20

1. Long-Distance Transport of Poultry Litter........................ 20
2. Pelletizing Poultry Litter 20
3. Composting 21
4. Electricity 21
5. Process Steam for an IPEP Ethanol Plant 21

G. References 23

XX. Conclusions... 1

XXI. Publications 1

XXII. Outreach... 1

Tables

Chapter III.

Table 1. AL corn, regional production (bushels). 7
Table 2. AL, area by region, square miles. 7
Table 3. Al corn, production density by region, bushels per square miles. 7
Table 4. AL corn, regional production trend by percent share of total. 8
Table 5. AL corn, regional production, percent change 8
Table 6. AL corn, production by top counties, percent of total. 10

Chapter IV.

Table 1. Catfish sales, number weight and value for all foodservice. 1
Table 2. Estimation of AL catfish consumption of corn, 2002. 2
Table 3. AL dairy production and marketings. 4
Table 4. Estimation of AL dairy consumption of corn, 2002. 5
Table 5. Estimation of AL hogs/pigs consumption of corn, 2002. 7
Table 6. Commercial broiler production, disposition and value. 10
Table 7. Estimation of AL poultry consumption of corn, 2002 11
Table 8. Estimate of total AL livestock (by major category) consumption of corn in 2002. 12

Chapter V.

Table 1. U.S. corn supply and demand. 2
Table 2. Baseline, low, and high forecasts of futures corn prices (Aug.-Sep. crop year). 7
Table 3. Baseline, low and high forecasts of futures corn prices (calendar year). 8
Table4. Summary of Decatur, Alabama cash and CBOT futures corn prices. 11
Table5. Summary of Pekin, IL cash and CBOT futures corn prices. 13

Chapter VI.

Table 1. DDGS, maximum potential domestic consumption, AL. 4
Table 2. DDGS, maximum potential domestic consumption, GA. 6

Chapter VII.

Table 1. Example value of corn oil extraction. 5

Chapter VIII.

Table 1. Historical U.S. fuel ethanol prices: yearly averages. 9
Table 2. RFS renewable fuel annual ethanol sales volumes. 12
Table 3. Current U.S. fuel ethanol production capacity. 18
Table 4. Ethanol plants under construction. 19

Chapter X.

Table 1. Projected average U.S. industrial natural gas prices. 2

Chapter XII.

Table 1. Ethanol transportation costs, excluding loading and unloading. 9
Table 2. DDGS transportation costs, excluding loading and unloading. 10
Table 3. Poultry litter feedstock costs. 10
Table 4. Cost comparison of transportation factors at Guntersville and Decatur. 10
Table 5. Cost comparison of transportation factors at Guntersville and Decatur. 10

Chapter XIII.

Table 1. Ultimate analysis (as-received) of sawdust and Delmarva poultry litter. 1
Table 2. Elemental analysis (%) of ash from sawdust and Delmarva poultry litter. 2
Table 3. Preliminary estimate of capital costs ($1000) for poultry litter energy... 10
Table 4. Incremental O&M costs for poultry litter energy system co-located with corn/ethanol dry mill. 12
Table 5. Net fuel cost. 13
Table 6. Net fuel cost. 13
Table 7. Poultry litter energy system costs, avoided natural gas costs, and cash flow: first approximation. 15
Table 8. Before-tax profit and cash flow projections for the base case assuming avoided NG costs. 17
Table 9. After-tax profit and cash flow projections for the base case assuming avoided NG cost. 18
Table 10. Poultry litter energy system costs and cash flow: first approximation. 21
Table 11. Before-tax profit and cash flow projections for the base case assuming steam revenues. 22
Table 12. After-tax profit and cash flow projections for the base case assuming steam revenues. 23
Table 13. Poultry litter energy plant: sensitivity of IRR and ROI to steam price. 24
Table 14. Poultry litter energy plant: sensitivity of IRR and ROI to capital costs. 25
Table 15. Poultry litter energy plant: sensitivity IRR and ROI to O&M. 25
Table 16. Poultry litter energy plant: sensitivity of IRR and ROI to poultry litter feedstock costs. 25
Table 17. Poultry litter energy plant: sensitivity of IRR and ROI to poultry litter ash revenue. 26

Chapter XIV.

Table 1. Broiler and broiler litter production in leading broiler counties in north Alabama. 1

Chapter XV.

Table 1. Broiler fuel parameters and metals content of broiler litter ash (data provided by Maryland Department of Natural Resources, Power Plant Assessment Division): Appendix B at www.nrbp.org/pdfs/pub20b.pdf. 7
Table 2. Projected net return to energy plant from poultry litter ash. 11
Table 3. Projected net return (after ash transportation costs) from ash, assuming 95 percent of the ash P2O5 can be claimed on a fertilizer label. 12
Table 4. Projected net return (after ash transportation costs), from ash, assuming 75 percent of the ash P2O5 can be claimed on a fertilizer label. 12
Table 5. Metals concentrations in broiler litter from Delmarva growers and projected maximum metal loading rates for land-applied broiler litter ash compared with levels allowed by the Uniform State Fertilizer Bill, American Association of Plant Food Control Officials. 15
Table 6. Metals concentrations in broiler litter ash from Delmarva growers and projected maximum metal loading rates for land applied broiler litter ash compared with the Canadian fertilizer standard for metals loading. 16
Table 7. Metals concentrations in broiler litter ash from Delmarva growers and projected maximum metal loading rates for land-applied broiler litter ash compared with EPA 503 regulations for land application of biosolids. 17

Chapter XVI.

Table 1. Composition of poultry litter ash. 1
Table 2. Composition and calculated analysis of experimental starter diets (Experiments 1 and 2). 9
Table 3. Composition and calculated analysis of experimental grower diets (Experiments 1 and 2). 10
Table 4. Composition and calculated analysis of experimental starter diets (Experiment 3). 11
Table 5. Composition and calculated analysis of experimental grower diets (Experiment 3). 12
Table 6. Composition and calculated analysis of experimental finisher diets (Experiment 3) 13
Table 7. Performance of mixed sex broilers fed graded levels of poultry litter ash (Experiment 1). 14
Table 8. Percentage of excreta moisture , dry bone ash and dry matter digestibility of nutrients in broiler diets utilizing graded levels of poultry litter ash (Experiment 2). 14

Table 9. Bodyweight, bodyweight gain, feed consumption, feed efficiency, and mortality of mixed sex broilers fed graded levels of poultry litter ash in the diet (Experiment 3). 15
Table 10. Processing performance of broilers at 41 days of age fed graded levels of poultry litter ash (Experiment 3). 16

Chapter XVII.

Table 1. Baseline economic tradeoffs: Decatur, AL NG vs. Pekin, IL NG (10-year averages). 2
Table 2. Baseline economic tradeoffs: Decatur, AL IPEP vs. Pekin, IL NG (10-year averages). 2
Table 3. Baseline economic tradeoffs: Guntersville, AL IPEP vs. Pekin, IL NG (10-year averages). 3
Table 4. Financial analysis assumptions (part 1): Pekin, IL NG Scenario. 4
Table 5. Financial analysis assumptions (part 1): Pekin, IL NG Scenario. 5
Table 6. Profit and cash flow analysis ($1000): Pekin, IL NG Scenario. 6
Table 7. Financial analysis assumptions (part 1): Decatur, AL NG Scenario. 7
Table 8. Financial analysis assumptions (part 1): Decatur, AL NG Scenario. 8
Table 9. Profit and cash flow analysis ($1000): Decatur, AL NG Scenario. 9
Table 10. Financial analysis assumptions (part 1): Decatur, AL IPEP Scenario. 10
Table 11. Financial analysis assumptions (part 1): Decatur, AL IPEP Scenario. 11
Table 12. Profit and cash flow analysis ($1000): Decatur, AL IPEP Scenario. ... 12
Table 13. Financial analysis assumptions (part 1): Guntersville, AL IPEP Scenario 13
Table 14. Financial analysis assumptions (part 1): Guntersville, AL IPEP Scenario. 14
Table 15. Profit and cash flow analysis ($1000): Guntersville, AL IPEP Scenario. 15
Table 16. Summary of returns for baseline ethanol plant scenarios 16
Table 17. North Alabama ethanol, corn, and DDGS prices (highlighted in yellow) for low, baseline, and high scenarios assessed in financial analyses. 17
Table 18. Sensitivity of ROI and IRR to ethanol and corn/DDGS prices for a north AL IPEP scenario 18
Table 19. Sensativity of ROI and IRR to steam price from poultry litter for a north AL IPEP scenario 19

Chapter XVIII.

Table 1. Well-to-pump fossil energy input per Btu of fuel at fueling station. 4
Table 2. ICM energy efficiency guarantee: natural gas requirement for converting corn to ethanol. 4
Table 3. Well-to-wheel reductions in greenhouse gas (GHG) emissions for ethanol from corn vs. conventional gasoline. 6
Table 4. Carbon dioxide emissions from natural gas based on ICM energy efficiency guarantee. 6

Chapter XIX.

Table 1. Value of commercial fertilizer potentially displaced by poultry litter. 2
Table 2. Maximum potential cost savings via substituting poultry litter for commercial N-P-K fertilizer. 3
Table 3. Maximum potential cost savings via substituting poultry litter for commercial N-P-K fertilizer. 4
Table 4. Economics of pelletizing poultry litter –15-year projection. 7
Table 5. Impact of pellet price on profitability of pelletizing poultry litter. 8
Table 6. Production cost for composting poultry litter for bulk market. 11
Table 7. Impact of bulk compost price on profitability of poultry litter composting. 12
Table 8. Operating characteristics of the Fibrowatt UK poultry litter power plants. 13
Table 9. Capital and O&M costs for producing electricity with EPI fluid bubbling bed. 15
Table 10. Economics of producing electricity from poultry litter—15 year projection. 15
Table 11. Impact of electricity price on profitability of producing electricity from poultry litter. 16

Chapter XXII.

Table 1. Outreach activities for the IPEP feasibility project. 2

Figures

Chapter III.

Figure 1. AL corn acres planted, long-run trend. 3
Figure 2. AL percent share of field crops' acres planted. 4
Figure 3. AL Corn production, long-run trend. 4
Figure 4. Variation in AL corn production: 1990-2003. 5
Figure 5. Indexation of corn production, AL vs. US, 1982 to 2002. 5
Figure 6. AL crop reporting districts 6
Figure 7. AL corn production by top counties (weighted avg. 00, 01, 02) 9
Figure 8. Corn production density by top counties (weighted avg. 00-02) 9
Figure 9. Corn production (weighted avg. 00, 01, 02), leading counties, comparison of production by volume, density & percentage share of state production. 11
Figure 10. AL corn production (weighted avg. 00,01, 02), stratification/identification of leading counties. 11
Figure 11. Total AL field crops (corn, sorghum, wheat, soybeans, cotton, hay, CRP) acres planted vs. % share of corn acres planted. 12
Figure 12. AL broiler numbers vs. corn production AL indexed, 1960 to 2001. 12

Chapter IV.

Figure 1. AL catfish foodservice sales, pounds. 2
Figure 2. AL milk cow inventory. 3
Figure 3. AL hogs & pigs inventory, Dec 1. 6
Figure 4. Broiler production density, pounds per sq. mile, 2002. 9
Figure 5. AL commercial broiler production, pounds produced. 10

Chapter V.

Figure 1. Composition of U.S. corn consumption (marketing year). 1
Figure 2. Monthly nearby corn futures. 3
Figure 3. CBOT price history and forecast. 5
Figure 4. Distribution of daily nearby corn futures prices, September 1989-present. 6
Figure 5. Decatur, AL farm corn prices, CBOT corn futures prices, and associated Decatur, AL corn basis for 1998-2006. 9
Figure 6. Average monthly corn basis for Decatur, AL (Mar 98 to Jun 06) 10
Figure 7. Trend in Decatur, AL corn basis (daily: 3/6/1998 to 6/5/2006). 10
Figure 8. Trend in Pekin, AL corn basis (daily: 3/6/1998 to 6/5/2006). 12

Chapter VI.

Figure 1. U.S. Consumption of distillers grains by species. 2

Figure 2. Distribution of broiler production within a 400 mile radius of Decatur, AL. 5

Chapter VIII.

Figure 1. U.S. crude, rack gasoline and fuel ethanol prices (crude in $/bbl, gasoline and ethanol in $/gallon). 7
Figure 2. Historical U.S. fuel ethanol prices: weekly vs. linear trend ($/gallon). 8
Figure 3. Historical U.S. fuel ethanol prices: individual markets ($/gallon). 10
Figure 4. Historical fuel ethanol sales (billions of gallons). 14
Figure 5. Fuel ethanol demand projections (billion gallons per year). 15
Figure 6. Projected netback to a N. Alabama facility from ethanol sales. 22
Figure 7. Current state user incentives for ethanol. 23
Figure 8. Current state producer incentives for ethanol. 24
Figure 9. CBI ethanol imports and duty-free cap (millions of gallons). 25

Chapter IX.

Figure 1. Estimated 2005 market share—worldwide gases business. 2
Figure 2. BOC gases locations in the southeastern U.S. 3

Chapter X.

Figure 1. Natural gas prices: average price sold to industrial consumers in AL vs. NYMEX (Henry Hub) nearby futures. 3
Figure 2. Spread between natural gas prices: NYMEX (Henry Hub) nearby futures to average industrial consumers price in AL. 4
Figure 3. Natural gas prices: Historical average price sold to industrial consumers in AL & forecast. 4
Figure 4. Natural gas prices: average price sold to industrial consumers in IL vs. AL. 5
Figure 5. Spread between natural gas prices: average industrial consumers price in IL vs. AL. 6
Figure 6. Natural gas prices: historical average price sold to industrial consumers in IL & forecast. 6

Chapter XI.

Figure 1. Alabama average cost per kWh for the industrial sector. 2
Figure 2. Illinois average cost per kWh for the industrial sector. 2
Figure 3. Comparison of Alabama and Illinois average cost per kWh for the industrial sector. 3

Chapter XII.

Figure 1. Broiler production density relative to Decatur and Guntersville, AL. 1
Figure 2. Decatur and Guntersville, AL are major ports on the Tennessee River. 2

Figure 3. Decatur and Guntersville, AL access to southeastern railroads. 3
Figure 4. Potential IPEP site at Beavers Creek rail spur in Decatur, AL. 3
Figure 5. Decatur site with access to rail (white “Y” on left and river. 4
Figure 6. Road access to the former Monsanto site on the Tennessee River. 5
Figure 7. Former Monsanto site near Guntersville, AL. 6
Figure 8. Feed mills on the Tennessee River at Guntersville, AL........................ 7
Figure 9. Feed mills on the Tennessee River at Guntersville, AL........................ 8

Chapter XIII.

Figure 1. Conceptual equipment arrangement for poultry litter energy plant........ 5
Figure 2. Elevation view of poultry litter energy plant. 6
Figure 3. Plan view of poultry litter energy plant.. 7
Figure 4. Plan view of poultry litter handling and storage facility. 8

Chapter XIV.

Figure 1. Counties (in red) with more manure phosphorus than removed by crops. 4
Figure 2. Poultry litter responsibility transfer form. 8

Chapter XV.

Figure 1. Poultry litter ash and granules containing ash...................................... 2

Chapter XVIII.

Figure 1. Ethanol energy balances depend on systems boundaries (Wang, 2005). 1
Figure 2. Fossil energy balances for ethanol produced from corn (Wang, 2005)... 2
Figure 3. Fossil energy inputs for corn ethanol and conventional gasoline (Wang, 2005)... 3

I. Executive Summary

The goal of this project is to assess the technical, economic, and environmental feasibility of an integrated poultry and ethanol production (IPEP) system in north Alabama that uses poultry litter as an alternative source of process energy for ethanol production from corn. Objectives were to:

- Determine the feasibility of an IPEP poultry litter energy plant in north Alabama and compare its feasibility with that of other alternative uses of poultry litter.
- Determine the feasibility of an IPEP corn/ethanol plant in north Alabama and compare its feasibility with that of traditional stand-alone corn/ethanol plants in the eastern Corn Belt.

Because of high crude oil and gasoline prices, the need for reducing dependence on foreign oil, and recent U.S. policies to encourage more ethanol production, the U.S. ethanol industry is growing rapidly and this growth is occurring at strategic locations outside the Corn Belt as well as in the Corn Belt.

One of the driving forces for considering an IPEP system in north Alabama is that using poultry litter instead of natural gas (NG) to provide process heat for a corn/ethanol plant holds promise as one of the most economical alternatives to local land application of poultry litter in north Alabama. Economical alternatives to local land application are needed because of water quality concerns related to regional phosphorus (P) surpluses and P runoff from poultry litter into surface waters in concentrated poultry areas such as north Alabama.

The other driving force for considering an IPEP system in north Alabama is the outlook for a competitive advantage over conventional ethanol plants in the eastern Corn Belt. Given high projected natural gas prices for the foreseeable future, a key economic advantage for an IPEP system is the prospect for significantly lower process energy costs using poultry litter rather than NG. Other economic advantages of an IPEP system vs. an eastern Corn Belt plant for corn/ethanol production are a local market for dried distillers grains and solubles (DDGS) in poultry diets, lower ethanol transportation costs, and good local markets for carbon dioxide. These economic advantages are partially offset by higher corn costs. A key part of this project is quantifying economic tradeoffs and the relative economics of an IPEP ethanol plant in north Alabama vs. a conventional corn/ethanol plant in the eastern Corn Belt.

Since poultry litter is a renewable energy source, use of poultry litter rather than natural gas to provide process heat significantly reduces fuel-cycle fossil energy usage and greenhouse gas emissions from ethanol production. These benefits are estimated in this project to provide a more complete picture of the environmental benefits of IPEP ethanol vs. traditional corn/ethanol vs. gasoline.

A fluidized bed poultry litter combustion and steam generation system, including poultry litter and ash handling and storage, was identified and evaluated that is technically feasible and can comply with atmospheric emissions standards. Conceptual designs and cost estimates for this system indicate that process steam can be provided to a corn/ethanol plant at about $4.50/MBtu NG displaced by poultry litter, assuming poultry litter prices and ash revenues discussed below; this price is a significant advantage over NG prices that are projected to average $6.94/MBtu over the next 10 years.

If current nutrient management regulations in north Alabama are broadly enforced, it is expected there will be strong interest from both poultry growers and litter vendors in providing poultry litter to produce process heat for an IPEP ethanol plant. It is projected that about 190,000 tons/year (approximately one-third of the litter produced by the top broiler counties in north Alabama) can be provided to an IPEP plant for an average delivered cost of approximately $10/ton. For growers, the primary motivation for supplying an IPEP ethanol plant is simplifying and reducing the cost of nutrient management planning and assuring a reliable long-term outlet for their litter. For litter vendors, the primary motivation is the option to shift to a more efficient and profitable poultry litter delivery system. If nutrient management regulations are not broadly enforced, then a somewhat higher price than $10/ton may have to be paid to acquire adequate supplies of poultry litter to provide process heat for an IPEP ethanol plant.

Factors were assessed that affect the potential value of poultry litter ash for use in fertilizers and as a mineral feed supplement for broilers. Options for incorporating poultry litter ash into granular fertilizers have been identified and the first known evaluation of poultry litter ash as a replacement for traditional sources of mineral phosphorus and calcium supplements for broilers was conducted. Compared with dicalcium phosphate and calcium carbonate, poultry litter ash gave comparable growth, feed efficiency, and dressing performance. The dioxin levels in the poultry litter ash were below the World Health Organization standard for mineral supplements; however, public perception about dioxin risks could limit the use of poultry litter ash for use as a mineral feed supplement. It was estimated that with proper poultry litter and energy conversion management, a poultry litter plant can net $40.00 to 80.00/ton of ash used in fertilizers and from $80 to 110/ton of ash used as a mineral feed supplement if dioxins are not a limiting factor.

An IPEP corn/ethanol plant on the Tennessee River in north Alabama was determined to be very competitive with traditional stand-alone corn/ethanol plants in the eastern Corn Belt that use NG for process heat. The main tradeoffs are that higher dried distillers grain and solubles (DDGS) and carbon dioxide revenues for an IPEP plant more than offset the higher cost of corn and that an IPEP plant saves $0.08 to 0.09/gallon of denatured ethanol on process energy costs and an average of $0.04 to 0.07/gallon on ethanol transportation costs to southeastern and eastern U.S. markets. Using baseline assumptions, a nominal 50 million gallon per year IPEP ethanol plant at Decatur, AL is projected to have a 10-year average after-tax ROI of 61.3% vs. 45.3% for a Pekin, IL NG plant. The sensitivity analysis indicated that a worst-case north AL IPEP scenario with a low average ethanol price ($1.55/gal), high average corn price ($3.37/bu), and other variables at baseline levels would result in a 10-year average after-tax ROI of 18.4%. This worst-case ROI for a north Alabama IPEP scenario would be reduced from 18.4% to 12.5% if the plant relied on NG (average projected price for the next 10 years of $6.94/MBtu) instead of process heat from a poultry litter energy plant at a baseline price of $4.94/MBtu NG displaced by the poultry litter. A north Alabama IPEP plant is projected to be very competitive with an eastern Corn Belt plant, have a very high rate of return with baseline conditions, and provide positive returns under worst-case conditions.

The economics of using poultry litter to provide process heat for a north Alabama IPEP ethanol plant were compared with the economics of the other primary alternatives to land application of poultry litter: (1) long-distance transport of unprocessed poultry litter, (2) pelletizing poultry litter, (3) composting poultry litter, and (4) electricity production for industrial uses or for sale to a utility grid. Each of these options is technically feasible. The main question is whether they are economical. Providing process steam for an IPEP system holds promise for being an economical alternative to local land application of poultry litter in concentrated poultry areas without financial incentives. In contrast, the other alternative uses of poultry litter evaluated will require significant financial incentives to achieve comparable profitability.

A fuel-cycle well-to-pump analysis indicated that current and near-future ethanol plants on average use 0.74 and 0.69 Btu of fossil fuel, respectively, per Btu of ethanol delivered to a refueling station pump. These estimates account for fossil energy used to produce fertilizers for corn, and other energy use for growing and transporting corn and producing and transporting ethanol. Using poultry litter rather than NG for ethanol process heat reduces the fossil energy requirement to 0.26 Btu of fossil fuel per Btu of ethanol delivered to a refueling station pump. This is a very significant improvement over gasoline which requires 1.23 Btu of fossil energy per Btu of gasoline on a well-to-pump basis; petroleum recovery, transportation, and refining and gasoline transportation to the pump account for 0.23 Btu fossil energy per Btu of gasoline and the fossil energy contained in gasoline itself accounts for 1.0 Btu of fossil energy per gallon of gasoline. Compared with gasoline, well-to-wheel greenhouse gas emissions were estimated to be 25% lower for current-case ethanol production, 40% lower for near-future case ethanol production, and 63% lower for near-future ethanol production relying on poultry litter for process energy.

In conclusion, an IPEP poultry litter energy plant in north Alabama is technically and economically feasible, is projected to be more economical than other alternative uses of poultry litter, is projected to be more profitable than an eastern

Corn Belt ethanol plant, and would provide significant environmental benefits over an ethanol plant using NG for process heat. Probably the main potential deterrent to commercialization of an IPEP project in north Alabama is a “not in my backyard” mentality regarding development of commercial projects. This is currently being experienced at one potential north Alabama location at which a corn/ethanol plant is being proposed. There is also some uncertainty about how broadly poultry litter land application rules will be enforced in the near future. This results in some uncertainty about poultry litter supply-price relationships in the near future that a project developer will have to take into consideration.

II. Introduction

A. Background

The objective of this project is to assess the technical and economic feasibility of an integrated ethanol and poultry production (IPEP) system in north Alabama that uses poultry litter as an alternative source of process energy for corn/ethanol production and is projected to improve the overall economic and environmental performance of both ethanol and poultry production.

Because of high crude oil and gasoline prices, the need for reducing dependence on foreign oil, and recent U.S. policies to encourage more ethanol production, the U.S. ethanol industry is growing rapidly and this growth is occurring at strategic locations outside the Corn Belt as well as in the Corn Belt.

One of the driving forces for considering an IPEP system in north Alabama is that using poultry litter instead of natural gas to provide process heat for a corn/ethanol plant holds promise as one of the most economical alternatives to local land application of poultry litter in north Alabama. Economical alternatives to local land application are needed because of water quality concerns related to regional phosphorus (P) surpluses and P runoff from poultry litter into surface waters in concentrated poultry areas such as north Alabama. The recent ban on land application of poultry litter in the Eucha-Spavinaw watershed and associated law suites in northwest Arkansas, a concentrated poultry area similar to north Alabama, are dramatic examples of this need. A key part of this project is to assess the feasibility of using poultry litter in north Alabama to provide process heat for an ethanol plant and to compare the economics of this alternative use with other alternative uses for poultry litter.

The other driving force for considering an IPEP system in north Alabama is the outlook for a competitive advantage over conventional ethanol plants in the eastern Corn Belt. Given high projected natural gas prices for the foreseeable future, a key economic advantage for an IPEP system is the prospect for significantly lower process energy costs using poultry litter rather than natural gas. Other economic advantages of an IPEP system vs. a Corn Belt plant for corn/ethanol production are a local market for dried distillers grains and solubles (DDGS) in poultry diets, lower ethanol transportation costs than for Midwest corn/ethanol plants, and good local markets for carbon dioxide. These economic advantages are partially offset by higher corn costs. A key part of this project is quantifying economic tradeoffs and the relative economics of an IPEP ethanol plant in north Alabama vs. a conventional corn/ethanol plant in the eastern Corn Belt.

Since poultry litter is a renewable energy source, use of poultry litter rather than natural gas to provide process heat significantly reduces fuel-cycle fossil energy usage and greenhouse gas emissions from ethanol production. These benefits are estimated in this project to provide a more complete picture of the environmental benefits of IPEP ethanol vs. traditional corn/ethanol vs. gasoline.

B. Approach

The technical and economic feasibility of an IPEP system in north Alabama was assessed by an interdisciplinary team with responsibilities as described below. T.R. Miles Technical Consultants, Inc. was the prime contractor and B.R. Bock Consulting, Inc. provided technical coordination for the project. Except for use of poultry litter ash as a mineral supplement, the individual components of IPEP have been shown to be technically feasible prior to this project. As part of the feasibility assessment, feeding trials were conducted to evaluate the use of poultry litter ash as a mineral feed supplement. The rest of the feasibility assessment focused on documenting the technical feasibility of system components and assessing economic feasibility. Regarding economic feasibility, the general approach was to determine whether using poultry litter to provide process energy for an IPEP system is more economical than other alternative uses for poultry litter in north Alabama and to determine whether an IPEP system in north Alabama would be competitive with ethanol plants in the eastern Corn Belt.

The economics of ethanol plant inputs (corn, natural gas, and electricity) and outputs (ethanol, dried distillers grains and solubles, and carbon dioxide) were assessed by Informa Economics, Inc in Chapters III to XI. Transportation costs for IPEP system inputs and outputs were estimated in Chapter XII by the TVA Economic Development Transportation Section and other siting considerations were assessed by B.R. Bock Consulting, Inc. in Chapter XII. The technical assessment, conceptual design, and capital and O&M costs of fluidized bed combustion of poultry litter were provided by Energy Products of Idaho in Chapter XIII. The conceptual design and capital and O&M costs for the poultry litter handling and storage system were provided by T.R. Miles Technical Consultants, Inc. in Chapter XIII. The overall economic assessment of fluidized bed combustion of poultry litter was provided by B.R. Bock Consulting, Inc. in Chapter XIII. Poultry litter supplies and prices for alternative uses in Chapter XIV are based on poultry grower and poultry litter vendor surveys conducted the Alabama Mountains, Rivers, and Valleys RC&D and an assessment of regulatory constraints on land application of poultry litter by B.R. Bock Consulting, Inc. Assessment of the fertilizer nutrient value of poultry litter ash was provided by B.R. Bock Consulting, Inc. in Chapter XV. Assessment of the nutritional value of poultry litter ash fed to broilers was provided by Auburn University Poultry Science in Chapter XVI. The economics of an IPEP system in north Alabama vs. conventional corn/ethanol systems in north Alabama and Central Illinois were assessed by Informa Economics, Inc. in Chapter XVII. Assessment of the fuel-cycle fossil energy balance and greenhouse gas emissions for an IPEP system vs. traditional corn/ethanol systems and gasoline was provided by B.R. Bock Consulting, Inc. in Chapter XVIII. An economic comparison of IPEP vs. other alternatives to local land application of poultry litter in north Alabama was provided by B.R. Bock Consulting, Inc. in Chapter XIV.

Most tasks in this project were completed on a preliminary basis by August of 2005. However, the Energy Policy Act that was passed in August of 2005 and subsequent revisions in energy price projections have had such strong implications for the economics of ethanol plant inputs and outputs and the ethanol industry in general that chapters pertaining to the economics of ethanol inputs and outputs and the economic evaluation of an IPEP system for north Alabama were updated for the September 2006 final report. Other chapters were completed as much as a year and half prior to September 2006, but are based on data and assumptions that are deemed to be sufficiently current.

III. Summary of Corn Feedstock Resources in Alabama

This section assesses trends related to the volumes and location of corn production in AL. Extensive use of figures and tables are designed to highlight down to the county level where the corn is produced in AL. This information along with Alabama corn demand information in the next section is used to determine the extent that an IPEP ethanol plant in north Alabama could rely on locally produced corn vs. corn transported in by rail and barge. A typical ethanol facility that produces 50,000 gallons annually requires approximately 18 million bushels of corn a year. The major findings of this section are summarized below:

<u>State Trends</u>

- The long-run trend of corn acres planted in AL has been one of decline from the 1950's to the present (Figure 1).

- Of the major crops planted in Alabama, only hay and cotton have grown in the percent allocation of total field crops acres planted from 1990 to 2003 (Figure 2).

- The long-run trend in corn production has been one of decline since the 1950's. However, corn production levels have shown persistence toward stabilization (Figure 3).

- There has been minimal variation in AL corn production over the recent period of 1990-2003, where the maximum corn produced was 28.1 million bushels, the minimum corn produced was 11 million bushels, and the mean level of production was 18.6 million. Corn production for 2003 is above the average level (Figure 4).

- Based on indexation analysis (base year 1982 representing 100), total AL corn production is approaching a level slightly over 60 in 2002 (Figure 5), much lower than the U.S. index score, and a reduction in output of 40 percent.

<u>Regional Trends</u>

- The northern valley region (crop reporting District 10) is the largest corn producing district in AL with a three year (00, 01, 02) average of 5.1 million bushels produced (Table 1). The mountains & eastern valley region (crop reporting District 20) is the second largest corn producing district in AL with a three year (00, 01, 02) average of 4.3 million bushels produced (Table 1). These two north Alabama regions potentially could supply on average about 10 million bushels of corn per year to an IPEP ethanol plant in north Alabama. As discussed in the next section, Alabama has a large corn deficit and most of the corn produced in north Alabama is currently being used by the poultry industry in north Alabama.

- Based on a production density calculation of corn production, the northern valley's (District 10) production is even more pronounced. The density calculation divides a region's total corn production by the respective region's area in square miles. The northern valley produces an average of 869 bushels per square mile and the next highest level is the mountains and eastern valley (District 20) region with 643 bushels per square mile (Table 3).

- The northern valley (District 10) region produces approximately 27% of all the corn that is produced in AL. This compares to only 4.1% share of total production for the northern valley region in 70, 71 and 72 (Table 4). Also, both northern valley and wiregrass (District 60) have the highest increases in regional production (Table 5).

<u>County Trends</u>

- In terms of total corn production based on absolute bushels, the leading counties are Jackson, DeKalb and Madison (Figure 7).

- The top producing counties based on corn density production are Madison (over 5,000 bu. per sq/mile), DeKalb (over 1,000 bu. per sq/mile) and Colbert (over 1,000 bu. per sq/mile), (Figure 8).

- Jackson, DeKalb, and Madison are the counties with the highest share of corn production (Table 6).

- A summary of the top producing counties based on total bushels produced per country relative to production density per county and growth over time is displayed in two bubble charts (Figures 9 and 10). The charts show that of the top corn producing counties in AL, four of them are located in the northern valley region (Lawrence, Madison, Colbert, and Limestone), and two are located in the mountains and eastern valley region (Jackson and DeKalb).

- Also included is a review of total acres planted for major field crops versus corn's percent share of total acres planted (Figure 11). This shows that field crop average peaked at about 4.5 million acres in the early 80's and has steadily declined to below 2 million acres, indicating that a large amount of land is still available for potential field crop production.

Implications

- Interestingly, even with the significant increase in the broiler complex in the state, corn production has fallen over the long-run (Figure 12). The livestock demand for corn will be discussed in the next section, bringing together an estimate of the net balance of the movement of corn.

A. AL Long-Run Trends in Corn Production

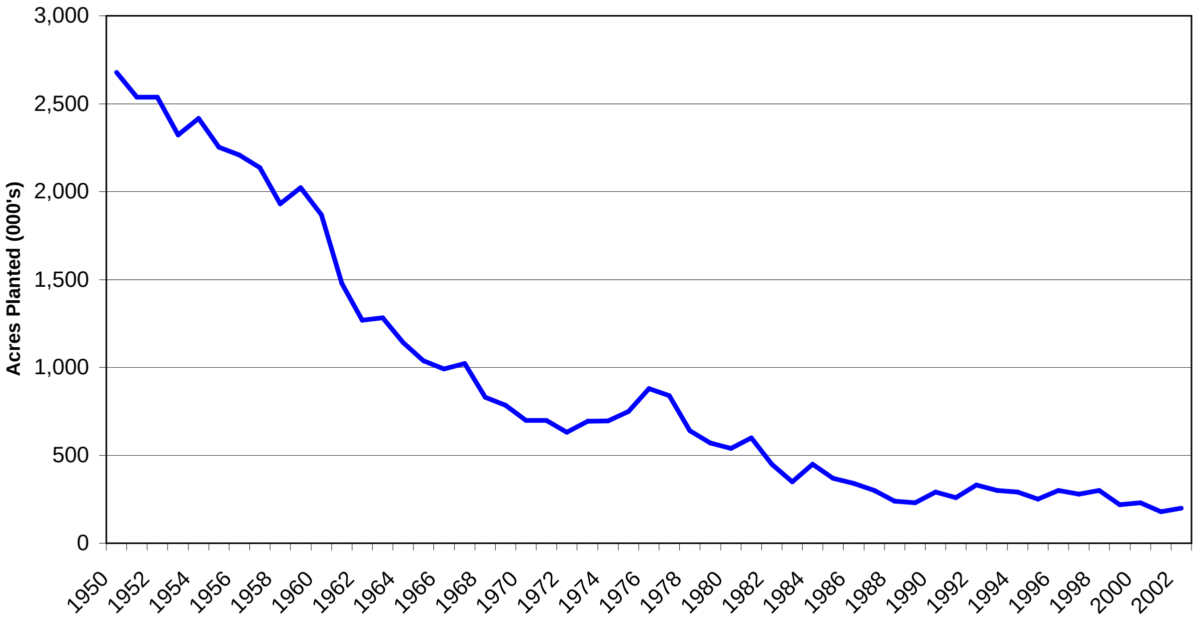


Figure 1: AL Corn Acres Planted, Long-Run Trend

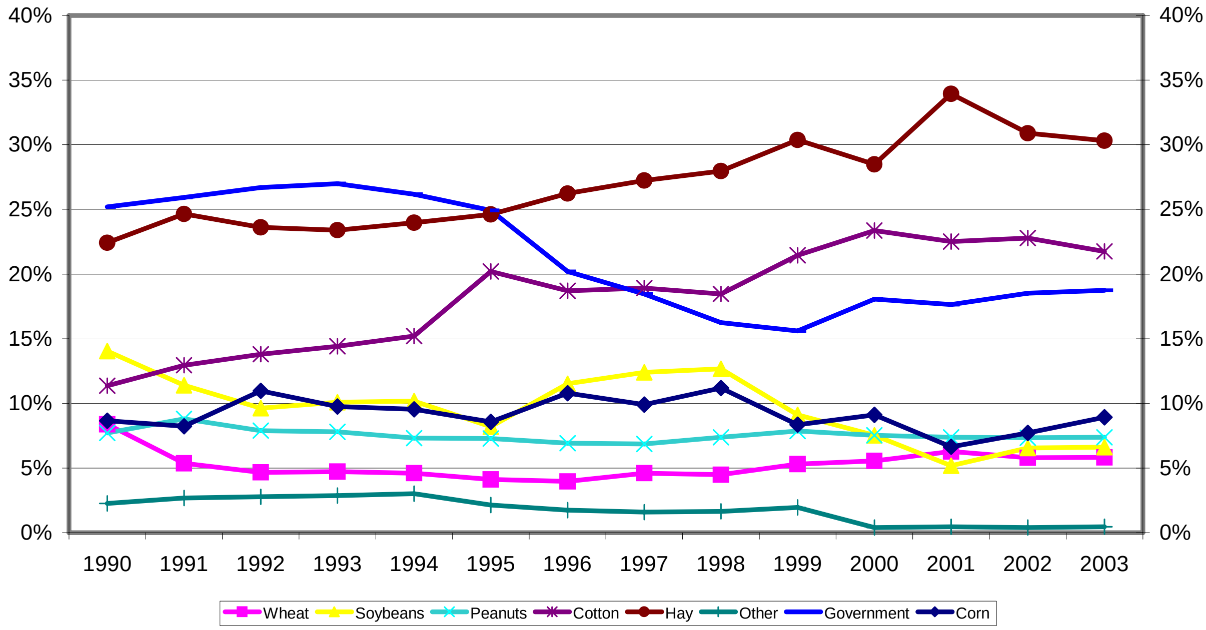


Figure 2: AL Percent Share of Field Crops' Acres Planted

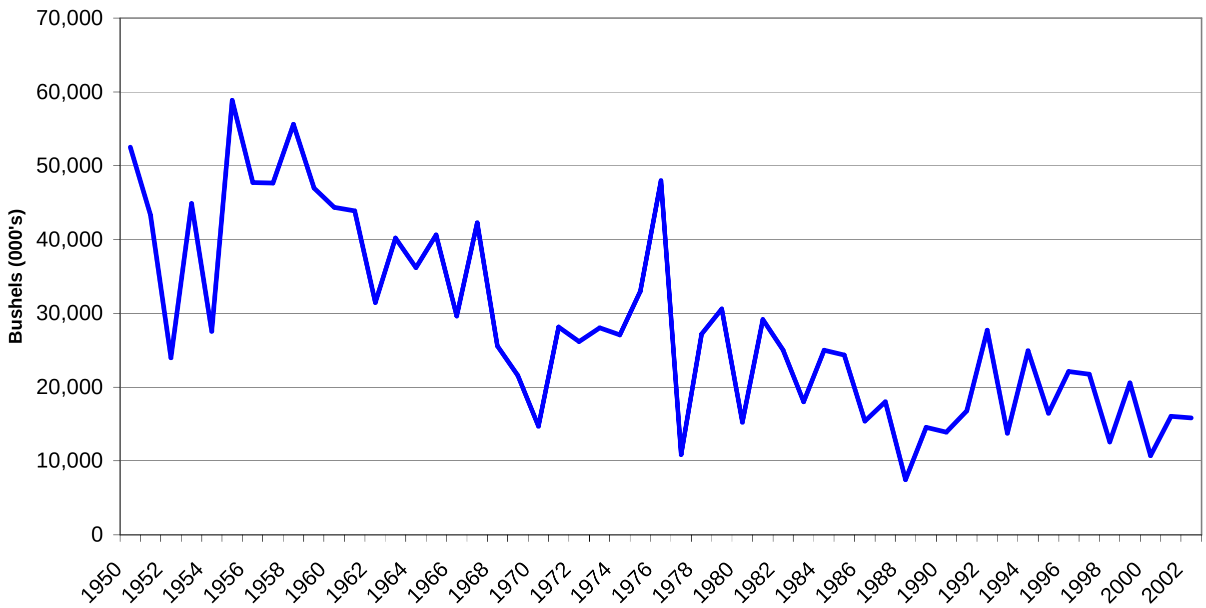


Figure 3: AL Corn Production, Long-Run Trend

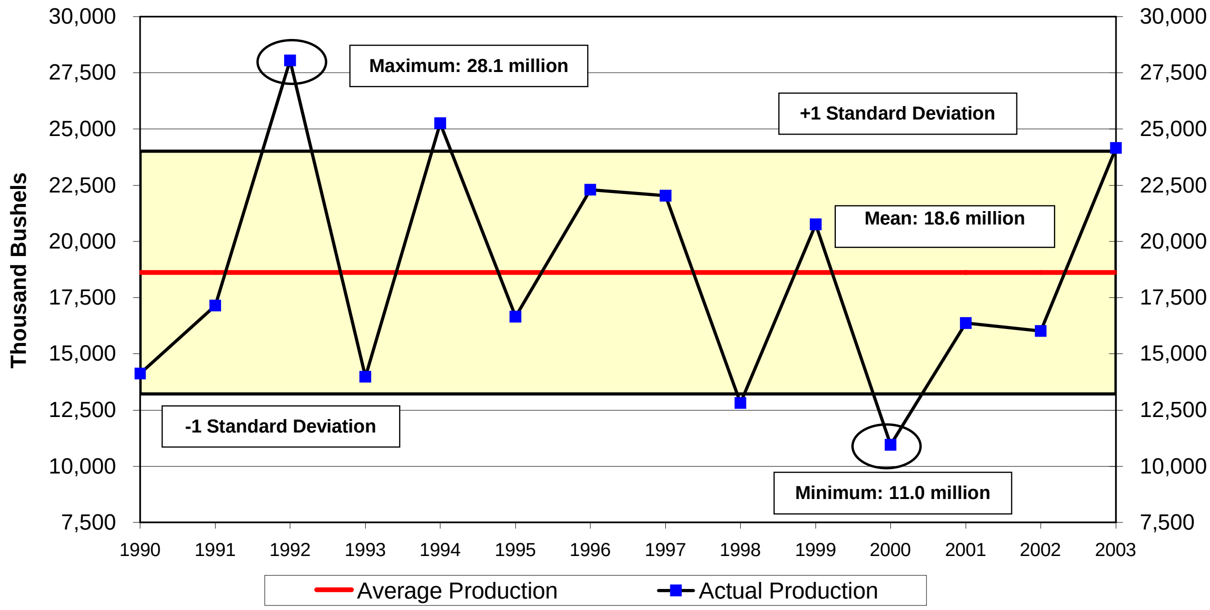


Figure 4: Variation in AL Corn Production: 1990-2003

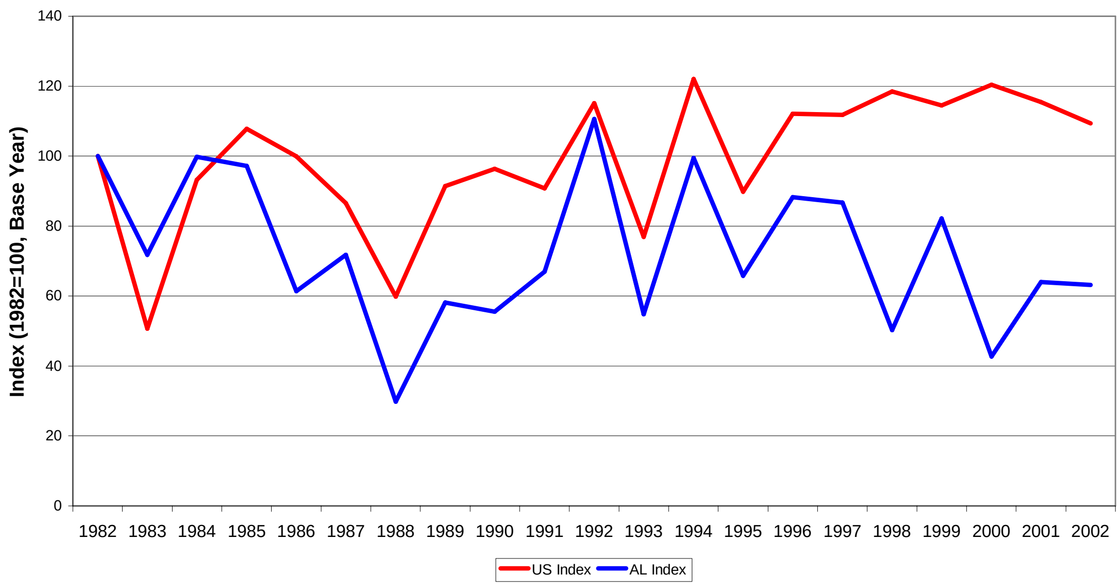


Figure 5: Indexation of Corn Production, AL vs. US, 1982 to 2002

B. Regional Trends in AL Corn Production

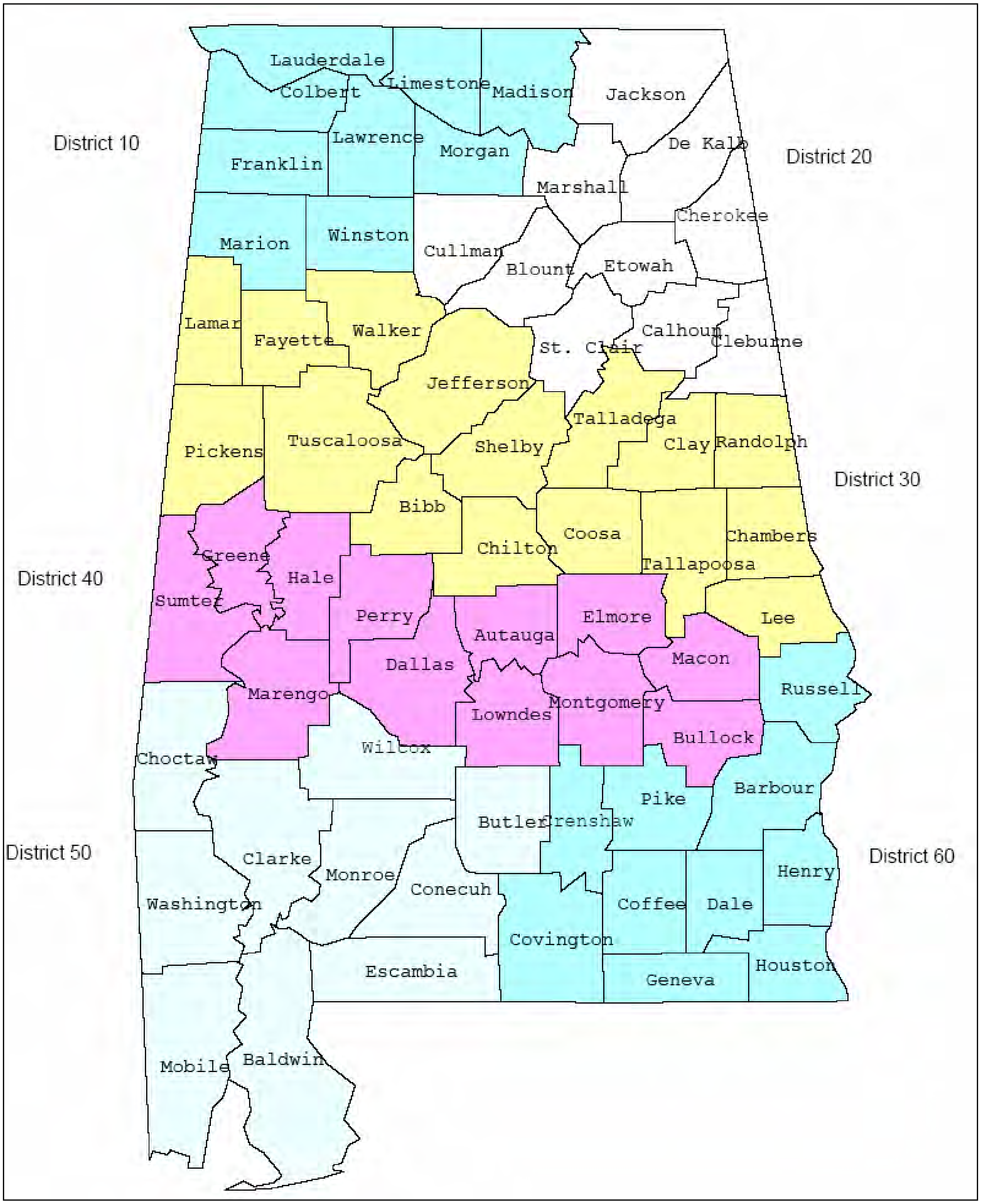


Figure 6: AL Crop Reporting Districts

Table 1: AL Corn, Regional Production (bushels)

Region	Average 70, 71, 72	Average 80, 81, 82	Average 90, 91, 92	Average 00, 01, 02
D10 Northern Valley	871,333	700,000	2,996,333	5,132,333
D20 Mountains & Eastern Valley	2,522,000	2,521,000	5,098,667	4,310,000
D21 Historic District 21	1,479,267	549,000		
D30 Upper Plains & Piedmont	3,736,667	2,042,333	1,141,000	1,098,333
D40 Black Belt	697,333	563,667	1,254,667	981,667
D50 Coastal Plains & Gulf Coast	1,272,667	1,111,333	3,853,333	994,333
D60 Wiregrass	736,400	495,333	5,139,333	1,688,333
D70 Historic District 70	1,599,333	5,234,000		
D80 Historic District 80	2,769,000	4,092,667		
D90 Historic District 90	7,328,667	5,843,333		
State Total	23,012,667	23,152,667	19,483,333	14,205,000

Table 2: AL, Area by Region, Square Miles

Region	Square Miles
D10 Northern Valley	5,904
D20 Mountains & Eastern Valley	6,698
D30 Upper Plains & Piedmont	11,959
D40 Black Belt	8,832
D50 Coastal Plains & Gulf Coast	10,552
D60 Wiregrass	6,799
State Total	50,744

Table 3: AL Corn, Production Density by Region, Bushels per Square Miles

Region	Average 70, 71, 72	Average 80, 81, 82	Average 90, 91, 92	Average 00, 01, 02
D10 Northern Valley	148	119	508	869
D20 Mountains & Eastern Valley	377	376	761	643
D30 Upper Plains & Piedmont	124	46	129	124
D40 Black Belt	423	231	119	93
D50 Coastal Plains & Gulf Coast	66	53	567	146
D60 Wiregrass	187	163	756	248
State Total	454	456	384	280

Table 4: AL Corn, Regional Production Trend by Percent Share of Total

Region	% Share 70, 71, 72	% Share 80, 81, 82	% Share 90, 91, 92	% Share 00, 01, 02
D10 Northern Valley	3.8%	3.0%	15.4%	36.1%
D20 Mountains & Eastern Valley	11.0%	10.9%	26.2%	30.3%
D21 Historic District 21	6.4%	2.4%		
D30 Upper Plains & Piedmont	16.2%	8.8%	5.9%	7.7%
D40 Black Belt	3.0%	2.4%	6.4%	6.9%
D50 Coastal Plains & Gulf Coast	5.5%	4.8%	19.8%	7.0%
D60 Wiregrass	3.2%	2.1%	26.4%	11.9%
D70 Historic District 70	6.9%	22.6%		
D80 Historic District 80	12.0%	17.7%		
D90 Historic District 90	31.8%	25.2%		
State Total	100.0%	100.0%	100.0%	100.0%

Table 5: AL Corn, Regional Production, Percent Change

Region	% Change 72 to 82	% Change 82 to 92	% Change 92 to 02	% Change 72 to 02
D10 Northern Valley	1%	497%	3%	520%
D20 Mountains & Eastern Valley	17%	188%	-50%	67%
D21 Historic District 21	-50%			
D30 Upper Plains & Piedmont	-39%	-33%	-10%	-63%
D40 Black Belt	-21%	138%	-25%	42%
D50 Coastal Plains & Gulf Coast	-21%	324%	-76%	-20%
D60 Wiregrass	-39%	1190%	-61%	209%
D70 Historic District 70	144%			
D80 Historic District 80	36%			
D90 Historic District 90	-28%			
State Total	-4%	11%	-100%	-43%

C. County Trends in AL Corn Production

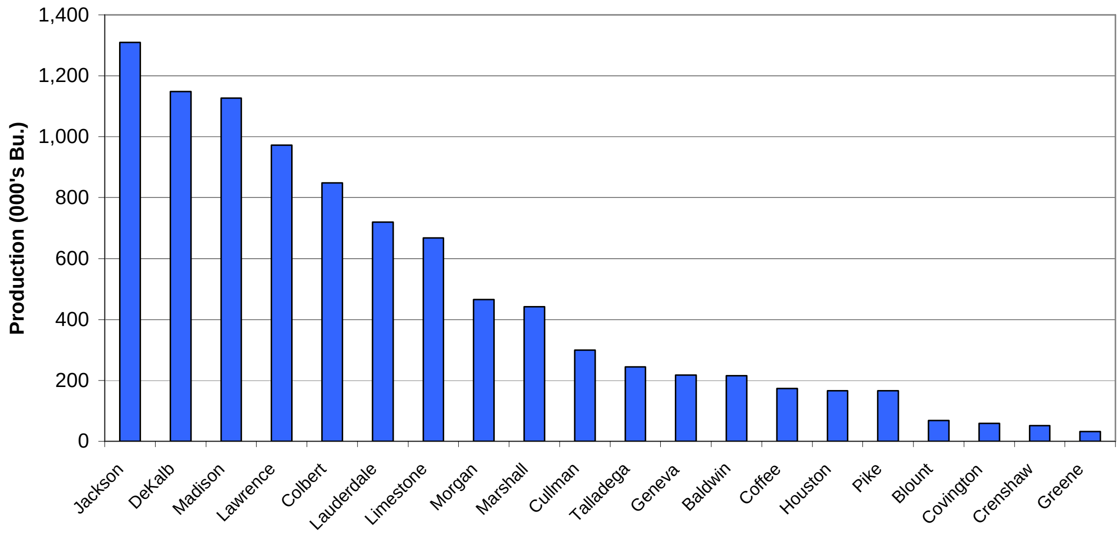


Figure 7: AL Corn Production by Top Counties (weighted avg. 00, 01, 02)

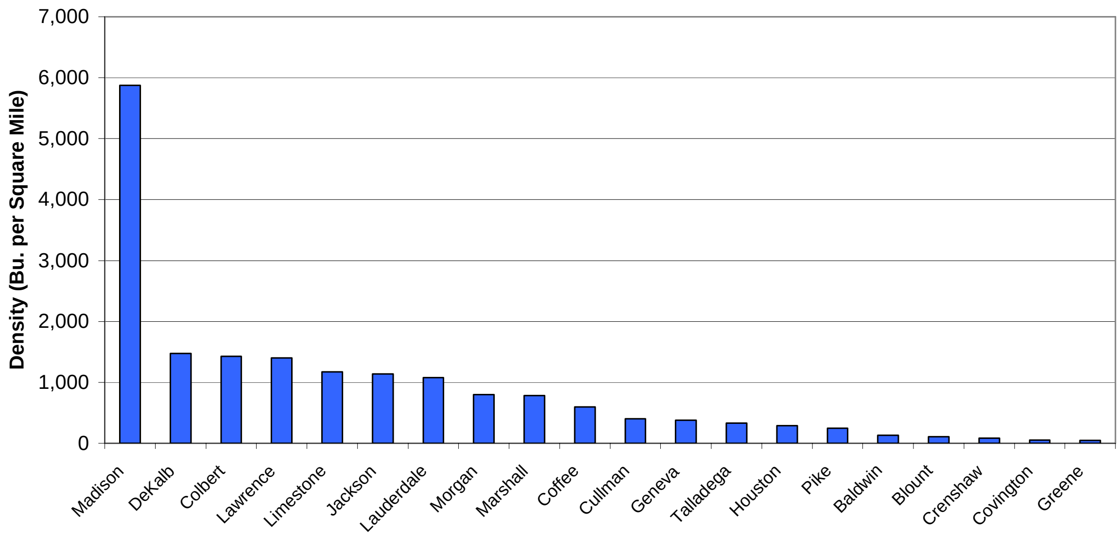


Figure 8: Corn Production Density by Top Counties (weighted avg. 00-02)

Table 6: AL Corn, Production by Top Counties, Percent Share of Total

County	Average 00, 01, 02	% Share
Jackson	1,225,000	8.6%
DeKalb	1,149,000	8.1%
Madison	1,126,667	7.9%
Lawrence	871,000	6.1%
Colbert	849,000	6.0%
Limestone	803,333	5.7%
Lauderdale	719,333	5.1%
Geneva	218,333	1.5%
Coffee	173,000	1.2%
Houston	166,000	1.2%
State Total	14,205,000	51.4%

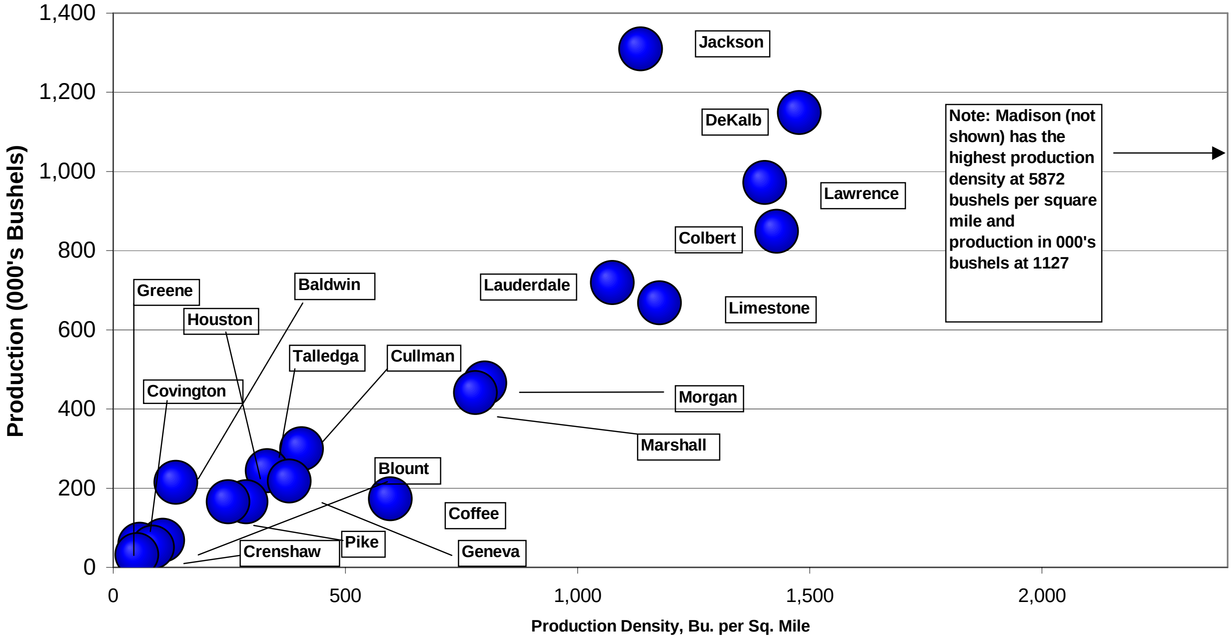


Figure 9: AL Corn Production (weighted avg. 00, 01, 02), Leading Counties, Comparison of Production by Volume, Density & Percentage Share of State Production

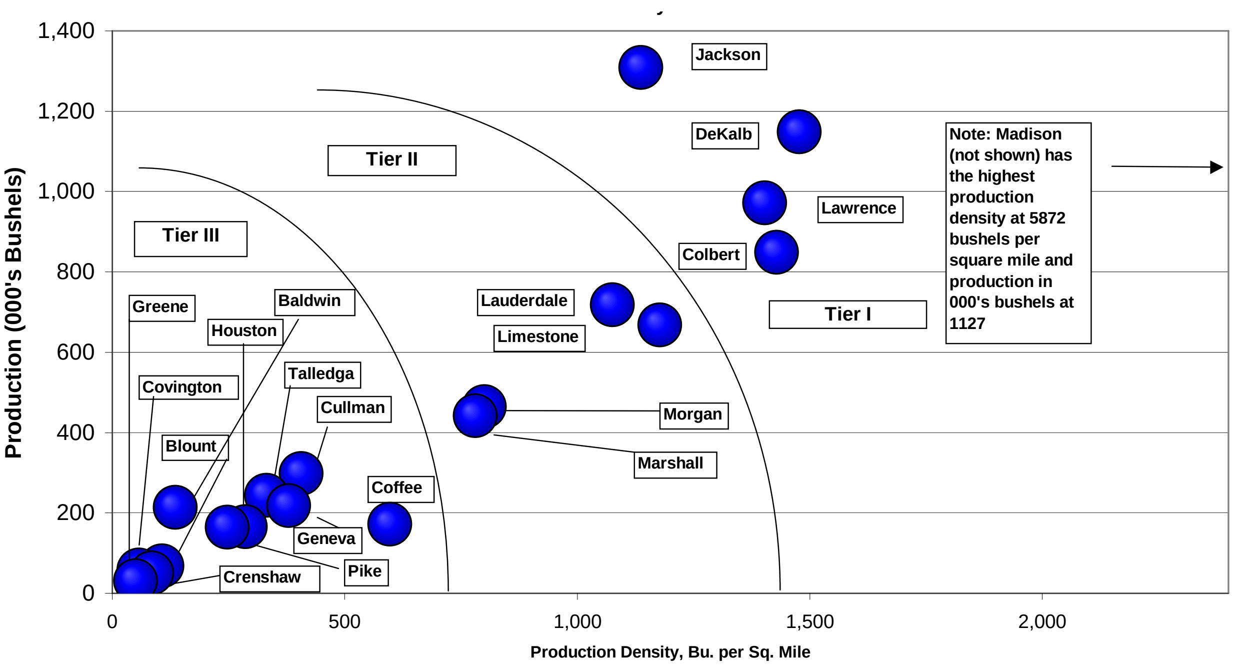


Figure 10: AL Corn Production (weighted avg. 00, 01, 02), Stratification/Identification of Leading Counties

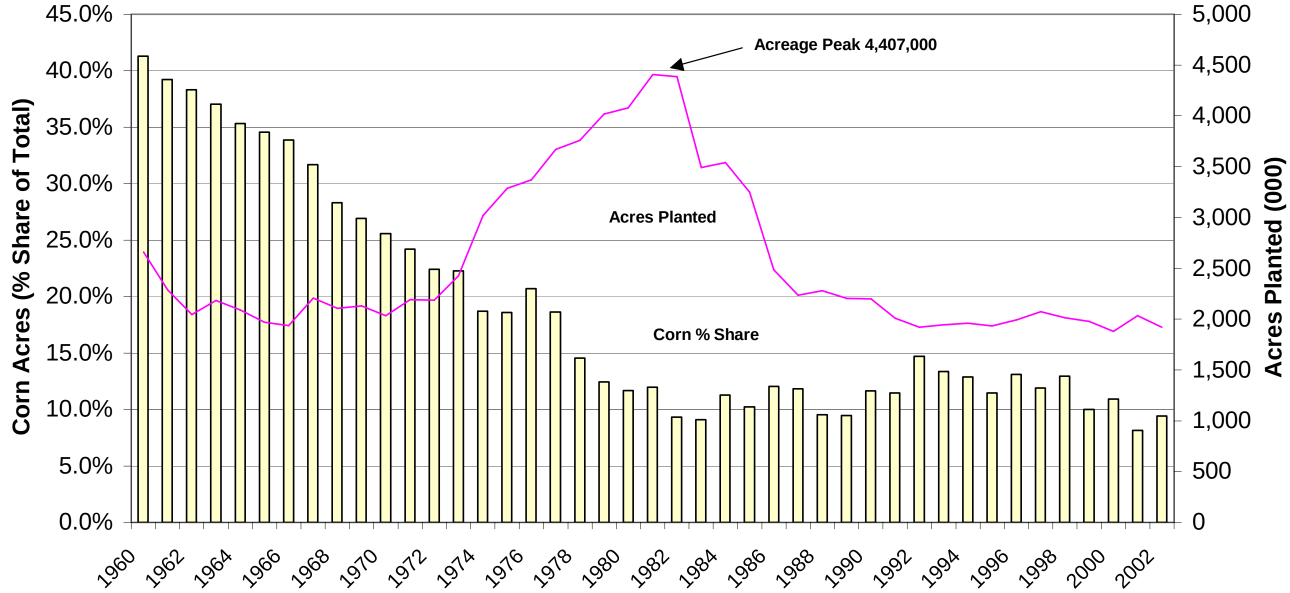


Figure 11: Total AL Field Crops (corn, sorghum, wheat, soybeans, cotton, hay, CRP) Acres Planted vs. % Share of Corn Acres Planted)

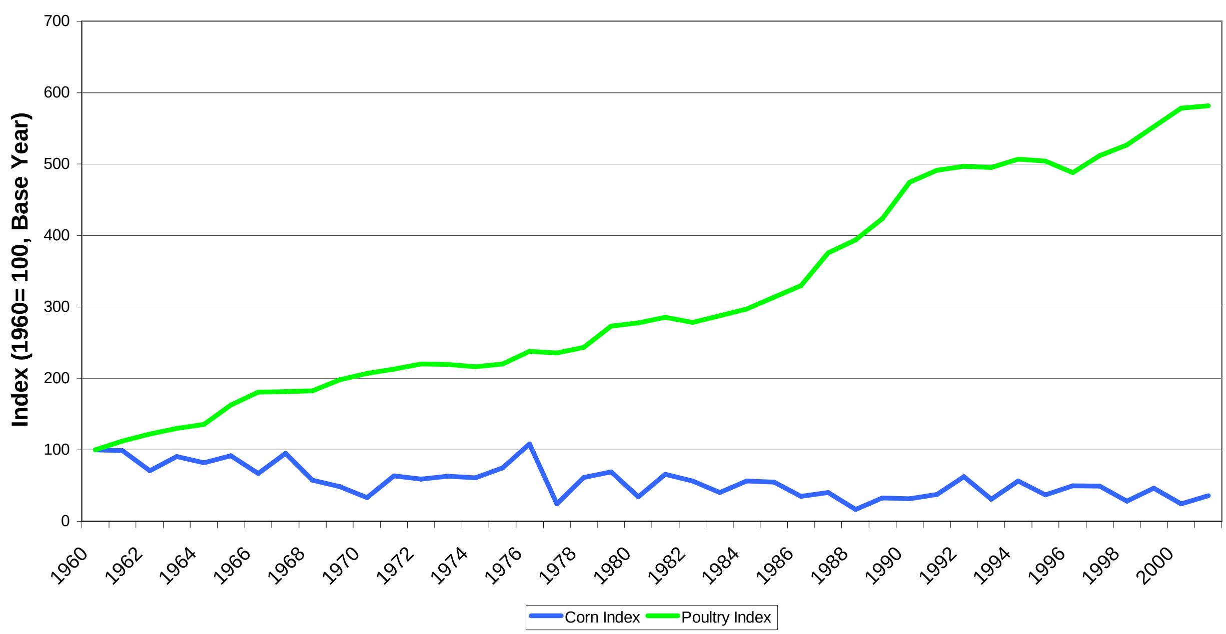


Figure 12: AL Broiler Numbers vs. Corn Production AL Indexed, 1960 to 2001

IV. Analysis of Corn Demand in Alabama

The demand section analyzes Alabama's major livestock sectors in order to estimate the total volume of corn consumed annually within the state. This exercise is critical since the catfish, swine, dairy and poultry sectors will be the primary competitors for state corn with an emerging ethanol industry. These four sectors were scrutinized by the number of animals produced annually and the ration formulas that are used in the industries to derive a total corn estimate within the state for AL.

A. Catfish Demand for Corn

As fish sales have steadily grown in the 90's (Table 1), the value of feed inputs have also expanded. Catfish feed is typically purchased in large volumes at the start of each season, enough inventory to last a whole year for each grower. The number of pounds of fish sold has risen from approximately 58 million pounds in 1993 to 142,000 pounds in 2002, up 147 percent. Total corn consumption by catfish in 2002 is estimated to be about 3 million bushels (Table 2). Alabama catfish foodservice sales (based on pounds) have more than doubled since 1993 (Figure 1).

Table 1: Catfish Sales, Number Weight and Value for All Foodservice

Year	Number of head	Total Pounds Sold	Avg Weight Per Fish	Total Value of Sales	Average Value Per Pound
	1,000		Pounds	1,000 $	Dollars
1989	25,751	34,302	1.33	21,620	0.63
1990	29,814	38,162	1.28	27,858	0.73
1991	42,265	45,000	1.06	27,450	0.61
1992	41,146	52,577	1.28	30,239	0.58
1993	47,844	57,609	1.20	39,143	0.68
1994	48,454	54,417	1.12	40,114	0.74
1995	50,021	68,067	1.36	49,284	0.72
1996	43,038	72,692	1.69	51,611	0.71
1997	34,407	77,416	2.25	52,643	0.68
1998	46,850	88,500	1.89	60,180	0.68
1999	54,800	103,000	1.90	69,010	0.67
2000	64,900	113,000	1.70	77,970	0.69
2001	60,000	115,000	1.90	67,850	0.59
2002	75,000	142,000	1.90	73,840	0.52

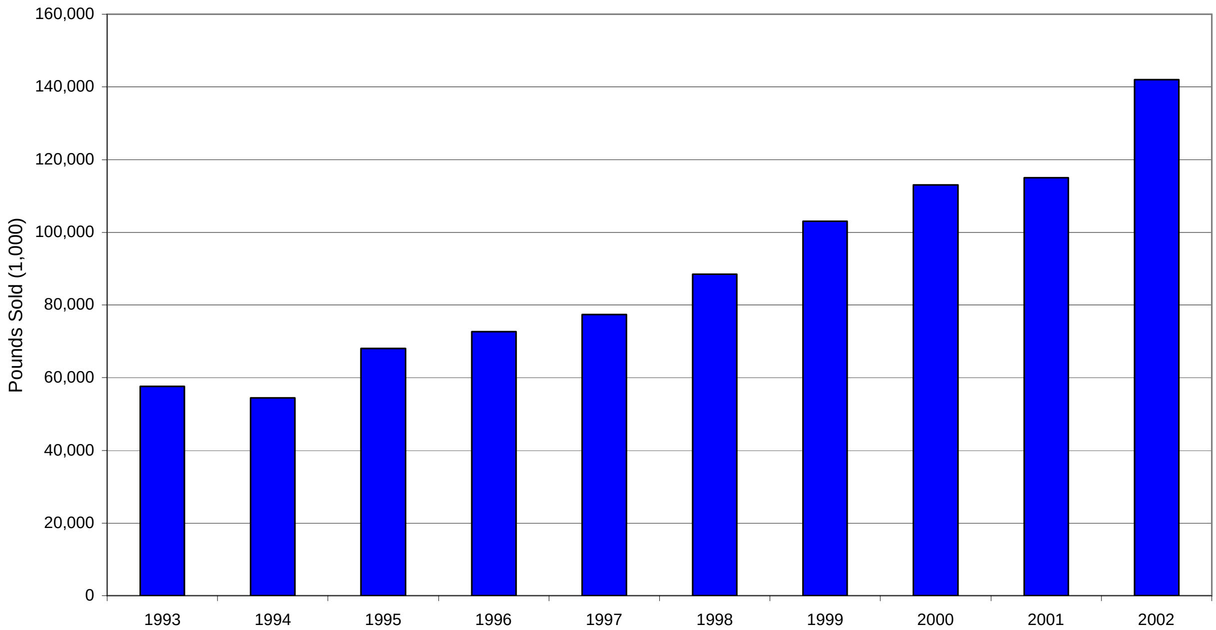


Figure 1: AL Catfish Foodservice Sales, Pounds

Table 2: Estimation of AL Catfish Consumption of Corn, 2002

Catfish, Corn Consumption Assumptions:

Approximate Catfish Feed Sales, Tons*		335,120
Pounds Per Ton	X	2,000
Est. Pounds of Feed Consumed		670,240,000
Corn % of Ration	X	25%
Est. Pounds of Corn Consumed		167,560,000
Pounds Per Bushel, Corn	/	56
Est. Bushels of Corn Consumed		2,992,143

* Sparks estimate

B. Dairy Demand for Corn

The dairy industry in AL has been declining for many years. Total cow numbers and milk output has slid consistently, going as far back as the 1960's (Figure 2). The number of cows has actually declined 54 percent since 1989 while milk yield per cow has increased 13 percent (Table 3). Corn is an important ingredient in a dairy cow's daily ration mix. It is estimated that the AL sector consumes over 1.2 million bushels of corn annually (Table 4). This is the second lowest corn consumption level of the four livestock sectors analyzed.

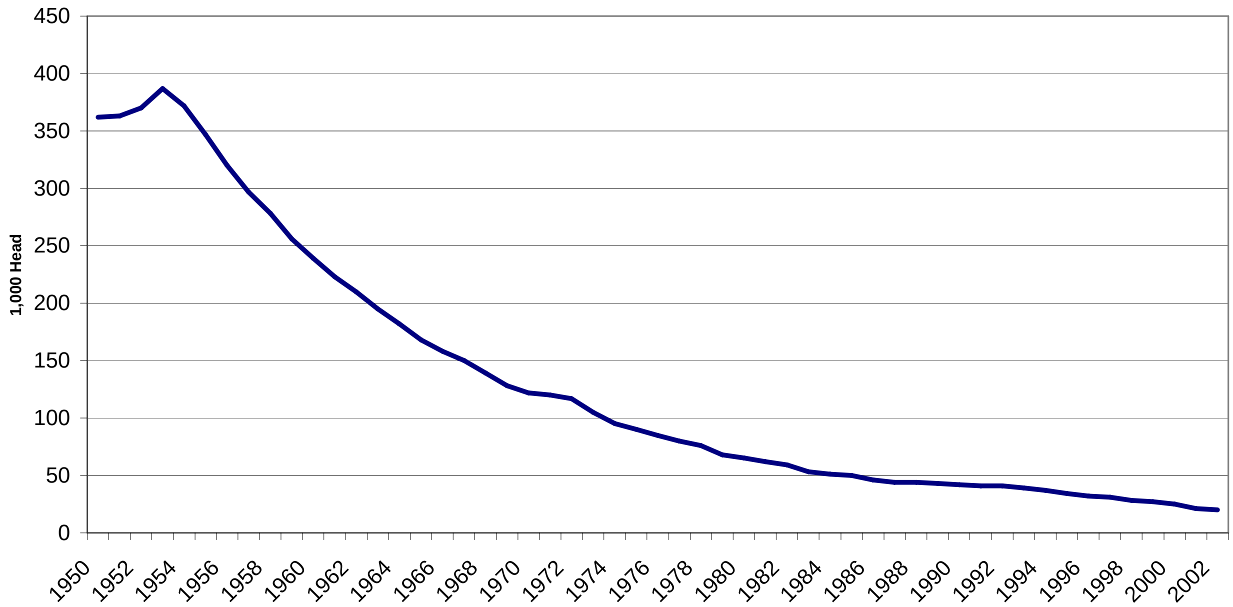


Figure 2: AL Milk Cow Inventory

Table 3: AL Dairy Production and Marketings

Year	Number Head	Total Pounds Produced	Per Cow Yield	Cash Receipts Marketings
	1,000	Million	Pounds	1,000 Dollars
1989	43	527	12,256	78,076
1990	42	513	12,214	81,090
1991	41	521	12,707	69,795
1992	41	503	12,268	72,500
1993	39	515	13,205	72,562
1994	37	500	13,514	72,912
1995	34	482	14,176	66,920
1996	32	434	13,563	70,520
1997	31	418	13,484	61,272
1998	28	386	13,786	63,030
1999	27	376	13,926	61,215
2000	25	348	13,920	48,990
2001	21	300	14,286	50,193
2002	20	277	13,850	38,500

Table 4: Estimation of AL Dairy Consumption of Corn, 2002

Dairy Production:

Year	Number Head	Total Pounds Milk Produced	Average Yield Per Cow	Est. Corn Consumption, Bu.
2002	20,000	277,000,000	13,850	1,218,839
			Total Corn Consumed, Bushels	1,218,839

Dairy, Corn Consumption Assumptions:

Number of Head		20,000
Average Daily Consumption of Grain and Concentrate Per Cow	X	17.0
Est. Pounds of Feed Consumed, 2002		340,000
Days in a Year	X	365
Total Feed Consumed in the Dairy Sector		124,100,000
Corn % of Ration	X	55%
Est. Pounds of Corn Consumed, 2002		68,255,000
Pounds Per Bushel, Corn	/	56
Est. Bushels of Corn Consumed, 2002		1,218,839

C. AL Hogs & Pigs Demand for Corn

The AL Hog industry has trended downward since the 1950's (Figure 3). Numbers have steadily decreased to an average level of almost 200,000 head in 2002. Although these low inventory numbers may not indicate support for demand of AL produced corn, the AL swine industry consumption of almost 4 million pounds of corn in 2002 is the second highest amount of corn consumed of the four livestock groups analyzed (Table 5).

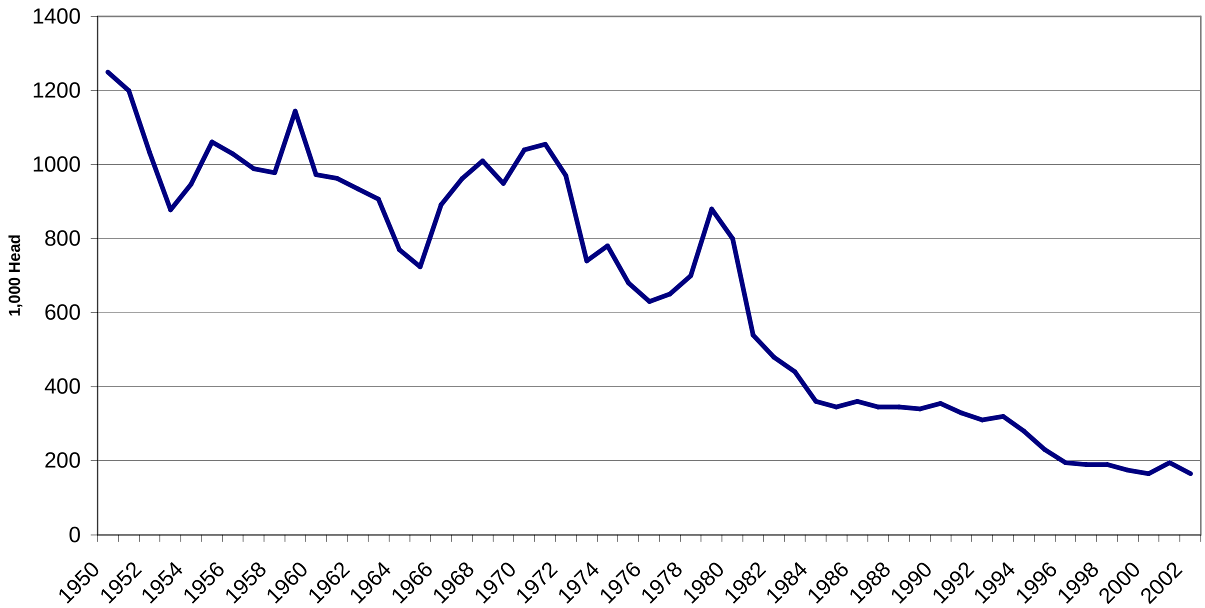


Figure 3: AL Hogs & Pigs Inventory, DEC 1

Table 5: Estimation of AL Hogs/Pigs Consumption of Corn, 2002

Assumptions	
93%	Ration, corn/meal % of total hogs diet*
591	lbs. of Corn consumed annually per animal*
356,000	AL Marketings (head) in 2002**
210,396,000	Estimated Annual Consumption of Corn, lbs.
56	Pounds of Corn per Bushel
3,757,071	Annual Corn Consumption, Bushels

* Informa Economics Livestock Group Estimate for Alabama

** USDA, Meat Animals Production, Disposition, and Income 2002 Summary, April 2003

D. Poultry Demand for Corn

- A mapping software program was utilized to analyze broiler production density[1] within a 50 mile radius, it was determined that the Guntersville region has a significant amount of broiler production density, as measured by higher pounds per square mile (Figure 4). The Guntersville region produced approximately 2.53 million pounds in 2002.

- The Decatur region produced a large volume of broilers in 2002; however, it was less than the Guntersville region at 1.95 million pounds of birds (Figure 4).

- Broiler production density is highest in the areas of Northern Alabama, Northeastern Georgia and Southern Mississippi. A resulting consequence is a significant requirement for corn as a feedstock to sustain the poultry infrastructure.

- The poultry industry in AL has steadily grown throughout the 70's, 80's and 90's. The number of birds produced/sold annually and the average weight of a bird are markedly higher (Table 6 and Figure 5). These figures show that since 1989, total broiler pounds produced has increased 70 percent and average bird weight has increased 21 percent. The combined effect of more birds sold and the larger size per bird has led to a significant elevation in the feed consumed by both the layer and broiler sectors.[2]

- The broiler complex consumes the largest amount of corn with an estimate of about 130 million bushels in 2002, and the layer complex consumes approximately 12 million bushels of corn annually (Table 7). It is important to note that broilers require more protein than layers, which is why corn has a higher inclusion in the feed ration for broilers (68 percent for broilers compared to 60 percent for layers).

---

[1] The broiler production density calculation divides a region's total poultry production by the respective region's area in square miles. This is done so that variations in land mass are accounted for and placed on an equal basis.

[2] Assumes 2 lb feed per lb live weight with 2/3 of the feed from corn..

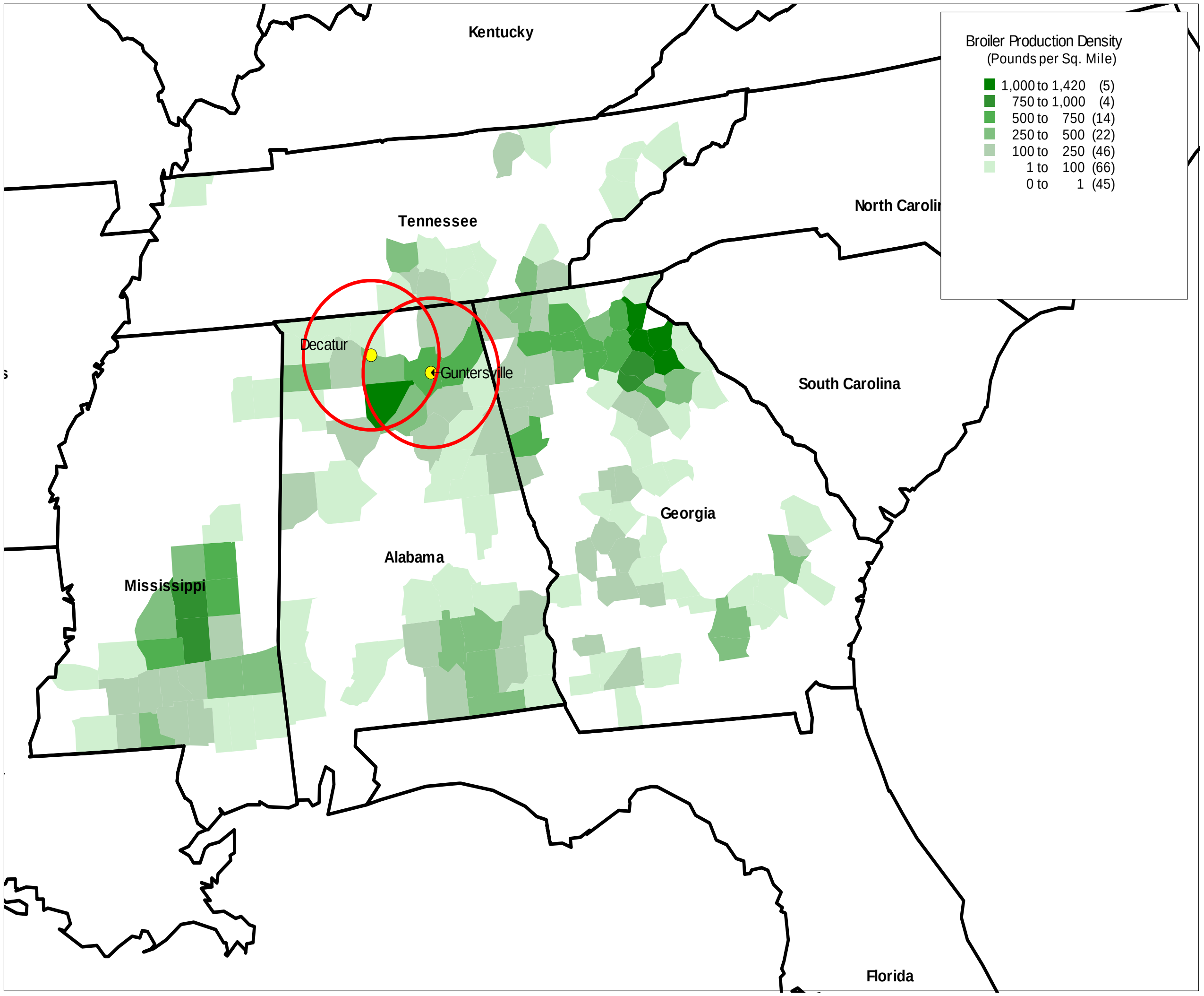


Figure 4: Broiler Production Density, Pounds per Sq. Mile, 2002

Table 6: Commercial Broiler Production, Disposition and Value

Year	Number Produced	Total Pounds Produced	Avg Weight Per Bird	Average Value Per Pound	Total Value of Sales
	1,000		Pounds	Cents	1,000 Dollars
1989	387,336	1,626,811	4.20	36.5	593,786
1990	413,100	1,693,710	4.10	31.5	533,519
1991	456,500	1,962,950	4.30	29.5	579,070
1992	487,400	2,144,560	4.40	31.0	664,814
1993	528,200	2,429,700	4.60	33.5	813,950
1994	602,600	2,711,700	4.50	34.0	921,978
1995	644,000	2,962,400	4.60	33.5	992,404
1996	675,900	3,109,100	4.60	38.5	1,197,004
1997	720,300	3,312,400	4.60	37.0	1,225,588
1998	722,400	3,467,500	4.80	39.5	1,369,663
1999	735,100	3,675,500	5.00	36.0	1,323,180
2000	739,900	3,699,500	5.00	33.0	1,220,835
2001	765,300	3,826,500	5.00	39.0	1,492,335

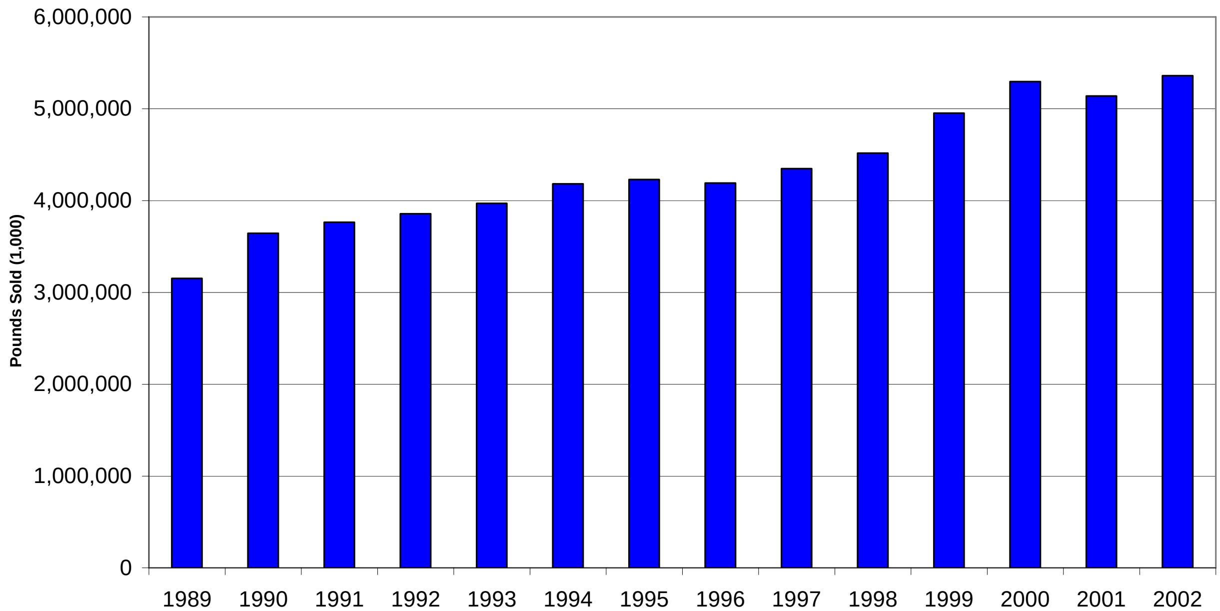


Figure 5: AL Commercial Broiler Production, Pounds Produced

Table 7: Estimation of AL Poultry Consumption of Corn, 2002

Commercial Broiler Production:

Year	Number Produced	Total Pounds Produced	Average Weight Per Bird	Estimated Corn Consumption, Bu.
2002	1,051,300,000	5,361,600,000	5.10	130,210,286

Inventory, Table Egg Layers (including hatchery flocks):

Year	Total Egg Production	Estimated Corn Consumption, Bu.
2002	684,300	1,957,587

Inventory, Broiler Layers (including hatchery flocks):

Year	Total Egg Production	Estimated Corn Consumption, Bu.
2002	1,596,158	9,690,959

Total Corn Consumed, Bushels 141,858,832

Broilers, Corn Consumption Assumptions:

Pounds Produced		5,361,600,000	
Feed Conversion, Pounds of Feed Per Pound of Bird	X	2.00	
Est. Pounds of Feed Consumed, 2002		10,723,200,000	
Corn % of Ration	X	68%	
Est. Pounds of Corn Consumed, 2002		7,291,776,000	
Pounds Per Bushel, Corn	/	56	
Est. Bushels of Corn Consumed, 2002		130,210,286	

Layers For Table Eggs, Corn Consumption Assumptions:

Total Egg Production		684,300	
Average Annual Consumption of Feed	X	267.0	Pounds/1000 eggs
Est. Pounds of Feed Consumed, 2002		182,708,100	
Corn % of Ration	X	60%	
Est. Pounds of Corn Consumed, 2002		109,624,860	
Pounds Per Bushel, Corn	/	56	
Est. Bushels of Corn Consumed, 2002		1,957,587	

Layers For Broilers, Corn Consumption Assumptions:

Total Egg Production		1,596,158	
Average Annual Consumption of Feed	X	500.0	Pounds/1000 eggs
Est. Pounds of Feed Consumed, 2002		798,079,000	
Corn % of Ration	X	68%	
Est. Pounds of Corn Consumed, 2002		542,693,720	
Pounds Per Bushel, Corn	/	56	
Est. Bushels of Corn Consumed, 2002		9,690,959	

*

E. AL Supply/Demand Balance for Corn

Each of the major livestock sector's corn consumption estimates is aggregated into a statewide total (Table 8). It is estimated that AL livestock consumed an average of 149 million bushels of corn in 2002. The poultry industry is by far the most significant, using approximately 142 million bushels for the layer and broiler complexes or 94 percent of the total corn consumed. The second largest animal sector regarding corn consumption is the Swine industry with an average annual level of 3.8 million bushels. The remaining two sectors, catfish and dairy, consume approximately 4 million bushels of corn annually. Interestingly, despite AL being one of the national leaders in catfish production, the sheer volume and weight of poultry animals produced and their voracious appetite for corn distances catfish consumption of corn by a wide margin.

Table 8: Estimate of Total AL Livestock (by major category) Consumption of Corn in 2002

Catfish	2,992,143
Cattle on Feed	*
Dairy	1,218,839
Hogs/Pigs	3,757,071
Poultry	141,858,832
Bushels of Corn Consumed	149,826,885

* Note, cattle on feed in the state is negligible
based on the NASS Annual Survey

The amount of corn consumed by the major livestock sectors has far reaching implications for the potential addition of ethanol production in AL. Based on the estimated annual animal consumption of 149 million bushels of corn in 2002 and an annual AL corn crop of approximately 23 million bushels in 2003, it is fairly conservative to estimate that AL corn is in deficit in the range of 126 million bushels per year. This requires significant corn imports to meet livestock demand. However, this shortage cannot even be met when combining the total corn production of the states of Georgia and Tennessee (about 34 million bushels and 66 million bushels, respectively). Much of the corn for an ethanol plant in north Alabama will have to be transported in from the Corn Belt. Therefore, access to rail and/or barge transportation is a very important siting consideration which will be addressed in a later section.

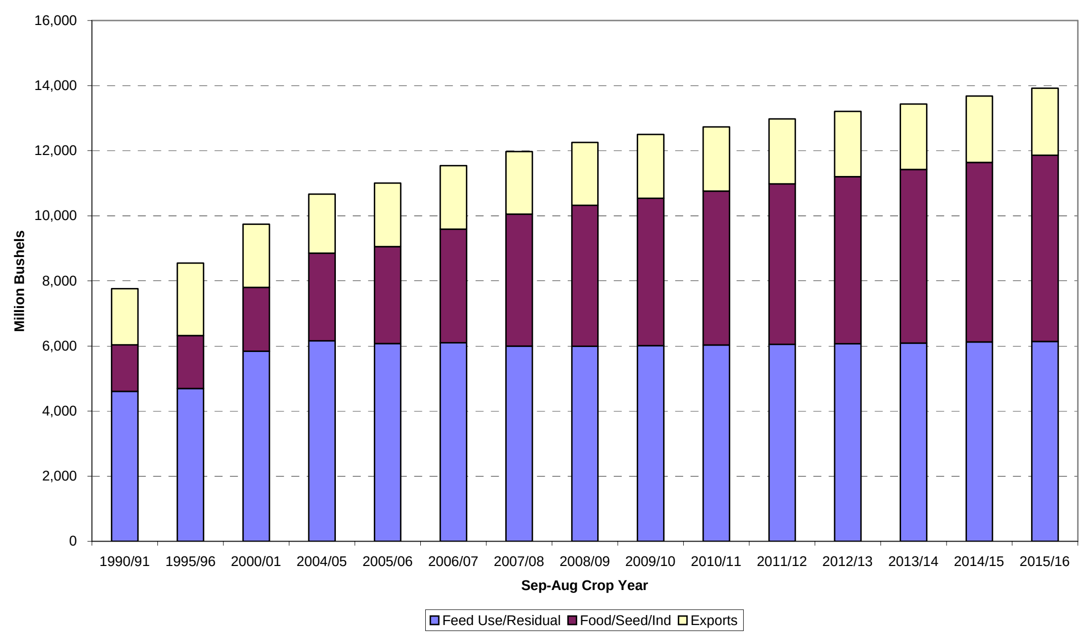
V. U.S. CORN MARKET DYNAMICS AND PRICING

A. CORN PRODUCTION AND CONSUMPTION

Corn is one of the three major row crops grown in the U.S., along with soybeans and wheat. The majority of the U.S. supply of corn comes from domestic production, with very little added to supply via imports (mostly from Eastern Canada). Because of favorable climate and geography, the U.S. is one of the world's major producers of corn, representing 40% of the world's total production.

The feeding of corn to livestock and poultry accounts for more than half of the consumption of corn in the U.S. (Figure 1 and Table 1). Corn is by far the dominant feed grain used in the U.S.; substitution of other grains for corn is a function of availability, nutritional content and price.

Historically, exports of corn also have been an important source of demand, although exports have been relatively stagnant since the end of the 1995/96 crop marketing year, staying within a range of 1.5 to 2.0 billion bushels annually. In the U.S., the marketing year for corn begins in September, when harvest gears up on a large scale, and ends in August of the following year. Corn exports vary from year to year due to a variety of factors, including domestic supply as well as available supply from competing countries (China, Argentina, South Africa and minor amounts from other countries). Since 1980, the "industrial" use of corn, which includes processing for ethanol, has grown significantly. Still, this category accounts for only 25% of corn consumption.



Source: USDA (Historical), Informa (Forecast)

Figure 1: Composition of U.S. Corn Consumption (Marketing Year)

Table 1: U.S. Corn Supply and Demand

	1990/91	1995/96	2000/01	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Planted Area (mil. acres)	74.2	71.5	79.6	80.9	81.8	78.1	84.0	86.0	86.5	87.5	87.5	87.5	87.5	88.0	87.5
Harvested Area	67.0	65.2	72.4	73.6	75.1	71.0	77.0	79.0	79.5	80.5	80.5	80.5	80.5	81.0	80.5
Harvested Yield (bu/acre)	118.5	113.5	136.9	160.4	147.9	150.8	153.0	155.3	157.6	160.0	162.4	164.8	167.3	169.8	172.4
Beginning Stocks (mil. bu)	1,344	1,558	1,718	958	2,114	2,231	1,408	1,223	1,248	1,288	1,448	1,553	1,628	1,673	1,753
Production	7,934	7,400	9,915	11,807	11,112	10,707	11,780	12,270	12,530	12,880	13,070	13,270	13,470	13,750	13,870
Imports	3	16	7	11	10	10	10	10	10	10	10	10	10	10	10
Total Supply	9,281	8,974	11,639	12,776	13,236	12,948	13,198	13,503	13,788	14,178	14,528	14,833	15,108	15,433	15,633
Feed Use/Residual	4,608	4,692	5,842	6,160	6,075	6,100	6,000	5,990	6,010	6,030	6,050	6,070	6,090	6,120	6,140
Food/Seed/Industrial	1,425	1,628	1,957	2,688	2,980	3,490	4,050	4,330	4,530	4,730	4,930	5,130	5,330	5,520	5,720
Total Domestic Disappearance	6,033	6,320	7,799	8,848	9,055	9,590	10,050	10,320	10,540	10,760	10,980	11,200	11,420	11,640	11,860
Exports	1,727	2,228	1,941	1,814	1,950	1,950	1,925	1,935	1,960	1,970	1,995	2,005	2,015	2,040	2,060
Total Disappearance	7,760	8,548	9,740	10,662	11,005	11,540	11,975	12,255	12,500	12,730	12,975	13,205	13,435	13,680	13,920
Ending Stocks	1,521	426	1,899	2,114	2,231	1,408	1,223	1,248	1,288	1,448	1,553	1,628	1,673	1,753	1,713
Stocks/Use	20%	5%	19%	20%	20%	12%	10%	10%	10%	11%	12%	12%	12%	13%	12%

Million bushels, except area in million acres, yield in bushels/acre
Exports are based on inspections for all countries except Canada and Mexico, which are based on Census export statistics.
Sources: USDA (Historical), Informa (Forecasts)

B. CORN PRICING

1. The Role of Futures in Corn Pricing and Risk Management

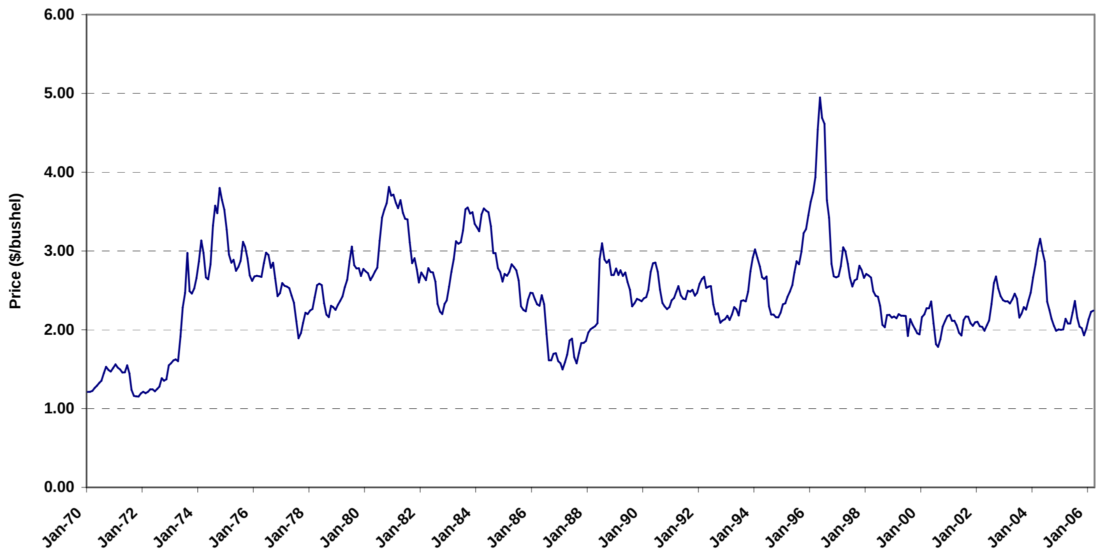
Participants in the physical market for corn can use corn futures and options contracts traded on the Chicago Board of Trade (CBOT) to manage, or "hedge," the risk related to the price they pay (or receive) for corn. Additionally, the CBOT futures price is essentially viewed as a world reference price for corn, given the position of the U.S. as the world's largest corn producer, as well as the liquidity and efficiency of the futures market.

In a conventional hedge, a position in the physical commodity is offset by taking an equal but opposite position in the futures market (or in options). For example, if 10,000 bushels of corn are purchased and held in inventory, 10,000 bushels of CBOT corn futures will be sold as an offset to the physical transaction. When the physical corn is sold or consumed, the original futures position is offset by purchasing a like amount of futures.

Still, not all of the price risk of owning (or selling) corn can be transferred to the futures market. For example, in aggregate, 93% of the risk associated with the prices farmers receive for corn can be transferred via hedging to the futures market, leaving a residual risk of 7%. The higher the correlation, the better the futures contract acts as a hedge for the physical commodity. The conventional view is that to be an effective hedge for a commodity, the price correlation (as measured by the R-squared statistic) should be 80% or preferably higher. The difference between the cash corn price at a specific location and the CBOT futures price is referred to as the basis; therefore, the residual price risk in the physical commodity market that cannot be managed through the use of futures is referred to as the basis risk.

“Nearby” corn futures refer to the futures contract closest to expiration. For example, March futures would serve as the nearby contract during January and February of any given year, since contracts are not traded with delivery during those months.

Weather had a substantial impact on futures prices in the 1980/81, 1983/84 and 1988/89 crop years, when poor crops resulted in high prices (Figure 2). In 1995/96, a drop in production coincided with very strong export demand, resulting in record prices that briefly hit $5/bushel. As noted previously, corn consumption tends to grow at a relatively stable rate, and as such, changes in supply (usually due to weather) are the main determinants of price volatility. Following record production in 2004 of 11.8 billion bushels and an 11.1-billion-bushel crop in 2005, futures prices have averaged $2.14 thus far in the current 2005/06 crop year.



Source: Chicago Board of Trade

Figure 2: Monthly Nearby Corn Futures

A fundamental driver of the price of corn is the ratio of stocks to use, that is, inventories at the end of the crop marketing year divided by total consumption during the year. Ending stocks are viewed by the industry as the “cushion” or “buffer” stocks available to incorporate increases in demand or reductions in supply in the following crop year. The larger the level of ending stocks, the more comfortable the market will be with a given level of demand. Corn prices tend to weaken when supplies are plentiful relative to usage, whereas they strengthen when stocks are drawn down compared to demand.

2. Corn Price Forecast

a. Agricultural Policy Foundation to the Forecast

Whereas farmers previously had been constrained in their acreage allocation decisions by government-designated base acres and acreage set-asides, the 1996 Farm Bill allowed producers nearly total planting flexibility and ended set-aside programs. This policy has been continued in the 2002 Farm Bill, which is effective through the 2007 crop. Farmers are permitted to plant their acreage to virtually any crop without losing program benefits, but are proscribed from planting certain fruits and vegetables. Over the last decade, U.S. acreage of corn has been sustained at levels similar to those experienced prior to the 1996 Farm Bill.

The 2002 Farm Bill provides direct government income support to eligible feed grain producers. In addition, subsidized crop and revenue insurance continue to be an important source of risk management to farmers. Feed grain producers also indirectly benefit from government programs promoting ethanol, trade liberalization and food aid.

Looking ahead, it is likely that government support for feed grains will continue in some form beyond 2007, though federal budget deficits might necessitate reductions in the level of support across a broad swath of commodities. The political base for agriculture remains strong, and corn is recognized as a critical element in the U.S. agricultural system. Unlike other crops such as cotton and sugar, government support for corn is considered less trade distorting, and thus less subject to change due to trade negotiations.

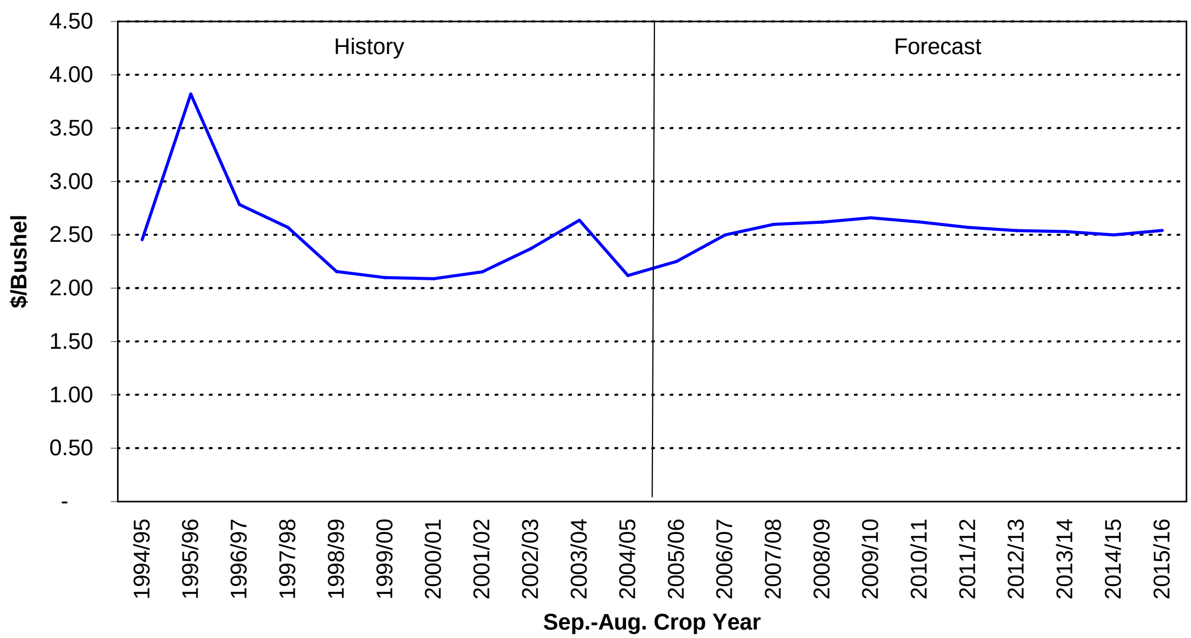
b. The Role of the Ethanol Industry

As discussed in detail in Section IV of this report, ethanol production is expected to continue to expand significantly, with volumes even higher than those mandated by the Renewable Fuels Standard contained in the Energy Policy Act of 2005, given current strong industry margins. This will bolster the consumption of corn (and sorghum as well) over the coming decade. Additionally, corn exports are expected to rebound to the top of their recent range, but not reach the levels of 1995/96, and the potential exists for the industrial usage of corn to grow not only due to ethanol but perhaps a resolution of sweetener trade issues, which would be favorable to the production of high fructose corn syrup. On the supply side, acreage levels are forecast to expand in response to ethanol-driven demand, and trend yield increases are expected to continue, implying tightened but sufficient inventories, assuming normal weather. Acreage is expected to trend higher at the expense of wheat and possibly cotton and soybeans, where the U.S. does not have as great a production advantage as in corn. Yield estimates are based on long-term trend increases that reflect incremental improvements in technology (e.g., better seeds) and management practices.

c. Price Forecast

As explained previously, the ratio of year-end stocks of corn to the quantity of corn used during the September-August crop year is a key determinant of prices. Following the record 11.8 billion bushel corn crop harvested in the fall of 2004, corn futures prices fell from their 2003/04 level of $2.63/bushel to an average of $2.12/bushel during the 2004/05 crop year, when the ending stocks-to-use ratio is estimated to have been 20%, which is relatively high by recent historical standards (refer back to Table 1). Stocks-to-use levels are forecast to remain near 20% in the current 2005/06 crop year following another large crop estimated at 11.1 billion bushels. The stocks-to-use ratio is then expected to recede to 12% in 2006/07, as a result of the reduction in planted acreage estimated by the USDA and a significant increase in corn usage for ethanol production, and in subsequent years the stocks-to-use ratio is forecast to remain between 10% and 13%, given continued growth in ethanol.

As a result of these fundamental supply/demand factors, futures are forecast to increase to an average of $2.25/bushel in the current 2005/06 crop year, to $2.56/bushel in 2006/07 and then to $2.66/bushel by 2009/10 (Figure 3). In the latter half of the forecast period, the futures price is expected to recede moderately to $2.54/bushel by 2015/16.



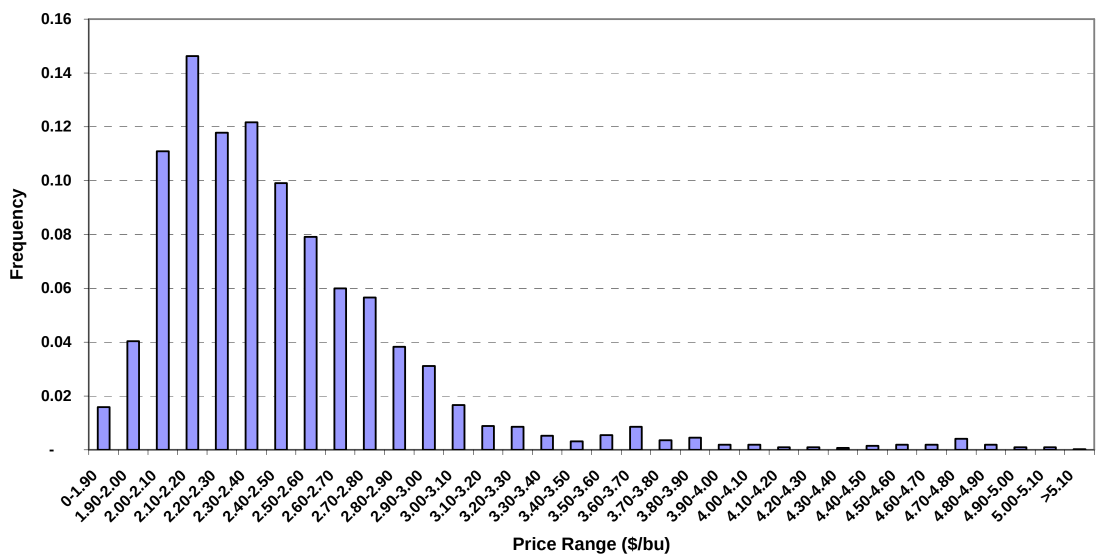
Source: CBOT (History), Informa (Forecast)

Figure 3: CBOT Price History and Forecast

d. High and Low Price Scenarios

As discussed previously, the baseline corn price forecasts are made assuming normal weather. The most significant source of risk to the corn price in any given year is abnormal weather that causes low yields and higher-than-expected prices. Changes in demand and policy developments, which can also affect prices, usually act more slowly.

As shown in Figure 4, the historical distribution of nearby corn futures prices is skewed positively. That is, futures prices are not normally distributed, but rather the distribution is truncated on the left because there is a fundamental value for corn below which prices are resistant to falling, whereas there is a long “tail” on the right since there is substantial upside potential for prices in years when there is a weather problem (or secondarily a large increase in demand).



Source: CBOT

Figure 4: Distribution of Daily Nearby Corn Futures Prices, September 1989-Present

Based on the baseline corn price forecast and the price distribution shown in Figure 4, a confidence interval encompassing 80% of the price outcomes was utilized to develop high and low price scenarios. Since corn prices are not normally distributed, the structure of the confidence interval differs somewhat from the common use of the mean plus or minus one or two standard deviations. Rather, due to the positive skew of the distribution, the high price limit of the confidence interval will be farther from the mean than the low price limit will be from the mean.

Because the size of the crop for the 2005/06 crop year is known and the demand for roughly two-thirds of the year is already known, the high and low price bands for this year were based on Informa's estimate of variance within a crop year, which is substantially lower than the variance across multiple crop years. The low end of the confidence interval for futures prices is $2.11/bushel, while the high end is $2.62/bushel. Then, for 2006/07, the baseline futures price forecast is $2.50/bushel, while the low end of the confidence interval is $2.17/bushel and the high end is $3.39/bushel (Table 2 and Table 3, which has been adjusted to calendar year format). By 2015/16, the low end of the confidence interval increases to $2.21/bushel, while the high end increases to $3.43/bushel.

Table 2: Baseline, Low and High Forecasts of Futures Corn Prices (Aug.-Sep. Crop Year)

Crop Year	Baseline	Low	High
1994/95	2.46		
1995/96	3.82		
1996/97	2.78		
1997/98	2.57		
1998/99	2.16		
1999/00	2.10		
2000/01	2.09		
2001/02	2.15		
2002/03	2.37		
2003/04	2.64		
2004/05	2.12		
2005/06	2.25	2.11	2.62
2006/07	2.50	2.17	3.39
2007/08	2.60	2.27	3.49
2008/09	2.62	2.29	3.51
2009/10	2.66	2.33	3.55
2010/11	2.62	2.29	3.51
2011/12	2.57	2.24	3.46
2012/13	2.54	2.21	3.43
2013/14	2.53	2.20	3.42
2014/15	2.50	2.17	3.39
2015/16	2.54	2.21	3.43

Shaded area indicates Informa forecast
Sources: CBOT (History), Informa (Forecast)

Table 3: Baseline, Low and High Forecasts of Futures Corn Prices (Calendar Year)

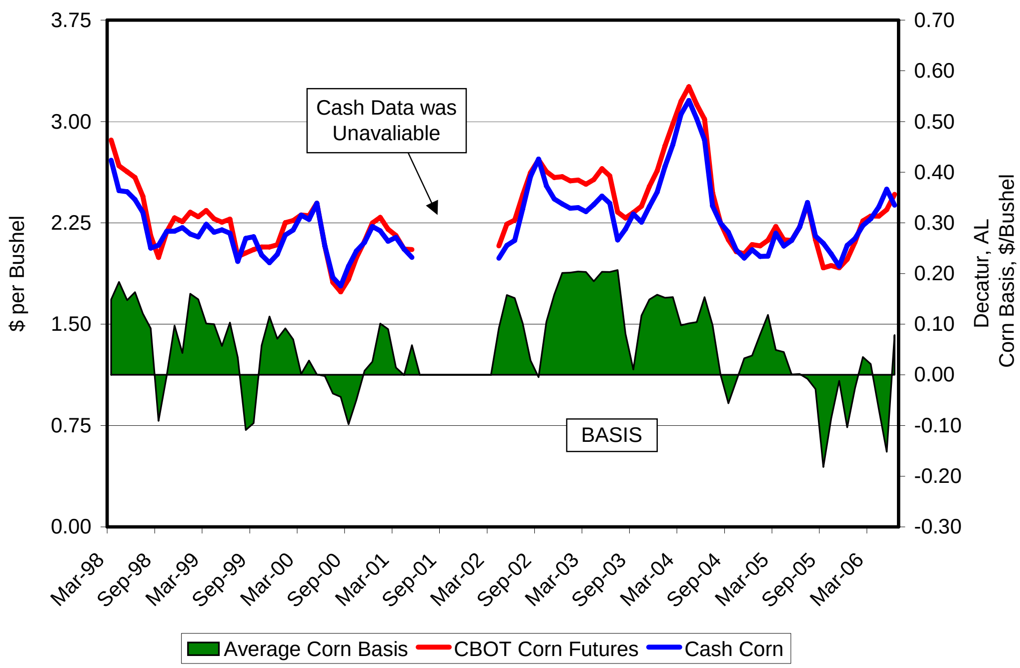
Calendar Year	Baseline	Low	High
1994	2.50		
1995	2.81		
1996	3.68		
1997	2.75		
1998	2.38		
1999	2.11		
2000	2.11		
2001	2.10		
2002	2.28		
2003	2.34		
2004	2.54		
2005	2.11		
2006	2.38	2.24	2.75
2007	2.53	2.26	3.28
2008	2.61	2.33	3.35
2009	2.63	2.36	3.38
2010	2.65	2.37	3.39
2011	2.60	2.33	3.35
2012	2.56	2.29	3.30
2013	2.54	2.26	3.28
2014	2.52	2.25	3.26
2015	2.52	2.24	3.26

Shaded area indicates Informa forecast
Sources: CBOT (History), Informa (Forecast)

e. North Alabama Basis

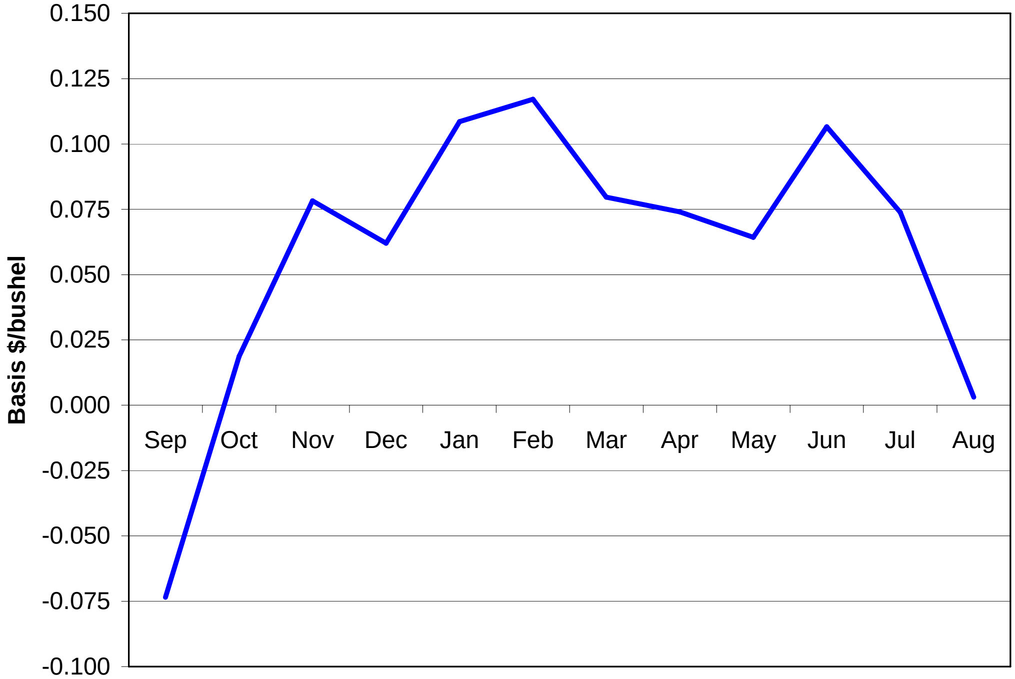
In the financial analyses section of this report, the projected CBOT futures prices in Table 3 were adjusted for the projected corn basis at Decatur, AL. As indicated in earlier sections on Alabama corn supply and demand, north Alabama has a very large corn deficit. North Alabama produces an average of 9 to 10 million bushels of corn per year and the poultry industry alone in Alabama uses over 140 million bushels of corn per year, most of which is transported in by barge and rail. Therefore, the price for corn in north Alabama is dominated by the prices paid by the poultry industry for corn transported into north Alabama by barge and rail. Barging and railing in an additional 18 million bushels of corn per year from the Corn Belt for a 50 million gallon per ethanol plant is not likely to significantly affect the local corn basis relative to CBOT futures prices. This contrasts with Corn Belt ethanol plants which rely on local corn supplies and generally increase the local corn basis. Therefore, the historical Decatur, AL corn basis should be applicable for projecting north Alabama corn prices based on CBOT futures prices.

Decatur, AL farm corn prices, CBOT corn futures prices, and the associated corn basis for 1998 to 2005 are presented in Figure 5. The average monthly corn basis for the same time period is presented in Figure 6, indicating that the basis has tended to be lower from August through October than during the rest of the year. The corn basis at Decatur, AL has generally declined from 1998 to 2006 (Figure 7) and the average basis for that period was $0.06/bu (Table 4). Therefore, the average corn basis should be a conservative value for projecting Decatur corn prices for the next ten years. In the subsequent financial analyses of Decatur ethanol plant scenarios, projected corn prices are based on a corn basis of $0.06/bu relative to the CBOT futures corn price projections discussed above.



Source: Informa Economics.

Figure 5. Decatur, AL farm corn prices, CBOT corn futures prices, and associated Decatur, AL corn basis for 1998-2006.



Source: Informa Economics.

Figure 6. Average Monthly Corn Basis for Decatur, AL (MAR 98 to JUN 06)

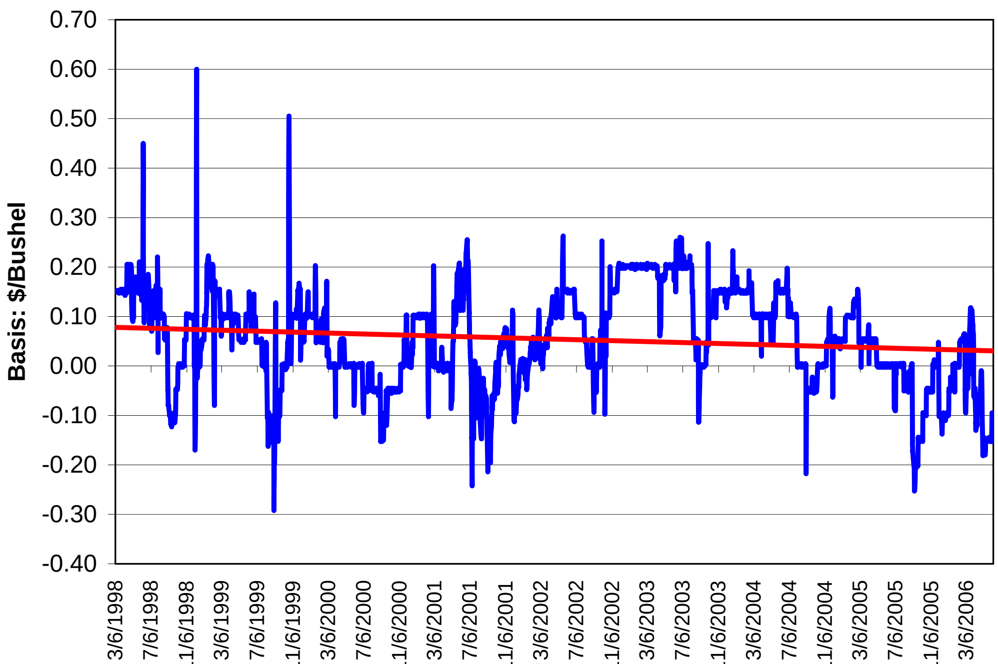


Figure 7. Trend in Decatur, AL Corn Basis (Daily: 3/6/1998 to 6/5/2006)

Table 4: Summary of Decatur, Alabama Cash and CBOT Futures Corn Prices

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Avg
Cash Price													
1997/98							2.86	2.67	2.63	2.59	2.45	2.15	2.56
1998/99	1.99	2.19	2.29	2.26	2.33	2.30	2.34	2.28	2.26	2.28	2.00	2.03	2.21
1999/00	2.05	2.07	2.07	2.09	2.25	2.27	2.31	2.30	2.40	2.08	1.81	1.74	2.12
2000/01	1.83	1.99	2.12	2.25	2.29	2.20	2.16	2.06	2.05				2.11
2001/02								2.08	2.24	2.27	2.46	2.62	2.33
2002/03	2.72	2.63	2.59	2.59	2.56	2.57	2.54	2.57	2.65	2.60	2.33	2.29	2.55
2003/04	2.33	2.37	2.52	2.64	2.82	2.98	3.15	3.26	3.13	3.02	2.47	2.25	2.74
2004/05	2.12	2.04	2.02	2.09	2.08	2.12	2.22	2.12	2.12	2.22	2.39	2.12	2.14
2005/06	1.92	1.93	1.92	1.98	2.11	2.26	2.30	2.30	2.35	2.46			2.15
Average	2.14	2.17	2.22	2.27	2.35	2.39	2.48	2.40	2.42	2.44	2.27	2.17	2.31
CBOT Corn Futures													
1997/98							2.71	2.49	2.48	2.42	2.33	2.06	2.42
1998/99	2.08	2.19	2.19	2.21	2.17	2.15	2.24	2.18	2.20	2.17	1.97	2.14	2.16
1999/00	2.15	2.01	1.96	2.02	2.16	2.20	2.31	2.27	2.40	2.08	1.85	1.78	2.10
2000/01	1.93	2.04	2.11	2.22	2.19	2.11	2.14	2.06	1.99				2.09
2001/02								1.99	2.08	2.12	2.35	2.59	2.23
2002/03	2.72	2.52	2.43	2.39	2.36	2.36	2.33	2.39	2.45	2.39	2.12	2.20	2.39
2003/04	2.31	2.26	2.37	2.48	2.67	2.83	3.05	3.16	3.02	2.86	2.37	2.25	2.64
2004/05	2.18	2.05	1.99	2.05	2.00	2.00	2.17	2.08	2.12	2.22	2.40	2.15	2.12
2005/06	2.10	2.02	1.93	2.08	2.13	2.23	2.28	2.37	2.50	2.38			2.20
Average	2.21	2.16	2.14	2.21	2.24	2.27	2.41	2.33	2.36	2.33	2.20	2.17	2.25
Basis													
1997/98							0.15	0.18	0.15	0.16	0.12	0.09	0.14
1998/99	-0.09	0.00	0.10	0.04	0.16	0.15	0.10	0.10	0.06	0.10	0.03	-0.11	0.05
1999/00	-0.10	0.06	0.11	0.07	0.09	0.07	0.00	0.03	0.00	0.00	-0.04	-0.04	0.02
2000/01	-0.10	-0.05	0.01	0.03	0.10	0.09	0.01	0.00	0.06				0.02
2001/02								0.09	0.16	0.15	0.10	0.03	0.11
2002/03	0.00	0.10	0.16	0.20	0.20	0.20	0.20	0.18	0.20	0.20	0.21	0.08	0.16
2003/04	0.01	0.12	0.15	0.16	0.15	0.15	0.10	0.10	0.10	0.15	0.10	0.00	0.11
2004/05	-0.06	-0.01	0.03	0.04	0.08	0.12	0.05	0.04	0.00	0.00	-0.01	-0.03	0.02
2005/06	-0.18	-0.09	-0.01	-0.10	-0.03	0.04	0.02	-0.07	-0.15	0.08			-0.05
Average	-0.07	0.02	0.08	0.06	0.11	0.12	0.08	0.07	0.06	0.11	0.07	0.00	0.06

Note: shaded area represents cash data that was not available.
Source: DTN

f. Central Illinois Basis

In subsequent financial analyses of ethanol plant scenarios, a Decatur, AL location will be compared with a Pekin, IL location. The corn basis for 1998 to 2006 at Pekin, IL is presented in Figure 8. In contrast to Decatur, AL, there has been a general up trend in the corn basis at Pekin, IL. The average corn basis for 1998 to 2006 was $-0.05/bu (Table 5). The corn basis in the Corn Belt likely will continue to increase over the next ten years due to rapid expansion of ethanol production in the area. In the subsequent financial analyses, we assume an average corn basis of $0.00/bu over the next 10 years.

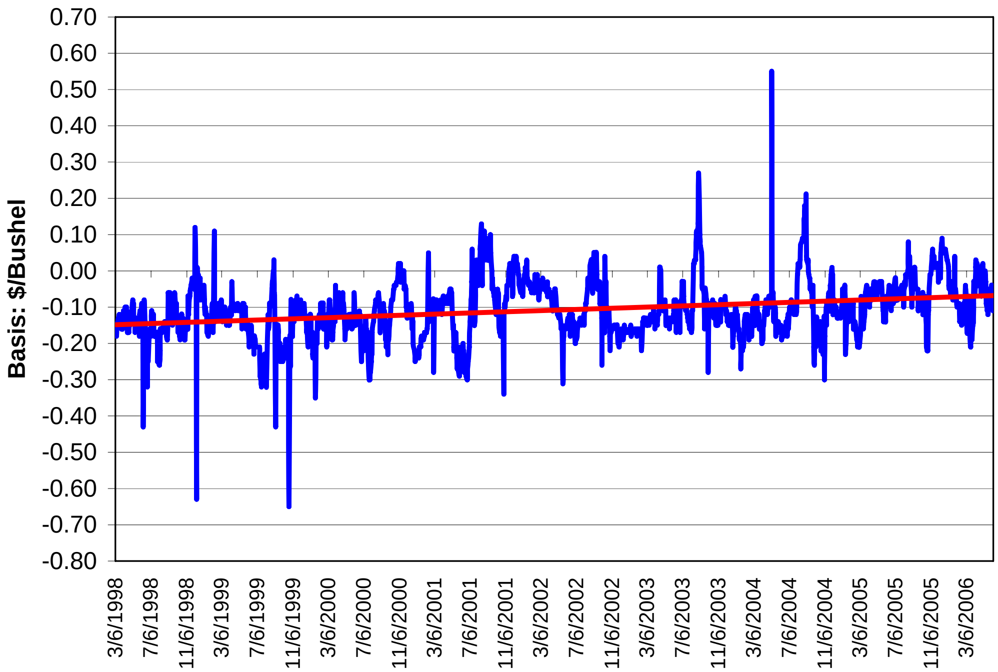


Figure 8. Trend in Pekin, IL Corn Basis (Daily: 3/6/1998 to 6/5/2006)

Table 5: Summary of Pekin, Illinois Cash and CBOT Futures Corn Prices

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Avg
Cash Price													
1997/98							2.72	2.54	2.50	2.40	2.30	1.97	2.41
1998/99	1.89	2.03	2.20	2.19	2.19	2.18	2.22	2.18	2.15	2.10	1.75	1.90	2.08
1999/00	1.86	1.83	1.95	1.97	2.07	2.15	2.18	2.21	2.26	1.94	1.60	1.62	1.97
2000/01	1.68	1.93	2.09	2.11	2.08	2.07	2.06	1.98	1.90				1.99
2001/02								2.02	2.06	2.14	2.31	2.58	2.22
2002/03	2.70	2.50	2.42	2.42	2.39	2.41	2.40	2.45	2.51	2.48	2.23	2.29	2.43
2003/04	2.29	2.26	2.43	2.49	2.64	2.84	3.03	3.16	3.04	2.84	2.37	2.32	2.64
2004/05	2.07	1.85	1.93	1.98	1.98	1.98	2.10	2.07	2.05	2.15	2.35	2.10	2.05
2005/06	1.86	1.81	1.93	2.02	2.06	2.15	2.18	2.28	2.29	2.36			2.10
Average	2.05	2.03	2.14	2.17	2.20	2.26	2.36	2.32	2.31	2.30	2.13	2.11	2.20
CBOT Corn Futures													
1997/98							2.71	2.49	2.48	2.42	2.33	2.06	2.42
1998/99	2.08	2.19	2.19	2.21	2.17	2.15	2.24	2.18	2.20	2.17	1.97	2.14	2.16
1999/00	2.15	2.01	1.96	2.02	2.16	2.20	2.31	2.27	2.40	2.08	1.85	1.78	2.10
2000/01	1.93	2.04	2.11	2.22	2.19	2.11	2.14	2.06	1.99				2.09
2001/02								1.99	2.08	2.12	2.35	2.59	2.23
2002/03	2.72	2.52	2.43	2.39	2.36	2.36	2.33	2.39	2.45	2.39	2.12	2.20	2.39
2003/04	2.31	2.26	2.37	2.48	2.67	2.83	3.05	3.16	3.02	2.86	2.37	2.25	2.64
2004/05	2.18	2.05	1.99	2.05	2.00	2.00	2.17	2.08	2.12	2.22	2.40	2.15	2.12
2005/06	2.10	2.02	1.93	2.08	2.13	2.23	2.28	2.37	2.50	2.38			2.20
Average	2.21	2.16	2.14	2.21	2.24	2.27	2.41	2.33	2.36	2.33	2.20	2.17	2.25
Basis													
1997/98							0.00	0.05	0.02	-0.02	-0.03	-0.09	-0.01
1998/99	-0.20	-0.15	0.01	-0.02	0.03	0.04	-0.02	0.00	-0.05	-0.08	-0.21	-0.23	-0.07
1999/00	-0.29	-0.18	0.00	-0.05	-0.09	-0.05	-0.13	-0.06	-0.14	-0.13	-0.24	-0.17	-0.13
2000/01	-0.25	-0.11	-0.01	-0.11	-0.11	-0.04	-0.08	-0.07	-0.10				-0.10
2001/02								0.03	-0.02	0.02	-0.05	-0.02	-0.01
2002/03	-0.02	-0.03	0.00	0.03	0.04	0.05	0.07	0.06	0.07	0.09	0.11	0.08	0.04
2003/04	-0.02	0.00	0.05	0.01	-0.02	0.01	-0.02	0.00	0.02	-0.02	-0.01	0.07	0.01
2004/05	-0.11	-0.20	-0.06	-0.07	-0.02	-0.03	-0.07	-0.01	-0.07	-0.07	-0.05	-0.05	-0.07
2005/06	-0.23	-0.21	0.00	-0.06	-0.07	-0.08	-0.10	-0.09	-0.21	-0.02			-0.11
Average	-0.16	-0.12	0.00	-0.04	-0.04	-0.01	-0.04	-0.01	-0.05	-0.03	-0.07	-0.06	-0.05

Note: shaded area represents cash data that was not available for the Decatur, Al location.
Source: DTN

VI. DISTILLERS GRAINS MARKET AND PRICING

A. BACKGROUND

In the dry-mill process for producing ethanol, the starch portion of the kernel is largely converted to ethanol, while the remaining material – mainly fiber and protein – is referred to as distillers grains and is usually sold as livestock feed. "Usually, (distillers grains) are dried to yield dried distillers grains (DDG), or dried distillers grains with solubles (DDGS) if solubles in the thin stillage are added back to the grains at drying. The solubles in the thin stillage may also be partially or totally dried to make condensed distillers solubles (CDS) or dried distillers solubles (DDS), respectively. Of these co-products, DDG and DDGS are the most commonly used, probably because of ease of handling, storage, and shipping." Since DDGS is the most common form in the market, it will be used in this report as the "common denominator" of this group of co-products.

B. UNITED STATES DDGS SUPPLY AND DEMAND

Domestic consumption of DDGS has risen along with the expansion of the ethanol industry during the last 15 years. Still, the volumes involved have been small compared with the overall size of the feed ingredient market, which includes feed grains, protein meals and non-grain feed ingredients (a category that includes DDGS).

In the mid-1990s, approximately 1.5 million tons (short tons) of distillers grains were produced in the U.S., according to Informa estimates. (This estimate is expressed in DDGS-equivalent production, given the different forms in which the co-product can be produced). Production of distillers grains roughly doubled by crop year 1999/2000, reaching 3.0 million tons of DDGS equivalent. Given that a large majority of the tremendous expansion of U.S. ethanol capacity over the last few years has come through the construction of dry mills, Informa estimates that production rose to 9.7 million tons of DDGS equivalent in crop year 2004/05.

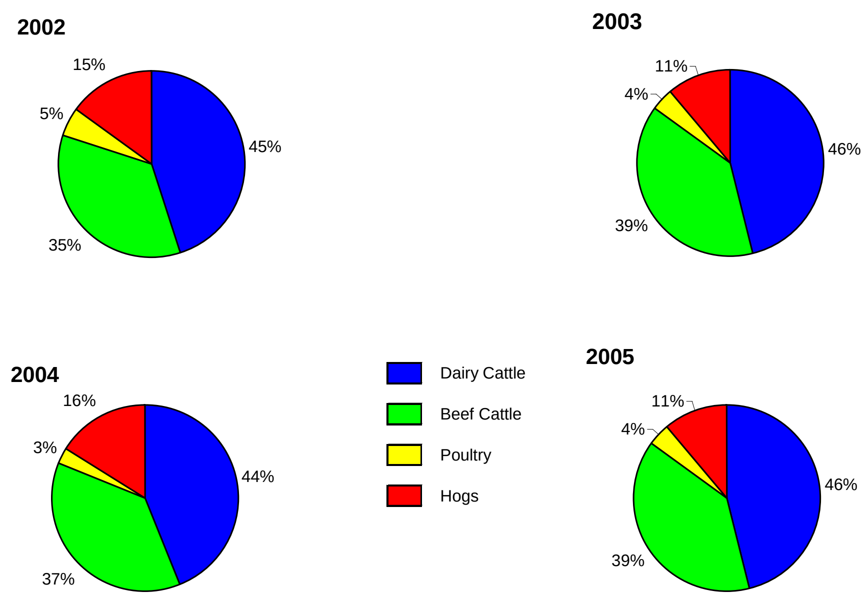
Almost all of the increase in DDGS volume has been consumed domestically, as the export market for DDGS has remained relatively flat. Exports have remained in a range between 580,000 tons and 1.2 million tons over the last decade. Since the reform of the European Union's (EU) Common Agricultural Policy in the mid-1990s resulted in a reduction in internal grain prices, this formerly important market for corn processing co-products has become substantially less attractive. Still, considerable efforts have been made during the last few years to develop export markets for DDGS, particularly in Asia and South America (Canada also remains a notable market, though one with expanding domestic ethanol production), and the potential exists for moderately higher exports in the future as these efforts strengthen demand and the geography of U.S. ethanol production continues to expand, with more plants such as the one considered for north Alabama in position to serve export markets.

DDGS is a middle-protein feed with a minimum crude protein content of approximately 30% (for older facilities, the crude protein content is roughly 27%).

Traditionally, the primary market outlet for distillers grains has been in feed rations for beef and especially dairy cattle, as its composition limits the inclusion rate in feed (i.e., the percentage of the feed ration that is accounted for by DDGS) for monogastric animals, particularly hogs and poultry. The high ruminally undegradable protein content of DDGS (52% of crude protein is ruminally undegradable) makes it particularly suitable for feeding to dairy cattle. As such, the theoretical nutritional value attributed by researchers to DDGS tends to be highest for dairy cattle compared to beef cattle and other species.

Maximum inclusion rates of DDGS cited in reports from feeding trials conducted by nutritionists tend to be considerably higher in cattle than monogastrics, at 35% for cattle on feed and 30% for dairy cows, compared to 15% for hogs and 12% for broilers. (There is some variation in these recommendations based on the stage in the animal's life cycle.) However, in practice, typical inclusion rates are considerably lower than the maximums that nutritionists indicate are allowable. Typical rates are 11% of the ration for cattle on feed, 12% for dairy cattle, 11% for hogs and up to 10% for broilers.

Given typical feeding patterns and the relative value in the rations for different species, a large majority of distillers grains consumption is still accounted for by dairy and beef cattle, despite the large increase in production. According to industry estimates, in 2004 dairy and beef cattle accounted for 85% of the distillers grains consumed domestically (see Figure 1).



Sources: Steve Markham, Commodity Specialists Co., via G.C. Shurson, Department of Animal Science, University of Minnesota, "Supply and Demand of U.S. DDGS," presented in South Korea, March 7-11, 2005, and Renewable Fuels Association, "Ethanol Industry Outlook 2006."

Figure 1: U.S. Consumption of Distillers Grains by Species

Still, both the percentage share and the absolute volume of distillers grains consumed by monogastric animals have increased significantly in recent years. This is especially the case for the swine market, which accounted for less than 4% of distillers grains consumption in 2001 but grew to 16% of the total by 2004 (the share receded to 11% in 2005, but given the growth in DDGS production, the absolute volume consumed by swine likely held relatively steady). This is due not only to efforts by marketing firms to broaden sales of distillers grains but also to an initiative by certain animal scientists, most notably Dr. Jerry Shurson and collaborating researchers at the University of Minnesota and other Land Grant Universities, to perform the basic feeding research necessary to convince hog operations (and their nutritionists) that distillers grains can be a useful and economical feed ingredient in swine rations.

The level of consumption in poultry has been increasing as well, estimated at 4% of domestic consumption in 2005. However, the volume consumed by poultry has been constrained by the single-digit inclusion rates recommended by nutritionists and the lower perceived value in poultry feed versus cattle rations, as well as the fact that ethanol production has historically been concentrated in a different geographic area than broiler production.

In a telephone survey, the nutritionists at poultry companies virtually all had positive opinions of conventional DDGS, so long as the DDGS were from a facility with modern drying technology that produced DDGS with a golden color rather than over-drying it and degrading the amino acids. Some of the companies use DDGS at their operations closer to the Corn Belt, but DDGS have not often priced into poultry rations in north Alabama. This is likely due to the fact that there are no ethanol dry-mills near north Alabama, and so the transportation cost per ton makes DDGS cost prohibitive; looked at in another way, the netback price (market sales price minus transportation costs) to dry-mills from selling their DDGS into north Alabama would not be attractive relative to other market outlets due to the freight cost that would have to be deducted from the price at the destination. An ethanol plant located in north Alabama would have a significant transportation advantage for local use of DDGS for use in poultry feed.

C. MARKETS AROUND NORTH ALABAMA

The largest potential market for DDGS in north Alabama is for broiler production. Additionally, there are moderate inventories of table and hatching layers located in Alabama. The maximum potential use of DDGS for poultry in Alabama is approximately 260,000 tons per year (Table 1). Hogs and cattle potentially can provide an additional market for about 80,000 tons DDGS per year in Alabama. A 50 million gallon per year ethanol plant would produce about 165,000 tons DDGS per year. Therefore, there is potential to use all the DDGS produced by a north Alabama IPEP ethanol plant within Alabama. Given that most of the Alabama broiler production is in the northern part of the state, there is potential for all the DDGS from a north Alabama IPEP ethanol plant to be used in the northern part of the state. In case the Alabama market potential is not realized, then poultry production in surrounding states would be the next best option. The distribution of broiler production within in a 400 mile radius of Decatur, AL is illustrated in Figure 2. Broiler production in Georgia would be the next best candidate for using DDGS produced in north Alabama with a potential use of about 400,000 tons DDGS per year (Table 2). Dairy cattle in Georgia could potentially use about 250,000 tons DDGS per year and swine could potentially use another roughly 50,000 tons per year.

Table 1: DDGS, Maximum Potential Domestic Consumption, AL

Animal/ Growth Stage	Maximum Inclusion Rate	Total feed/day (lbs.)	Quantity co-products /day (lbs.)	Units	Animal Quantity 2002/2003	Units	Maximum use 2002/2003 (pounds)	Maximum use 2002/2003 (tons)
Poultry								
Growing Broiler Pullets (1)	5.0%		0.096	Lbs.	10,723,200,000	Liveweight	51,471,360	25,736
Broiler Hatching Layers	20.0%		0.500	Lbs. (2)	1,596,158,000	Liveweight	159,615,800	79,808
Broiler Starter	2.5%		0.125	Lbs.	2,905,820,000	Liveweight	9,080,688	4,540
Broiler Finisher	5.0%		1.875	Lbs.	2,905,820,000	Liveweight	272,420,625	136,210
Table Egg Layers	15.0%		0.267	Lbs. (3)	684,300,000	Liveweight	27,406,215	13,703
Total maximum poultry feed use					**18,815,298,000**		**519,994,688**	**259,997**
Hogs and Pigs								
Nursery pigs, under 60 lbs	5.0%	1.15	0.06	Lbs. (4)	67,000	Head	1,406,163	703
Grower pigs, 60-119 lbs	15.0%	4.77	0.72	Lbs.	31,000	Head	8,095,883	4,048
Finish pigs, 120-179 lbs	20.0%	5.06	1.01	Lbs. (5)	28,000	Head	10,342,640	5,171
Hogs and pigs 180 lbs and over	22.0%	6.00	1.32	Lbs.	29,000	Head	13,972,200	6,986
Hogs and pigs for breeding	35.0%	5.00	1.75	Lbs.	10,000	Head	6,387,500	3,194
Developing gilts	20.0%	6.62	1.32	Lbs.	2,000	Head	966,520	483
Total maximum swine feed use					**167,000**		**41,170,905**	**20,585**
Dairy: Cattle and Calves								
Lactating cows	30.0%	50.00	15.00	Lbs.	20,000	Head	109,500,000	54,750
Replacement Heifers	20.0%	14.50	2.90	Lbs.	7,000	Head	7,409,500	3,705
Total maximum cattle feed use					**27,000**		**116,909,500**	**58,455**

(1) Pounds, broilers produced multiplied by 2 lbs. feed per pound liveweight
(2) Per egg produced
(3) Per egg produced
(4) over three phases
(5) over four phases

*Source of data: NASS, Informa ration estimates

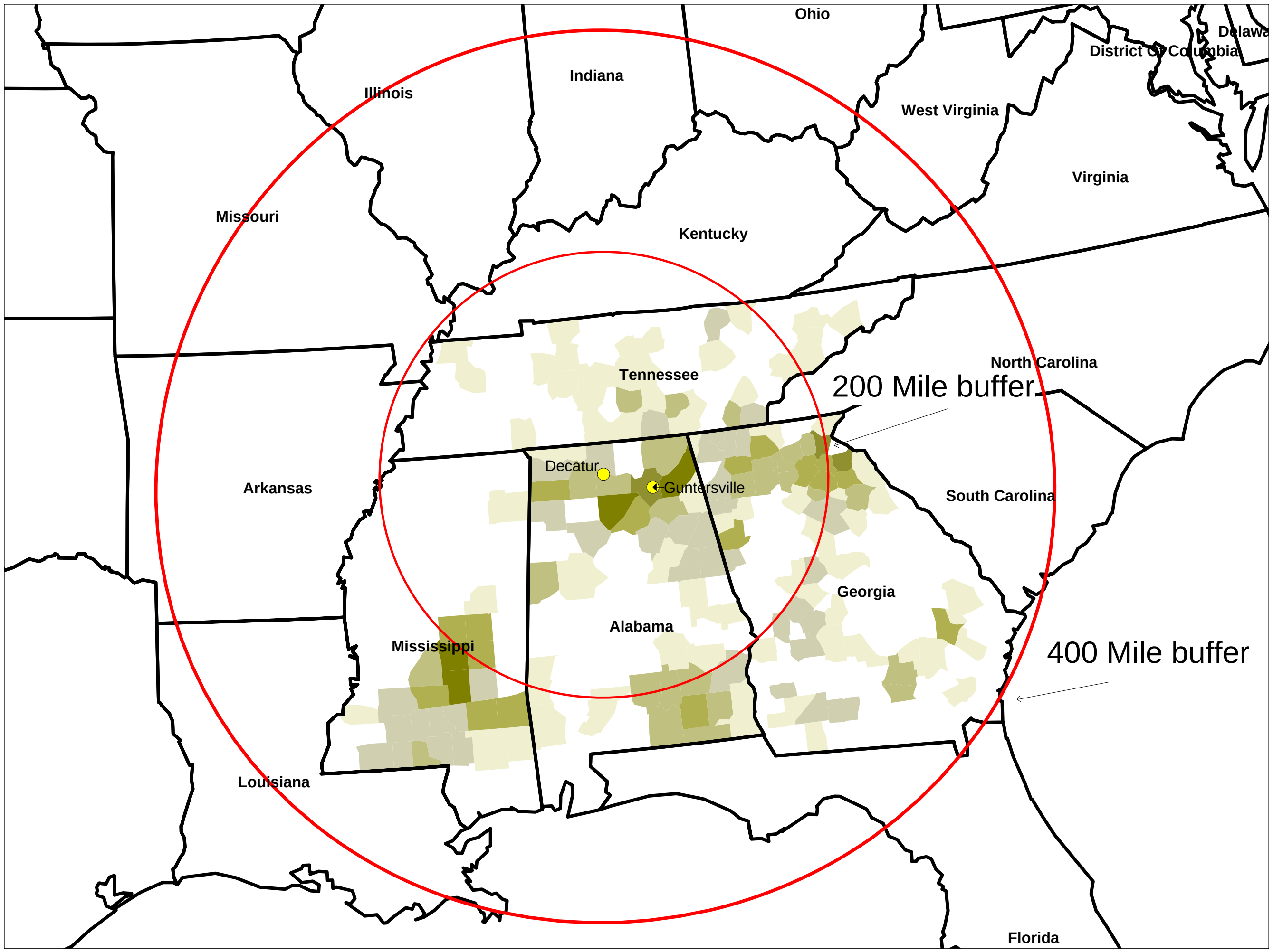


Figure 2: Distribution of broiler production within a 400 mile radius of Decatur, AL.

Table 2: DDGS, Maximum Potential Livestock Consumption, GA

Animal/Growth Stage	Maximum Inclusion Rate	Total feed/day (lbs.)	Quantity co-products /day (lbs.)	Units	Animal Quantity 2002/2003 (000's)	Units	Maximum use 2002/2003 (pounds)	Maximum use 2002/2003 (tons)
Poultry								
Growing Broiler Pullets (1)	5.0%		0.096	Lbs.	12,905,000,000	Liveweight	61,944,000	30,972
Broiler Hatching Layers	20.0%		0.500	Lbs. (2)	3,472,700,000	Liveweight	347,270,000	173,635
Broiler Starter	2.5%		0.125	Lbs.	3,497,255,000	Liveweight	10,928,922	5,464
Broiler Finisher	5.0%		1.875	Lbs.	3,497,255,000	Liveweight	327,867,656	163,934
Table Egg Layers	15.0%		0.267	Lbs. (3)	1,488,300,000	Liveweight	59,606,415	29,803
Total maximum poultry feed use					**24,860,510,000**		**807,616,993**	**403,808**
Hogs and Pigs								
Nursery pigs, under 60 lbs	5.0%	1.15	0.06	Lbs. (4)	133,000	Head	2,791,338	1,396
Grower pigs, 60-119 lbs	15.0%	4.77	0.72	Lbs.	67,000	Head	17,497,553	8,749
Finish pigs, 120-179 lbs	20.0%	5.06	1.01	Lbs. (5)	50,000	Head	18,469,000	9,235
Hogs and pigs 180 lbs and ove	22.0%	6.00	1.32	Lbs.	40,000	Head	19,272,000	9,636
Hogs and pigs for breeding	35.0%	5.00	1.75	Lbs.	55,000	Head	35,131,250	17,566
Developing gilts	20.0%	6.62	1.32	Lbs.	4,485	Head	2,167,421	1,084
Total maximum swine feed use					**349,485**		**95,328,561**	**47,664**
Dairy: Cattle and Calves								
Lactating cows	30.0%	50.00	15.00	Lbs.	85,000	Head	465,375,000	232,688
Replacement Heifers	20.0%	14.50	2.90	Lbs.	29,000	Head	30,696,500	15,348
Total maximum cattle feed use					**114,000**		**496,071,500**	**248,036**

(1) Pounds, broilers produced multiplied by 2 lbs. feed per pound liveweight
(2) Per egg produced
(3) Per egg produced
(4) over three phases
(5) over four phases

*Source of data: NASS, Informa ration estimates

D. DDGS Pricing

1. Historical DDGS Prices

Because there has not historically been significant ethanol production in Alabama, local historical price series for DDGS are not available. The origin market for which DDGS prices have consistently been quoted in which the market is similar to Alabama is in northern Indiana. Informa's publication *Feed Ingredient Daily* has collected and reported prices for DDGS in the Indiana market since 1996. Although there is not a significant amount of broiler production in Indiana, it is the fourth largest egg producing state in the U.S. There are moderate hog inventories and only limited inventories of cattle on feed and dairy cows. Thus, it is assumed that DDGS in the two markets will exhibit similar price relationships to other poultry ration ingredients such as corn and soybean meal.

2. Forecast DDGS Prices

It is expected that DDGS will sell at a significant premium in Alabama and the surrounding areas compared to Indiana because of higher corn and soybean meal prices in Alabama. The corn price forecast was discussed in an earlier section of this report. Soybean meal prices (as measured by CBOT futures) were $250/ton in 2003/04 but fell to $181/ton in 2004/05. Soybean meal prices are forecast to fall to $162/ton in 2005/06 and then increase to $168/ton in 2009/10 and then remain between $158/ton and $166/ton for the rest of the forecast period.

Based on the forecasts of corn and soybean meal prices, f.o.b. plant DDGS prices for a facility in north Alabama are forecast to average $106/ton in 2007, gradually increase to $111/ton in 2010 and then gradually decrease to $108/ton by 2016. This forecast assumes normal weather patterns will be experienced for crops in the U.S. and other major corn- and soybean-producing countries. If a large enough glut of DDGS develops in the Corn Belt, sufficient quantities of Corn Belt DDGS could possibly be shipped to north Alabama to depress DDGS prices to closer to parity with north Alabama corn on a per ton basis.

In subsequent financial analyses of ethanol plant scenarios, a Decatur, AL location will be compared with a Pekin, IL location. The same general approach was used for projecting DDGS prices at Pekin, IL as was described above for Decatur, IL. Based on the forecasts of corn and soybean meal prices, f.o.b. plant DDGS prices for a facility at Pekin, IL are forecast to average $104/ton in 2007, gradually increase to $109/ton in 2010 and then gradually decrease to $103/ton by 2016. If a large enough glut of DDGS develops in the Corn Belt, DDGS prices are likely to be depressed to near parity with corn at Corn Belt locations such as Pekin, IL.

VII. ASSESSMENT OF DRY MILL FRACTIONATION

Ethanol and carbon dioxide result from all of the major process technologies that are used to mill corn and ferment the cornstarch into alcohol. The distillers grains product assessed in the previous section is the other co-product of a conventional dry-milling ethanol facility. Virtually all of the ethanol facilities built over the last decade have been dry-mills. Dry mills require significantly lower capital expenditure and historically had higher ethanol yields than wet mills, which steep the corn in tanks with water before processing and remove the germ (the oil-bearing portion of the kernel) and the high-protein gluten component (sold as corn gluten meal) before producing ethanol and a residual feed product called corn gluten feed. However, there has been increasing interest in fractionation of the corn kernel at dry mills in order to derive a different and more valuable product stream than only producing distillers grains provides.

This interest has been partly spurred by the fact that the corn germ remains in the distillers grains, and thus corn oil, for which crude prices have averaged just under 30 ¢/lb over the last couple of years, is effectively being sold at feed ingredient prices of roughly 5 ¢/lb. Additionally, the presence of the oil has been cited as one reason that DDGS tend to stick together and cause unloading problems when transported by rail over long distances, especially in warm weather.

There are several technologies for fractionating corn at a dry-mill ethanol plant. Some methods involve steeping the corn prior to processing, similar to a wet mill, and utilizing enzymes and specialized grinding. An “advanced” ethanol production facility involving dry fractionation was selected and investigated in a study conducted by the University of Georgia’s Center for Agribusiness and Economic Development, for which the estimation of the production costs and capital expenditures was conducted by the engineering firm of Frazier Barnes & Associates (FB&A). The report indicated that the reason for considering fractionation was so that the facility would have more valuable products to sell, thus offsetting the higher cost of corn in Georgia than in the Corn Belt. This study appears to be equally applicable to north Alabama.

The advanced ethanol production facility would use dry fractionation to remove the germ and bran at the front end of the dry mill. According to the report,

> “Dry fractionation reduces the corn kernel to three parts – the bran, the germ and the endosperm. Fractionation would allow bran from the feedstock to fire the boiler for the plant, thus saving on energy costs. In addition, the dry fractionation process was theorized to increase the protein level of the co-product dried distillers grains and solubles … to around 40 to 42 percent. It was also thought to be able to increase the efficiency of the plant as well, by running just the endosperm through the plant … The corn germ would be sold as a by-product.”

This type of dry fractionation appears to have potential merit for an IPEP ethanol plant because the plant would already have a solid fuel boiler suitable for using bran in conjunction with poultry litter. However, the economics of dry fractionation will depend primarily on the markets for the higher value co-products, high-protein distillers grains and corn germ, which are discussed below.

A. The Potential Market for High Protein Distillers Grains

According to statistics discussed in an earlier section on DDGS markets, only 4% of conventional DDGS are consumed by poultry, and maximum inclusion rates of conventional DDGS in poultry rations are considerably lower than those for other species. Yet, the animal agriculture sector in north Alabama is dominated by poultry. Poultry consume a relatively high protein ration, in which soybean meal is the main protein ingredient. Therefore, at first the concentration of protein through fractionation would appear to be well suited for north Alabama.

However, in an article on the value of high-protein distillers grains, Jerry Shurson developed some key findings for the use of this co-product in monogastric rations:

1 "The quality of the protein (amino acid balance) in feed ingredients is probably equally if not more important than the concentration of protein.
2 Despite increases in other essential amino acids, the lysine content is not increased in this product.
3 Much of the increase in crude protein content is at the expense of fat (reduced by 59 percent) and phosphorous (reduced by 42 percent).
4 The large reduction in phosphorous content in high-protein DDGS would make it more difficult to provide the same degree of diet cost savings as provided by the typical coproduct."

Although the article specifically addressed the value of high-protein DDGS in swine diets, these compositional changes also directly affect the value in poultry feed. Dr. Shurson concluded the article, "Based upon the assumption that high-protein distillers grains have a lower metabolizable energy value, these products will have less value than regular DDGS in swine diets compared to ruminant diets because of the higher levels of nitrogen (crude protein), and lower levels of fat and phosphorous. Notably, high-protein DDGS is worth much more than DDGS in ruminant diets and minimizes some of the concerns of feeding high levels of DDGS to beef and dairy cattle." He calculated that if conventional DDGS were priced at $80/ton, high-protein DDGS would be worth only $51/ton in swine diets. These conclusions are expected to be generally applicable to poultry.

In research specific to poultry, Sally Noll and a team of researchers stated, "Similar to corn, protein in DDGS is limiting in lysine, arginine and tryptophan."

(Lysine is one of the first two limiting amino acids in poultry rations.) Noll cited other research that had determined that for the co-product of fractionation via modified dry milling, the high-protein DDGS contained less fat, lysine and phosphorous than conventional DDGS. In regard to high-protein DDGS, the report concluded, “In fact, the high crude protein:lysine ratio may likely be detrimental to energy utilization because of the additional energy that will be expended by the pig or chick to remove excess nitrogen.”

The usefulness in broiler rations of the phosphorous contained in conventional DDGS also was highlighted in research by poultry nutritionists. Nick Dale and Amy Batal of the University of Georgia’s Poultry Science Department determined, “The available phosphorous content of most plant ingredients is estimated to be about 33%. However, due to the fermentation process in which microbes synthesize phytase so as to access phosphorous for their own metabolic needs, it can be postulated that the fermentation vessel acts much like a rumen in improving phosphorous availability. On the basis of evaluating the total and phytate phosphorous composition of several samples of DDGS it was observed that phytate phosphorous comprised only 37% of the total phosphorous in these samples, suggesting a phosphorous availability in excess of 60% for this ingredient. This was in fact confirmed in later broiler chick studies.” Dale and Batal determined that for broilers, “6% DDGS can safely be used in starter feeds, while this level can be doubled to 12% in subsequent feeds,” and for laying hens, “6-8% DDGS can be included in layer diets from the onset of production, and this can easily increase to levels above 10%, once body weight and feed intake have stabilized.” In fact, they did not detect any apparent negative effects of using a 15% inclusion rate for conventional DDGS in layer rations.

Telephone conversations with leading nutritionists at academic institutions and poultry companies with a significant presence in the southeastern U.S. revealed opinions on high-protein distillers grains that ranged from neutral to decidedly negative. At best, nutritionists at poultry companies stated that they would consider using the product if it priced its way into their least-cost linear programming models. Salient points that were made during these telephone interviews include:

1 Corn protein is not well suited for poultry, compared to another protein source such as soybean meal, so concentrating it in high-protein DDGS is not necessarily positive. The maximum inclusion rate would likely be lower than for conventional DDGS, and it will need to be supplemented with synthetic lysine.
2 Broiler diets are not only high protein but also high energy. Removing the oil from DDGS will eliminate a good energy source. The processing of corn into ethanol already removes the starch, which is one source of energy in corn, so degermination would eliminate the rest of the energy in high-protein DDGS. More corn or fat will have to be added to make up for the lower energy content of high-protein DDGS.

3 The imbalance in amino acids and lack of oil as an energy source might result in little if any premium for high-protein DDGS over conventional DDGS.

On the other hand, as indicated in the DDGS market and pricing section, the nutritionists surveyed at poultry companies virtually all had positive opinions of conventional DDGS, so long as the DDGS were from a facility with modern drying technology that produced DDGS with a golden color rather than over-drying it and degrading the amino acids. Some of the companies use DDGS at their operations closer to the Corn Belt, but DDGS have not often priced into poultry rations in north Alabama. This is likely due to the fact that there are no ethanol dry-mills near north Alabama, and so the transportation cost per ton makes DDGS cost prohibitive; looked at in another way, the netback price to dry-mills from selling their DDGS into north Alabama would not be attractive relative to other market outlets due to the freight cost that would have to be deducted from the price at the destination. An ethanol plant located in north Alabama would have a significant transportation advantage.

B. The Potential Market for Corn Germ

The installation of corn oil extraction equipment at an IPEP plant is highly likely to be cost-prohibitive, as was acknowledged in the advanced ethanol plant study by the University of Georgia. There are only a handful of companies that process corn germ into corn oil in the U.S., and even some relatively large wet-mill companies sell their germ to these processors. In addition to the cost, the use of hexane for extraction could result in environmental and operating constraints, and mechanical expelling is inefficient and typically targeted at niche markets. Therefore, an IPEP plant would have three options in selling the germ produced from dry-mill fractionation:

1 Sell the germ to a wet-mill corn facility that processes germ for outside companies;
2 Sell the germ to a dry-mill food corn processor (i.e., a plant that produces corn-based food ingredients, not ethanol) that extracts oil from germ manufactured using the dry-degermination process and that will accept germ from outside companies;
3 Sell the germ to a oilseed-processing facility that either has or is willing to install the moderate amount of equipment required to process corn germ (or have it processed based on a tolling agreement where the IPEP plant retains ownership).

The germ that would be produced by the dry-degermination process incorporated into the advanced ethanol plant would not be the same as the germ produced by wet mills. Most significantly, it would have an oil content of 20-25% compared to 40+% for wet-mill germ. For this reason, it is sometimes referred to as "dirty germ."

Yet, this germ is similar to the germ produced by the segment of the dry-mill corn-based food products industry that uses dry degermination on the front end of its process. Reportedly, Bunge, which is one of the major companies in this industry, extracts corn oil at its Danville, Illinois, facility and has the capacity to take in germ from other companies. Most wet mills are not geared to take germ with low oil content, and the closest wet mill to north Alabama that would be capable of doing this is the Cargill facility in Memphis. Both of these facilities are located a considerable distance from north Alabama, requiring transportation by rail. However, given a rail tariff of roughly $25/ton (plus a surcharge that is currently $3.75/ton) to both locations and the fact that the charge to process the germ would be approximately $35/ton (dependent upon negotiations), the economics of extracting oil from the germ at Danville or Memphis are unlikely to be attractive, as shown in the example in Table 1.

Table 1: Example Value of Corn Oil Extraction

Renevues	**% of Germ**	**Value ($/Lb. Product)**	**Revenue ($/Ton Germ)**
Crude Corn Oil	24%	$0.28	$134
Defatted Corn Germ	76%	$0.03	$48
Total	100%		$182
Costs			**Costs ($/Ton Germ)**
Rail Tariff			$25
Fuel Surcharge			$4
Processor Fee			$35
Total			$64
Net Revenue			$119
Price Assumptions		**Unit**	**Value**
Distillers Grains		$/Ton	87
Corn Gluten Feed		$/Ton	63
Corn Oil		Cents/Lb.	28

In the example, the net revenue to the advanced ethanol plant was $119/ton, which is only moderately higher than the price at which the material could be sold if it were still contained in the DDGS; however, importantly this is before deducting the additional operating costs and the effective per ton capital expenditure for installing and operating the dry degermination equipment. In the University of Georgia study, a conventional 30-mmgy ethanol facility was estimated to cost $52.5 million, while an advanced ethanol plant was estimated to cost $70.0 million.

Ironically, this might not help make a north Alabama facility be more competitive with a Corn Belt facility. As one participant in the oil market noted, why would a destination ethanol plant incur the cost of procuring corn by rail or barge from the Corn Belt and then pay to have part of the material transported back to the Corn Belt, where the 75% of the germ that winds up as a feed product has no higher value than near the ethanol facility?

The final option is to sell the germ to an oilseed-processing facility that either has or is willing to install the moderate amount of equipment required to process corn germ (or have it processed based on a tolling agreement where the IPEP plant retains ownership). In order to avoid high transportation costs, it is likely that the economics would work best to utilize a soybean or cottonseed crushing facility within Alabama or in a surrounding state. Since it is not known which processors have suitable equipment and would be willing to take corn germ from an IPEP plant, and since there is no standard cost for such a plant to process corn germ, it would be necessary to negotiate with such operations to determine which would offer the best deal and what the resulting economics would be.

C. CONCLUSION

Because the composition of high-protein distillers grains is of questionable suitability and added value for poultry rations and the economics of corn germ sales are questionable, it is difficult to justify the significant added expense of building an advanced ethanol plant involving dry mill fractionation. For this reason, the dry-mill fractionation option was not considered in the financial analyses.

VIII. ETHANOL MARKET DYNAMICS AND PRICING

Energy prices are projected to remain at or near record levels in the near-term. High crude oil and gasoline prices, combined with growing requirements from the Energy Policy Act of 2005, which contained a Renewable Fuels Standard (RFS) mandating biofuels usage, provide the primary foundation for the fundamental interest in ethanol in motor fuel markets.

As a result of worldwide energy trends, and the specific energy and environmental policy actions underway in the U.S., it is projected that a growing market will exist for the incremental volume of fuel ethanol to be produced by an IPEP ethanol plant in north Alabama. Several key marketplace and public policy drivers will continue to strengthen fuel ethanol's growing position in the U.S. and worldwide gasoline pool.

As a result of high world crude oil prices, the U.S. government continues to support ethanol policies designed to decrease dependence on foreign sources of oil, seek new value added markets for America's agricultural resources, and promote clean-burning fuels to reduce vehicle emissions. In combination, these policies continue to add value and open new markets to ethanol use in America's refining and gasoline markets.

Due to these favorable public policy trends, and the Energy Policy Act signed into law by President Bush in August 2005, the production of ethanol in the U.S. is projected to grow substantially from its current level of just above 4.7 billion gallons per year. At a minimum, the size of the ethanol market should be approximately 8 to 10 billion gallons per year by 2012, with 7.5 billion gallons required by the RFS alone. As much as an incremental 2 to 4 billion gallons per year is projected to be utilized in U.S. refiner and marketer "clean octane" applications, based on favorable economic incentives for refiner blending. Informa projects ethanol producers will continue to offer fuel ethanol on favorable terms to U.S. refiners and gasoline blenders throughout the forecast period.

Congressional legislation has already been introduced to increase the RFS beyond further current levels, to as much as 25 billion gallons by 2025, and provide supplemental incentives for fuel ethanol (see Appendix E)

Higher energy prices, incremental fuel and air quality demands on U.S. refiners brought about by the curtailed use or elimination of methyl tertiary butyl ether (MTBE, a competing fuel additive) at the state level, make ethanol a very attractive blending option for refiners to produce clean octane – and manufacture the clean-burning gasolines required for future environmental and octane compliance of the U.S. motor fuel pool. Ethanol is in the process of replacing the majority of MTBE supplies in the nation's clean-burning gasoline markets. These new markets now range from New Jersey, Massachusetts and Delaware to Pennsylvania, Maryland, Washington (DC), Virginia and as far south as Dallas and Houston in the state of Texas.

New ethanol demand in these Mid-Atlantic and Southern areas, as well as existing markets in California and the Midwest, will serve to raise overall U.S. demand for ethanol. A north Alabama IPEP plant will benefit as the overall demand for ethanol in the U.S. gasoline market continues to increase.

Located between East Coast/Mid-Atlantic and Gulf Coast gasoline markets, with rail and truck transportation options available to large metropolitan gasoline markets, a north Alabama IPEP plant has abundant ethanol sales options and opportunities available to favorably market its ethanol production. These options include, but are not limited to the following:

1 Rail/truck transport to the large gasoline markets of the East Coast/Mid-Atlantic and Gulf Coast, for use as a fuel oxygenate and clean octane component.
2 Sale of ethanol as a gasoline blending component and octane enhancer in these same gasoline markets.
3 Sale to other conventional Gulf Coast and Mid-Atlantic gasoline markets as a clean-burning octane enhancer, and as an option to reduce tailpipe emissions of hydrocarbons, carbon monoxide and particulate matter (pm) – and reduce air toxics.
4 Possible transportation to previous MTBE production facilities that could convert to make ethyl tertiary butyl ether (ETBE). In future years, ETBE supplies could be sent to U.S. gasoline markets, or possibly exported to countries such as Japan and China.

Future projections for ethanol prices produced by the proposed facility in north Alabama would be expected to average $1.90, an average of 42 cents per gallon above the recent five-year simple average (2001-2005) of $1.48 per gallon. When the recent five-year average is calculated based on total sales volume per year, and not the simple average of the five-year period, the weighted ethanol sales price increases to $1.55 per gallon over the 2001-2005 period. Furthermore, given the fundamental changes in global crude oil and energy markets, combined with increased public policy support at both Federal and State levels, future projections for fuel ethanol are expected to average $0.54 above the 15-plus year history of $1.36 (weighted sales average) per gallon (1989-2005).

Based on more than 25 years of experience analyzing the U.S. fuel ethanol industry, and a close study of current ethanol, gasoline market conditions, and public policy trends, Informa Energy has reached several primary findings regarding the future of the U.S. fuel ethanol industry. The following primary market report findings related to the additional production from a north Alabama IPEP ethanol plant are highlighted to provide an overview of the market.

A. PRIMARY ETHANOL MARKET ANALYSIS REPORT FINDINGS

Continued Growth Projected in U.S. Fuel Ethanol Demand:

Refiner market demand is projected to more than double over the next decade, driven by higher global energy costs, the demand for clean-burning, renewable fuel ethanol in the U.S. in the aftermath of the Energy Policy Act of 2005. U.S. fuel ethanol use is forecasted to range from 8.5 to 12 billion gallons per year in the 2012-2015 time frame.

Environmental Policies Support Expanded Ethanol Use:

In addition to the direct environmental benefits of ethanol (improving octane and reducing tailpipe emissions of primary pollutants), other factors now drive future ethanol demand. These include the incremental fuel quality demands on refiners to reduce sulfur levels in gasoline and lower air toxics, and include limiting or banning the use of MTBE at the state level. These environmental trends will continue to make ethanol an attractive component to produce the clean-burning gasolines that will be increasingly required from U.S. refiners in the future.

Fuel-grade ethanol in the U.S. is expected to grow from its current level of about 4.7 billion gallons of capacity in 2006, to a projection of 10-12 billion gallons in 2015. The potential high case scenario for U.S. fuel ethanol demand is projected to be as much as 12 billion gallons by 2015. New Federal legislation introduced in Congress also proposes to increase ethanol use beyond these levels.

Future Fuel Ethanol Supply Growth Projected:

A north Alabama plant would be a welcome addition to Gulf Coast and East Coast ethanol supply, and would represent only a small percentage (approximately 1%) of the overall expansion projected for the entire U.S. fuel ethanol industry.

U.S. fuel ethanol supply is forecast to continue to grow quickly in the near future, and increase further over the coming decade. Current U.S. fuel ethanol capacity is set at 4.7 billion gallons. If ethanol project financing continues at its current pace, additional capacity of 2.34 billion gallons is expected to be on line by yearend 2007, or early 2008. Informa forecasts that ethanol producers will sell ethanol at market prices that are economically attractive to U.S. refiners – so that all fuel ethanol production produced from available capacity is utilized in the motor fuel marketplace. Three different fuel ethanol value range scenarios were projected for this analysis – high demand, balanced baseline, and low demand cases relative to ethanol supply were forecast over the study period. The RFS should be considered a minimum floor in calculating future ethanol demand in the United States.

U.S. Fuel Ethanol Prices Expected to Remain Strong:

Following high world crude oil and U.S. gasoline prices throughout 2003-2006 period, ethanol prices have remained at historic highs. Informa's future forecast for the markets that would be served by a north Alabama IPEP plant that fuel ethanol prices will range from an annual average high of $2.46 in 2006 to an annual average low of $1.71 in 2014 in the balanced case scenario projected for the East Coast market region. The average price of fuel ethanol over the next ten years is projected to be more than 35 cents per gallon above the average price over the previous five years – even in the low-demand case scenario.

East Coast and Gulf Coast Gasoline Markets Provide High Value:
Multiple state decisions to utilize ethanol as a replacement for MTBE have created a new market for more than 1 billion gallons of ethanol annually. Based on the market analysis, 50% of the ethanol produced by a north Alabama facility would be expected to be sold in the East Coast/Mid-Atlantic region, and 50% would be expected to be sold in Gulf Coast markets. As U.S. refiners and gasoline marketers continue to increase their demand for clean-burning sources of renewable ethanol, ethanol demand is expected to grow by an additional 5-7 billion gallons over the 2006-2017 time period. It is reasonable to assume production of the volumes being considered by a north Alabama IPEP plant would be entirely consumed in the regional Mid-Atlantic and Gulf Coast gasoline pool.

Multiple Transportation Options Available:
Rail and truck transportation are generally and widely available to transport ethanol to the large gasoline markets of the East and Gulf Coasts. A north Alabama IPEP plant can utilize either of these major transportation options that most cost effectively reach preferred gasoline markets, and provide the highest ethanol plant netback (market sales price minus transportation costs). Truck transportation can also be utilized for selected local markets where supplies do not require high volume rail transportation options.

United States has Extended Federal Tax Credit for Fuel Ethanol:
During the 2004 session of the U.S. Congress, the Federal tax credit for fuel ethanol was again extended, through calendar year 2010. This is the eighth consecutive time the Federal tax incentive for clean-burning, renewable ethanol has been extended since its inception in 1978. For more than 25 years, public policy support has been expressed through legislation supporting the production and use of renewable ethanol by leading members of the House and Senate and the President of the United States. President George W. Bush is on record strongly supporting expanded production and use of ethanol – and the President's support for ethanol was most recently highlighted again in his State of the Union Address delivered on January 31, 2006.

Many State Incentives for Fuel Ethanol Also Available:
In addition to the federal tax incentive, more than thirty states offer some form of tax credits or related public policy support to promote the production or use of ethanol. The combination of these various policies offer solid supplemental incentives and marketplace support to encourage refiners and gasoline marketers to blend ethanol and support good value pricing for ethanol.

State MTBE Bans Create New Markets for Ethanol:
Liability concerns of major refiners regarding the use of MTBE now make it increasingly unlikely that MTBE production or use will return in high volumes over the forecast period. Nearly 30 states have already enacted legislation to severely limit, or ban, the use of MTBE, which competes with ethanol as a clean-burning, high-oxygen motor fuel compound. State bans of MTBE, primarily in the

states of California, New York and Connecticut, have created a new market for ethanol of more than one billion gallons in 2004 and 2005. Most of the states have banned MTBE due to the concern over groundwater contamination. These environmental concerns support the expanded use of ethanol as an economic and marketplace alternative to MTBE. Market growth for ethanol continues in 2006 as refiners continue to replace MTBE with ethanol in many regional markets.

The Energy Policy Act of 2005 also repealed the year-round oxygen standard for reformulated gasoline, causing refiners to look for new supplies of ethanol. MTBE replacement in U.S. gasoline will require an additional 1-2 billion gallons of ethanol annually. Ethanol is in the process of replacing the majority of MTBE supplies in the nation's clean-burning gasoline market.

Growing Global Market for Renewable Ethanol is on the Rise

Many regions of the world including Canada, China, India, Europe, Japan, Brazil, Thailand, Australia and other countries are increasing incentives and placing requirements on the global gasoline pool to use increasing amounts of renewable ethanol. Often these policies are designed to increase the production of ethanol domestically. New biofuel requirements are also encouraging importation of ethanol from other countries, such as Brazil. As a result of the growing global appetite for renewable ethanol, imports of ethanol to the U.S. are generally expected to continue to be less than 10% of the total supply and are projected to be available in volumes that approach 10% only when ethanol sales price is highest. Technically, up to 7% of the previous year's ethanol consumption in the U.S. is allowed duty-free from Caribbean Basin Initiative (CBI) countries. Historically, that import threshold to the U.S. has not been reached – and neither capacity nor readily available supplies of Caribbean feedstock can meet that threshold in 2006.

As the U.S. continues to support a range of public policies designed to decrease its dependence on foreign oil, seeks new value-added markets for America's agricultural resources and pursues policies to promote clean-burning octane to reduce automotive emissions, the marketplace demand and public policy support for ethanol is expected to continue to grow. While legislation has been introduced in the Congress to support more ethanol use from Brazil by temporarily suspending the existing tariff, it is not expected to be passed into law.

B. HISTORY AND BACKGROUND OF U.S. FUEL ETHANOL

1. Ethanol's History as a Motor Fuel

High global energy prices, combined with the recent passage of Federal energy legislation, has sparked a remarkable interest in fuel ethanol from U.S. refiners and in financial equity and capital markets around the world. Yet, the peaked 2006 interest in ethanol isn't anything new. Ethanol has been an important part of the U.S. motor fuel pool since the introduction of the automobile in the early 1900s. In fact, Henry Ford designed his first mass-production car to run on renewable ethanol. With the oil crises of the 1970s, the government realized that domestically produced fuel sources were vital to the nation's security. This realization created the first of a long series of tax incentives and other public policy initiatives that have supported increased production and use of renewable ethanol.

Increased air pollution in the late 1980s resulted in the U.S. Congress strengthening the Clean Air Act by passing significant amendments to this legislation in 1990. Included in the 1990 Clean Air Act Amendments was a provision creating two major clean fuels programs, which targeted ethanol's use as a clean gasoline-blending component to reduce emissions from automobiles. Ethanol's key use in these clean air programs was as an oxygenate. Oxygenates, which include ethanol and MTBE, are added to gasoline to increase the amount of oxygen in the fuel mixture, thus improving combustion and reducing automotive tailpipe emissions, particularly carbon monoxide (CO) and hydrocarbons.

The first clean air program to utilize ethanol was the Wintertime CO program. Participation in this program, which began in 1992, was required in the cities with the highest levels of CO and mandated the use of an oxygenate during the high-CO season, generally October through February. Ethanol quickly became the oxygenate of choice in this program and was tremendously effective. The use of ethanol was so effective in reducing emissions in the nation's first clean air programs, that most of the areas originally designated as non-attainment for the federal CO standards have since reached their air quality goals. However, many states continue to use ethanol to maintain this improved air quality.

Another key clean air program was the federal Reformulated Gasoline (RFG) program, which was also part of the 1990 Clean Air Act Amendments and went into effect in 1995. Unlike the CO program, RFG was a year-round air quality improvement tool, targeting ground-level ozone pollution. Again, the cities with the highest ozone concentrations were required to participate in the program and other areas to "opt-in" if they did not meet the federal standard *Note: The Energy Policy Act of 2005 eliminated the oxygenate requirement for U.S. refiners but replaced it with the RFS.*

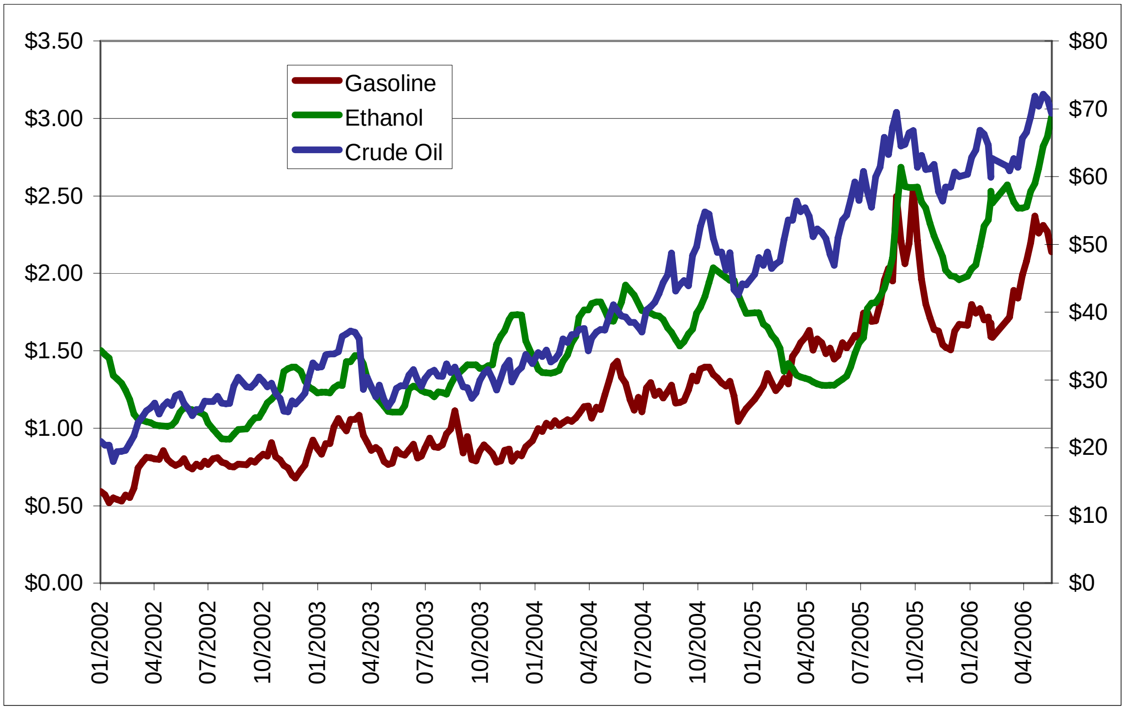
Outside the major Midwestern metropolitan markets such as Chicago, Milwaukee and Louisville, ethanol did not take advantage of this emerging RFG fuels market as quickly as the Wintertime CO program. Ethanol had not initially been widely used in East Coast and West Coast gasoline markets, as many markets initially opted not to attempt to overcome perceived challenges of transportation and summertime gasoline blending, which include meeting controls on the vapor pressure (RVP) of gasoline. Instead many of these coastal markets used MTBE as the primary oxygenate for their RFG programs.

However, MTBE was not without its difficulties. After several highly publicized incidents of groundwater contamination with gasoline containing MTBE, many public policy officials have pointed to MTBE's affinity for water as an issue – and key markets have reduced or limited its use.

Today, refiners are using ethanol as a means to replace other gasoline components, (such as MTBE, aromatics and benzene) as a clean-burning octane component in their gasoline supplies. The U.S. Environmental Protection Agency (EPA) has also required North American refiners to substantially limit sulfur levels in gasoline and to reduce emissions of mobile source air toxics (MSAT) further. These incremental demands for improvements in gasoline quality will continue to place a growing emphasis on the favorable economics of ethanol use as a clean-burning gasoline component in today's modern gasolines.

2. Understanding Historical U.S. Ethanol Market Prices

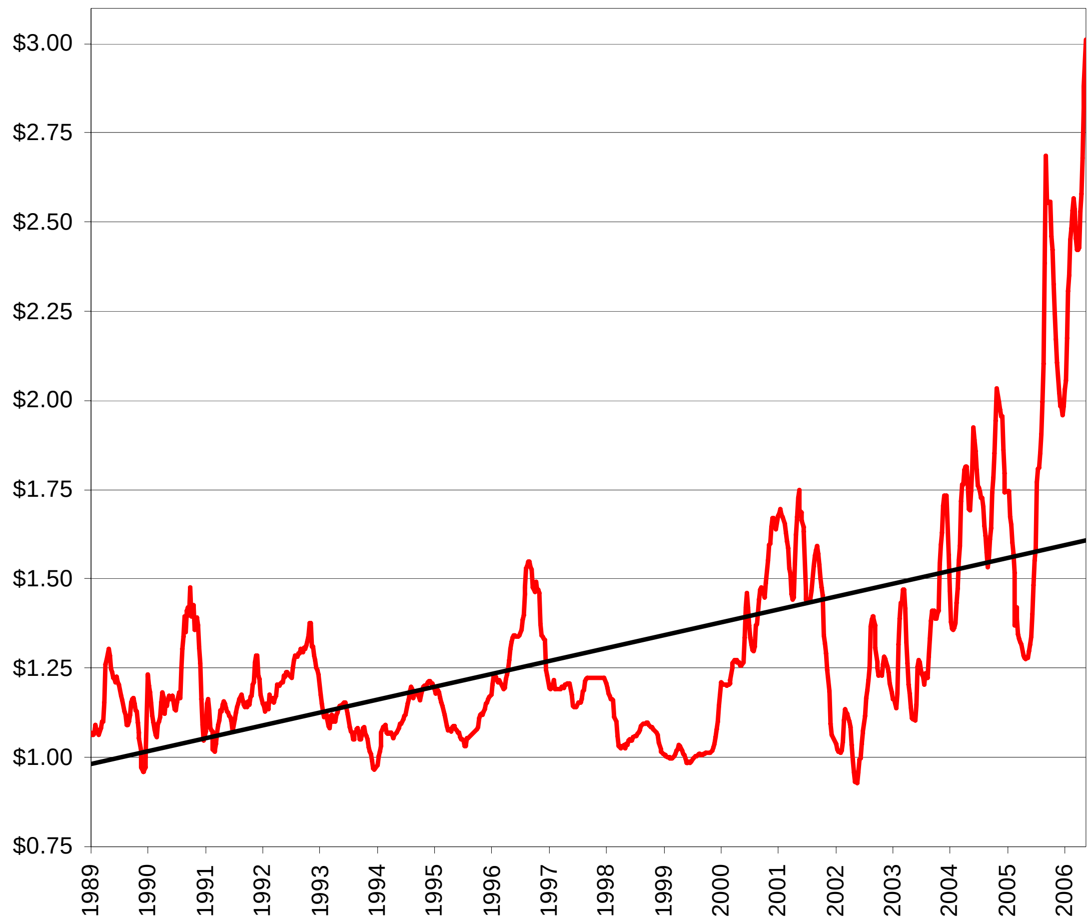
Historically, fuel ethanol prices in the U.S. have generally followed the fluctuations in wholesale gasoline and, to a lesser extent, crude oil prices in the U.S. markets. As mentioned above, ethanol is at its most basic level a component of gasoline; therefore, it is destined to follow gasoline pricing. While this connection between the gasoline price and the ethanol price can vary based on supply and demand issues and the added value that ethanol brings as an octane enhancer and an oxygenate, the pricing correlation is consistently clear over time (see Figure 1).



Source: Hart Energy Publishing

Figure 1: U.S. Crude, Rack Gasoline and Fuel Ethanol Prices
(crude in $/bbl, gasoline and ethanol in $/gallon)

When considered over time, U.S. fuel ethanol prices have risen substantially over the past 15 years – generally following in line with gasoline prices over the same period (see Figure 2).



Source: Hart Energy Publishing

Figure 2: Historical U.S. Fuel Ethanol Prices: Weekly vs. Linear Trend
($/gallon)

As of the writing of this report, the price of ethanol was between $2.90 - $3.15/gallon. The simple 17-year annual average ethanol price is nearly $1.30 per gallon. When the sales volume over this same period is weighted based on the sales volume, the historical annual average price increases to nearly $1.40. Importantly, since 2000, the annual yearly average has been much higher, averaging $1.48 per gallon. Again, when these sales are weighted based on growing sales volumes, the average sales price during the 2000-2005 time period increases to $1.55 per gallon (see Table 1).

Table 1: Historical U.S. Fuel Ethanol Prices: Yearly Averages

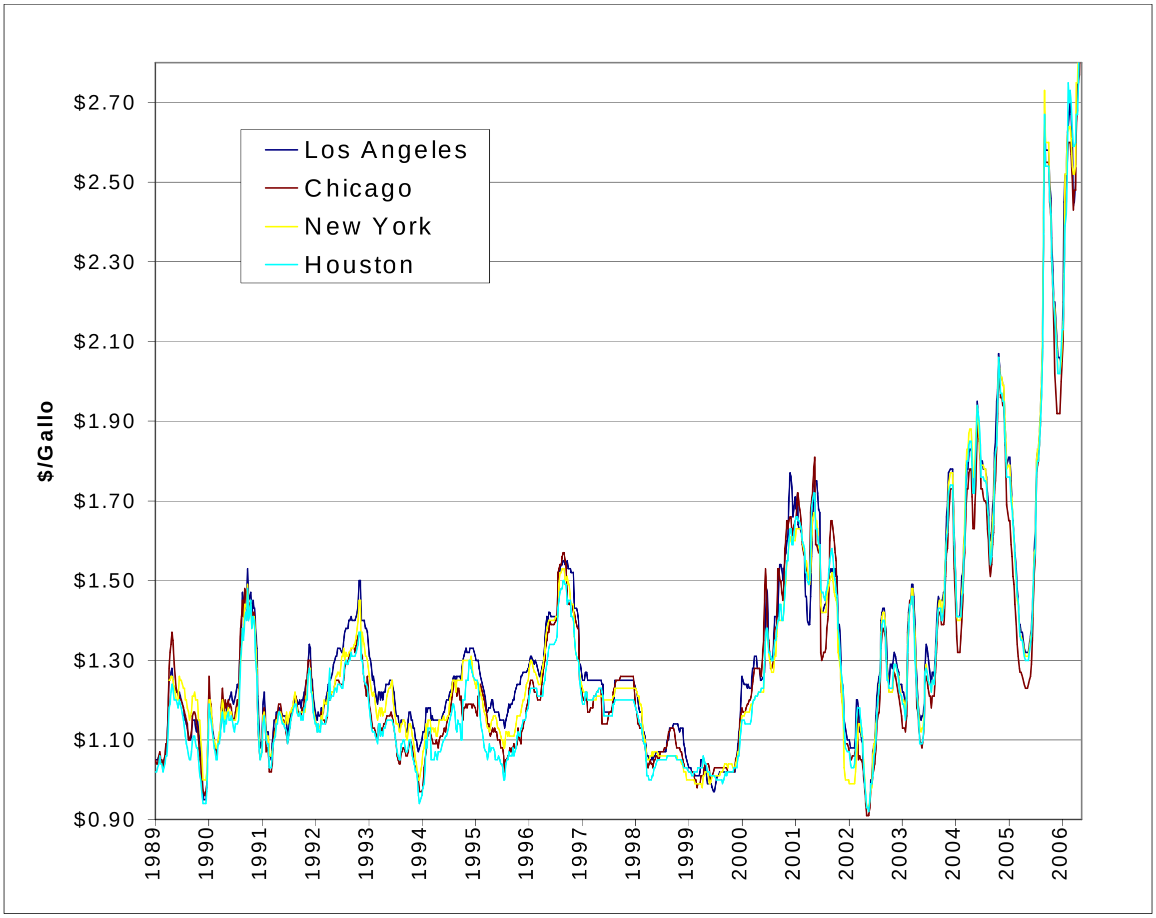
($/gallon)

1989	$1.13	1994	$1.12	1999	$1.01	2004	$1.72
1990	$1.22	1995	$1.10	2000	$1.37	2005	$1.78
1991	$1.14	1996	$1.34	2001	$1.51	2006*	$2.54
1992	$1.24	1997	$1.20	2002	$1.14		
1993	$1.09	1998	$1.08	2003	$1.33		

**** 2006 is average thru 5/18/06*** ***Source: Hart Energy Publishing***

Since the year 2000, the yearly average fuel ethanol price in the U.S. has experienced double-digit percent increases, with the single exception of 2002. In 2002, then-California Governor Grey Davis delayed that state's ban on MTBE for more than a year. Since the ethanol industry had already taken steps to meet the oxygenate demand generated by the MTBE ban on its original schedule, the market support for ethanol prices softened. However, ethanol prices bounced back with a 17% increase in 2003 and a further increase of almost 25% in 2004. The above average growth can be largely attributed to the increase in crude oil prices over this same period, as well as the reduction of MTBE.

While there are variations in fuel ethanol prices in different markets, overall pricing trends tend to hold true across the U.S. markets, as reflected in the average U.S. ethanol price (see Figure 3).



Source: Hart Energy Publishing

Figure 3: Historical U.S. Fuel Ethanol Prices: Individual Markets
($/gallon)

3. Itemization of Public Policy Support History (from 1978 to present)

Since the passage of the Energy Tax Act of 1978, the presidents, House of Representatives and Senate have passed a series of public policy initiatives designed to support and increase the production and use of ethanol:

<u>In 1980</u>, both the Energy Security Act and the Windfall Profits Tax Act were passed, each supporting the expanded use of ethanol.

<u>In 1982</u>, the Tax Equity and Fiscal Responsibility Act increased federal tax support.

<u>In 1985</u>, tax credit legislation was passed by the Congress and signed by the President to increase tax credit support for ethanol again from a $.05 per gallon to $.06 per gallon of 10% ethanol blends.

<u>In 1988</u>, the Alternative Motor Fuels Act was passed, encouraging ethanol use as an alternative fuel by government and private fleets – primarily as E-85 (a blend of 85% ethanol and 15% gasoline). Automakers receive credit for the production

of cars capable of E-85 use. These credits are applied against federal mileage requirements (CAFE).

In 1990, the Clean Air Act Amendments were passed, providing a wide range of incentives and requirements that encouraged ethanol blending in many major metropolitan areas – particularly those with the most severe air pollution problems.

In 1992, Congress passed the Energy Security Act, providing additional incentives.

In 1995, the Federal Reformulated Gasoline program took effect, and ethanol use increased in many cities across the country, including the Midwestern markets of Chicago and Milwaukee.

In 1998, the Federal tax incentive for ethanol was extended to 2007.

In 1999 and 2000, the U.S. EPA took action to limit the use of sulfur in gasoline and diesel fuel, creating additional incentives for refiners to use ethanol as an octane enhancer.

In 2004, with full support from the president and both houses of Congress, the Volumetric Ethanol Excise Tax Credit (VEETC) of $0.51 per gallon of ethanol was extended to 2010. The application was made more "friendly" to refiners that blend ethanol directly into gasoline, use ethanol to make ETBE, or use ethanol as an alternative fuel in E-85.

Congress, in July 2005, enacted comprehensive national energy legislation containing provisions including a nationwide mandate to use biofuels in gasoline.

In President George W. Bush's State of the Union Address on January 31, 2006, the President announced and Advanced Energy Initiative to facilitate breakthroughs in cutting-edge methods of producing ethanol as a substitute for gasoline, in order to reduce U.S. dependence on Middle Eastern petroleum. Informa projects that public policy initiatives to support and expand the fuel ethanol industry will continue through 2015.

4. Enactment of the Federal Renewable Fuel Standard

In August 2005, President George W. Bush signed into law the Domenici-Barton Energy Policy Act of 2005. Various titles in the legislation contained biofuels-related provisions; however, Title 15 includes a Renewable Fuels Standard that will require, beginning in 2006, a substantial increase in the use of biofuels, particularly ethanol, in the U.S. The RFS requires that a certain amount of renewable fuel, known as the "applicable volume," shall be used in the gasoline pool (see Table 2). It should be noted that the federal requirement for the RFS establishes a minimum annual volume of fuel ethanol.

Table 2: RFS Renewable Fuel Annual Ethanol Sales Volumes
(billion gallons - minimum)

Year	Minimum Annual RFS Volume Required	Projected Ethanol Market Range	Ethanol Blends (10%) Market Share Range	Direct Ethanol Production/Use % of Total Gasoline Consumption	Total Gasoline Sales Volume
2006	4.0	4.5 - 5.2	32% - 37%	3.2% - 3.7%	142
2007	4.7	5.5 – 6.5	38% - 45%	3.8% - 4.5%	145
2008	5.4	6.2 – 7.5	42% - 51%	4.2% - 5.1%	147
2009	6.1	7.0 – 8.0	47% - 54%	4.7% - 5.4%	149
2010	6.8	8.0 – 9.0	52% - 59%	5.2% - 5.9%	152
2011	7.4	8.5 – 10.0	55% - 65%	5.5% - 6.5%	155
2012	7.5	9.0 – 10.5	57% - 67%	5.7% - 6.7%	157
2013	7.65	9.5 – 11.0	59% - 69%	5.9% - 6.9%	160
2014	7.80	9.5 – 11.5	58% - 71%	5.8% - 7.1%	163
2015	8.0	10.0 – 12.0	60% - 73%	6.0% - 7.3%	165

Source: Hart Energy Publishing

The projected annual market volume range exceeds these minimums, based on the expectation that ethanol will be offered economically to refiners for application in U.S. motor fuel. These applications include traditional octane enhancement, wintertime oxygenate blending, and replacement for MTBE. Ethanol will be utilized to provide “clean octane” to ease refiner compliance with low-sulfur standards, and to reduce mobile source air toxics MSAT – derived primarily when ethanol is used as a substitute for benzene and aromatic content in gasoline.

For each year of the program, EPA is required to publish “renewable fuel obligations” that will apply to refineries, blenders and importers in the contiguous United States. The renewable fuel obligations must be expressed in terms of a volume percentage of gasoline sold or introduced into commerce in the U.S. and consist of a single applicable percentage that applies to all categories of refiners, blenders and importers. The approximate projection for calendar year 2007 is just above 3.0 volume percent ethanol, or the equivalent of blending 10% ethanol in approximately 30% of a refiner or blender’s annual gasoline sales volume.

Refiners, blenders and importers can generate, transfer and use credits for gasoline that contains a greater quantity of renewable fuel than required under the RFS. Cellulosic biomass ethanol qualifies for more credits under the RFS program than corn-derived ethanol, at a ratio of 2.5 credits to each physical gallon. Biodiesel is considered a "renewable fuel," and EPA is directed to provide in its regulations for the generation of an "appropriate amount" of biodiesel credits. EPA has not announced its regulations providing for these credits, but it is clear from a plain reading of the legislation that the general intent behind the RFS program is to promote ethanol while also encouraging biodiesel, although the "renewable fuel obligations" and "applicable percentages" provisions apply strictly to gasoline.

Other noteworthy provisions related to biofuels in the Energy Policy Act of 2005 include:

Oxygen Content Requirement for RFG: The oxygen content requirement in the RFG program was eliminated for California immediately after the president signed the legislation and was eliminated for the rest of the country in May 2006.

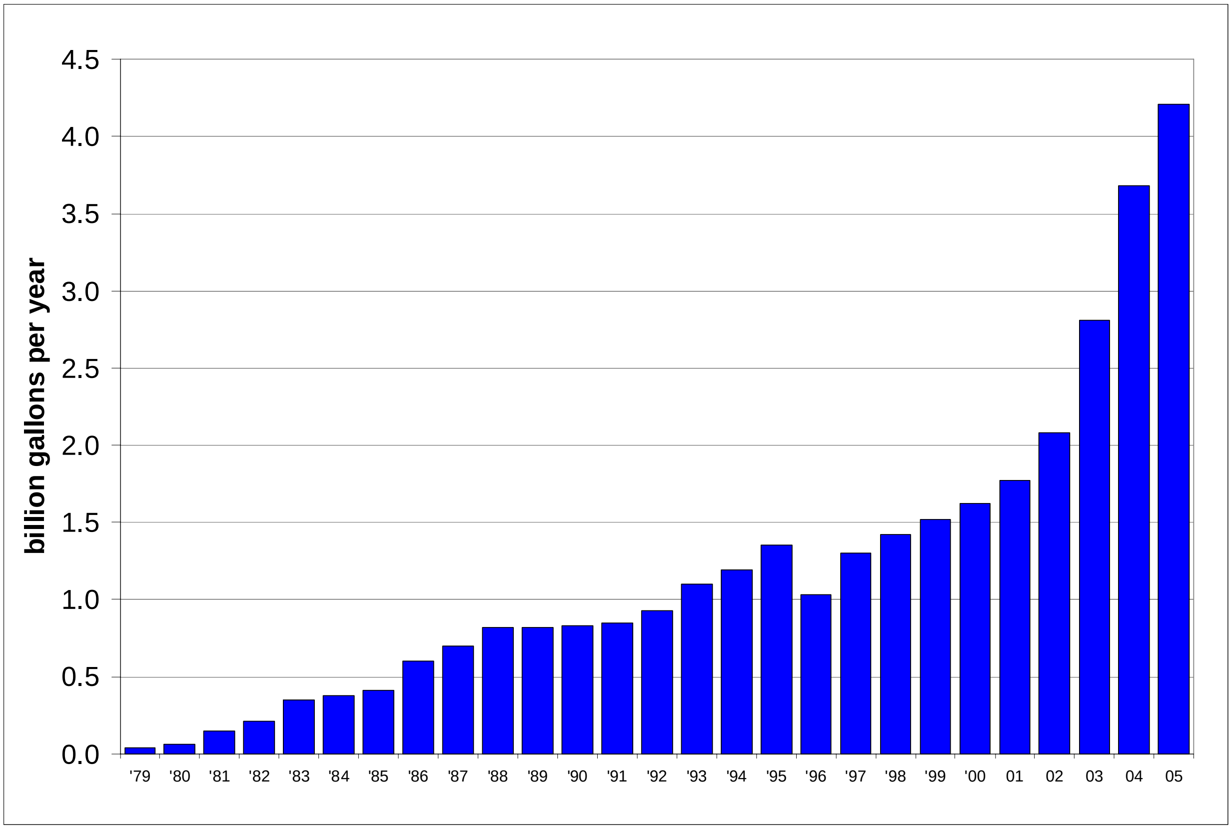
Cellulosic Biomass: In 2013 and after, the applicable volume must include a minimum of 250 million gallons of renewable fuel derived from cellulosic biomass. There are several programs to foster the research and development of cellulosic biomass as well. For example, the Department of Energy (DOE), in consultation in with the USDA, U.S. Department of Defense and EPA, is directed to establish an incentive program for eligible entities for the production of cellulosic biofuels. The goal of the program is to deliver 1 billion gallons in cellulosic biofuels production by 2015 and ensure that these fuels are competitive with gasoline and diesel thereafter.

E85 Infrastructure: This provision provides a tax credit in an amount equal to 30% of the cost of any qualified alternative fuel vehicle (AFV) refueling property placed into service in the U.S. – which includes E85 and 20% or more biodiesel (B20) mixtures. The credit cannot exceed $30,000 subject to an allowance for depreciation and $1,000 in any other case. The tax credit does not apply to residences and expires after December 31, 2009. The lack of sufficient infrastructure is a barrier to the wider use of E85 and flexible fuel vehicles (FFVs) in the U.S., and it is thought that this tax credit may help spur its development.

Small Ethanol Producer Tax Credit: The small ethanol producer credit provides a 10-cent per gallon tax credit to small producers for the first 15 million gallons in ethanol production per year, or $1.5 million. Formerly, this was available to operations with capacity not exceeding 30 mmgy. The definition of "small ethanol producer" was revised in the energy legislation, increasing production capacity limitation to 60 mmgy. A majority of the ethanol production facilities in the U.S. will now qualify for the credit. Specifically, approximately 80 of the existing 97 operating U.S. ethanol production facilities have a production capacity that meets the small ethanol producer definition. <u>Note</u>: An IPEP project will qualify for this credit.

5. Definition of Historical Fuel Ethanol Demand Growth

For nearly thirty consecutive years, production and sale of fuel ethanol has set ongoing and consistent annual records – growing to approximately 4 billion gallons in calendar year 2005. Since 1979, there has only been one instance of a reduction in U.S. fuel ethanol sales (see Figure 4). In 1996, corn prices hit historic levels, causing several smaller and some mid-sized producers to curtail ethanol production. All other years recorded consecutive growth.



Source: Hart Energy Publishing and U.S. Energy Information Administration

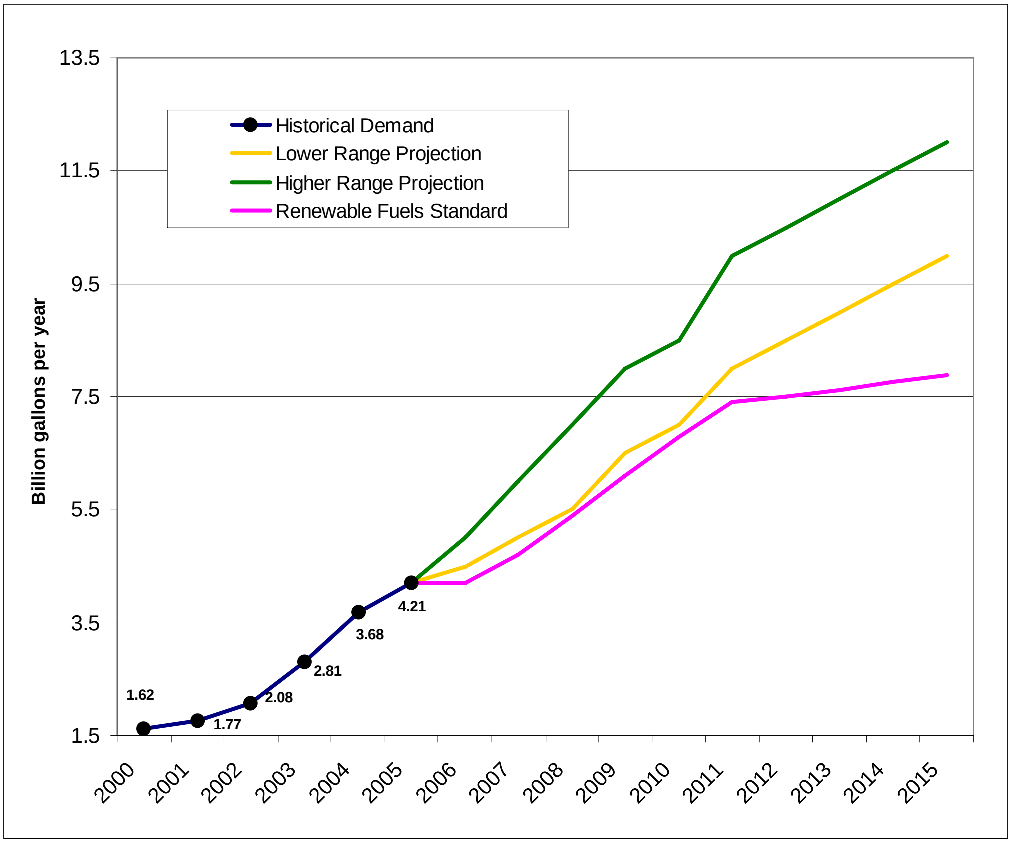
Figure 4: Historic Fuel Ethanol Sales
(billions of gallons)

Between 2002 and 2005, U.S. ethanol production and sales increased more than 100%. For 2006, Informa projects a further increase of between 500 million and 1 billion gallons, driven by the MTBE bans in several states and efforts by refiners and blenders to meet the required ethanol blending volume. Informa projects this level of growth to continue over the study period at a range between 500 million and 1 billion gallons per year.

C. Continued Growth Projected in Ethanol Demand, 2005-2015

Ethanol will continue to be a vital and growing component of the U.S. gasoline pool throughout the term forecasted in this study. Continued state pressure to ban the use of MTBE, refiners' interest to utilize ethanol as a substitute for MTBE, the recent enactment of Federal energy legislation, environmental pressures on refiners to reduce sulfur and reduce air toxics, all continue to combine and create economic incentives to use ethanol as a clean-burning octane component in U.S. gasoline.

By 2015, Informa projects that U.S. fuel ethanol demand will range between a low of 10 billion gallons and a high of 12 billion gallons (see Figure 5). A market minimum of 8 billion gallons will be required by the RFS. Future public policy initiatives to control greenhouse gas emissions or make further strides in lessening U.S. dependence on foreign oil could drive these figures higher.



Source: Hart Energy Publishing

Figure 5: Fuel Ethanol Demand Projections
(billion gallons per year)

1. Projecting Future Ethanol Demand: Baseline Forecast Projections

The baseline balanced demand scenario represents a conservative demand projection for fuel ethanol in the U.S. It assumes a continuation of the *status quo* for market and public policies, allows for the full implementation of the RFS and projects a steady increase in future gasoline demand in the nation. In this baseline case, Informa assumes:

U.S. Gasoline Demand Growth at 1.7% Annually: A 1.7% annual growth rate for U.S. gasoline is based on historical gasoline growth patterns.

Historical Ethanol Use Remains: While ethanol blending will increase in RFG areas, areas that have historically blended ethanol – primarily the Midwest – will continue to use ethanol for octane improvement and gasoline supply extension the price model allows for economic blending.

Federal Reformulated Gasoline (RFG): Without Congressional repeal, refiners must continue meeting the federal minimum NOx, VOC, and air toxic requirements for RFG. Informa believes the president and the Congress will be unwilling to give up these motor fuel provisions without institution of a National Gasoline Standard, or an expanded RFS or similar plan to further increase ethanol demand beyond existing law.

No Federal MTBE Ban, State Bans Continue: The Federal Government does not take action to ban MTBE, yet many refiners quickly leave the majority of the MTBE market in 2006 & 2007 and convert to ethanol blending to avoid potential MTBE liability and corporate litigation issues.

Imports - When ethanol prices are high, ethanol has been imported directly from Brazil to the U.S. Up to 7% of annual U.S. ethanol consumption is also allowed duty-free from the Caribbean. Modest levels of ethanol imports are expected to continue, particularly when ethanol prices are well above historic averages – yet imports are expected to average less than 10% of U.S. supply going forward.

This baseline ethanol demand scenario represents a steady growth in ethanol demand, with sales projected to range from a minimum of 8.5 billion gallons in 2012 to a potential of more than 12 billion gallons in 2015.

2. Projecting Future Ethanol Demand: High-Demand Scenario

Energy prices increase beyond Informa's crude oil assumptions in the high-price scenario issued by the DOE's Energy Information Administration (EIA). Higher ethanol prices would then be factored into baseline demand for Informa's market analysis. The EPA and individual states take further action to reduce Mobil Source Air Toxics, lower gasoline sulfur and generally increase the "clean octane requirements," which put in place an incremental economic driver for ethanol demand. In this scenario, ethanol trades at basic parity with full octane value. Note: This is a value that the market has historically provided back to U.S. refiners and gasoline blenders. While the petroleum refiner and marketer would no longer receive economic advantage on ethanol's octane blending value, they would benefit from all of ethanol's environmental premiums (reducing air toxics, lowering gasoline sulfur, etc.) Informa's marketplace projections do not allow ethanol to trade over octane values in the high demand scenario. If Congress also moves to take action to increase the RFS, this could result in ethanol trading in volumes and prices projected in the high demand scenario.

3. Projecting Future Ethanol Demand: Low-Demand Scenario

In this scenario, available ethanol supply substantially exceeds both the minimum requirement established by the RFS and demand generated by refiners for "clean octane" requirements. Informa then assumes average ethanol prices to U.S. refiners drop and trade at $.30 - $.35 per gallon below octane values – thereby providing each refiner and gasoline marketer a full $.03 per gallon profit incentive on all gallons of 10% ethanol sold. This incentive should be clear enough to allow all volume of ethanol produced in the marketplace to be sold, but trades that volume at lower prices than the baseline costs to U.S. refiners and gasoline blenders.

D. LIABILITY CONCERNS & MTBE BANS CREATE NEW ETHANOL MARKETS

Ethanol is in the process of replacing the majority of MTBE in the nation's clean-burning gasoline markets. These markets range from New Jersey, Massachusetts and Delaware, to Pennsylvania, Maryland and Virginia, and as far south as Dallas and Houston. The primary business reason that ethanol is replacing MTBE is U.S. refiner concern about the lack of liability protection for continued use of MTBE, now that the oxygenate requirement has been eliminated for RFG.

More than 50% of states have legislation on the books to severely curtail, or ban, the use of MTBE. In calendar year 2004 and 2005, state bans of MTBE, primarily in the states of California, New York and Connecticut, created a new market for ethanol of more than one billion gallons. Similar market demands will be created in 2006 as refiners on the East Coast and Southern states (e.g., Texas) replace MTBE with large blending volumes of ethanol. (Appendix C lists all states in the United States that already have a ban or are scheduled to curtail the use of MTBE in the future.) As new ethanol supplies are required in Eastern markets, traditional supplies of ethanol may shift to serve growing Eastern markets. Even in states where MTBE is not currently banned, many refiners are reluctant to continue its use due to concerns about liability.

E. U.S. FUEL ETHANOL PRODUCTION AND CAPACITY OUTLOOK

Today, there are currently 101 operating ethanol plants in the U.S. with a nameplate production capacity of approximately 4.7 billion gallons (see Table 3). These plants range in size and complexity from a large 300-mmgy-plus wet mill plant run by agri-business leader Archer Daniels Midland, to a 20- and 40-million-gallons-per-year dry mill plant operated by a farmer cooperative in the Midwest, to small-scale commercial plants using unique beverage and waste feedstocks. The average plant is projected to run in an annual rate of approximately 95% - 100%of capacity, which leads to an estimated 4.5 billion gallons effective capacity for existing plants.

Table 3: Current U.S. Fuel Ethanol Production Capacity

Company	City	ST	Capacity Mmgy	Company	City	ST	Capacity Mmgy
Abengoa Bioenergy	Colwich	KS	25	Iowa Ethanol, LLC	Hanlontown	IA	45
Abengoa Bioenergy	York	NE	55	James Valley Ethanol	Groton	SD	50
Abengoa Bioenergy	Portales	NM	30	KAAPA Ethanol, LLC	Minden	NE	45
ACE Ethanol	Stanley	WI	39	Land O' Lakes	Melrose	MN	2.6
Adkins Energy, LLC	Lena	IL	42.5	LincolnLand Agri-Energy	Robinson	IL	48
Ag Processing Inc. (AGP)	Hastings	NE	52	Liquid Resources	Medina	OH	3
Agra Resources Coop	Albert Lea	MN	45	Little Sioux Corn Processors	Marcus	IA	52
Agri-Energy, LLC	Luverne	MN	21	Merrick/Coors	Golden	CO	3
Alchem Ltd. LLLP	Grafton	ND	10.5	MGP Ingredients, Inc.	Pekin	IL	78
Al-Corn Clean Fuel	Claremont	MN	35	MGP Ingredients, Inc.	Atchison	KS	9
Amaizing Energy	Denison	IA	40	Michigan Ethanol, LLC	Caro	MI	45
Archer Daniels Midland	Cedar Rapids	IA	300	Mid-Missouri Energy	Malta Bend	MO	46
Archer Daniels Midland	Clinton	IA	150	Midwest Renewable Energy, LLC	Sutherland	NE	22
Archer Daniels Midland	Decatur	IL	250	Miller Brewing Co	Olympia	WA	0.7
Archer Daniels Midland	Peoria	IL	200	Minnesota Energy	Buffalo Lake	MN	18
Archer Daniels Midland	Marshall	MN	40	New Energy Corp	South Bend	IN	102
Archer Daniels Midland	Walhalla	ND	40	Nebraska Energy	Tifton	NE	50
Archer Daniels Midland	Columbus	NE	90	North Country Ethanol	Rosholt	SD	20
Aventine Renewable Energy, Inc.	Pekin	IL	100	Northeast Missouri Grain, LLC	Macon	MO	45
Aventine Renewable Energy, Inc.	Tifton	NE	50	Northern Lights Ethanol	Big Stone City	SD	50
Badger State Ethanol	Monroe	WI	50	Northstar Ethanol	Lake Crystal	MN	52
Big River Resources, LLC	West Burlington	IA	40	Otter Creek Ethanol, LLC	Ashton	IA	55
Broin Enterprises, Inc.	Scotland	SD	9	Parallel Products	Rancho Cucamongo	CA	4
Bushmills Ethanol	Atwater	MN	40	Parallel Products	Louisville	KY	5.4
Cargill, Inc.	Eddyville	IA	35	Permeate Refining	Hopkinton	IA	1.5
Cargill, Inc.	Blair	NE	85	Phoenix Bio-Industries,	Goshen	CA	25
Central Iowa Renewable Energy (Corn, LP)	Goldfield	IA	50	Pine Lake Corn Processors,	Steamboat Rock	IA	20
Central MN Ethanol Coop	Little Falls	MN	21.5	Platte Valley Fuel Ethanol,	Central City	NE	40
Central Wisconsin Alcohol	Plover	WI	4	Pro-Corn, LLC	Preston	MN	42
Chief Ethanol	Hastings	NE	62	Quad-County Corn Processors	Galva	IA	27
Chippewa Valley Ethanol	Benson	MN	45	Reeve Agri-Energy	Garden City	KS	12
Commonwealth Agri-Energy, LLC	Hopkinsville	KY	33	Sioux River Ethanol	Hudson	SD	55
Corn Plus	Winnebago	MN	44	Sterling Ethanol	Sterling	CO	42
Dakota Ethanol, LLC	Wentworth	SD	50	Siouxland Energy & Livestock Coop.	Sioux Center	IA	25
DENCO, LLC	Morris	MN	20.5	Tall Corn Ethanol, LLC	Coon Rapids	IA	49
East Kansas Agri-Energy	Garnett	KS	35	Tate & Lyle	Loudon	TN	67
ESE Alcohol Inc.	Leoti	KS	1.5	Trenton Agri-Products	Trenton	NE	45
Ethanol 2000, LLP	Bingham Lake	MN	32	United Wisconsin Grain Pr.	Friesland	WI	40
Glacial Lakes Energy, LLC	Watertown	SD	50	U.S. Liquids	Bartow	FL	4
Global Ethanol Holdings	Lakota	IA	100	U.S. Energy Partners, LLC	Russell	KS	46
Golden Cheese Company of CA	Corona	CA	5	Utica Energy, LLC	Oshkosh	WI	52
Golden Grain Energy LLC	Mason City	IA	40	VeraSun Energy	Tifton	SD	120
Golden Triangle Energy	Craig	MO	20	VeraSun Energy	Fort Dodge	IA	110
Grain Processing Corp	Muscatine	IA	20	Voyager Ethanol	Emmetsburg	IA	50
Granite Falls Energy	Granite Falls	MN	45	Western Plains Energy	Campus	KS	41
Great Plains Ethanol, LLC	Chancellor	SD	50	Wind Gap Farms	Baconton	GA	0.4
Hawkeye Renewables	Iowa Falls	IA	80	Wyoming Ethanol	Torrington	WY	5.3
Heartland Corn Products	Winthrop	MN	36	Xethanol Corporation	Blairstown	IA	6
Heartland Grain Fuels, LP	Aberdeen	SD	9				
Heartland Grain Fuels, LP	Huron	SD	12				
Horizon Ethanol LLC	Jewell	IA	60		TOTAL		**4,701.90**
Husker Ag, LLC	Plainview	NE	26.5				

Source: Hart Energy Publishing May 22, 2006

Table 4: Ethanol Plants Under Construction

Company	City	State	Capacity Mgpy	Start Up Date
Abengoa Bioenergy	Ravenna	NE	88	2nd Q 2007
Advanced BioEnergy	Faimont	NE	100	2nd Q 2007
ASAlliances Biofuels, LLC	Albion	NE	100	4th Q 2007
ASAlliances Biofuels, LLC	Linden	NE	100	4th Q 2007
Aventine Renewable Energy, Inc.	Pekin	IL	60	4th Q 2006
Big River Resources	W. Burlington	IA	15	1st Q 2007
Central Indiana Ethanol LLC	Marion	IN	40	1st Q 2007
Cornhusker Energy (CH Energy)	Lexington	NE	40	3rd Q 2006
E3 BioFuels (Nebraska BioClean)	Mead	NE	24	3rd Q 2006
Global Ethanol Holdings Pty. Ltd.	Blissfield	MI	50	3rd Q 2006
Global Ethanol Holdings Pty. Ltd.	Riga	IA	57	4th Q 2006
Great River Energy (Blue Flint)	Underwood	ND	50	1st Q 2007
Green Plains Renewable Energy Inc.	Shenandoah	IA	50	1st Q 2007
Harrison Ethanol LLC	Cadiz	OH	20	2nd Q 2007
Hawkeye Renewables, LLC	Fairbank	IA	100	2nd Q 2006
Heartland Grain Fuels, L.P.	Huron	SD	18	3rd Q 2006
Heron Lake BioEnergy LLC	Heron Lake	MN	50	2nd Q 2007
Horizon Renewable Energy/MAAP-Horizon	Cambridge	NE	44	2nd Q 2007
Illinois River Energy	Rochelle	IL	50	1st Q 2007
Iroquois Bio-Energy Company, LLC	Rensselaer	IN	40	3rd Q 2006
Lincolnway Energy	Nevada	IA	50	2nd Q 2006
Little Souix Corn Processors (expansion)	Marcus	IA	52	3rd Q 2007
Mid America Agri Products	Madrid	NE	44	1st Q 2007
Midwest Renewable Energy, LLC	Sutherland	NE	3	4th Q 2006
Missouri Ethanol	Laddonia	MO	45	4th Q 2006
Pacific Ethanol Inc.	Madera	CA	35	4th Q 2006
Pinnacle Ethanol	Corning	IA	60	3rd Q 2007
Pinal Energy, LLC	Maricopa	AZ	55	2nd Q 2007
Prairie Ethanol, LLC	Loomis	SD	60	4th Q 2006
Putnam Ethanol LLC	Cloverdale	IN	60	2nd Q 2007
Prairie Horizon Agri-Energy, LLC	Phillipsburg	KS	40	3rd Q 2006
Red Trail Energy LLC	Richardson	ND	50	3rd Q 2006
Redfield Energy	Redfield	SD	50	4th Q 2006
Siouxland Ethanol LLC	Jackson	NE	50	2nd Q 2007
Tate & Lyle (formerly AE Staley)	Loudon	TN	33	3rd Q 2006
The Andersons Albion Ethanol LLC	Albion	MI	55	3rd Q 2006
The Andersons Albion Ethanol LLC	Clymers	IN	110	2nd Q 2007
U.S. BioEnergy Corp.	Albert City	IA	100	4th Q 2006
U.S. BioEnergy Corp.	Woodbury	MI	45	3rd Q 2006
United Ethanol LLC	Milton	WI	42	1st Q 2007
Val-E Ethanol	Ord	NE	45	2nd Q 2007
VeraSun Energy	Charles City	IA	110	2nd Q 2007
Western WI Renewable Energy Co-op	Boyceville	WI	40	4th Q 2006
Wyoming Ethanol (expansion)	Torrington	WY	6.7	4th Q 2007
		TOTAL	2,336.70	

Source: Hart Energy Publishing, May 22, 2006

With the growth in annual ethanol demand, comes a corresponding increase in ethanol production. Informa estimates that as much as 2.34 billion gallons of new production are likely to be fully operational by the end of 2007, or 1st quarter 2008.

F. U.S. FUEL ETHANOL CAPACITY WILL CONTINUE EXPANSION

It is expected that many of the ethanol plants currently in the planning stages will also be built. These projects certainly include new plants announced by agri-processors such as ADM and Cargill. Several other projects seeking third-party financing also appear to be well along. Additional expansion from facilities currently operating can be expected by companies such as VeraSun and Aventine. At the same time, not all plants in early planning stages will come to fruition. Depending on the level of supply in this market range, ethanol market prices will adjust to meet the octane and clean-burning gasoline needs of the U.S. refining and petroleum marketing industry.

G. CONGRESS AND THE PRESIDENT EXTENDED FEDERAL ETHANOL TAX CREDIT

The Federal tax credit for ethanol is in place through calendar year 2010. Informa assumes the credit will remain in place over the financing period of an IPEP project, as the incentive has become a means for public policy leaders to reduce dependence on foreign oil, improve clean-burning fuel sources and create new markets for agricultural resources. To be conservative, although the credit for ethanol is 51 ¢/gallon from 2007 to 2010, Informa has projected the credit at 45 ¢/gallon during the 2011 - 2017 time frame.

As the structure of the Federal ethanol tax incentive has changed to a credit from an exemption from the excise tax on gasoline that funded the nation's highway system, the opposition to continuing the credit has been reduced substantially. Furthermore, now that U.S. refiners and petroleum marketers are the parties obligated to blend ethanol under the RFS, these industries now have the business incentive to promote the extension of the credit for ethanol in the public policy arena in Washington.

Proposed legislation in the 2006 Congress would extend the RFS for ethanol:

1 S.2817 – Biofuels Security Act of 2006
2 S.2571 – Breaking Our Long Term Dependence
3 HR.4573- Biofuels Act of 2006
4 HR.5370 – Amendment to Clean Air Act
5 HR.4409 – Fuel Choices for American Security Act of 2005
6 HR.5208 – Independence from Oil With Agriculture (IOWA Act)

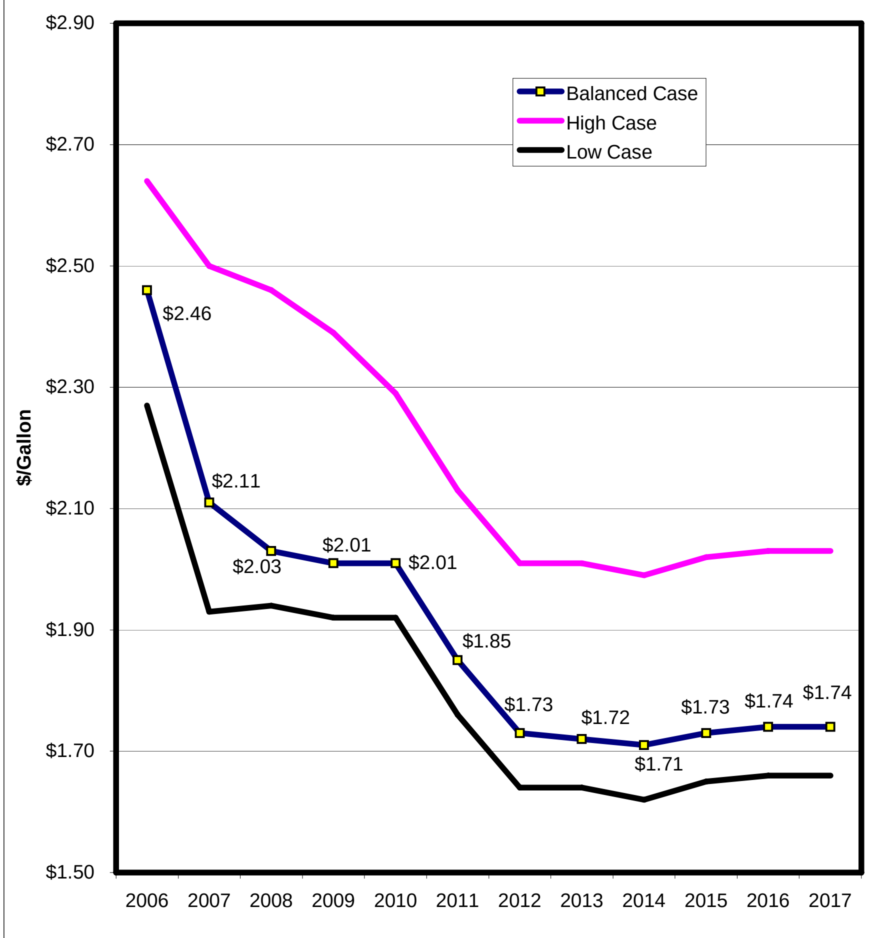
H. FUTURE U.S. ETHANOL PRICES EXPECTED TO REMAIN STRONG

U.S. fuel ethanol prices are not projected to remain as high as the current levels (approximately $2.90 - $3.15 per gallon) but are projected to range well above historic averages. The balanced scenario projects prices when the ethanol market is in relative supply and demand balance, and refiners are recognizing ethanol's octane value in the marketplace. Currently, the ethanol market greatly favors the ethanol producer as demand for ethanol is high relative to supply. On a going forward basis, over the next ten years it seems likely that there will be approximately one to two years where the ethanol market is in high demand relative to supply, followed by a period where the market advantage favors the purchaser – especially during the times when the ethanol industry is in the process of opening vast new markets.

In the Balanced Case, average annual prices range from a high of $2.46/gallon in 2006 to a low of $1.71/gallon in 2014. If ethanol supply were to severely outpace RFS and marketplace demand, then ethanol prices would adjust downward – increasing the 20-25 cents per gallon net octane blending incentive for refiners assumed by Informa in the balanced case scenario. This 20-25 cents per gallon should provide more than enough economic value for refiners and gasoline marketers throughout the Mid-Atlantic and Gulf Coast markets to use ethanol – taking full advantage of gasoline blending economics, and the environmental and octane benefits of renewable ethanol produced by an IPEP project.

1. Defining Ethanol Plant Netback Prices

The primary markets for a facility in north Alabama would be regional Mid-Atlantic/East Coast and Gulf Coast markets. It is expected that the local Mid-Atlantic market will receive about 50% of the plant's production, while the Alabama and Gulf Coast markets will receive about 50%. It is estimated that the transportation cost will average approximately 6 ¢/gallon for Gulf Coast product, and about 8 ¢/gallon for East Coast product. Given these assumptions, a north Alabama IPEP plant would receive between a high of $2.46 per gallon in 2006 and $1.71 per gallon in 2014 for its product in Informa's balanced demand cased (see Figure 6).



Note: Plant netback is projected weighted ethanol sales minus transportation. Sales expected to be 50% Gulf Coast and 50% East Coast markets.

Figure 6: Projected Netback to a N. Alabama Facility from Ethanol Sales
($/gallon)

I. STATE INCENTIVES FOR ETHANOL ALSO AVAILABLE

Approximately 40 states provide a variety of incentives to users of ethanol. These are most typically categorized as tax exemptions; tax reductions; tax credits for the purchase of AFVs, including those that are powered by ethanol; grants and loans; and fleet mandates (see Figure 7).

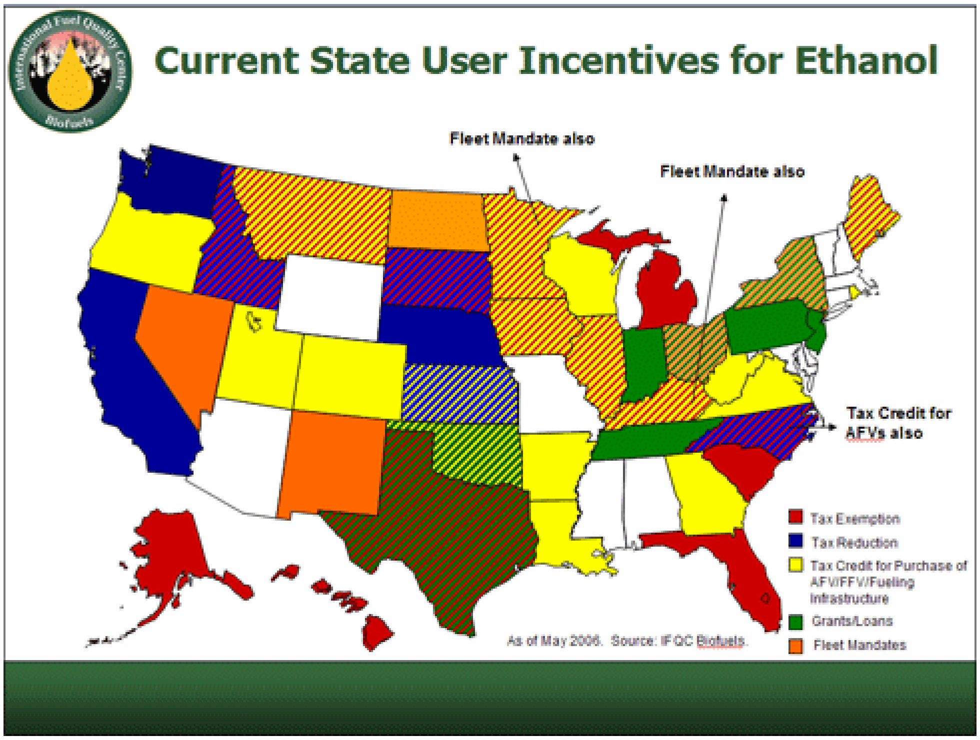


Figure 7: Current State User Incentives for Ethanol

In addition, 23 states have implemented incentives to encourage ethanol production that are most typically categorized as tax credits, producer payments, loans and grants (see Figure 8). While it is true that the Midwestern states, the agricultural center of the country, have initiated most of the programs and policies to foster ethanol production and development, states on the East and West coasts are increasingly doing so as well. Moreover, it is no accident that in many of these same states, new ethanol production facilities are under consideration.

J. Worldwide Growth Market Projected for Renewable Ethanol

Many countries, such as Canada, China, India, the European Union, Japan, Thailand, Australia, are increasing incentives and placing requirements on their gasoline pool for increasing amounts of renewable ethanol. Often these policies are designed to increase the production of ethanol in their own countries, while also encouraging importation of ethanol from other countries, such as Brazil. Informa projects as much as 10 billion gallons of additional ethanol will be required to serve worldwide markets in the next six to eight years. As a result for the growing global appetite for ethanol, imports of ethanol to the U.S. are generally expected to be less than 10% of the total supply.

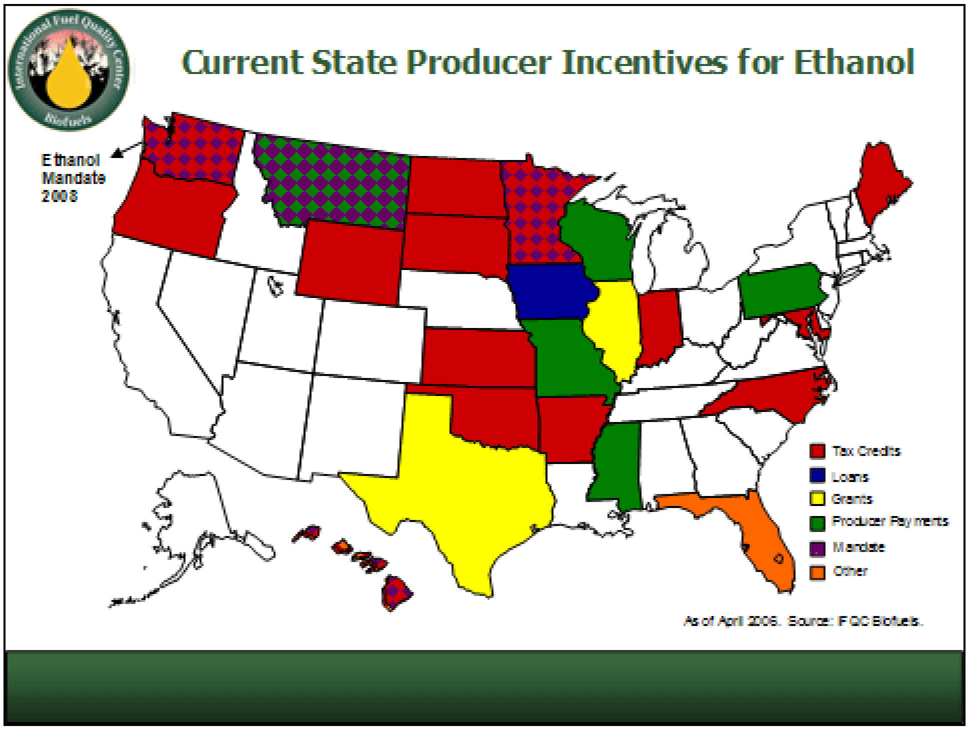
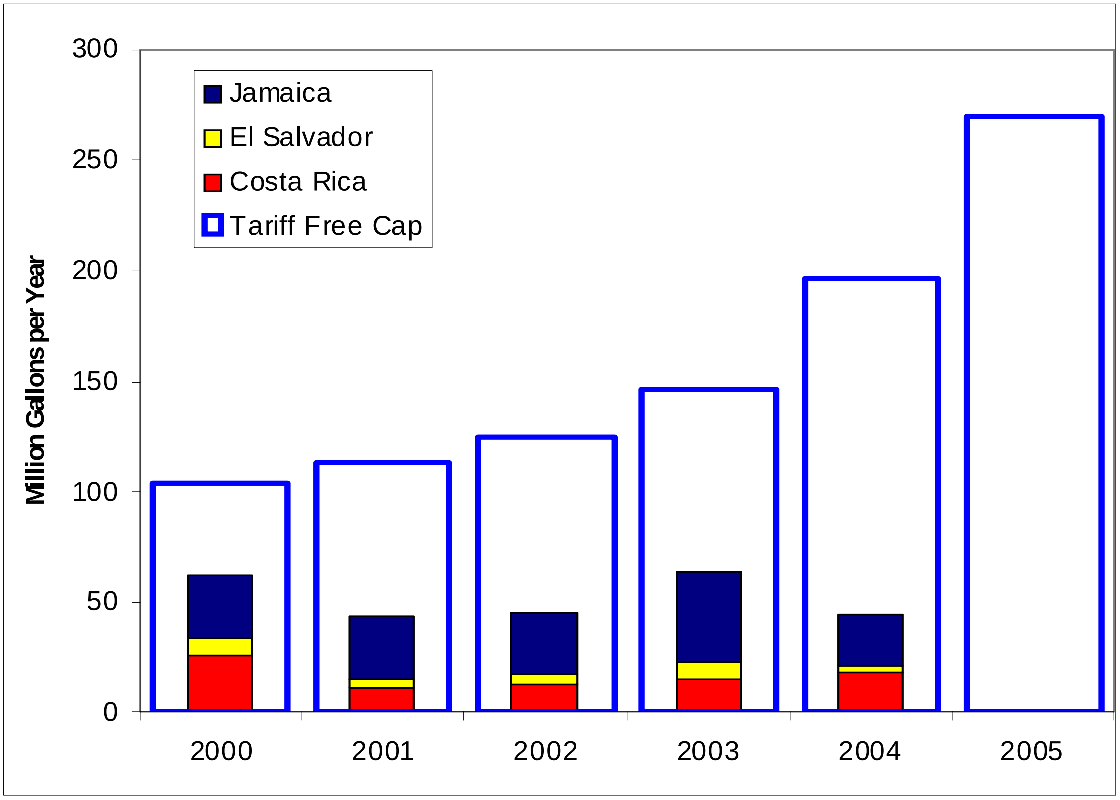


Figure 8: Current State Producer Incentives for Ethanol

1. CBI Imports Remain Below Quota, May Face Legal Challenges

Losing market share to imported ethanol should not be a concern in the overall development of an IPEP ethanol plant. The U.S. ethanol industry is protected from imported ethanol by tariffs, and even the few countries that are allowed to import fuel ethanol duty-free are not meeting their quotas.

The Caribbean Basin Initiative (CBI) was put in place to help grow the economies of certain Caribbean nations. Part of the program allowed a small amount of fuel ethanol, not more than 7% of the previous year's domestic U.S. consumption, to enter the U.S. without paying the 54 ¢/gallon duty. However, the CBI program has never reached full potential. Even now, with ethanol prices and demand at very high levels, the CBI nations have not reached the duty-free cap under the program (see Figure 9).



Source: Hart Energy Publishing, U.S. Department of Commerce, U.S. Department of Treasury, and the U.S. International Trade Commission

Figure 9: CBI Ethanol Imports and Duty-Free Cap
(millions of gallons)

To make the threat of imported ethanol even less of an issue, key members of Congress, including Iowa's Sen. Chuck Grassley, Chairman of the Senate Finance Committee, have continued to threaten to pass legislation to stop or limit ethanol imports from the CBI if they become a challenge for domestic ethanol producers.

K. Strategic Location in North Alabama Benefits IPEP Ethanol Sales

In summary, the proposed facility's location in north Alabama, with ethanol transportation options of rail, barge and truck, strategically positions an IPEP plant to serve both the growing Mid-Atlantic/East Coast and Gulf Coast markets for fuel ethanol needed by U.S. refiners and gasoline marketers.

As the U.S. continues to support a range of public policies designed to decrease its dependence on foreign oil, seeks new value-added markets for America's agricultural resources, and pursues policies to promote clean-burning octane to reduce emissions, both the market place demand and public policy support for ethanol are expected to grow. The market outlook for the U.S. fuel ethanol industry, and for an IPEP project, is stronger and more robust than it ever has been.

IX. CARBON DIOXIDE MARKET

During fermentation, yeast releases large amounts of carbon dioxide gas (CO_2). This gas can be captured, purified, compressed, and sold. It is used primarily in the food and beverage industry in three main areas: carbonation of beverages, food freezing, and dry ice. In many instances, however, the gas is not captured but simply vented into the atmosphere due to the saturation of regional markets, especially in the concentrated ethanol production area in the Corn Belt.

A. DEMAND

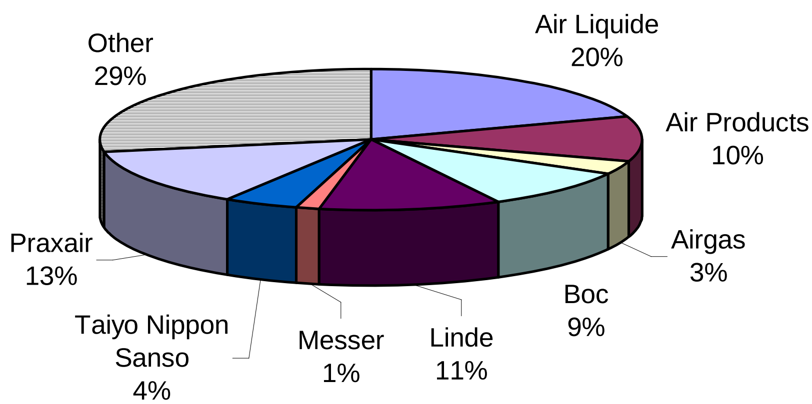
Most CO_2 demand is driven by food and beverage, estimated to be about 70% of the demand. In addition to food and beverage applications, carbon dioxide is used in diverse applications covering many industries, including chemicals, food and beverage, metal fabrication, pulp and paper, and wastewater treatment. The CO_2 market is now mature and little growth is observed. Currently, the fastest growing application is injecting liquids under very high pressure into geologic formations to encourage natural gas recovery (Rocky Mountains). Beverage uses, on the other hand, have been declining.

B. SUPPLY

Most commercial CO_2 is recovered as a by-product of other processes: ammonia plants, refineries, natural wells, and ethanol plants. Historically CO_2 plants were built around ammonia production from natural gas, which has typically provided consistent, high quality sources of raw CO_2. The fertilizer industry, however, has been weakened by high natural gas prices. Currently, the ethanol industry is the fastest growing source of CO_2 in North America.

There are over 100 supply points of CO_2 in North America. Approximately three quarters of those are production plants located near sources of raw gas (ethanol plants for instance). Other areas are served by rail, with centralized storage of CO_2. The Southeast market, in particular, is a net CO_2 importer, with shipments originating from the Mississippi area.

In 2005, the largest gas-products companies present in the North American market were: Air Liquide, Air Products, Airgas, BOC, Linde, and Praxair. As illustrated in Figure 1, these companies are leaders in the gases business.



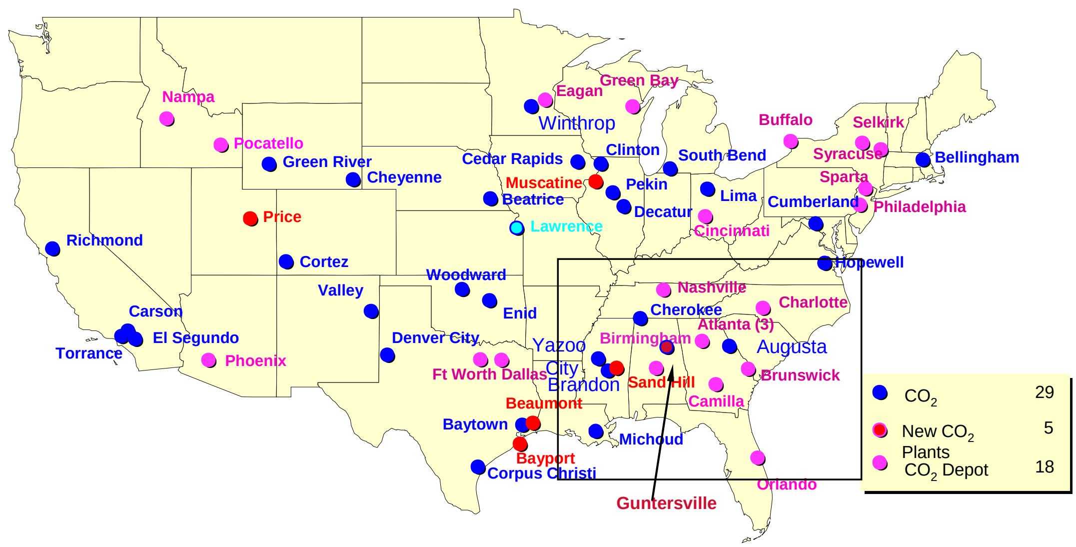
Gas and services revenues only and based on subsidiary undertakings only.
Source: Spiritus Consulting

Figure 1: Estimated 2005 Market Share – Worldwide Gases Business

C. PRICE

For those Midwestern ethanol facilities that are able to sell CO_2, it is currently sold for $5-10/ton, based on the plant location and the contract negotiated with gas-products companies. These prices are lower than the national average due to the large number of ethanol plants in the region. As a result, most ethanol plants there do not capture CO_2 and simply vent it into the atmosphere; there is already overcapacity and no additional demand. Since there is overcapacity, a part of the CO_2 surplus is shipped by rail to other markets. In these other markets, CO_2 is acquired at the Midwest cost plus transportation. There is therefore potential for ethanol facilities away from the concentrated ethanol production area in the Midwest, and close to population centers, to generate revenues by capturing and selling CO_2.

The conventional route for a new ethanol facility to take advantage of this market is to work through a gas-products company selling CO_2. BOC Gases is a major CO_2 supplier in the southeastern U.S. with numerous CO_2 facilities within trucking distance from north Alabama (Figure 2). They have a demand for more CO_2 in the Atlanta area and in the poultry processing industry in north Alabama and indicated they would pay between $12 and 14/ton for raw CO_2 produced from and IPEP ethanol plant. A price of $13/ton was used in the financial analyses.



Source: BOC Gases

Figure 2: BOC Gases Locations in the Southeastern U.S.

X. Natural Gas Prices

A. Background

- The long term outlook for natural gas prices implies levels likely will remain higher than the historical averages. NYMEX natural gas futures for the period 1990 to 2000 generally averaged between $1 and $4 per Mbtu. In the 2000 to 2006 time frame the market has undergone a sharp increase in volatility with prices spiking into the $10 to $16 per Mbtu on several occasions.

- Prices are currently trading between $5.50 and $8.50 in spite of large stocks. Many industry observers and trade analysts think we are now on a new price plateau and that a return to the $2 to $4 price range is unlikely during the coming ten year period.

- The market is reflecting expectations of strong demand and potential for weather related supply interruptions. A significant share of US production is located in the Gulf of Mexico and subject to interruptions from tropical storms and hurricanes. The industry benchmark for working gas stocks at the start of each heating season is just over 3.0 billion cubic ft (Bcf). The five year average has been 3.1 Bcf and we are likely to meet or exceed that level at the start of the season this fall.

- Demand has shown significant growth over the past 10 to 15 years. In response to the Clean Air act effective in the early 1990s many industrial and commercial user of coal and petroleum switched to natural gas to help meet air pollution standards. This demand allowed consumption to increase at an average 2% rate during the mid to late 1990s.

- Higher prices and tightness in supplies in the 2000 to 2005 period cut demand growth. Although there were years with strong growth, the average for the period was about -1%. The US DOE-EIA anticipates recovery in 2006 with demand holding about even with 2005.

- The DOE's long term projections suggest renewed growth in the coming decade with a return to a 2% annual demand growth anticipated.

- A projected 1% annual growth in production and a 2% increase in annual imports (of both natural gas and LNG) will allow supply to keep pace with demand growth.

- However, as might be anticipated prices during the coming ten year period will likely average significantly higher than historical levels in response to the continuation of demand pressure on supplies.

B. Price Projections

Natural gas price projections used in economic analyses in later sections are based on projections in the EIA Annual Energy Outlook 2006 (EIA, 2006). The general approach was to adjust the EIA projections for average U.S industrial natural gas prices (Table 1) by the average historical spread between those prices and average Alabama industrial natural gas prices. The same general approach was used for projecting average Illinois industrial natural gas prices to be used in comparing the economics of Alabama and Illinois IPEP systems in a later section.

Table 1. Projected average U.S. industrial natural gas prices. [1/]

Year	Projected price, $/Mcf
2006	7.56
2007	6.84
2008	6.45
2009	6.02
2010	5.69
2011	5.46
2012	5.38
2013	5.45
2014	5.35
2015	5.16
2016	5.15
2017	5.19
2018	5.36
2019	5.49
2020	5.49
2021	5.62

1/ EIA Annual Energy Outlook 2006

A comparison of historical average industrial natural gas prices for the United States and Alabama is presented in Figure 1 and the associated long-term spread is presented in Figure 2. The average long-term spread is $1.24/Mcf. Based on this spread and average U.S industrial natural gas prices, projected Alabama industrial natural gas prices are presented in Figure 3.

Figure 1. Natural Gas Prices: Average Price Sold to Industrial Consumers in AL vs. NYMEX (Henery Hub) Nearby Futures (Source: US DOE, Energy Information Administration, NYMEX)

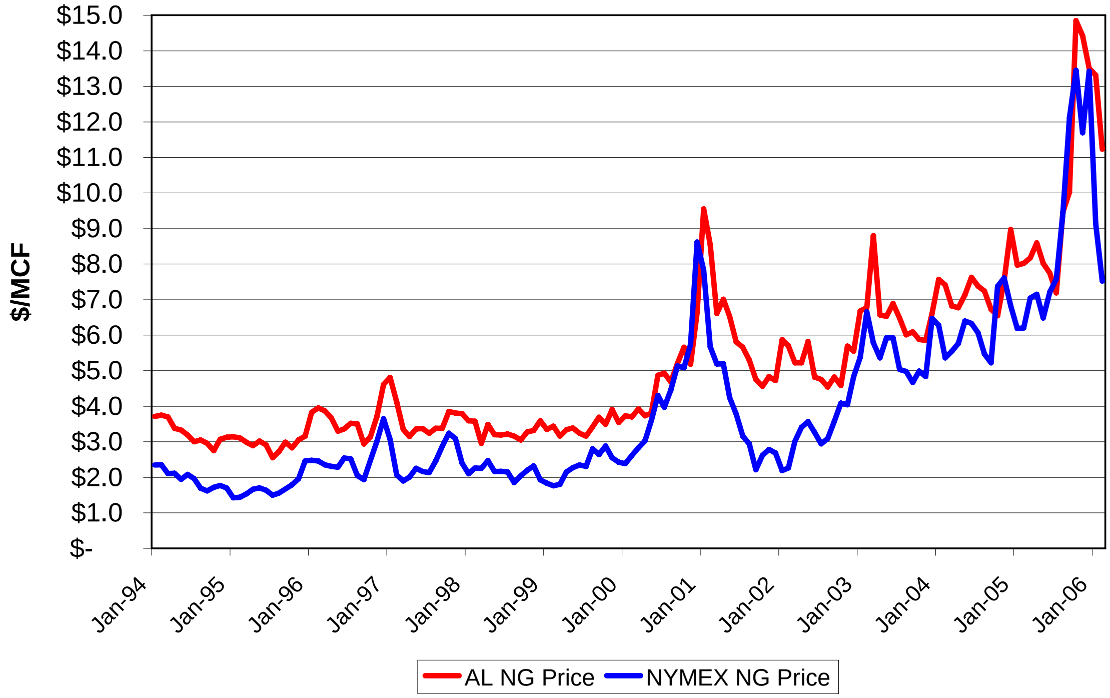


Figure 2. Spread Between Natural Gas Prices: NYMEX (Henery Hub) Nearby Futures to Average Industrial Consumers Price in AL
Source: US DOE, Energy Information Administration & NYMEX

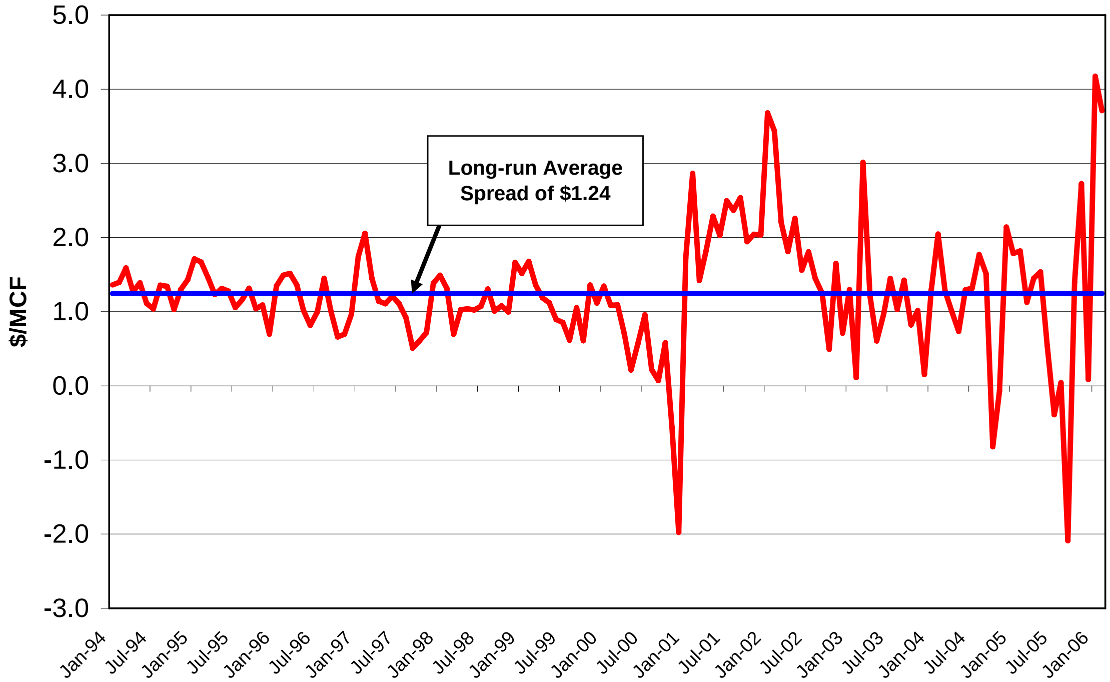
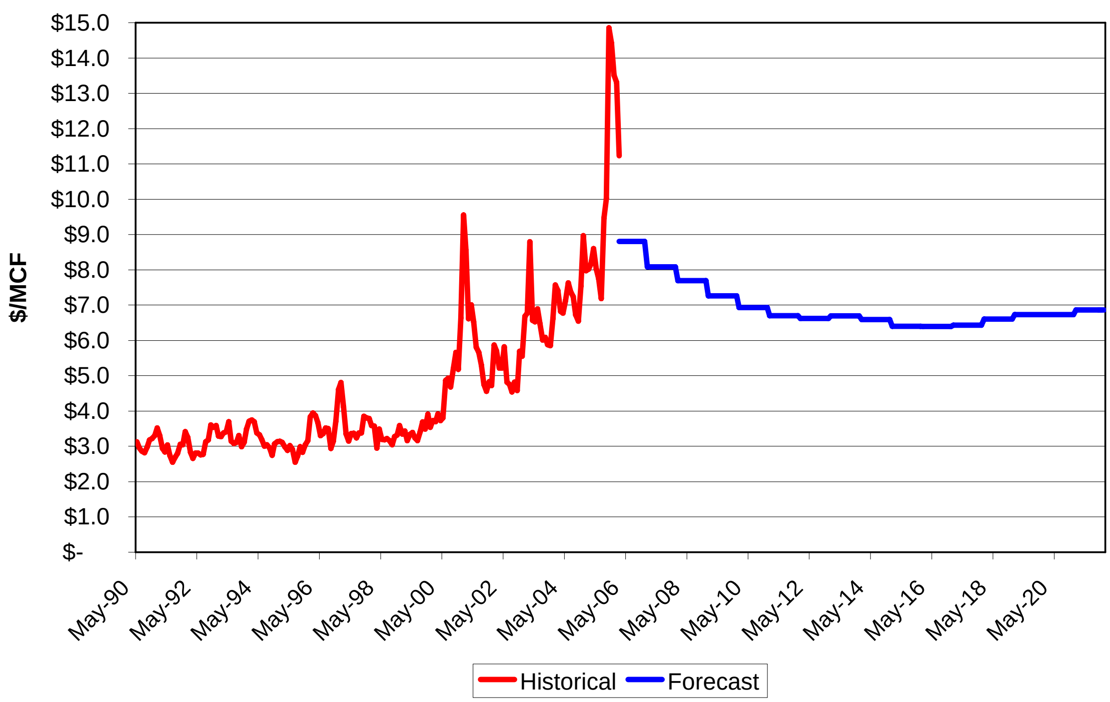


Figure 3. Natural Gas Prices: Historical Average Price Sold to Industrial Consumers in AL & Forecast (Source: US DOE, Energy Information Administration, NYMEX, Decision Economics & Informa)



A comparison of historical average industrial natural gas prices for Alabama and Illinois is presented in Figure 4 and the associated long-term spread is presented in Figure 5. The average long-term spread for Illinois vs. Alabama is $0.53/Mcf. Projected Illinois industrial natural gas prices are presented in Figure 6 based on the combined spreads of Illinois vs. Alabama ($0.53/Mcf, Figure 5) and Alabama vs. U.S. ($1.24/Mcf, Figure 2).

Figure 4. Natural Gas Prices: Average Price Sold to Industrial Consumers in IL vs. AL (Source: US DOE, Energy Information Administration)

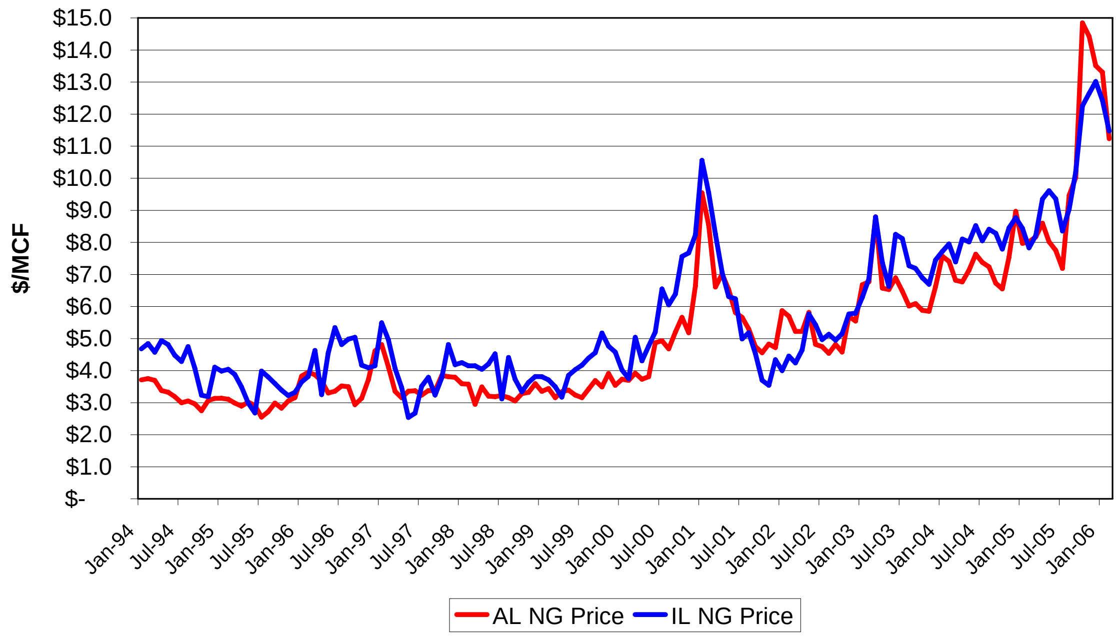


Figure 5. Spread Between Natural Gas Prices: Average Industrial Consumers Price in IL versus AL

Source: US DOE, Energy Information Administration

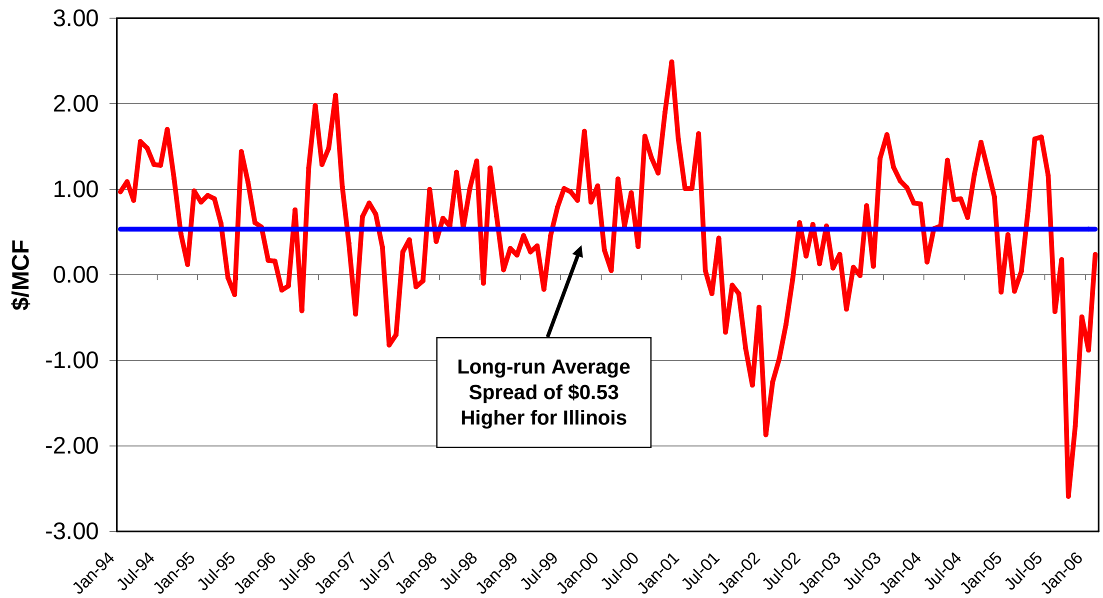
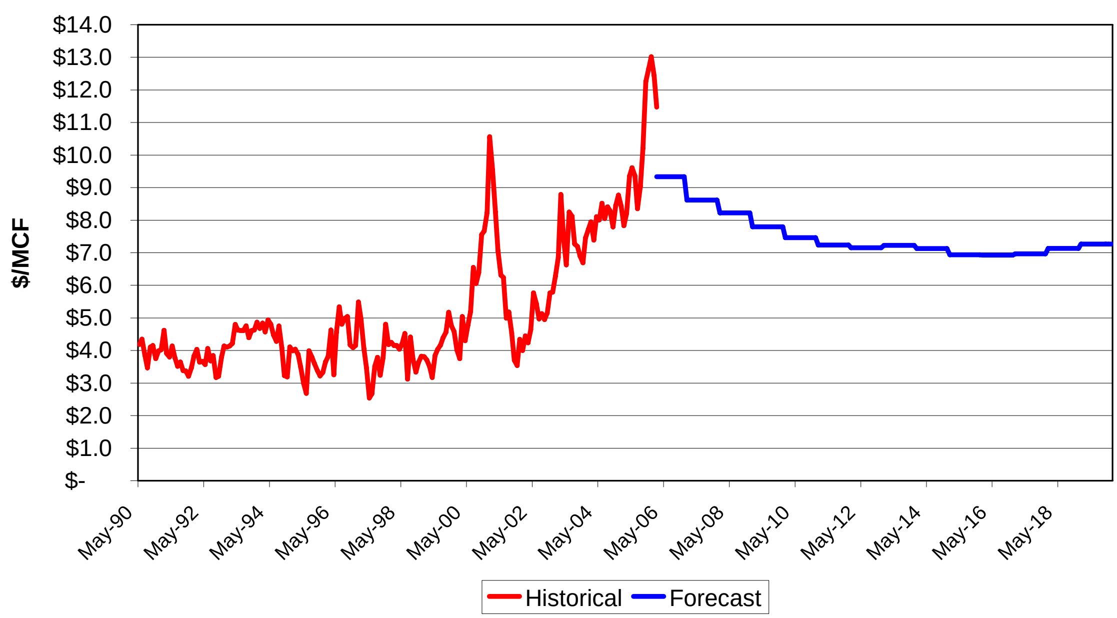


Figure 6. Natural Gas Prices: Historical Average Price Sold to Industrial Consumers in IL & Forecast (Source: US DOE, Energy Information Administration, NYMEX, Decision Economics & Informa)



C. References

EIA. 2006. Annual Energy Outlook 2006. February 2006. www.eia.doe.gov/oiaf/aeo/

XI. Electricity Prices

A. Background

Electricity prices have been much more stable than natural gas prices. Average U.S. retail electricity prices experienced spikes in 2004-2006 due to increased fuel costs for generation but are expected to decline back to 2000-2004 levels over the next 10 years (EIA, 2006). Therefore, historical electricity prices are expected to be an adequate first-approximation of projected electricity prices for this analysis. Historical electricity prices are presented below for Alabama and Illinois and will be used as a basis for projected electricity prices in subsequent economic analyses of Alabama and Illinois ethanol plant scenarios.

B. Historical Prices

Average Alabama industrial electricity prices for 1990 to 2005 are presented in Figure 1. Prices generally decreased gradually from 1990 to 1998 and then increased gradually through 2005. The average price from 1990-2005 was 4.06¢/kwh.

Average Illinois industrial electricity prices for 1990 to 2005 are presented in Figure 2. Prices generally decreased throughout that period. The average price was 5.08¢/kwh.

Average Alabama and Illinois industrial electricity prices for 1990 to 2005 are compared in Figure 3. By the end of 2005, these prices had reached parity at about 4.5¢/kwh. An electricity price of 4.6¢/kwh will be used in subsequent economic analyses that compare Alabama and Illinois ethanol plant scenarios.

Figure 1. Alabama Average Cost Per KWH for the Industrial Sector

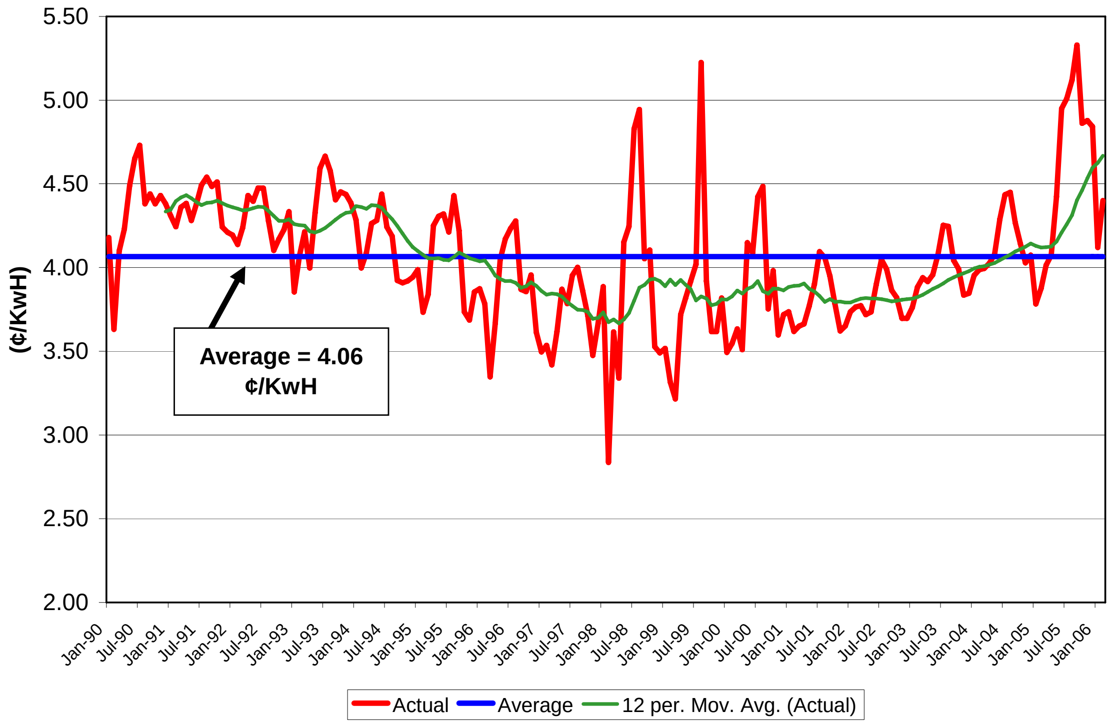


Figure 2. Illinois Average Cost Per KWH for the Industrial Sector

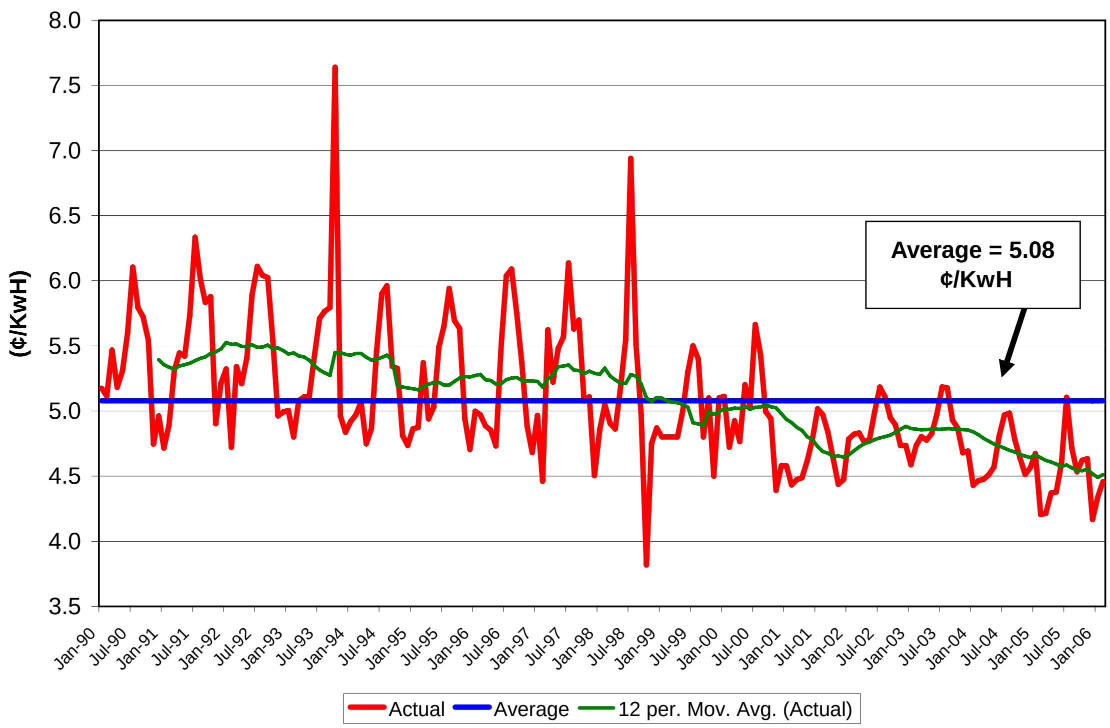
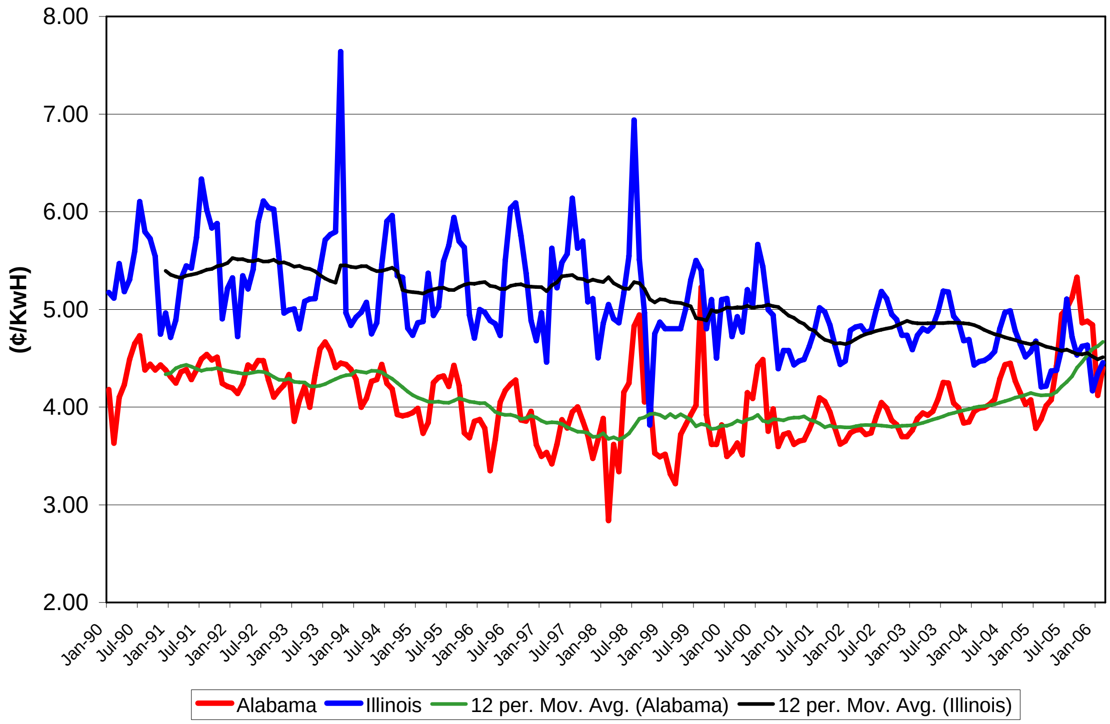


Figure 3. Comparison of Alabama and Illinois Average Cost Per KWH for the Industrial Sector



XII. Siting Considerations and Transportation Costs

A. Siting Considerations

Key siting considerations for an IPEP project in north Alabama are proximity to the poultry industry (especially for poultry litter supplies, but also for DDGS and carbon dioxide markets), water access for barge transportation (especially for corn), rail access (especially for ethanol), natural gas access (sufficient capacity for back-up and possibly as supplemental fuel), and electricity access (sufficient capacity for entire IPEP facility). Prospective sites must be zoned for industrial development and relatively non-controversial for industrial development from a public perspective.

Broiler production density in north Alabama is presented in Figure 1. Guntersville is centered within a 50-mile radius of the largest poultry producing counties in north Alabama. Decatur is somewhat off-center from the largest poultry producing counties but as discussed below, transportation infrastructure advantages at Decatur at least partially offset the lack of central location relative to the largest poultry producing counties in north Alabama.

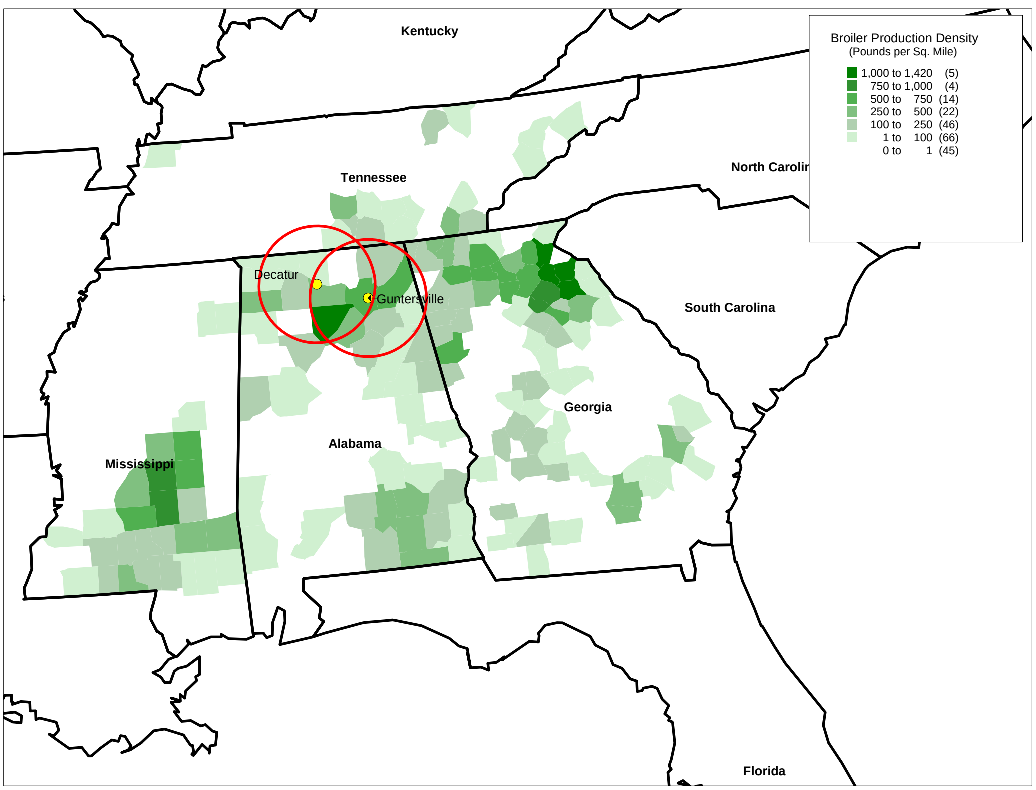


Figure 1. Broiler production density relative to Decatur and Guntersville, AL.

Barge transportation is expected to generally be the least-cost option for transporting corn to north Alabama, so barge access is a critical requirement for an IPEP site. Both Guntersville and Decatur are major barge destinations on the Tennessee River (Figure 2) which provides access to the major inland waterways.

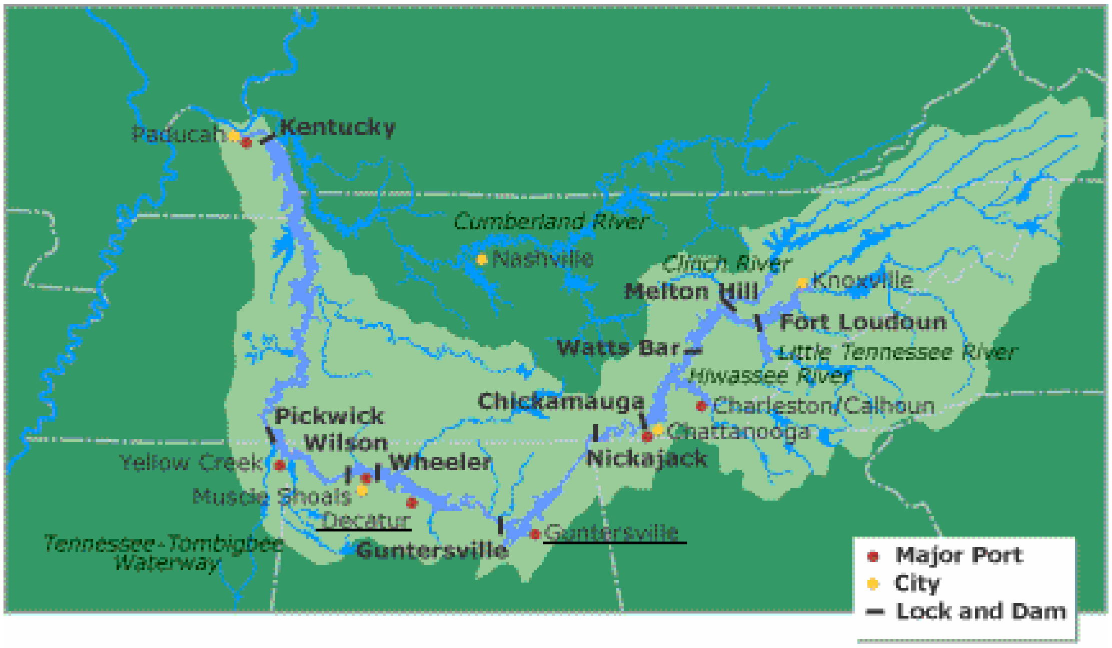


Figure 2. Decatur and Guntersville, AL are major ports on the Tennessee River.

Rail is expected to be the least-cost option for transporting most of the ethanol for an IPEP project except in some cases for shorter hauls such as to Atlanta and Birmingham. The Norfolk Southern railroad runs east-west through Decatur and the CSX railroad runs north-south through Decatur (Figure 3). A spur of the CSX railroad runs generally south from Guntersville to Gadsden (Figure 3). The site being considered at Decatur is on a Norfolk Southern spur near Bakers Creek (Figure 4). An aerial view of the Decatur site showing access to both rail and the Tennessee River is presented in Figure 5. Electricity transmission lines run across the property and a natural gas main is nearby. This site is in an industrial park which should minimize “not in my back yard” objections. Decatur is close to Interstate 65 and other good highways. The main negative is its distance from the largest poultry producing counties.

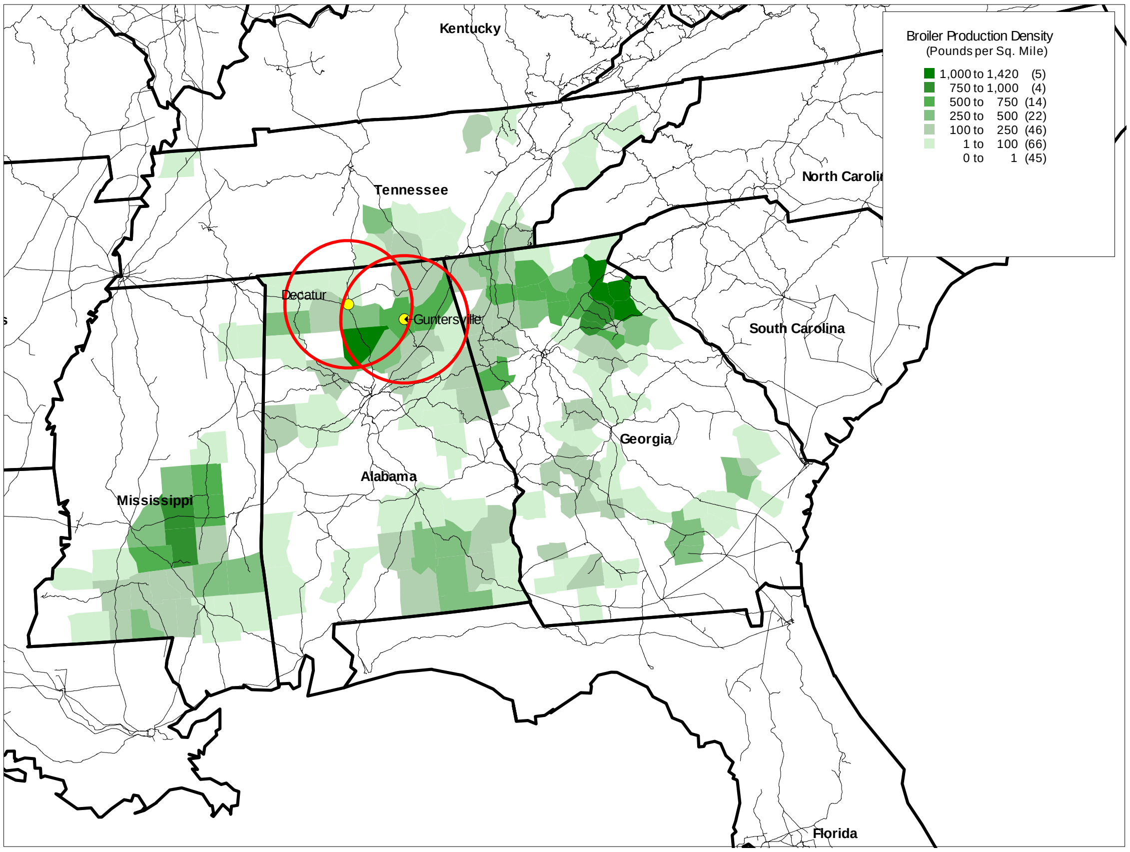


Figure 3. Decatur and Guntersville, AL access to southeastern railroads.

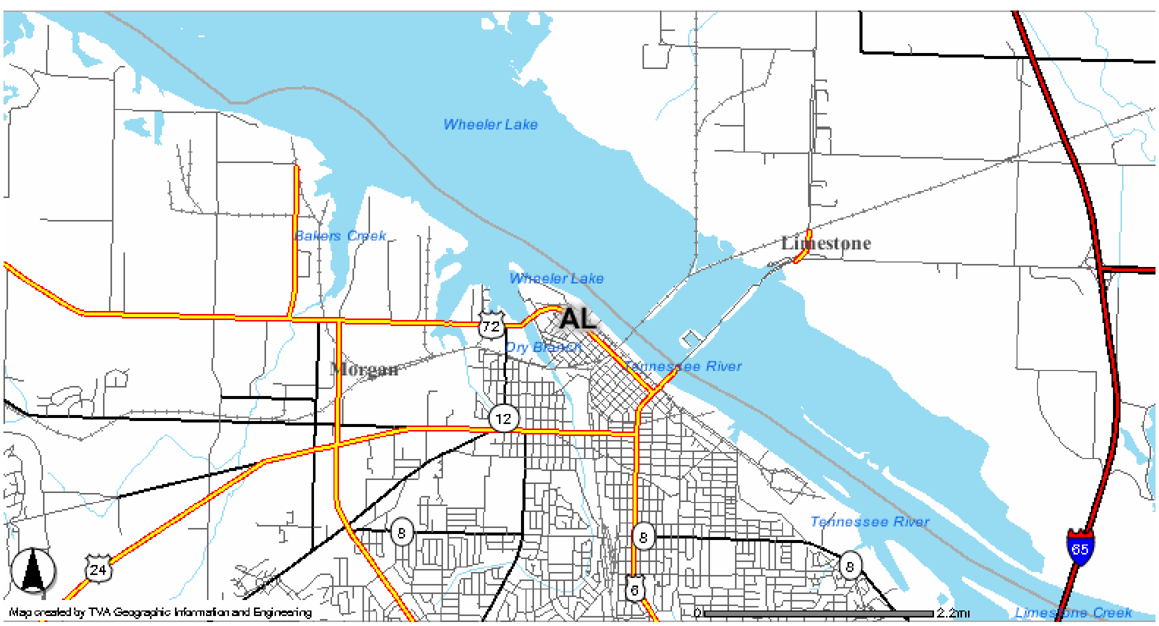


Figure 4. Potential IPEP site at Beavers Creek rail spur in Decatur, Al.

Figure 5. Decatur site with access to rail (white "Y" on left) and river.

The Guntersville site being considered is actually about 4 miles up river from Guntersville (Figures 6 and 7). It is the former site of a Monsanto plant that manufactured polyester. The access road is the portion of the green road in Figure 6 extending west from highway 227 toward the Tennessee River. This site has excellent access to the river, electricity, and natural gas and may not suffer strongly from "not in my backyard" objections since it is a former industrial site. The main negative is that it is not on a railroad. However, preliminary investigations indicate that it may be economical to use a barge shuttle to transfer ethanol to rail at Guntersville. The concept would be to use two barges as primary storage of ethanol product so that one barge could be filling while the other barge is transferring to rail. The roundtrip towing cost to the railroad at Guntersville would be approximately $250 which is a negligent per gallon cost for a 400,000 gallon barge. A preliminary estimate of the cost of ethanol transfer to rail is $0.014 per gallon. Part of the cost of transfer from barge to rail would be offset by having no railroad infrastructure and loading costs at the IPEP site.

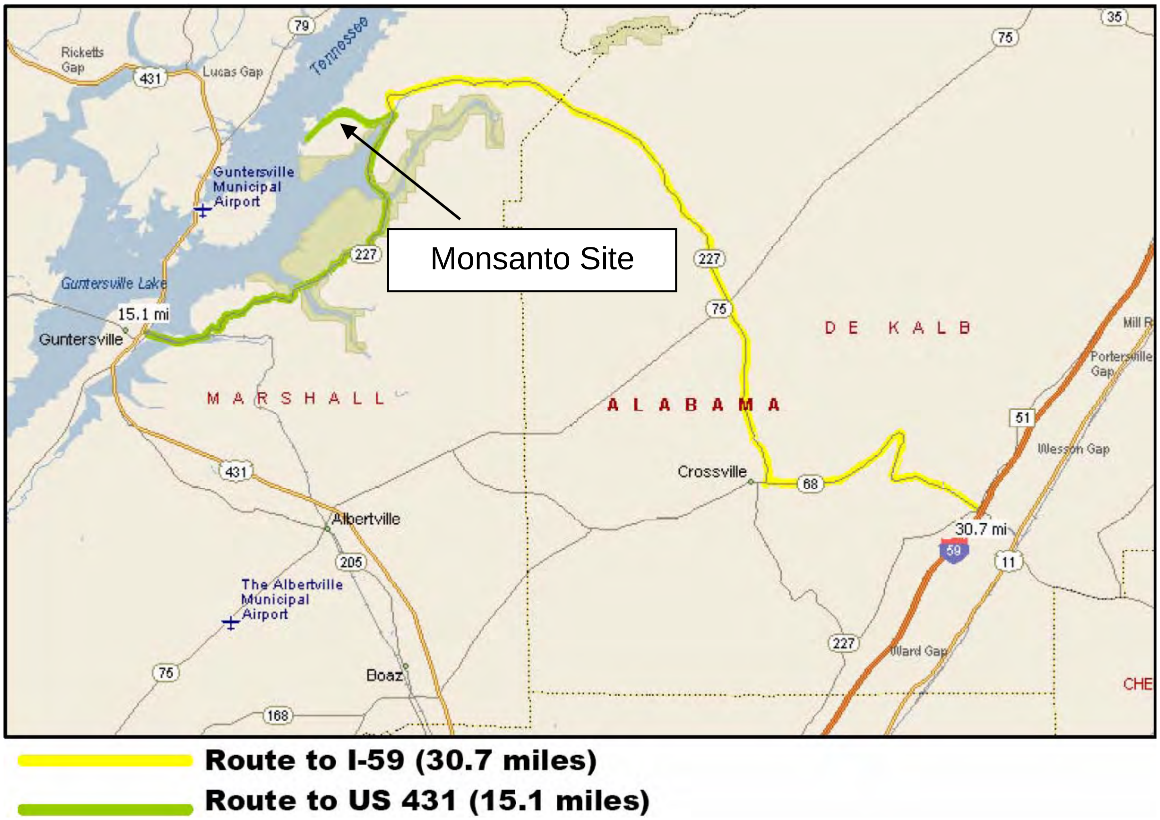


Figure 6. Road access to the former Monsanto site on the Tennessee River.

Figure 7. Former Monsanto site near Guntersville, AL.

An advantage of the Monsanto site near Guntersville is that large feed mills are located at Guntersville (Figures 8 and 9) which would be good markets for DDGS. The roundtrip cost for shuttling barges to the feed mills would be only $250 per barge (negligible cost per ton DDGS). Transportation costs for DDGS to other feed mills on the Tennessee River would also be very low. The Monsanto site is also well positioned for trucking DDGS to feed mills in north Alabama.

Figure 8. Feed mills on the Tennessee River at Guntersville, AL.

Figure 9. Feed mills on the Tennessee River at Guntersville, AL.

Rail access is not an important factor regarding transport of carbon dioxide from an IPEP project because the carbon dioxide would be transported by truck, in some cases to nearby poultry processing plants for use in making dry ice and for fast freezing meat.

B. Transportation Costs

Assuming candidate sites at Decatur and Guntersville discussed above, transportation costs for ethanol, DDGS, and poultry litter were provided by Chris Dager, transportation specialist in Economic Development at TVA. A summary of these costs is presented in Tables 1-5. These cost estimates were made in early 2004. Transportation costs have increased since that time but these estimates still provide a good relative indication of transportation costs for the two sites.

Ethanol transportation costs for origins and destinations of interest are presented in Table 1. Atlanta was used as a representative destination because of the potentially very large ethanol market there and because it is an intermediate distance relative to other primary ethanol markets in the southeastern US. Since the potential IPEP site at the former Monsanto site near Guntersville does not have direct access to rail, truck transportation costs for ethanol were used in the base case (highlighted in yellow) for Guntersville. As discussed earlier, shuttling ethanol barges to rail at Guntersville may also be an option and that option was also included in the assessment.

DDGS transportation costs for origins and destinations of interest are presented in Table 2. Westwego is near New Orleans and could be used as a point of transfer to ships for export markets. The local transportation distances by truck assume that DDGS would be sold to poultry feed mills in north Alabama. A longer distance was assumed for Decatur because it is not as centrally located among poultry feed mills in north Alabama.

Poultry litter transportation costs are presented in Table 3. Combined poultry litter transportation and clean-out costs are also presented, assuming $4.00 per ton of poultry litter for clean-out costs. The average combined costs for clean-out and transportation are $8.38 per ton for Guntersville and $11.50 per ton for Decatur, assuming $0.125 per ton-mile. Poultry litter feedstock costs are discussed in more detail in a later section.

An overall comparison of transportation costs for ethanol, DDGS, and poultry litter is presented in Tables 4 and 5. Table 4 includes Guntersville ethanol transportation costs by truck and Table 5 includes Guntersville ethanol transportation costs by rail. Carbon dioxide was not included in this comparison because it was assumed that an IPEP project would sell raw carbon dioxide for $13 per ton FOB at both the Decatur and the Guntersville sites and that carbon dioxide transportation costs would not affect the relative costs for the two sites. The overall transportation costs for ethanol, DDGS, and poultry litter are similar for Guntersville and Decatur. The higher DDGS and poultry litter transportation costs at Decatur are offset by higher ethanol transportation costs for Guntersville.

Table 1. Ethanol transportation costs, excluding loading and unloading.

	Origin						
Destination	Peoria	Loudon	Guntersville[1/]	Decatur(CSX)	Decatur(NS)	Guntersville	Decatur
	rail, $/ton					truck, $/ton	
Birmingham	28.54	10.69	8.97	6.38	8.82	14.00	11.48
Atlanta	32.53	9.91	14.83	13.70	12.01	21.71	25.32
Charlotte	32.70	20.93	22.24	21.09	19.22	40.80	45.20
Nashville	17.89	13.08	13.36	7.68	11.35	20.15	15.21
	rail, $/gallon					truck, $/gallon	
Birmingham	0.094	0.035	0.043	0.021	0.029	0.046	0.038
Atlanta	0.107	0.033	0.063	0.045	0.039	0.071	0.083
Charlotte	0.107	0.069	0.087	0.069	0.063	0.134	0.148
Nashville	0.059	0.043	0.058	0.025	0.037	0.066	0.050

[1/] Includes $0.014/gallon for barge to rail transfer

Table 2. DDGS transportation costs, excluding loading and unloading.

Destination	Origin: Guntersville	Decatur	Peoria	Loudon
	$/ton			
Local by truck (35 mi.)[1/]	4.38			
Local by truck (60 mi)[1/]		7.50		
Westwego by barge[2/]	9.26	8.83	11.21	12.92
	$/gallon			
Local by truck (35 mi.)[1/]	0.014			
Local by truck (60 mi)[1/]		0.023		
Westwego by barge[2/]	0.029	0.027	0.035	0.040

[1/] Including linehaul but not loading and unloading charges

[2/] Including linehaul and unloading charges

Table 3. Poultry litter feedstock costs.

	Clean out	Transportation			Total	
	$/ton PL	$/ton-mile	miles	$/ton	$/ton	$/gallon
Guntersville	$4.00	0.125	35	4.38	$8.38	$0.031
Decatur	$4.00	0.125	60	7.50	$11.50	$0.043

Table 4. Cost comparison of transportation factors at Guntersville and Decatur.

	Guntersville (truck)	Decatur (CSX)	Decatur (NS)
	$/gallon		
Ethanol transportation to Atlanta[1/]	0.071	0.045	0.039
DDGS transportation (local)	0.014	0.023	0.023
Poultry litter feedstock costs	0.031	0.043	0.043
Total	0.116	0.111	0.106

[1/] Representative of average ethanol transportation cost.

Table 5. Cost comparison of transportation factors at Guntersville and Decatur.

	Guntersville (w/ rail)	Decatur (CSX)	Decatur (NS)
	$/gallon		
Ethanol transportation to Atlanta[1/]	0.063	0.045	0.039
DDGS transportation (local)	0.014	0.023	0.023
Poultry litter feedstock costs	0.031	0.043	0.043
Total	0.108	0.111	0.106

[1/] Representative of average ethanol transportation cost; includes $0.014/gal for barge to rail transfer

XIII. Fluidized Bed Combustion of Poultry Litter

A. Technical Assessment

1. Technical Challenges and Solutions

Poultry litter is a more challenging fuel than wood for several reasons. The ultimate analyses (Table 1) indicate some of the reasons. One reason is that the nitrogen content is about 10 times higher in poultry litter than wood. This increases the potential for fuel NO_X emissions and requires special measures to reduce these emissions. The sulfur content of poultry litter is more than 10 times higher than that of wood. This increases the potential for SO_X emissions and requires special measures to reduce these emissions. Chloride levels are higher in poultry litter than in wood. High chloride levels, in conjunction to high alkali levels, increase the potential for particulate emissions, corrosion problems, and acid gas emissions, and requires special measures. Ash levels are much higher in poultry litter than in wood, requiring higher-volume ash-handling equipment and more attention to particulate removal, slagging, and fouling.

Table 1. Ultimate Analysis (As-Received) of Sawdust and Delmarva Poultry Litter.[1/]

	Sawdust	Poultry litter
Carbon, %	24.2	27.2
Hydrogen, %	2.8	3.7
Oxygen (by difference), %	18.3	23.1
Nitrogen, %	0.22	2.7
Sulfur, %	0.02	0.3
Chlorine, %	--	0.7
Ash, %	2.0	15.7
Moisture, %	52.6	27.4
Higher heating value (HHV), Btu/lb	4,150	4,637
HHV (dry), Btu/lb	8,760	6,394

[1/]Poultry litter samples from Maryland Department of Environmental Resources (Bock, 1999).

Elemental analyses of the ash (Table 2) indicate additional reasons that poultry litter is a more challenging fuel than wood. The concentration of alkali metals (sodium oxide, Na_2O, and potassium oxide, K_2O) is much higher in poultry litter than in wood. The lb alkali/MBtu is 9.3 for poultry litter vs. 0.4 for wood. High alkali content, especially in conjunction with high chloride levels, results in a high potential for slagging, fouling, particulate emissions, and corrosion.

Following are key measures that have been employed for dealing with the challenging fuel properties of poultry litter.

<u>NO_X Emissions:</u> Staged combustion is a widely used option for lowering NO_X emissions from a high-nitrogen fuel such as poultry litter. With staged combustion, combustion conditions are somewhat more reducing and less fuel nitrogen is converted to NO_X. Flue gas recirculation in the upper vapor space can also be used to reduce NO_X emissions. Ammonia injection, selective noncatalytic reduction (SNCR), under appropriate conditions also reduces NO_X emissions, and the naturally occurring ammoniacal nitrogen in poultry litter helps keep NO_X emissions low.

Table 2. Elemental Analysis (%) of Ash From Sawdust and Delmarva Poultry Litter.[1/]

	Sawdust	Poultry litter
SiO_2	35.6	8.1
Al_2O_3	11.5	1.9
TiO_2	0.9	0.2
Fe_2O_3	7.6	1.2
CaO	24.9	17.3
MgO	3.8	5.0
Na_2O	1.7	9.2
K_2O	5.8	16.3
P_2O_5	1.9	24.4
SO_3	0.8	6.7
CO_2/other	5.7	9.7
Total	100.0	100.0
lb alkali/MBtu	0.35	9.3

[1/]Poultry litter samples from Maryland Department of Environmental Resources (Bock, 1999).

<u>SO_X Emissions:</u> The naturally occurring calcium and magnesium in poultry litter can trap some SO_X in the form of sulfates. If additional measures are needed, lime injection, either with the fuel or downstream, is the primary option for reducing SO_X emissions.

<u>Alkali Problems:</u> Maintaining low combustion or gasification temperatures is the main line of defense in controlling alkali-related slagging and fouling problems. Lower combustion or gasification temperatures mean that more heat exchange surface area is needed to achieve a given boiler efficiency. In some cases, lime injection also helps alleviate alkali problems. In fluidized-bed systems, lime injection prevents agglomeration of the bed material, and at the same time, alleviates slagging, fouling, corrosion, and acid-gas emission problems.

<u>Chloride-Related Problems:</u> For electrical power generation, the superheated steam temperature is limited to about 750^{o}F to avoid rapid corrosion of

superheater boiler tubes. The high chloride concentrations found in poultry litter requires expensive alloys in the design of superheater boiler tubes to improve longevity. Refractories used in the furnace must be an ultra-low cement material, since refractories containing calcium are rapidly attacked by chlorine. Careful attention to flue gas dewpoint temperatures is necessary to avoid cold-end corrosion in economizers and air heaters. From an air pollution perspective, chloride abatement can be minimally accomplished with the addition of a dry scrubber, depending on the size of the boiler project. Chloride is listed as a hazardous air pollutant under the Clean Air Act, with a 10-ton/year emission limit to avoid major source designation.

<u>Particulate Emissions:</u> In addition to normal fine particulate emissions that occur from burning wood, volatile alkali compounds (mainly KCl) from poultry litter can carry through to the boiler and increase the particulate load that must be removed from the flue gas. Baghouse capacity may need to be increased relative to that required for wood; in some cases, cloth-to-air ratios have been increased for high-ash fuels to reduce cleaning frequency and increase bag life.

2. Technical Feasibility of the EPI Fluidized Bed Technology for Poultry Litter

Pilot plant tests indicate that use of the EPI fluidized bed technology with poultry litter addresses the challenges discussed above and is technically feasible from both operational and atmospheric emissions perspectives, Murphy (2000) and Bock (2004). In a 15-day 24/7 test with turkey litter, atmospheric emissions were controlled within permittable limits without adding lime for SOx control or adding ammonia for NOx control and slagging and fouling were controlled without amending the poultry litter with lime (Bock, 2004).

3. System Description

The following is the description of an EPI bubbling fluidized bed system designed to provide 175,000 lb/hr of 125 psi process steam for a nominal 50 million gallon per year corn/ethanol plant. This system will provide all the process heat required for the ethanol plant, including steam for drying of distiller dried grains and solubles (DDGS) and will require 218 MBtu/hr of heat input from poultry litter (45,096 lb/hr). Exhaust from the ethanol plant DDGS dryer is used as part of the combustion air as a means of destroying dryer VOCs. This eliminates the need for a thermal oxidizer on the DDGS dryer.

The conceptual equipment arrangement (Figure 1), elevation view (Figure 2), and plan view (Figure 3) indicate the main equipment included in the fluidized bed combustion system: combustor, boiler, economizer, multiclone, spray dryer, and baghouse. As discussed in an earlier section, atmospheric emissions except for particulate and possibly HCl from the EPI fluidized bed system are achieved in the combustor. The spray dryer is included to remove HCl, if necessary.

The conceptual design for the poultry litter handling and storage facility is illustrated in Figure 4. The design considered many components including: biosecurity, on-farm storage, multiple litter sources, transportation, enclosed unloading and storage, venting, ammonia, pH, alternate fuels, and fire hazards.

Litter handling characteristics and composition are easily identified. Compared with other fuels, additional controls are required to ensure operator health and biosecurity, avoiding contamination between poultry farms. Litter is received and fired in as coarse and unprocessed a form as possible with a minimum of fuel handling to reduce hazards of odor, dust, and health exposure. Since a variety of qualities of litter will be received, it may be necessary to have a receiving facility capable of segregating litter into different storage bins.

The receiving building and conveyors to storage silos are enclosed to minimize fugitive emissions. Litter is stored under negative pressure, maintained by induced draft fans, to prevent noxious odors from escaping into the atmosphere. Combustion air flows were obtained from EPI to determine how much odor and ventilation air can be used from the receiving and processing facility. Part of the combustion air is obtained from the storage and handling facility. Withdrawal of the combustion air from the poultry litter storage and handling facility maintains a negative pressure in the facility, thereby preventing escape of odors. VOCs and ammonia from the poultry litter storage and handling facility are destroyed in the combustor.

Two ash storage silos are located between the combustor and poultry litter storage and handling facility. One silo is for baghouse ash and the other silo is for the coarser ash that drops out earlier in the system. The two ashes are stored separately because in some cases they will go to different markets. The biosecurity truck washing station (not included in this view) is located just beyond the truck scale.

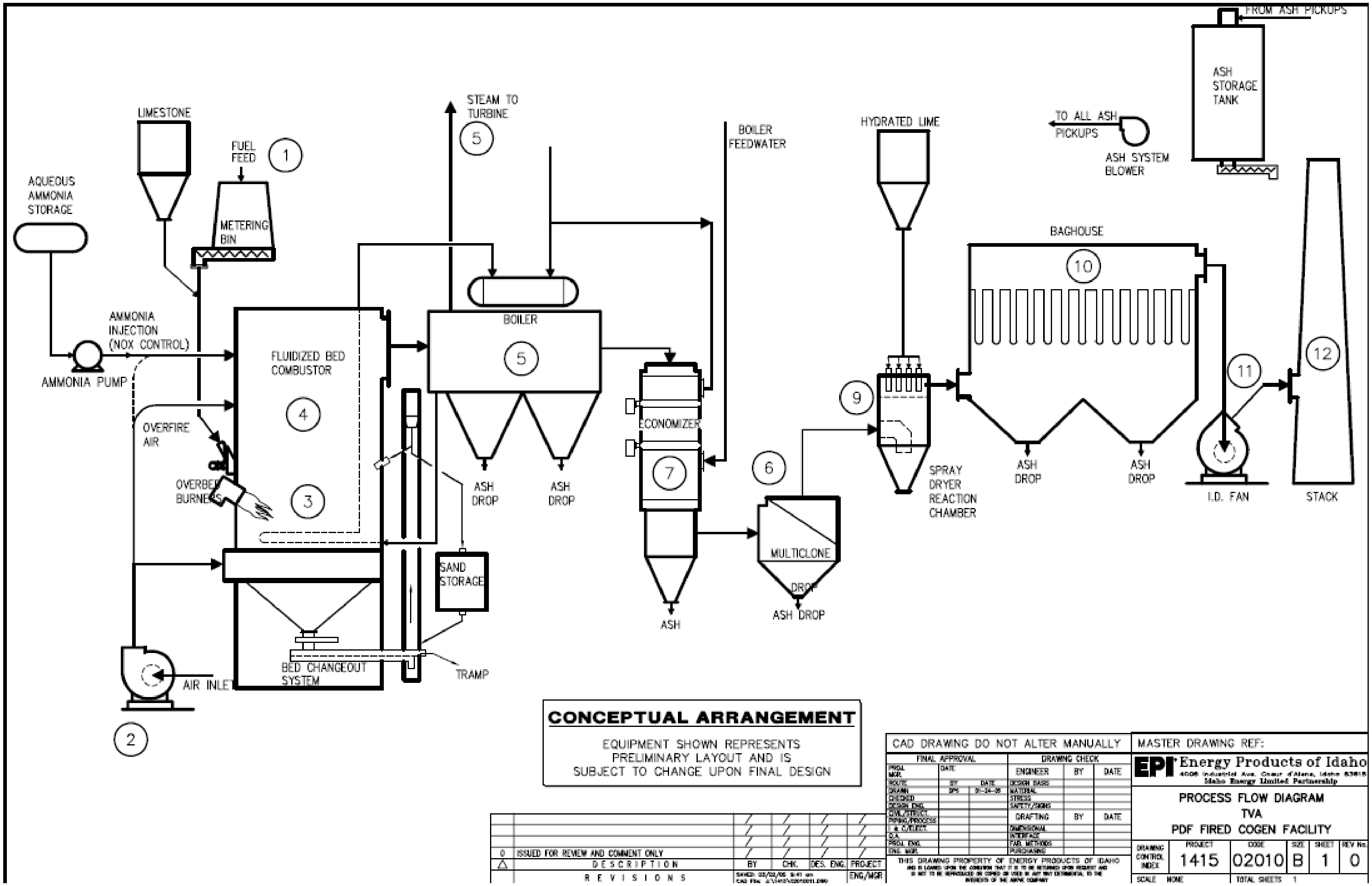


Figure 1. Conceptual equipment arrangement for poultry litter energy plant.

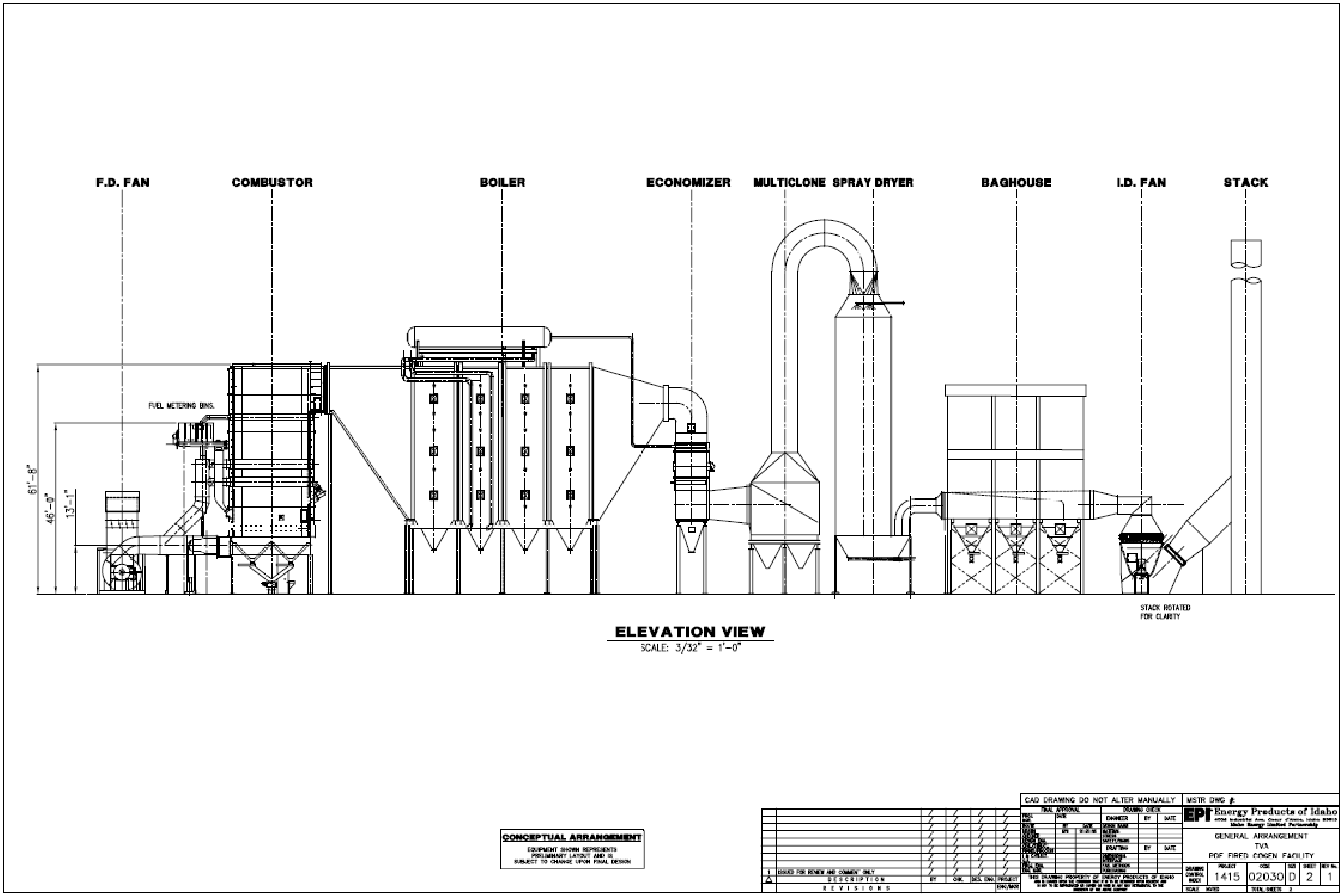


Figure 2. Elevation view of poultry litter energy plant.

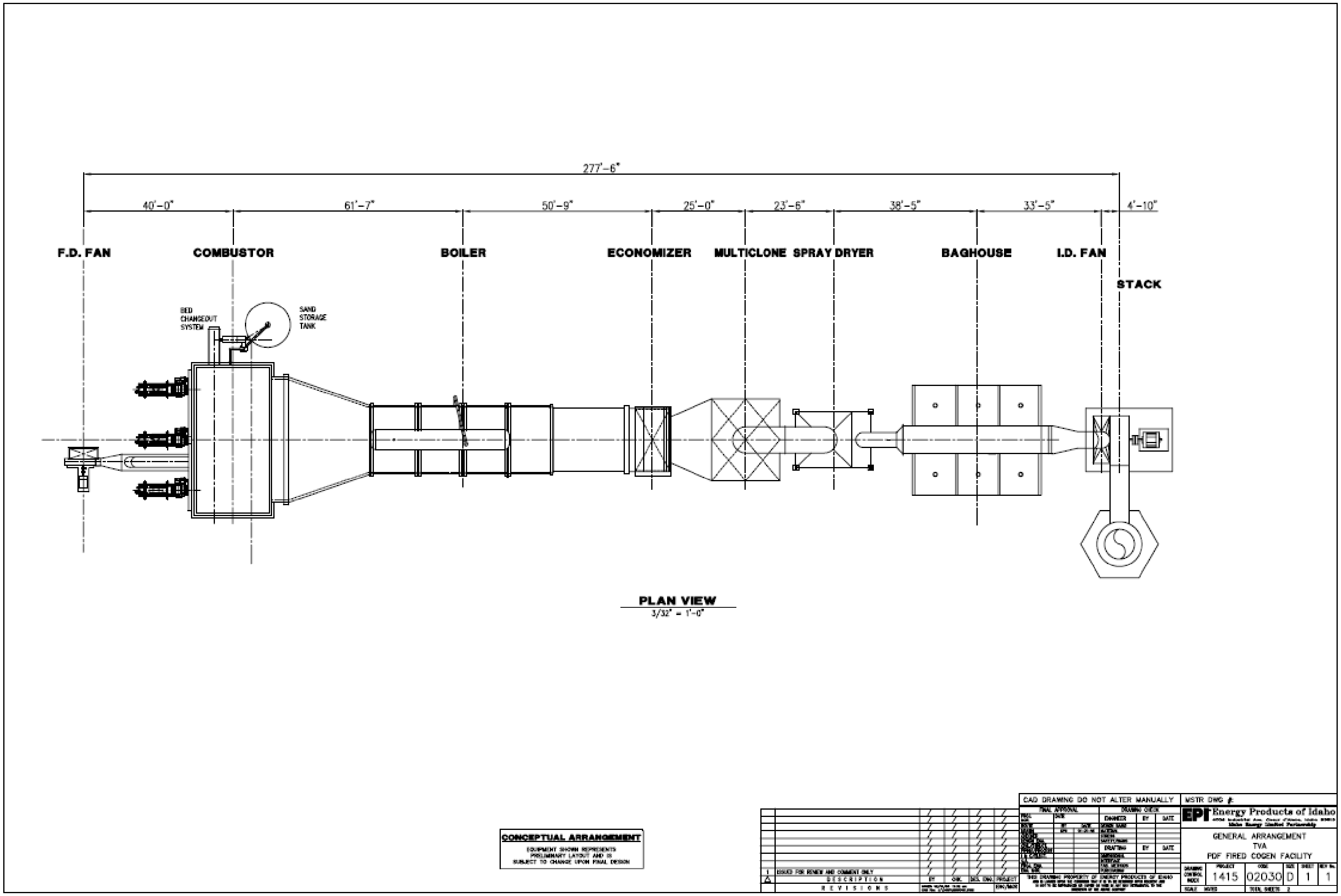


Figure 3. Plan view of poultry litter energy plant.

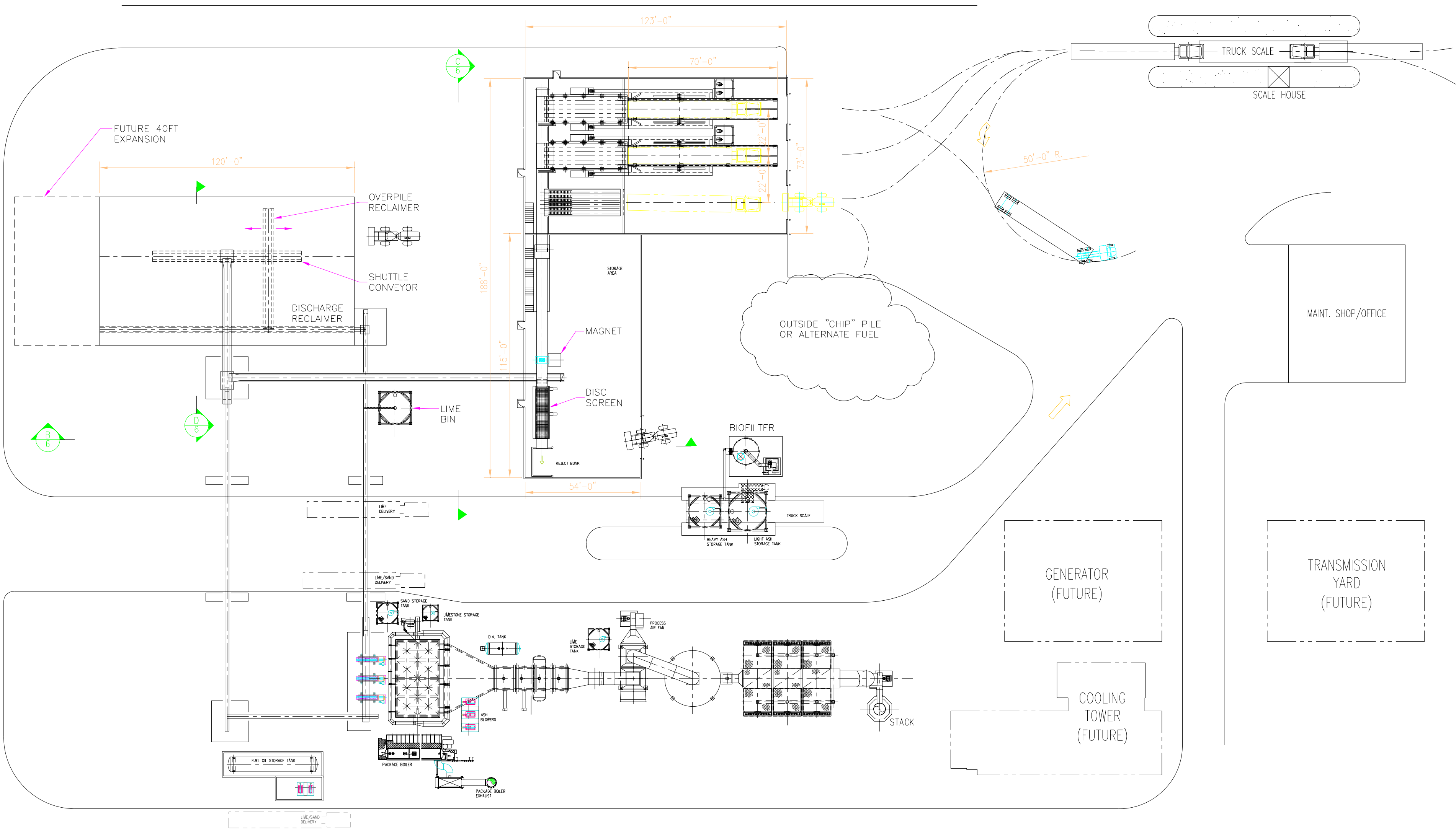


Figure 4. Plan view of poultry litter handling and storage facility.

B. Economic Assessment

Two approaches were used for the economic assessment as follows:

1. In the first approach, costs for energy system capital, O&M, and poultry litter feedstock were estimated, NG prices were projected for the next 10 years, the total avoided NG costs were assigned to the poultry litter energy system as an increase in cash flow, and no NG savings were assigned to the ethanol plant. This approach indicates the profitability of replacing NG with poultry litter-derived energy but doesn't assign any of the cost savings to the ethanol plant.
2. In the second approach, the same costs for energy system capital, O&M, and poultry litter feedstock were used but the energy plant was assumed to sell process heat to the ethanol plant at a price ($/MBtu NG displaced) significantly less than the average projected NG price for the next 10 years. With this approach, the energy plant sells process heat to the ethanol plant at a price that gives the energy plant an attractive rate of return and at the same time provides significant energy cost savings to the ethanol plant. The cost savings to the ethanol plant were expressed in units of $/MBtu NG displaced by poultry litter. This approach provides a simple means of partitioning avoided NG costs between the energy plant and the ethanol plant and facilitates an easy economic comparison of ethanol plants getting their process energy from poultry litter vs. from NG.

1. Poultry Litter Energy System Costs

The base-case estimates of capital costs for the system described above are summarized in Table 3. The cost estimate for primary equipment components shown in Figures 2 to 4 was based on an EPI quote (EPI, 2005). Installation costs for EPI equipment were estimated as 40 percent of EPI equipment costs. Installation costs likely would be higher in higher cost urban areas. The other capital costs were estimated based on conceptual designs and are highly dependent on site-specific factors that are not totally defined at this point.

Table 3. Preliminary estimate of capital costs ($1000) for poultry litter energy plant.	
EPI equipment	12,600
Installation of EPI equipment	5,040
Poultry litter storage and handling	4,000
Remaining balance of plant	4,000
Engineering fees	500
Permitting	250
Land	1,000
Total	27,390

Our base-case capital cost estimate of $27,390,000 is similar to published costs for a new EPI fluidized bed system using coal to supply steam for a 50 million gallon per year ethanol plant at Goldfield, Iowa (Des Moines Register, 2006). Total capital costs for the ethanol plant and energy system were listed at $18 to 20 million more for the Goldfield plant with coal-fired system vs. what an ethanol plant with NG system would have cost. A NG system would have included a NG package boiler, NG burner for the DDGS dryer, and a thermal oxidizer to destroy VOCs from the DDGS dryer with a combined cost of about $4 million. None of the NG system components was required for the coal-fired unit. A thermal oxidizer was not required for the coal-fired unit because VOCs from the DDGS dryer are destroyed in the coal combustor. Therefore, the implied cost of the Goldfield coal-fired system was about $22 to 24 million. This is comparable to our estimated capital cost for a poultry litter energy system using the same EPI fluidized bed combustion technology to provide steam for the same size ethanol plant (Table 3). Somewhat higher capital costs would be expected for a poultry litter energy plant because of added costs for a dry scrubber for removing Cl-containing compounds and higher costs for the poultry litter handling system. A sensitivity analysis of internal rate of return (IRR) and return on investment (ROI) is provided in a later section for capital costs ranging from $20 to 35 million in order to cover possible contingencies.

Preliminary estimates of incremental O&M costs (excluding fuel) for the poultry litter energy system (combustion system and poultry litter storage and handling facility) co-located with a corn/ethanol dry mill are presented in Table 4. The operator costs assume that ethanol plant operators can serve as back-up operators for the poultry litter energy plant. Five full-time operators would provide 25 shifts per week, assuming 5 shifts/week/operator. Assuming a 24/7 operation with 21 shifts/week, 4 extra shifts/week would be available to cover vacation and holidays. Only one maintenance staff is included, assuming significant sharing of maintenance staff with the corn/ethanol plant. Management and administrative staff are assumed to be supplied by the corn/ethanol plant. No emission control additive costs are included in the base case because pilot plant testing with turkey litter (Bock, 2004) indicated that they will not be required to maintain SOx and NOx emissions below required limits. A sensitivity analysis of IRR and ROI is provided in a later section for O&M costs that include (1) base case, (2) base case plus 5 percent lime with poultry litter (2250 lb lime/hr at $30/ton = $287,550/year) to control SOx, and (3) base case plus 5 percent lime to control SOx plus 2 percent anhydrous ammonia (900 lb/hr at $350/ton = $1,341,900/year) to control NOx.

Table 4. Incremental O&M Costs for Poultry Litter Energy System Co-located with Corn/Ethanol Dry Mill

		Pay rate		Direct	Burden		OT hr	OT burden	OT	Total
Operation & Maintenance Staff	No.	$/hr	hr/yr	$/yr	%	$/yr	%	%	$/yr	$/yr
Senior operator(s)	5	25.00	2080	260,000	40	364,000	0	20	-	364,000
Maintenance staff	1	20.00	2080	41,600	40	58,240	0	20	-	58,240
Fuel receiving staff	5	15.00	2080	156,000	40	218,400	0	20	-	218,400
Total										**640,640**

Electricity	days/yr	kW	$/kWh	$/yr
	355	900	0.046	**352,728**

Maintenance/Replacement		% of capital	Capital Million $	$/yr
		1.5	27.39	**410,850**

Emissions additives	lb/hr	tons/yr	$/ton	$/yr
Limestone for SOx control	0	-	30	**-**
Anhydrous ammonia for NOx control	0	-	480	**-**
Total				**1,404,218**

Logistical considerations and projected costs of providing poultry litter to an IPEP project are provided in a subsequent section. As a base case, we assume that poultry litter can be obtained by an IPEP project for poultry litter cleanout and transportation costs which are estimated to average $10/ton. Sample calculations of poultry litter feedstock costs are provided in Tables 5 and 6. A sensitivity analysis of IRR and ROI is provided in a later section for poultry litter feedstock costs ranging from $6 to 14/ton.

The fertilizer nutrient value of poultry litter ash is discussed in a subsequent section. As a base case, we assume that a poultry litter energy plant can net $50/ton of ash after subtracting ash transportation costs. Also, as discussed in a later section, research conducted as part of this feasibility project indicates that poultry litter ash performs the same as dicalcium phosphate as a phosphorus and calcium mineral feed supplement for broilers. It is estimated on a preliminary basis that an energy plant may be able to net as much as $100/ton of ash used as a mineral feed supplement and that a net of $70/ton of ash after ash transportation costs is a conservative estimate. Additional research is needed to verify ash values for use as a mineral supplement for broilers. A sensitivity analysis of IRR and ROI is provided in a later section for net ash revenues ranging from $30 to 70/ton.

Assuming $10/ton of poultry litter and $50/ton of poultry litter ash gives an annual net fuel cost of $486,000 which is equivalent to $2.50/ton poultry litter (Table 5). Assuming $10/ton of poultry litter and $70/ton of poultry litter ash gives an annual net fuel cost of -$97,200 which is equivalent to $-0.50/ton poultry litter (Table 6). It is possible that in some cases net ash revenues may more than offset the delivered cost of poultry litter.

Table 5. Net Fuel Cost

Poultry litter (PL)		Poultry litter ash		
% ash:	15			
tons/year:	194,400	tons/year:	29,160	
Delivered PL cost		Net ash revenue		Net fuel cost
$/ton	$/year	$/ton	$/year	$/year
10	1,944,000	50	1,458,000	486,000
				$/ton
				2.50

Table 6. Net Fuel Cost

Poultry litter (PL)		Poultry litter ash		
% ash:	15			
tons/year:	194,400	tons/year:	29,160	
Delivered PL cost		Net ash revenue		Net fuel cost
$/ton	$/year	$/ton	$/year	$/year
10	1,944,000	70	2,041,200	(97,200)
				$/ton
				(0.50)

2. Approach 1: Avoided Natural Gas Costs and First Approximation of Cash Flow

A first approximation of avoided NG costs and cash flow is presented in Table 7. Projected NG prices average $6.94/MBtu over the next 10 years and $6.85/MBtu over the next 15 years. Details of capital, O&M, and poultry litter feedstock costs were presented in the previous section. It is assumed that an IPEP ethanol plant has the normal package boiler and thermal oxidizer for use as a backup to the poultry litter energy system, resulting in an IPEP ethanol plant per se (i.e., excluding the poultry litter energy system) having the same capital cost as a NG ethanol plant. Avoided NG costs for a given year were calculated as the product of $/MBtu NG displaced and MBtu NG displaced/year. It was assumed that 1,785,000 MBtu of NG per year would be displaced by the poultry litter energy system described above. This is the amount of NG used by a package boiler and a DDGS dryer combined in a conventional nameplate 50 million gallon per year corn/ethanol plant operating at 52,500,000 gallons per year (105% of nameplate capacity). This estimate of NG displaced assumes a requirement of 34,000 Btu NG/denatured gallon of ethanol produced in a conventional ethanol plant.

Table 7. Poultry Litter Energy System Costs, Avoided Natural Gas Costs, and Cash Flow: First Approximation

Capital costs, $1000	
EPI equipment[1/]	12,600
Installation of EPI equipment[2/]	5,040
Poultry litter storage	4,000
Remaining balance of plant	4,000
Engineering fees	500
Permitting	250
Land	1,000
Back-up package boilers	-
Total	27,390

[1/] Includes ash storage

[2/] 40% of equipment cost

Non-fuel O&M, $1000/yr	1,404
Net fuel cost[1/], $1000/yr	486
Back-up fuel costs:	
Days/year	-
Back-up fuel price, $/MBtu	7.18
Back-up fuel costs, $1000/yr	-

[1/] Poultry litter cost minus ash revenue

Year	$/MBtu NG displaced[4/]	Annual Avoided Natural Gas Costs[1/], $1000	Annual O&M[2/], $1000	Cash flow[3/] (before income tax), $1000	IRR
0				(27,390)	
1	8.08	14,430	1,890	12,539	-54.2%
2	7.69	13,734	1,890	11,843	-7.5%
3	7.26	12,966	1,890	11,076	14.4%
4	6.93	12,377	1,890	10,487	25.4%
5	6.70	11,966	1,890	10,076	31.4%
6	6.62	11,824	1,890	9,933	34.9%
7	6.69	11,949	1,890	10,058	37.1%
8	6.59	11,770	1,890	9,880	38.5%
9	6.40	11,431	1,890	9,541	39.4%
10	6.39	11,413	1,890	9,523	40.0%
11	6.43	11,484	1,890	9,594	40.4%
12	6.60	11,788	1,890	9,898	40.7%
13	6.73	12,020	1,890	10,130	40.9%
14	6.73	12,020	1,890	10,130	41.0%
15	6.86	12,252	1,890	10,362	41.1%
Mean--10-year	6.94				
Mean--15-year	6.85			Simple payback, years	2.18

[1/] Assumes:

52,500,000	denatured gallons ethanol produced/year
34,000	Btu natural gas (NG) displaced/denatured gallon ethanol
1,785,000	MBtu NG displaced/year

[2/] Includes non-fuel O&M, net pooultry litter, and back-up fuel oil or natural gas costs

[3/] Assumes 100% equity

[4/] Implied Alabama forecast using US industrial NG price projections from EIA Annual Energy Outlook (EIA, 2006) and historical spread between US and Alabama NG industrial prices.

3. Approach 1: Base Case Economic Projections Based on Avoided Natural Gas Costs

Before-tax profit and cash flow projections are presented in Table 8 for 2007-2021, assuming the base case revenues and costs discussed above. The following financial parameters were also assumed: 50% equity, 9.0% interest, 10-year loan, and 10-year straight-line depreciation. IRR for the equity portion of the capital investment was calculated based on the equity portion of the capital investment in year zero and subsequent annual free cash flows to equity during 15 years of operation. Annual free cash flows to equity were calculated as the annual project cash flow minus the annual principal payment on the debt. Annual ROI was calculated as annual profit divided by the equity portion of the capital investment. No tax credits or other financial incentives were assumed.

After 10 years, the projected before-tax IRR is 69.4% and the projected average before-tax ROI is 51.1%. After-tax profit and cash flow projections are presented in Table 9, assuming 40% corporate tax. After 10 years, the projected after-tax IRR is 43.8% and the projected average after-tax ROI is 30.6%. These are very attractive returns that would be expected to attract commercial interest.

Table 8. Before-tax profit and cash flow projections for the base case assuming avoided NG costs.

Year	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cash Flow									$1,000							
Avoided natural gas costs		14,430	13,734	12,966	12,377	11,966	11,824	11,949	11,770	11,431	11,413	11,484	11,788	12,020	12,020	12,252
Avoided electricity costs		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Avoided Costs		14,430	13,734	12,966	12,377	11,966	11,824	11,949	11,770	11,431	11,413	11,484	11,788	12,020	12,020	12,252
Annual O&M, including net fuel costs		1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890
Principal and interest		2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	0	0	0	0	0
Total Costs		4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	1,890	1,890	1,890	1,890	1,890
Gross Profit		10,406	9,709	8,942	8,353	7,942	7,799	7,924	7,746	7,407	7,389	9,594	9,898	10,130	10,130	10,362
Add back Principal on Debt		901	983	1,071	1,167	1,272	1,387	1,512	1,648	1,796	1,958	0	0	0	0	0
Subtract Depreciation on Plant Capital (number of years)	10	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739					
Profit (Loss) before Taxes & Principal		8,568	7,953	7,274	6,781	6,476	6,447	6,697	6,655	6,464	6,608	9,594	9,898	10,130	10,130	10,362
Loss Carry-Forward		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Federal Tax Credit	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Tax Credits (state or local)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit, after Taxes & Producer Credits		8,568	7,953	7,274	6,781	6,476	6,447	6,697	6,655	6,464	6,608	9,594	9,898	10,130	10,130	10,362
Return on Equity Investment (ROI), %		62.6	58.1	53.1	49.5	47.3	47.1	48.9	48.6	47.2	48.2	70.1	72.3	74.0	74.0	75.7
Capital Costs for Plant and Working Capital	$27,390								10-year average ROI		51.1			15-year average ROI		58.4
Plant Capital	$27,390															
Working Capital	$0															
PROJECT CASH FLOW (Profit + Depreciation)	($27,390)	11,307	10,692	10,013	9,520	9,215	9,186	9,436	9,394	9,203	9,347	9,594	9,898	10,130	10,130	10,362
IRR, %		(58.7)	(13.6)	8.4	19.69	26.0	29.8	32.3	33.9	35.0	35.7	36.2	36.6	36.8	37.0	37.2
FREE CASH FLOW TO EQUITY	($13,695)	10,406	9,709	8,942	8,353	7,942	7,799	7,924	7,746	7,407	7,389	9,594	9,898	10,130	10,130	10,362
IRR, %		(24.0)	30.4	51.3	60.4	64.7	66.9	68.1	68.8	69.2	69.4	69.6	69.6	69.7	69.7	69.8
Project Finances																
Equity	$13,695															
Debt	$13,695															
Interest Rate	9.00%															
Years	10															
Principal, Payment		901	983	1,071	1,167	1,272	1,387	1,512	1,648	1,796	1,958	0	0	0	0	0
Interest , Payment		1,233	1,151	1,063	967	862	747	622	486	338	176	0	0	0	0	0
Total Principal & Interest Payment		2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	0	0	0	0	0

Table 9. After-tax profit and cash flow projections for the base case assuming avoided NG costs.

Year	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cash Flow									$1,000							
Avoided natural gas costs		14,430	13,734	12,966	12,377	11,966	11,824	11,949	11,770	11,431	11,413	11,484	11,788	12,020	12,020	12,252
Avoided electricity costs		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Avoided Costs		14,430	13,734	12,966	12,377	11,966	11,824	11,949	11,770	11,431	11,413	11,484	11,788	12,020	12,020	12,252
Annual O&M, including net fuel costs		1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890
Principal and interest		2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	0	0	0	0	0
Total Costs		4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	1,890	1,890	1,890	1,890	1,890
Gross Profit		10,406	9,709	8,942	8,353	7,942	7,799	7,924	7,746	7,407	7,389	9,594	9,898	10,130	10,130	10,362
Add back Principal on Debt		901	983	1,071	1,167	1,272	1,387	1,512	1,648	1,796	1,958	0	0	0	0	0
Subtract Depreciation on Plant Capital (number of years)	10	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739					
Profit (Loss) before Taxes & Principal		8,568	7,953	7,274	6,781	6,476	6,447	6,697	6,655	6,464	6,608	9,594	9,898	10,130	10,130	10,362
Loss Carry-Forward		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax	40%	3,427	3,181	2,910	2,712	2,590	2,579	2,679	2,662	2,586	2,643	3,838	3,959	4,052	4,052	4,145
Federal Tax Credit	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Tax Credits (state or local)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit, after Taxes & Producer Credits		5,141	4,772	4,364	4,069	3,885	3,868	4,018	3,993	3,878	3,965	5,757	5,939	6,078	6,078	6,217
Return on Equity Investment (ROI), %		37.5	34.8	31.9	29.7	28.4	28.2	29.3	29.2	28.3	28.9	42.0	43.4	44.4	44.4	45.4
Capital Costs for Plant and Working Capital	$27,390								10-year average ROI		30.6			15-year average ROI		35.1
Plant Capital	$27,390															
Working Capital	$0															
PROJECT CASH FLOW (Profit + Depreciation)	($27,390)	7,880	7,511	7,103	6,808	6,624	6,607	6,757	6,732	6,617	6,704	5,757	5,939	6,078	6,078	6,217
	IRR, %	(71.2)	(31.3)	(9.4)	2.83	10.1	14.8	18.0	20.1	21.6	22.7	23.4	24.0	24.4	24.7	24.9
FREE CASH FLOW TO EQUITY	($13,695)	6,978	6,528	6,032	5,640	5,352	5,220	5,246	5,084	4,821	4,746	5,757	5,939	6,078	6,078	6,217
	IRR, %	(49.0)	(0.9)	20.7	31.2	36.7	39.9	41.9	43.1	43.8	44.3	44.6	44.9	45.1	45.2	45.3
Project Finances																
Equity	$13,695															
Debt	$13,695															
Interest Rate	9.00%															
Years	10															
Principal, Payment		901	983	1,071	1,167	1,272	1,387	1,512	1,648	1,796	1,958	0	0	0	0	0
Interest , Payment		1,233	1,151	1,063	967	862	747	622	486	338	176	0	0	0	0	0
Total Principal & Interest Payment		2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	0	0	0	0	0

4. Approach 2: Process Heat Sold to Ethanol Plant at a Cost Savings Relative to Using Natural Gas

Costs are the same for this approach as for Approach 1. The price for steam produced from poultry litter is expressed in units of $/MBtu NG displaced by poultry litter in order to simplify economic comparisons of ethanol plants producing process heat from poultry litter vs. from NG. This approach allows a simple substitution of price of steam from poultry litter (units of $/MBtu NG displaced) for NG price in the economic analyses of ethanol production scenarios compared in this project. In these comparisons, it is assumed that an IPEP ethanol plant has the normal package boiler and thermal oxidizer for use as a backup to the poultry litter energy system, resulting in an IPEP ethanol plant per se (i.e., excluding the poultry litter energy system) having the same capital cost as a NG ethanol plant.

The energy plant is assumed to receive $4.94/MBtu NG displaced by poultry litter energy (Table 10); this provides a savings to the ethanol plant of $2.00/MBtu NG displaced (i.e., $4.94 vs. 6.94/MBtu NG displaced, the 10-year average projected NG price as presented in Table 7). This translates to an average savings for the ethanol plant of $3,150,000/year while at the same time the poultry litter energy plant makes an attractive return (Tables 11 and 12). The same financial parameters were assumed as in Approach 1.

After 10 years, the projected before-tax IRR is 33.0% and the projected average before-tax ROI is 25.0% (Table 10). After-tax profit and cash flow projections are presented in Table 11, assuming 40% corporate tax. After 10 years, the projected after-tax IRR is 22.0% and the projected average after-tax ROI is 15.0%. In addition to improving average rates of return, a long-term contract for displacing natural gas with steam from poultry litter would also significantly reduce financial risk for the ethanol plant due to NG price volatility.

The Renewable Fuels Standard (RFS) enacted in the Energy Policy Act of 2005 provides another potential economic advantage of providing process heat from waste materials such as poultry litter. The RFS requires that each refiner or importer either use a given percentage of ethanol in their overall system or purchase credits to compensate for any deficit that occurs. When 90% or more of the on-site fossil energy normally used to produce corn/ethanol is displaced by energy from wastes, the ethanol receives 2.5 gallons RFS credit per gallon produced. Corn/ethanol produced using fossil fuels for process energy receives 1.0 gallon RFS credit per gallon of ethanol produced. The 2.5X RFS credit is expected to provide another economic advantage over using fossil fuel for process heat.

The rules for the 2.5X RFS credit have not been finalized and it is not clear what the market price of the credits will be. Therefore, effects of the 2.5X credit could not be reflected in the above economic analyses. However, for purposes of illustration the following hypothetical example describes generally how the system may work and provides a general indication of the theoretical added value to a refiner of getting 2.5 vs. 1.0 gallon of RFS credit per gallon of ethanol blended. As a hypothetical example, consider one gallon of IPEP ethanol sold to a refiner who has a relatively high cost of using ethanol (e.g., because of high ethanol transportation costs and inadequate ethanol infrastructure). Because more than 90% of the IPEP on-site process energy comes from animal waste, the refiner gets 2.5 gallons RFS credit for blending 1.0 gallon of IPEP ethanol. That is an extra 1.5 gallon RFS credit over the 1.0 gallon RFS credit he would have received from blending 1.0 gallon of ethanol produced with fossil-based process energy. If the refiner's cost of supplying gasoline is lower than his cost of supplying ethanol after accounting for the blenders' credit, then the theoretical added value of the RFS credits from 1.0 gallon of IPEP ethanol vs. conventional corn/ethanol is 1.5 x (ethanol cost/gal-gasoline cost/gal). The actual market price for RFS credits will depend on supply and demand. The larger the positive cost differential (ethanol cost/gal-gasoline cost/gal), the larger the theoretical added value of the 2.5X credit. In general, the larger positive cost differentials likely will be in the east and west coast markets and the small positive or negative cost differentials likely will be in the Corn Belt. If the refiner's cost differential is small positive or negative, then the refiner likely will have excess RFS credits and may be able to sell his excess RFS credits to a refiner with a large positive cost differential, in which case the 2.5X credit may have significant value also. It seems conceivable that an RFS credit for IPEP ethanol could easily have an added market value over that of conventional corn/ethanol of at least $0.05/gallon of ethanol produced. This would equate to $2,625,000/year for a plant producing 52,500,000 gallons ethanol/year. RFS credits were not factored into the above economic analyses because the RFS system has not yet been fully developed and implemented and the market price for RFS credits remains theoretical at this time.

Assuming both a $2.00/MBtu savings on NG and an RFS credit of $0.05/gallon ethanol produced, providing process heat from poultry litter has potential for increasing the cash flow of an IPEP ethanol plant by between $5 and 6 million/year and at the same time providing an attractive return on the 40% equity invested in the poultry litter energy plant.

Table 10. Poultry Litter Energy System Costs and Cash Flow: First Approximation

Capital costs, $1000	
EPI equipment[1/]	12,600
Installation of EPI equipment[2/]	5,040
Poultry litter storage	4,000
Remaining balance of plant	4,000
Engineering fees	500
Permitting	250
Land	1,000
Back-up package boilers	-
Total	27,390

[1/] Includes ash storage

[2/] 40% of equipment cost

Non-fuel O&M, $1000/yr	1,404
Net fuel cost[1/], $1000/yr	486
Back-up fuel costs:	
Days/year	-
Back-up fuel price, $/MBtu	7.18
Back-up fuel costs, $1000/yr	-

[1/] Poultry litter cost minus ash revenue

Year	Steam Price	Annual Steam Revenue[1/], $1000	Annual O&M[2/], $1000	Cash flow[3/] (before income tax), $1000	IRR
	$/MBtu NG displaced[4/]				
0				(27,390)	
1	4.94	8,818	1,890	6,928	-74.7%
2	4.94	8,818	1,890	6,928	-35.5%
3	4.94	8,818	1,890	6,928	-12.6%
4	4.94	8,818	1,890	6,928	0.5%
5	4.94	8,818	1,890	6,928	8.4%
6	4.94	8,818	1,890	6,928	13.4%
7	4.94	8,818	1,890	6,928	16.7%
8	4.94	8,818	1,890	6,928	19.0%
9	4.94	8,818	1,890	6,928	20.6%
10	4.94	8,818	1,890	6,928	21.8%
11	4.94	8,818	1,890	6,928	22.6%
12	4.94	8,818	1,890	6,928	23.2%
13	4.94	8,818	1,890	6,928	23.7%
14	4.94	8,818	1,890	6,928	24.1%
15	4.94	8,818	1,890	6,928	24.3%
Mean--10-year	4.94				
Mean--15-year	4.94			Simple payback, years	3.95

[1/] Assumes:

52,500,000	denatured gallons ethanol produced/year
34,000	Btu natural gas (NG) displaced/denatured gallon ethanol
1,785,000	MBtu NG displaced/year

[2/] Includes non-fuel O&M, net poultry litter, and back-up fuel oil or natural gas costs

[3/] Assumes 100% equity

[4/] Steam revenue priced at $2.00/MBtu NG displaced less than the Implied average 10-year Alabama forcast ($6.94/MBtu NG) using US industrial NG price projections from EIA Annual Energy Outlook (EIA, 2006) and historical spread between US and Alabama industrial NG prices.

Table 11. Before-tax profit and cash flow projections for the base case assuming steam revenues.

Year	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cash Flow									$1,000							
Steam revenues		8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818
Electricity revenues		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Revenue		8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818
Annual O&M, including net fuel costs		1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890
Principal and interest		2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	0	0	0	0	0
Total Costs		4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	1,890	1,890	1,890	1,890	1,890
Gross Profit		4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	6,928	6,928	6,928	6,928	6,928
Add back Principal on Debt		901	983	1,071	1,167	1,272	1,387	1,512	1,648	1,796	1,958	0	0	0	0	0
Subtract Depreciation on Plant Capital (number of years)	10	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739					
Profit (Loss) before Taxes & Principal		2,956	3,037	3,126	3,222	3,327	3,442	3,566	3,703	3,851	4,012	6,928	6,928	6,928	6,928	6,928
Loss Carry-Forward		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Federal Tax Credit	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Tax Credits (state or local)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit, after Taxes & Producer Credits		2,956	3,037	3,126	3,222	3,327	3,442	3,566	3,703	3,851	4,012	6,928	6,928	6,928	6,928	6,928
Return on Equity Investment (ROI), %		21.6	22.2	22.8	23.5	24.3	25.1	26.0	27.0	28.1	29.3	50.6	50.6	50.6	50.6	50.6
Capital Costs for Plant and Working Capital	$27,390								10-year average ROI		25.0			15-year average ROI		33.5
Plant Capital	$27,390															
Working Capital	$0															
PROJECT CASH FLOW (Profit + Depreciation)	($27,390)	5,695	5,776	5,865	5,961	6,066	6,181	6,305	6,442	6,590	6,751	6,928	6,928	6,928	6,928	6,928
	IRR, %	(79.2)	(42.5)	(19.7)	(6.13)	2.3	7.9	11.6	14.3	16.2	17.6	18.7	19.5	20.1	20.6	20.9
FREE CASH FLOW TO EQUITY	($13,695)	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	6,928	6,928	6,928	6,928	6,928
	IRR, %	(65.0)	(20.8)	2.5	15.0	22.1	26.4	29.2	31.0	32.2	33.0	33.8	34.4	34.7	35.0	35.2
Project Finances																
Equity	$13,695															
Debt	$13,695															
Interest Rate	9.00%															
Years	10															
Principal, Payment		901	983	1,071	1,167	1,272	1,387	1,512	1,648	1,796	1,958	0	0	0	0	0
Interest , Payment		1,233	1,151	1,063	967	862	747	622	486	338	176	0	0	0	0	0
Total Principal & Interest Payment		2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	0	0	0	0	0

Table 12. After-tax profit and cash flow projections for the base case assuming steam revenues.

Year	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cash Flow									$1,000							
Steam revenues		8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818
Electricity revenues		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Revenue		8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818	8,818
Annual O&M, including net fuel costs		1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890
Principal and interest		2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	0	0	0	0	0
Total Costs		4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	4,024	1,890	1,890	1,890	1,890	1,890
Gross Profit		4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794	6,928	6,928	6,928	6,928	6,928
Add back Principal on Debt		901	983	1,071	1,167	1,272	1,387	1,512	1,648	1,796	1,958	0	0	0	0	0
Subtract Depreciation on Plant Capital (number of years)	10	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739	2,739					
Profit (Loss) before Taxes & Principal		2,956	3,037	3,126	3,222	3,327	3,442	3,566	3,703	3,851	4,012	6,928	6,928	6,928	6,928	6,928
Loss Carry-Forward		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax	40%	1,182	1,215	1,250	1,289	1,331	1,377	1,427	1,481	1,540	1,605	2,771	2,771	2,771	2,771	2,771
Federal Tax Credit	$0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Tax Credits (state or local)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit, after Taxes & Producer Credits		1,774	1,822	1,875	1,933	1,996	2,065	2,140	2,222	2,311	2,407	4,157	4,157	4,157	4,157	4,157
Return on Equity Investment (ROI), %		13.0	13.3	13.7	14.1	14.6	15.1	15.6	16.2	16.9	17.6	30.4	30.4	30.4	30.4	30.4
Capital Costs for Plant and Working Capital	$27,390								10-year average ROI		15.0			15-year average ROI		20.1
Plant Capital	$27,390															
Working Capital	$0															
PROJECT CASH FLOW (Profit + Depreciation)	($27,390)	4,513	4,561	4,614	4,672	4,735	4,804	4,879	4,961	5,050	5,146	4,157	4,157	4,157	4,157	4,157
	IRR, %	(83.5)	(50.1)	(28.0)	(14.21)	(5.4)	0.5	4.6	7.6	9.8	11.4	12.4	13.2	13.9	14.4	14.8
FREE CASH FLOW TO EQUITY	($13,695)	3,611	3,579	3,543	3,505	3,463	3,417	3,367	3,313	3,253	3,189	4,157	4,157	4,157	4,157	4,157
	IRR, %	(73.6)	(34.0)	(11.3)	1.6	9.3	14.1	17.3	19.5	21.0	22.0	23.0	23.8	24.3	24.7	25.0
Project Finances																
Equity	$13,695															
Debt	$13,695															
Interest Rate	9.00%															
Years	10															
Principal, Payment		901	983	1,071	1,167	1,272	1,387	1,512	1,648	1,796	1,958	0	0	0	0	0
Interest , Payment		1,233	1,151	1,063	967	862	747	622	486	338	176	0	0	0	0	0
Total Principal & Interest Payment		2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	2,134	0	0	0	0	0

5. Sensitivity Analyses for Projected Returns vs. Key Variables

Sensitivity analyses for IRR and ROI vs. the following ranges of key variables are presented in this section. The rationale for the base levels and ranges selected for these variables was discussed earlier:

- Steam price
    - Base: $4.94/MBtu NG displaced by poultry litter
    - Range: $4.00 to $6.00/MBtu NG displaced by poultry litter
- Capital cost
    - Base: $27,390,000
    - Range: $20,000,000 to $35,000,000
- O&M cost
    - Base: $1,404,218/year
    - Range: $1,404,218 to $2,573,588/year
- Poultry litter cost
    - Base: $10/ton
    - Range: $6 to $14/ton
- Net ash revenue
    - Base: $50/ton
    - Range: $30 to $70/ton

The sensitivity analysis for steam revenues is presented in Table 13. Returns are very sensitive to steam price. Assuming the base case for other variables, an increase in steam price from $4.00 to 6.00/MBtu NG displaced would increase before-tax ROI from 12.8 to 38.8% and before-tax IRR from 18.6 to 47.8% Steam prices at the base rate or higher would provide a very attractive rate of return.

Table 13. Poultry Litter Energy Plant: Sensitivity of IRR and ROI to Steam Price[1/]

	Steam price,	Corporate tax, %			
	$/MBtu NG	0	40	0	40
Case	displaced	IRR after 10 years, %		ROI (10-yr. avg.), %	
	4.00	18.6	12.4	12.8	7.7
Base	4.94	33.0	22.0	25.0	15.0
	6.00	47.8	31.8	38.8	23.3

[1/] Assumes $27,390,000 capital, $1,404,218 O&M, poultry litter feedstock cost $10/ton, ash revenue $50/ton, 40% equity, and 7.5% interest

The sensitivity analysis for capital costs is presented in Table 14. Returns are moderately sensitive to capital costs. An increase in capital costs from the base case of $27,390,000 to $35,000,000 would reduce before-tax ROI from 25.0 to 13.4% and before-tax IRR from 33.0 to 19.4%. An increase in capital costs of this magnitude likely would have to be offset by more favorable levels of other variables.

Table 14. Poultry Litter Energy Plant: Sensitivity of IRR and ROI to Capital Costs[1/]

		Corporate tax, %			
		0	40	0	40
Case	Capital, $1,000	IRR after 10 years, %		ROI (10-yr. avg.), %	
	20,000	54.1	35.8	44.8	26.9
Base	27,390	33.0	22.0	25.0	15.0
	35,000	19.4	13.7	13.4	8.7

[1/] Assumes steam revenue $4.594/MBtu NG displaced, $1,404,218 O&M, poultry litter feedstock cost $10/ton, ash revenue $50/ton, 40% equity, and 7.5% interest

The main uncertainty in O&M costs is whether limestone will have to be added for SOx control and whether ammonia will have to be added for NOx control. Based on pilot-scale tests referred to earlier, the base case does not include adding lime or ammonia. The following sensitivity analysis for O&M costs (Table 15) includes adding lime only and then both lime and ammonia. Adding 5% limestone for SOx control would reduce before-tax ROI from 25.0 to 22.9%. Adding 2% anhydrous ammonia for NOx control in addition to 5% lime for SOx control would reduce before-tax ROI from 22.9 to 13.1% and likely would require more favorable levels of other variables to achieve an adequate return.

Table 15. Poultry Litter Energy Plant: Sensitivity of IRR and ROI to O&M[1/]

		Corporate tax, %			
		0	40	0	40
Case	O&M, $1,000	IRR after 10 years, %		ROI (10-yr. avg.), %	
Base	1,404	33.0	22.0	25.0	15.0
+5% limestone for SOx control, etc.	1,692	30.6	20.5	22.9	13.7
+2% anhydrous ammonia for NOx control	2,574	19.1	12.7	13.1	7.9

[1/] Assumes steam revenue of $4.94/MBtu NG displaced, $27,390,000 capital, poultry litter feedstock cost $10/ton, ash revenue $50/ton, 40% equity, and 7.5% interest

The sensitivity analysis for poultry litter feedstock costs is presented in Table 16. Returns are moderately sensitive to poultry litter feedstock costs. Increasing of poultry litter feedstock costs from $10.00 to $14.00/ton reduced before-tax ROI from 25.0 to 19.3%.

Table 16. Poultry Litter Energy Plant: Sensitivity of IRR and ROI to Poultry Litter Feedstock Costs[1/]

		Corporate tax, %			
	Poultry litter costs	0	40	0	40
Case	$/ton	IRR after 10 years, %		ROI (10-yr. avg.), %	
	6.00	39.2	26.2	30.7	18.4
	8.00	36.1	24.1	27.8	16.7
Base	10.00	33.0	22.0	25.0	15.0
	12.00	29.8	19.9	22.2	13.3
	14.00	26.5	17.7	19.3	11.6

[1/] Assumes $27,390,000 capital, $1,404,218 O&M, steam price $4.94/MBtu NG displaced, ash revenue $50/ton, 40% equity, and 7.5% interest

The sensitivity analysis for net ash revenue is presented in Table 17. Returns are moderately sensitive to net ash revenue. A doubling of net ash revenue from $30.00 to $60.00/ton increased before-tax ROI from 20.7 to 27.1%.

Table 17. Poultry Litter Energy Plant: Sensitivity of IRR and ROI to Poultry Litter Ash Revenue[1/]

		Corporate tax, %			
	Net ash revenue	0	40	0	40
Case	$/ton	IRR after 10 years, %		ROI (10-yr. avg.), %	
	30	28.2	18.8	20.7	12.4
	40	30.6	20.4	22.9	13.7
Base	50	33.0	22.0	25.0	15.0
	60	35.3	23.6	27.1	16.3
	70	37.7	25.1	29.3	17.6

[1/] Assumes $27,390,000 capital, $1,404,218 O&M, steam revenue of $4.94/MBtu NG displaced, poultry litter feedstock cost $10/ton, 40% equity, and 7.5% interest

The above sensitivity analyses indicate that returns are most sensitive to steam price. Very attractive returns from the specified poultry litter energy plant can be achieved with steam prices near $5.00/MBtu NG displaced, but become marginal at $4.00/MBtu NG displaced. A steam price of $4.50 to $5.00/MBtu NG displaced likely will provide an ethanol plant average savings of at least $2.00/MBtu of NG; this translates to savings of at least $0.068/denatured gallon of ethanol, assuming a NG requirement of 34,000 Btu/gallon and in turn translates to savings of a least $3,570,000/year, assuming production of 52,500,000 denatured gallons of ethanol per year. The next greatest sensitivity is to capital costs and O&M. Capital costs at the high end of the evaluation range ($35,000,000) would require a more favorable level of one or more of the other parameters to provide rates of return sufficient to achieve commercialization. The next greatest sensitivity is to O&M, primarily the possibility that significant amounts of anhydrous ammonia would be required to control NOx. This could possibly require a more favorable level of one or more of the other parameters to provide rates of return sufficient to achieve commercialization. Returns are least sensitive to poultry litter price and ash revenues. Attractive returns can be realized throughout the full ranges for poultry litter price and ash revenue, assuming base levels of the other parameters.

If the total avoided cost of NG (projected 10-year average of $6.94/MBtu NG displaced, Table 7) is credited to the poultry litter energy plant as discussed under Approach 1 above, and the highest costs and lowest ash revenue discussed in sensitivity analyses above were assumed (see list below), the before-tax 10-year average ROI would be 19.3% and the before-tax IRR after 10 years would be 31.0%. This is a worst-case scenario. Actual returns are likely to be higher than this because it is highly unlikely that all the parameters will be at the least attractive levels assessed in the sensitivity analyses above. These levels of return should attract commercial interest.

- Avoided NG cost: $6.94/MBtu NG displaced by poultry litter
- Capital cost: $35,000,000
- O&M cost: $2,678,738/year*
- Poultry litter cost: $14/ton
- Net ash revenue: $30/ton

  * Includes maintenance/replacement costs calculated as 1.5% of $35,000,000 capital cost

C. Conclusion

Fluidized bed combustion of poultry litter to supply process heat for an IPEP ethanol plant is technically and economically feasible, assuming adequate supplies of poultry litter can be obtained within the price range discussed above. The poultry litter supply/price issue is discussed in a separate section of this report. Attractive rates of return were projected without tax incentives or other financial incentives.

D. References

Bock, B.R. 2004. Demonstrating optimum fertilizer value of ash from the Biomass Energy Sustainable Technology (BEST) demonstration project for swine &poultry manure management. Final Report Summary to Farm Pilot Project Coordination, North Carolina State University, and Smithfield Foods. http://www.fppcinc.org/pdf/capefear.pdf

Des Moines Register. 2006. Ethanol plant counts on coal for power. http://www.desmoinesregister.com/apps/pbcs.dll/article?AID=/20060205/BUSINESS04/602050315/1033

EIA. 2006. Annual energy outlook. http://www.eia.doe.gov/oiaf/aeo/index.html

EPI. 2005. System design study for a poultry derived fuel (PDF) fired fluidized bed energy system to supply energy to a co-located ethanol plant. March 2005

Murphy, Michael L. 2000. Fluidized bed technology solution to animal waste disposal. 17th Annual International Pittsburgh Coal Conference. September, 2000.

XIV. Poultry Litter Supplies and Prices for Alternative Uses

A. Amount of Poultry Litter Produced in North Alabama

Chamblee and Todd (2000) summarized estimates of the amount of broiler litter produced per 1,000 broilers produced in Alabama, Georgia, Mississippi, and Pennsylvania. The broiler litter production rate ranges from 1.0 to 1.4 ton/1,000 broilers produced in Alabama and from 1.0 to 1.6 ton/1,000 broilers produced in Mississippi. The amount of broiler litter produced/1000 birds decreases when broiler litter is cleaned out of the house less frequently because the broiler litter decays the longer it is left in the house. For example, in Mississippi 1.6 ton litter/1,000 birds was produced when litter was removed from the houses each year, and 1.0 ton litter/1,000 birds was produced when litter was removed every two years. Pelletier et al. (2001) assumed an average of 1.25 ton broiler litter/1,000 birds produced in Virginia. A recent survey in the Sand Mountain area of north Alabama indicated an average broiler litter production rate of 1.22 ton/1,000 broilers produced (Adams, 2005). This factor was assumed in the estimate of broiler litter production in the top broiler producing counties in north Alabama (Table 1), resulting in an estimate of 572,840 tons poultry litter produced per year in the top poultry producing counties of north Alabama.

Table 1. Broiler and broiler litter production in leading broiler counties in north Alabama.

Leading Counties	Broilers[1] (1,000/yr)	Broiler Litter (tons/yr)
Cullman	165,861	202,350
DeKalb	103,113	125,798
Marshall	69,742	85,085
Blount	53,270	64,989
Franklin	45,965	56,077
Morgan	31,591	38,541
TOTAL	**469,542**	**572,840**

[1]Alabama Agricultural Statistics. 2002

A nominal 50 million gallon per year ethanol plant would require about 190,000 tons per year of broiler litter which is about one-third of the broiler litter produced in the top broiler counties in north Alabama. Whether or not this much broiler litter can be diverted from current land application practices to an energy end use will depend on environmental pressures and associated regulation of land application of broiler litter as well as relative costs and revenues for the competing practices. These factors are discussed below.

B. Environmental Concerns Associated with Current Poultry Litter Practices

It is important to understand the environmental concerns associated with current poultry litter practices because these concerns are resulting in stricter nutrient management regulations which in turn are expected to affect supplies and prices of poultry litter for alternative uses such as energy. This section is an overview of environmental concerns associated with poultry litter practices. The next section overviews Alabama nutrient management regulations that have been implemented in recent years to address these environmental concerns.

The primary environmental concern regarding land application of poultry litter is the potential for nutrient runoff into surface waters. Phosphorus runoff from land application of poultry litter into surface waters is of particular concern because of the potential for causing excess algae growth which in turn can cause ecological problems and odor and taste problems in drinking water (USDA, 2003). The predominant use of poultry litter in north Alabama is for application on local pastures and hay fields as a substitute for commercial fertilizer. Since the poultry litter is not incorporated into the soil with tillage, it remains on the soil surface and there is significant potential for soluble phosphorus in the poultry litter to be carried off into surface waters during rainfall events.

In addition to the potential for phosphorus in the poultry litter itself to runoff, there is also potential for phosphorus contained in the soil to runoff, especially if soil is highly concentrated in phosphorus (USDA, 2003). Land that has received long-term applications of poultry litter usually has high levels of soil phosphorus. This is because poultry litter has traditionally been applied in north Alabama and other poultry producing areas at rates required to supply the nitrogen needs of the pastures and hay land. Applying poultry litter on a nitrogen basis provides considerably more phosphorus than is removed by the crop. For example, a ton of broiler litter provides about 50 lb of available nitrogen and 60 lb of phosphorus expressed on an oxide (P_2O_5) basis whereas production of a ton of bermudagrass hay removes about 50 lb of nitrogen and 12 lb of P_2O_5 (ACES, 2001b). Therefore, applying poultry litter on a nitrogen basis for bermudagrass hay supplies about five times more phosphorus than removed by the hay. If the bermudagrass is grazed rather than removed for hay, much of the phosphorus taken up in the grass is recycled back to soil by grazing animals rather than being removed from the field, and the ratio of phosphorus applied to phosphorus removed is greater than five. The amount of phosphorus runoff into surface waters depends on a number of transport factors as well as the amount of phosphorus supplied from poultry litter and the soil (see later discussion of the Alabama risk index for phosphorus runoff).

Continued application of poultry litter on a nitrogen basis will continue to increase soil phosphorus levels at a rapid pace. Because this not a sustainable long-term approach from a water quality perspective in many situations, nutrient management regulations are moving toward application of poultry litter on a phosphorus basis (more details are provided in the next section). Generally, this means that in situations with highest risk for phosphorus runoff, little or no poultry litter application is allowed. In situations with moderate risk for phosphorus runoff, only 1, 2, or 3 times as much poultry litter phosphorus can be applied as removed by the crop; this will result in significantly lower rates of poultry litter application than when applied on a nitrogen basis. Applying poultry litter on a phosphorus basis will not be a simple matter of redistributing poultry litter among existing local fields because the main poultry producing counties in north Alabama produce more poultry litter phosphorus than is removed by crops and grazing livestock as indicated by the red north Alabama counties in Figure 1. Other concentrated poultry areas in the southeastern US have similar regional phosphorus surpluses. These regional phosphorus surpluses occur because most of the grain fed to poultry in the southeastern US is imported from the Midwest and there is not nearly enough cropland and pastureland in concentrated poultry areas to remove the phosphorus contained in the imported grain. The phosphorus in imported grain is supplemented with mineral phosphorus which further increases the regional phosphorus surpluses. Since the basic problem is a regional phosphorus surplus, redistributing poultry litter among fields in the surplus area will not solve the problem.

New approaches are needed to export surplus phosphorus out of concentrated poultry areas such as north Alabama. This means less local land application of poultry litter and more alternative uses that facilitate transport of the surplus phosphorus to areas that need the phosphorus. The approach being evaluated in this IPEP project is to combust the litter which concentrates the phosphorus in the ash to the point where it is economical to transport the ash out of the phosphorus surplus region in north Alabama to areas where the phosphorus is needed.

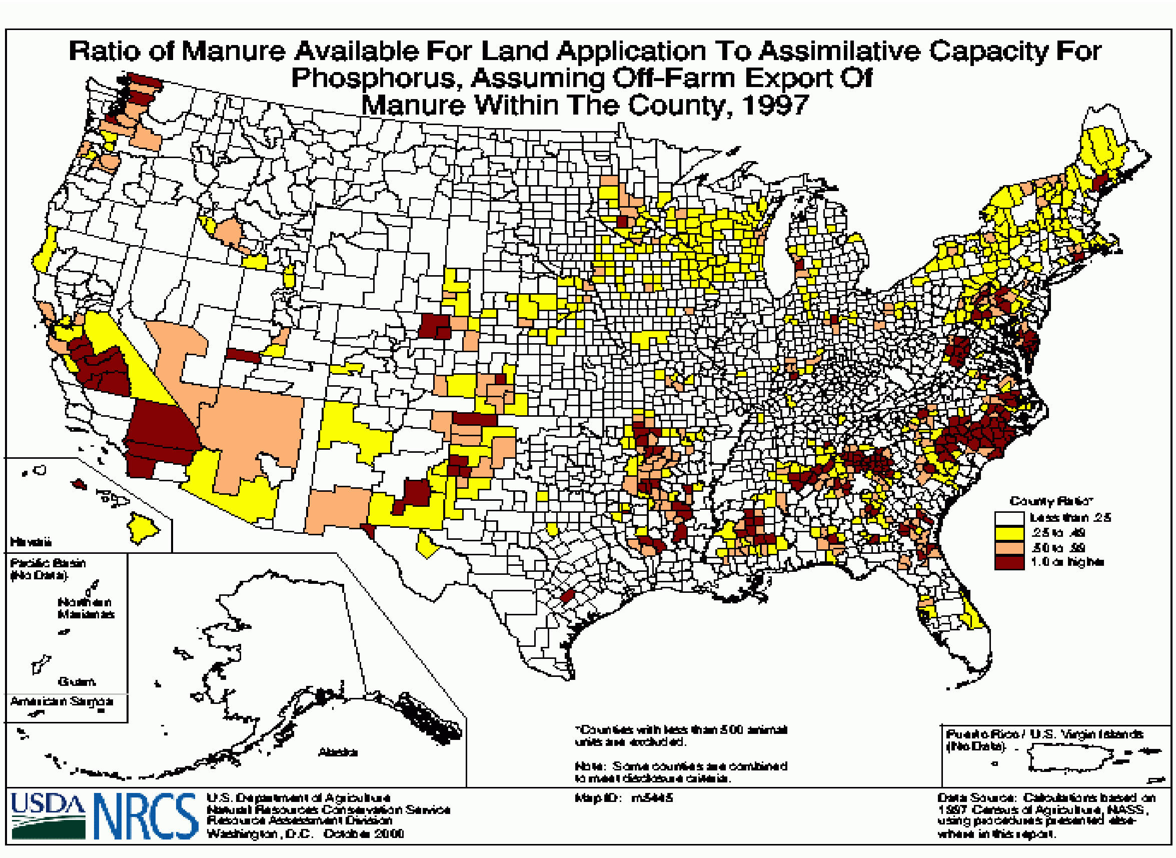


Figure 1. Counties (in red) with more manure phosphorus than removed by crops.

Environmental concerns about effects of phosphorus runoff from poultry litter have resulted in legal actions in northwest Arkansas and northeast Oklahoma. The city of Tulsa, Oklahoma has been experiencing algae-related odor and taste problems in drinking water drawn from the Eucha and Spavinaw reservoirs in northwest Arkansas. Tulsa blames phosphorus runoff from land-applied poultry litter for the odor and taste problems and sued six of the poultry integrators in northwest Arkansas. The settlement of the suit was announced on July 17, 2003. The integrators paid $7.5 million to settle the lawsuit. A moratorium was imposed on land application of poultry litter in the Eucha-Spavinaw watershed until a risk-based phosphorus index can be developed and agreed upon by scientists from the University of Arkansas and Oklahoma State University. Also, application of nutrients in the watershed must be done according to a nutrient-management plan based on the phosphorus index. The settlement of the Tulsa lawsuit may set a precedent for other watersheds containing concentrated poultry production. It is noteworthy that Tulsa was able to successfully sue the poultry integrators even though it is the growers rather than the integrators who have legal responsibility for management of the poultry litter.

In June 2005, the Attorney General of Oklahoma filed a lawsuit against eight poultry integrators operating in northwest Arkansas, northeast Oklahoma, and southwest Missouri (Morning News, 2005). The lawsuit classifies poultry litter as a hazardous substance, seeks reductions in the amount of poultry litter that can be land applied, and seeks compensation for environmental damages from past applications of poultry litter on the land. The attorney general has indicated that he likely will file a motion for an injunction to cease all land application of poultry litter while the issue is litigated. The settlement of this lawsuit may set a precedent for other watersheds containing concentrated poultry production and significantly affect the speed with which alternatives to local land application of poultry litter are adopted. North Alabama is similar to northwest Arkansas in that both regions have had long-term applications of poultry litter, mostly on pastures and hay land; both areas are applying significantly more poultry litter phosphorus that can be removed by crops; and both areas are close to significant surface waters.

C. Regulatory Constraints on Land Application of Poultry Litter

Because of environmental concerns discussed in the previous section, management of poultry litter nutrients is becoming heavily regulated in Alabama. These regulations likely will play an important role in determining how much poultry litter will be available for alternative uses such as energy.

In 1998, the Alabama Department of Environmental Management instituted rules requiring all Concentrated Animal Feeding Operations (CAFOs) to file and implement a comprehensive nutrient/waste management plan and implement best management practices as prescribed by the Natural Resources Conservation Service (NRCS) for Alabama (ACES, 2001a). CAFOs are poultry operations with more than 125,000 birds at any one time; this generally corresponds to poultry operations with more than four poultry houses. The CAFO nutrient management plans must be prepared by a qualified credentialed professional (QCP). There are about 600 poultry CAFOs in Alabama. Smaller animal feeding operations (AFOs) do not have to file but must have a written nutrient management plan and implement best management practices as prescribed by NRCS. AFO nutrient management plans do not have to be prepared by a QCP. There are about 3500 poultry AFOs in Alabama. Non-poultry-producing farms that apply poultry litter on their farms are also required to use the poultry litter in a manner that meets or exceeds NRCS technical standards and guidelines (ACES, 2005).

A nutrient management plan involves five steps (ACES, 2001b):

1. Estimate amount of poultry litter produced and amount of poultry litter storage available.

2. Estimate the nutrient value of the broiler litter based on quantity and availability of nutrients in the litter.
3. Map and calculate the spreadable land area available for application; this is the total land area in fields receiving litter minus required buffers for property lines, streams and water bodies, roads, wells, and public use areas. See ACES, 2003, for an example determination of spreadable land area.
4. Determine crop and nutrient needs for each field, including whether poultry litter is applied based on a nitrogen limit or on phosphorus removal by the crop. Phosphorus application in excess of that recommended by soil test is based on a phosphorus index (PI) of field vulnerability for phosphorus runoff into surface waters. The PI is calculated based on four source factors affecting the amount of phosphorus available to potentially runoff into streams and seven transport factors that determine the risk for the available phosphorus to actually run off into streams (ACES, 2001c). The source factors affecting the amount of phosphorus available to potentially runoff are:
    a. Soil test P value
    b. Amount of poultry litter P applied
    c. Poultry litter application method (e.g., surface applied, not incorporated; surface applied, incorporated, etc.)
    d. Access of grazing animals to surface water and/or fed in sensitive area

    The transport factors are:
    e. Frequency and characteristics of underground outlets
    f. Erosion rate
    g. Hydrologic soil group
    h. Field slope
    i. P application distance to water
    j. Filter strip width
    k. P application distance to impaired waters

    The basis for poultry litter application rates in relation to PI rating is as follows:

PI rating	Basis for poultry litter application
Very low/low	Nitrogen basis
Medium	3X P removal by crop
High	2X P removal by crop
Very high	1X P removal by crop
Extremely high	No application

5. Determine uses for excess litter that cannot be used on the farm where it is produced.

In addition to the nutrient management plan per se as overviewed above, there are three other important regulations that restrict land application of poultry litter:

1. Application of poultry litter is severely restricted in north Alabama from November 15 to February 15 because crop growth and nutrient uptake are very low during that period (ACES, 2003). During this period, no more than one-half ton poultry litter per acre can be applied and then only on cool season annuals with a stem length of at least 4 inches and orchard grass with a stem length of at least 3 inches. Records must be kept of stem lengths and amounts and time of application. This is in effect a virtual ban of winter application in north Alabama because quite often stem lengths will be too short during this time period and it is highly questionable whether it is economical to run a spreader truck over fields to apply no more than one-half ton of litter per acre. If this rule were broadly enforced, there would be very little poultry litter applied from November 15 to February 15.
2. Another restriction is a ban on application of poultry litter if there is a 50% or greater chance of significant rainfall in the 72 hours following application (ACES, 2006). A web-based farmers map is available that indicates whether poultry litter can be applied. A printed copy of the map can be used as documentation that poultry litter application was allowed at the time of application. Currently, a majority of the poultry litter in north Alabama is applied in the spring and fall. During spring and fall there is frequently greater than 50% chance of significant rainfall within the next 72 hours. If this rule were broadly enforced, it would severely limit the number of days that poultry litter that could be applied in the spring and fall in north Alabama. If broadly enforced, the rainfall rule in addition to the virtual winter ban would dramatically increase down time and severely reduce the efficiency of poultry litter application operations.
3. Poultry litter must remain covered and positioned to ensure no contact with stormwater until it is spread. This means that poultry litter that is not applied at the time it is cleaned out of the house must be stored either in a storage building or in a covered pile that does not come in contact with stormwater.

The Certified Animal Waste Vendor (CAWV) program is another aspect of the nutrient management regulations in north Alabama. A CAWV is a person certified by the Alabama Department of Agriculture and Industries who is in the business of removing waste from the premises of an AFO or CAFO for land application to another site (ACES, 2000). The CAWV is responsible for keeping accurate records of what happens to litter removed from poultry houses. They assume responsibility for compliance with nutrient management regulations and legal responsibility for any environmental consequences of improper management or application of such wastes. It is the responsibility of the CAWV to inform land owners of the legal and regulatory requirements involved in land application of animal wastes. Also, CAWVs must report to appropriate authorities any improper land applications. A sample form for transferring responsibility and liability for land applied poultry litter to a CAVW or other receiving party is presented in Figure 2 (ACES, 2006); it summarizes responsibilities of the receiving party.

ACES/AU Form R-9 **POULTRY LITTER/ANIMAL MANURE BY-PRODUCT**
Responsibility/Liability TRANSFER FORM

I, ________________________________ have received approximately _____ tons of poultry

litter/animal manure by-product from ____________________________, who is (CHECK ONE)

☐ the original poultry litter/animal manure by-product producer; OR
☐ a third party who obtained the poultry litter/animal manure by-product from the producer; OR
☐ an Alabama Certified Animal Waste Vendor (CAWV).

The poultry litter/animal manure by-product came from ___________________ farm located near _______________, in __________ County, Alabama.

I am accepting this poultry litter/animal manure by-product with the understanding that I am responsible for making sure that the litter/animal manure by-product is utilized in accordance with all regulations pertinent to ADEM Animal Feeding Operation/Concentrated Animal Feeding Operation Rules. *If I have a current Alabama CAWV #, I am also accepting liability for this poultry litter/animal manure by-product under these same ADEM Rules (see Rule 335-6-7excerpt page 2, R-9).*

These rules state, among other things, that:

1) the litter/animal manure by-product must remain covered and positioned to ensure no contact with stormwater until it is spread,
2) a soil sample of the planned application field for the intended crop, following Auburn University Soil Testing Lab recommended procedures, will be taken no earlier than 3 years prior to planned litter application, and submitted to AU Soils Testing Lab (or an AU-approved soils testing lab),
3) a Phosphorus Index for Alabama (NRCS Agronomy Tech Note AL-72 Jan 2001) will be calculated for each planned application field prior to land application,
4) AU Soils Testing Lab (or AU-approved soils testing lab) recommendations based on the soil sample test in 2) above will be used, along with the application field Phosphorus Index (PI), to determine litter application rates and timing that will be in accordance with NRCS Conservation Practice Standard "Nutrient Management Code 590",
5) other NRCS590-required land application procedures, including buffer/set-back distances from surface water, water wells, public roads, property lines etc., appropriate vegetation type and height at application, and at-least-annual spreader truck calibration, will be followed.

I also understand that:

1) field conditions and land application activities must be recorded to show compliance with ADEM rules.
2) litter/animal manure by-products can only be spread when weather conditions are appropriate and this must be validated by the spreader truck operator having a printout of the current National Weather Service forecast showing the chance of rain for the planned application field being less than 50% for the next three days or a copy of the Alabama Animal Waste/Nutrient Land Application "farmers_map" for the day(s) that the litter/animal manure by-product is applied.

______________________________ Date: ______/______/________
Signature of individual receiving litter

Address of individual receiving litter ________________________________

Phone number of individual receiving litter ________________________________

FOR CAWVs ONLY: CAWV Name: ________________________________
CAWV #: ______ CAWV Expiration Date ______ /______ /______

page 1 of 2 (Rev June 2006)

Figure 2. Poultry litter responsibility/liability transfer form.

At the present time, it appears that Alabama nutrient management regulations are not being strictly enforced on a broad scale, especially regarding the AFOs. Due to constraints discussed above, strict enforcement of existing regulations on a broad scale likely would result in significant increased interest in practical alternatives to local land application for a significant portion of the poultry litter in north Alabama.

An alternative use for poultry litter such as energy would allow CAWVs to operate year-round and 24/7, if desired, rather than only in the daytime and primarily in spring and fall and when the weather map allows. Hauling distances generally would be longer but that would be offset by being able to operate on a year-round basis with larger trucks and not having to do field application. The CAWV role in assuring and documenting proper management of poultry litter would be greatly simplified. He would only have to document delivery to an energy plant rather than all the things summarized in Figure 2. In a survey of poultry litter vendors (Attachment A), 94% of vendors indicated a desire to participate in transportation of litter to an energy facility.

Poultry growers would not have to have a detailed nutrient management plan; their nutrient management plan could be as simple as documenting that their poultry litter went to an energy plant. Also, they would not have to be concerned about whether, under strict enforcement of existing nutrient management regulations, sufficient land resources will be available to accept their litter. In a survey of poultry growers in north Alabama (Attachment A), 74% of growers indicated that they would be willing to consider providing litter to an alternative use such as an energy operation; 10% of growers said they might consider an alternative and 16% said they would not.

Ultimately, grower and vendor participation in providing poultry litter to an energy facility will depend on price received for litter as well as regulatory constraints on local land application and the extent that the efficiency and economics of their overall operations can be increased. Prices that an energy facility likely would have to pay for poultry litter supplied to an energy plant are discussed in the next section.

D. Projected Poultry Litter Prices

The following projections for poultry litter prices that an energy plant would have to pay are based on a survey of poultry growers and vendors in north Alabama (Attachment A) and three reference points as discussed below.

Three reference points serve as a base for projecting what delivered price an energy facility might have to pay for poultry litter. One is the cost of removing litter from the house. Pelletier et al. (2001) estimated the cost of cleanout at \$3.56/ton. Lichtenberg et al. (2002) estimated cleanout costs at \$4.00/ton. An energy plant would likely have to pay cleanout costs of approximately \$4.00/ton of litter.

It is common for poultry growers, especially those with little or no cropland or pasture land, to give the vendor the litter in exchange for cleanout and removing the litter from the farm. In this type of arrangement, the receiving farm pays the vendor an agreed price per ton of litter applied on his field. The price received by the vendor is a second reference point. A survey of poultry growers in north Alabama (Attachment A) indicated that 68% expect in the future to trade litter for the cost of cleanout and 8% indicated maybe. A survey of vendors in north Alabama (Attachment A) indicated that the average price they get for land applied litter is $38/truck load with an average truck load size of 6 tons; this translates to $6.33/ton of litter. When asked the average price per ton that they receive for litter, the surveyed vendors said $11/ton. The reason for this discrepancy is not clear, but it is possible that the vendors normally think in terms of $/truck load and were hedging their position with their $/ton answer. A recent inquiry indicates that north Alabama vendors are currently typically receiving about $10/ton for land applied litter. The higher price vs. $6.33/ton likely reflects higher recent prices for nitrogen fertilizer that otherwise would have to be purchased and higher recent fuel costs for applying the poultry litter. As a first approximation we assume as our base case that vendors could deliver poultry litter to an energy plant for a cleanout cost of $4.00/ton plus $6.00/ton for hauling an average of 40 miles at $0.15/ton-mile. This would be the same total price ($10/ton) that vendors are currently receiving for cleaning out and land applying the litter. Because of the tradeoffs discussed earlier, a vendor likely can make a greater profit delivering poultry litter year-round in larger trucks to an energy plant at $10/ton than cleaning out and land applying using smaller trucks, mainly in the spring and fall, in accordance with nutrient management regulations at $10/ton. This comparison assumes that poultry houses supplying litter to an energy plant can be switched from a primarily fall and spring cleanout schedule to a staggered year-round cleanout schedule that would minimize the amount of intermediate storage and double handling of poultry litter.

The vendor survey (Attachment A) indicated that vendors would require a significantly higher price to deliver litter to an IPEP plant than to land apply the litter; it appears that the vendors were not considering the added efficiencies involved with supplying litter in larger trucks on a year-round basis to an energy plant with no weather restrictions and greatly simplified procedures for complying with nutrient management regulations.

If the grower is giving his litter to a vendor in exchange for cleanout and removal from the farm, then the grower's bottom line is not affected by where the vendor delivers the poultry litter. However, with increasing pressure from nutrient management regulations, poultry growers likely will be increasingly interested in assuring that they have a reliable long-term outlet for their litter. An energy plant is likely to be a more reliable long-term outlet than local land application for their litter as nutrient management regulations become more broadly enforced and perhaps stricter. In some cases, growers are storing litter on farm before the litter is land applied. The grower survey indicated that 61% of the growers in north Alabama have on-farm storage. In these cases, the added cost of storing the litter and handling it a second time can be avoided by participating in a staggered year-round cleanout system supplying litter for an energy end use.

A third reference point is the cost of commercial nitrogen fertilizer that would be required if poultry litter were not land applied as a fertilizer. The cost of other fertilizer nutrients in lieu of poultry litter would not need to be considered because land that has received long-term applications of poultry litter has an excess of phosphorus, potassium, and other plant nutrients and these nutrients would not have to be supplied from fertilizer. Mitchell and Donald (1999) estimated that poultry litter generally provides about 40 lb of available nitrogen/ton. Assuming a retail fertilizer price of $0.29/lb N, they estimated the cost of nitrogen fertilizer required to replace poultry litter at $11.40/ton of poultry litter. Nitrogen fertilizer prices have increased substantially since 1999. In April 2006, Mitchell (2006) assumed a retail price for ammonium nitrate of $0.45/lb nitrogen which results in an estimated value of nitrogen fertilizer required to replace poultry litter at $18.00/ton of poultry litter. The cost of urea required to replace available nitrogen in poultry litter would be somewhat less the cost of ammonium nitrate, but still would be significantly more than the approximately $10/ton of poultry litter that north Alabama vendors are currently receiving for land-applied litter. This difference suggests that local land application will be a strong competitor for poultry litter. However, with broader enforcement of nutrient management regulations, it is likely that less land application of poultry litter will be allowed and more litter will be available for roughly the cost of cleanout and hauling to an alternative use such as energy. Also, the cost and inconvenience of developing and complying with nutrient management plans partially offsets the apparent cost advantage of using poultry litter vs. commercial nitrogen fertilizer. The main driving force for vendors to supply an energy plant rather than local land application is that nutrient management constraints for land application discussed earlier are becoming so stringent that vendors likely can make more profit at $10/ton supplying an energy plant than they can make at a somewhat higher price for litter land applied locally.

In addition to competing with local land application, an energy plant will also have to compete with other alternative uses. This is addressed in a later section entitled “Economic Comparison of IPEP vs. Other Alternatives to Local Land Application of Poultry Litter.” The conclusion of that section is that using poultry litter to provide process heat for an IPEP ethanol plant is more economical than other alternative uses of poultry litter.

E. Conclusions

If current nutrient management regulations in north Alabama are broadly enforced, it is expected there will be strong interest from both growers and vendors in providing poultry litter to produce process heat for an IPEP ethanol plant. It is projected that about 190,000 tons/year (approximately one-third of the litter produced by the top broiler counties in north Alabama) can be provided to an IPEP plant for a delivered cost of approximately $10/ton. For growers, the primary motivation for supplying an IPEP ethanol plant is simplifying and reducing the cost of nutrient management planning and assuring a reliable long-term outlet for their litter. For vendors, the primary motivation is the option to shift to a more efficient and profitable poultry litter delivery system. If nutrient management regulations are not broadly enforced, then a somewhat higher price than $10/ton may have to be paid to acquire adequate supplies of poultry litter to provide process heat for an IPEP ethanol plant.

F. References

Alabama Agricultural Statistics. 2002. http://www.aces.edu/department/nass/bulletin/2002/pg40.pdf

ACES. 2000. Alabama's Certified Animal Waste Vendor Program: What You Need to Know. Alabama Cooperative Extension System. ANR-1176. http://www.aces.edu/pubs/docs/A/ANR-1176/ANR-1176.pdf

ACES. 2001a. Late Fall and Winter Application of Nutrients to Cool-season Forges in Alabama. Alabama Cooperative Extension System. http://www.aces.edu/department/aawm/S-01-01new.pdf

ACES 2001b. Nutrient Management Planning for Small AFOs: Broiler Operations. Alabama Cooperative Extension System. http://www.aces.edu/pubs/docs/A/ANR-0926/ANR-0926.pdf

ACES. 2001c. Phosphorus Index for Alabama. Alabama Cooperative Extension System. http://www.aces.edu/department/aawm/PINDEXFinal2001.pdf

ACES. 2003. A Quarterly Poultry News Update. Late Fall 2003. Alabama Cooperative Extension System. http://www.aces.edu/department/aawm/ScoopFall2003.pdf

ACES. 2005. The Simplest Nutrient Management Plan…A Soil Test. Alabama Cooperative Extension System. http://www.aces.edu/timelyinfo/Ag%20Soil/2005/November/s-04-05.pdf

ACES. 2006a. National Weather Service (NWS) Forecast and Farmers Map ADEM AFO/CAFO Program for Land Application. Alabama Cooperative Extension System. http://www.adem.state.al.us/FieldOps/Permitting/CAFO/CAFOFARMERSMAPexplan.doc

ACES. 2006b. Poultry Litter/Animal Manure By-Product Responsibility/Liability Transfer Form. Alabama Cooperative Extension System. http://www.aces.edu/dept/aawm/R-9%20Form%20(JUNE%202006).pdf

Adams, Zachry Clay. 2005. Comparison of Broiler Litter, Broiler Litter Ash with Reagent Grade Materials as Sources of Plant Nutrients. M.S. Thesis. Auburn University.

Chamblee and Todd. 2000. Mississippi Broiler Litter: Fertilizer Value and Quantity Produced. http://msucares.com/pubs/researchreports/rr23-5.pdf

Mitchell and Donald. 1999. The Value of Poultry Manures as Fertilizer. http://www.aces.edu/pubs/docs/A/ANR-0244/ANR-0244.pdf?PHPSESSID=0bed61b65c403797a5f836980b13a617

Mitchell. 2006. Moving Poultry Litter in Alabama. http://www.aces.edu/timelyinfo/Ag%20Soil/2006/April/s-03-06.pdf

Morning News. 2005. Door Slams Shut on Water Quality Talks. http://www.nwaonline.net/articles/2005/08/19/business/01poultrytalks.txt

NRCS. 2000. Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients; Spatial and Temporal Trends for the United States. http://www.nrcs.usda.gov/technical/land/pubs/manntr.pdf

Pelletier et al. 2001. Economic Analysis of Virginia Poultry Litter Transportation. http://www.vaes.vt.edu/research/publications/01-1.pdf

USDA. 2003. Agricultural Phosphorus and Eutrophication. http://www.sera17.ext.vt.edu/Documents/AG_Phos_Eutro_2.pdf

Attachment A
Summary of Poultry Grower and Waste Vendor Surveys

To ascertain pertinent information related to the availability and perceived value of the poultry litter in north Alabama the Tennessee Valley RC&D Council surveyed and met with poultry farmers and certified animal waste vendors in roughly a 50 mile radius of the Guntersville area of north Alabama (four county area) in December 2003. The following information was collected.

1) Availability of poultry litter
   a) Estimates based on the litter under nitrogen on phosphorus based comprehensive nutrient management plans.

   b) Estimates based on research by Auburn University and the Sand Mountain Watershed Conservancy District.

   c) Producer survey on litter availability

2) Potential Participation From Certified Animal Waste Vendors
   a) Mail out survey
   b) Vendor meetings
   c) Costs

Summary / Conclusion:
<u>Litter Availability:</u>
Estimates related to the availability of poultry litter are variable due to the following facts:

- ❑ Individual companies and their growers clean out litter on variable schedules.
- ❑ While it may be relatively easy to estimate the tonnage of raw manure produces by the number of birds in an area, it is much more difficult to estimate the tonnage of bedding material that is added between flocks impacting the total volumes removed.
- ❑ The variability in bird size between companies.
- ❑ The percentage of Comprehensive Nutrient Management Plans (CNMP) that are nitrogen or phosphorus based.

Assuming the need of 190,000 tons of poultry litter to operate a litter-fired ethanol facility, the results of this study clearly show adequate amounts produced in the top four broiler counties in north Alabama:

- ❑ Estimate of poultry litter produced per year based on number of broilers produced and 1.22 tons litter produced per 1000 broilers as determined in a recent Sand Mountain study by Auburn University** 478,223 tons

- Phosphorus based plans 28,693 tons
- Nitrogen based plans 449,530 tons

** Cullman, Marshall, DeKalb, & Blount Counties

On Farm Litter Prices:

Poultry litter is a valued by-product of poultry farms. Historically litter has been used as fertilizer for the farmer's field and has been sold and /or traded. Recently, due to the shear volume of the litter being land applied in some areas, the litter is now considered a major contributor to the degradation of the water quality in north Alabama. Alabama regulations now severely restrict the land application of the litter in the winter months and require comprehensive nutrient management plans, usually developed by the Natural Resources Conservation Service. However, the availability of the litter and the relative value of the litter is directly related to:

1) The poultry growers understanding of the Alabama Department of Environmental Management's (ADEM) Regulations and ADEM's enforcement of these rules.
2) The variability in understanding and or compliance with the rules, results in geographic variability in the value of the litter. Interestingly, even with these realities, the farmers and companies surveyed did not expect environmental rules to "go away" and indicated that they would be interested in litter disposal alternatives in the future.
3) The percentage of the CNMP's that are nitrogen or phosphorus based. (Liter can be land applied much more liberally with nitrogen based plans.)

Price of the litter:

Currently vendors identified the average price per ton for litter at $11 per ton.
When asked for the value if hauled to a litter to ethanol facility:

Guntersville location $18 per ton
Decatur location $26 per ton

The increase in the future price is likely a function of potential profit taking and would likely reduce due to competition in the event this project becomes a reality.

Potential Participation as Transportation Contractors from Animal Waste Vendors

Currently, the vendors overwhelmingly (94%) indicated a desire to participate in transportation of raw litter to a centralized litter- fired ethanol facility.

Potential Participation from growers:

Growers willing to participate with a litter disposal alternative to land application.

Yes	74%
Maybe	10%
No	16%

North Alabama Poultry Grower Survey

County	Growers in survey	Average houses	Bedding Material			Average Moisture Content			Frequency of Cleanout			Average Cost of Clean out	Manure Shed			Currently do you expect to be paid for litter?			In the future do you expect to give litter away for cost of cleaning?			Are you willing to partici-pate in an alternate disposal plan?		
Blount	16	3	sawdust	25		low	19		yearly	32			yes	8		yes	3		yes	5		yes	6	
			shavings	30		medium	32		2 / year	6			no	6		no	5		no	4		no	1	
						high			per flock	9			no response	2		no response	8		no response	5		no response	6	
									other	4									maybe	2		maybe	3	
Cullman	74	3	sawdust	29		low	104		yearly	133		$942	yes	21		yes	19		yes	39		yes	56	
			shavings	149		medium	91		2 / year	28			no	48		no	20		no	12		no	9	
			mixed	24		high	15		per flock	27			no response	5		swap	1		no response	22		no response	6	
			other	4					other	4						no response	34					maybe	3	
									3 years	8														
DeKalb	13	3	sawdust	22		low	23		yearly	21		$552	yes	6		yes	6		yes	5		yes	5	
			shavings	9		medium	11		2 / year	0			no	7		no	4		no	4		no	3	
						high	0		per flock	8									no response	4		no response	2	
																						maybe	3	
Marshall	28	4	sawdust	69		low	41		yearly	47		$1,072	yes	12		yes	7		yes	14		yes	19	
			shavings	23		medium	42		2 / year	23			no	14		no	5		no	2		no	6	
			mixed	8		high	4		batch	14			no response	2		no response	13		no response	6		no response	0	
									as needed	15						maybe	3		maybe	6		maybe	3	
									other	2														
Totals	131	3.25	sawdust	145	37%	low	187	49%	yearly	233	61%		yes	47	39%	yes	35	49%	yes	63	68%	yes	86	74%
			Shavings	211	54%	medium	176	46%	2 / year	57	15%		no	74	61%	no	34	47%	no	22	24%	no	19	16%
			mixed	32	8%	high	19	5%	batch	58	15%					maybe	3	4%	maybe	8	8%	maybe	12	10%
			other	4	1%				other	33	9%													
			(392)			(382)			(381)				(121)			(72)			(93)			(117)		

To Animal Waste Vendors:

The Tennessee Valley Resource Conservation and Development Council is a volunteer non-profit non- regulatory agency that works in north Alabama to improve the environment, the communities, and the way of life for our citizens.

We are currently partnering with the Soil and Water Conservation Districts, the Natural Resources Conservation Service, the Electric Power Institute (through TVA) and with private consultants to evaluate the possibilities of locating a chicken litter fired Ethanol plant in north Alabama. Since this plant would burn approximately 200,000 tons of litter per year, this may offer a solution to excess land application (in some watersheds) by providing a year round demand for the litter. However, before this can be considered, some important questions need to be addressed.

1) How much litter is or will be available?
2) Are existing certified animal waste vendors willing to contract with a litter combustion
 facility or will the company need to do the hauling?
3) At what price will vendors be willing to sell the litter to company?
4) What will the company be willing to pay vendors for the litter?

Certified Animal Waste Vendors may have opportunities.

We will be hosting two sessions to explain the process and to get your input.

December 3 at 11:30 at King's Restaurant on highway 35 in Rainsville.
December 4 at 11:30 at Shaw's Restaurant in highway 278 in Holly Pond.

Participation is limited to the first twenty (20) at each location and lunch will be provided. The meetings will only last approximately 30 to 45 minutes followed by lunch.

If you want to participate in one of these listening sessions please confirm by calling the Poultry Litter Hotline @ 1-866-litt123 or (256) 353-6146 extension 2. If you can not attend one of the meetings and still wish to comment, please complete the enclosed questionnaire and return. Otherwise fill out the attached questionnaire and bring it to the listening session.

Thank you for your help with this important effort.

Mike Roden
Coordinator
Tennessee Valley RC&D Council

Poultry Litter Animal Waste Vendor Survey

1) Are you a certified animal waste vendor? **Yes 19 No 1**

2) For whom do you clean out or haul for?

my own farm 12
other farmers 6
both 5

3) In what counties do you primarily work?

Marshall	**(7)**	**Jackson**	**(2)**
Dekalb	**(5)**	**Etowah**	**(1)**
Cullman	**(7)**	**Lawrence**	**(1)**
Blount	**(9)**	**Morgan**	**(2)**

4) How many loads or tons do you haul:

average per month 7,633 tons
(36,000 to 60 ton range)
average per year 15,349 tons
(150,000 to 2000 ton range)

5) Average distance that you now transport litter:

17.3 miles (152 to 2 mile range)

6) Average price that you now get for the litter.

per load $38 per load(assume 6 ton/load)
per ton $11 per ton($18.50 to $7.00 range

6) Size and number of trucks available.

(2) 12 ft spreaders	**(3) 14ft. trucks**	**(2) 16ft. trucks**	**(1) 4 ton spreader**
(1) 7 ton truck	**(2) 10 ton trucks**	**(1) 20 ton truck**	**(1) 5 ton truck**
(1) 8x20x4 dump	**(1) 25 ton dump**	**(2) 25 ton tractor trailer trucks**	

7) Would you be willing to contract to supply a combustion facility, assuming a mutually acceptable price is agreed to? **Yes: 16 No: 1**

8) In today's market what is the price that you would be willing to accept for litter delivered to an ethanol facility.

(For a Guntersville location): **per (6T)load $ 83** ($150 to $35 range)
per ton $ 18 ($ 30 to $4.5 range)
(For a Decatur Location): **per (6T)load $140** ($150 to $120 range)
per ton $ 26 ($45 to $12 range)

9) Items or concerns or you would like to be addressed in any future contracts.

- Storage questions: when and where on delivery / wet or dry?
- If company trucks, most farmers don't have equipment to load litter

- Company line up hauling with 40 walking floor trailers
- Need to have a way of weighing each load of litter close to the source
- Moisture content?

XV. Fertilizer Nutrient Value of Poultry Litter Ash

The following is an assessment of the fertilizer nutrient value of poultry litter ash projected to be produced in an IPEP project in north Alabama. This assessment identifies fertilizer market niches for poultry litter ash, estimates expected net return to an energy plant from poultry litter ash sold for use used in fertilizers, and assesses whether trace metals in poultry litter ash are likely to limit use of poultry litter ash in fertilizers from an environmental perspective.

A. Market Niches for Using Poultry Litter Ash in Fertilizers

In identifying market niches for using poultry litter ash in fertilizers, it is helpful to consider potential benefits to the traditional commercial fertilizer industry from using poultry litter ash:

1. Lower-cost source of P and K, micronutrients, and sulfur from ash-containing fertilizers than from traditional fertilizers
2. Hedge against poultry litter nutrient penetration of traditional fertilizer markets—excess nutrients in concentrated poultry areas ultimately will spill over into traditional fertilizer markets in one form or another (e.g., unprocessed poultry litter, pellets, compost, or ash). Use of poultry litter ash appears to be the most efficient way for the traditional fertilizer industry to benefit rather than suffer from the nutrient spillover.
3. Help assure the environmental and economic sustainability of the concentrated poultry industry by reducing regional nutrient surpluses and thereby maintain or increase markets for:
    a. Fertilizer used on grain crops sold to the poultry industry
    b. Other farm inputs (e.g., important for cooperatives and other agricultural supply businesses that sell a broad range of farm inputs in addition to fertilizers)
4. Stewardship image benefits—especially important for larger companies

These are important potential benefits to the fertilizer industry that go well beyond simply acquiring a low-cost source of plant nutrients. Because of these benefits, several key players in the U.S. fertilizer industry have shown interest in using poultry litter ash as a nutrient source for commercial fertilizers.

Unprocessed poultry litter ash (Figure 1) is too finely divided to be handled easily in commercial fertilizer distribution and application systems. In order to have significant value in existing commercial fertilizer markets, poultry litter ash will have to be granulated (Figure 1). Additional added value can be achieved by processing the ash to increase the fraction of ash nutrients that can be claimed on fertilizer labels. This means that existing or new fertilizer granulation plants likely will be the primary market for poultry litter ash. Products from these granulation plants will then be distributed in existing commercial fertilizer markets where the nutrients in poultry litter ash are needed.

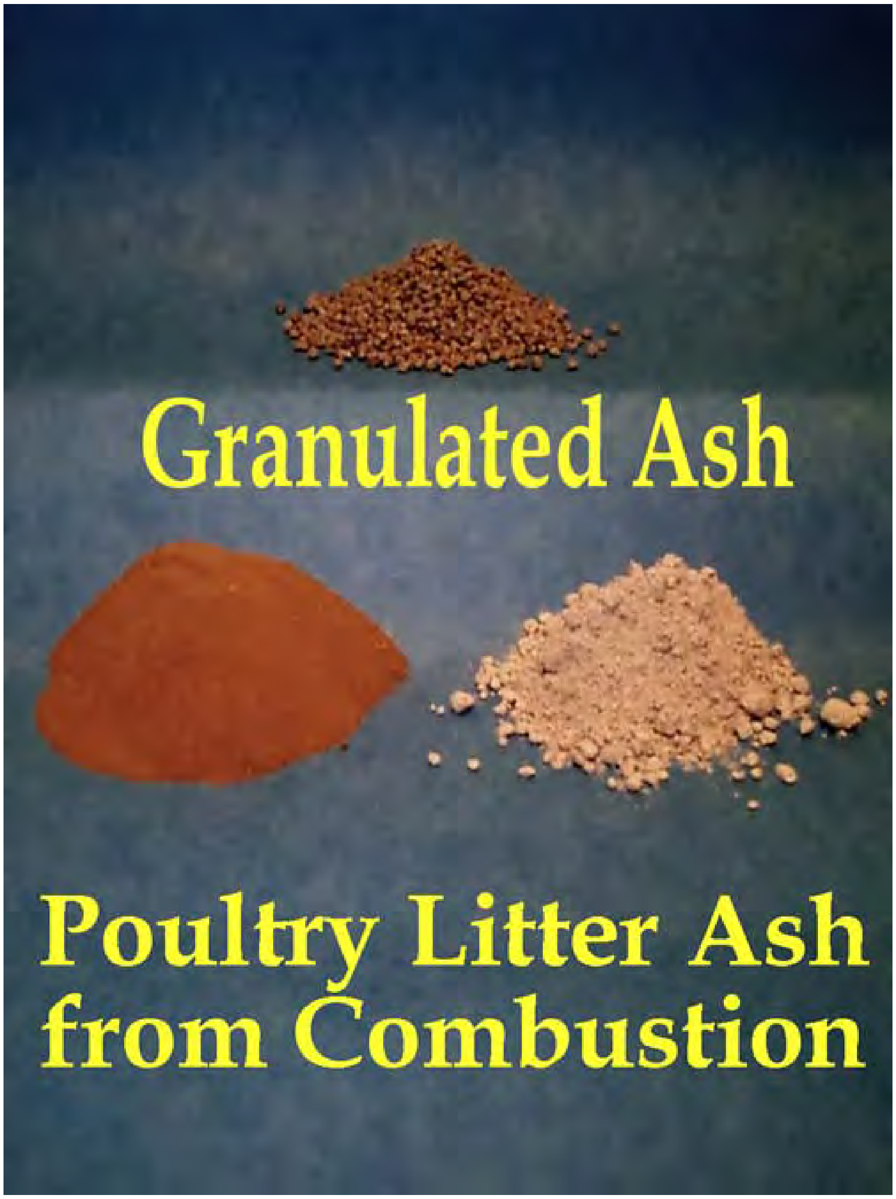


Figure 1. Poultry litter ash and granules containing ash.

There are two types of granular fertilizer markets. One market uses homogenous NPK granules in which each granule contains the full suite of fertilizer nutrients. Fertilizer plants that produce homogenous NPK granules use a lot of by-products in their standard grades as a way of reducing costs. NPK granulation plants also use significant quantities of sulfur and micronutrients in their products and in some cases can derive added value from these components.

Another type of granular fertilizer market uses bulk blends in which single-compound granules (e.g., diammonium phosphate to supply N and P, urea to supply N, and potash to supply K) are produced in very large facilities, shipped to local blend plants, and custom blended locally to produce NPK formulations. Existing fertilizer plants that produce granules for bulk blends are not well suited for using by-products in their processes. A new granulation plant dedicated to using poultry litter ash with other appropriate fertilizer inputs could be built to produce homogenous NPK granules that in turn could be used in bulk blends. However, the economics of this type of dedicated plant would not be as good as for existing NPK granulation plants. Costs of a new plant likely would preclude a dedicated plant, even though ash transportation costs would be low.

In addition to ash processing costs, transportation costs for poultry litter ash and other fertilizer inputs formulated with ash are a key consideration. The closest NPK granulation plant to the concentrated poultry area in north Alabama is the Royster-Clark plant in Florence, Alabama. This plant is about 50 miles from Decatur, Alabama and about 100 miles from Guntersville, Alabama, the two prospective IPEP project locations. Ash transportation costs by truck would be about $0.12 per ton-mile which corresponds to $6.00 and $12.00 per ton of ash for the two locations, respectively. There would be no ash transportation costs for a dedicated ash granulation plant located at an energy plant. However, a $6 to 12 per ton advantage for ash transportation costs for a dedicated fertilizer granulation plant likely will be more than offset by the smaller economies of scale and the requirement for new capital and new product introduction.

The Royster-Clark NPK granulation plant at Florence, Alabama is recommended as the primary market for poultry litter ash from north Alabama. Pilot-scale granulation tests (Bock, 2004) indicate that this plant can partially substitute poultry litter ash for standard fertilizer inputs in its existing operations to produce products for existing markets with little or no impact on granulation costs.

The NPK granulation market niche discussed above represents the “low hanging fruit” in terms of providing greatest ash revenue to the energy plant generating the ash. This niche is smaller in volume than bulk blend markets that exist in the same geographic areas. However, the NPK granulation plant market at Florence, Alabama is large enough to utilize the projected ash stream discussed earlier.

B. Net Return from Poultry Litter Ash Used in Fertilizers

The purpose of this section is to estimate the net return to a poultry litter energy plant from poultry litter ash sold to an NPK granulation plant. The basic approach is to estimate the quantity of nutrients displaced by ash, the wholesale price of the nutrients displaced, and then apply a discount as an incentive for a NPK granulation plant to use a nontraditional source of plant nutrients. This approach is based on the assumption that partially substituting poultry litter ash for standard fertilizer inputs such phosphoric acid and potassium chloride will not significantly affect fertilizer processing, distribution, and marketing costs. This is a reasonable assumption for NPK granulation plants. With this approach, the net return from poultry litter ash depends on (1) the ash and nutrient content of the poultry litter feedstock, (2) effects of the energy conversion process on the concentrations and availability of nutrients in the ash, (3) effects of fertilizer processing on the fraction of ash can be claimed on a fertilizer label, (4) wholesale prices for fertilizer inputs displaced by poultry litter ash, (5) discount required to provide an incentive to partially substitute ash for traditional fertilizer inputs, and (6) cost of transporting ash from the energy plant to the NPK granulation plant.

Most of the fertilizer value of poultry litter ash is associated with the P and K content. These are the nutrients present in highest quantities in poultry litter ash. These nutrients are classified as macronutrients because they are required in relatively large amounts by crops. In the fertilizer industry, P and K are expressed on an oxide basis (P_2O_5 and K_2O). In some situations, secondary and micronutrients in the ash such as sulfur, zinc, manganese, and boron may have significant fertilizer nutrient value; however, crop responses to these nutrients are not as widespread as are crop responses to P and K. In some cases, the sulfur, zinc, manganese, and boron content of poultry litter ash may provide a marketing advantage even if they do not have direct effect on price received for the ash.

The following parameters were used to estimate the expected net return from poultry litter ash used in granular fertilizers:

1. Percent total P_2O_5 and K_2O in laboratory-generated ash from poultry litter—these values don't reflect potential dilution of nutrients in the ash from unburned carbon, sand from the fluid bed, or injected lime to prevent bed agglomeration and trap SO_3.
2. Expected percent reduction of total P_2O_5 in poultry litter ash due to use of phytase additive in poultry feed
3. Nutrient dilutants associated with the energy conversion process expressed as a percent of intrinsic inorganic ash (not percent of intrinsic inorganic ash + dilutant)
   a. % unburned carbon
   b. % sand from fluid bed
   c. % injected lime (CaO basis)
4. Percent of the total P_2O_5 and total K_2O in process ash that can be claimed on a fertilizer label after the ash has been incorporated into fertilizer granules (i.e., percent of total P_2O_5 that is available and percent of K_2O that is soluble as determined by prescribed laboratory procedures that provide an index of plant availability)
5. Wholesale price for fertilizer inputs displaced by ash (prices expressed as $ per per lb or unit (20 lb) of available P_2O_5 and soluble K_2O displaced)
6. Discount for switching to an nontraditional nutrient source

7. Cost of transporting ash from energy plant to NPK granulation plant

Values for parameters 1 to 7 and the rationale for selecting these values are described below.

1. Total P_2O_5 and K_2O in Laboratory-Generated Ash

The ash and nutrient contents of poultry litter were estimated based on a 1998 survey of 24 broiler houses on the Delmarva Peninsula operated under contract with three poultry integrators (Table 1). The mean P_2O_5 content in laboratory-generated ash was 24.4 percent and the mean K_2O in the Laboratory-generated ash was 16.3 percent. The mean ash content of the poultry litter on an as-received basis was 15.7percent.

2. Expected Reduction in Total P_2O_5 Due to Use of Phytase Enzyme in Poultry Feed

The Delmarva survey referred to above was conducted before phytase enzyme amendment of poultry feed was implemented. Phytase is a feed additive that increases the availability of organic (phytate) P to poultry and swine. With phytase, poultry uses more of the P from grain, less inorganic P supplement is required, and less P is excreted in the manure. It is projected that use of a phytase feed supplement and a concurrent reduction in inorganic P supplementation can reduce the total P_2O_5 in poultry litter ash by about 25 percent. Phytase is not currently used in north Alabama but potentially could be implemented, so examples are provided below with and without phytase. Without phytase, no adjustment of the survey level of P_2O_5 content in ash is made. It is assumed that use of phytase would reduce the P_2O_5 content of poultry litter ash by 25percent.

3. Nutrient Dilutants in Process Ash

Dilution of ash nutrients by the energy conversion process was estimated based on EPI pilot plant tests using broiler litter as a feed stock (unpublished data). In an EPI fluid bed combustion system, ash is lifted out of the sand bed by air injected at the base of the sand bed. The higher density ash material is removed from the flue gas with a cyclone at the combustor exit or drops out on its own in the heat recovery system. The remaining lower density ash is removed from the flue gas with a baghouse. There is potential for a portion of the sand bed to be ground finely enough to leave the bed with the ash. However, in unpublished EPI pilot-scale tests with broiler litter the SiO_2 content of laboratory-generated ash from the poultry litter feedstock was similar to that in the process ash, indicating no significant ash nutrient dilution by bed sand. Therefore, it is assumed that nutrients in the process ash will not be diluted with sand from the bed.

EPI estimates that the ratio of unburned carbon to inorganic ash is less than 0.01. This is consistent with observations from the pilot-scale tests. EPI is projecting adding a ratio of injected lime (CaO) to inorganic ash of 0.11 (test run: 500 lb per hr of broiler litter, 11 lb per hr of lime which was calculated by EPI to correspond to a 1.07:1 mole ratio of Ca:S, and 99 lb per hr of ash). This level of lime addition was sufficient to prevent bed agglomeration and control SO_3 emissions in initial EPI pilot-scale tests. Subsequent EPI tests indicated that no lime addition was required to prevent bed agglomeration and control SO_3 emissions (Bock, 2004). Therefore, no lime addition with poultry litter was assumed.

Table 1. Broiler litter fuel parameters and metals content of broiler litter ash (data provided by Maryland Department of Natural Resources, Power Plant Assessment Division): Appendix B at http://www.nrbp.org/pdfs/pub20b.pdf.

Sample Description	Tyson Farm Shed, Top Fresh	Tyson Farm Shed, Bottom Fresh	Tyson Farm Shed Top Old	Tyson Farm Shed Bottom Old	Tyson Farm House Top Crust Water Line	Tyson Farm House Botton Open	Tyson Farm House Top Crust Open	Tyson Farm House Composi te Open	*Average Tyson Farm Sample*	Perdue Farm Shed Top Old	Perdue Farm Shed Bottom Old	Perdue Farm House Top Crust Water Line	Perdue Farm House Bottom Open	Perdue Farm House Top Crust	Perdue Farm House Composite Open	Perdue Farm Schroch Crust	Perdue Farm Schroch Total Clean Out	*Average Perdue Farm Sample*	Mountaire Dryden (1) Shed Top, Freshest	Mountaire Dryden (2) Shed Bottom, Freshest	Mountaire Dryen (3) Shed Top, Oldest	Mountaire Dryen (4) Shed Bottom, Oldest	Mountaire Dryen (5) House Top Crust Waterline	Mountaire Dryen (6) House Bottom Open	Mountaire Dryen (7) House Top Crust Open	Mountaire Dryen (8) House Composite Open	*Average Mountaire Farm Sample*	*AVERAGE SAMPLE*
Proximate Analysis (%)																												
Moisture	24.8	27.6	18.5	22.9	32.5	31.1	27.3	25.1	26.2	24.7	33.6	54.0	23.0	19.6	22.8	23.5	17.3	27.3	24.9	31.1	17.8	25.6	43.4	24.5	27.0	35.6	28.7	27.4
Volatile Matter	50.1	49.5	54.0	51.6	45.6	43.8	49.5	50.7	49.4	49.6	43.0	31.6	52.7	57.1	52.0	50.5	49.5	48.3	48.9	45.6	51.9	40.0	37.3	42.8	48.6	40.4	44.4	47.3
Fixed Carbon	9.9	9.3	11.2	10.8	9.9	10.0	10.3	10.6	10.2	9.6	9.0	5.1	10.2	11.3	9.7	12.0	12.0	9.9	10.4	9.0	13.2	6.9	6.5	8.6	9.8	8.9	9.2	9.8
Ash	15.2	13.7	16.4	14.7	12.0	14.8	12.9	13.6	14.2	16.0	14.3	9.3	14.2	12.0	15.5	14.0	21.3	14.6	15.9	14.3	17.2	27.5	12.9	24.1	20.0	15.1	18.4	15.7
Total	100.0	100.1	100.1	100.0	100.0	99.7	100.0	100.0	100.0	99.9	99.9	100.0	100.1	100.0	100.0	100.0	100.1	100.0	100.1	100.0	100.1	100.0	100.1	100.0	105.4	100.0	100.7	100.2
Ultimate Analysis (%)																												
Carbon	27.50	26.40	30.20	30.10	26.70	24.70	28.70	29.10	27.93	28.40	24.80	18.90	30.10	34.20	29.80	30.10	29.00	28.16	27.60	24.90	32.10	22.50	19.90	25.10	28.20	24.30	25.58	27.22
Hydrogen	3.94	3.92	4.15	3.95	3.52	3.18	3.83	3.86	3.79	3.77	3.32	2.55	4.13	4.69	4.02	4.02	3.93	3.80	3.97	3.75	4.26	3.10	2.94	3.38	3.86	3.29	3.57	3.72
Nitrogen	2.64	2.65	3.09	2.44	2.74	2.16	2.64	2.82	2.65	3.22	2.94	1.79	3.24	4.00	3.77	2.33	2.91	3.03	2.96	2.23	2.49	3.47	1.77	1.65	2.57	2.14	2.41	2.69
Oxygen (by diff.)	25.50	25.30	27.30	25.60	22.20	23.50	24.30	25.10	24.85	23.50	20.70	13.20	24.90	25.20	23.60	25.70	25.30	22.76	24.40	23.40	25.80	17.50	18.80	21.00	23.40	19.20	21.69	23.10
Sulfur	0.43	0.41	0.32	0.29	0.31	0.04	0.41	0.41	0.33	0.43	0.36	0.23	0.45	0.39	0.45	0.31	0.37	0.37	0.40	0.03	0.33	0.42	0.35	0.24	0.31	0.34	0.30	0.33
Ash	15.2	13.7	16.4	14.7	12.0	14.8	12.9	13.6	14.2	16.0	14.3	9.3	14.2	12.0	15.5	14.0	21.3	14.6	15.9	14.3	17.2	27.5	12.9	24.1	20.0	15.1	18.4	15.7
Moisture	24.8	27.6	18.5	22.9	32.5	31.1	27.3	25.1	26.2	24.7	33.6	54.0	23.0	19.6	22.8	23.5	17.3	27.3	24.9	31.1	17.8	25.6	43.4	24.5	27.0	35.6	28.7	27.4
Total	100.0	100.0	100.0	100.0	100.0	99.5	100.1	100.0	99.9	100.0	100.0	100.0	100.0	100.1	99.9	100.0	100.1	100.0	100.1	99.7	100.0	100.1	100.1	100.0	105.3	100.0	100.7	100.2
Chlorine	1.05	1.01	0.91	0.09	0.07	0.59	0.75	0.89	0.67	0.93	0.81	0.52	0.79	0.62	0.79	1.00	0.93	0.80	0.80	0.78	0.63	0.58	0.61	0.42	0.68	0.75	0.66	0.71
Sieve Analysis (Percent Retained)																												
1/4 Inch	5.1	3.4	2.7	2.1	4.1	2.6	6.2	4.5	3.8	2.6	1.9	2.7	2.4	0.1	-	2.9	2.9	1.9	6.2	13.5	8.9	0.6	6.6	3.5	4.1	3.9	5.9	3.9
1/8 Inch	15.0	26.5	15.2	18.6	19.0	12.1	13.3	14.0	16.7	22.4	24.0	21.3	4.4	7.8	3.4	26.1	4.7	14.3	24.1	27.0	21.0	9.3	24.7	19.8	12.6	19.3	19.7	16.9
16 Mesh	30.1	31.9	41.0	39.6	28.8	42.4	32.0	26.3	34.0	30.4	33.8	37.0	23.6	35.6	16.2	40.3	20.2	29.6	36.2	35.1	36.5	26.3	37.9	36.5	42.2	31.9	35.3	33.0
Thru	49.8	38.2	41.1	39.7	48.1	42.9	48.5	55.2	45.4	44.6	40.3	39.0	69.6	56.5	80.4	30.7	72.2	54.2	33.5	24.4	33.6	63.8	30.8	40.2	41.1	44.9	39.0	46.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Heat Content (Btu/lb) & Density (lb/ft^3)																												
Heating Value (wet)	4,700	4,440	5,200	5,130	4,580	4,350	4,860	4,950	4,776	4,850	4,270	3,350	5,120	5,770	5,160	4,930	4,910	4,795	4,720	4,160	5,280	3,740	3,430	4,440	4,790	4,160	4,340	4,637
Heating Value (dry)	6,250	6,130	6,380	6,650	6,790	6,330	6,690	6,610	6,479	6,440	6,430	7,280	6,650	7,180	6,680	6,440	5,940	6,630	6,280	6,040	6,420	5,030	6,060	5,880	6,560	6,460	6,091	6,400
Density (lb/ft^3)	28.5	27.4	24.5	22.0	30.7	27.5	30.7	32.4	28.0	31.6	31.1	38.4	31.6	31.9	33.4	24.3	29.1	31.4	24.5	23.5	19.6	30.0	24.2	20.5	29.2	24.1	24.5	27.9
Elemental Analysis of Ash (%)																												
Al_2O_3	< 1.0	<1.0	<1.0	1.2	<1.0	2.6	<1.0	1.1	1.6	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.4	2.4	1.5	1.1	2.5	2	1.1	4.4	1.3	1.3	1.9	1.9
CaO	16.0	15.3	18.9	18.0	15.9	15.2	16.7	16.2	16.5	20.4	19.7	20.6	20.2	21.0	21.2	17.9	15.3	19.5	17.5	17.9	14.5	15.5	18.5	6.9	18.0	17.7	15.8	17.3
Fe_2O_3	< 1.0	<1.0	<1.0	<1.0	<1.0	1	<1.0	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.2	1.2	<1.0	<1.0	<1.0	1	<1.0	1.3	<1.0	1.3	1.2	1.16
MgO	5.7	5.8	5.3	5.1	5.9	4.8	5.7	5.6	5.5	4.8	5.5	5.7	5.3	5.8	5.2	6.0	4.1	5.3	4.6	5.1	4.1	4.3	4.9	1.9	4.7	4.5	4.3	5.0
P_2O_5	25.4	26.3	25.1	24.9	26.0	20.5	27.0	25.1	25.0	24.1	25.1	25.3	26.5	27.7	25.9	28.5	21.5	25.6	23.1	26.8	22.7	23.5	25.7	9.3	25.7	24.0	22.6	24.4
K_2O	22.1	23.6	21.0	18.8	28.2	18.0	20.6	18.8	21.4	16.7	15.7	17.1	14.7	16.7	13.1	17.5	12.3	15.5	12.2	13.6	12.4	9.5	15.4	8.0	15.2	11.3	12.2	16.3
SiO_2	4.7	4.8	4.3	8.9	5.6	21.3	4.7	6.6	7.6	5.5	6.1	4.1	4.2	4.4	6.0	3.7	14.1	6.0	9.1	7.2	12.6	13.0	7.0	19.3	7.9	9.1	10.7	8.1
Na_2O	11.5	11.6	11.4	10.4	10.6	7.7	10.8	11.0	10.6	9.2	9.9	9.9	9.8	10.0	9.4	12.5	8.6	9.9	7.9	8.6	5.5	5.8	8.3	3.5	8.8	7.9	7.0	9.2
$S0_3$	5.9	6.9	7.0	6.5	6.4	5.5	6.1	6.7	6.4	7.1	8.0	7.6	8.2	7.5	7.6	7.9	5.9	7.5	4.9	6.4	6.0	6.8	6.5	7.1	6.1	6.5	6.3	6.7
TiO_2	< 0.17	<0.17	<0.17	<0.17	0.17	0.22	<0.17	<0.17	0.2	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	0.23	0.2	<0.17	<0.17	0.21	0.18	<0.17	0.42	<0.17	<0.17	0.3	0.2
Total	91.3	94.3	92.9	93.8	98.8	96.7	91.6	91.1	95.8	87.8	90.0	90.3	88.9	93.2	88.4	94.0	85.6	93.1	80.8	86.7	80.5	81.6	87.5	62.1	87.7	83.5	82.2	90.3
Ash Fusion Temperatures (deg. F)																												
Initial Deformation	2,257	2,236	2,416	2,302	2,272	2,153	2,296	2,197	2,266	2,418	2,475	2,554	2,479	2,555	2,360	2,466	2,301	2,451	2,339	2,273	2,321	2,302	2,287	2,341	2,353	2,281	2,312	2,343
Softening	2,392	2,314	2,604	2,442	2,412	2,314	2,417	2,299	2,399	2,617	>2800	2,771	2,769	>2800	2,631	2,786	2,455	2,672	2,398	2,351	2,385	2,334	2,503	2,404	2,381	2,388	2,393	2,471
Hemispherical	2,544	2,452	>2800	2,650	2,546	2,402	2,612	2,408	2,516	>2800	>2800	>2800	>2800	>2800	>2800	>2800	2,484	2,484	2,470	2,472	2,501	2,436	2,731	2,468	2,453	2,550	2,510	2,511
Fluid	2,770	2,589	>2800	>2800	2,791	2,515	>2800	2,580	2,649	>2800	>2800	>2800	>2800	>280	>2800	>2800	2,549	2,549	2,523	2,585	2,636	2,513	>2800	2,503	2,503	2,601	2,552	2,589
Trace Metal Analysis of ash(mg/kg)																												
As	196	167	263	159	197	153	177	166	185	75	78	81	85	91	82	107	34	79	128	122	116	108	125	51	113	99	108	124
Cd	< 2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<0.500	0.5	0.6	0.7	0.5	<0.500	0.7	<0.500	<2.50	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<2.50	0.6
Cr	26.2	23.8	30.0	22.2	24.9	23.0	27.0	25.8	25.4	19.2	21.0	17.8	22.9	22.3	22.1	19.3	25.4	21.3	25.9	25.3	21.4	31.1	25.5	21.0	29.7	33.5	26.7	24.4
Co	6.9	5.5	6.6	4.2	6.9	4.6	6.3	5.6	5.8	3.4	3.8	3.4	4.1	4.3	3.8	3.7	3.6	3.8	3.1	3.1	2.6	3.1	2.9	2.5	3.5	4.3	3.1	4.2
Cu	3,040	2,560	4,370	2,650	2,510	866	1,840	2,350	2,523	1,610	1,640	2,210	2,060	1,640	1,450	1,350	752	1,589	823	790	5	791	960	235	720	595	615	1,576
Pb	32.6	19.5	19.0	18.2	15.9	6.9	10.9	13.0	17.0	7.3	7.8	13.4	16.3	9.8	8.3	10.8	11.9	10.7	6.2	4.4	2.6	4.2	4.6	2.4	4.2	4.1	4.1	10.6
Mn	3,690	3,110	4,260	2,730	3,910	2,570	3,390	3,360	3,378	2,630	2,790	2,720	3,070	2,960	2,950	2,840	2,240	2,775	1,980	1,890	1,500	1,670	1,920	817	1,990	1,780	1,693	2,615
Mo	37.8	34.4	40.4	26.3	38.5	25.1	37.6	35.9	34.5	14.4	13.2	13.3	17.0	15.3	13.6	29.8	12.2	16.1	12.7	13.8	11.8	15.0	14.9	5.6	12.8	11.1	12.2	20.9
Ni	39.7	34.1	42.7	25.3	38.8	27.1	36.5	35.6	35.0	25.8	26.9	24.0	47.4	26.8	37.5	32.9	43.9	33.2	20.8	21.7	19.1	25.7	20.8	13.0	23.0	20.6	20.6	29.6
Se	< 5.00	<5.00	6.1	<5.00	<5.00	<5.00	5.0	<5.00	5.6	4.1	3.7	4.8	4.7	3.8	3.9	3.3	2.4	3.8	4.0	4.2	2.3	1.2	3.8	<0.500	3.2	2.2	3.0	3.7
Zn	3,270	2,720	3,840	2,330	3,370	1,790	3,000	2,990	2,914	2,810	2,890	2,920	3,360	3,020	3,070	2,280	1,570	2,740	1,430	1,470	1,080	1,200	1,450	397	1,450	1,150	1,203	2,286
Hg	< 0.10	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
B	284.0	256.0	302.0	203.0	281.0	171.0	255.0	257.0	251.1	176.0	182.0	177.0	204.0	204.0	184.0	204.0	138.0	183.6	142.0	141.0	109.0	108.0	125.0	52.2	136.0	113.0	115.8	183.5
Fines Analysis (%, dry basis)																												
Ash	20.2	19.4	20.3	18.6	18.0	23.3	17.6	19.8	19.7	21.5	21.6	20.9	18.8	15.3	20.2	19.0	26.0	20.4	19.0	22.7	24.3	35.8	21.2	24.7	20.0	26.5	24.3	21.4
Ca in ash	10.5	11.2	12.4	12.4	11.8	9.8	10.1	9.7	11.0	13.5	12.2	14.7	11.3	14.4	12.5	10.6	10.9	12.5	9.9	10.2	10.0	9.7	11.9	7.2	11.4	10.1	10.1	11.2
K in ash	18.3	19.6	17.4	15.6	23.4	14.9	17.1	15.6	17.7	13.9	13.0	14.2	12.2	13.9	10.9	14.5	10.2	12.9	10.1	11.3	10.3	7.9	12.8	6.6	12.6	9.3	10.1	13.6
Na in ash	5.7	6.1	6.1	5.8	6.6	4.3	5.4	4.8	5.6	5.6	5.1	5.8	4.7	5.6	4.4	6.5	4.9	5.3	3.5	3.9	3.0	2.6	4.4	2.4	4.6	3.4	3.5	4.8

4. Percent of Total P_2O_5 and K_2O That can be Claimed on a Fertilizer Label

The percent of ash P_2O_5 and K_2O that can be claimed on a fertilizer label after the ash is co-granulated with standard fertilizer inputs was based on bench-scale granulation tests of broiler litter ash (Bock and Miles, 2001). In the unprocessed cyclone ash, 72 percent of the P_2O_5 and 90 percent of the K_2O can be claimed on a fertilizer label. After co-granulation of the cyclone ash with the most promising standard fertilizer inputs and process, 95 percent (calculated value) of the cyclone ash P_2O_5 and 89 percent of the cyclone ash K_2O can be claimed on a fertilizer label.

In the unprocessed baghouse ash, 100 percent of the P_2O_5 and 100 percent of K_2O can be claimed on a fertilizer label (Bock and Miles, 2001). Co-granulation of baghouse ash with standard fertilizer inputs is not expected to change these percentages.

EPI estimated an ash material balance of 80 percent cyclone ash and 20 percent baghouse ash based on unpublished pilot-scale tests with broiler litter. With an 80/20 composite of the two ashes on a weight basis, the cyclone ash provided 98 percent of the total ash P_2O_5 and 55 percent of the total ash K_2O. Using these weighting factors, it was calculated that after co-granulation of the composited cyclone and baghouse ashes, 95 percent of the composite ash P_2O_5 and 94 percent of the composite ash K_2O can be claimed on a fertilizer label; these percentages were used to calculate the fertilizer nutrient value of the EPI ash. The calculations on a fractional basis are as follows:

P_2O_5:
(0.98 from cyclone ash x 0.95 available) + (0.02 from baghouse ash x 1.00 avail.) = 0.95
K_2O:
(0.55 from cyclone ash x 0.89 available) + (0.45 from baghouse ash x 1.00 avail.) = 0.94

The above assessment from Bock and Miles (2001) was used as a base case for calculating net return from broiler litter ash. In a subsequent study with broiler litter ash co-granulated with standard fertilizer inputs, only 75 percent of the P_2O_5 in the ash could be claimed on fertilizer label (Bock, 2004). Estimates of net return from ash will be provided for both 75 and 95 percent of the ash P_2O_5 being sufficiently available to be claimed on a fertilizer label.

5. Wholesale Price of Fertilizer Nutrients Displaced by Ash

Diammonium phosphate (DAP, 16-48-0) is the dominant source of P_2O_5 and muriate of potash (KCl, 0-0-60) is the dominant source of K_2O in US fertilizer markets. Poultry litter ash will compete primarily with these two fertilizer materials as sources of P_2O_5 and K_2O. Fertilizer prices from Green Markets (12/05/05) were used to estimate the wholesale price of available P_2O_5 in DAP and soluble K_2O in KCl. These prices are $3.80 per unit (20 lb) of available P_2O_5 in DAP and $3.50 per unit of soluble K_2O in KCl. The price per unit of P_2O_5 in DAP was calculated by assigning the N in DAP a value based on the price of anhydrous ammonia ($480 per ton with an analysis of 83-0-0) and subtracting the N value from the DAP price which was $275 per ton; the calculation is as follows: $3.80 per unit of P_2O_5 = (275-(480/83*16))/48.

6. Discount Relative to Wholesale Price of Fertilizer Nutrients Displaced

Poultry litter ash likely will not displace traditional fertilizer materials unless nutrients from the ash can be provided at a lower price. Potential ash buyers have indicated that a 30 percent discount relative to the wholesale price of fertilizer nutrients displaced may be reasonable; however, it is difficult to predict in advance what level of discount will be determined by fertilizer markets. A 30 percent discount relative to the wholesale price of fertilizer nutrients displaced by ash is assumed as a base case.

7. Ash Transportation Costs

As indicated earlier, ash transportation costs are estimated at $6.00 per ton from Decatur, Alabama and $12.00 per ton from Guntersville, Alabama. To provide a conservative estimate of net return from ash, the higher ash transportation cost of $12 per ton is assumed.

8. Parametric Estimates of Net Return from Poultry Litter Ash

A summary of the parameter estimates discussed above and the resulting net return to an energy plant from poultry litter ash are presented in Table 2. Net return to the energy plant is calculated by subtracting ash transportation costs from the discounted wholesale price of fertilizer nutrients replaced by ash which gives a net return to the energy plant of $87.10, assuming no use of phytase in poultry feed, 95percent of the ash P_2O_5 claimed on a fertilizer label, and a 30 percent discount. If phytase were used in north Alabama and reduced the P_2O_5 content of the ash by 25 percent, the net return to the energy plant would be $71.70.

A summary of projected net returns from ash is presented in Table 3 for 20, 30, and 40 percent discounts, 95 percent of the ash P_2O_5 claimed on a fertilizer label, an ash transportation cost of $12 per ton, and poultry litter produced with and without use of phytase in poultry feed. Without phytase, net return ranges from \$72.94 to \$101.26 per ton of ash and with phytase net return ranges from \$59.74 to \$83.66 per ton of ash. Table 4 is based on the same parameters as for Table 3 except assuming 75 instead of 95 percent of the ash P_2O_5 claimed on a fertilizer label. Without phytase, net return ranges from \$61.83 to \$86.44 per ton of ash and with phytase net return ranges from \$51.41 to \$72.54 per ton of ash. These assessments indicate that conservatively a poultry litter energy plant in north Alabama should be able to net at least \$51 per ton, even if only 75 percent of ash P_2O_5 can be claimed on the fertilizer label, phytase is used in the poultry feed, and the ash is sold at a 40 percent discount relative the traditional fertilizer inputs displaced. In the most favorable case, a poultry litter energy plant could net \$101 per ton if 95 percent of the ash P_2O_5 can be claimed on a fertilizer label, phytase is not used in poultry feed, and the ash is sold at a 20 percent discount.

Table 2. Projected net return to energy plant from poultry litter ash.

Total nutrient concentration in laboratory-generated ash:		
	without phytase	with phytase
% reduction in P_2O_5 with phytase		25
Total P_2O_5, %	24.4	18.3
Total K_2O, %	16.3	16.3
Nutrient dilutants in process ash, % of inorganic ash:		
Unburned carbon, %	0.1	0.1
Fluid bed sand, %	0.0	0.0
Injected lime, % CaO basis	0.0	0.0
Total, %	0.1	0.1
Total nutrient concentration in process ash after accounting for dilution:		
Total P_2O_5, %	24.4	18.3
Total K_2O, %	16.3	16.3
Fraction of ash nutrients that can be claimed on fertilizer label:		
Available P_2O_5/Total P_2O_5	0.95	0.95
Soluble K_2O/Total K_2O	0.94	0.94
Concentration of ash nutrients that can be claimed on the fertilizer label:		
Available P_2O_5, %	23.2	17.4
Soluble K_2O, %	15.3	15.3
Total, %	38.5	32.7
Wholesale price of fertilizer nutrients displaced by ash:		
\$/20 lb available P_2O_5	3.80	3.80
\$/20 lb soluble K_2O	3.50	3.50
\$/ton for available P_2O_5	88.00	66.00
\$/ton for soluble K_2O	53.57	53.57
Total, \$/ton of ash	**141.57**	119.57
By-product discount, %	30	30
Discounted wholesale price of fertilizer nutrients replaced by ash, **\$/ton of ash**	**99.10**	83.70
Ash transportation, **\$/ton of ash**	**12.00**	12.00
Net return to energy plant, **\$/ton of ash**	**87.10**	71.70

Table 3. Projected net return (after ash transportation costs[1/]) from ash, assuming 95 percent of the ash P_2O_5 can be claimed on a fertilizer label.		
	Phytase	
	Without	With[2/]
Discount, %	$/ton of ash	
20	101.26	83.66
30	87.10	71.70
40	72.94	59.74
[1/] Ash transportation costs=$12/ton		
[2/] Assumes a 25 percent reduction in ash P due to use of phytase enzyme in poultry feed.		

Table 4. Projected net return (after ash transportation costs[1/]) from ash, assuming 75 percent of the ash P_2O_5 can be claimed on a fertilizer label.		
	Phytase	
	Without	With[2/]
Discount, %	$/ton of ash	
20	86.44	72.54
30	74.13	61.97
40	61.83	51.41
[1/] Ash transportation costs=$12/ton		
[2/] Assumes a 25 percent reduction in ash P due to use of phytase enzyme in poultry feed.		

C. Physical Properties of Poultry Litter Ash

In addition to nutrient properties, the physical properties of poultry litter ash can affect value of the ash as a nutrient source. These properties are discussed below for broiler litter ash from the EPI fluidized combustion process.

1. Bulk Density

Bulk density affects how much hauling and storage space is required per ton of ash. Traditional granular fertilizers have bulk densities ranging from about 45 lb per ft^3 for urea to about 65 lb per ft^3 for diammonium phosphate, monoammonium phosphate, and potassium chloride. Powdered monoammonium phosphate has a bulk density of about 55 lb per ft^3. Unprocessed poultry litter has a bulk density of about 25 lb per ft^3. The tapped bulk density of broiler litter ash from a fluidized bed combustion test ranged from

66 lb per ft^3 for the coarse ash to 34 lb per ft^3 for the baghouse ash (Bock and Miles, 2001). About 80 percent of the ash produced was coarse ash and about 20 percent of the ash produced was baghouse ash. The coarse ash has a bulk density comparable to granular ammonium phosphates and potassium chloride, materials that the ash would compete with in the fertilizer market. The baghouse ash has a bulk density significantly lower than urea, a relatively low-density conventional fertilizer material; the low bulk density of baghouse ash may detract somewhat from its value as a replacement for traditional fertilizer inputs. Both ashes have a bulk density significantly higher than that of unprocessed poultry litter.

2. Particle Size

A relatively fine particle size is easier to process in NPK granulation plants. Data are not available for particle size of poultry litter ash from fluidized combustion, but visual assessments indicate that this ash has small enough particle size for granulation in NPK granulation plants. No size reduction of the ash will be required to facilitate use of the ash in NPK granulation plants.

D. Environmental Considerations for Trace Metals in Poultry Litter Ash Used in Fertilizers

Trace metals in poultry litter ash are an environmental consideration that potentially could limit the use of the ash as a fertilizer. Environmental limitations on the use of poultry litter ash in fertilizers could reduce the fertilizer value of the ash. The following assessment was done to determine whether trace metals in poultry litter ash are likely to limit use of the ash as a fertilizer. Trace metal concentrations in laboratory-generated ash from broiler litter samples collected in a Delmarva Peninsula survey (Table 1) were used in the assessment. Means from the Delmarva survey are used to illustrate that poultry litter ash either used alone or co-granulated with standard fertilizer inputs should easily comply with metals standards for land application of fertilizers and biosolids.

The American Association of Plant Food Control Officials (AAPFCO) recently approved a revised Uniform State Fertilizer Bill with limits on metals content in fertilizers (AAPFCO, 2005). Fertilizer metal limits proposed by AAPFCO are presented in Table 5 on a P_2O_5 basis and a micronutrient basis. For fertilizers claiming both P_2O_5 and micronutrients, the higher of the two limits is used. For the example in Table 5, the P_2O_5 basis results in lower metal limits than does the micronutrient basis. In either case, poultry litter ash easily complies with AAPFCO metals limits.

For purposes of comparison, projected maximum poultry litter ash metal loading rates are presented in Table 6 in comparison with the maximum metal loading rates allowed by the Canadian standard. The assumed application rate of 100 lb available P_2O_5/acre/year from poultry litter ash is greater than the amount of P_2O_5 taken up and removed by crops annually. Therefore, the long-term average application rate of poultry litter ash likely will be lower than 100 lb available P_2O_5/acre/year (667 lb ash/acre/year assuming 15 percent available P_2O_5 in the ash) and the actual metal loading rates will be lower than projected. The Canadian standard is based on a 45-year planning horizon. The ratio of the Canadian standard maximum allowable metal loading rate to the projected maximum metal loading rate from poultry litter ash ranges from 4 for As to 300 for Hg, indicating that land application of poultry litter ash should easily comply with the Canadian standard.

Also for purposes of comparison, projected maximum metal loading rates for poultry litter ash are presented in Table 7 in comparison with the maximum metal loading rates allowed by the EPA 503 regulations for biosolids. The assumed application rate for poultry litter ash is the same as for the Canadian fertilizer example above. The ratio of the EPA 503 maximum allowable metal loading rate to the projected maximum metal loading rate for poultry litter ash ranges from 22 for As to 11998 for Hg, indicating that land application of poultry litter ash should easily comply with the EPA 503 standard for biosolids.

Poultry litter ash used alone as a fertilizer should easily comply with metals standards based on AAPFCO, Canadian, or EPA 503 standards. Poultry litter ash formulated with conventional inorganic fertilizers generally will have lower metals levels than poultry litter ash alone, further reducing the probability of metal levels limiting the use poultry litter ash in fertilizers. If for some reason poultry litter ash were applied at disposal rates (i.e., rates significantly higher than required to supply macronutrient needs of the crop), it is possible that metals application might exceed the metals standards discussed above; however, this is not a likely scenario for purchased fertilizers that can be formulated to conform to nutrient ratios required by the crop. In contrast, when poultry litter is applied on a nitrogen basis, for example, phosphorus is applied at a much higher rate than required by the crop, metal application rates are correspondingly higher than if the poultry litter were applied on a phosphorus basis, and the potential for exceeding metals standards for land application are greater than if poultry litter were applied on a phosphorus basis.

Table 5. Metals concentrations in broiler litter from Delmarva growers and projected maximum metal loading rates for land-applied broiler litter ash compared with levels allowed by the Uniform State Fertilizer Bill, American Association of Plant Food Control Officials.

		P_2O_5 basis		Micronutrient basis	
Metals [1/]	Actual conc., ppm	ppm/1% P_2O_5	ppm limit	ppm/1% total conc. minor elements	ppm limit
As	124	13	195	112	1,264
Cd	0.6	10	150	83	936
Co	4.2	3,100	46,500	**23,000**	**259,486**
Pb	10.6	61	915	463	5,224
Hg	0.1	1	14	6	68
Mo	20.9	42	630	**300**	**3,385**
Ni	29.6	250	3,750	1,900	21,436
Se	3.7	26	390	180	2,031
Zn	2286	420	6,300	**2,900**	**32,718**

Numbers in bold only apply when metal is not guaranteed on fertilizer label

Control factor		
P_2O_5, %	15	
Micronutrients, %		
Fe		0.80
Mn		0.26
Zn		0.23
Cu		0.16
Mo		0.00
B		0.02
Co		0.00
Cl		3.00
Na		6.81
Total, %		11.28

[1/] Mean of 24 broiler litter samples (Table 1)

Table 6. Metals concentrations in broiler littter ash from Delmarva growers and projected maximum metal loading rates for land applied broiler litter ash compared with the Canadian fertilizer standard for metals loading.

Metal	Broiler litter ash[1]	Canadian Standard -- maximum metal loading rate/45 years	Canadian Standard-- maximum metal loading rate/year	Metal loading rate for 100 lb P2O5/acre/year (667 lb ash/acre/year)[2]	Ratio of Canadian Std.max. to actual loading rates
	mg metal/ kg ash	lb metal/acre	lb metal /acre/year	lb metal/acre/year	
As	124	13	0.30	0.0827	4
Cd	0.6	4	0.08	0.0004	200
Co	4.2	27	0.60	0.0028	213
Hg	0.1	1	0.02	0.0001	300
Mo	20.9	4	0.08	0.0139	6
Ni	29.6	32	0.71	0.0197	36
Pb	10.6	89	1.98	0.0071	281
Se	3.7	3	0.06	0.0025	23
Zn	2,286	330	7.34	1.5248	5

[1]Mean of 24 broiler litter samples (Table 1).

[2]Assumes application of 667 lb/acre of ash (15 percent plant-available P_2O_5) to supply 100 lb plant-available P_2O_5/acre/year.

Table 7. Metals concentrations in broiler litter ash from Delmarva growers and projected maximum metal loading rates for land-applied broiler litter ash compared with EPA 503 regulations for land application of biosolids.

Metal	Concentration (dry basis)[1]	EPA 503 maximum metal concentration[2]	Metal loading rate for 100 lb P_2O_5/acre/year[3]	EPA 503 maximum metal loading rate[2]	Ratio of EPA 503 max. to actual metal loading rates
	mg metal/kg ash		lb metal /acre/year		
As	124	75	0.08	1.8	22
Cd	0.6	85	0.00	1.7	4,249
Cr	24.4	3,000	0.02	134	8,236
Cu	2,615	4,300	1.74	67	38
Hg	0.1	57	0.00	0.8	11,998
Mo	20.9	75	0.01	0.8	57
Ni	29.6	420	0.02	18.8	953
Pb	10.6	840	0.01	13.4	1,896
Se	3.7	100	0.00	4.5	1,824
Zn	2,286	7,500	1.52	125	82

[1]Mean of 24 broiler litter samples from Bock, 1999.

[2]Code of Federal Regulations, Vol. 58, no. 32, parts 257, 404, and 503: Standards for the Use of Disposal of Sewage Sludge. Feb. 19, 1993.

[3]Assumes application of 667 lb/acre of ash (15 percent plant-available P_2O_5) to supply 100 lb plant-available P_2O_5/acre/year.

E. References

AAPFCO. 2005. http://www.aapfco.org/aapfcorules.html#SUIP25

Bock, B.R. and T.R. Miles. 2001. Energy options for producing value-added coastal bermudagrass and reducing nutrient surpluses in southeastern North Carolina. Report to: Cape Fear Resource Conservation and Development, Inc., Energy Division, North Carolina Department of Commerce, and North Carolina Rural Economic Development Center.

Bock, B.R. 2004. Demonstrating optimum fertilizer value from the biomass energy sustainable technology (BEST) demonstration project for swine & poultry manure management. Final report to Farm Pilot Project Coordination, North Carolina State University, and Smithfield Foods. http://www.fppcinc.org/pdf/capefear.pdf.

Green Markets. 2005. Pike & Fischer. December 5, 2005.

XVI. Nutritional Value of Poultry Litter Ash Fed to Broiler Chickens

A. Executive Summary

A series of experiments were conducted to evaluate the nutritional and economic value of poultry litter ash as a replacement for dicalcium phosphate in the diet of broiler chickens. In Experiment 1, poultry litter ash was fed at graded levels (0, 25, 50, 75, and 100%) as a substitute for dicalcium phosphate. The resulting diets were formulated based on an equal substitution of dicalcium phosphate with poultry litter ash on a weight:weight basis. Results indicated a slight growth response from poultry litter ash at the 25% substitution rate. While a significant growth decrease occurred at the 100% substitution rate during the starting period, any effect on growth rate disappeared by the conclusion of the study at 41 days. Results indicate that the complete substitution of dicalcium phosphate with poultry litter ash failed to compromise growth rate, feed consumption or feed efficiency in market age broilers. Although bone ash percentages varied among treatments, no specific pattern was observed. Overall results from the measurement of bone ash indicate that the integrity of the bones should not be compromised by the addition of poultry litter ash to the diet.

Results from Experiment 2 indicate pronounced differences in the dry matter digestibility of specific nutrients. Dry matter digestibility of calcium and phosphorus tended to increase with increasing level of poultry litter ash. Such a relationship infers that the calcium and phosphorus component of the diet was more efficiently utilized as the level of poultry litter ash increased. It is plausible that the calcium and phosphorus contained in the poultry litter ash may be more available to the bird as compared to the dicalcium phosphate used in the control diet.

Experiment 3 was designed to evaluate the poultry litter ash under commercial conditions at graded levels. Broilers were fed graded levels of the poultry litter ash up to 100% replacement for dicalcium phosphate in the starter, grower and finisher diets. All diets were formulated to meet the nutrient requirements of the broiler utilizing poultry litter ash as a replacement for dicalcium phosphate. Results indicate that there were no significant effects ($P>.05$) on bodyweight, bodyweight gain or feed consumption when broilers were fed graded levels of the poultry litter ash up to 100% replacement for dicalcium phosphate in the diet. However, bodyweights and bodyweight gains tended to trend downward (not significantly) for those birds that were fed the highest levels of poultry litter ash supplement in the starter and grower feeds. These differences diminished by day 41, indicating that compensatory growth may have been achieved to a slight degree. Processing performance of broilers at 41 days of age was also unaffected. Results indicate that the complete substitution of dicalcium phosphate with poultry litter ash failed to compromise growth and processing performance in market age broilers.

B. Objective

To evaluate the nutritional and economic value of poultry litter ash when fed to broiler chickens.

C. Introduction

The overall project that complements this research is the assessment of the feasibility of an integrated ethanol and poultry production (IPEP) system in North Alabama that uses poultry litter as an alternative source of process energy for corn/ethanol production. This project will also contribute to improving the overall economic and environmental performance of both ethanol and poultry production. Advantages of the IPEP system for poultry production are an economical alternative use for broiler litter and the potential to lower broiler feed costs with the availability of dried distillers grains and solubles (DDGS) and poultry litter ash. Practical alternatives to land application of poultry litter are needed because of concerns about phosphorus runoff into surface waters. The poultry litter ash that results from the combustion of broiler litter has potential for use as a phosphorus supplement for use in poultry diets, and has greater value in this respect as compared to its fertilizer value. Local sources of products obtained from the corn ethanol production system such as DDGS and poultry litter ash provide a distinct economic advantage in reducing feed costs and maintaining bird performance.

A series of experimental trials were conducted to determine the effect of graded levels of poultry litter ash on the growth performance of broiler chickens. The first study was designed to evaluate increasing levels of poultry litter ash in the diet of broiler chickens in battery cages. A second study was designed to evaluate the nutrient bioavailablity of the poultry litter ash as a source of macro minerals for the broiler chicken. A third study was conducted to evaluate the poultry litter ash under commercial conditions.

D. Materials and Methods

1. Evaluation of Poultry Litter Ash

Initial analyses were completed to determine the mineral composition of the litter poultry ash (Table 1) along with values for the nutrient composition of macro and micro minerals used in the computer formulation matrix.

2. Experiment 1

A direct substitution of poultry litter ash for dicalcium phosphate on a weight:weight basis was accomplished at dietary levels of 0, 25, 50, 75, and 100%. (Tables 2 and 3). All feeds were computer formulated to meet or exceed the recommended nutrient requirements of the birds. A starter feed was fed from 0-21 days of age (Table 2) followed by a grower feed from 21-41 days of age (Table 3). For each of the five dietary treatments, nine replicates of eight birds were used. In this study, birds were reared in heated wire batteries with eight birds per pen in accordance with recommendations published in "Guide for the Care and Use of Agricultural Animal in Agricultural Teaching and Research." This experiment was terminated when the birds were 41 days of age. Birds were provided feed and water *ad libitum* throughout the course of the experiment. Birds were weighed at 21 and 41 days of age. On day 41, femur bones were obtained from three birds per pen and were pooled (by pen) for ash analysis.

3. Experiment 2

This study evaluated the nutrient bioavailability of poultry litter ash as a source to supplement the macro mineral requirements of the broiler chicken. Those minerals of interest include: calcium, phosphorus, and potassium. This study was simultaneously conducted with Experiment 1. For this study, the 45 pens of birds were utilized for a 24-hour total excreta collection to calculate mineral bioavailability. Birds were introduced to the grower diets (Table 3) on the 21st day of the experiment and allowed a one-day orientation period. On the 22nd day, feed weights were obtained and excreta collection trays were lined with aluminum foil. Following a 24-hr period, feed weights were obtained and excreta were quantitatively collected from all 45 pens. Excreta were pooled, freeze-dried, ground and analyzed for nitrogen, calcium, phosphorus, and potassium. Bioavailability for each of these minerals was determined as a percentage of the difference between amount consumed versus amount excreted.

4. Experiment 3

For this experimental trial a total of 1600 broiler chicks were obtained from a commercial hatchery (Cobb X Ross) and 25 birds were randomly assigned to each of 64 pens, each being 1.98 x 2.29 m in dimension. The average amount of space allotted for each bird (0.181 m^2/bird) is in excess of that published in the "Guide for the Care and Use of Agricultural Animals in Agricultural Teaching and Research". The number of birds required reflect the required number of replicate pens per treatment required to generate sound statistical data for growth and processing performance. The open-sided housing had thermostatically controlled heating, curtains, and cross-ventilation. Each pen had fresh pine shavings and was equipped with one hanging feeder (22.5 kg capacity) and nipple water line system. Chicks were vaccinated for Marek's disease at the hatchery

Pens are separated by wire partitions and the floor and isles are concrete. Electric brooders and forced-air furnaces supply heat. Natural curtain and fan ventilation is typical of that found in the commercial broiler industry. Tube-type feeders and a nipple water system are provided in each pen. Five centimeters of pine shavings were supplied as the bedding material in each pen. Standard husbandry and good management practices were followed and meet industry guidelines. Birds were fed starter (1.8 lbs/bird), grower (3.5 lbs/bird), and finisher (6.7 lbs/bird) diets to meet or exceed National Research Council (NRC) recommendations (Tables 4-6). Diets and water were available *ad libitum*. In each trial, live performance (weight gain, feed consumption and daily mortality) and processing performance (abdominal fat content, carcass yield, and meat yield) were determined. Birds were weighed at 14, 28 and 41 days of age to determine body weight gain as a measure of performance. Feed consumption was also determined for the duration of the experiment. The experiment was terminated at 41 days of age.

Dietary treatments for the experiment were as follows:

Treatment	Starter	Grower	Finisher
	Level of Poultry Litter Ash (%)		
1	0	0	0
2	25	25	25
3	50	50	50
4	75	75	75[1]
5	100	100	100
6	25	100	100
7	50	100	100
8	75	100	100

[1]An adequate amount of poultry litter ash was not available to formulate a 75% finisher diet and substitution with the control diet (0% poultry litter ash) resulted.

5. Processing and Yield Determination

Carcass yield was evaluated (at 42 days of age) for ten broilers from each pen at the AU Poultry Science Research Unit Processing Facility. Individual birds were randomly selected at terminal weighing when on full feed. Ten birds per pen were wing-banded, and placed back in the pens. Feed and water withdrawal was introduced eight hours (11 p.m.) prior to processing. A second weighing prior to processing followed the eight-hour feed withdrawal period. Carcass and abdominal fat weight were determined after a two-hour ice chilling to slightly less than 40 F. Following chilling, the front half and rear half were separated, weighed and the respective yield of each component calculated as a percent of preslaughter live weight.

6. Statistical Analysis

Data from this experiment was analyzed by analysis of variance using the General Linear Models procedure of the Statistical Analysis System (SAS Institute, 1985; Cary, NC). Diet main effects were tested using replicate pens as the error term. All percentage data were subjected to arc sine square root transformation prior to analysis; however, actual data are reported. Feed efficiency was corrected for mortality. When significant (P<0.05), means were separated by Tukey's HD multiple comparison procedure.

7. Facilities

All experimental procedures were performed in the Department of Poultry Science at Auburn University. The Poultry Science Research Unit at Auburn University possesses unique facilities to support this research. This facility offers the required growing equipment for the completion of Experiment 1. Rooms located in the Battery House provide temperature and lighting control required for appropriate management of birds for excreta collection and for completing Experiment 2. A research building containing 64 floor pens with commercial feeding and watering systems complemented Experiment 3. The feed mill at the Unit is fully functional and capable of producing commercial-type-pelleted diets.

E. Results and Discussion

A series of experiments were conducted to evaluate the nutritional and economic value of poultry litter ash as a replacement for dicalcium phosphate in the diet of broiler chickens. The poultry litter ash was submitted for analysis and these results and values used in the computer formulation of the diets have been referenced previously (Table 1).

Concern for the levels of dioxin in animal feed ingredients as well as other contaminants has been an ongoing concern and a feed safety-related issue. Dioxins are a group of chemical compounds that share certain chemical structures and biological characteristics, but exhibit a wide envelope of toxicity. Several hundred dioxin compounds exist including the well-known family of polychlorinated biphenyls (PCBs). The most toxic form of dioxin is 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD). Dioxins are usually the result of a combustion process and are extremely persistent and stable compounds.

The poultry litter ash was analyzed for dioxin analysis and the results were subjected to a toxic equivalency factor (TEF) where compounds are assigned a relative TEF value when compared to the toxicity of 2378-TCDD. To find the actual amount of dioxin in a sample based on the toxic equivalency quotient (TEQ), one multiplies the TEF by the concentration and adds each together. In 1998, the World Health Organization (WHO) derived the TEFs that most of the world uses now. Currently, the maximum limit for dioxin in a feed ingredient that falls into the category for poultry litter ash is 1.0 ng WHO-PCDD/F-TEQ/kg. Results from the dioxin analysis of poultry litter ash and the associated calculation of TEF indicate a level of 0.632 ng/kg, which is less than the current EU maximum limit for a mineral class of feed ingredient. The level of non-quantified PCBs was found to be 115 ng/kg. A certified analysis and results of a dioxin and PCB analysis are included in Appendix A. Results of the dioxin and PCB analysis indicates that there are no related compounds that appear to be significant to bird health or that pose a potential threat to the quality of meat that will be obtained from the slaughter of birds fed the poultry litter ash product. Therefore the poultry litter ash was deemed safe for use as a feed supplement in poultry diets.

In Experiment 1, poultry litter ash was fed at graded levels (0, 25, 50, 75, and 100%) as a substitute for dicalcium phosphate. Diets in this study were based on the direct substitution of poultry litter ash as a replacement for dicalcium phosphate on a weight:weight basis. The principle use for poultry litter ash is as a substitute for meeting the bird's phosphorus requirement. Phosphorus is the second most expensive ingredient in the diet, after protein, and the poultry litter ash may offer exceptional advantage as a source of phosphorus. Although poultry litter ash contains micro minerals such as iron, zinc, copper, manganese, and selenium, changes in the rate of micro mineral addition were not altered via the trace mineral premix in this experiment. This approach to diet formulation resulted in decreasing levels of calcium and phosphorus as levels of poultry litter ash increased in the diet. It can be recognized that this approach may produce adverse effects due to inadequacies in meeting nutrient requirements, but may also challenge the bioavailability of minerals contained in the test ingredient.

Results indicated a slight growth response from poultry litter ash at the 25% substitution rate (Table 7). Factors contributing to this increased performance could not be identified. While a significant growth decrease occurred at the 100% substitution rate during the starting period, any effect on growth rate disappeared by the conclusion of the study at 41 days. Since the resulting diets were formulated based on an equal substitution of dicalcium phosphate with poultry litter ash, the concomitant decrease in phosphorus and calcium levels in the diet may have contributed to this decline in performance. Results indicate that the complete substitution of dicalcium phosphate with poultry litter ash failed to compromise growth rate, feed consumption or feed efficiency in market age broilers.

With increasing level of ash there was a significant ($P<.001$) increase in excreta moisture (Table 8). It was not determined whether this increase is related to an increased water intake by birds fed increasing levels of poultry litter ash; however, this type of assumption would be justified. Although bone ash percentages varied among treatments, no specific pattern was observed (Table 8). Birds receiving the highest level of poultry litter ash exhibited the highest bone ash, while those receiving the 25% poultry litter ash treatment exhibited a significantly lower ash value. Overall results from the measurement of bone ash indicate that the integrity of the bones should not be compromised by the addition of poultry litter ash to the diet. It is interesting to note that even though phosphorus and calcium levels decreased in the diets as level of poultry litter ash increased, there appears to be no negative impact on bone mineralization.

Results from Experiment 2 indicate pronounced differences in the dry matter digestibility of specific nutrients (Table 8). Although differences in the digestibility of nitrogen were detected, they are more likely related to differences in feed intake and not to the addition of poultry litter ash to the diet. The dry matter digestibility of calcium and phosphorus tended to increase (P<0.05) with increasing level of poultry litter ash. Such a relationship infers that the calcium and phosphorus component of the diet was more efficiently utilized as the level of poultry litter ash increased. It is also necessary to recall that the dietary levels of calcium and phosphorus decreased with increasing level of poultry litter ash. It is plausible that the calcium and phosphorus contained in the poultry litter ash may be more available to the bird as compared to the dicalcium phosphate used in the control diet.

Experiment 3 was designed to evaluate the poultry litter ash under commercial conditions at graded levels. The experimental design was established based on responses obtained in Experiment 1. Results indicate that there were no significant effects (P>0.05) on bodyweight, bodyweight gain or feed consumption when broilers were fed graded levels of the poultry litter ash up to 100% replacement for dicalcium phosphate in the diet (Table 9). However, bodyweights and bodyweight gains tended to trend downward (not significant) for those birds that were fed the highest levels of poultry litter ash supplement in the starter and grower feeds. These differences were not as great by day 41, indicating that compensatory growth may have been achieved to a slight degree. Also, there were no significant differences (P>0.05 in the processing performance of broilers at 41 days of age that received graded levels of the poultry litter ash as a substitute for dicalcium phosphate in the diet (Table 10). Results indicate that the complete substitution of dicalcium phosphate with poultry litter ash failed to compromise growth and processing performance in market age broilers.

F. Economic Evaluation of Poultry Litter Ash

The value of the poultry litter ash is more directly related to the value of dicalcium phosphate or defluorinated phosphate that will be used to meet the phosphorus requirements of the bird. A survey of the diets formulated in the previous experiments should provide insight concerning the value of the poultry litter ash in comparison to a typical dicalcium phosphate supplement. In Experiment 1 the resulting diets were formulated based on an equal substitution of dicalcium phosphate with poultry litter ash. Therefore results of this type of substitution places the economic value of poultry litter ash equal to that of dicalcium phosphate since performance results were not significant between the two products.

In Experiment 3, the commercial formulation provides a more likely scenario for the substitution of poultry litter ash for dicalcium phosphate. In the 100% supplemented starter, grower and finisher diet, substitution of dicalcium phosphate with poultry litter ash was 1.73 vs. 3.22 lbs, 1.60 vs. 2.96 lbs, and 1.38 vs. 2.56 lbs, respectively. As a result, there is a requirement to use almost twice as much (ca. 46% more) poultry litter ash to meet the phosphorus requirements of the broiler. The breakeven value of the poultry litter ash used in these experiments can be estimated at approximately 54% the value of dicalcium phosphate on a weight:weight basis.

Table 1. Composition of Poultry Litter Ash

Nutrient	Analyzed Values[1]	Computer Values[2]
Calcium (%)	16.68	16.70
Phosphorus (%)	10.08	10.00
Copper (%)	0.165	1500.00 ppm
Iron (%)	0.593	5000.00 ppm
Magnesium (%)	2.650	2.70 %
Manganese (%)	0.209	1900.00 ppm
Potassium (%)	7.64	7.5 %
Sodium (%)	4.34	4.2 %
Chloride (%)	0.99	1.0 %
Zinc (%)	0.136	1300.00 ppm
Selenium (ppm)	2.40	2.4 ppm
Fluoride (ppm)	436.0	
Aluminum (ppm)	7,260	
Antimony (ppm)	<5	
Arsenic (ppm)	52.0	
Cadmium (ppm)	0.80	
Chromium (ppm)	34.0	
Lead (ppm)	4.4	
Mercury (ppm)	<0.1	
Vanadium (ppm)	26.0	

[1]Values obtained from analysis of sample submitted to Eurofins, Memphis, TN
[2]Values assigned to Poultry Litter Ash when used as an ingredient in the computer feed formulation matrix.

Table 2. Composition and calculated analysis of experimental starter diets (Experiments 1 and 2)

Ingredient	Level of Poultry Litter Ash (%) 0	25	50	75	100
	g/100 g				
Ground yellow corn	58.52	58.52	58.52	58.52	58.52
Soybean meal (48% CP)	30.80	30.80	30.80	30.80	30.80
Poultry by-product meal (50% CP)	4.00	4.00	4.00	4.00	4.00
Poultry oil	2.80	2.80	2.80	2.80	2.80
Dicalcium phosphate[1]	1.40	1.05	0.70	0.35	0.00
Limestone (38% Ca)	1.12	1.12	1.12	1.12	1.12
Poultry litter ash[2]	0.00	0.35	0.70	1.05	1.40
Salt	0.40	0.40	0.40	0.40	0.40
DL-methionine	0.26	0.26	0.26	0.26	0.26
L-lysine	0.12	0.12	0.12	0.12	0.12
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[4]	0.25	0.25	0.25	0.25	0.25
Coban-60[5]	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Crude protein (%)	22.00	22.00	22.00	22.00	22.00
Metabolizable energy (kcal/kg)	3087.	3087.	3087.	3087.	3087.
Calcium (%)	0.93	0.90	0.88	0.85	0.83
Non-phytate phosphorus (%)	0.45	0.44	0.39	0.36	0.33
Methionine (%)	0.62	0.62	0.62	0.62	0.62
Met + Cys (%)	0.95	0.95	0.95	0.95	0.95
Lysine (%)	1.27	1.27	1.27	1.27	1.27

[1] Contains 18.5% phosphorus and 24.1% calcium.
[2] Poultry litter ash was added to the diet at the expense of dicalcium phosphate on a weight:weight basis.
[3] Supplied the following per kg of complete feed: vitamin A, 8,000 IU (retinyl palmitate); cholecalciferol, 2,000 IU; vitamin E, 8 IU (di-tocopheryl acetate); menadione, 2 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; vitamin B_{12}, 0.02 mg; folic acid, 5 mg; thiamin, 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; ethoxyquin, 125 mg.
[4] Supplied the following per kg of complete feed: manganese, 125 mg; iodine, 1 mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg, selenium, 0.3 mg.
[5] Monensin Sodium; Elanco Animal Health, Inc., Indianapolis, IN 46285.

Table 3. Composition and calculated analysis of experimental grower diets (Experiments 1 and 2)

Ingredient	Level of Poultry Litter Ash (%) 0	25	50	75	100
	----------g/100 g----------				
Ground yellow corn	64.00	64.00	64.00	64.00	64.00
Soybean meal (48% CP)	25.67	25.67	25.67	25.67	25.67
Poultry by-product meal (50% CP)	4.00	4.00	4.00	4.00	4.00
Poultry oil	2.77	2.77	2.77	2.77	2.77
Dicalcium phosphate[1]	1.28	0.96	0.64	0.32	0.00
Limestone (38% Ca)	0.98	0.98	0.98	0.98	0.98
Poultry litter ash[2]	0.00	0.32	0.64	0.96	1.28
Salt	0.42	0.42	0.42	0.42	0.42
DL-methionine	0.22	0.22	0.22	0.22	0.22
L-lysine	0.08	0.08	0.08	0.08	0.08
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[4]	0.25	0.25	0.25	0.25	0.25
Coban-60[5]	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Crude protein (%)	20.00	20.00	20.00	20.00	20.00
Metabolizable energy (kcal/kg)	3153.	3153.	3153.	3153.	3153.
Calcium (%)	0.84	0.82	0.79	0.77	0.75
Non-phytate phosphorus (%)	0.42	0.39	0.37	0.34	0.31
Methionine (%)	0.56	0.56	0.56	0.56	0.56
Met + Cys (%)	0.86	0.86	0.86	0.86	0.86
Lysine (%)	1.10	1.10	1.10	1.10	1.10

[1] Contains 18.5% phosphorus and 24.1% calcium.
[2] Poultry litter ash was added to the diet at the expense of dicalcium phosphate on a weight:weight basis.
[3] Supplied the following per kg of complete feed: vitamin A, 8,000 IU (retinyl palmitate); cholecalciferol, 2,000 IU; vitamin E, 8 IU (di-tocopheryl acetate); menadione, 2 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; vitamin B_{12}, 0.02 mg; folic acid, 5 mg; thiamin, 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; ethoxyquin, 125 mg.
[4] Supplied the following per kg of complete feed: manganese, 125 mg; iodine, 1 mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg, selenium, 0.3 mg.
[5] Monensin Sodium; Elanco Animal Health, Inc., Indianapolis, IN 46285.

Table 4. Composition and calculated analysis of experimental starter diets (Experiment 3).

Ingredient	Level of Poultry Litter Ash (%) 0	25	50	75	100
	g/100 g				
Ground yellow corn	55.75	55.44	55.14	54.79	54.47
Soybean meal (48% CP)	35.09	35.12	35.14	35.17	35.19
Poultry oil	4.53	4.65	4.77	4.90	5.02
Dicalcium phosphate[1]	1.73	1.30	0.86	0.43	0.00
Limestone (38% Ca)	1.23	1.12	1.01	0.90	0.79
Poultry litter ash[2]	0.00	0.80	1.60	2.41	3.22
Salt	0.45	0.37	0.28	0.20	0.11
DL-methionine	0.27	0.27	0.27	0.27	0.27
L-lysine	0.12	0.10	0.10	0.10	0.10
Vitamin premix[3]	0.50	0.50	0.50	0.50	0.50
Trace mineral premix[4]	0.25	0.25	0.25	0.25	0.25
Coban-60[5]	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Crude protein (%)	21.50	21.50	21.50	21.50	21.50
Metabolizable energy (kcal/kg)	3142.	3142.	3142.	3142.	3142.
Calcium (%)	0.93	0.93	0.93	0.93	0.93
Non-phytate phosphorus (%)	0.45	0.45	0.45	0.45	0.45
Methionine (%)	0.62	0.62	0.62	0.62	0.62
Met + Cys (%)	0.95	0.95	0.95	0.95	0.95
Lysine (%)	1.27	1.27	1.27	1.27	1.27

[1] Contains 18.5% phosphorus and 24.1% calcium.
[2] Poultry litter ash was added to the diet at the expense of dicalcium phosphate.
[3] Supplied the following per kg of complete feed: vitamin A, 8,000 IU (retinyl palmitate); cholecalciferol, 2,000 IU; vitamin E, 8 IU (di-tocopheryl acetate); menadione, 2 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; vitamin B_{12}, 0.02 mg; folic acid, 5 mg; thiamin, 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; ethoxyquin, 125 mg.
[4] Supplied the following per kg of complete feed: manganese, 125 mg; iodine, 1 mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg, selenium, 0.3 mg.
[5] Monensin Sodium; Elanco Animal Health, Inc., Indianapolis, IN 46285.

Table 5. Composition and calculated analysis of experimental grower diets (Experiment 3).

	Level of Poultry Litter Ash (%)				
Ingredient	0	25	50	75	100
	g/100 g				
Ground yellow corn	63.00	62.70	62.31	62.01	61.62
Soybean meal (48% CP)	29.70	29.71	29.81	29.82	29.93
Poultry oil	3.28	3.41	3.53	3.65	3.77
Dicalcium phosphate[1]	1.60	1.20	0.80	0.40	0.00
Limestone (38% Ca)	1.09	0.99	0.89	0.80	0.70
Poultry litter ash[2]	0.00	0.74	1.48	2.22	2.96
Salt	0.45	0.37	0.30	0.22	0.14
DL-methionine	0.23	0.23	0.23	0.23	0.23
L-lysine	0.07	0.07	0.07	0.07	0.07
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[4]	0.25	0.25	0.25	0.25	0.25
Coban-60[5]	0.08	0.08	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Crude protein (%)	19.50	19.50	19.50	19.50	19.50
Metabolizable energy (kcal/kg)	3153.	3153.	3153.	3153.	3153.
Calcium (%)	0.84	0.84	0.84	0.84	0.84
Non-phytate phosphorus (%)	0.42	0.42	0.42	0.42	0.42
Methionine (%)	0.56	0.56	0.56	0.56	0.56
Met + Cys (%)	0.86	0.86	0.86	0.86	0.86
Lysine (%)	1.10	1.10	1.10	1.10	1.10

[1] Contains 18.5% phosphorus and 24.1% calcium.
[2] Poultry litter ash was added to the diet at the expense of dicalcium phosphate.
[3] Supplied the following per kg of complete feed: vitamin A, 8,000 IU (retinyl palmitate); cholecalciferol, 2,000 IU; vitamin E, 8 IU (di-tocopheryl acetate); menadione, 2 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; vitamin B_{12}, 0.02 mg; folic acid, 5 mg; thiamin, 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; ethoxyquin, 125 mg.
[4] Supplied the following per kg of complete feed: manganese, 125 mg; iodine, 1 mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg, selenium, 0.3 mg.
[5] Monensin Sodium; Elanco Animal Health, Inc., Indianapolis, IN 46285.

Table 6. Composition and calculated analysis of experimental finisher diets (Experiment 3).

	Level of Poultry Litter Ash (%)[1]			
Ingredient	0	25	50	100
	g/100 g			
Ground yellow corn	72.54	72.25	71.95	71.33
Soybean meal (48% CP)	21.76	21.82	21.87	21.97
Poultry oil	1.98	2.08	2.18	2.41
Dicalcium phosphate[2]	1.38	1.03	0.69	0.00
Limestone (38% Ca)	1.02	0.94	0.85	0.68
Poultry litter ash[3]	0.00	0.64	1.28	2.56
Salt	0.45	0.39	0.32	0.20
DL-methionine	0.24	0.24	0.24	0.24
L-lysine	0.12	0.12	0.12	0.12
Vitamin premix[4]	0.25	0.25	0.25	0.25
Trace mineral premix[5]	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Crude protein (%)	16.50	16.50	16.50	16.50
Metabolizable energy (kcal/kg)	3175.	3175.	3175.	3175.
Calcium (%)	0.75	0.75	0.75	0.75
Non-phytate phosphorus (%)	0.37	0.37	0.37	0.37
Methionine (%)	0.54	0.54	0.54	0.54
Met + Cys (%)	0.79	0.79	0.79	0.79
Lysine (%)	0.92	0.92	0.92	0.92

[1]An adequate amount of poultry litter ash was not available to formulate a 75% diet and substitution with the control diet (0% poultry litter ash) resulted.
[2] Contains 18.5% phosphorus and 24.1% calcium.
[3] Poultry litter ash was added to the diet at the expense of dicalcium phosphate.
[4] Supplied the following per kg of complete feed: vitamin A, 8,000 IU (retinyl palmitate); cholecalciferol, 2,000 IU; vitamin E, 8 IU (di-tocopheryl acetate); menadione, 2 mg; riboflavin, 5.5 mg; pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; vitamin B_{12}, 0.02 mg; folic acid, 5 mg; thiamin, 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; ethoxyquin, 125 mg.
[5] Supplied the following per kg of complete feed: manganese, 125 mg; iodine, 1 mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg, selenium, 0.3 mg.

Table 7. Performance of mixed sex broilers fed graded levels of poultry litter ash (Experiment 1).

Ash[1]	Bodyweight (g/bird)[2]			Bodyweight gain (g/bird)			Feed Consumed (g/bird)			Feed Efficiency (f:g)[3]		
(%)	0-day	21-day	41-day	0-21d	21-41d	0-41d	0-21d	21-41d	0-41d	0-21d	21-41d	0-41d
	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
0	46.6	866.1[ab]	2359.0	819.8[ab]	1416.8	2236.6	1146.1	3042.4	4188.9	1.317	2.118	1.773
25	47.0	878.8[a]	2299.0	831.8[a]	1370.7	2202.5	1169.5	2964.6	4134.6	1.307	2.166	1.787
50	46.5	848.8[ab]	2278.6	802.3[ab]	1368.0	2170.3	1119.9	2956.3	4076.6	1.319	2.146	1.789
75	46.6	839.3[ab]	2237.4	792.7[ab]	1350.7	2143.4	1110.4	2888.9	3999.6	1.314	2.141	1.783
100	45.7	824.0[b]	2263.7	778.3[b]	1362.6	2140.9	1124.6	2967.7	4092.6	1.323	2.124	1.776
SEM[4]	0.46	11.07	37.72	11.07	29.74	36.42	20.40	51.94	65.01	0.009	.026	.014

[ab]Means in a column with different superscripts are significantly different ($P<0.05$).
[1]Percentage of poultry litter ash used as a replacement for supplemental phosphorus in the diet.
[2]All values represent least square means of measurements on eight battery cages each having eight birds.
[3]Feed efficiency calculated as amount of feed consumed per gram of bodyweight gain, corrected for mortality.
[4]Pooled standard error of mean.

Table 8. Percentage of excreta moisture, dry bone ash and dry matter digestibility of nutrients in broiler diets utilizing graded levels of poultry litter ash (Expriment 2).

Ash[1]	Excreta Moisture	Bone Ash	Nitrogen	Calcium	Phosphorus	Potassium
0	72.93[a]	69.39[ab]	61.72[a]	26.32[a]	30.23[a]	27.99[ab]
25	73.63[a]	68.71[b]	67.08[b]	37.71[b]	35.21[a]	30.68[a]
50	76.45[b]	69.49[ab]	66.28[b]	56.37[cd]	35.67[a]	25.70[ab]
75	79.49[c]	69.88[ab]	61.17[a]	50.42[d]	42.29[b]	22.87[b]
100	81.72[c]	70.60[a]	62.28[a]	58.65[c]	42.68[b]	27.99[ab]
SEM[2]	0.64	0.38	0.93	1.82	1.53	1.54

[ab]Means in a column with different superscripts are significantly different ($P<0.05$).
[1]Percentage of poultry litter ash used as a replacement for supplemental phosphorus in the diet.
[2]Pooled standard error of mean.

Table 9. Bodyweight, bodyweight gain, feed consumption, feed efficiency, and mortality of mixed sex broilers fed graded levels of poultry litter ash in the diet (Experiment 3).

Level of Addition[1] Start/Grow/Finish (%)	Initial Weight[2] (g/bird)	14-d Body Weight (g/bird)	14-d Feed Consumed (g/bird)	14-d FE (g/g)	14-d Mortality[3] (%)	28-d Body Weight (kg/bird)	14-28 d BW Gain (kg/bird)	14-28 d Feed Consumed (kg/bird)	0-28 d Feed Consumed (kg/bird)	14-28 d FE (g/g)[4]
0/0/0	46.73	452.2	515.7	1.142	1.50	1.476	1.071	2.041	2.557	1.491[b]
25/25/25	47.05	469.6	511.1	1.089	0	1.517	1.095	2.081	2.592	1.500[b]
50/50/50	46.88	465.6	514.4	1.105	1.50	1.500	1.082	2.085	2.599	1.519[ab]
75/75/75	47.60	464.0	521.2	1.123	0.50	1.495	1.079	2.059	2.580	1.491[b]
100/100/100	47.50	461.2	485.8	1.054	1.00	1.452	1.038	2.037	2.523	1.570[a]
25/100/100	46.18	473.5	520.7	1.101	1.50	1.452	1.025	2.065	2.585	1.580[a]
50/100/100	46.80	466.9	512.0	1.097	0	1.462	1.042	2.051	2.563	1.550[ab]
75/100/100	46.75	464.9	519.1	1.118	1.50	1.477	1.059	2.087	2.606	1.552[ab]
SEM[5]	0.35	5.47	8.47	0.019		0.017	0.014	0.026	0.032	0.014
Probability	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.0001

Table 9. Continued

Level of Addition[1] Start/Grow/Finish (%)	0-28 d FE (g/g)	14-28 d Mortality (%)	41-d Body Weight (kg/bird)	28-41 d BW Gain (kg/bird)	28-41 d Feed Consumed (kg/bird)	0-41 d Feed Consumed (kg/bird)	28-41 d FE (g/g)	0-41 d FE (g/g)	28-41 d Mortality (%)	0-41 d Mortality (%)
0/0/0	1.375[ab]	0.51	2.557	1.080	2.295	4.416	2.129	1.731	0.50	2.50
25/25/25	1.364[b]	0.50	2.567	1.049	2.294	4.458	2.193	1.739	1.01	1.50
50/50/50	1.389[ab]	0.51	2.603	1.103	2.334	4.506	2.120	1.732	3.57	5.50
75/75/75	1.377[ab]	0	2.562	1.066	2.240	4.448	2.105	1.739	2.10	2.50
100/100/100	1.381[ab]	1.52	2.517	1.065	2.261	4.332	2.128	1.722	0	2.50
25/100/100	1.422[a]	0.51	2.537	1.085	2.213	4.378	2.044	1.778	3.57	5.50
50/100/100	1.393[ab]	1.0	2.555	1.093	2.307	4.490	2.119	1.759	1.52	2.50
75/100/100	1.397[ab]	1.52	2.596	1.119	2.394	4.498	2.036	1.734	5.24	4.50
SEM[5]	0.012		0.044	0.042	0.074	0.056	0.034	0.014		
Probability	0.036	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Percentage of poultry litter ash used as a replacement for supplemental phosphorus in the diet.
[2]Values are grand means involving 64 pens each with 25 chicks at placement.
[3]Total mortality percentages were transformed to the arcsine √ for GLM, whereas there is no valid SEM since data were transformed and subject to analysis.
[4]Feed efficiency calculated as amount of feed consumed per gram of bodyweight gain, corrected for mortality.
[5]Pooled standard error of mean.
[ab]Means in a column with different superscripts are significantly different.

Table 10. Processing performance of broilers at 41 days of age fed graded levels of poultry litter ash (Experiment 3).

Level of Addition[1] Start/Grow/Finish (%)	Pre-Slaughter Live Weight[2] (g)	Carcass Yield[3] (%)	Chilled Carcass[4]		Abdominal fat[6]		Front-half		Rear-half	
			Weight (g)	Yield[5] (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)
	NS[7]	NS	NS	NS	NS	NS	NS	NS	NS	NS
0/0/0	2648	71.39	1938	73.20	48.00	1.81	1072	40.49	818	30.90
25/25/25	2686	74.19	2045	76.00	48.50	1.81	1109	41.25	887	32.94
50/50/50	2701	70.07	1945	71.92	50.00	1.86	1072	39.60	823	30.46
75/75/75	2649	71.36	1944	73.23	49.63	1.87	1048	39.45	847	31.90
100/100/100	2654	72.85	1983	74.77	51.13	1.93	1075	40.47	857	32.37
25/100/100	2707	71.69	1993	73.66	53.25	1.97	1100	40.62	840	31.07
50/100/100	2641	70.45	1912	72.38	51.13	1.94	1057	39.99	804	30.46
75/100/100	2688	70.83	1955	72.75	51.63	1.92	1087	40.43	817	30.40
SEM[8]	66.74	1.16	61.29	1.16	1.78	0.051	32.56	0.419	33.55	0.978

[1]Percentage of poultry litter ash used as a replacement for supplemental phosphorus in the diet.
[2]All values represent least square means of eight pens, each providing data from ca. 10 carcasses.
[3]Statistical analysis employed transformed values (arcsine √%), whereas the respective SEM values were estimates derived from actual percentages.
[4]Carcass without neck and giblets after 2 hr of slush-ice chilling and removal of abdominal fat expressed on an absolute basis and relative to the full-fed live bird. Depot fat removed from the abdominal cavity of carcasses without neck and giblets after 2 hr of slush ice chilling expressed on an absolute basis and relative to the full-fed live weight.
[5] As percent of pre-slaughter live weight.
[6]Abdominal fat expressed on an absolute basis and relative to the chilled carcass.
[7]NS = Not-significant (P>0.05)
[8] SEM = Pooled standard error of mean.

APPENDIX A

Certified Laboratory Analysis

Analysis of Poultry Litter Ash for Nutrient Composition and Dioxins

eurofins | Woodson-Tenent Laboratories Division

PO Box 2135
345 Adams Ave.
Memphis, TN 38103
(901) 521-4500

Eurofins Sample: ME2003-041079
Sample of: Poultry Litter Ash
Sample ID: No ID
PO Number:
Cust #: 1092755

Reporting Date: 1/7/2004
Entry Date: 11/21/2003

Auburn University
Attn John P. Blake
249 Upchurch Hall
Dept. Of Poultry Science
Auburn AL 36849-5416

REPORT OF ANALYSIS

Test	Result	Units
Iron	0.593	%
Magnesium	2.65	%
Manganese	0.209	%
Potassium	7.64	%
Sodium	4.34	%
Zinc	0.136	%
Aluminum	7,260	ppm
Antimony	<5	ppm
Arsenic	52	ppm
Cadmium	0.8	ppm
Calcium At High Levels	~~10.40~~ 16.83	%
Chromium	34	ppm
Copper	0.165	%
Fluoride	436	ppm
Lead	4.4	ppm
Mercury	<0.1	ppm
Phosphorus	10.08	%
Selenium	2.4	ppm

eurofins | Woodson-Tenent Laboratories Division

Eurofins Sample: ME2003-041079 Sample ID: No ID

REPORT OF ANALYSIS

Test	Result	Units
Vanadium	26	ppm
Chloride-Soluble	0.99	%
Dioxins	Listed Below	
2378-TCDD	<0.26	ng/kg
12378-PeCDD	<0.30	ng/kg
123478-HxCDD	<0.59	ng/kg
123678-HxCDD	<0.59	ng/kg
123789-HxCDD	<0.59	ng/kg
1234678-HpCDD	<3.95	ng/kg
OCDD	<9.88	ng/kg
2378-TCDF	<0.89	ng/kg
12378-PeCDF	<0.40	ng/kg
23478-PeCDF	0.63	ng/kg
123478-HxCDF	1.10	ng/kg
123678-HxCDF	0.82	ng/kg
234678-HxCDF	1.23	ng/kg
123789-HxCDF	<0.59	ng/kg
1234678-HpCDF	<3.95	ng/kg
1234789-HpCDF	<3.95	ng/kg
OCDF	<9.88	ng/kg
TEQ (WHO) excl. LOQ [a]	0.632	ng/kg
TEQ (WHO) incl. ½ LOQ [b]	1.14	ng/kg
TEQ (WHO) incl. LOQ [c]	1.65	ng/kg
I-TEQ (NATO/CCMS) excl. LOQ [a]	0.632	ng/kg
I-TEQ (NATO/CCMS) incl. ½ LOQ [b]	1.08	ng/kg
I-TEQ (NATO/CCMS) incl. LOQ [c]	1.52	ng/kg
Dry matter	100	%

< :Concentration below the indicated limit of quantification (LOQ)
ND :Not determined since none of the corresponding congeneres was above the LOQ
[a] :TEQ-value calculated by including the quantified congeneres only
[b] :TEQ-value calculated by including the non-quantified congeneres by taking half of their LOQ
[c] :TEQ-value calculated by including the non-quantified congeneres by taking the full value of their LOQ

eurofins | Woodson-Tenent Laboratories Division

Eurofins Sample: ME2003-041079 Sample ID: No ID

REPORT OF ANALYSIS

Test	Result	Units
Dioxins Like PCB's	Listed Below	
Tetra PCB #81	<4.9	ng/kg
Tetra PCB #77	<9.9	ng/kg
Penta PCB #123	<9.9	ng/kg
Penta PCB #118	<99	ng/kg
Penta PCB #114	<9.9	ng/kg
Penta PCB #105	<49.4	ng/kg
Penta PCB #126	<2.5	ng/kg
Hexa PCB #167	<9.9	ng/kg
Hexa PCB #156	<9.9	ng/kg
Hexa PCB #157	<9.9	ng/kg
Hexa PCB #169	<4.9	ng/kg
Hepta PCB #189	<9.9	ng/kg
TEQ 12 WHO PCB excl. LOQ [a]	ND	
TEQ 12 WHO PCB incl. ½ LOQ [b]	0.16	ng/kg
TEQ 12 WHO PCB incl. LOQ [c]	0.33	ng/kg
Dry matter	100	%

< :Concentration below the indicated limit of quantification (LOQ)
ND :Not determined since none of the corresponding congeneres was above the LOQ
[a] :TEQ-value calculated by including the quantified congeneres only
[b] :TEQ-value calculated by including the non-quantified congeneres by taking half of their LOQ
[c] :TEQ-value calculated by including the non-quantified congeneres by taking the full value of their LOQ

7 Indicator PCB's	Listed Below	
PCB 28	115	ng/kg
PCB 52	<99	ng/kg
PCB 101	<99	ng/kg
PCB 118	<99	ng/kg
PCB 153	<99	ng/kg
PCB 138	<99	ng/kg
PCB 180	<99	ng/kg
Total 7 Indicator PCB excl. LOQ [a]	115	ng/kg
Total 7 Indicator PCB incl. ½ LOQ [b]	412	ng/kg
Total 7 Indicator PCB incl. LOQ [c]	708	ng/kg

Respectfully Submitted,
Eurofins Scientific Inc.

Doug Winters, Business Unit Manager

XVII. Economics of Corn Ethanol: North Alabama IPEP vs. Traditional North Alabama and Central Illinois Scenarios

Projected prices and transportation costs for ethanol plant inputs (corn, natural gas, and electricity) and outputs (ethanol, DDGS, and carbon dioxide) from previous chapters are used in this chapter to compare the economics of ethanol production for north Alabama IPEP vs. traditional north Alabama and central Illinois scenarios. The IPEP scenario assumes that process heat for producing ethanol is provided from poultry litter and the traditional scenarios assume that process heat is provided from natural gas (NG). Ethanol plant capital costs are assumed to be the same for all three scenarios. In the north Alabama IPEP scenario, it is assumed that the ethanol plant will have a package boiler and thermal oxidizer to be used as a backup for the poultry litter energy plant. Therefore, the package boiler and thermal oxidizer costs are assumed to be the same for all three scenarios. The cost of process heat from the poultry litter energy plant is expressed in units of $/MBtu of NG displaced by the poultry litter to facilitate easy comparison with scenarios using NG for process heat. Operating & maintenance costs other than for the inputs and outputs mentioned above are assumed to be the same for all three scenarios.

Economic interpretations in this chapter are based 10-year projections. For purposes of illustration, year-10 projections are extrapolated to years 11 to 15 and 15-year averages are presented in the financial analysis section, but only projections and averages for years 1 to 10 are discussed.

A. Baseline Comparisons

1. Economic Tradeoffs

Tradeoffs for baseline levels of economic factors that vary between Decatur, AL and Pekin, IL NG ethanol plant scenarios are presented in Table 1 based on 10-year averages. Tradeoffs are expressed in units of $/gal ethanol. The average corn cost is $0.021/gal higher at Decatur, AL than at Pekin, IL. The higher corn cost at Decatur, AL is more than offset by higher co-product revenues ($0.058/gal ethanol). The ethanol transportation cost advantage for Decatur, AL is $0.070/gal ethanol, assuming a destination point of Atlanta, GA. The NG advantage for Decatur, AL is $0.018/gal and the overall net advantage for Decatur, AL is $0.124/gal ethanol. This is a significant financial advantage for the Decatur, AL site. The same comparison is presented in Table 2 except with the assumption that a poultry litter energy plant can supply process heat at Decatur, AL for a cost of $4.94/MBtu of NG displaced as discussed in Chapter XIII; this results in a NG cost advantage over a Pekin, IL NG scenario of $0.086/gal ethanol and an overall net advantage for Decatur, AL of $0.192/gal ethanol. A comparison of a Guntersville IPEP vs. a Pekin, IL NG scenario is presented in Table 3. The overall net advantage for the Guntersville IPEP scenario is $0.176/gal ethanol. The tradeoffs summarized in Tables 1-3 indicate that the north Alabama scenarios are very competitive with the eastern Corn Belt scenario at Pekin, IL and that providing process heat from poultry litter instead of NG is has a larger positive economic effect than any other single factor in the comparisons.

Table 1. Baseline economic tradeoffs: Decatur, AL NG vs. Pekin, IL NG (10-year averages).

	Decatur, AL NG	Pekin, IL NG	Difference	
				$/denatured gal
Higher corn price, $/bu	2.63	2.57	0.06	**0.021**
$/ton	93.93	91.78	2.14	
Higher co-product revenues:				
fob DDGS price, $/ton	108.00	105.00	3.00	0.009
DDGS transportation cost, $/ton	7.50	12.00	-4.50	-0.014
DDGS netback, $/ton	100.50	93.00	7.50	0.023
Raw CO_2 price, $/ton	13.00	0.00	13.00	0.035
			Total	**0.058**
Lower ethanol transportation costs, $/gal	0.037	0.107	0.070	**0.070**
Energy cost savings via renewable energy:				
NG price, $/MBtu NG or NG replaced	6.94	7.47	0.53	0.018
Electricty price, $/kWh	0.046	0.046	0.00	0.000
			Total	**0.018**
Net advantage for Decatur, AL				**0.124**

Table 2. Baseline economic tradeoffs: Decatur, AL IPEP vs. Pekin, IL NG (10-year averages).

	Decatur, AL IPEP	Pekin, IL NG	Difference	
				$/denatured gal
Higher corn price, $/bu	2.63	2.57	0.06	**0.021**
$/ton	93.93	91.78	2.14	
Higher co-product revenues:				
fob DDGS price, $/ton	108.00	105.00	3.00	0.009
DDGS transportation cost, $/ton	7.50	12.00	-4.50	-0.014
DDGS netback, $/ton	100.50	93.00	7.50	0.023
Raw CO_2 price, $/ton	13.00	0.00	13.00	0.035
			Total	**0.058**
Lower ethanol transportation costs, $/gal	0.037	0.107	0.070	**0.070**
Energy cost savings via renewable energy:				
NG price, $/MBtu NG or NG replaced	4.94	7.47	2.53	0.086
Electricty price, $/kWh	0.046	0.046	0.00	0.000
			Total	**0.086**
Net advantage for Decatur, AL IPEP				**0.192**

Table 3. Baseline economic tradeoffs: Guntersville, AL IPEP vs. Pekin, IL NG (10-year averages).

	Guntersville, AL IPEP	Pekin, IL NG	Difference	
				$/denatured gal
Higher corn price, $/bu	2.63	2.57	0.06	**0.021**
$/ton	93.93	91.78	2.14	
Higher co-product revenues:				
fob DDGS price, $/ton	108.00	105.00	3.00	0.009
DDGS transportation cost, $/ton	4.38	12.00	-7.62	-0.023
DDGS netback, $/ton	103.62	93.00	10.62	0.032
Raw CO_2 price, $/ton	13.00	0.00	13.00	0.035
			Total	**0.067**
Lower ethanol transportation costs, $/gal	0.063	0.107	0.044	**0.044**
Energy cost savings via renewable energy:				
NG price, $/MBtu NG or NG replaced	4.94	7.47	2.53	0.086
Electricty price, $/kWh	0.046	0.046	0.00	0.000
			Total	**0.086**
Net advantage for Guntersville, AL IPEP				**0.176**

2. Financial Projections

Income and cash flow projections were developed using baseline inputs for a nominal 50 million gallon per year ethanol plant. Projected prices and transportation costs for ethanol plant inputs (corn, natural gas, and electricity) and outputs (ethanol, DDGS, and carbon dioxide) from previous chapters were used as inputs for these financial projections; these projections are highlighted in green in the assumptions tables presented below. The other O&M cost projections, capital cost projections, and ethanol plant operating parameters were based on input from ICM, a leading engineering company for the ethanol industry.

The following financial parameters were assumed: 50% equity, 9.0% interest, 10-year loan, annual loan payments, and 10-year double declining-balance depreciation. A corporate tax rate of 40% was assumed for calculation of after-tax returns. Internal rate of return (IRR) on the equity portion of the capital investment was calculated based on the equity portion of the capital investment in year zero and subsequent annual free cash flows to equity during 15 years of operation. Annual free cash flows to equity were calculated as the annual project cash flow minus the annual principal payment on the debt. Annual return on investment (ROI) was calculated as annual profit divided by the equity portion of the capital investment. A small-producer tax credit of $1,500,000 per year was assumed for the first ten years of the project. All assumptions and before-tax profit and cash flows for 2007-2021 are presented for the following four ethanol plant scenarios (tables indicated in parentheses): Pekin, IL NG (Tables 4-6); Decatur, AL NG (Tables 7-9); Decatur, AL IPEP (Tables 10-12); and Guntersville, AL IPEP (Tables 13-15).

Table 4. Financial analysis assumptions (part 1): Pekin, IL NG scenario.

	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Plant (Technical/Processing)																
Nameplate Ethanol Production (denatured gal/	50,000,000	95%	105%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Actual Ethanol Production (denatured gal/year)		47,500,000	52,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000
Ethanol Yield (gallons extractrated/bushel)	2.66															
Anl Feedstock Requirement (bu of corn)		16,964,286	18,750,000	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714
DDG, Yield (pounds/bushel corn)	17.50															
Anl DDG Production (tons)		148,438	164,063	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688
Production of CO_2 (pounds)	15.00															
Anl CO_2 Production (tons)		127,232	140,625	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018
Natural Gas Conversion for Hot Air (MCF/bu corn)	0.000	-	MCF/den gal													
Anl Gas Needed for Hot Air (MCF)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas Conversion for Steam (MCF/bu corn	0.095	34,000	MCF/den gal													
Anl Gas Needed for Steam (MCF)		1,615,000	1,785,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000
Electricity Conversion (KwH/bu corn)	2.100	0.75	kWh/den gal													
Anl Electricity Needed (KwH)		35,625,000	39,375,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000
Waste Disposal (% of corn)	1.00%															
Anl Waste Disposal (tons)		4,750	5,250	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750
Denaturant Percent of Ethanol Sold	5.0%															
Anl Denaturant Needed (gallons)		2,375,000	2,625,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000
Chemicals/Enzymes Conversion (% of ethanol)	95.69%															
Anl Chemical/Enzymes Needed (gal)		45,452,750	50,237,250	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750
Revenue Assumptions																
Rack Price of Ethanol (gallon)		$2.18	$2.10	$2.08	$2.08	$1.92	$1.80	$1.79	$1.78	$1.80	$1.81	$1.81	$1.81	$1.81	$1.81	$1.81
Total Ethanol Revenue		$103,550,000	$110,250,000	$119,600,000	$119,600,000	$110,400,000	$103,500,000	$102,925,000	$102,350,000	$103,500,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000
Price of DDG (per ton)		$104.00	$107.00	$108.00	$109.00	$107.00	$105.00	$104.00	$103.00	$103.00	$103.00	$103.00	$103.00	$103.00	$103.00	$103.00
Total DDGS Revenue		$15,437,500	$17,554,688	$19,406,250	$19,585,938	$19,226,563	$18,867,188	$18,687,500	$18,507,813	$18,507,813	$18,507,813	$18,507,813	$18,507,813	$18,507,813	$18,507,813	18,507,813
Price of CO_2 ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total CO_2 Revenue		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	0
State Payment for Ethanol ($/denat gal)	$0.000	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Illinois Producer Payment[1/]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
USDA, CCC, Bio Energy Credit, $		$0.00														

Table 5. Financial analysis assumptions (part 2): Pekin, IL NG scenario.

	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Variable Cost Assumptions																
Illinois Farm Price of Corn (bu)		$2.53	$2.61	$2.63	$2.65	$2.60	$2.56	$2.54	$2.52	$2.52	$2.52	$2.52	$2.52	$2.52	$2.52	$2.52
Estimated Transportation Cost for Corn ($/bu)	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Storage Cost for Corn ($/bu)	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Total Corn Price (bu)		$2.53	$2.61	$2.63	$2.65	$2.60	$2.56	$2.54	$2.52	$2.52	$2.52	$2.52	$2.52	$2.52	$2.52	$2.52
Total Corn Cost		$42,919,643	$48,937,500	$54,008,929	$54,419,643	$53,392,857	$52,571,429	$52,160,714	$51,750,000	$51,750,000	$51,750,000	$51,750,000	$51,750,000	$51,750,000	$51,750,000	$51,750,000
Natural Gas for hot air ($/MCF)	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94
Natural Gas (NG) or IPEP NG eq.for steam ($/MCF)		$8.61	$8.22	$7.79	$7.46	$7.23	$7.15	$7.22	$7.12	$6.93	$6.92	$6.96	$7.13	$7.26	$7.26	$7.39
Total Natural Gas Expense		$13,905,150	$14,672,700	$15,229,450	$14,584,300	$14,134,650	$13,978,250	$14,115,100	$13,919,600	$13,548,150	$13,528,600	$13,606,800	$13,939,150	$14,193,300	$14,193,300	$14,447,450
Electricity ($/KwH)	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460
Total Electricity Expense		$1,638,750	$1,811,250	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750
Fresh Water ($/1,000 gal)	$3.00	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000
Total Water Expense		$142,500	$157,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500
Denaturant ($/gal)		$1.5900	$1.5100	$1.4400	$1.4200	$1.4300	$1.4200	$1.4100	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300
Total Denaturant Expense		$3,776,250	$3,963,750	$4,140,000	$4,082,500	$4,111,250	$4,082,500	$4,053,750	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250
Waste ($/ton)	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Total Waste Disposal Expense		$71,250	$78,750	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250
Enzymes/Chemicals ($/1,000 gal ethanol)	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00
Total Enzymes/Chemicals Expense		$3,408,956	$3,767,794	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631
Marketing Cost ($/1,000 gal)	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00
Total Marketing Expense		$617,500	$682,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500
Estimated Transportation Cost for Ethanol ($/gal)	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107	$0.107
Total Ethanol Transportation Expense		$5,082,500	$5,617,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500	$6,152,500
Estimated Transportation Cost for DDGS ($/ton)	$12.00	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000	$12.000
Total DDG Transportation Expense		$1,781,250	$1,968,750	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250	$2,156,250
Direct Labor Benefits Expense ($/ 1000 gal)	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35
Direct Labor Benefits Expense		$470,476	$520,000	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523
Fixed Cost Assumptions																
G&A Total	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000
Production & Maintenance Labor	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Property Taxes & Insurance	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000
Debt (Principal & Interest)		$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$0	$0	$0	$0	$0

Table 6. Profit and cash flow analysis ($1000): Pekin, IL NG scenario.

Year	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cash Flow																
Total Revenues		118,988	127,805	139,006	139,186	129,627	122,367	121,613	120,858	122,008	122,583	122,583	122,583	122,583	122,583	122,583
Variable Costs		73,814	82,178	89,373	89,081	87,634	86,627	86,324	85,776	85,404	85,385	85,463	85,795	86,049	86,049	86,304
Fixed Costs		9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	3,090	3,090	3,090	3,090	3,090
Total Costs		83,137	91,501	98,696	98,404	96,956	95,950	95,647	95,099	94,727	94,708	88,553	88,885	89,139	89,139	89,394
Gross Profit		35,850	36,304	40,310	40,782	32,670	26,417	25,965	25,759	27,281	27,875	34,030	33,698	33,443	33,443	33,189
Add back Principal on Debt		2,633	2,870	3,128	3,410	3,716	4,051	4,415	4,813	5,246	5,718	0	0	0	0	0
Subtract Depreciation on Plant Capital (number of years)	10	12,688	11,963	9,570	7,685	6,163	4,930	4,785	4,785	4,785	4,785	0	0	0	0	0
Federal Small Producer Tax Credit[1/]	$1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	0	0	0	0	0
Profit (Loss) before Taxes & Principal		27,296	28,711	35,368	38,006	31,724	27,038	27,096	27,287	29,242	30,308	34,030	33,698	33,443	33,443	33,189
Loss Carry-Forward		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit after Taxes		27,296	28,711	35,368	38,006	31,724	27,038	27,096	27,287	29,242	30,308	34,030	33,698	33,443	33,443	33,189
Return on Investment, %		68.2	71.8	88.4	95.0	79.3	67.6	67.7	68.2	73.1	75.8	85.1	84.2	83.6	83.6	83.0
Capital Costs for Plant and Working Capital	$80,000								10-year average ROI		75.5			15-year average ROI		78.3
Plant Capital	$72,500															
Working Capital	$7,500															
PROJECT CASH FLOW (Profit + Depreciation)	($80,000)	39,983	40,674	44,938	45,691	37,887	31,968	31,881	32,072	34,027	35,093	34,030	33,698	33,443	33,443	33,189
	IRR, %	(50.0)	0.5	25.8	38.02	43.4	46.0	47.6	48.6	49.2	49.6	49.9	50.1	50.2	50.3	50.3
FREE CASH FLOW TO EQUITY	($40,000)	37,350	37,804	41,810	42,282	34,170	27,917	27,465	27,259	28,781	29,375	34,030	33,698	33,443	33,443	33,189
	IRR, %	(6.6)	54.5	78.9	88.6	92.1	93.4	94.1	94.4	94.6	94.7	94.7	94.8	94.8	94.8	94.8
Project Finances																
Equity	$40,000															
Debt	$40,000															
Interest Rate	9.00%															
Years	10															
Principal, Payment		2,633	2,870	3,128	3,410	3,716	4,051	4,415	4,813	5,246	5,718	0	0	0	0	0
Interest , Payment		3,600	3,363	3,105	2,823	2,516	2,182	1,817	1,420	987	515	0	0	0	0	0
Total Principal & Interest Payment		6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	0	0	0	0	0

[1/] Eligible for Small Producer Tax credit of $1,500,000 per year, if annual production is less than 60 million gallons per year.

Critical Assumptions Used in the Model:

Nameplate capacity, denatured gallons/year	50,000,000
10 yr avg actual production, denatured gallons/year	56,500,000
10 yr avg ethanol price/gallon, after transportation and mkt	$1.81
10 yr avg corn price/bu	$2.57
10 yr avg DDGS price/ton, after transportation	$93.30
10 yr avg price for raw CO_2 at plant, $/ton	$0.00
10 yr avg NG price for hot air production, $/MCF	
10 yr avg NG price for steam production, $/MCF	$7.53
10 yr avg price for electricity, $/kWh	$0.046

Table 7. Financial analysis assumptions (part 1): Decatur, AL NG scenario.

	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Plant (Technical/Processing)																
Nameplate Ethanol Production (denatured gal/	50,000,000	95%	105%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Actual Ethanol Production (denatured gal/year)		47,500,000	52,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000
Ethanol Yield (gallons extractrated/bushel)	2.66															
Anl Feedstock Requirement (bu of corn)		16,964,286	18,750,000	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714
DDG, Yield (pounds/bushel corn)	17.50															
Anl DDG Production (tons)		148,438	164,063	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688
Production of CO_2 (pounds)	15.00															
Anl CO_2 Production (tons)		127,232	140,625	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018
Natural Gas Conversion for Hot Air (MCF/bu corn)	0.000	-	MCF/den gal													
Anl Gas Needed for Hot Air (MCF)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas Conversion for Steam (MCF/bu corn	0.095	34,000	MCF/den gal													
Anl Gas Needed for Steam (MCF)		1,615,000	1,785,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000
Electricity Conversion (KwH/bu corn)	2.100	0.75	kWh/den gal													
Anl Electricity Needed (KwH)		35,625,000	39,375,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000
Waste Disposal (% of corn)	1.00%															
Anl Waste Disposal (tons)		4,750	5,250	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750
Denaturant Percent of Ethanol Sold	5.0%															
Anl Denaturant Needed (gallons)		2,375,000	2,625,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000
Chemicals/Enzymes Conversion (% of ethanol)	95.69%															
Anl Chemical/Enzymes Needed (gal)		45,452,750	50,237,250	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750
Revenue Assumptions																
Rack Price of Ethanol (gallon)		$2.18	$2.10	$2.08	$2.08	$1.92	$1.80	$1.79	$1.78	$1.80	$1.81	$1.81	$1.81	$1.81	$1.81	$1.81
Total Ethanol Revenue		$103,550,000	$110,250,000	$119,600,000	$119,600,000	$110,400,000	$103,500,000	$102,925,000	$102,350,000	$103,500,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000
Price of DDG (per ton)		$106.37	$109.66	$110.48	$111.30	$109.25	$107.61	$106.78	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96
Total DDGS Revenue		$15,789,913	$17,991,067	$19,852,101	$19,999,700	$19,630,702	$19,335,504	$19,187,905	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	19,040,305
Price of CO_2 ($/ton)	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00
Total CO_2 Revenue		$1,654,018	$1,828,125	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	2,002,232
State Payment for Ethanol ($/denat gal)	$0.000	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Alabama Producer Payment[1/]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
USDA, CCC, Bio Energy Credit, $		$0.00														

Table 8. Financial analysis assumptions (part 2): Decatur, AL NG scenario.

	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Variable Cost Assumptions																
Alabama Farm Price of Corn (bu)		$2.59	$2.67	$2.69	$2.71	$2.66	$2.62	$2.60	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58
Estimated Transportation Cost for Corn ($/bu)	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Storage Cost for Corn ($/bu)	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Total Corn Price (bu)		$2.59	$2.67	$2.69	$2.71	$2.66	$2.62	$2.60	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58
Total Corn Cost		$43,937,500	$50,062,500	$55,241,071	$55,651,786	$54,625,000	$53,803,571	$53,392,857	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143
Natural Gas for hot air ($/MCF)	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94
Natural Gas (NG) or IPEP NG eq.for steam ($/M(	$4.94	$8.08	$7.69	$7.26	$6.93	$6.70	$6.62	$6.69	$6.59	$6.40	$6.39	$6.43	$6.60	$6.73	$6.73	$6.86
Total Natural Gas Expense		$13,049,200	$13,726,650	$14,193,300	$13,548,150	$13,098,500	$12,942,100	$13,078,950	$12,883,450	$12,512,000	$12,492,450	$12,570,650	$12,903,000	$13,157,150	$13,157,150	$13,411,300
Electricity ($/KwH)	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460
Total Electricity Expense		$1,638,750	$1,811,250	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750
Fresh Water ($/1,000 gal)	$3.00	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000
Total Water Expense		$142,500	$157,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500
Denaturant ($/gal)		$1.5900	$1.5100	$1.4400	$1.4200	$1.4300	$1.4200	$1.4100	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300
Total Denaturant Expense		$3,776,250	$3,963,750	$4,140,000	$4,082,500	$4,111,250	$4,082,500	$4,053,750	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250
Waste ($/ton)	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Total Waste Disposal Expense		$71,250	$78,750	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250
Enzymes/Chemicals ($/1,000 gal ethanol)	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00
Total Enzymes/Chemicals Expense		$3,408,956	$3,767,794	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631
Marketing Cost ($/1,000 gal)	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00
Total Marketing Expense		$617,500	$682,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500
Estimated Transportation Cost for Ethanol ($/gal)	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037
Total Ethanol Transportation Expense		$1,757,500	$1,942,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500
Estimated Transportation Cost for DDGS ($/ton)	$7.50	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500
Total DDG Transportation Expense		$1,113,281	$1,230,469	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656
Direct Labor Benefits Expense ($/ 1000 gal)	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35
Direct Labor Benefits Expense		$470,476	$520,000	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523
Fixed Cost Assumptions																
G&A Total	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000
Production & Maintenance Labor	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Property Taxes & Insurance	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000
Debt (Principal & Interest)		$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$0	$0	$0	$0	$0

Tabble 9. Profit and cash flow analysis ($1000): Decatur, AL NG scenario.

Year	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cash Flow																
Total Revenues		120,994	130,069	141,454	141,602	132,033	124,838	124,115	123,393	124,543	125,118	125,118	125,118	125,118	125,118	125,118
Variable Costs		69,983	77,944	84,736	84,444	82,996	81,989	81,687	81,138	80,767	80,747	80,825	81,158	81,412	81,412	81,666
Fixed Costs		9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	3,090	3,090	3,090	3,090	3,090
Total Costs		79,306	87,266	94,058	93,767	92,319	91,312	91,010	90,461	90,090	90,070	83,915	84,248	84,502	84,502	84,756
Gross Profit		41,688	42,803	47,396	47,835	39,714	33,525	33,105	32,932	34,453	35,048	41,202	40,870	40,616	40,616	40,362
Add back Principal on Debt		2,633	2,870	3,128	3,410	3,716	4,051	4,415	4,813	5,246	5,718	0	0	0	0	0
Subtract Depreciation on Plant Capital (number of years)	10	12,688	11,963	9,570	7,685	6,163	4,930	4,785	4,785	4,785	4,785	0	0	0	0	0
Federal Small Producer Tax Credit[1/]	$1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	0	0	0	0	0
Profit (Loss) before Taxes & Principal		33,133	35,210	42,454	45,060	38,768	34,146	34,236	34,459	36,414	37,481	41,202	40,870	40,616	40,616	40,362
Loss Carry-Forward		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit after Taxes		33,133	35,210	42,454	45,060	38,768	34,146	34,236	34,459	36,414	37,481	41,202	40,870	40,616	40,616	40,362
Return on Investment, %		82.8	88.0	106.1	112.6	96.9	85.4	85.6	86.1	91.0	93.7	103.0	102.2	101.5	101.5	100.9
Capital Costs for Plant and Working Capital	$80,000								10-year average ROI		92.8				15-year average ROI	95.8
Plant Capital	$72,500															
Working Capital	$7,500															
PROJECT CASH FLOW (Profit + Depreciation)	($80,000)	45,821	47,172	52,024	52,745	44,930	39,076	39,021	39,244	41,199	42,266	41,202	40,870	40,616	40,616	40,362
	IRR, %	(42.7)	10.6	35.9	47.59	52.7	55.1	56.5	57.4	57.9	58.3	58.5	58.6	58.7	58.7	58.7
FREE CASH FLOW TO EQUITY	($40,000)	43,188	44,303	48,896	49,335	41,214	35,025	34,605	34,432	35,953	36,548	41,202	40,870	40,616	40,616	40,362
	IRR, %	8.0	72.3	96.2	105.2	108.4	109.6	110.1	110.4	110.5	110.5	110.6	110.6	110.6	110.6	110.6
Project Finances																
Equity	$40,000															
Debt	$40,000															
Interest Rate	9.00%															
Years	10															
Principal, Payment		2,633	2,870	3,128	3,410	3,716	4,051	4,415	4,813	5,246	5,718	0	0	0	0	0
Interest , Payment		3,600	3,363	3,105	2,823	2,516	2,182	1,817	1,420	987	515	0	0	0	0	0
Total Principal & Interest Payment		6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	0	0	0	0	0

[1/] Eligible for Small Producer Tax credit of $1,500,000 per year, if annual production is less than 60 million gallons per year.

Critical Assumptions Used in the Model:

Nameplate capacity, denatured gallons/year	50,000,000
10 yr avg actual production, denatured gallons/year	56,500,000
10 yr avg ethanol price/gallon, after transportation and mkt	$1.88
10 yr avg corn price/bu	$2.63
10 yr avg DDGS price/ton, after transportation	$100.43
10 yr avg price for raw CO_2 at plant, $/ton	$13.00
10 yr avg NG price for hot air production, $/MCF	
10 yr avg NG price for steam production, $/MCF	$6.94
10 yr avg price for electricity, $/kWh	$0.046

Table 10. Financial analysis assumptions (part 1): Decatur, AL IPEP scenario.

	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Plant (Technical/Processing)																
Nameplate Ethanol Production (denatured gal/	50,000,000	95%	105%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Actual Ethanol Production (denatured gal/year)		47,500,000	52,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000
Ethanol Yield (gallons extractrated/bushel)	2.66															
Anl Feedstock Requirement (bu of corn)		16,964,286	18,750,000	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714
DDG, Yield (pounds/bushel corn)	17.50															
Anl DDG Production (tons)		148,438	164,063	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688
Production of CO_2 (pounds)	15.00															
Anl CO_2 Production (tons)		127,232	140,625	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018
Natural Gas Conversion for Hot Air (MCF/bu corn)	0.000	-	MCF/den gal													
Anl Gas Needed for Hot Air (MCF)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas Conversion for Steam (MCF/bu corn	0.095	34,000	MCF/den gal													
Anl Gas Needed for Steam (MCF)		1,615,000	1,785,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000
Electricity Conversion (KwH/bu corn)	2.100	0.75	kWh/den gal													
Anl Electricity Needed (KwH)		35,625,000	39,375,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000
Waste Disposal (% of corn)	1.00%															
Anl Waste Disposal (tons)		4,750	5,250	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750
Denaturant Percent of Ethanol Sold	5.0%															
Anl Denaturant Needed (gallons)		2,375,000	2,625,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000
Chemicals/Enzymes Conversion (% of ethanol)	95.69%															
Anl Chemical/Enzymes Needed (gal)		45,452,750	50,237,250	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750
Revenue Assumptions																
Rack Price of Ethanol (gallon)		$2.18	$2.10	$2.08	$2.08	$1.92	$1.80	$1.79	$1.78	$1.80	$1.81	$1.81	$1.81	$1.81	$1.81	$1.81
Total Ethanol Revenue		$103,550,000	$110,250,000	$119,600,000	$119,600,000	$110,400,000	$103,500,000	$102,925,000	$102,350,000	$103,500,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000
Price of DDG (per ton)		$106.37	$109.66	$110.48	$111.30	$109.25	$107.61	$106.78	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96
Total DDGS Revenue		$15,789,913	$17,991,067	$19,852,101	$19,999,700	$19,630,702	$19,335,504	$19,187,905	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	19,040,305
Price of CO_2 ($/ton)	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00
Total CO_2 Revenue		$1,654,018	$1,828,125	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	2,002,232
State Payment for Ethanol ($/denat gal)	$0.000	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Alabama Producer Payment[1/]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
USDA, CCC, Bio Energy Credit, $		$0.00														

[1/] Will claim Alabama state ethanol grant ($5 million/year based on $0.30/gallon for first 12.5 million gallons and $0.10/gallon for second 12.5 million gallons) for five years, if proposed bill is passed.

Table 11. Financial analysis assumptions (part 2): Decatur, AL IPEP scenario.

	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Variable Cost Assumptions																
Alabama Farm Price of Corn (bu)		$2.59	$2.67	$2.69	$2.71	$2.66	$2.62	$2.60	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58
Estimated Transportation Cost for Corn ($/bu)	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Storage Cost for Corn ($/bu)	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Total Corn Price (bu)		$2.59	$2.67	$2.69	$2.71	$2.66	$2.62	$2.60	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58
Total Corn Cost		$43,937,500	$50,062,500	$55,241,071	$55,651,786	$54,625,000	$53,803,571	$53,392,857	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143
Natural Gas for hot air ($/MCF)	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94
Natural Gas (NG) or IPEP NG eq.for steam ($/M(	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94
Total Natural Gas Expense		$7,978,100	$8,817,900	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700
Electricity ($/KwH)	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460
Total Electricity Expense		$1,638,750	$1,811,250	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750
Fresh Water ($/1,000 gal)	$3.00	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000
Total Water Expense		$142,500	$157,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500
Denaturant ($/gal)		$1.5900	$1.5100	$1.4400	$1.4200	$1.4300	$1.4200	$1.4100	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300
Total Denaturant Expense		$3,776,250	$3,963,750	$4,140,000	$4,082,500	$4,111,250	$4,082,500	$4,053,750	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250
Waste ($/ton)	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Total Waste Disposal Expense		$71,250	$78,750	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250
Enzymes/Chemicals ($/1,000 gal ethanol)	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00
Total Enzymes/Chemicals Expense		$3,408,956	$3,767,794	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631
Marketing Cost ($/1,000 gal)	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00
Total Marketing Expense		$617,500	$682,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500
Estimated Transportation Cost for Ethanol ($/gal)	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037	$0.037
Total Ethanol Transportation Expense		$1,757,500	$1,942,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500	$2,127,500
Estimated Transportation Cost for DDGS ($/ton)	$7.50	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500	$7.500
Total DDG Transportation Expense		$1,113,281	$1,230,469	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656	$1,347,656
Direct Labor Benefits Expense ($/ 1000 gal)	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35
Direct Labor Benefits Expense		$470,476	$520,000	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523
Fixed Cost Assumptions																
G&A Total	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000
Production & Maintenance Labor	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Property Taxes & Insurance	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000
Debt (Principal & Interest)		$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$0	$0	$0	$0	$0

Table 12. Profit and cash flow analysis ($1000): Decatur, AL IPEP scenario.

Year	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cash Flow																
Total Revenues		120,994	130,069	141,454	141,602	132,033	124,838	124,115	123,393	124,543	125,118	125,118	125,118	125,118	125,118	125,118
Variable Costs		64,912	73,035	80,200	80,553	79,555	78,705	78,266	77,912	77,912	77,912	77,912	77,912	77,912	77,912	77,912
Fixed Costs		9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	3,090	3,090	3,090	3,090	3,090
Total Costs		74,235	82,358	89,523	89,876	88,878	88,028	87,588	87,235	87,235	87,235	81,002	81,002	81,002	81,002	81,002
Gross Profit		46,759	47,711	51,931	51,726	43,155	36,810	36,527	36,157	37,307	37,882	44,115	44,115	44,115	44,115	44,115
Add back Principal on Debt		2,633	2,870	3,128	3,410	3,716	4,051	4,415	4,813	5,246	5,718	0	0	0	0	0
Subtract Depreciation on Plant Capital (number of years)	10	12,688	11,963	9,570	7,685	6,163	4,930	4,785	4,785	4,785	4,785	0	0	0	0	0
Federal Small Producer Tax Credit[1/]	$1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	0	0	0	0	0
Profit (Loss) before Taxes & Principal		38,204	40,119	46,989	48,950	42,209	37,431	37,657	37,685	39,268	40,315	44,115	44,115	44,115	44,115	44,115
Loss Carry-Forward		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit after Taxes		38,204	40,119	46,989	48,950	42,209	37,431	37,657	37,685	39,268	40,315	44,115	44,115	44,115	44,115	44,115
Return on Investment, %		95.5	100.3	117.5	122.4	105.5	93.6	94.1	94.2	98.2	100.8	110.3	110.3	110.3	110.3	110.3
Capital Costs for Plant and Working Capital	$80,000									10-year average ROI	102.2				15-year average ROI	104.9
Plant Capital	$72,500															
Working Capital	$7,500															
PROJECT CASH FLOW (Profit + Depreciation)	($80,000)	50,892	52,081	56,559	56,635	48,371	42,361	42,442	42,470	44,053	45,100	44,115	44,115	44,115	44,115	44,115
	IRR, %	(36.4)	18.5	43.4	54.53	59.3	61.5	62.8	63.5	64.0	64.2	64.4	64.5	64.5	64.6	64.6
FREE CASH FLOW TO EQUITY	($40,000)	48,259	49,211	53,431	53,226	44,655	38,310	38,027	37,657	38,807	39,382	44,115	44,115	44,115	44,115	44,115
	IRR, %	20.6	86.6	109.7	118.0	120.8	121.8	122.3	122.5	122.6	122.6	122.6	122.6	122.6	122.6	122.6
Project Finances																
Equity	$40,000															
Debt	$40,000															
Interest Rate	9.00%															
Years	10															
Principal, Payment		2,633	2,870	3,128	3,410	3,716	4,051	4,415	4,813	5,246	5,718	0	0	0	0	0
Interest , Payment		3,600	3,363	3,105	2,823	2,516	2,182	1,817	1,420	987	515	0	0	0	0	0
Total Principal & Interest Payment		6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	0	0	0	0	0

[1/] Eligible for Small Producer Tax credit of $1,500,000 per year, if annual production is less than 60 million gallons per year.

Critical Assumptions Used in the Model:

Nameplate capacity, denatured gallons/year	50,000,000
10 yr avg actual production, denatured gallons/year	56,500,000
10 yr avg ethanol price/gallon, after transportation and mkt	$1.88
10 yr avg corn price/bu	$2.63
10 yr avg DDGS price/ton, after transportation	$100.43
10 yr avg price for raw CO_2 at plant, $/ton	$13.00
10 yr avg hot air price, $/MCF NG displaced, $/MCF	
10 yr avg steam price, $/MCF NG displaced, $/MCF	$4.94
10 yr avg price for electricity, $/kWh	$0.046

Table 13. Financial analysis assumptions (part 1): Guntersville, AL IPEP scenario.

	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Plant (Technical/Processing)																
Nameplate Ethanol Production (denatured gal/	50,000,000	95%	105%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Actual Ethanol Production (denatured gal/year)		47,500,000	52,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000	57,500,000
Ethanol Yield (gallons extractrated/bushel)	2.66															
Anl Feedstock Requirement (bu of corn)		16,964,286	18,750,000	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714	20,535,714
DDG, Yield (pounds/bushel corn)	17.50															
Anl DDG Production (tons)		148,438	164,063	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688	179,688
Production of CO_2 (pounds)	15.00															
Anl CO_2 Production (tons)		127,232	140,625	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018	154,018
Natural Gas Conversion for Hot Air (MCF/bu corn)	0.000	-	MCF/den gal													
Anl Gas Needed for Hot Air (MCF)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas Conversion for Steam (MCF/bu corn	0.095	34,000	MCF/den gal													
Anl Gas Needed for Steam (MCF)		1,615,000	1,785,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000	1,955,000
Electricity Conversion (KwH/bu corn)	2.100	0.75	kWh/den gal													
Anl Electricity Needed (KwH)		35,625,000	39,375,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000	43,125,000
Waste Disposal (% of corn)	1.00%															
Anl Waste Disposal (tons)		4,750	5,250	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750	5,750
Denaturant Percent of Ethanol Sold	5.0%															
Anl Denaturant Needed (gallons)		2,375,000	2,625,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000	2,875,000
Chemicals/Enzymes Conversion (% of ethanol)	95.69%															
Anl Chemical/Enzymes Needed (gal)		45,452,750	50,237,250	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750	55,021,750
Revenue Assumptions																
Rack Price of Ethanol (gallon)		$2.18	$2.10	$2.08	$2.08	$1.92	$1.80	$1.79	$1.78	$1.80	$1.81	$1.81	$1.81	$1.81	$1.81	$1.81
Total Ethanol Revenue		$103,550,000	$110,250,000	$119,600,000	$119,600,000	$110,400,000	$103,500,000	$102,925,000	$102,350,000	$103,500,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000	$104,075,000
Price of DDG (per ton)		$106.37	$109.66	$110.48	$111.30	$109.25	$107.61	$106.78	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96	$105.96
Total DDGS Revenue		$15,789,913	$17,991,067	$19,852,101	$19,999,700	$19,630,702	$19,335,504	$19,187,905	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	$19,040,305	19,040,305
Price of CO_2 ($/ton)	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00
Total CO_2 Revenue		$1,654,018	$1,828,125	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	$2,002,232	2,002,232
State Payment for Ethanol ($/denat gal)	$0.000	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Alabama Producer Payment[1/]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
USDA, CCC, Bio Energy Credit, $		$0.00														

[1/]Will claim Alabama state ethanol grant ($5 million/year based on $0.30/gallon for first 12.5 million gallons and $0.10/gallon for second 12.5 million gallons) for five years, if proposed bill is passed.

Table 14. Financial analysis assumptions (part 2): Guntersville, AL IPEP scenario.

	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Variable Cost Assumptions																
Alabama Farm Price of Corn (bu)		$2.59	$2.67	$2.69	$2.71	$2.66	$2.62	$2.60	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58
Estimated Transportation Cost for Corn ($/bu)	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Storage Cost for Corn ($/bu)	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Total Corn Price (bu)		$2.59	$2.67	$2.69	$2.71	$2.66	$2.62	$2.60	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58	$2.58
Total Corn Cost		$43,937,500	$50,062,500	$55,241,071	$55,651,786	$54,625,000	$53,803,571	$53,392,857	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143	$52,982,143
Natural Gas for hot air ($/MCF)	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94	$6.94
Natural Gas (NG) or IPEP NG eq.for steam ($/MC	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94	$4.94
Total Natural Gas Expense		$7,978,100	$8,817,900	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700	$9,657,700
Electricity ($/KwH)	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460	$0.0460
Total Electricity Expense		$1,638,750	$1,811,250	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750	$1,983,750
Fresh Water ($/1,000 gal)	$3.00	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000	$3.0000
Total Water Expense		$142,500	$157,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500	$172,500
Denaturant ($/gal)		$1.5900	$1.5100	$1.4400	$1.4200	$1.4300	$1.4200	$1.4100	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300	$1.4300
Total Denaturant Expense		$3,776,250	$3,963,750	$4,140,000	$4,082,500	$4,111,250	$4,082,500	$4,053,750	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250	$4,111,250
Waste ($/ton)	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Total Waste Disposal Expense		$71,250	$78,750	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250	$86,250
Enzymes/Chemicals ($/1,000 gal ethanol)	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00	$75.00
Total Enzymes/Chemicals Expense		$3,408,956	$3,767,794	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631	$4,126,631
Marketing Cost ($/1,000 gal)	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00	$13.00
Total Marketing Expense		$617,500	$682,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500	$747,500
Estimated Transportation Cost for Ethanol ($/gal)	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063	$0.063
Total Ethanol Transportation Expense		$2,992,500	$3,307,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500	$3,622,500
Estimated Transportation Cost for DDGS ($/ton)	$4.38	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380	$4.380
Total DDG Transportation Expense		$650,156	$718,594	$787,031	$787,031	$787,031	$787,031	$787,031	$787,031	$787,031	$787,031	$787,031	$787,031	$787,031	$787,031	$787,031
Direct Labor Benefits Expense ($/ 1000 gal)	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35
Direct Labor Benefits Expense		$470,476	$520,000	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523	$569,523
Fixed Cost Assumptions																
G&A Total	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000
Production & Maintenance Labor	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000	$1,300,000
Property Taxes & Insurance	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000	$590,000
Debt (Principal & Interest)		$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$6,232,804	$0	$0	$0	$0	$0

Table 15. Profit and cash flow analysis ($1000): Guntersville, AL IPEP scenario.

Year	Variables	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cash Flow																
Total Revenues		120,994	130,069	141,454	141,602	132,033	124,838	124,115	123,393	124,543	125,118	125,118	125,118	125,118	125,118	125,118
Variable Costs		65,684	73,888	81,134	81,488	80,490	79,639	79,200	78,847	78,847	78,847	78,847	78,847	78,847	78,847	78,847
Fixed Costs		9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	9,323	3,090	3,090	3,090	3,090	3,090
Total Costs		75,007	83,211	90,457	90,810	89,812	88,962	88,523	88,170	88,170	88,170	81,937	81,937	81,937	81,937	81,937
Gross Profit		45,987	46,858	50,997	50,791	42,220	35,875	35,592	35,223	36,373	36,948	43,181	43,181	43,181	43,181	43,181
Add back Principal on Debt		2,633	2,870	3,128	3,410	3,716	4,051	4,415	4,813	5,246	5,718	0	0	0	0	0
Subtract Depreciation on Plant Capital (number of years)	10	12,688	11,963	9,570	7,685	6,163	4,930	4,785	4,785	4,785	4,785	0	0	0	0	0
Federal Small Producer Tax Credit[1/]	$1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	0	0	0	0	0
Profit (Loss) before Taxes & Principal		37,432	39,266	46,055	48,016	41,274	36,496	36,723	36,751	38,334	39,381	43,181	43,181	43,181	43,181	43,181
Loss Carry-Forward		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit after Taxes		37,432	39,266	46,055	48,016	41,274	36,496	36,723	36,751	38,334	39,381	43,181	43,181	43,181	43,181	43,181
Return on Investment, %		93.6	98.2	115.1	120.0	103.2	91.2	91.8	91.9	95.8	98.5	108.0	108.0	108.0	108.0	108.0
Capital Costs for Plant and Working Capital	$80,000								10-year average ROI		99.9				15-year average ROI	102.6
Plant Capital	$72,500															
Working Capital	$7,500															
PROJECT CASH FLOW (Profit + Depreciation)	($80,000)	50,120	51,228	55,625	55,701	47,437	41,426	41,508	41,536	43,119	44,166	43,181	43,181	43,181	43,181	43,181
	IRR, %	(37.4)	17.3	42.1	53.32	58.1	60.4	61.6	62.4	62.8	63.1	63.3	63.4	63.4	63.5	63.5
FREE CASH FLOW TO EQUITY	($40,000)	47,487	48,358	52,497	52,291	43,720	37,375	37,092	36,723	37,873	38,448	43,181	43,181	43,181	43,181	43,181
	IRR, %	18.7	84.3	107.5	115.9	118.7	119.7	120.2	120.4	120.5	120.5	120.6	120.6	120.6	120.6	120.6
Project Finances																
Equity	$40,000															
Debt	$40,000															
Interest Rate	9.00%															
Years	10															
Principal, Payment		2,633	2,870	3,128	3,410	3,716	4,051	4,415	4,813	5,246	5,718	0	0	0	0	0
Interest , Payment		3,600	3,363	3,105	2,823	2,516	2,182	1,817	1,420	987	515	0	0	0	0	0
Total Principal & Interest Payment		6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	6,233	0	0	0	0	0

[1/] Eligible for Small Producer Tax credit of $1,500,000 per year, if annual production is less than 60 million gallons per year.

Critical Assumptions Used in the Model:

Nameplate capacity, denatured gallons/year	50,000,000
10 yr avg actual production, denatured gallons/year	56,500,000
10 yr avg ethanol price/gallon, after transportation and mkt	$1.86
10 yr avg corn price/bu	$2.63
10 yr avg DDGS price/ton, after transportation	$103.55
10 yr avg price for raw CO_2 at plant, $/ton	$13.00
10 yr avg hot air price, $/MCF NG displaced, $/MCF	
10 yr avg steam price, $/MCF NG displaced, $/MCF	$4.94
10 yr avg price for electricity, $/kWh	$0.046

A summary of before-tax and after-tax returns for the four baseline ethanol plant scenarios assessed above is presented in Table 16. The 10-year average after-tax ROI ranged from 45.3% for the Pekin, IL NG scenario to 61.3% for the Decatur, AL IPEP scenario. Using baseline assumptions, all the ethanol plant scenarios are highly profitable and the north Alabama IPEP scenarios are significantly more profitable than the eastern Corn Belt scenario at Pekin, IL.

Table 16. Summary of returns for baseline ethanol plant scenarios

Ethanol Plant Scenario	10-year average before-tax ROI, %	10-year average after-tax ROI, %	10-year average before-tax IRR, %	10-year average after-tax IRR%
Pekin, IL NG	75.5	45.3	94.7	63.6
Decatur, AL NG	92.8	55.7	110.5	73.9
Decatur, AL IPEP	102.2	61.3	122.6	81.3
Guntersville, AL IPEP	99.9	60.0	120.5	80.1

B. Sensitivity Analyses

Baseline analyses in the previous sections indicate that a north Alabama IPEP ethanol plant is projected to be highly profitable and very competitive with eastern Corn Belt NG ethanol plants. Returns for the two north Alabama scenarios (Decatur and Guntersville, AL) are very similar. The purpose of this section is to indicate sensitivity of returns for a north Alabama IPEP scenario to corn and ethanol prices and to price of process heat ($/MBtu NG displaced by poultry litter energy).

Low, baseline, and high price projections for corn and ethanol in north Alabama are presented in Table 17 (highlighted in yellow). These price projections are the same for Decatur and Guntersville, AL. The rationale for the corn price projections was discussed in Chapter V and the rationale for the ethanol price projections was discussed in Chapter VIII. In the sensitivity analyses discussed below, DDGS prices varied proportionally with corn prices as indicated in Table 17. The rationale for the DDGS price projections was discussed in Chapter VI.

Table 17. North Alabama ethanol, corn, and DDGS prices (highlighted in yellow) for low, baseline, and high scenarios assessed in financial analyses.

Rack ethanol price, $/gal	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	10-yr avg	15-yr avg
Low	2.00	2.01	1.99	1.99	1.83	1.71	1.71	1.69	1.72	1.73	1.73	1.73	1.73	1.73	1.73	1.84	1.79
Baseline	2.18	2.10	2.08	2.08	1.92	1.80	1.79	1.78	1.80	1.81	1.81	1.81	1.81	1.81	1.81	1.93	1.87
High	2.57	2.53	2.46	2.36	2.20	2.08	2.08	2.06	2.09	2.10	2.10	2.10	2.10	2.10	2.10	2.25	2.18
Transportation cost, $/gal	0.07																
Ethanol netback, $/gal[1/]																	
Low	1.93	1.94	1.92	1.92	1.76	1.64	1.64	1.62	1.65	1.66	1.66	1.66	1.66	1.66	1.66	1.77	1.72
Baseline	2.11	2.03	2.01	2.01	1.85	1.73	1.72	1.71	1.73	1.74	1.74	1.74	1.74	1.74	1.74	1.86	1.80
High	2.50	2.46	2.39	2.29	2.13	2.01	2.01	1.99	2.02	2.03	2.03	2.03	2.03	2.03	2.03	2.18	2.11
Corn & DDGS prices[2/]																	
Low																	
CBOT corn, $/bu	2.26	2.33	2.36	2.37	2.33	2.29	2.26	2.25	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.29	2.28
Decatur, AL basis, $/bu	0.06																
Decatur, AL corn, $/bu	2.32	2.39	2.42	2.43	2.39	2.35	2.32	2.31	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.35	2.34
DDGS:Corn price ratio ($/ton basis)	1.15																
Decatur, AL DDGS, $/ton	95	98	99	100	98	97	95	95	94	94	94	94	94	94	94	97	96
Baseline																	
CBOT corn, $/bu	2.53	2.61	2.63	2.65	2.6	2.56	2.54	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.57	2.55
Decatur, AL corn, $/bu	2.59	2.67	2.69	2.71	2.66	2.62	2.6	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.63	2.61
Decatur, AL DDGS, $/ton	106	110	110	111	109	108	107	106	106	106	106	106	106	106	106	108	107
High																	
CBOT corn, $/bu	3.28	3.35	3.38	3.39	3.35	3.3	3.28	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.31	3.30
Decatur, AL corn, $/bu	3.34	3.41	3.44	3.45	3.41	3.36	3.34	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.37	3.36
Decatur, AL DDGS, $/ton	137	140	141	142	140	138	137	136	136	136	136	136	136	136	136	138	138

[1/] From Chapter VIIII.

[2/] From Chapter V.

The sensitivity of 10-year average ROI and IRR to corn and ethanol prices in Table 17 is presented in Table 18 for the north Alabama IPEP scenario. Results are presented for before and after corporate income taxes. Returns are also projected for ethanol prices of $1.55 and $1.65/gal as well as the low, baseline, and high scenarios in order to cover the possibility of lower than projected ethanol prices. Except for corn, DDGS, and ethanol prices, baseline assumptions for the Decatur, AL IPEP scenario were used in the sensitivity analysis. Returns are very sensitive to both ethanol and corn prices. Before-tax 10-year average ROI ranged from 150.7% for the high ethanol, low corn scenario to 30.7% for the $1.55/gal ethanol, high corn (worst-case) scenario. Since even the worst-case scenario provided an attractive ROI, a north Alabama IPEP project at Decatur or Guntersville, AL is judged to have good potential for commercialization.

Table 18. Sensitivity of ROI and IRR to ethanol and corn/DDGS prices for a north AL IPEP scenario.

		Ethanol netback, $/gal				
				Low	Baseline	High
		1.55	1.65	avg.=1.77	avg.=1.86	avg.=2.18
Corn, $/bu	**DDGS, $/ton**	10-year average before-tax ROI, %				
Low	Low					
2.35	97	63.3	77.3	93.2	106.4	150.7
Baseline	Baseline					
2.63	108	54.4	68.4	84.3	97.6	141.9
High	High					
3.37	138	30.7	44.7	60.6	73.8	118.1
Corn, $/bu	**DDGS, $/ton**	10-year average after-tax ROI, %				
Low	Low					
2.35	97	38.0	46.4	55.9	63.8	90.4
Baseline	Baseline					
2.63	108	32.7	41.1	50.6	58.6	85.2
High	High					
3.37	138	18.4	26.8	36.3	44.3	70.9
Corn, $/bu	**DDGS, $/ton**	10-year average before-tax IRR on equity, %				
Low	Low					
2.35	97	64.1	76.6	109.3	126.3	175.1
Baseline	Baseline					
2.63	108	56.2	68.8	104.1	118.4	167.4
High	High					
3.37	138	33.7	47.1	79.3	96.3	146.0
Corn, $/bu	**DDGS, $/ton**	10-year average after-tax IRR on equity, %				
Low	Low					
2.35	97	45.3	53.6	73.5	83.7	114.0
Baseline	Baseline					
2.63	108	40.0	48.4	68.3	78.6	109.1
High	High					
3.37	138	24.2	33.7	53.7	64.3	95.6

Table 19. Sensitivity of ROI and IRR to steam price from poultry litter for a north AL IPEP scenario.[1/]						
		Steam price, $/MBtu NG displaced by poultry litter				
		4.00	4.50	4.94	5.50	6.94
Corn, $/bu	**DDGS, $/ton**	10-year average before-tax ROI, %				
Low	Low					
2.35	97	67.7	65.4	63.3	60.6	53.7
Baseline	Baseline					
2.63	108	58.9	56.5	54.4	51.8	44.9
High	High					
3.37	138	35.1	32.7	30.7	28.0	21.1
Corn, $/bu	**DDGS, $/ton**	10-year average after-tax ROI, %				
Low	Low					
2.35	97	40.6	39.2	38	36.4	32.2
Baseline	Baseline					
2.63	108	35.4	33.9	32.7	31.1	27
High	High					
3.37	138	21.4	19.6	18.4	16.8	12.5
Corn, $/bu	**DDGS, $/ton**	10-year average before-tax IRR on equity, %				
Low	Low					
2.35	97	68.1	66.0	64.1	61.7	55.5
Baseline	Baseline					
2.63	108	60.2	58.1	56.2	53.8	47.4
High	High					
3.37	138	38.1	35.8	33.7	31.1	24.0
Corn, $/bu	**DDGS, $/ton**	10-year average after-tax IRR on equity, %				
Low	Low					
2.35	97	48.0	46.6	45.3	43.7	39.5
Baseline	Baseline					
2.63	108	42.7	41.2	40.0	38.3	33.9
High	High					
3.37	138	27.3	25.7	24.2	22.3	16.7

[1/]Baseline assumptions for variables not shown except for ethanol price; assumes $1.55/gal ethanol.

C. Conclusions

A north Alabama IPEP ethanol plant is projected to be more profitable than a central Illinois ethanol plant. Using baseline assumptions, a Decatur, AL IPEP ethanol plant is projected to have a 10-year average after-tax ROI of 61.3% vs. 45.3% for a Pekin, IL NG plant. The sensitivity analysis indicated that a worst-case north AL IPEP scenario with a low average ethanol price ($1.55/gal), high average corn price ($3.37/bu), and other variables at baseline levels would result in a 10-year average after-tax ROI of 18.4%. This worst-case ROI for a north Alabama IPEP scenario would be reduced from 18.4% to 12.5% if the plant relied on NG (average projected price for the next 10 years of of $6.94/MBtu) instead of process heat from a poultry litter energy plant at a baseline price of $4.94/MBtu NG displaced by the poultry litter. A north Alabama IPEP plant is projected to be very competitive with an eastern Corn Belt plant, have a very high rate of return with baseline conditions, and provide positive returns under worst-case conditions.

XVIII. Fuel-Cycle Fossil Energy Balance and Greenhouse Gas Emissions for IPEP and Traditional Ethanol vs. Conventional Gasoline

A. Energy Balance

Results of ethanol energy balance assessments depend on system boundaries as depicted in Figure 1. The following ethanol energy balance information is based on operation-related activities depicted in Figure 1 and does not consider ethanol plant materials and construction, farming equipment materials and manufacture, solar energy embedded in biomass, and food intake by farmers.

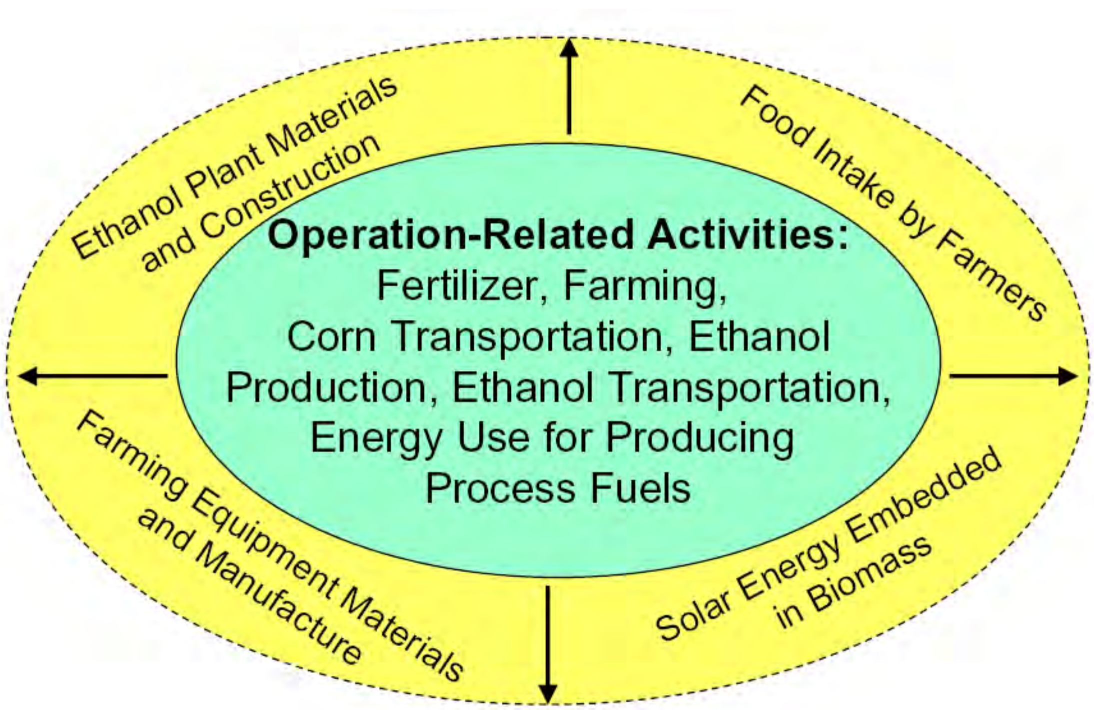


Figure 1. Ethanol energy balances depend on systems boundaries (Wang, 2005).

There has been considerable confusion about whether ethanol produced from corn contains more or less energy than required to produce and transport the corn and ethanol. Part of the confusion arises from the fact that some of the total (not fossil or petroleum) energy used in the production of ethanol is “free” solar energy used to grow the corn feedstock. If solar energy is included in a life-cycle assessment, then 1.5 to 2.0 Btu of total energy is required to produce a Btu of ethanol. However, since solar energy is free, renewable, and environmentally benign, the amount of solar energy is not of concern. Therefore, energy balance assessments for ethanol are usually performed on a fossil energy basis. The following energy balance information is presented on a fossil energy basis.

A comparison of results from fossil energy balance assessments is presented in Figure 2 (Wang, 2005). Assumptions for these studies through 2002 were reviewed by Shapouri et al., 2002. The net fossil energy balance for ethanol produced from corn has been positive in most assessments and has generally improved over time. The primary exceptions have been assessments by Pimentel and Pimentel and Patzek who have incorrectly ignored energy credits for co-products and used assumptions that are generally considered to be outdated, especially regarding amount of nitrogen fertilizer required per bushel of corn produced and energy efficiency in converting corn to ethanol (Shapouri et al., 2002 and Farrell et al., 2006). Wang used the GREET model (GREET, 2002) to generate the energy balance results attributed to him in Figure 2. Wang obtained results similar to those from Pimentel and Patzek when their assumptions were used in the GREET model (Figure 2).

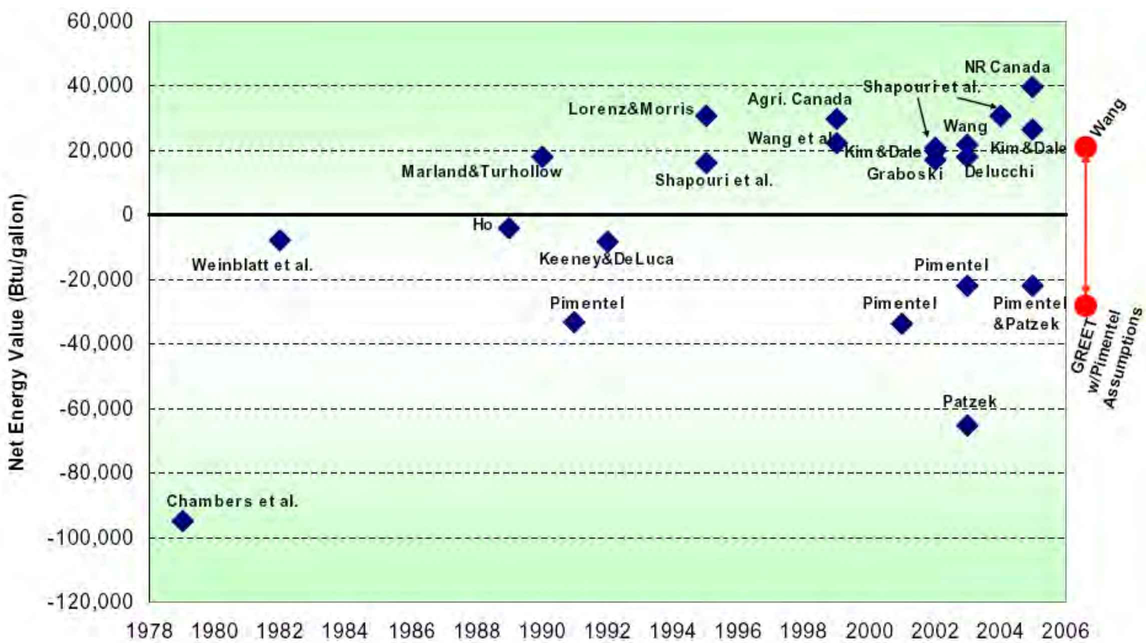


Figure 2. Fossil energy balances for ethanol produced from corn (Wang, 2005).

Inputs and operations considered in assessing the life-cycle fossil energy input required to produce and deliver corn/ethanol and conventional gasoline to refueling stations are illustrated in Figure 3. This type of assessment is referred to as a well-to-pump assessment. In this example, 0.74 Btu of fossil energy is required per Btu of ethanol from corn and 1.23 Btu of fossil energy is required per Btu of conventional gasoline. These fossil energy requirements were calculated using the GREET model, version 1.6 (GREET, 2002) with current-case assumptions presented by Wang et al., 1999, including a 50%/50% mix of coal and natural gas for process heat, the national mix for electricity supply, and a total of 41,400 Btu (LHV) from coal, natural gas, and electricity per gallon ethanol extracted. Using natural gas for process heat, the national mix for electricity supply, and near-future case assumptions (36,900 Btu (LHV) from natural gas and electricity combined per gallon ethanol extracted) by Wang et al., 1999, 0.69 Btu of fossil energy is required per Btu of ethanol from corn (Table 1). The key point is that significantly less well-to-pump fossil energy is required for ethanol from corn (even with no renewable energy used for process heat or electricity) than for conventional gasoline. Using the same assumptions and supplying all the process heat and electricity for ethanol processing from renewable energy lowers the ethanol well-to-pump fossil energy requirement to 0.18 Btu per Btu of ethanol from corn.

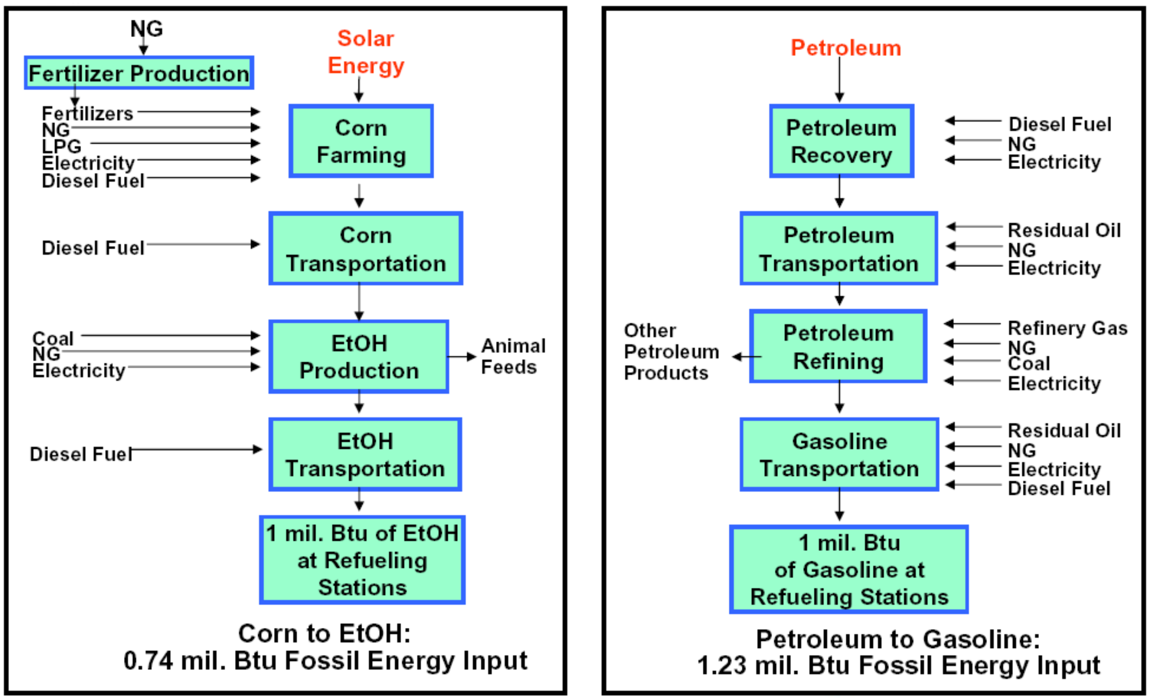


Figure 3. Fossil energy inputs for corn ethanol and conventional gasoline (Wang, 2005)

In the base-case IPEP system, renewable energy (i.e., poultry litter) is used to replace natural gas for producing process heat and electricity is supplied from the grid. Using ICM energy efficiency guarantees, natural gas for producing process heat equates to 0.43 Btu per Btu of ethanol from corn (Table 2). Subtracting the ICM-based natural gas fossil energy requirement from 0.69 Btu per Btu of ethanol from corn (near-future case, Table 1) gives a well-to-pump fossil energy requirement of 0.26 Btu per Btu of ethanol from corn; this is approximately one-fourth as much fossil energy as required per Btu of conventional gasoline. Substituting poultry litter for natural gas significantly improves an already positive fossil energy balance for ethanol produced from corn.

Table 1. Well-to-pump fossil energy input per Btu of fuel at fueling station

		Btu (LHV) fossil energy input/ Btu (LHV) fuel at refueling station	% reduction in fossil energy input vs. conventional gasoline
Petroleum to Conventional Gasoline[1/]		1.23	0
Corn to Ethanol			
A	Current case with process heat from 50% natural gas/50% coal and electricity from national mix[1,2/]	0.74	40
B	Near-future case with process heat from natural gas and electricity from national mix[2/]	0.69	44
C	Near-future case with process heat and electricity from renewable energy[2/]	0.18	85
D	Near future case with process heat from renewable energy and electricity from national mix[3/]	0.26	79

[1/]Wang, 2005

[2/]GREET 1.6 model : http://www.transportation.anl.gov/software/GREET/downloads/GREETGUI-readme.pdf and assumptions in GREET-based paper: http://www.transportation.anl.gov/pdfs/TA/58.pdf

[3/]0.26=0.69 from B above minus 0.43 from Table 2 based on the ICM energy efficiency guarantee for natural gas; does not account for the negligible amount of fossil energy required for poultry litter transport and conversion of poultry litter to steam

Table 2. ICM Energy Efficiency Guarantee: Natural Gas Requirement for Converting Corn to Ethanol

Btu NG (HHV)/ gal denatured EtOH[1/]	gal EtOH extracted/ gal denatured EtOH	Btu NG (LHV)/ Btu NG (HHV)	Btu NG (LHV)/ gal EtOH extracted
34000	0.950	0.909	32533

Btu EtOH (LHV)/ gal EtOH	Btu NG (LHV)/ Btu EtOH extracted (LHV)
76000	0.428

[1/] Efficiency guaranteed by ICM

B. Greenhouse Gas Emissions

The scenarios assessed in the energy balance section of this report were also assessed for greenhouse gas emissions. The GREET model (GREET, 2002) was used to estimate well-to-wheel greenhouse gas emissions for conventional gasoline and ethanol produced from corn. The well-to-wheel assessments include greenhouse gas emissions (carbon dioxide, methane, and nitrous oxide) from the well-to-pump operations illustrated in Figure 3 plus emissions from vehicle operation. In the ethanol assessments, use of E100 was assumed for vehicle operation in order to reflect the full potential impact of ethanol from corn vs. conventional gasoline on well-to-wheel greenhouse gas emissions per mile of vehicle travel.

Default assumptions for conventional gasoline and ethanol from corn (current and near-future cases) are described by Wang et al., 1999, and a summary of greenhouse gas emissions from these scenarios is presented in Table 3. Relative to conventional gasoline, current-case ethanol from corn (no renewable process energy) results in a 25% reduction in well-to-wheel greenhouse gas emissions and the near-future case for ethanol from corn (no renewable process energy) results in a 40% reduction in well-to-wheel greenhouse gas emissions. If both process steam and electricity for ethanol production were produced from poultry litter, well-to-wheel greenhouse gas emissions would be reduced by 72% relative to emissions from conventional gasoline.

Compared with conventional gasoline, an IPEP system producing process steam for ethanol production using poultry litter rather than natural gas reduces greenhouse gas emissions by 63% (Table 3). The GREET model indicates the aggregate effect of fossil-based process heat and electricity on greenhouse gas emissions but does not provide a break out of greenhouse gas emissions due to fossil fuels used for process steam vs. electricity. Therefore, the reduction in carbon dioxide emissions resulting from eliminating natural gas use for making process steam was calculated in Table 4 based on IMC energy efficiency guarantees; the resulting value of 120 grams carbon dioxide per mile was subtracted from 174 grams carbon dioxide equivalent per mile (near-future case with natural gas, Table 3) to give an estimate of 54 grams carbon dioxide equivalent per mile for ethanol production using poultry litter for process heat.

Table 3. Well-to-wheel reductions in greenhouse gas (GHG) emissions for ethanol from corn vs. conventional gasoline

	Feedstock	Fuel	Vehicle operation	Total	Reduction in GHG's vs. conventional gasoline
	GHG's (CO_2 eq.), grams/mile				%
Conventional Gasoline[1/]	31	76	401	508	0
Ethanol from corn; vehicle operating with E100					
Current case with process heat from natural gas and electricity from national mix[1/]	-249	250	382	383	25
Near-future case with process heat from natural gas and electricity from national mix[1/]	-249	174	382	307	40
Near-future case with process heat and electricity from renewable energy[1/]	-249	9	382	142	72
Near-future case with process heat from renewable energy and electricity from national mix[2/]	-249	54	382	187	63

[1/]GREET 1.6 model: http://www.transportation.anl.gov/software/GREET/downloads/GREETGUI-readme.pdf and assumptions in GREET-based paper: http://www.transportation.anl.gov/pdfs/TA/58.pdf

[2/]Fuel GHG emissions of 54=174-120; see Table 4 for calculation of 120 value; does not account for the negligible amount of greenhouse gases emitted from poultry litter transport and conversion of poultry litter to steam.

Table 4. Carbon Dioxide Emissions from Natural Gas Based on ICM Energy Efficiency Gaurantee

Btu NG (LHV)/ gal EtOH extracted[1/]	Btu (LHV)/ gal EtOH extracted	Btu (LHV)/ gal gasoline	miles/ gal gasoline eq.	lb CO_2/ MBtu NG (HHV)	Btu NG (HHV)/ Btu NG (LHV)	grams CO_2/ lb CO_2	grams CO_2/ mile
32533	76000	113400	23.5	116.4	1.1	454	120.1

[1/] Value calculated in Table 2.

C. References

GREET. 2002. GREET 1.6 GUI Beta Release II: ***G***reenhouse Gases, ***R***egulated ***E***missions, and ***E***nergy Use in ***T***ransportation graphical user interface. Argonne National Laboratory. Argonne, IL. http://www.transportation.anl.gov/software/GREET/downloads/GREETGUI-readme.pdf

Farrell, Alexander E., Richard J. Plevin, Brian T. Turner, Andrew D. Jones, Michael O'Hare, and Daniel M. Kammen. 2006. Ethanol can contribute to energy and environmental goals. Science 311: 506-508.

Shapouri, Hosein, James A. Duffield, and Michael Wang. 2002. The energy balance of corn ethanol: an update. U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses. Agricultural Economic Report No. 813
http://www.usda.gov/oce/oepnu/aer-814.pdf

Wang, M., C. Saricks, and D. Santini. 1999. Effects of fuel ethanol use on fuel-cycle energy and greenhouse gas emissions. Center for Transportation Research. Argonne National Laboratory. Argonne, IL.
http://www.transportation.anl.gov/pdfs/TA/58.pdf

Wang, Michael. 2005. Energy and greenhouse gas emissions impacts of fuel ethanol. NGCA Renewable Fuels Forum. The National Press Club. August 23. http://www.anl.gov/Media_Center/News/2005/NCGA_Ethanol_Meeting_050823.ppt#256,1,Energy and Greenhouse Gas Emissions Impacts of Fuel Ethanol

XIX. Economic Comparison of IPEP vs. Other Alternatives to Local Land Application of Poultry Litter

There are several options in addition to IPEP that are being considered outside this project as alternatives to local land application of poultry litter. The primary alternatives to local land application that are being evaluated and/or implemented are the following:

- Long-distance transport of unprocessed litter—Transporting unprocessed poultry litter out of P surplus areas to areas that can better use the phosphorus and other nutrients
- Pelletizing—Pelletizing poultry litter to improve handling characteristics and facilitate more options for hauling, storing, and application
- Composting—Production of stable organic products used primarily as a soil amendment in home and garden, horticultural, and landscaping applications
- Electricity production—Combusting or gasifying poultry litter to produce electricity and nutrient-rich ash for use in fertilizers or feed supplements
- Process heat production—Combusting or gasifying poultry litter to produce process steam and/or hot air and nutrient-rich ash for use in fertilizers or feed supplements. IPEP is an example of this option.

Each of these options is technically feasible. The main question is whether they are economical. The purpose of this assessment is to briefly compare the relative economics of these alternative uses of poultry litter based on published information. Each of these alternatives was assessed based on net returns in units of $ per ton of poultry litter. Net returns for long-distance transport of poultry litter were assessed based on overall cost savings ($ per ton of poultry litter transported) via substituting poultry litter for commercial fertilizer. For purposes of comparison, the other alternative uses of poultry litter were assessed based on net returns ($ per ton of poultry litter input) from products and co-products produced from poultry litter; these alternatives were assessed based on before-tax net returns. In cases with negative net returns, subsidy requirements were estimated based on the level of negative net returns. A general economic assessment of the economic feasibility of producing process heat for an IPEP system using the same assumptions is included in this section for purposes of comparison. A detailed assessment of the economic feasibility of producing process heat for an IPEP system is included in a separate section of this report.

A. Long-Distance Transport of Unprocessed Litter

Long-distance transport of unprocessed poultry litter out of P surplus areas is an intuitively attractive option because capital requirements are small compared with other options and the nutrients in poultry litter potentially have significantly greater value in nutrient deficit areas in which benefits are derived from P and K in the poultry litter as well as from the N. Using assumptions from Lichtenberg et al., 2002, the value of fertilizer nutrients potentially displaced by poultry litter is about $35 per ton (Table 1). If not all the nutrients in poultry litter are needed in a given application (due to inappropriate nutrient ratios) then the value of nutrients displaced by poultry litter is less than indicated in Table 1. On fields that have received long-term applications of poultry litter, crops don't benefit from additional P and K and no value is derived from the P and K; in those cases, poultry litter is only substituting for commercial N fertilizer that is worth about $13 per ton of poultry litter (Table 1). Therefore, the value of fertilizer nutrients potentially displaced by poultry litter is much greater in nutrient deficit areas that can benefit from additional P and K as well as N. Poultry litter provides organic matter in addition to inorganic nutrients such as N, P, and K. The added organic matter can improve soil productivity in some cases, but farmers generally have not been willing to pay a premium for the organic component of poultry litter and the value of poultry litter usually is based on the value of commercial fertilizer nutrients displaced.

Table 1. Value of commercial fertilizer potentially displaced by poultry litter[1/]

	Total	Available		
	lb/ton		$/lb	$/ton
N	70	53	0.25	13.25
P_2O_5	59	59	0.25	14.75
K_2O	47	47	0.15	7.05
			Total	35.05

[1/]Based on assumptions by Lichtenberg et al., 2002;
www.arec.umd.edu/policycenter/Policyreports/full-texts/02-02.pdf

A University of Maryland study (Lichtenberg et al., 2002) indicates that the maximum potential fertilizer cost savings via substituting poultry litter for commercial fertilizer ranges from about $8 to 17 per ton of poultry litter before including transportation costs (Table 2). The value of fertilizer nutrients displaced is less when poultry litter is applied on an N basis because more P and K is applied than required by the crop and the excess P and K does not displace any fertilizer nutrients. When poultry litter is applied on a P basis, credit can be taken for nearly all the N, P, and K in the poultry litter, but additional N and K fertilizer must be applied in addition to the poultry litter. A higher application cost per ton of poultry litter was assumed for poultry litter applied on a P basis because the rate of poultry litter per acre is much lower (roughly one-third as high) than when poultry litter is applied on an N basis.

Table 2. Maximum Potential Cost Savings via Substituting Poultry Litter for Commercial N-P-K Fertilizer[1/]

Nutrient Management Plan	Value of Fertilizer Nutrients Displaced	Poultry Litter Cleanout Costs	Poultry Litter Testing Costs	Poultry Litter Appln. Costs	Cost Savings before Poultry Litter Transportation	Cost Savings with 100 mi Transportation[2/]	Break-even Transportation Distance, mi.[2/]
	$/ton poultry litter						
Continuous Corn:							
P based	32.26	4.00	0.20	14.63	13.43	2.43	122
N based	19.24	4.00	0.20	7.27	7.77	-3.23	71
Corn-Soybean Rotation:							
P based	31.20	4.00	0.20	14.63	12.37	1.37	112
N based	24.02	4.00	0.20	7.27	12.55	1.55	114
Corn-Wheat-Soybean Rotation:							
P based	34.40	4.00	0.20	14.63	15.57	4.57	142
N based	28.60	4.00	0.20	7.27	17.13	6.13	156

[1/] Based on Lichtenberg et al., 2002; www.arec.umd.edu/policycenter/Policyreports/full-texts/02-02.pdf
[2/] Assumes $0.11/ton-mile for poultry litter transportation costs: Pelletier et al., 2001; http://scholar.lib.vt.edu/mirrors/vaes/01-1.pdf

Lichtenberg et al. (2002) performed a theoretical analysis assuming a uniform distribution of the poultry houses within each of the concentrated poultry counties of Maryland and Delaware. That analysis indicated that theoretically poultry litter should not have to be transported more than about two miles on average to comply with nutrient management standards in the two states. A second theoretical analysis assumed that all poultry houses within a county are located at the center of the county and indicated a maximum average transportation distance of less than 18 miles in order to comply with nutrient management standards. Assuming a poultry litter transportation cost of $0.11 per ton-mile, the break-even transportation distance ranges from 71 to 156 miles, depending on cropping system and whether poultry litter is applied on a P basis or an N basis (Table 2). These break-even transportation distances are much greater than the average distances noted above for complying with nutrient management standards in Maryland and Delaware. Therefore, the potential cost savings from substituting poultry litter for commercial fertilizer in Maryland and Delaware are substantial. As discussed later in this section, intangibles appear to largely offset these cost savings, Pelletier et al. (2000). These intangibles are probably the main reason that long-distance transport of unprocessed poultry litter from Maryland poultry houses is being subsidized by up to $20 per ton.

A Virginia study similar to the Maryland and Delaware study discussed above was conducted by Pelletier et al., 2001 (Table 3). Virginia regulations require that poultry litter applications in all parts of the state be made on a P basis as reflected in Table 3. The break-even transportation distance in Virginia ranges from 86 to 176 miles which is similar to the break-even distance for Maryland and Delaware (Table 2). The main P surplus region in Virginia (the Shenandoah Valley) is more like the concentrated poultry area in north Alabama in that there is not much crop land in close proximity to the concentrated poultry area and poultry litter would have to be transported further than in the Maryland and

Delaware case in order to comply with nutrient management standards. Most of the cotton land in north Alabama is 40 to 100 miles from the center of the concentrated poultry area. The Black Belt region of Alabama, the next closest major crop area, is 150 to 200 miles from the center of the concentrated poultry area which is in or nearly in the breakeven range.

Table 3. Maximum Potential Cost Savings via Substituting Poultry Litter for Commercial N-P-K Fertilizer[1/]

Crop	Litter Applied[2/]	Cost Savings before litter transportation vs. Commercial Fertilizer[2/]	Cost Savings with 100 mi transportation[3/]	Break-even Transportation Distance[3/]
	tons/acre	$/ton	$/ton	miles
Corn Grain	0.9	17.72	6.72	161
Corn Silage	0.9	17.70	6.70	161
Wheat	0.9	17.64	6.64	160
Barley	0.8	19.41	8.41	176
Alfalfa	0.8	9.41	-1.59	86
Other Hay	0.9	18.00	7.00	164
Pasture	1.0	18.27	7.27	166

[1/]Based on Pelletier et al., 2001; http://scholar.lib.vt.edu/mirrors/vaes/01-1.pdf

[2/]Assumes application of poultry litter on a P basis

[3/]Assumes $0.11/ton-mile for poultry litter transportation

The potential cost savings in Table 3 are substantial. However, the crop producer survey conducted by Pelletier et al., 2001, indicated there are intangibles that are not reflected in the potential cost savings. The survey of crop producer attitudes indicated the following main concerns about substituting poultry litter for commercial fertilizer (note: discussion points in italics added by Bert Bock, B.R. Bock Consulting, Inc.) :

- Price—want a competitive price *considering intangibles as well as tangibles*
- Logistics of handling, storing, and spreading litter—*logistics of using poultry litter will be significantly more difficult than for commercial fertilizers unless significant development of the physical and organizational infrastructure occurs. For example, in order to optimize efficiency of nutrient use, much of the commercial fertilizer is applied in a relatively narrow window in the spring. Given the relatively low nutrient content and nongranular form of poultry litter, application of most of the poultry litter in the narrow spring window will be difficult to achieve without significant added expense for litter storage facilities and application capability. Also, placing starter fertilizer close to seed rows and other precision fertilizer placement practices are becoming more important with conservation-tillage practices. Precision placement will be very difficult to achieve with unprocessed poultry litter.*
- Performance as a nutrient source—some uncertainty about consistency of nutrient content and availability
- Weed seeds in litter—some concern about weed seeds in poultry litter that would increase weed problems in fields; *mostly a perceived problem*

- Requirements for supplemental fertilizer applications—supplemental fertilizer is required when poultry litter is applied on a P basis. *This requires separate trips over the field for applying poultry litter and fertilizer at a time of the year when timely field operations are critical and the farmer's time is at a premium. Adding another trip over the field is also a concern on fields with potential compaction problems. As indicated in Table 3, poultry litter applications on a P basis are generally less than one ton per acre. In many cases, it likely will be difficult to justify a separate trip over the field to apply such a small of amount of poultry litter.*
- Regulatory concerns—want to be sure that using poultry litter would meet long-term regulatory criteria *so that changes in physical and organizational infrastructure could be fully utilized over a long period of time*.

Based on stakeholder input in the Virginia Tech study, it was concluded that poultry litter transported out of P surplus areas would be competitive with commercial fertilizers under the following conditions: "In the best case scenario, the producer would call a broker or an existing fertilizer dealer to order poultry litter several months in advance of application. The end user would indicate which crops or pasture to be fertilized. When application time arrives, poultry litter would be spread on the indicated fields within the time period requested. Producers would not have to store or spread the poultry litter themselves or purchase any additional equipment. A minimum nutrient concentration would be certified by the broker or dealer. The bill for litter brokering, litter, transportation, handling, and spreading would be paid to one business entity. Ideally, total cost of using poultry litter for fertilizer would be equal to or less than the cost of commercial fertilizer. End users would like to have the option to apply up to two or three years of phosphorus in one application to reduce the need for supplemental fertilizer applications."

The physical and organizational infrastructure required to achieve the best-case scenario described above for using poultry litter <u>on an equal basis with commercial fertilizer</u> are not yet in place. Therefore, the Virginia Tech study concluded that incentives will be required to achieve a significant amount of long-distance transport of unprocessed poultry litter from P surplus regions. An $11.00 per ton of poultry litter transportation subsidy was evaluated as a means of achieving a projected 50 percent adoption on suitable corn, wheat, and barley acres. As mentioned earlier, long-distance transport of poultry litter is being subsidized up to $20 per ton in Maryland. Long-distance transport of poultry litter is being subsidized in other states, including Alabama, as well. It is likely that long-distance transport of significant quantities of unprocessed poultry litter will continue to require subsidies because in the final analysis the cost of achieving the best-case scenario described above is likely to be comparable to, and in some cases greater than, the value of the commercial fertilizer nutrients displaced.

Fertilizer prices have increased significantly since the Pelletier et al. (2001) and Lichtenberg et al. (2002) studies discussed above. After accounting for higher N fertilizer prices, Mitchell (2006) estimated the value of N fertilizer displaced by poultry litter at $18 per ton of poultry litter as compared with $13.25 in Table 1. Prices for phosphate and potash fertilizers also have increased since 2002 but to a lesser extent than N fertilizer prices. Overall as of July 2006, N, phosphate, and potash fertilizer prices are about 30% higher than in 2001/2002. Therefore, it should be recognized that values of fertilizer nutrients displaced and the breakeven transportation distances in Tables 2 and 3 are somewhat higher now than in 2001/2002. However, even with higher fertilizer prices, subsidies still appear to be required to facilitate long-distance transport of poultry litter.

B. Pelletizing and Transporting Poultry Litter

Pelletizing adds value to poultry litter because it improves handling characteristics and facilitates more options for hauling, storing, and application. Compared with unprocessed litter, pellets are denser, drier, less dusty, and have much better flowability and less odor (at least until they absorb moisture after application). Pellets can be crushed to form granules comparable in size to commercial fertilizer and then applied with conventional application equipment. The main question is whether the added cost of pelletizing is more than offset by the added value of pellets vs. unprocessed poultry litter.

The Perdue AgriRecycle poultry litter pelletizing plant at Seaford, Delaware (www.perdueagrirecycle.com) has been in operation since 2001 and probably provides the best basis for assessing the economics of pelletizing poultry litter. The capital investment was $13 million of which $1 million was offset by a grant from the state of Delaware, Montgomery (2004). The $13 million capital investment includes $3.5 million in environmental upgrades, Tributary Times (2003). A first-approximation economic assessment is presented in Table 4, assuming a wholesale pellet price at the point of delivery of $65/ton of pellets and a pellet transportation cost of $10 per ton. The pellet transportation cost assumes that pellets are backhauled to the Corn Belt by rail in grain cars owned by Perdue. Otherwise the pellet transportation cost would be significantly higher. The plant sells in bulk, so there are no bagging and palleting costs. The plant was planned to produce 90,000 tons of pellets per year but was only permitted to produce 60,000 tons of pellets per year due to emissions considerations, Montgomery (2004). The basis for other assumptions is indicated in footnotes. Before-tax assessments are provided for both the actual and the planned production levels. Following the capital investment, the annual cash flows for determining payback period and internal rate of return (IRR) were calculated as the difference between annual revenues and annual O&M, assuming 100 percent equity (i.e., no debt service).

Table 4. Economics of Pelletizing Poultry Litter--15-Year Projection

	Actual	Planned
Poultry litter feedstock, tons/year	70,588	105,882
Shrinkage, %[1/]	15.00	15.00
Pellet production, tons/year[2/]	60,000	90,000
Pellet price (delivered), $/ton[1/]	65.00	65.00
Revenue, $/year	3,900,000	5,850,000
Plant Capital, $[2/]	13,000,000	13,000,000
Annualized over 15-year plant life, $/ton pellets[3/]	14.44	9.63
O&M:		
Labor, $/year[2/]	650,000	650,000
Maintenance other than pellet mill, % of capital[4/]	1.0	1.0
Maintenance other than pellet mill, $/year	130,000	130,000
Pellet mill maintenance, $/ton pellets[5/]	2.97	2.97
Other maintenance, $/ton pellets	2.17	1.44
Labor, $/ton pellets[2/]	10.83	7.22
Clean out and hauling, $/ton pellets[1/]	16.47	16.47
Natural gas, $/ton pellets[6/]	5.33	5.33
Electricity, $/ton pellets[5/]	4.68	4.68
Product shipping, $/ton pellets[1/]	10.00	10.00
Total O&M, $/ton pellets	52.44	48.11
Total O&M, $/year	3,146,596	4,329,895
Payback, years	17.3	8.6
Before tax IRR after 15 years, %	(1.7)	8.0
Annualized capital + O&M, $/ton pellets	66.89	57.74
Net return, $/ton pellets	(1.89)	7.26
Net return, $/ton poultry litter	(1.60)	6.17

[1/]Lichtenberg et al., 2002; www.arec.umd.edu/policycenter/Policyreports/full-texts/02-02.pdf

[2/]Montgomery, 2004

[3/]Assumes 100% equity, no debt service

[4/]Estimate based on rule of thumb

[5/]Smith, 2002

Pellet mill die maintenance, $/ton pellets	1.32
Pellet mill roller shell maintenance, $/ton pellets	0.66
Pellet mill roller bearings, $/ton pellets	0.99
kW/ton pellets	85
$/kWh	0.055

[6/]Expert opinion

Poultry litter moisture content entering dryer, %	25.0
Poultry litter moisture content leaving dryer, %	7.0
Btu natural gas/lb water removed	1,800
$/MBtu natural gas	6.50

The impact of pellet price on returns from pelletizing poultry litter is presented in Table 5. With a pellet price of $65 per ton and production level of 90,000 tons of pellets per year for 15 years, the net return would be $6.17 per ton of pellets, the payback period would be 8.6 years, and the IRR would be 8.0% after 15 years. These before-tax rates of return could possibly attract investors. Prices of $45 and 55 per ton result in negative returns. Without subsidies, a price of at least $65 per ton of pellets would be required to provide acceptable returns. A price higher than $65 per ton of pellets very likely may be required to attract investors.

Table 5. Impact of Pellet Price on Profitability of Pelletizing Poultry Litter[1/]

Pellet Price (delivered) $/ton	Net Return $/ton poultry litter	Payback years	IRR %
60,000 tons pellets/year:			
45	-18.60	[2/]	[2/]
55	-10.10	84.7	-16.5
65	-1.60	17.3	-1.7
90,000 tons pellets/year:			
45	-10.83	[2/]	[2/]
55	-2.33	21.0	-3.9
65	6.17	8.6	8.0

[1/]Assumptions other than price are the same as for Table 4.

[2/]Negative cash flow during years of operation

There is considerable uncertainty about whether a wholesale delivered price of $65 per ton of pellets is realistic on a large scale. The value of the primary plant nutrients displaced by Microstart60 is much less than $65 per ton. The Microstart60 pellets produced by Perdue AgriRecycle contain 60 percent organic matter and have a 3-3-3 analysis (Perdue AgriRecycle, 2005) which implies that a ton of pellets displaces roughly 60 lb of N, 60 lb of P_2O_5, and 60 lb of K_2O that otherwise would come from commercial fertilizers. Therefore, a ton of Microstart60 pellets displaces about the same amount of commercial fertilizer nutrients as displaced by a ton of unprocessed poultry litter with values specified in Tables 1 and 2. These values range from about $20 to 35 per ton of pellets, depending on cropping system and P- vs N-based nutrient management. This means that a pellet market price of $65 per ton carries a premium of roughly $30 to 45 per ton of pellets for attributes other than the commercial N, P, and K fertilizer displaced. Other attributes that in some cases may command a higher price than the value of commercial N, P, and K displaced include that the pellets qualify for use on farms certified for organic production and the pellets add organic matter and micronutrients to the soil. In some specialty uses such as on certified organic farms and on some specialty turf and horticultural crops, Micostart60 may command a premium of $30 to 45 per ton over the value of commercial N, P, K fertilizer displaced. However, experience has shown that traditional farms generally will not pay a premium for organic fertilizers. Therefore, there is significant uncertainty about whether sufficient markets exist for pelletized poultry litter at a wholesale price of $65 per ton or even at a price significantly less than $65 per ton.

The above analysis indicates that, without subsidies, a 90,000 ton per year poultry litter pelletizing operation will require a wholesale pellet price at the point of delivery of at least $65 per ton of pellets to provide an adequate return. A higher price would be required in cases in which a rail backhaul is not available and the cost of transporting the pellets is more than the $10 per ton assumed in Table 4.

At the 90,000 ton production rate, a pellet price of $65 per ton provides a net return of $6.17 per ton poultry litter input, a payback period of 8.6 years, and an internal rate of return (IRR) of 8.0%, Table 5. Returns somewhat higher than this likely would be required to attract investors. However, if $6.17 per ton of poultry litter input is used as an acceptable net return, then with a pellet price of $55 per ton, a subsidy of $8.50 per ton of poultry litter input would be required [i.e., $6.17-(-2.33), Table 5] and with a pellet price of $45 per ton, a subsidy of $17 per ton of poultry litter input would be required [i.e., $6.17-(-10.83), Table 5].

The Perdue AgriRecycle plant is receiving a poultry litter transportation subsidy of $400,000 per year for five years (~$7 per ton of pellets at a production rate of 60,000 tons of pellets per year from the state of Delaware) and a poultry litter transportation subsidy of up to $20 per ton of poultry litter from the state of Maryland, Lichtenberg et al, 2002. The $7 per ton pellets subsidy equals ~$6 per ton of poultry litter input. The above analysis indicates that with the current transportation subsidies ranging from $6 to 20 per ton of poultry litter input, the Perdue AgriRecycle plant likely can provide an acceptable rate of return with a pellet price in the range of $45 to 55 per ton, if it can operate at the planned capacity of 90,000 tons of pellets per year. It remains to be seen whether markets can be found for 90,000 tons of pellets per year at a delivered price of $45 to 55 per ton.

The bottom line for pelletizing poultry litter is that if markets can be found for poultry litter pellets in the $45 to 55 per delivered ton price range and pellet transportation costs are $10 per ton or less, a poultry litter transportation subsidy of $10 to 20 per ton of poultry litter input appears to be necessary in order to achieve even a marginal level of return required to attract investors. There is significant uncertainty about the size of the market for poultry litter pellets at a delivered price of $45 to 55 per ton. Also, backhauling pellets in grain cars may not be an option for reaching some the specialty crop markets, in which case pellet transportation costs may be greater than $10 per ton of pellets; with pellet transportation costs greater than $10 per ton, the poultry litter transportation subsidy likely would need to be greater than $10 to 20 per ton of poultry litter input.

C. Composting

Composting poultry litter involves mixing the litter with a carbon source, often sawdust, and aerating the mixture periodically to accelerate the rate of decomposition and ultimately produce a stable organic material with minimal odor and pathogen content. Temperatures in the compost must be maintained above approximately 130^{o}F to kill pathogens and promote efficient composting. The carbon source dilutes the nutrients in the poultry litter and a portion of the nitrogen is volatilized during the composting process, resulting in a final analysis of about 2-2-2 (N-P_2O_5-K_2O). These nutrient levels are roughly two-thirds as high as in raw poultry litter and poultry litter pellets that were discussed in previous sections. The primary value of poultry litter compost is for use as a soil amendment in home and garden, horticultural, and landscaping applications. These markets are generally significant distances from concentrated poultry areas. This implies that either the poultry litter feedstock or the final compost product generally must be transported from concentrated poultry areas to urban areas to be marketed.

Composting methods are well developed. There are five general methods: passive, aerated static pile, standard windrow, improved windrow, and in-vessel (PWQC, 2004). Passive composting involves stacking the poultry litter and carbon source mixture in a pile for a long period of time at relatively low temperatures; this method is too slow for the large quantities of poultry litter produced on poultry farms. Also, anaerobic zones can develop that produce objectionable odors. Static pile involves mixing the litter with a carbon source, putting the mixture in a pile, and aerating the pile from below. Aeration can be provided either passively or actively though a piping network at the base of the pile. Windrow methods involve piling the poultry litter/carbon source mixture in tall rows and turning the rows periodically to increase aeration and speed the composting process. Standard windrow composting is generally well suited for on-farm operations using farm-scale equipment. Improved windrow involves greater capital expenditure that facilitates more aggressive turning of larger windrows and improves efficiency and reduces production time. Improved windrow composting is generally more suitable for off-farm operations. In-vessel composting involves both aerating from below and mixing in a vessel and costs more than other methods. These methods are well developed technically. The main question concerning their commercial feasibility is their economics.

The windrow methods provide moderate efficiency at moderate cost and appear to have the most favorable economics for large volume operations. Lichtenberg et al. (2002) assessed the economics of on-farm production of bulk compost using a standard windrow method and off-farm production of bulk compost using an improved windrow method. In both cases, poultry litter was mixed with saw dust before being composted. The on-farm system was evaluated with a capacity of 10,000 tons input annually and the off-farm system was evaluated at scales of 10,000; 40,000; and 80,000 tons of input annually, assuming an average bulk compost price of $18.10 at the production facility (Table 6). A poultry litter cleanout cost of $3.00 per ton compost (~$4.00/ton poultry litter input) and a poultry litter transportation cost of $7.29 per ton compost (~$10.00 per ton poultry litter input) were assumed; these are the same costs as assumed by Lichtenberg et al. (2002) for transport of unprocessed poultry litter as an input for pelletized poultry litter (see previous section on pelletizing poultry litter). With an average bulk compost price of $18.10 per ton, the net return was slightly positive for the on-farm operation and strongly negative for the three off-farm operations.

Table 6. Production cost for composting poultry litter for bulk market1/

	On-farm	Off-farm		
Capacity, tons input	10,000	10,000	40,000	80,000
Poultry litter, tons	6,500	6,500	26,000	52,000
Sawdust, tons	3,500	3,500	14,000	28,000
Compost product, tons	8,920	8,920	35,920	71,840
Land required, acres	7.2	3.7	10.1	19.7
Annual capital cost, $/ton compost	3.66	16.59	9.05	7.92
Annual variable cost, $/ton compost	3.63	2.59	2.59	2.59
Sawdust cost, $/ton compost	6.30	6.30	6.30	6.30
Poultry litter clean out costs, $/ton compost	3.00	3.00	3.00	3.00
Poultry litter hauling costs, $/ton compost	0.00	7.29	7.29	7.29
Total cost, $/ton compost	16.59	35.77	28.23	27.10
Bulk compost price, $/ton	18.10	18.10	18.10	18.10
Net return, $/ton compost	1.51	-17.67	-10.13	-9.00
Net return, $/ton poultry litter	2.07	-24.25	-13.99	-12.43

1/ Lichtenberg etal., 2002.

The impact of bulk compost price on profitability of poultry litter composting is presented in Table 7; assumptions other than bulk compost price are the same as in Table 6. Net returns are expressed in units of $ per ton of poultry litter input to allow comparison of net returns from other alternative uses assessed in this report. Lichtenberg et al. (2002) indicated that bulk compost prices range from $5 to 20 per ton in the northeastern US. With a bulk compost price of $20 per ton, net return from all three off-farm operations is strongly negative and net return from the on-farm operation is positive ($4.68 per ton poultry litter input). Given the low capital investment for an on-farm operation, an on-farm operation would possibly consider operating with a net return of $4.68 per ton of bulk compost. With 10,000 and 40,000 ton per year off-farm operations, a bulk compost price significantly greater than $30 per ton will be required to provide adequate net return. With an 80,000 ton per year off-farm operation, a bulk compost price of at least $30 per ton will be required to provide adequate return. This implies that, on average, a subsidy equal to or greater than $11.90 per ton bulk compost (i.e., $30.00-18.10 per ton bulk compost) will be required to provide adequate net return from off-farm operations. A subsidy of $11.90 per ton of bulk compost is equivalent to $16.30 per ton of poultry litter input. The above analysis indicates that a subsidy of at least $16.30 per ton poultry litter input will be required to provide an acceptable net return to off-farm composting. In some cases, a tipping fee can be received for using food processing wastes or other wastes as the carbon source for composting poultry litter. In those cases, off-farm composting operations can possibly operate without a poultry litter subsidy.

Table 7. Impact of bulk compost price on profitability of poultry litter composting[1/]

Bulk compost price $/ton	Net Return $/ton poultry litter
On-farm, 10,000 ton/year input:	
10.00	-9.04
15.00	-2.18
18.10	2.07
20.00	4.68
25.00	11.54
30.00	18.40
Off-farm, 10,000 ton/year input:	
10.00	-35.36
15.00	-28.50
18.10	-24.25
20.00	-21.64
25.00	-14.78
30.00	-7.92
Off-farm, 40,000 ton/year input:	
10.00	-25.19
15.00	-18.28
18.10	-13.99
20.00	-11.37
25.00	-4.46
30.00	2.45
On-farm, 80,000 ton/year input:	
10.00	-23.62
15.00	-16.72
18.10	-12.43
20.00	-9.81
25.00	-2.90
30.00	4.01

[1/]Assumptions other than price are the same as for Table 6.

D. Electricity Production

As discussed in the previous two sections, markets for pellets and compost are not well developed and appear to be relatively small. A potential advantage of producing electricity from poultry litter is that there are large well developed markets for electricity. The key question is: can electricity produced from poultry litter compete in established electricity markets?

Both utility-scale and industrial-scale production of electricity from poultry litter were assessed in a detailed study (NRBP, 1999a and NRBP, 1999b). The general conclusion of these assessments was that utility-scale production of electricity from poultry litter generally will require large incentives and/or subsidies and that the economics of producing electricity for industrial applications in concentrated poultry areas is generally even less favorable. Some direct combustion examples based on commercial experience are cited below to further illustrate typical economics for utility-scale production of electricity from poultry litter.

Production of electricity from poultry litter is technically feasible as demonstrated by the three stoker-type Fibrowatt plants that have been operating in the United Kingdom for several years. Some characteristics of these plants are presented in Table 8 taken from NRBP (1999b). Fibrowatt also commissioned a poultry litter bubbling fluidized bed plant ($3,794 per kW) in 2001 at Westfield, Scotland, EPRL (2005). These plants are highly subsidized. The main question concerning production of electricity from poultry litter is the economic feasibility.

Table 8. Operating characteristics of the Fibrowatt UK poultry litter power plants

	Plant		
	Eye	Glanford	Thetford
Initial operating year	1992	1993	1998
Boiler type	Moving-grate stoker	Spreader stoker w/ chain grate	Spreader stoker w/ chain grate
Installed capacity, MW	12.7	13.5	38.5
Litter usage, tons/year	165,000	187,000	500,000
Installed cost, million U.S. $	35.2	38.4	110.4
Unit cost, $/kW	2772	2844	2868
Steam pressure, bar	65	1/	1/
Steam temperature, ^oC	450		
Steam pressure, psig	940		
Steam temperature, ^oF	840		
Furnace Combustion temp., ^oC	850		
Furnace Combustion temp., ^oF	1560		

1/ Operating temperatures and pressures were only reported for one plant (Eye) but are assumed to be similar for the other two plants.

Fibrowatt has been trying to develop poultry litter energy plants in the United States for several years without success, the main reason being that generally a large subsidy would be required in order for their proposed plants to provide adequate return. These proposed plants generally have been in the 40 to 50 MW size range. An example is the Fibrowatt plant proposed for south central Mississippi. A pre-feasibility study was conducted for that plant by McCallum and Sweeney Consulting, 2002. The study indicated that if electricity from a 40 MW plant using primarily poultry litter and limited amounts of wood as fuel could be sold for $40 per MWh, a subsidy of $45 per MWh would be required to provide an adequate return on investment. Concentrated poultry areas generally don't have industrial operations that require anywhere close to 40 MW of electricity supply. The most likely scenario is that the plant would have to sell the electricity to a utility grid for a price equal to the utility's avoided cost of reducing its output by that amount. The utility avoided cost would be roughly the fuel and O&M cost avoided by not having to dispatch some of the existing generating facilities and generally is in the neighborhood of $25 per MWh. This implies that the proposed plant in south central Mississippi likely would require a large subsidy, even with the $18 per MWh Section 45 tax credit that is available for electricity production from poultry litter.

An atypical circumstance in Minnesota has facilitated initial phases of development of a 55 MW Fibrowatt project using turkey litter as the primary fuel in a stoker-type boiler. Xcel Energy reportedly contracted to pay $86 per MWh for 21 years for electricity from the plant (Morris, 2005). This contract will serve as partial fulfillment of an Xcel Energy commitment to purchase renewable electricity as part of an agreement concerning operation of its nuclear power plants in the state (Xcel Energy Development Fund, 2005). It is not clear whether Fibrowatt is receiving renewable energy incentives in addition to the price guaranteed in the Xcel Energy contract. Presumably, Fibrowatt will get the $18 per MWh Section 45 tax credit. The Xcel Energy contract price is clearly atypical for utility power purchase agreements for renewable energy.

Renewable Energy Weekly (2005) reported a project cost of $142 million for the Minnesota Fibrowatt project; this is presumably the capital cost of the project. A $142 million capital cost translates to $2,582 per kW which is slightly lower than capital costs for the earlier Fibrowatt plants in the United Kingdom (Table 6). Higher capital costs per kW would be expected with the Fibrowatt approach at scales smaller than 55 MW and a higher contract price than $86 per MWh likely would be required with smaller utility scales.

It is possible that alternatives to the Fibrowatt approach can produce electricity from poultry litter at somewhat lower cost. Capital and O&M costs for 12 and 21 MW Energy Products of Idaho bubbling fluidized bed systems are presented in Table 9 taken from Bock (2000). These capital cost estimates are based on Energy Products of Idaho commercial experience with wood-fired plants built several years ago and their recent pilot plant tests with poultry litter. These capital cost estimates don't reflect increases in material costs or added costs for feedstock handling and storage for poultry litter vs. wood. Therefore, these cost estimates are very conservative. The O&M costs assume that ash revenues will offset the delivered cost of poultry litter fuel. A strong case for this assumption is made later in this report.

Table 9. Capital and O&M costs for producing electricity with EPI fluid bubbling bed

	$/kW	$/MWh
12 MW	2,400	40
21 MW	2,100	30

The very conservative cost estimates in Table 9 were used to calculate net returns, payback period, IRR using techniques similar to those used for the previous technologies evaluated (i.e., long-distance transport of unprocessed poultry litter, pelletizing poultry litter, and composting poultry litter (Table 10).

Table 10. Economics of producing electricity from poultry litter--15-year projection

MW	12	21
Capacity factor, %	95	95
kWh/year	99,864	174,762
$/MWh	70.00	70.00
Revenue, $/year	6,990,480	12,233,340
$/ton poultry litter	46.16	46.16
Plant Capital, $	28,000,000	44,100,000
Annualized over 15-year plant life, $/ton poultry litter	12.33	11.09
O&M:		
$/MWh	40.00	30.00
$/year	3,994,560	5,242,860
$/ton poultry littter	26.38	19.78
Poultry litter heating value, MBtu/ton	9.0	9.0
Heat rate, Btu/kWh	13,648	13,648
Annual poultry litter requirement, tons	151,438	265,017
Payback, years	9.3	6.3
Before tax IRR after 15 years, %	6.6	13.5
Annualized capital + O&M, $/ton poultry litter	38.70	30.88
Net return, $/ton poultry litter	7.46	15.28

A summary of returns for electricity prices ranging from $30 to 80 per MWh is presented in Table 11. With a 12 MW capacity, an electricity price of at least $70 to 80 per MWh would be required to attract investors. With a 21 MW capacity, an electricity price of at least $60 to 70 per MWh would be required to attract investors. These are much higher electricity prices than are likely to be received in general for electricity sold to a utility grid. With a typical utility grid electricity price of $30 per MWh and a 12 MW scale, a subsidy of about $50 per MWh

(~$35 per ton of poultry litter) would be required to achieve an acceptable rate of return. With a typical utility grid electricity price of $30 per MWh and a 21 MW scale, a subsidy of about $40 per MWh (~$25 per ton of poultry litter) would be required to achieve an acceptable rate of return. These estimates are based on very conservative capital costs, indicating that the required subsidies likely would be even somewhat higher than indicated above. Therefore, even with very conservative costs, producing utility-scale electricity would require larger subsidies than required for long-distance transport of unprocessed poultry litter, composting poultry litter, or pelletizing poultry litter. The NRBP (1999b) assessment indicates that the economics of producing electricity for industrial operations in concentrated poultry areas are even less favorable in general than the economics of producing utility-scale electricity.

Table 11. Impact of electricity price on profitability of producing electricity from poultry litter[1/]

Electricity Price $/MWh	Net Return $/ton poultry litter	Payback years	IRR %
12 MW:			
30	-18.92	[2/]	[2/]
40	-12.33	[2/]	[2/]
50	-5.73	28.0	-7.0
60	0.86	14.0	0.9
70	7.46	9.3	6.6
80	14.05	7.0	11.5
21 MW:			
30	-11.09	[2/]	[2/]
40	-4.50	25.2	-5.9
50	2.10	12.6	2.2
60	8.69	8.4	8.3
70	15.28	6.3	13.5
80	21.88	5.0	18.2

[1/]Assumptions other than price are the same as for Table 10.

[2/]Negative cash flow during years of operation

Some energy conversion technology providers claim to be able to produce electricity from poultry litter at lower cost than presented above. However, these technologies have not been fully developed and demonstrated. It is possible that some of these technologies will eventually be able to produce electricity from poultry litter more economically than indicated above, especially at a large industrial scale with co-generation of electricity and process steam. In general, significant financial incentives will be required to achieve economical production of electricity from poultry litter. Potential financial incentives for production of electricity from poultry litter in north Alabama are discussed below.

Because of the environmental, economic development, and energy security benefits of using renewable sources of energy, several financial incentives are currently or potentially applicable to production of electricity from poultry litter. A national production tax credit is currently applicable for production of electricity from poultry litter; also, green power premiums, tradable renewable certificates (also known as green tags), renewable portfolio standard credits, and greenhouse gas credits may be applicable to bioenergy in the near future. In general, these incentives hold promise for improving the economics of producing electricity from poultry litter; however, as discussed below, the applicability of these incentives in north Alabama appears to be quite limited in the foreseeable future.

The Energy Policy Act of 2005 reduced the Section 45 tax credit for production of electricity from poultry litter by 50 percent. After adjusting for inflation, the Section 45 production tax credit is now $9/MWh for production and sale of electricity from poultry litter to an unrelated party (NRBP, 2005). This financial incentive is available to electricity generating facilities placed in service between December 31, 2003 and January 8, 2008; a poultry litter-to-electricity plant that starts up during this time period is eligible to receive the credit for 10 years. Private organizations that pay taxes are eligible for the Section 45 production tax credit if they sell the electricity to an unrelated party.

Green power programs are being developed by many electricity providers in response to consumers who are willing to pay a premium for electricity produced from renewable resources as a means of promoting development and implementation of renewable electricity. These consumers are willing to pay a premium for renewable energy because of environmental benefits, such as reduced emissions and conservation of natural resources. So far, green power consumers have supported primarily wind and solar; however, bioenergy generally is a much lower-cost source of renewable energy, and use of biomass wastes and by-products for energy eliminates environmental problems associated with traditional methods of waste disposal, such as open burning, landfills, and land application. North Alabama is in the TVA power service area. The TVA Green Power Switch Program currently includes only wind, solar, and landfill gas (TVAGPS, 2005). Customers of TVA distributors pay a premium of $26.67/MWh power provided through Green Power Switch. With proper marketing and education, some consumers may be willing to pay a green power premium for electricity from poultry litter because of environmental benefits in both electricity production and water quality because of less land application of poultry litter; however, inclusion of electricity from biomass is not expected to be included in the TVA Green Power Switch Program in the foreseeable future.

Green tags are another type of financial incentive for producing renewable electricity. Green tags are also called Tradable Renewable Certificates (TRC), Resource Solutions (2005). Green tags are the green attributes of renewable electricity that are sold separately from renewable electricity. Therefore, the sale of green tags is not limited by physical constraints of transmission and distribution and can be sold at locations with no physical electrical connection with the renewable energy producer. In this way, a customer can choose green power even if the local utility does not offer a green power product. A typical market price for green tags is $10 to 40/MWh.

Certification standards for TRCs are posted at TRC Standard, 2005. The green attributes of renewable electricity can be claimed only once. For example, renewable electricity can not be sold at a premium in a green power program if the green attributes have been sold as TRCs. In general, the TRC standard includes electricity produced from solar, wind, geothermal, LIHI-certified hydro, and the following biomass sources: landfill gas, digester gas, plant-based agricultural, vegetative, and food processing waste, bioenergy crops, clean urban waste wood, and mill residues. Poultry litter is a plant-based agricultural waste because it is a mixture of plant-based bedding (usually wood shavings or rice hulls) and manure which is also derived from plants (mainly corn and soybean meal). Therefore, poultry litter appears to conform to the TRC standards as a biomass source for generating renewable electricity with associated green tags. An exception is that "when regional or state-based Green-e and Green Pricing definitions of eligible renewable resources exclude any of the above types of eligible generation, **non-eligible generation plants located in the regions with exclusions** may NOT be used in certified TRC products." This exclusion currently applies to poultry litter in the TVA region (which includes north Alabama) since electricity generated from biomass sources other than landfill gas is excluded from the TVA Green Power Switch Program.

As part of utility restructuring, utilities may be required to provide some percentage of their electricity production from renewable sources, a concept referred to as a renewable portfolio standard (RPS). Several RPS bills have been proposed in recent years, but passage of an RPS does not seem imminent, at least under the current administration. In these bills, the percentage requirement for electricity from renewables typically ranges from 2.5 to 7.5 percent within a period of 10 to 20 years. Under an RPS, renewable energy sources would compete with each other rather than with fossil-based electricity.

Because of concerns about global climate change, markets are emerging for greenhouse gas credits. Biomass is considered a CO_2-neutral fuel because CO_2 is absorbed from the atmosphere when plants grow, and a comparable amount of CO_2 is released back into the atmosphere when the biomass is used for energy, resulting in no net increase of CO_2 in the atmosphere except for emissions from mechanical operations associated with production, harvesting, transporting, and preprocessing the biomass. Therefore, if markets for greenhouse gas credits continue to develop, CO_2 credits from using biomass for energy will have a market value. The goal of the DOE Carbon Sequestration Program is to lower the cost of carbon sequestration from greater than $100/ton C avoided to $10/ton C avoided (DOE, 2005). If a significant market does develop for CO_2 credits, carbon sequestration, renewables, and improved energy efficiency will likely all play a role in providing CO_2 credits; however, it is not clear when a significant market for CO_2 credits may develop.

In summary, financial incentives for producing electricity from poultry litter are not expected to play a significant role in north Alabama in the foreseeable future for the following reasons:

- The Section 45 tax credit for poultry litter has recently been reduced from $18 to 9/MWh for eligible electricity producers
- Green power premiums and tags are not applicable to poultry litter in north Alabama and are not expected to become applicable in the foreseeable future
- It is not clear that an RPS will be implemented in north Alabama in the foreseeable future
- It is not clear that CO_2 credits will have significant monetary value in the foreseeable future

As indicated earlier, significant financial incentives will be required to produce electricity from poultry litter. Since significant financial incentives are not currently available in north Alabama and do not appear to be forthcoming in the foreseeable future, producing electricity is not expected to be a significant alternative use for poultry litter in north Alabama.

E. Process Steam for an IPEP Ethanol Plant

Given projections for high NG prices in the foreseeable future, using poultry litter instead of NG to provide process steam for an IPEP ethanol plant in north Alabama is a promising option with favorable economics.

A detailed economic assessment in an earlier section of this report indicates that producing process steam from poultry litter for an IPEP ethanol plant in north Alabama can provide attractive rates of return without financial incentives. The base case with a steam price of $4.94 per MBtu of NG displaced by poultry liter provided a 10-year average before-tax return on investment (ROI) of 25.0% for the poultry litter energy plant without any financial incentives. Assuming the projected 10-year average NG price in Alabama of $6.94, a steam price of $4.94/MBtu NG displaced would save an IPEP ethanol plant in north Alabama $2.00/MBtu of NG displaced over the next 10 years. Assuming 34,000 Btu NG per gallon ethanol and 52,500,000 gallons ethanol produced per year, this translates to an average savings for the ethanol plant of $3,570,000 per year while at the same time the poultry litter energy plant makes an attractive ROI of 25.0%.

The detailed economic assessment also included a base case in which the total avoided NG cost achieved by using poultry litter was credited to the poultry litter energy plant. An average Alabama NG price over the next 10 years of $6.94 per MBtu was assumed. This resulted in a 10-year average before-tax return on investment (ROI) of 51.1% for the poultry litter energy plant without any financial incentives. A sensitivity analysis using the highest cost projections for capital, O&M, and poultry litter feedstock; the lowest ash revenue projection; and crediting the poultry litter energy plant with $6.94 per MBtu of avoided NG use by the ethanol plant resulted in a 10-year average before-tax return on investment (ROI) of 19.3% for the poultry litter energy plant without any financial incentives. Actual returns are likely to be higher than this worst-case scenario because it is highly unlikely that all the cost and ash revenue parameters will be at the least attractive levels assessed in the sensitivity analysis.

The projected returns for using poultry litter to provide process steam for an IPEP ethanol plant in north Alabama are more attractive than for the other alternative uses assessed in this report.

F. Summary and Conclusion

1. Long-distance transport of poultry litter

Although university studies indicate that the value of fertilizer nutrients displaced by poultry litter can offset the cost of hauling poultry litter significant distances, experience thus far indicates that significant subsidies will be required to achieve long-distance transport and use of significant quantities of poultry litter on an equal basis with commercial fertilizer. After evaluating stakeholder input concerning ling-distance transport of poultry litter for use as a fertilizer, the Virginia Tech study by Pelletier et al. (2001) evaluated an $11.00 per ton of poultry litter transportation incentive as a means of achieving a projected 50 percent adoption on suitable corn, wheat, and barley acres in Virginia. The state of Maryland provides poultry litter transportation subsidies of up to $20.00 per ton of poultry litter. Other states, including Alabama, are providing a poultry litter transportation subsidy on a trial basis. It is likely that long-distance transport of poultry litter will continue to require significant subsidies after accounting for all the factors required to transport and use poultry litter <u>on an equal basis with commercial fertilizer</u>.

2. Pelletizing poultry litter

The bottom line for pelletizing poultry litter is that if markets can be found for poultry litter pellets in the $45 to 55 per delivered ton price range and pellet transportation costs are $10 per ton or less, a poultry litter transportation subsidy of $10 to 20 per ton of poultry litter input appears to be necessary in order to achieve even a marginal level of return required to attract investors. There is significant uncertainty about the size of the market for poultry litter pellets at a delivered price of $45 to 55 per ton. Also, backhauling pellets in grain cars may not be an option for reaching some of the specialty crop markets for poultry litter pellets, in which case pellet transportation costs may be greater than $10 per ton of pellets; with pellet transportation costs greater than $10 per ton, the poultry litter transportation subsidy likely would need to be greater than $10 to 20 per ton of poultry litter input.

3. Composting

With average compost prices, slightly positive net returns can be achieved with on-farm composting, but these returns are likely not large enough in most cases to justify starting a new enterprise. Off-farm composting operations appear to be less profitable and generally would require subsidies of roughly $15 per ton of poultry litter or more to attract investors. In some cases, a tipping fee can be received for using food processing wastes or other wastes as the carbon source for composting poultry litter. In those cases, off-farm composting operations can possibly operate without a poultry litter subsidy. As with poultry litter pellets, there is uncertainty about the size of the specialty markets for compost.

D. Electricity

Producing electricity on a utility scale and selling the electricity on a utility grid would require incentives and/or subsidies of at least $20 to 30 per ton of poultry litter, even after accounting for the $9 per MWh Section 45 tax credit available for producing electricity from poultry litter. Other potential incentives such as green power and greenhouse gas credits are not likely to be large enough to attract investors without subsidies that are larger than required for long-distance transport of poultry litter, pelletizing poultry litter, and composting poultry litter. Although a higher price can be received for electricity supplied to industrial customers, the higher price is largely offset by higher costs per unit of electricity produced. Without large subsidies, production of electricity from poultry litter is likely to be economically viable only in special situations that provide a higher than normal price for utility-scale electricity (e.g., the Fibrowatt Minnesota project discussed earlier).

E. Process steam for an IPEP system

Given the current and projected high NG prices, it is much more economical to produce process steam than electricity from poultry litter. This is the case especially if there is a large continuous user of process steam near supplies of surplus poultry litter, as is the case in an IPEP system. In contrast with the other alternative uses for poultry litter discussed above, providing process steam from poultry litter for a dry mill ethanol plant holds promise for providing very attractive economic returns without financial incentives. In order for providing process steam for an IPEP system to be viable, the ethanol production component of the

IPEP system must be economical. We make that case in other sections of this report.

Providing process steam for an IPEP system holds promise for being an economical alternative to local land application of poultry litter in concentrated poultry areas without financial incentives. In contrast, the other alternative uses of poultry litter evaluated will require significant financial incentives to achieve comparable profitability.

G. References

Bock, B.R., 2000. Economic and technical feasibility of energy production from poultry litter. p. 133-148. *In* John P. Blake and Paul H. Patterson (eds.) 2000 National Poultry Waste Management Symposium. October 16-18. Ocean City, Maryland.
http://www.brbock.com/PoultryLitter_Energy.doc

DOE. 2005.
http://www.netl.doe.gov/publications/factsheets/carbon/carbon_seq.pdf

EIA. 2005. http://www.eia.doe.gov/emeu/steo/pub/contents.html

EMS. 2005. http://www.ems.org/renewables/information.html

EPRL, 2005. Energy Power Resources Limited. www.eprl.co.uk/index.html

Xcel Energy Development Fund, 2005.
www.cleanenergystates.org/Funds/fund.php?fund_id=3

Lichtenberg, Erik, Doug Parker, and Lori Lynch. 2002. Economic value of poultry litter supplies in alternative uses. Policy Analysis Report No. 02-02. Center for Agricultural and Natural Resource Policy. University of Maryland.
www.arec.umd.edu/policycenter/Policyreports/full-texts/02-02.pdf

McCallum Sweeney Consulting. 2002. Pre-feasibility study for 40-50 MW poultry litter fueled power generation facility. Mississippi Alternative Energy Enterprise. Jackson, Mississippi. http://www.msenergy.ms/Report.pdf

Mitchell, Charles. 2006. Moving poultry litter in Alabama.
http://www.aces.edu/timelyinfo/Ag%20Soil/2006/April/s-03-06.pdf

Montgomery, Jeff. 2004. Perdue recycling plant shows promise. The News Journal-Delaware Online. New Castle, Delaware. Archives (9/14/04) at http://www.delawareonline.com

Morris, David. 2005. Minnesota's biomass mandate: an assessment. Institute for Local Self-Reliance. Minneapolis, MN.
http://www.ilsr.org/biomass/mnbiomass.pdf

NRBP, 1999a. http://www.nrbp.org/pdfs/pub20a.pdf

NRBP, 1999b. http://www.nrbp.org/pdfs/pub20b.pdf

NRBP. 2005. http://www.nrbp.org/pdfs/energy_policy_act_2005.pdf

Pelletier, Beth Ann, James Pease, and David Kenyon. 2001. Economic analysis of Virginia poultry litter transportation. Bulletin 01-1. Virginia Agricultural Experiment Station. Virginia Tech. http://scholar.lib.vt.edu/mirrors/vaes/01-1.pdf

Perdue AgriRecycle. 2005. Our products. www.perdueagrirecycle.com/our_products.htm

Rewnewable Energy Week.2005.Biomass plants slowly developing in Minnesota. P. 4. September 23. Charlottesville, VA.

PWQC. 2004. Poultry Water Quality Handbook. Third Edition Expanded. p. 51-56. Poultry Water Quality Consortium. www.poultryegg.org/PWQC

Resource Solutions. 2005. http://www.resource-solutions.org/TRCs.htm

Smith, Eric D., 2002. An introduction to wood pelleting. ESA Process Equipment, Inc. Vancouver, WA.

TRC Standard. 2005. http://www.green-e.org/pdf/trc_standard.pdf

Tributary Times. 2003. Perdue-Agrirecycle Poultry Manufacturing Pelletizing Plant. www.dnrec.state.de.us/water2000/Sections/Watershed/ws/trib_times_2003_2_nc_perdue.htm

TVAGPS. 2005. http://www.tva.com/greenpowerswitch/index.htm

XX. Conclusions

The summary conclusion of this study is that an Integrated Poultry and Ethanol Production (IPEP) system using poultry litter to provide process heat for a corn/ethanol plant in north Alabama is technically and economically feasible, is projected to be more economical than other alternative uses of poultry litter, is projected to be more profitable than an eastern Corn Belt ethanol plant, and would provide significant environmental benefits over an ethanol plant using natural gas for process heat. Poultry producers, integrators, ethanol marketing and technology providers, fertilizer and carbon dioxide gas producers, and local agricultural and economic development agencies have been interested participants in this study. Probably the main potential deterrent to commercialization of an IPEP project in north Alabama is a “not in my backyard” mentality regarding development of commercial projects. This is currently being experienced at one potential north Alabama location at which a corn/ethanol plant is being proposed. There is also some uncertainty about how broadly poultry litter land application rules will be enforced in the near future. This results in some uncertainty about poultry litter supply-price relationships in the near future that a project developer will have to take into consideration.

Conclusions from individual project components are as follows:

A fluidized bed poultry litter combustion and steam generation system, including poultry litter and ash handling and storage, was identified and evaluated that is technically feasible and can comply with atmospheric emissions standards. Conceptual designs and cost estimates for this system indicate that process steam can be provided to a corn/ethanol plant at about \$4.50/MBtu natural gas displaced by poultry litter, assuming poultry litter prices and ash revenues discussed below; this price is a significant advantage over natural gas prices that are projected to average \$6.94/MBtu over the next 10 years.

If current nutrient management regulations in north Alabama are broadly enforced, it is expected there will be strong interest from both poultry growers and litter vendors in providing poultry litter to produce process heat for an IPEP ethanol plant. It is projected that about 190,000 tons/year (approximately one-third of the litter produced by the top broiler counties in north Alabama) can be provided to an IPEP plant for an average delivered cost of approximately \$10/ton. For growers, the primary motivation for supplying an IPEP ethanol plant is simplifying and reducing the cost of nutrient management planning and assuring a reliable long-term outlet for their litter. For litter vendors, the primary motivation is the option to shift to a more efficient and profitable poultry litter delivery system. If nutrient management regulations are not broadly enforced, then a somewhat higher price than \$10/ton may have to be paid to acquire adequate supplies of poultry litter to provide process heat for an IPEP ethanol plant.

Factors were assessed that affect the potential value of poultry litter ash for use in fertilizers and as a mineral feed supplement for broilers. Options for incorporating poultry litter ash into granular fertilizers were identified and the first known evaluation of poultry litter ash as a replacement for traditional sources of mineral phosphorus and calcium supplements for broilers was conducted. Compared with dicalcium phosphate and calcium carbonate, poultry litter ash gave comparable growth, feed efficiency, and dressing performance. The dioxin levels in the poultry litter ash were below the World Health Organization standard for mineral supplements; however, public perception about dioxin risks could limit the use of poultry litter ash for use as a mineral feed supplement. It was estimated that with proper poultry litter and energy conversion management, a poultry litter plant can net $40.00 to 80.00/ton of ash used in fertilizers and from $80 to 110/ton of ash used as a mineral feed supplement if dioxins are not a limiting factor.

An IPEP corn/ethanol plant on the Tennessee River in north Alabama was determined to be very competitive with traditional stand-alone corn/ethanol plants in the eastern Corn Belt that use NG for process heat. The main tradeoffs are that higher dried distillers grain and solubles (DDGS) and carbon dioxide revenues for an IPEP plant more than offset the higher cost of corn and that an IPEP plant saves $0.08 to 0.09/gallon of ethanol on process energy costs and an average of $0.04 to 0.07/gallon on ethanol transportation costs to southeastern and eastern U.S. markets. Using baseline assumptions, a nominal 50 million gallon per year IPEP ethanol plant at Decatur, AL is projected to have a 10-year average after-tax ROI of 61.3% vs. 45.3% for a Pekin, IL NG plant. The sensitivity analysis indicated that a worst-case north AL IPEP scenario with a low average ethanol price ($1.55/gal), high average corn price ($3.37/bu), and other variables at baseline levels would result in a 10-year average after-tax ROI of 18.4%. This worst-case ROI for a north Alabama IPEP scenario would be reduced from 18.4% to 12.5% if the plant relied on NG (average projected price for the next 10 years of $6.94/MBtu) instead of process heat from a poultry litter energy plant at a baseline price of $4.94/MBtu NG displaced by the poultry litter. A north Alabama IPEP plant is projected to be very competitive with an eastern Corn Belt plant, have a very high rate of return with baseline conditions, and provide positive returns under worst-case conditions.

The economics of using poultry litter to provide process heat for a north Alabama IPEP ethanol plant were compared with the economics of the other primary alternatives to land application of poultry litter: (1) long-distance transport of unprocessed poultry litter, (2) pelletizing poultry litter, (3) composting poultry litter, and (4) electricity production for industrial uses or for sale to a utility grid. Each of these options is technically feasible. The main question is whether they are economical. Providing process steam for an IPEP system holds promise for being an economical alternative to local land application of poultry litter in concentrated poultry areas without financial incentives. In contrast, the other alternative uses of poultry litter evaluated will require significant financial incentives to achieve comparable profitability.

A fuel-cycle well-to-pump analysis indicated that current and near-future ethanol plants on average use 0.74 and 0.69 Btu of fossil fuel, respectively, per Btu of ethanol delivered to a refueling station pump. These estimates account for fossil energy used to produce fertilizers for corn, and other energy use for growing and transporting corn and producing and transporting ethanol. Using poultry litter rather than natural gas for ethanol process heat reduces the fossil energy requirement to 0.26 Btu of fossil fuel per Btu of ethanol delivered to a refueling station pump. This is a very significant improvement over gasoline which requires 1.23 Btu of fossil energy per Btu of gasoline on a well-to-pump basis; petroleum recovery, transportation, and refining and gasoline transportation to the pump account for 0.23 Btu fossil energy per Btu of gasoline and the fossil energy contained in gasoline itself accounts for 1.0 Btu of fossil energy per gallon of gasoline. Compared with gasoline, well-to-wheel greenhouse gas emissions were estimated to be 25% lower for current-case ethanol production, 40% lower for near-future case ethanol production, and 63% lower for near-future case ethanol production relying on poultry litter for process energy.

XXI. Publications

Blake, J.P. and J.B. Hess. 2005. Nutritional value of poultry litter ash fed to broiler chickens. p. 63. Poultry Science Association Abstracts. 94th Annual Meeting. July 31-August 3. Auburn University. Auburn, Alabama.

Blake, J.P. and J.B. Hess. 2005. Direct substitution of poultry litter ash fed to broiler chickens. p. 63. Poultry Science Association Abstracts. 94th Annual Meeting. July 31-August 3. Auburn University. Auburn, Alabama.

XXII. Outreach

See next page.

Table 1. Outreach Activities for the IPEP Feasibility Project.

Date	Organization	Location	Purpose
4/17/2003	Tennessee Valley Poultry Litter Task Force	Cullman, AL	Overview of proposed IPEP feasibility project
4/24/2003	Alabama Department of Agriculture & Industries	Montgomery, AL	Overview of proposed IPEP feasibility project
5/22/2003	Poultry Water Quality Consortium	Atlanta, GA	Overview of proposed IPEP feasibility project
6/17/2003	TN Valley RC&D Bio-Energy Conference	Hanceville, AL	Overview of proposed IPEP feasibility project
8/26/2003	Alabama Department of Agriculture & Industries Bioenergy Workshop	Montgomery, AL	Overview of proposed IPEP feasibility project
10/21/2003	IPEP project organizational meeting	Memphis, TN	Organize feasibility study; inform industry stakeholders about IPEP
10/30/2003	Monsanto	Memphis, TN	Update on IPEP project; options for Monsanto high fermentable corn
11/17/2003	BioCycle Renewable Energy Conference	Minneapolis, MN	Update on IPEP project
12/10/2003	PMC Marketing Group	Muscle Shoals, AL	Update on IPEP project
12/18/2003	TVA Regional Review	Chattanooga, TN	Update on IPEP project
2/16/2004	Monsanto	St. Louis, MO	Update on IPEP project; options for Monsanto high fermentable corn
3/18/2004	Tennessee Valley Poultry Litter Task Force	Cullman, AL	Update on IPEP project
5/3/2004	Cargill	Phone conference	Update on IPEP project; commercialization opportunities
5/19/2004	TVA Economic Development	Huntsville, AL	Update on IPEP project
5/25/2004	Poultry Water Quality Consortium	Atlanta, GA	Update on IPEP project
6/15/2004	General Marine Services	Guntersville, AL	Update on IPEP project; considerations for barge facilities
6/22/2004	Abengoa	Phone conference	Update on IPEP project; commercialization opportunities
7/13/2004	Center for Economic Development and Resource Stewardship	Nashville, TN	Update on IPEP project; commercialization opportunities
7/15/2004	Sand Mountain Electric Cooperative	Rainsville, AL	Update on IPEP project; electricity infrastructure and prices
8/2/2004	Tennessee Department of Agriculture	Nashville, TN	Update on IPEP project; IPEP opportunities in TN
9/9/2004	ICM	Central City, NE	Update on IPEP project; ethanol plant tradeoffs for IPEP
9/22/2004	IPEP project coordination meeting	Huntsville, AL	Review progress, coordinate; inform industry stakeholders re IPEP
10/19/2004	Tennessee Valley Poultry Litter Task Force	Cullman, AL	Update on IPEP project
11/10/2004	Alabama Economic Development Office	Montgomery, AL	Update on IPEP project; discuss potential state incentives
11/12/2004	Gold Kist grower and board member	Cullman, AL	Update on IPEP project
12/7/2004	Gold Kist executive	Cullman, AL	Update on IPEP project
2/10/2005	Tennessee Valley Poultry Litter Task Force	Cullman, AL	Update on IPEP project
4/18/2005	IPEP project coordination meeting	Huntsville, AL	Review progress, coordinate; inform industry stakeholders re IPEP
10/4/2005	Southern Nutrient Management Group	Memphis, TN	Presentation on IPEP and fertiliizer products from poultry litter ash
10/5/2005	North Carolina Animal Waste Sympposium	Raleigh, NC	Presentation on IPEP and fertiliizer products from poultry litter ash
10/11/2005	Eastern Biofuels Workshop	Atlanta, GA	Presentation on IPEP et al. alt. fuels for ethanol plant process energy
12/19/2005	Cameron Chemicals	Norfolk, VA	Discussion of commerial options for granulating poultry litter ash
1/1/2005	Decatur farmers group--potential ethanol plant	Decatur, AL	Started discusions concerning poultry litter for process energy
7/29/2006	Sand Mountain Poultry Litter Field Day	Crossville, AL	Discussed poultry litter supply considerations for IPEP
9/7/2006	Alabama Water Resources Conference	Mobile, AL	Presentation on IPEP project and use of PL ash as feed supplement