INTERREGIONAL COMPETITION IN THE BIOREFINERY INDUSTRY

by

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ABSTRACT

A major story in the recent history of US agriculture is the evolution and growth of the ethanol industry. A crucial factor in the profitability of an ethanol plant is the choice of its fixed location, as this has implications in the transportation costs associated with the acquisition of grain and sale of distiller's grains. When the industry was in its infancy, where to locate, often, was based on strictly local factors. Primary considerations were local availability of grain and producer and community investment interests. Today, the ethanol industry is more mature and consolidated. As such, investment criteria have broadened from a localized to a total systems perspective. The focus of this study was to analyze construction, abandonment, and expansion of plant locations in ethanol producing regions, and the effects of regional transportation costs on the geographic growth of the industry. Comparison to previous research provided the basis to evaluate industry change.

Current ethanol plant locations and their capacities were complied and compared with earlier data to identify plant exits, expansions and new construction. Aggregating those plant capacities by USDA crop reporting districts, feedstock consumption by biorefineries were calculated by crop reporting district, as was livestock feed demand from livestock numbers. Those data along with coarse grain production by crop reporting district were used to calculate excess feedgrain demand (supply) by region. Those regional data were used to construct linear programming network-flow models for the transportation of feedstock and for DDGS, respectively. Two models were used; the first was used minimize the interregional cost to transport feedstocks from excess supply regions to excess demand regions. The second was used to minimize the interregional cost to

transport DDGS from excess supply regions to excess demand regions. These regional transportation costs were combined to find the total interregional transport by crop reporting district. Differences in such interregional transport costs affect the competitiveness of plants across crop reporting districts and should affect the strategic position of each plant location. Current plant locations and transportation cost results were compared with those from previous research and, with additional consideration to changes in production factors, provided further understanding of the recent growth and development of the ethanol industry.

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CHAPTER I: INTRODUCTION

1.1 Introduction

The focus of this research is to study interregional competition in the biorefinery industry and to analyze the changes brought on over the past 5 years as it has gone from an infant industry to a more mature one. The biorefinery industry began, mostly, as locally owned and operated plants with annual capacities mostly under 10 million gallons per year (mgy). With the growth in demand for ethanol, the industry has evolved into more consolidated operations, many of which are owned by publicly listed investor companies. Many of the new plants have capacities over 100 mgy and operate with the newest technologies that offer greater efficiencies and higher quality DDGS. Finally, nutritionists in the livestock industries from beef to dairy to hogs to chicken have learned how to include DDGS in rations profitably, turning DDGS into a co-product instead of a by-product.

In this modern era, the earliest plants date to 1980 and were located in Iowa and Minnesota. It was in those areas that the local corn basis was the most negative of anywhere in the nation. That was because any corn not used there had to be shipped long distances, such as to export or barge ports or to the commercial feedlots on the High Plains. That long distance meant high transportation costs and a poor local basis than elsewhere. Consequently, corn growers and community leaders were interested in anything that would add value to the excess local supply of corn and promote local economic development. Those interests, either in combination or acting alone, invested in building those early ethanol plants. Their business strategy was strictly to add value to the local excess corn supply and to stimulate local economic development with no considerations of locational competitiveness. The latter could be expected because of the lack of competition at that time.

Stimulated by federal and state ethanol policies, the industry grew rapidly in the past decade. Biorefinery growth, new technologies and realization of major economies of scale, all have made significant changes to the industry , with the annual production growth stemming from increases both in number and size of biorefineries. There has also been significant consolidation of ownership. Current leaders in the industry, such as POET and Archer Daniels Midland, have acquired and expanded many smaller locally owned plants.

Another factor that has impacted the industry is the emergence of a strong market for wet distillers' grains with solubles (WDGS) and dried distillers' grains with solubles (DDGS). No longer is distillers' grain a by-product of limited value, but rather a co-product valued as a high-protein feedstuff for most livestock. That was driven by research in animal nutrition which provided the information on the use of WDGS and DDGS in rations and demonstrated their value in cost-effective rations. Today, both WDGS and DDGS are increasingly popular in animal rations. This growth is not strictly domestic, there is a strong export market for DDGS. The growth in the demand for these co-products is reflected in their prices. DDGS may even sell at a premium to corn in some areas because of its higher protein content.

Ryan McMillan's thesis on the biorefinery industry based on 2007 data and market conditions provides a historical base point for studying industry growth and development since 2007 (McMillan 2007). This research will follow a comparable study structure, with adjustments in estimation and calculation to account for the current nature of the industry. The average transportation cost for both grain and DDGS will serve as the primary basis of geographic comparison. With inputs and outputs being ,primarily, commodity products, transportation costs are the main source of interregional competition. The optimal flows and transportation costs are found using two linear programming network-flow transportation models: one for feedstocks—mostly corn—and the other for DDGS.

For regional designations, eleven states in or adjacent to the Corn Belt were divided into regions that coincide to the USDA crop reporting district lines. Those regions represent the majority of the corn and ethanol production in the US. Three adjoining states were made into state-wide regions. The remaining states were grouped into four multistate regions. Regional supply and demand estimates for feedstock and DDGS were determined using crop and livestock inventories from the National Agricultural Statistics Service (NASS) and using ethanol production data from the Renewable Fuels Association (RFA). RFA data will also allow comparison of the overall geographic distribution of ethanol production, and changes in ownership and operating capacity since McMillan's study.

1.2 History of Ethanol Industry

Growth and evolution of the ethanol industry has been closely tied to public policy. The 1978 National Energy Act established regulations for gasohol, gasoline containing at least ten percent alcohol from biomass. It also created a subsidy of 40 cents per gallon of ethanol blended into gasoline. The industry benefited further from the Energy Security Act of 1980, which insured loans for small ethanol producers and for the construction of new biorefineries (Cole 2006). At the time, fewer than 10 biorefineries were in operation with an annual output of 50 million gallons per year (mgy).

Early expansion resulted from a localized need to find a market for excess feedstocks in Iowa and Southwest Minnesota, where the corn basis is weakest throughout the whole country. This area is a heavy corn producer, but is distant from many corn consuming areas, including export terminals. One way to address the problem was to turn the corn into ethanol, a higher value product per pound and per cube space. That, combined with the policy incentives for small ethanol producers, led to the formation of many small, locally operated facilities in the area. By 1983, domestic ethanol production had grown to 600 mgy produced from 163 plants. The tax reform act of 1984 raised the effective subsidy to 60 cents per gallon of ethanol blended, which increased the incentive to produce ethanol. Despite the new federal incentives, the number of operating facilities decreased to 74 by 1985 (Cole 2006).

Amendments to the Clean Air Act in 1990 created fuel standards requiring reductions in carbon monoxide and smog emissions by the inclusion of oxygenate additives. This expanded the market for ethanol as it became the default oxygenator additive. States also began creating ethanol incentives--subsidies and tax credits--to encourage investment in ethanol production. By 1990, ethanol production had grown to 1 billion gallons per year (bgy), but the industry was still in a relatively infant state. Only seventeen biorefineries, operated by thirteen companies, could produce 10 or more mgy. The remainder of production came from numerous, locally-based facilities with less than 10mgy capacity (Informa Economics, Inc. 2005).

In response to increased demand, ethanol capacity increased to 3 billion gallons a year capacity in 2004, triple the 1990 capacity. The demand for ethanol as a fuel additive expanded further when many states banned the use of MTBE as an oxygenator, due to concerns over groundwater contamination from MTBE production. Additional federal energy policies sustained ethanol growth. The Renewable Fuels Standard in 2005 mandated 7.5 billion gallons of renewable fuel production by 2012. The Energy Independence and Security Act of 2007 raised the target to 15 billion gallons per year of starch based ethanol by 2015. As a result of industry profitability and policy incentives, domestic ethanol production grew from 4.5 bgy in 2005 to 10.2 bgy in 2009 (Westcott 2007).

During this period of rapid growth, considerable gains were made in the efficiency of biorefinery operation. From 1993 to 2007 ethanol yields increased by 10 percent, resulting in an average additional revenue of 31 cents per bushel of capacity. At the same time, unit production costs shrank by 30 percent, and non-operating expenses shrank significantly, too. Part of the efficiency gain was from exploiting the economies of scale that leaders in the industry realized were possible. In 2007 Gallagher et al found that 90 to 110 mgy was the optimal size (Gallagher, Shapouri and Brubaker 2007).

This increased efficiency in production, specifically the improved yields, provided another unsuspected benefit, higher quality DDGS, which created greater value for livestock producers using DDGS. The newer, more-efficient production processes use more of the starch and sugar, resulting in DDGS higher in protein and easier to handle and store. With higher quality DDGS, better understanding of using DDGS in livestock rations, and increased availability of DDGS, DDGS became a co-product instead of a by-product. It became a co-product because it was no longer a low value product to dispose of, but rather a valuable and desired feed source (Markham 2005).

The efficiency gains and expansion of DDGS markets have enabled the ethanol industry to become the mature, economically viable business it is today. Despite the expiration of federal ethanol subsidies in January 2012, ethanol production is at a high point with 211 operating facilities having a combined capacity of 13.7 bgy (Renewable Fuels Association 2012).

CHAPTER II: LITERATURE REVIEW

This section contains examination of previous research that is relevant to this study: studies of the ethanol industry—in general, on feeding DDGS, and studies using network flow models in agricultural research.

2.1 Ethanol Market Studies

A study by Informa Economics in 2005 examined the outlook and structure of the US biofuel industry. The research consisted primarily of policy effects on the industry, addressed previously, and the relationship between ethanol production and feedstocks, specifically corn. Because 90 percent of ethanol capacity at that time relied on corn as the feedstock, the conclusion was that biorefinery demand for corn is relatively inelastic, due to its necessity in production and the lack of a readily available substitute. Thus, the supply of and the price of corn was found to be key to biorefinery profitability (Informa Economics, Inc. 2005).

Tokgoz and Elobeid, in their 2006 research, shared the same conclusion, showing the influence of the gasoline, sugar, and corn markets on the production and profitability of ethanol production. It was shown that feedstock price was the key determinant in both the price of ethanol and the profitability of production. The authors also found that competition between ethanol production and other feedstock users critically influenced biorefinery profitability (Tokgoz and Elobeid 2006).

The 2006 USDA guide to assessing ethanol plant requirements identifies feedstocks, transportation, and markets for DDGS as keys to plant operation. In addition, water and energy availability influence location of production. The guide's recommendation for researching the feasibility of locating a biorefinery is to begin by assessing feedstock availability and the market and preferences for DDGS in the area.

Proximity to feedstocks is the suggested focus of choosing a plant location. The next step is to then consider the methods of transportation available (United States Department of Agriculture; Nebraska Ethanol Board 2006).

An article in the 1984 Southern Journal of Agricultural Economics by Baldwin, Thraen, and Larson, using multivariate linear discriminant analysis, isolated the economic variables which associate with the type and mix of grain processing facilities in the South and Corn Belt. It was theorized that the structural differences in grain market regions could be explained by differences in local grain supply. Using USDA crop-reporting districts as the unit of analysis, Baldwin calculated estimates of corn demand for processing and livestock production in each area. The three conditions significantly affecting grain processing facility growth and development were corn supply, corn demand, and transportation for corn and DDGS (Baldwin, Thraen and Larson 1984).

A 2007 publication by the Economic Research Service reviews impact on the agricultural sector resulting from the expansion in US ethanol production. The primary impacts were from the increased corn demand and subsequent price. Higher corn prices resulted in increased corn production and a shift away from other crops, especially soybeans. Despite the increase in corn production, the increased corn utilization was expected to deplete domestic corn stocks and bring greater volatility to the corn and soybean markets. The increases in corn consumption for ethanol production were projected to reduce corn exports and corn used as livestock feed by approximately ten percent. Reduced corn consumption would reflect substitution away from the high priced corn to lower cost feedstuffs whenever possible, and a reduction in livestock inventories. Another projection was that eventually a decrease in ethanol margins would shift the view of DDGS from that of a byproduct to a co-product, to take advantage of its use as a livestock feed ingredient (Westcott 2007).

While research by ERS and others focused on market conditions and government policy as factors affecting expansion of the biofuel industry, Gallagher et al [2007] studied the effects of scale operation and other organizational issues on biofuel profitability. He found numerous gains due to improved production efficiency and from reducing non-operating expenses. The authors suggest that these cost reductions are due in part to the discovery of the optimal scale of production. He found the optimal plant size was between 91 and 108 mgy, depending on the organizational structure. Whether the organization is strictly a processor, a producer/processor, or a profit seeking cooperative has an effect on the optimal scale of operation. At the optimal size, ethanol production in 2007 was found to be a profitable enterprise, with a return on capital of 14 percent (Gallagher, Shapouri and Brubaker 2007).

2.2 Dried Distillers' Grains with Solubles

Steve Markham [2005] researched the impact of DDGS on grain and livestock markets. At the time of the study, 40 percent of dry-grind co-product was sold as wet distiller's grains with solubles (WDGS). The advantage of using WDGS is the reduced cost of not drying the co-product. Dryers for DDGS are the biggest source of energy consumption and of pollution for a biorefinery. Removing just one pound of water from WDGS requires 1,200 BTUs. However, WDGS cannot be shipped long distances, and rail transportation requires private railcars because of the common problem of lodging in the cars. The high cost of freight for DDGS slowed export growth at that time. He noted, however, that the new, better processing technology reduced the amount of residual starches and sugars in the DDGS, which improved DDGS handling characteristics and palatability, as well as increased its protein content. These improvements in DDGS quality allowed for expanded use in the livestock feed market, particularly for monogastric species such as swine. The high quality DDGS increases the ability of simple stomached animals to digest the available amino acids as well as phosphorus, which is not digestible in corn. The digestibility of phosphorus is a key benefit, as it reduces the need for expensive feed additives, which result in more phosphates in the manure. At the time of the study several states had enacted legislation limiting phosphate levels in manure, and in some areas shifting to a ration including DDGS was essentially required (Markham 2005).

Another ERS publication [2011] examines the potential domestic market for DDGS and their substitutability for corn and soybean meal in livestock feed. The potential consumption of DDGS for various classes of livestock was estimated by both market share and the extent of inclusion. Inclusion rates were estimated for each class of livestock and applied to an appropriate ration to establish a daily DDGS intake for each class. This figure was then multiplied by an average annual days fed to determine a yearly per head consumption estimate for each livestock class. ERS used those values to estimate potential demand for each class of livestock. That was done by multiplying annual head figures from NASS and the USDA to give the potential demand for each class. This potential demand was also projected forward, using livestock projections for 2020/2021. It was estimated that the share of potential demand by species would remain relatively stable over that timeframe, with beef cattle having a 49 percent share, dairy 25 percent, swine 14 percent, and poultry 12 percent. The potential rations were also used to approximate the rate DDGS can be substituted for both corn and soybean meal. It was found that in aggregate one metric ton of DDGS can replace a combined 1.22 metric tons of corn and soybean meal (Hoffman and Baker 2011). (I used the work, above, to estimation livestock consumption for my thesis research, here.)

2.3 The Transshipment Problem Using Linear Programming

In 1995 Ziari et al. conducted an analysis of the effects of new grain cleaning standards on the sorghum market using a cost minimization model. A transshipment model was used to determine the location of new grain cleaning facilities, as well as to estimate the additional systems cost imposed by the new standards. The model identified elevator locations and their operating and transportation costs in addition to supply and demand regions. Grain movement was optimized for the flow amongst regions, terminal elevators, barge loading and unloading sites, and terminal ports by truck, rail, or barge (Ziari, et al. 1995).

King and Logan [1964] used a cost minimization transshipment LP to determine the location and size of slaughterhouses in California, given the location and quantity of livestock and demand for the final products. Costs were minimized for the flow of livestock from producers to processors to the final customer. The size of the potential facilities was also taken into consideration. A second model included parameters representing estimates for economies of scale (King and Logan 1964).

A 1978 article by Fuller and Shanmugham in the Southern Journal of Agricultural Economics conducts an evaluation of network flow models for use in solving rural freight problems. A cost minimization transshipment model was used to optimize movement of wheat from farm to elevator to inland and port terminals. Both truck and rail transportation was available for each leg except for the farm to elevator segment. The authors found the network flow framework to be an excellent choice for this type of problem, and it had superior solution efficiency to other methods (Fuller and Shanmugham 1978).

CHAPTER III: METHODS

3.1 Data Collection and Scope

The data used in conducting this research can be thought of in two primary categories: biorefinery data and livestock inventories and feedstuff production. The Renewal Fuels Association (RFA) ethanol plant list was used to determine locations and capacities of existing biorefineries and of those under construction. That information provides a picture of the current geographic structure of the industry. Previous research by McMillan [2007] provides data that will allow historical comparison of the industry to determine plant closures, expansions, and other geographic shifts. Average and total capacity figures also provide an understanding of changes in the scale of production.

The plant location and capacity data is also used to estimate regional grain demand from biorefineries and to determine DDGS supply. For this estimation it was assumed that one bushel of corn produces approximately 2.7 gallons of ethanol and 17.5 pounds of DDGS (Swenson and Eathington 2006). Another component necessary for the supply estimation was regional inventories of livestock and feedstock production, which were compiled using USDA Agriculture Census and NASS survey data. Human and industrial consumption of feedstocks also have an impact on the excess supply of feedstocks and DDGS, but were not accounted for as regional figures were not available.

The total feedstock available in an area was determined to be the sum of its 2011 corn and grain sorghum production. Beef and dairy cattle, poultry, and swine are the primary consumers of feedstocks and DDGS, and livestock inventory categories were chosen to determine their regional presence. For beef cattle, classes were included for the inventory of cattle on feed, beef cows, and other cattle. Other cattle are grain fed bulls, cows, and calves not in feedlots, and are assumed to be primarily located in backgrounding operations. Regional inventories of producing dairy cows were used for the dairy cattle classification. Swine were divided into market hog and breeding inventories. The poultry classifications included laying hens and broilers. The sources for the inventory classes are listed below.

*When the summation of regions within a state was less than the reported total for the state, the difference was split equally between the regions.

Ethanol Production

- Regional & State

  Renewable Fuels Association Biorefinery List 6/13/12

Corn

- Regional

  NASS 2011 Survey: Corn, total annual grain production in bushels, by USDA crop reporting district*
- State

  NASS 2011 Survey: Corn, total annual grain production in bushels, by state

  *Minnesota districts 20 & 30 shown combined at 1,948,000 bu, split equally at 974,000 bu per district

Sorghum

- Regional

  NASS 2010 Survey: Sorghum, total annual grain production in bushels, by USDA crop reporting district*
- State

  NASS 2010 Survey: Sorghum, total annual grain production in bushels, by state**

  *No data for Indiana, Iowa, Michigan, Minnesota, North Dakota, and Wisconsin.

  Illinois: districts 10, 20, 30, 40, 50, &70 combined at 728,000 bu, split equally at 121,333 bu per district

  Missouri: districts 10 & 20 combined at 283,000 bu, split equally at 141,500 bu per district

  Nebraska: districts 20 &30 combined at 80,000 bu, split equally at 40,000 bu per district

  South Dakota: districts 10, 20, 30, 50, 60, 70 combined at 551,000 bu, split equally at 91,833 bu per district

  **No data for Northwest or Northeast subregion, California, Nevada, Utah, Alabama, Florida, South Carolina, and Tennessee

Total Grain

- Regional & State

  Sum of corn and sorghum data for that region*

  *Illinois district 20 adjusted for 2,065,000 bu of export demand, Texas adjusted for 113,100,000 bu of export demand, subregions Northwest, Northeast, Southwest, and Southeast adjusted for 365,641,000 bu; 5,046,000 bu; 1,467,000 bu; and 1,080,468,000 bu respectively

Cattle on Feed

- Regional

  2007 USDA Census of Agriculture December 31 cattle on feed inventory in head by county is aggregated by USDA crop reporting district. Then a district's percentage share of the state total was used as a weight and multiplied by the state's January 1, 2011 cattle on feed inventory in head from NASS survey data*

- State

  NASS 2011 survey: January 1 cattle on feed inventory in head by state**

  *Kansas and Minnesota use NASS 2011 survey: January 1 cattle on feed inventory in head by county aggregated by USDA crop reporting District

  ** an average number of 5,106 hd per state was determined using the unspecified total for Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, North Carolina, Rhode Island, Vermont, New Mexico, Alabama, Florida, Georgia, Louisiana, Mississippi, and South Carolina

Beef Cows

- Regional

  NASS 2011 Survey: January 1 beef cow inventory in head by county aggregated by USDA crop reporting district*

- State

  NASS 2011 Survey: January 1 beef cow inventory in head by state

  *Michigan and Wisconsin calculated using 2007 USDA Census of Agriculture December 31 beef cow inventory in head by county, aggregated by USDA crop reporting district. Then a district's percentage share of the state total was used as a weight and multiplied by the state's January 1, 2011 beef cow inventory in head from NASS survey data

Dairy Cows

- Regional

  NASS 2011 Survey: January 1 milk cow inventory in head by county aggregated by USDA crop reporting district*

- State

NASS 2011 Survey: January 1 milk cow inventory in head by state

*Nebraska calculated using 2007 USDA Census of Agriculture December 31 milk cow inventory in head by county, aggregated by USDA crop reporting district. Then a district's percentage share of the state total was used as a weight and multiplied by the state's January 1, 2011 milk cow inventory in head from NASS survey data

Other Cattle

- Regional

Calculated using NASS 2011 Survey: January 1 cattle including calves total inventory in head by county aggregated by USDA crop reporting district. This total cattle inventory less cattle on feed, beef cow, and dairy cow data gives the other cattle value.

- State

Calculated using NASS 2011 Survey: January 1 cattle including calves total inventory in head by state. This total cattle inventory less cattle on feed, beef cow, and dairy cow data gives the other cattle value.

Market Hogs

- Regional

2007 USDA Census of Agriculture December 31 total market hog inventory in head by county is aggregated by USDA crop reporting district. Then a district's percentage share of the state total was used as a weight and multiplied by the state's January 1, 2011 total market hog inventory in head from NASS survey data

- State

NASS 2011 Survey: January 1 total market hog inventory in head by state*

*Idaho and Washington use 1,314,000 head average of unspecified total

Breeding Swine

- Regional

2007 USDA Census of Agriculture December 31 total breeding hog inventory in head by county is aggregated by USDA crop reporting district. Then a district's percentage share of the state total was used as a weight and multiplied by the state's January 1, 2011 total breeding hog inventory in head from NASS survey data

- State

NASS 2011 Survey: January 1 total breeding hog inventory in head by state*

*Idaho and Washington use 206,500 head average of unspecified total

Broilers

- Regional

  2007 USDA Census of Agriculture December 31 total broiler inventory in head by county is aggregated by USDA Crop Reporting District. Then the 2007 district amount is adjusted for a -3.16% growth rate* to give the 2010 estimate.
- State

  2007 USDA Census of Agriculture December 31 total broiler inventory in head by state. Then the 2007 amount is adjusted for a -3.16% growth rate* to give the 2010 estimate.

  *national growth rate calculated using 2007 USDA Census of Agriculture December 31 broiler inventory national total and NASS 2011 Dairy and Poultry Stat Book national broiler inventory total.

Laying Hens

- Regional

  2007 USDA Census of Agriculture December 31 total laying chicken inventory in head by county is aggregated by USDA crop reporting district. Then a district's percentage share of the state total was used as a weight and multiplied by the state's 2010 total laying chicken inventory in head from NASS 2011 Dairy and Poultry Stat Book
- State

  NASS 2011 Dairy and Poultry Stat Book: table 8-36 2010 total layers in head by state*

  *Kansas, North Dakota, Idaho, Delaware, New Hampshire, New Jersey, Rhode Island, Arizona, Nevada, and New Mexico use other state average of 721,455 head per state

To complete the estimation, figures were needed for the potential yearly consumption of grain and DDGS per head for each class of livestock. Research by the Economic Resource Service provided estimates for DDGS consumption by class (Hoffman and Baker 2011). These estimates are for the potential consumption of DDGS, and represent the maximum inclusion level in each particular diet. They do not take into account regional differences in inclusion rates, which are effected by local prices. Feedstock consumption amounts were calculated using the framework from the ERS research with information on corn inclusion in rations. Calculations are included in the appendix. The estimates of annual consumption per head used are shown below in table 3.1.

Table 3.1 Estimate Annual Feed Consumption per head

	pounds consumed (lb/head)	
Livestock Class	Feedstock	DDGS
Cattle on Feed	4,065	3,106
Beef Cows	517	320
Other Cattle	899	337
Dairy Cows	7,254	3,669
Market Hogs	952	250
Breeding Swine	1,370	489
Laying Hens	44	9
Broilers	39	8

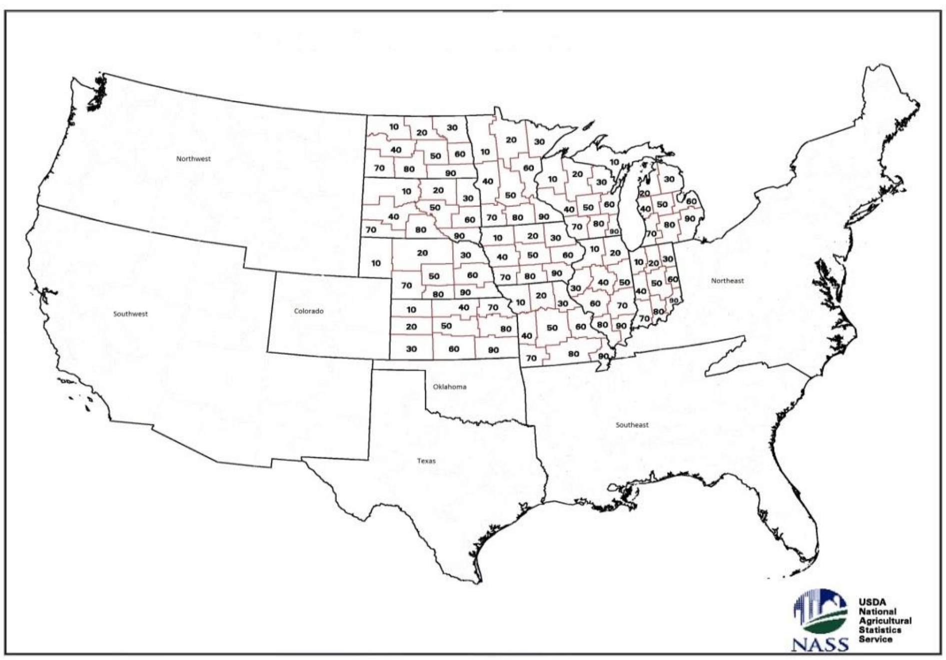
The transportation costs for the linear programming models were calculated using distances from Google maps, and average trucking cost per mile of $2.56 per ton was obtained from the Agricultural Marketing Service (AMS) grain transportation advisory (United States Department of Agriculture 2012). To determine interregional distances an identifying city was chosen for each region, typically the county seat of the most central county of the region. BNSF shuttle train routes and tariff rates were used to determine rail transport costs for the grain model. AMS grain inspection reports were used to determine regional feedstock export demand (United States Department of Agriculture 2012). Regional export demand for DDGS was estimated using AMS data on exports by destination and a list of US port locations; calculations are included in the appendix.

3.2 Supply and Demand Estimation

3.2.1 Regions

For the purposes of this research regional boundaries were assigned for supply and demand estimation and use as regions in the transportation models. Eleven states in the corn belt and northern plains; Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin, were the primary area of interest, as these states contain the majority of the ethanol and corn production in the country. Each of those states was divided into nine districts (based on USDA crop reporting district) with the exception of Nebraska, which has only eight. The thirty seven states in the continental US outside the primary area are combined into seven secondary regions. Colorado, Oklahoma, and Texas were each assigned their own secondary region due to their proximity to the primary area and the amount of livestock demand present. The remaining thirty four states were then aggregated into the last four secondary regions, Northeast, Northwest, Southeast, and Southwest.

Figure 3.1 Regions of Study



3.2.2 Feedstock

The first step used in the estimation of feedstock supply and demand was to determine the supply in the area using the total grain inventory figure. Next the grain demand was calculated for ethanol production in the area and the feeding of livestock. The estimate that one bushel of corn produces 2.7 gallons of ethanol is used to calculate the corn demand for ethanol production. Thus, the annual ethanol production of the region in gallons is divided by 2.7 to determine the bushels of grain required for the amount of production.

The feedstock demand for livestock feeding is calculated using the regional inventories for the eight classes of livestock and estimates on yearly per head grain consumption by class. The grain demand of each class of livestock is calculated by multiplying the livestock inventory in head by yearly per head consumption estimates. Grain Supply in a region was then reduced by the grain allocated to ethanol and livestock production in that region to determine the excess supply (demand) of feedstock in a region. In regions that contain a major shipping port, supply was also reduced by the bushels of grain estimated to be exported. These excess supply figures were the values used in the model.

3.2.3 DDGS

The gross supply of DDGS for each region was calculated using the bushels of grain needed for ethanol production. For this calculation, the bushels of grain used in the region's ethanol production were multiplied by the estimated 17.5 pounds of DDGS produced by each bushel of corn used. This regional supply is then reduced by the estimated consumption of DDGS by its livestock inventory.

DDGS consumption was determined by allocating estimated national DDGS production amongst the classes of livestock and then by region. National DDGS pounds of production were divided into species, with 41% for beef cattle, 39% for dairy, 10% for swine, and 9% for poultry, giving the estimated actual DDGS consumption by species.

Estimates of potential consumption are then used to allocate these estimated actual amounts by livestock class and region.

The national potential consumption was calculated using both national inventory totals and estimates of potential consumption from ERS for each class of livestock. The ERS figures are given in potential annual consumption per head. These estimates are then multiplied by the total number of head nationally for each corresponding class of livestock, giving the potential annual consumption of DDGS for each class. This potential DDGS consumption was then aggregated by species to correspond with the estimated actual consumption categories of beef cattle, dairy cattle, swine, and poultry. The percent share of the potential consumption of each class of livestock relative to its corresponding species then serves as a weight to distribute the actual consumption from species to class of livestock. For example the species beef cattle is composed of three classes: cattle on feed, beef cows, and other cattle. The potential consumption of cattle on feed is 65.58% of the potential consumption for all beef cattle. We multiply the estimated actual consumption of all beef cattle by the 65.58% share of cattle on feed to determine the actual pounds consumed by cattle on feed. The same is done for beef cows and other cattle, and for the other three species. This gives actual pounds of DDGS consumed nationally by each class of livestock.

These national class totals are then allocated to the regions based on the regions weight for that livestock class. The regional weights used are the region's share of the national total for that livestock class. For example, the number of cattle on feed inventory in the region divided by the national total of cattle on feed would be that region's weight for the class cattle on feed. This weight is then multiplied by the national pounds of DDGS consumption for cattle on feed to determine the cattle on feed consumption for that region. This continues for the other seven classes for the region, and on through the other regions, giving regional consumption estimates for each class of livestock. The regional supply of DDGS is then reduced by the regional amount of consumption estimated for each class of livestock to determine the excess supply (demand) in the region. In regions containing ports, DDGS supply was reduced by the estimated amount DDGS shipped in the region to account for export demand.

CHAPTER IV: MODELS

This section will discuss the two network flow linear programming models for the movement of feedstocks and DDGS, respectively. The biorefineries already exist at a fixed location, allowing the analysis of DDGS and feedstocks in separate models with no loss in accuracy. Both models were solved using the General Algebraic Modeling System (GAMS) software using the MINOS solver. The primary difference between the two models is that the feedstock model is a transshipment problem, while the DDGS model is a simpler transportation model. This difference is primarily due to the absence of rail transportation for DDGS without private ownership of railcars. In the grain model, it is possible to truck grain from a supply region without rail service to a nearby region where it is available to take advantage of the potential costs savings of rail transport over longer distances. This inclusion of a transshipment point is not possible in the DDGS model, as rail service is considered unavailable and a constant trucking rate per mile was used, no benefit can be gained in diverting from a direct path between two regions.

4.1 Feedstock

This model uses a transshipment network flow linear programming format to determine routes and shipment quantities that minimize the total cost of the movement of grain from supply to demand regions. The interregional transportation costs include figures for both truck and rail transportation, with rail rates replacing truck rates for routes where it is available. Supply and demand regions are not expressed as separate sets of variables, but rather all 105 regions are listed together, with a duplicate set being made to illustrate movement between locations. This results in a 105 by 105 matrix of possible shipment paths. The amount of excess supply or demand in a region is expressed as a single figure, with supply amounts being expressed as negative and demand as positive. This organization as a single set and a single parameter allows for the transshipment nature of the model; that is grain can flow through as many regions as is desired regardless of demand or supply, rather than being restricted to a direct path between two regions. All regions are allowed to function as transshipment nodes. This allows the incorporation of potential cost savings from intermodal transportation. The mathematical representation of the model is as follows.

$Min\ Z = \sum_k \sum_{kk} C_{k,kk}\, X_{k,kk}$

Subject to:

1. $\sum_{kk} X_{kk,k} - \sum_{kk} X_{k,kk} \leq W_k$
2. $X_{k,kk} \geq 0, \forall k, kk$

Where:

k = set of 105 supply and demand region origins

kk = copy of set k to represent destinations

Z = total transportation costs for feedstocks, the sum of the cost of moving each quantity

$C_{k,kk}$ = the cost of moving 1 bushel of grain from region k to region kk

$X_{k,kk}$ = the quantity of grain in bushels moved from region k to region kk

$\sum_{kk} X_{kk,k}$ = the total flow of grain in bushels into region k

$\sum_{kk} X_{k,kk}$ = the total outflow of grain in bushels from region k

W_k = the amount of excess demand (supply) for grain at region k

The objective is to minimize (Z) the total transportation costs for all feedstock movement in the model. The purpose of the first constraint is to ensure that the flow of grain between regions balances. A region cannot supply more grain than it has available, and similarly a region cannot be supplied with more grain than it has demand for. The constraint is structured as a region's inflows less outflows must be less than or equal to the excess supply/demand parameter for that region. In the case of a demand region the parameter is positive; the constraint ensures the net flow into the region cannot exceed the demand present. For a supply region the parameter is negative ensuring the left-hand side is negative with outflows exceeding inflows. However; the net outflow cannot be greater than the available supply. With both net outflows and regional supply being expressed as negative values a less than or equal to sign enables this relationship.

A ≤ relationship is imposed because the total demand for feedstock exceeds the available supply. Under these circumstances, it is impossible for all demand to be satisfied. In the opposite scenario, where supply exceeds demand, the sign should be changed to a greater than or equal to, to ensure that all regional demand is met (Ragsdale 2011). The second constraint is a simple non-negativity constraint for the shipment amounts, as it is impossible to ship a negative amount of something.

4.2: DDGS

This model uses a linear programming transportation problem to determine the routes and shipment quantities of DDGS to find the least cost movement between supply and demand regions. The sets of supply (i) and demand (j) nodes consist of 49 and 56 regions respectively. Values for supply (S_i), demand (D_j), and interregional transportation costs (C_{ij}) are those previously estimated. A mathematical representation of the model is as follows

$$Min\ Z = \sum_i \sum_j C_{ij}\, X_{ij}$$

Subject to:

1. $\sum_j X_{ij} \leq S_i$

2. $\sum_i X_{ij} \geq D_j$

3. $X_{ij} \geq 0, \forall i, j$

Where:

i = a set of DDGS supply nodes

j = a set of DDGS demand nodes

Z = total transportation costs for DDGS

C_{ij} = the cost of moving one ton of DDGS from node i to node j

X_{ij} = the quantity of DDGS in tons shipped from node i to node j

S_i = supply of DDGS in tons available at node i

D_j = demand for DDGS in tons at node j

The objective is to minimize (Z) the total transportation costs incurred by the movement of DDGS. It is the sum of the costs of moving each individual quantity between two nodes. The first constraint ensures that the outflows of DDGS from supply node i do not exceed the available supply at that node. In this case the supply of DDGS slightly exceeded the demand estimates, so all of the supply available in an area may not be moved. Due to this relationship the constraint is held to equality or less rather than at exact equality. The second constraint states that the amount of DDGS flowing into demand region j must meet the demand in that region. Since the overall supply for the model exceeds demand and the supply constraint doesn't impose equality, it is necessary to impose the condition for demand nodes, so that all demand is met. Without this constraint, the model would show no shipments being made, because it is a cost minimization and no costs are incurred if nothing is shipped. This demand constraint could also be expressed at equality, but as mentioned above, excess product will not be shipped because it would add additional costs (Ragsdale 2011). The last constraint requires shipment quantities be non-negative.

CHAPTER V: RESULTS

5.1: Feedstock Model Results

This chapter contains a review of the results from the feedstock network flow model. The focus will be on the results of feedstock movements into demand regions having ethanol production. Only interregional costs are considered, thus all intraregional transportation costs are ignored (treated as $0). In this scenario the only regions incurring transportation costs are those that require grain from other regions. (Results for the 7 secondary regions were not included, as they are too large to relate to a particular biorefinery.) The demand estimates for feedstock exceeded the available supply by 84.3 million bushels, due in part to the inclusion of ethanol capacity from planned expansions. The demand will not be fully satisfied for each region; however, the excess demand is less than one percent of the total corn supply, so effects are minimal.

5.1.1: Feedstock Average Transportation Costs

There were 16 demand nodes with ethanol production located in the 11 state primary region. The grain shipment routes and quantities determined by the transshipment model were used to calculate the total and average transportation costs for each of these 16 nodes. Shipment quantities were multiplied by their corresponding transportation cost per bushel to yield the cost of the shipment. These shipment costs are summed by demand node to give the total transportation costs incurred by that region. The total transportation cost for the region is divided by the total bushels of feedstock consumed in the region to give the average transportation costs per bushel. Locally produced grain is considered to have no transportation costs. In the model solution no demand nodes were used as transshipment nodes, but in the case this occurs the least expensive grain is assumed to be used locally and the more expensive shipped on.

5.1.2: Cost per Unit of Production

Average transportation costs per bushel were converted to the average transportation cost per million gallons of ethanol production. This conversion allows for a more informative comparison of the costs for each region, and better focus of the impact on ethanol production. The conversion uses the estimate of 2.7 gallons of ethanol production per bushel of grain consumed to determine the number of bushels necessary to produce one million gallons of ethanol. The amount of bushels is then multiplied by the average cost per bushel to give the cost per million gallons.

Table 5.1 Feedstock Interregional Transport Cost

Average Interregional Cost per million gal production		
Plant Region	$/million gal. production	
NE60	$	6,624.27
ND60	$	8,361.25
KS30	$	9,543.63
IN20	$	11,851.44
IA10	$	13,094.57
WI80	$	13,789.99
WI50	$	15,295.12
KS50	$	15,580.05
KS80	$	20,092.80
MO20	$	26,938.64
WI60	$	35,839.14
MO50	$	49,248.41
IA60	$	55,709.59
WI20	$	62,598.97
ND40	$	127,784.09
ND70	$	147,519.16

The regional costs varied widely, even within the same state. For example, North Dakota contained both the region with the second lowest cost and the two regions with the highest cost. Overall, the average cost for the group as a whole was $38,741 per million gallons of ethanol production. Only five of the 16 regions had regional average costs that exceeded this group average, showing it is skewed slightly upward.

5.2: DDGS Model Results

This section contains a review of the results from the DDGS transportation model. Similar to the feedstock model, intraregional transportation costs are assumed to be $0 and results for the 7 secondary regions were not included. The focus will be on the results of DDGS movements from ethanol producing regions to those with demand for DDGS. In this case, regions incurring cost are those that have excess DDGS to ship to other areas, opposed to the feedstock model which focused on demand nodes. The demand estimates for DDGS were slightly less than the available supply, due almost entirely to computer rounding errors in applying the district weights for regional livestock consumption estimates. The excess supply will be left over in a region or regions, but the potential for DDGS consumption exceeds the estimates used so it would likely still be consumed within the region. The effects of this difference will be minimal, as the excess is less than a quarter of one percent of the total supply.

To ensure the shipment paths and quantities determined by the model were reasonable, an interview was conducted with a specialist in the livestock industry who is familiar with DDGS movements in the U.S. A key point of the discussion was that Texas, Nebraska, and Kansas are primary drivers in the market, and the gross demand for DDGS in those regions should be of roughly equal proportions to give an accuarate picture.

5.2.1: DDGS Average Transportation Costs

There were 49 DDGS supply nodes located in the 11 state primary region. The shipment routes and quantities determined by the transportation model were used to calculate the total and average transportation costs for each of these 49 nodes. Similar to the feedstock model, shipment quantities were multiplied by their corresponding cost per ton to yield the cost of the shipment. However; the shipment costs are summed by supply node rather than demand node to give the total transportation costs incurred by that region. The total transportation cost for the region is divided by the total tons of DDGS produced in the region to give the average transportation costs per ton. Locally consumed DDGS is considered to have no transportation costs.

5.1.2: Cost per Unit of Production

As in the feedstock model, the average transportation cost per ton were converted to the average transportation cost per million gallons of ethanol production to enable a more informative comparison of the costs for each region, and better focus of the impact on ethanol production. With the bushels of grain per million gallons of production already calculated, it is simply multiplied by the yield of 17.5 pounds of DDGS produced by each bushel of grain used in ethanol production. This value is then divided by 2000 to change units from pounds to tons. The amount of tons is then multiplied by the average cost per ton to give the cost per million gallons.

As in the feedstock model, the resulting costs display a wide range of regional variation, including within a state. Overall, the average cost for the group as a whole was $147,916 per million gallons of ethanol production. Twenty three of the 49 regions had a regional average cost that exceeded this group average, again showing a slight upward skew.

Table 5.2 DDGS Interregional Transport Cost 1

Plant Region	Average Interregional Cost per million gal production < $200,000 $/million gal. production
IN10	$ 948.12
MN50	$ 1,920.63
KS60	$ 8,045.30
MI80	$ 10,166.32
WI50	$ 15,005.03
WI80	$ 17,734.71
KS50	$ 20,159.44
IA30	$ 23,745.68
MO10	$ 29,842.18
NE80	$ 34,571.45
IL80	$ 37,590.91
NE30	$ 49,143.89
ND30	$ 52,546.73
IL30	$ 61,973.38
IL70	$ 66,273.23
IA90	$ 80,834.59
NE90	$ 88,316.04
NE70	$ 113,503.52
IN70	$ 113,845.17
MO30	$ 114,369.96
IN30	$ 114,840.37
MI90	$ 129,597.59
MN80	$ 134,122.41
IN60	$ 143,366.40
IN40	$ 143,888.02
IN50	$ 144,473.78
IA50	$ 153,892.44
IL50	$ 155,807.53
SD90	$ 167,162.51
IL10	$ 169,549.75
IA10	$ 178,568.03
IN20	$ 182,402.45
NE50	$ 185,916.41
IA70	$ 190,291.30
MN70	$ 195,699.99

Table 5.3 DDGS Interregional Transport Cost 2

Average Interregional Cost per million gal production		
> $200,000		
Plant Region		$/million gal. production
MO20	$	203,231.75
IL40	$	217,383.83
MN40	$	226,517.25
IA60	$	228,451.90
ND70	$	233,905.90
ND40	$	235,196.18
SD60	$	289,189.44
IA20	$	295,189.18
SD30	$	296,366.68
ND90	$	312,552.10
SD20	$	322,203.57
NE60	$	326,820.14
IA40	$	335,484.04
ND60	$	395,286.59

To further review the highest cost DDGS shipment paths, all shipments of DDGS traveling over 500 miles were compiled in table 5.4. The shipment cost per mile remains consistent across all paths in the model, so distance is an effective measurement of this price differential. Due to the geographic proximity of the primary region of study, the majority of these shipments are to the 7 subregions. The shipments are grouped by the destination region. These long distance shipments are responsible for a large portion of the total DDGS transport cost. The majority of the costs for industry movement of DDGS as determined by this model stem from these long distance shipments rather than the more numerous shorter movements.

Table 5.4 DDGS Shipments by Destination

Shipment distance > 500 miles			
to Northeast			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
IL10	666.96	$ 60,647,221.27	$ 90.93
IL40	872.24	$ 75,919,488.46	$ 87.04
IN20	731.31	$ 51,072,686.82	$ 69.84
IN30	218.47	$ 13,780,844.02	$ 63.08
IN50	245.83	$ 16,689,887.86	$ 67.89
IN60	235.30	$ 14,336,639.89	$ 60.93
IA60	852.59	$ 83,026,866.02	$ 97.38
MI90	213.91	$ 13,427,262.48	$ 62.77
to Southeast			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
IL40	854.58	$ 55,306,002.64	$ 64.72
IL50	275.15	$ 15,580,753.23	$ 56.63
IL70	66.95	$ 3,181,115.34	$ 47.51
IL80	38.01	$ 1,669,929.27	$ 43.93
IN40	781.26	$ 38,240,643.17	$ 48.95
IN70	638.98	$ 25,387,472.77	$ 39.73
to Northwest			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
MN40	288.00	$ 39,134,258.48	$ 135.88
MN70	289.36	$ 39,289,761.72	$ 135.78
MN80	38.62	$ 5,599,591.71	$ 145.00
ND40	120.51	$ 11,759,808.97	$ 97.59
ND60	474.23	$ 59,292,987.80	$ 125.03
ND70	126.20	$ 11,695,295.37	$ 92.67
ND90	279.59	$ 34,012,617.15	$ 121.65
SD20	749.31	$ 85,706,148.81	$ 114.38
SD60	534.54	$ 68,640,654.42	$ 128.41
to Southwest			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
IA10	707.71	$ 101,675,255.74	$ 143.67
IA40	1,172.79	$ 165,729,118.19	$ 141.31
IA70	174.89	$ 23,908,788.66	$ 136.70
NE30	104.49	$ 13,760,288.56	$ 131.69
NE50	463.22	$ 55,403,091.85	$ 119.60
NE60	2,183.32	$ 273,875,274.44	$ 125.44
NE70	119.39	$ 12,371,883.88	$ 103.63
SD30	375.86	$ 56,153,759.68	$ 149.40
SD90	93.31	$ 12,364,689.84	$ 132.51

to Texas			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
IL30	23.98	$ 2,293,015.01	$ 95.64
IA20	1,830.20	$ 196,595,992.29	$ 107.42
IA50	120.25	$ 11,906,872.94	$ 99.02
IA60	1,111.43	$ 122,118,305.66	$ 109.88
MO20	235.27	$ 20,526,406.90	$ 87.24
MO30	65.47	$ 5,718,498.02	$ 87.35
to Oklahoma			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
IA50	803.90	$ 47,910,048.69	$ 59.60
to Colorado			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
MN80	460.77	$ 36,944,193.24	$ 80.18
to KS30			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
IA90	97.44	$ 6,163,611.35	$ 63.25
to NE10			
District	DDGS (1,000 tons)	Total Transport Cost	Cost($/ton)
MN80	155.93	$ 9,532,370.26	$ 61.13

5.3: Total Regional Average and Marginal Transportation Cost

This section includes presentation and discussion of total and marginal interregional transportation cost comparisons for all ethanol producing regions. This allows a full evaluation of the relative advantages of plant location, based on grain and DDGS markets. These figures are again expressed in terms of cost per million gallons of production.

The average transportation costs for feedstock demand regions from table 5.1 and DDGS supply regions from tables 5.2 and 5.3 are combined to yield the total average transportation costs for each region. Some regions only incur cost from bringing in feedstock, while others only from dispersing their supply of DDGS. Nine regions had no transportation costs, with enough local grain to satisfy regional demand and local markets for all DDGS produced. Price changes within the region would be the primary concern in this case, as no transportation is needed outside the region. Of these nine regions, three were located in Kansas and two in Nebraska.

The marginal cost of transportation for these regions was also determined for both feedstocks and DDGS. For the feedstock deficit regions the transportation cost per bushel of the most costly shipment into the region serves as the marginal cost measurement. For DDGS supply regions the price per ton incurred shipping to the most costly region provides the marginal cost. The cost per bushel of feedstock and ton of DDGS are converted into costs per million gallons of production as described in sections 5.1.2 and 5.2.2, to facilitate a more informative comparison. The marginal costs for feedstock and DDGS are combined for each region to provide a total figure. Results are presented in state groups in table 5.5 and again in order of greatest marginal cost in table 5.6.

Table 5.5 Interregional Biorefinery Transportation Cost by region of Plant Location

	Average Interregional Cost			Marginal Interregional Cost		
Region	Feedstock	DDGS	Total	Feedstock	DDGS	Total
			Iowa, Illinois and Indiana			
IA10	$ 13,095	$ 178,568	$ 191,663	$ 130,445	$ 465,588	$ 596,033
IA20		$ 295,189	$ 295,189		$ 348,113	$ 348,113
IA30		$ 23,746	$ 23,746		$ 90,231	$ 90,231
IA40		$ 335,484	$ 335,484		$ 457,956	$ 457,956
IA50		$ 153,892	$ 153,892		$ 320,901	$ 320,901
IA60	$ 55,710	$ 228,452	$ 284,161	$ 208,992	$ 356,077	$ 565,069
IA70		$ 190,291	$ 190,291		$ 443,022	$ 443,022
IA90		$ 80,835	$ 80,835		$ 204,985	$ 204,985
IL10		$ 169,550	$ 169,550		$ 294,684	$ 294,684
IL30		$ 61,973	$ 61,973		$ 309,950	$ 309,950
IL40		$ 217,384	$ 217,384		$ 282,074	$ 282,074
IL50		$ 155,808	$ 155,808		$ 183,514	$ 183,514
IL70		$ 66,273	$ 66,273		$ 153,979	$ 153,979
IL80		$ 37,591	$ 37,591		$ 142,364	$ 142,364
IN10		$ 948	$ 948		$ 67,996	$ 67,996
IN20	$ 11,851	$ 182,402	$ 194,254	$ 139,228	$ 226,323	$ 365,551
IN30		$ 114,840	$ 114,840		$ 204,421	$ 204,421

IN40		$ 143,888	$ 143,888		$ 158,625	$ 158,625
IN50		$ 144,474	$ 144,474		$ 220,018	$ 220,018
IN60		$ 143,366	$ 143,366		$ 197,452	$ 197,452
IN70		$ 113,845	$ 113,845		$ 128,759	$ 128,759

	Average Interregional Cost			Marginal Interregional Cost		
Region	Feedstock	DDGS	Total	Feedstock	DDGS	Total
			Michigan, Minnesota, Wisconsin			
MI60			$ -			$ -
MI80		$ 10,166	$ 10,166		$ 76,226	$ 76,226
MI90		$ 129,598	$ 129,598		$ 203,425	$ 203,425
MN40		$ 226,517	$ 226,517		$ 440,367	$ 440,367
MN50		$ 1,921	$ 1,921		$ 52,764	$ 52,764
MN70		$ 195,700	$ 195,700		$ 440,036	$ 440,036
MN80		$ 134,122	$ 134,122		$ 469,902	$ 469,902
MN90			$ -			$ -
WI20	$ 62,599		$ 62,599	$ 151,704		$ 151,704
WI40			$ -			$ -
WI50	$ 15,295	$ 15,005	$ 30,300	$ 122,760	$ 83,826	$ 206,586
WI60	$ 35,839		$ 35,839	$ 195,618		$ 195,618
WI80	$ 13,790	$ 17,735	$ 31,525	$ 157,692	$ 33,517	$ 191,209

	Average Interregional Cost			Marginal Interregional Cost		
Region	Feedstock	DDGS	Total	Feedstock	DDGS	Total
			Kansas, Missouri, Nebraska			
KS10			$ -			$ -
KS20			$ -			$ -
KS30	$ 9,544		$ 9,544	$ 107,290		$ 107,290
KS40			$ -			$ -
KS50	$ 15,580	$ 20,159	$ 35,739	$ 52,996	$ 55,320	$ 108,316
KS60		$ 8,045	$ 8,045		$ 53,727	$ 53,727
KS80	$ 20,093		$ 20,093	$ 63,576		$ 63,576
MO10		$ 29,842	$ 29,842		$ 42,112	$ 42,112
MO20	$ 26,939	$ 203,232	$ 230,170	$ 142,322	$ 282,738	$ 425,060
MO30		$ 114,370	$ 114,370		$ 283,070	$ 283,070
MO50	$ 49,248		$ 49,248	$ 230,250		$ 230,250
NE10			$ -			$ -
NE20			$ -			$ -
NE30		$ 49,144	$ 49,144		$ 426,761	$ 426,761
NE50		$ 185,916	$ 185,916		$ 387,603	$ 387,603
NE60	$ 6,624	$ 326,820	$ 333,444	$ 128,050	$ 406,519	$ 534,568
NE70		$ 113,504	$ 113,504		$ 335,834	$ 335,834
NE80		$ 34,571	$ 34,571		$ 72,045	$ 72,045
NE90		$ 88,316	$ 88,316		$ 131,546	$ 131,546

	Average Interregional Cost			Marginal Interregional Cost		
Region	Feedstock	DDGS	Total	Feedstock	DDGS	Total
			Dakotas			
ND30		$ 52,547	$ 52,547		$ 86,348	$ 86,348
ND40	$ 127,784	$ 235,196	$ 362,980	$ 162,882	$ 316,255	$ 479,137
ND60	$ 8,361	$ 395,287	$ 403,648	$ 94,116	$ 405,191	$ 499,307
ND70	$ 147,519	$ 233,906	$ 381,425	$ 197,115	$ 300,326	$ 497,441
ND90		$ 312,552	$ 312,552		$ 394,240	$ 394,240
SD20		$ 322,204	$ 322,204		$ 370,679	$ 370,679
SD30		$ 296,367	$ 296,367		$ 484,172	$ 484,172
SD50			$ -			$ -
SD60		$ 289,189	$ 289,189		$ 416,142	$ 416,142
SD90		$ 167,163	$ 167,163		$ 429,416	$ 429,416

Table 5.6 Interregional Biorefinery Transportation Cost by Greatest Marginal Cost

	Average Interregional Cost			Marginal Interregional Cost		
Region	Feedstock	DDGS	Total	Feedstock	DDGS	Total
			Total Marginal Cost > $300,000			
IA10	$ 13,095	$ 178,568	$ 191,663	$ 130,445	$ 465,588	$ 596,033
IA60	$ 55,710	$ 228,452	$ 284,161	$ 208,992	$ 356,077	$ 565,069
NE60	$ 6,624	$ 326,820	$ 333,444	$ 128,050	$ 406,519	$ 534,568
ND60	$ 8,361	$ 395,287	$ 403,648	$ 94,116	$ 405,191	$ 499,307
ND70	$ 147,519	$ 233,906	$ 381,425	$ 197,115	$ 300,326	$ 497,441
SD30		$ 296,367	$ 296,367		$ 484,172	$ 484,172
ND40	$ 127,784	$ 235,196	$ 362,980	$ 162,882	$ 316,255	$ 479,137
MN80		$ 134,122	$ 134,122		$ 469,902	$ 469,902
IA40		$ 335,484	$ 335,484		$ 457,956	$ 457,956
IA70		$ 190,291	$ 190,291		$ 443,022	$ 443,022
MN40		$ 226,517	$ 226,517		$ 440,367	$ 440,367
MN70		$ 195,700	$ 195,700		$ 440,036	$ 440,036
SD90		$ 167,163	$ 167,163		$ 429,416	$ 429,416
NE30		$ 49,144	$ 49,144		$ 426,761	$ 426,761
MO20	$ 26,939	$ 203,232	$ 230,170	$ 142,322	$ 282,738	$ 425,060
SD60		$ 289,189	$ 289,189		$ 416,142	$ 416,142
ND90		$ 312,552	$ 312,552		$ 394,240	$ 394,240
NE50		$ 185,916	$ 185,916		$ 387,603	$ 387,603
SD20		$ 322,204	$ 322,204		$ 370,679	$ 370,679
IN20	$ 11,851	$ 182,402	$ 194,254	$ 139,228	$ 226,323	$ 365,551
IA20		$ 295,189	$ 295,189		$ 348,113	$ 348,113
NE70		$ 113,504	$ 113,504		$ 335,834	$ 335,834
IA50		$ 153,892	$ 153,892		$ 320,901	$ 320,901
IL30		$ 61,973	$ 61,973		$ 309,950	$ 309,950

Region	Average Interregional Cost			Marginal Interregional Cost		
	Feedstock	DDGS	Total	Feedstock	DDGS	Total
			Total Marginal Cost < $300,00			
IL10		$ 169,550	$ 169,550		$ 294,684	$ 294,684
MO30		$ 114,370	$ 114,370		$ 283,070	$ 283,070
IL40		$ 217,384	$ 217,384		$ 282,074	$ 282,074
MO50	$ 49,248		$ 49,248	$ 230,250		$ 230,250
IN50		$ 144,474	$ 144,474		$ 220,018	$ 220,018
WI50	$ 15,295	$ 15,005	$ 30,300	$ 122,760	$ 83,826	$ 206,586
IA90		$ 80,835	$ 80,835		$ 204,985	$ 204,985
IN30		$ 114,840	$ 114,840		$ 204,421	$ 204,421
MI90		$ 129,598	$ 129,598		$ 203,425	$ 203,425
IN60		$ 143,366	$ 143,366		$ 197,452	$ 197,452
WI60	$ 35,839		$ 35,839	$ 195,618		$ 195,618
WI80	$ 13,790	$ 17,735	$ 31,525	$ 157,692	$ 33,517	$ 191,209
IL50		$ 155,808	$ 155,808		$ 183,514	$ 183,514
IN40		$ 143,888	$ 143,888		$ 158,625	$ 158,625
IL70		$ 66,273	$ 66,273		$ 153,979	$ 153,979
WI20	$ 62,599		$ 62,599	$ 151,704		$ 151,704
IL80		$ 37,591	$ 37,591		$ 142,364	$ 142,364
NE90		$ 88,316	$ 88,316		$ 131,546	$ 131,546
IN70		$ 113,845	$ 113,845		$ 128,759	$ 128,759
KS50	$ 15,580	$ 20,159	$ 35,739	$ 52,996	$ 55,320	$ 108,316
KS30	$ 9,544		$ 9,544	$ 107,290		$ 107,290
IA30		$ 23,746	$ 23,746		$ 90,231	$ 90,231
ND30		$ 52,547	$ 52,547		$ 86,348	$ 86,348
MI80		$ 10,166	$ 10,166		$ 76,226	$ 76,226
NE80		$ 34,571	$ 34,571		$ 72,045	$ 72,045
IN10		$ 948	$ 948		$ 67,996	$ 67,996
KS80	$ 20,093		$ 20,093	$ 63,576		$ 63,576
KS60		$ 8,045	$ 8,045		$ 53,727	$ 53,727
MN50		$ 1,921	$ 1,921		$ 52,764	$ 52,764
MO10		$ 29,842	$ 29,842		$ 42,112	$ 42,112
KS10			$ -			$ -
KS20			$ -			$ -
KS40			$ -			$ -
MI60			$ -			$ -
MN90			$ -			$ -
NE10			$ -			$ -
NE20			$ -			$ -
SD50			$ -			$ -
WI40			$ -			$ -

A side by side comparison shows that transportation costs for DDGS far exceed those of feedstocks. This makes sense when the limited transportation options for handling qualities of DDGS are considered. The ability to use private railcars for DDGS in reality would likely reduce these amounts; however, it is still likely that DDGS transportation accounts for a greater amount of interregional transportation costs. Ethanol production is a water reducing process, so it is preferential to ship DDGS after production rather than import grain with the additional water weight. In fact the aggregate average total transportation cost for all plants was less than the group average for average DDGS transportation cost, $124,885 and $147,916 respectively.

Overall, Kansas had the lowest transportation costs, primarily due to the proximity to a great deal of livestock production. This is likely due to the higher cost of DDGS shipment relative to feedstock. The large livestock herd creates a strong local market for DDGS. On the other end of the spectrum, North Dakota had the highest transportation costs by far. The three highest cost regions were all located in North Dakota, with two of them being amongst the highest cost regions for both DDGS and feedstock. One contributing factor would be its relative location to the rest of the study region; it is located on an outside border. The climate in the state limits the extent of livestock and grain production, and to operate a plant at a profitable scale a large amount of grain must be shipped in and DDGS shipped out. This conclusion is further supported by the recent plant closure in North Dakota; it is a relatively poor area to operate a biorefinery.

Table 5.7 offers an alternative view of marginal interregional transportation cost by including current ethanol capacity, and the expansion or contraction over the last five years. A review of the table shows that there appears to be a relationship between interregional marginal transportation costs and regional ethanol production capacity. Much of the expansion has occurred in regions that now have high marginal transportation costs.

Table 5.7 Regional Ethanol Capacity and Interregional Costs by Biorefinery Region

	Ethanol Capacity in MGY		Marginal and Avg Cost in $/MGY	
District	2012	Change +(-) 05-12	Averrage Cost	Marginal Cost
		Iowa, Illinois, Indiana		
IA10	593	59	$ 191,663	$ 596,033
IA20	666	151	$ 295,189	$ 348,113
IA30	325	110	$ 23,746	$ 90,231
IA40	494	168	$ 335,484	$ 457,956
IA50	439	-291	$ 153,892	$ 320,901
IA60	997	499	$ 284,161	$ 565,069
IA70	230	-100	$ 190,291	$ 443,022
IA90	135	48	$ 80,835	$ 204,985
IL10	445	155	$ 169,550	$ 294,684
IL30	37	0	$ 61,973	$ 309,950
IL40	637	-106	$ 217,384	$ 282,074
IL50	100	100	$ 155,808	$ 183,514
IL70	48	0	$ 66,273	$ 153,979
IL80	54	0	$ 37,591	$ 142,364
IN10	40	0	$ 948	$ 67,996
IN20	280	68	$ 194,254	$ 365,551
IN30	120	19	$ 114,840	$ 204,421
IN40	270	170	$ 143,888	$ 158,625
IN50	118	78	$ 144,474	$ 220,018
IN60	100	-60	$ 143,366	$ 197,452
IN70	223	223	$ 113,845	$ 128,759

	Ethanol Capacity in MGY		Marginal and Avg Cost in $/MGY	
District	2012	Change +(-) 05-12	Averrage Cost	Marginal Cost
		Michigan, Minnesota, Wisconsin		
MI60	53	3	$ -	$ -
MI80	105	0	$ 10,166	$ 76,226
MI90	110	3	$ 129,598	$ 203,425
MN40	181	5	$ 226,517	$ 440,367
MN50	189.5	75	$ 1,921	$ 52,764
MN70	201	58	$ 195,700	$ 440,036
MN80	482	228	$ 134,122	$ 469,902
MN90	91	-1	$ -	$ -
WI10	0	-41	$ -	$ -
WI20	41	41	$ 62,599	$ 151,704

WI40	40	40	$ -	$ -
WI50	90	40	$ 30,300	$ 206,586
WI60	48	0	$ 35,839	$ 195,618
WI80	285	-34	$ 31,525	$ 191,209

	Ethanol Capacity in MGY		Marginal and Avg Cost in $/MGY	
District	2012	Change +(-) 05-12	Averrage Cost	Marginal Cost
		Kansas, Missouri, Nebraska		
KS10	20	0	$ -	$ -
KS20	46.5	0	$ -	$ -
KS30	177	0	$ 9,544	$ 107,290
KS40	50	10	$ -	$ -
KS50	108	5	$ 35,739	$ 108,316
KS60	80	0	$ 8,045	$ 53,727
KS70	0	-6	$ -	$ -
KS80	42	7	$ 20,093	$ 63,576
MO10	70	50	$ 29,842	$ 42,112
MO20	101	56	$ 230,170	$ 425,060
MO30	50	5	$ 114,370	$ 283,070
MO50	50	5	$ 49,248	$ 230,250
NE10	54	54	$ -	$ -
NE20	44	-100	$ -	$ -
NE30	280	63.5	$ 49,144	$ 426,761
NE50	298	120	$ 185,916	$ 387,603
NE60	838	444	$ 333,444	$ 534,568
NE70	109	0	$ 113,504	$ 335,834
NE80	219	65	$ 34,571	$ 72,045
NE90	160	10	$ 88,316	$ 131,546

	Ethanol Capacity in MGY		Marginal and Avg Cost in $/MGY	
District	2012	Change +(-) 05-12	Averrage Cost	Marginal Cost
		Dakotas		
ND30	10	-13	$ 52,547	$ 86,348
ND40	50	0	$ 362,980	$ 479,137
ND60	150	150	$ 403,648	$ 499,307
ND70	50	0	$ 381,425	$ 497,441
ND90	110	10	$ 312,552	$ 394,240
SD20	266	57	$ 322,204	$ 370,679
SD30	199	29	$ 296,367	$ 484,172
SD50	32	-118	$ -	$ -
SD60	238	128	$ 289,189	$ 416,142
SD90	287	16	$ 167,163	$ 429,416

A linear regression was used to further analyze the relationship between marginal interregional transportation cost and regional ethanol production capacity. The regression shows a statistically significant positive relationship between regional capacity and marginal interregional transportation costs.

Marginal Interregional Transport Cost = 132705 + 514 * regional capacity
Std. Errors: (24923) (89)
R-squared: 0.344

This positive relationship makes sense. We would expect that production volume is highly correlated with regional capacity. Therefore this relationship, above, reflects not only the impact of capacity but also of volume. The greater the volume of ethanol production within a region, the greater the likelihood that long distance shipments of DDGS are necessary. As shown earlier in table 5.4, shipments of DDGS over long distances account for a large portion of total interregional transportation cost. This relationship between the existing biorefinery capacity in a region and its marginal interregional transport costs raises other questions on the dynamics of the relationship. How does the change in regional capacity relate with the marginal interregional transportation costs? A second linear regression was used to analyze this relationship.

Marginal Interregional Transport Cost = 205511 + 604 * regional cap. change
Std. Errors: (22180) (187)
R-squared: 0.142

A statistically significant positive relationship was found for marginal cost and change in capacity. As regional capacity increases the marginal transportation cost follows, yet many regions have seen continued expansion in biorefinery capacity. This relationship may indicate that grain availability and economies of scale are more important factors in locating ethanol production than additional interregional transportation costs, which are driven by the shipments of additional DDGS. This is an unanticipated finding, as it was initially expected that transportation costs would be the primary determinant for biorefinery siting.

5.4: Results Comparison

To analyze changes in the industry structure over time, results were compared with those of McMillian [2007]. This comparison can show shifts in interregional transportation costs and capacity over a five year window.

5.4.1: Average Transportation Cost

A review of the interregional transportation costs for both DDGS and feedstocks shows several trends. On average the regions in the primary area of study showed a decrease in feedstock average transportation cost of $136.50 per mgy production, and an increase in DDGS ATC of $104,395 per mgy production. This shift is also illustrated by cost distributions. McMillan's [2007] estimates showed that feedstock movement was responsible for 48% of total average interregional transportation costs, with the remaining 58% from DDGS. The estimates of this study show that feedstock costs are about 8% of total transportation costs while DDGS movement is responsible for 92%. This drastic increase in DDGS transportation costs is due in part to differences in estimation between the studies. This research used an estimate of actual DDGS consumption in supply and demand calculation, while the previous research used potential DDGS consumption. Potential DDGS consumption exceeds the available supply; in this case the estimated demand for all regions cannot be met, so the model solution chooses to ship on the least cost routes. This results in lower DDGS transportation costs as shipment is not enforced for distant regions with higher transportation costs. Export demand for DDGS was also not accounted for in the prior study. An illustration of the changes in individual regions is provided by table 5.8.

Table 5.8 Interregional Biorefinery Transport Cost Change 2007-2012

by Region of Plant Location

	Avg Transport Cost per million gallons production			
Plant Region	Feedstock 2012	Change +(-)	DDGS 2012	Change +(-)
		Iowa, Illinois, Indiana		
IA10	$ 13,095	$ 7,976	$ 178,568	$ 163,448
IA20			$ 295,189	$ 253,617
IA30			$ 23,746	$ 18,184
IA40			$ 335,484	$ 319,850
IA50		$ (4,139)	$ 153,892	$ 90,662
IA60	$ 55,710	$ 50,064	$ 228,452	$ 199,801
IA70		$ (2,619)	$ 190,291	$ 130,643
IA90			$ 80,835	$ 80,835
IL10			$ 169,550	$ 169,550
IL30			$ 61,973	$ 61,973
IL40		$ (3,678)	$ 217,384	$ 217,384
IL50			$ 155,808	$ 155,808
IL70			$ 66,273	$ 66,273
IL80			$ 37,591	$ 33,781
IN10			$ 948	$ 948
IN20	$ 11,851	$ 11,851	$ 182,402	$ 154,806
IN30			$ 114,840	$ 96,719
IN40			$ 143,888	$ 126,004
IN50			$ 144,474	$ 144,474
IN60			$ 143,366	$ 114,052
IN70			$ 113,845	$ 113,845

	Avg Transport Cost per million gallons production			
Plant Region	Feedstock 2012	Change +(-)	DDGS 2012	Change +(-)
		Michigan, Minnesota, Wisconsin		
MI60		$ (14,962)		
MI80			$ 10,166	$ 10,166
MI90			$ 129,598	$ 129,598
MN40			$ 226,517	$ 203,859
MN50			$ 1,921	$ 1,921
MN70			$ 195,700	$ 188,823
MN80			$ 134,122	$ 110,068
MN90				
WI20	$ 62,599	$ 62,599		

WI40				
WI50	$ 15,295	$ 15,295	$ 15,005	$ 15,005
WI60	$ 35,839	$ 35,839		
WI80	$ 13,790	$ 13,790	$ 17,735	$ 1,271

	Avg Transport Cost per million gallons production			
Plant Region	Feedstock 2012	Change +(-)	DDGS 2012	Change +(-)
		Kansas, Missouri, Nebraska		
KS10				
KS20		$ (33,493)		
KS30	$ 9,544	$ (25,348)		
KS40				
KS50	$ 15,580	$ 15,580	$ 20,159	$ 18,485
KS60			$ 8,045	$ 8,045
KS80	$ 20,093	$ 20,093		
MO10			$ 29,842	$ 29,842
MO20	$ 26,939	$ (50,195)	$ 203,232	$ 203,232
MO30		$ (22,178)	$ 114,370	$ 114,370
MO50	$ 49,248	$ (37,036)		
NE10				
NE20		$ (1,980)		
NE30			$ 49,144	$ 49,144
NE50			$ 185,916	$ 185,916
NE60	$ 6,624	$ 6,624	$ 326,820	$ 321,505
NE70			$ 113,504	$ 113,504
NE80			$ 34,571	$ 34,571
NE90			$ 88,316	$ 84,101

	Avg Transport Cost per million gallons production			
Plant Region	Feedstock 2012	Change +(-)	DDGS 2012	Change +(-)
		Dakotas		
ND30		$ (15,224)	$ 52,547	$ 38,075
ND40	$ 127,784	$ 7,665	$ 235,196	$ 226,390
ND60	$ 8,361	$ 8,361	$ 395,287	$ 395,287
ND70	$ 147,519	$ (11,240)	$ 233,906	$ 224,659
ND90			$ 312,552	$ 244,368
SD20		$ (19,087)	$ 322,204	$ 278,470
SD30		$ (5,822)	$ 296,367	$ 261,436
SD50		$ (14,702)		$ (29,341)
SD60			$ 289,189	$ 283,576
SD90		$ (2,633)	$ 167,163	$ 117,897

5.4.2: Regional Capacity

Total domestic ethanol production capacity increased by 2.76 billion gallons per year over the comparison timeframe. This increase was due to 70 additional biorefineries and growth in average plant size by approximately 10 million gallons per year. On a regional level, ethanol production capacity grew by roughly 40 million gallons per year. Capacity comparisons for all of the primary regions are displayed in table 5.9.

Table 5.9 Regional Ethanol Capacity Change 2007-2012

by Lowest Capacity Change

	Ethanol Capacity in MGY		
District	2012	2007	Change +(-)
		Capacity decreased	
IA50	439	730	(291)
SD50	32	150	(118)
IL40	637	743	(106)
IA70	230	330	(100)
NE20	44	144	(100)
IN60	100	160	(60)
WI10	0	41	(41)
WI80	285	319	(34)
ND30	10	23	(13)
KS70	0	6	(6)
MN90	91	92	(1)
	Ethanol Capacity in MGY		
District	2012	2007	Change +(-)
		Capacity Unchanged	
IL30	37	37	-
IL70	48	48	-
IL80	54	54	-
IN10	40	40	-
KS10	20	20	-
KS20	46.5	47	-
KS30	177	177	-
KS60	80	80	-
MI80	105	105	-
ND40	50	50	-
ND70	50	50	-
NE70	109	109	-

WI60	48	48	-

	Ethanol Capacity in MGY		
District	2012	2007	Change +(-)
		Capacity increase < 50 mgy	
MI60	53	50	3
MI90	110	107	3
KS50	108	103	5
MN40	181	176	5
MO30	50	45	5
MO50	50	45	5
KS80	42	35	7
KS40	50	40	10
ND90	110	100	10
NE90	160	150	10
SD90	287	271	16
IN30	120	101	19
SD30	199	170	29
WI40	40	-	40
WI50	90	50	40
WI20	41	-	41
IA90	135	87	48

	Ethanol Capacity in MGY		
District	2012	2007	Change +(-)
		Capacity increase 50-100 mgy	
MO10	70	20	50
NE10	54	-	54
MO20	101	45	56
SD20	266	209	57
MN70	201	143	58
IA10	593	534	59
NE30	280	217	64
NE80	219	154	65
IN20	280	212	68
MN50	189.5	115	75
IN50	118	40	78
IL50	100	-	100

	Ethanol Capacity in MGY		
District	2012	2007	Change +(-)
		Capacity increase > 100 mgy	
IA30	325	215	110
NE50	298	178	120
SD60	238	110	128
ND60	150	-	150
IA20	666	515	151
IL10	445	290	155
IA40	494	326	168
IN40	270	100	170
IN70	223	-	223
MN80	482	254	228
NE60	838	394	444
IA60	997	498	499

A review of cost and capacity changes revealed an interesting relationship. The few regions that showed a reduction in capacity also showed significant reductions in the feedstock transportation cost estimates. This suggests that the need to bring in grain from other regions was a factor in the decreased production for those regions.

5.4.3: Idled Facilities

In recent history drought and other production factors have created extreme conditions in the corn market, with shortages in some areas. In response to these and other factors, several ethanol producers have suspended operations at their facilities. These facilities along with their corresponding region, capacity, and cost are listed in table 5.10 below.

Table 5.10 Biorefineries with Suspended Operations as of 10/31/12

Facility	Capacity	Region	Total ATC
East Kansas Agri-Energy	42	KS80	$ 20,092.80
BioFuel Energy - Buffalo Lake Energy	115	MN80	$ 8,045.30
Central MN Ethanol Coop	21.5	MN50	$ 134,122.41
Golden triangle energy	20	MO10	$ 1,920.63
Alchem Ltd.	10	NE30	$ 29,842.18
Midwest Renewable Energy	25	NE70	$ 49,143.89
NEDAK Ethanol	44	NE20	$ 113,503.52

The first similarity between these facilities is their location on the fringe of the major corn producing region. These regions already have less corn availability and are more affected by the corn market. The facilities are also in low transportation cost regions, suggesting livestock availability for a DDGS market, as DDGS shipments are a majority of total transportation cost. Reduced corn stocks and strong competition from livestock producers for available feedstocks can drive up price. Another factor is the size of these facilities, all of which are significantly smaller than the optimal plant size of 90-100 mgy estimated by Gallagher. As discussed in the previous chapter, lack of grain availability and economies of scale likely outweigh the benefits of lower transportation costs. It is possible that these plants have been able to operate on a suboptimal scale due to their location in low cost regions, and current market stress is too much to overcome. A key factor in the determination of the optimal plant size was the influence a larger plant can have on the local corn market.

CHAPTER VI: CONCLUSIONS

6.1: Summary

The focus of this study was the changes in the geographic structure of the ethanol industry, with a focus on the primary ethanol producing region of the Corn Belt and Northern Plains. This primary area was divided into sub regions using USDA crop reporting districts, with the remaining continental US being divided into larger secondary regions. Regional estimates of excess supply and demand of both feedstocks and DDGS were calculated using USDA grain and livestock production data and calculated feed consumption. These regional supply and demand estimates, along with interregional distances from Google maps, provide the basis for two transportation models.

Two cost minimization network flow linear programming models were used in the research. The first model determined the flow of feedstocks from supply to demand regions that minimized transportation cost for the industry as a whole. This model used a transshipment framework, with transshipment nodes representing regions with rail service. This framework allows the movement of feedstock by truck to a nearby rail location, to take advantage of the savings rail transportation provides over longer distances. The second model determined the least cost flow of DDGS from supply to demand regions. This model used a simpler transportation problem framework, as shipment on railroad owned cars is not readily available for DDGS, because lodging in the cars that can result in abuse and damage to cars in getting the material out of the hopper cars.

The resulting shipment paths and quantities were used to determine the average interregional transportation cost of both feedstock and DDGS for regions with ethanol production. The average transportation costs serve as a basis of comparison for the merits of various plant locations. The results of the current research were then compared with those of McMillan in 2007 to establish a time comparison. Average interregional transportation costs and regional ethanol production capacity were compared, as well as measures of the industry as a whole.

Over the period of review, ethanol capacity grew by 22%, with over 2 billion gallons per year in additional capacity stemming from growth in both the number of facilities and their average size. Average transportation costs showed an increase, with the majority stemming from the shipment of DDGS. The cost of DDGS movement grew from roughly 50% of total average transportation costs to 92%. A positive relationship between total interregional marginal transportation cost and regional ethanol production capacity was found. This indicates that local availability of grain and economies of scale are more important factors for a biorefinery, rather than interregional transportation costs as initially expected. A review was then conducted of the facilities that have recently suspended operations to determine the possible regional cost effects driving the decisions. It was found that these facilities were actually located in regions with low interregional transportation costs. Common characteristics of low corn availability and suboptimal scale likely created unfavorable financial conditions for these operations.

6.2: Limitations

The main hindrance in conducting this research was the general lack of information on DDGS usage. No actual figures on DDGS consumption were available, so estimates of the potential market were used and adjusted in an attempt to reflect reality. It is highly likely that the inclusion rates for DDGS vary widely by region, based on DDGS price and availability and livestock species, but this information was also unavailable. Another factor that was not accounted for is the cost savings of marketing WDGS as opposed to DDGS. Cost of transport for WDGS is higher, and would be limited to a localized area, but it can result in significant cost savings through reduced energy consumption. The presence of publically available rail transportation information for DDGS also would have enhanced the accuracy of estimation.

Another limitation of the study was its scope. Only an 11 state region was examined by crop reporting district. However, it is not clear that expanding this treatment to the secondary regions would yield improved results, as those regions account for little ethanol and DDGS production. Additionally, county information could be used in place of crop reporting district, especially for the primary region. Once again this would enhance the accuracy. The smaller regions would also better facilitate the examination of individual plants, as many crop reporting districts contain multiple biorefineries dispersed throughout.

Another consideration could be the inclusion of corn demand for human consumption. It was determined in previous research (McMillan 2007) that the production of high fructose corn syrup had a negligible impact on transportation costs for the ethanol industry, but overall food and industrial demand for corn could affect these costs. It was decided for the purpose of this study that the omission of this information facilitated a more accurate comparison with the prior study.

6.3: Implications for Future Research

Several limitations of this study provide interesting potential for future research. An analysis of regional differences in the inclusion of DDGS in livestock rations could add a great deal of clarity in understanding of DDGS markets. This information could also greatly improve the accuracy of regional DDGS supply and demand estimates.

Another intriguing topic would be the effect of transportation costs for ethanol as well as grain and DDGS on the relative profitability of biorefinery locations. This would be another main transportation cost not considered in the framework of this study.

Tightening the scope of the study provides another opportunity for additional research. Growth in the ethanol industry is occurring outside of the Corn Belt and Northern Plains, and closer analysis of these other regions could bring greater clarity to the understanding of the expansion in the ethanol industry. Also, as mentioned previously, analysis at the county level rather than by crop reporting district could improve results and allow a more accurate comparison of individual facilities.

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APPENDIX

Appendix A

This section contains the inventories of grain in bushels, ethanol production in million gallons per year, and livestock in number of head. The calculations to determine regional supply and demand of feedstocks and DDGS are also included. All regional information is listed in tables by state.

Table A.1 Regional Supply and Demand Calculations

Illinois

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
IL10	371,837,333	445,000,000	71,281	27,133	62,122	122,564	873,793	53,343	10,687	1,042,145
IL20	204,657,333	-	22,435	8,533	24,422	29,010	363,817	44,077	6,585	339,347
IL30	187,838,333	37,000,000	18,435	3,933	58,022	79,510	610,555	125,367	2,786	190,980
IL40	290,295,333	637,000,000	6,353	2,233	28,022	32,092	437,505	36,121	4,103	148,417
IL50	269,618,333	100,000,000	7,813	4,233	23,322	13,632	381,676	26,390	2,774	247,887
IL60	261,586,000	-	10,980	6,533	39,422	77,665	559,712	86,900	3,241	337,918
IL70	225,685,333	48,000,000	13,536	15,133	38,022	59,709	419,548	47,783	69,235	327,567
IL80	60,783,000	54,000,000	7,339	28,133	45,722	51,606	410,504	40,351	3,032	157,757
IL90	75,602,000	-	1,827	2,133	32,922	24,218	112,891	19,669	3,047	1,750,982

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
IL10	371,837,333	164,814,815	5,173,994	3,514,567	573,243	1,967,563	14,861,906	1,304,831	7,501	825,528	178,793,386
IL20	204,657,333	-	1,628,438	1,105,289	225,359	465,713	6,187,975	1,078,168	4,622	268,812	193,692,958
IL30	187,838,333	13,703,704	1,338,116	509,446	535,409	1,276,405	10,384,617	3,066,622	1,955	151,283	156,870,776
IL40	290,295,333	235,925,926	461,156	289,243	258,579	515,181	7,441,304	883,555	2,880	117,567	44,399,943
IL50	269,618,333	37,037,037	567,130	548,305	215,208	218,836	6,491,744	645,542	1,947	196,362	223,696,222
IL60	261,586,000	-	796,983	846,226	363,774	1,246,788	9,519,856	2,125,683	2,275	267,679	246,416,735
IL70	225,685,333	17,777,778	982,552	1,960,194	350,855	958,524	7,135,884	1,168,839	48,593	259,480	195,042,634
IL80	60,783,000	20,000,000	532,696	3,644,098	421,909	828,453	6,982,060	987,024	2,128	124,966	27,259,665
IL90	75,602,000	-	132,621	276,290	303,794	388,780	1,920,099	481,135	2,138	1,387,028	70,710,116

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
IL10	164,814,815	2,884,259,259	133,216,867	112,667,867	11,955,335	24,819,021	115,153,514	13,755,592	49,217	5,508,306	2,467,133,539
IL20	-	-	41,928,032	35,432,680	4,699,997	5,874,549	47,945,872	11,366,104	30,326	1,793,635	(149,071,194)
IL30	13,703,704	239,814,815	34,452,994	16,331,505	11,166,293	16,100,693	80,462,437	32,328,474	12,830	1,009,433	47,950,156
IL40	235,925,926	4,128,703,704	11,873,564	9,272,375	5,392,814	6,498,543	57,656,956	9,314,481	18,896	784,463	4,027,891,613
IL50	37,037,037	648,148,148	14,602,125	17,577,234	4,488,302	2,760,412	50,299,546	6,805,337	12,777	1,310,217	550,292,197
IL60	-	-	20,520,231	27,127,821	7,586,736	15,727,104	73,762,063	22,409,056	14,926	1,786,080	(168,934,018)
IL70	17,777,778	311,111,111	25,298,162	62,838,714	7,317,307	12,090,918	55,290,497	12,321,955	318,838	1,731,368	133,903,353
IL80	20,000,000	350,000,000	13,715,539	116,820,296	8,799,166	10,450,190	54,098,633	10,405,256	13,963	833,834	134,863,123
IL90	-	-	3,414,633	8,857,132	6,335,816	4,904,102	14,877,377	5,072,146	14,030	9,254,893	(52,730,128)

Indiana

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
IN10	152,715,000	40,000,000	16,053	36,911	11,978	36,758	416,451	27,920	106,685	9,607
IN20	116,569,000	280,000,000	17,408	42,911	14,778	78,803	783,807	53,263	775,051	390,866
IN30	70,075,000	120,000,000	18,895	37,711	15,778	71,016	448,686	41,630	1,606,199	10,263,944
IN40	109,700,000	270,000,000	8,800	6,611	19,478	21,011	220,164	36,999	106,686	36,895
IN50	166,465,000	118,000,000	21,568	8,511	22,178	25,943	854,240	74,770	107,383	74,114
IN60	67,525,000	100,000,000	13,588	14,211	17,578	10,223	281,414	14,484	106,868	8,772,625
IN70	109,825,000	223,000,000	18,265	9,911	37,478	28,346	394,025	33,046	108,752	3,446,389
IN80	24,411,000	-	7,783	8,911	45,378	45,228	91,058	8,275	2,337,924	376,701
IN90	22,215,000	-	6,640	6,311	28,378	18,671	60,154	9,613	106,420	17,860

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
IN10	152,715,000	14,814,815	1,165,212	4,781,121	110,529	590,091	7,083,203	682,953	74,878	7,610	123,404,587
IN20	116,569,000	103,703,704	1,263,581	5,558,308	136,367	1,265,053	13,331,382	1,302,878	543,977	309,622	(10,845,871)
IN30	70,075,000	44,444,444	1,371,476	4,884,746	145,595	1,140,054	7,631,477	1,018,321	1,127,325	8,130,510	181,052
IN40	109,700,000	100,000,000	638,734	856,330	179,737	337,302	3,744,665	905,038	74,878	29,226	2,934,090
IN50	166,465,000	43,703,704	1,565,545	1,102,439	204,652	416,469	14,529,345	1,828,975	75,368	58,709	102,979,796
IN60	67,525,000	37,037,037	986,277	1,840,766	162,204	164,117	4,786,434	354,292	75,006	6,949,172	15,169,695
IN70	109,825,000	82,592,593	1,325,808	1,283,782	345,836	455,042	6,701,779	808,348	76,329	2,730,032	13,505,452
IN80	24,411,000	-	564,935	1,154,251	418,734	726,062	1,548,764	202,418	1,640,893	298,401	17,856,540
IN90	22,215,000	-	481,966	817,471	261,864	299,733	1,023,126	235,152	74,692	14,148	19,006,848

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
IN10	14,814,815	259,259,259	30,001,165	153,270,321	2,305,158	7,443,470	54,882,313	7,199,726	491,302	50,776	3,615,029
IN20	103,703,704	1,814,814,815	32,533,925	178,184,898	2,844,016	15,957,496	103,294,662	13,735,000	3,569,244	2,065,941	1,462,629,634
IN30	44,444,444	777,777,778	35,311,938	156,592,265	3,036,465	14,380,747	59,130,466	10,735,184	7,396,821	54,250,537	436,943,355
IN40	100,000,000	1,750,000,000	16,445,745	27,451,711	3,748,527	4,254,758	29,014,535	9,540,957	491,306	195,009	1,658,857,451
IN50	43,703,704	764,814,815	40,308,694	35,341,327	4,268,140	5,253,377	112,576,753	19,281,139	494,517	391,731	546,899,137
IN60	37,037,037	648,148,148	25,394,065	59,010,174	3,382,874	2,070,190	37,086,405	3,734,961	492,144	46,368,100	470,609,236
IN70	82,592,593	1,445,370,370	34,136,096	41,154,728	7,212,614	5,739,945	51,926,944	8,521,646	500,823	18,216,042	1,277,961,533
IN80	-	-	14,545,603	37,002,298	8,732,964	9,158,621	12,000,185	2,133,904	10,766,540	1,991,071	(96,331,187)
IN90	-	-	12,409,375	26,205,982	5,461,326	3,780,864	7,927,422	2,478,984	490,084	94,401	(58,848,437)

Iowa

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
IA10	356,250,000	593,000,000	443,806	48,655	95,333	335,806	5,522,716	201,238	629,426	40,760,720
IA20	357,250,000	666,000,000	86,393	11,055	57,333	81,419	3,000,708	98,231	44,022	74,065
IA30	316,350,000	325,000,000	217,492	96,555	110,633	239,820	2,219,331	143,943	361,120	5,220,188
IA40	364,850,000	494,000,000	246,162	4,655	57,933	215,050	2,146,391	150,644	38,637	58,551
IA50	352,000,000	439,000,000	80,250	7,355	85,133	76,762	2,599,550	140,199	43,661	2,736,178
IA60	250,650,000	997,000,000	148,395	25,155	135,633	135,417	1,123,109	76,033	42,563	1,902,714
IA70	162,250,000	230,000,000	89,453	3,455	52,133	149,459	330,544	8,902	266,840	33,131
IA80	73,200,000	-	31,833	5,055	164,833	144,979	348,700	61,727	282,554	56,764
IA90	123,600,000	135,000,000	36,215	8,055	81,033	91,297	1,698,949	129,082	37,614	2,151,689

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
IA10	356,250,000	219,629,630	32,213,926	6,302,334	879,704	5,390,819	93,933,109	4,922,537	441,768	32,288,313	(39,752,140)
IA20	357,250,000	246,666,667	6,270,882	1,431,966	529,052	1,307,051	51,037,547	2,402,864	30,897	58,670	47,514,405
IA30	316,350,000	120,370,370	15,786,797	12,506,873	1,020,888	3,849,919	37,747,498	3,521,030	253,455	4,135,134	117,158,036
IA40	364,850,000	182,962,963	17,867,832	602,967	534,588	3,452,275	36,506,894	3,684,950	27,118	46,381	119,164,031
IA50	352,000,000	162,592,593	5,824,975	952,701	785,581	1,232,294	44,214,451	3,429,447	30,644	2,167,444	130,769,870
IA60	250,650,000	369,259,259	10,771,355	3,258,354	1,251,580	2,173,897	19,102,405	1,859,867	29,873	1,507,221	(158,563,812)
IA70	162,250,000	85,185,185	6,492,966	447,530	481,067	2,399,330	5,622,066	217,742	187,284	26,245	61,190,585
IA80	73,200,000	-	2,310,600	654,780	1,521,029	2,327,408	5,930,869	1,509,908	198,313	44,965	58,702,128
IA90	123,600,000	50,000,000	2,628,707	1,043,373	747,748	1,465,622	28,896,577	3,157,518	26,399	1,704,445	33,929,612

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
IA10	219,629,630	3,843,518,519	829,424,650	202,036,452	18,346,768	68,000,303	727,815,645	51,893,623	2,898,615	215,442,611	1,727,659,851
IA20	246,666,667	4,316,666,667	161,458,868	45,905,107	11,033,695	16,487,269	395,450,826	25,331,105	202,727	391,473	3,660,405,599
IA30	120,370,370	2,106,481,481	406,468,884	400,937,820	21,291,242	48,563,249	292,476,419	37,118,866	1,663,021	27,591,536	870,370,444
IA40	182,962,963	3,201,851,852	460,050,129	19,329,559	11,149,165	43,547,325	282,863,932	38,846,919	177,931	309,476	2,345,577,416
IA50	162,592,593	2,845,370,370	149,977,919	30,541,118	16,383,785	15,544,270	342,583,886	36,153,392	201,068	14,462,192	2,239,522,740
IA60	369,259,259	6,462,037,037	277,334,337	104,454,361	26,102,475	27,421,740	148,009,889	19,606,809	196,010	10,056,878	5,848,854,538
IA70	85,185,185	1,490,740,741	167,176,947	14,346,644	10,032,959	30,265,380	43,561,077	2,295,445	1,228,843	175,117	1,221,658,330
IA80	-	-	59,491,918	20,990,531	31,721,994	29,358,149	45,953,760	15,917,524	1,301,209	300,030	(205,035,115)
IA90	50,000,000	875,000,000	67,682,358	33,447,819	15,594,743	18,487,492	223,897,418	33,286,701	173,217	11,372,847	471,057,404

Kansas

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
KS10	105,940,000	20,000,000	185,967	8,556	48,644	167,622	8,327	1,270	253	27,852
KS20	66,660,000	46,500,000	414,467	9,156	80,344	40,822	49	577	463	10,533
KS30	139,350,000	177,000,000	1,167,267	31,056	81,744	625,722	531	778	1,041	40,164
KS40	77,835,000	50,000,000	72,067	11,556	204,744	190,922	489,514	50,302	910	48,887
KS50	43,330,000	108,000,000	153,967	12,056	162,644	249,122	155,677	16,750	1,117	96,683
KS60	65,080,000	80,000,000	137,767	13,856	241,644	321,022	94,324	5,381	3,284	98,737
KS70	84,100,000	-	85,567	15,856	203,144	113,522	532,491	52,736	5,364	106,369
KS80	21,402,000	42,000,000	88,367	10,056	183,844	244,622	118,501	10,549	5,460	149,413
KS90	16,703,000	-	94,567	9,856	271,244	346,622	320,586	31,656	1,023	142,817

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
KS10	105,940,000	7,407,407	13,498,514	1,108,268	448,872	2,690,902	141,626	31,066	177	22,063	80,591,104
KS20	66,660,000	17,222,222	30,084,309	1,185,986	741,390	655,332	840	14,121	325	8,344	16,747,131
KS30	139,350,000	65,555,556	84,726,701	4,022,717	754,309	10,044,961	9,032	19,026	731	31,815	(25,814,847)
KS40	77,835,000	18,518,519	5,231,022	1,496,861	1,889,315	3,064,946	8,325,898	1,230,460	639	38,725	38,038,616
KS50	43,330,000	40,000,000	11,175,777	1,561,627	1,500,829	3,999,253	2,647,834	409,732	784	76,587	(18,042,423)
KS60	65,080,000	29,629,630	9,999,891	1,794,783	2,229,817	5,153,492	1,604,307	131,623	2,305	78,214	14,455,938
KS70	84,100,000	-	6,210,927	2,053,845	1,874,551	1,822,413	9,056,871	1,289,991	3,765	84,260	61,703,378
KS80	21,402,000	15,555,556	6,414,166	1,302,564	1,696,457	3,927,013	2,015,532	258,043	3,832	118,356	(9,889,519)
KS90	16,703,000	-	6,864,196	1,276,658	2,502,957	5,564,459	5,452,680	774,351	718	113,132	(5,846,152)

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
KS10	7,407,407	129,629,630	347,551,572	35,528,186	9,361,503	33,943,290	1,097,351	327,501	1,164	147,213	(298,328,152)
KS20	17,222,222	301,388,889	774,592,574	38,019,644	15,462,146	8,266,415	6,510	148,864	2,132	55,674	(535,165,069)
KS30	65,555,556	1,147,222,222	2,181,491,772	128,957,847	15,731,575	126,708,091	69,983	200,575	4,794	212,287	(1,306,154,702)
KS40	18,518,519	324,074,074	134,685,181	47,985,474	39,402,837	38,661,518	64,510,998	12,971,564	4,192	258,393	(14,406,083)
KS50	40,000,000	700,000,000	287,747,142	50,061,689	31,300,722	50,446,960	20,516,036	4,319,415	5,142	511,023	255,091,870
KS60	29,629,630	518,518,519	257,471,150	57,536,062	46,504,216	65,006,640	12,430,546	1,387,572	15,123	521,878	77,645,332
KS70	-	-	159,915,175	65,840,920	39,094,919	22,988,094	70,174,747	13,599,145	24,702	562,220	(372,199,921)
KS80	15,555,556	272,222,222	165,148,062	41,756,830	35,380,647	49,535,715	15,616,812	2,720,299	25,143	789,727	(38,751,013)
KS90	-	-	176,735,171	40,926,344	52,200,715	70,190,615	42,248,639	8,163,248	4,709	754,868	(391,224,308)

Michigan

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
MI10	840,000	-	3,298	14,567	8,722	19,845	1,828	495	32,985	14,665
MI20	3,690,000	-	6,454	18,767	6,601	24,211	2,522	456	34,995	32,885
MI30	3,430,000	-	4,191	19,267	9,571	28,104	1,407	867	35,301	20,104
MI40	8,910,000	-	4,585	27,767	5,110	20,672	12,093	1,398	32,326	22,419
MI50	36,290,000	-	22,757	47,867	15,260	70,748	108,534	14,594	43,519	52,724
MI60	68,350,000	53,000,000	57,664	69,067	7,839	80,663	68,320	4,628	35,636	15,160
MI70	65,280,000	-	19,545	46,767	12,043	74,779	492,119	59,467	262,945	10,135,583
MI80	101,690,000	105,000,000	37,322	90,767	23,028	96,416	231,690	25,465	141,700	75,010
MI90	46,590,000	110,000,000	14,183	26,167	10,827	44,556	21,487	2,630	41,330	63,450

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
MI10	840,000	-	239,423	1,886,879	80,486	318,584	31,084	12,105	23,151	11,617	(1,763,329)
MI20	3,690,000	-	468,458	2,430,910	60,910	388,674	42,903	11,151	24,562	26,050	236,383
MI30	3,430,000	-	304,225	2,495,675	88,320	451,158	23,930	21,199	24,776	15,925	4,790
MI40	8,910,000	-	332,775	3,596,689	47,149	331,853	205,676	34,199	22,688	17,759	4,321,210
MI50	36,290,000	-	1,651,863	6,200,264	140,816	1,135,752	1,845,998	356,986	30,544	41,765	24,886,012
MI60	68,350,000	19,629,630	4,185,591	8,946,323	72,332	1,294,918	1,162,027	113,211	25,012	12,009	32,908,948
MI70	65,280,000	-	1,418,659	6,057,780	111,127	1,200,449	8,370,202	1,454,629	184,550	8,028,830	38,453,774
MI80	101,690,000	38,888,889	2,709,055	11,757,147	212,497	1,547,797	3,940,703	622,914	99,454	59,419	41,852,126
MI90	46,590,000	40,740,741	1,029,491	3,389,440	99,905	715,278	365,467	64,343	29,008	50,261	106,067

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
MI10	-	-	6,164,518	60,488,439	1,678,582	4,018,654	240,844	127,614	151,900	77,514	(72,948,066)
MI20	-	-	12,061,567	77,928,642	1,270,322	4,902,767	332,419	117,556	161,158	173,818	(96,948,250)
MI30	-	-	7,833,013	80,004,857	1,841,958	5,690,951	185,417	223,482	162,568	106,262	(96,048,509)
MI40	-	-	8,568,098	115,300,507	983,329	4,186,030	1,593,626	360,526	148,868	118,498	(131,259,482)
MI50	-	-	42,531,171	198,764,338	2,936,795	14,326,488	14,303,224	3,763,363	200,412	278,673	(277,104,464)
MI60	19,629,630	343,518,519	107,768,073	286,795,841	1,508,519	16,334,221	9,003,660	1,193,476	164,111	80,126	(79,329,509)
MI70	-	-	36,526,770	194,196,666	2,317,628	15,142,583	64,854,276	15,334,770	1,210,906	53,572,078	(383,155,677)
MI80	38,888,889	680,555,556	69,751,120	376,903,559	4,431,759	19,524,056	30,533,485	6,566,791	652,554	396,468	171,795,764
MI90	40,740,741	712,962,963	26,506,699	108,656,620	2,083,588	9,022,582	2,831,726	678,304	190,333	335,366	562,657,744

Minnesota

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
MN10	45,119,000	-	3,100	19,000	50,389	83,078	21,811	1,487	31,452	5,253
MN20	974,000	-	1,150	3,000	29,889	29,328	473	403	31,354	15,014
MN30	974,000	-	1,150	1,300	4,789	3,328	535	67	33,725	8,606
MN40	213,003,000	181,000,000	33,200	62,300	41,789	137,478	516,002	41,861	76,261	22,226
MN50	196,000,000	189,500,000	61,700	186,900	66,389	329,678	715,245	66,916	7,404,642	10,284,381
MN60	19,880,000	-	6,300	18,800	39,989	63,178	13,104	2,429	36,607	27,630
MN70	244,650,000	201,000,000	121,300	25,900	43,089	235,678	2,180,506	147,971	485,721	13,025
MN80	286,600,000	482,000,000	43,900	35,900	21,189	117,578	2,975,045	235,210	144,244	34,269
MN90	194,000,000	91,000,000	48,200	116,800	62,489	230,778	817,279	63,657	132,238	75,596

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
MN10	45,119,000	-	225,015	2,461,090	464,974	1,333,684	370,981	36,375	22,075	4,161	40,200,645
MN20	974,000	-	83,473	388,593	275,807	470,814	8,049	9,849	22,006	11,893	(296,484)
MN30	974,000	-	83,473	168,390	44,191	53,426	9,095	1,629	23,670	6,817	583,308
MN40	213,003,000	67,037,037	2,409,840	8,069,786	385,616	2,206,988	8,776,420	1,023,976	53,524	17,606	123,022,207
MN50	196,000,000	70,185,185	4,478,528	24,209,357	612,618	5,292,450	12,165,242	1,636,847	5,197,014	8,146,699	64,076,060
MN60	19,880,000	-	457,289	2,435,184	369,006	1,014,221	222,872	59,428	25,693	21,887	15,274,419
MN70	244,650,000	74,444,444	8,804,625	3,354,855	397,612	3,783,432	37,087,133	3,619,548	340,908	10,318	112,807,125
MN80	286,600,000	178,518,519	3,186,505	4,650,165	195,526	1,887,526	50,601,061	5,753,526	101,239	27,146	41,678,788
MN90	194,000,000	33,703,704	3,498,623	15,129,229	576,630	3,704,770	13,900,687	1,557,123	92,812	59,883	121,776,540

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
MN10	-	-	5,793,554	78,896,159	9,697,327	16,823,213	2,874,445	383,472	144,840	27,764	(114,640,774)
MN20	-	-	2,149,222	12,457,288	5,752,117	5,938,891	62,366	103,825	144,390	79,356	(26,687,455)
MN30	-	-	2,149,222	5,398,158	921,640	673,917	70,470	17,178	155,307	45,486	(9,431,377)
MN40	67,037,037	1,173,148,148	62,047,095	258,696,351	8,042,263	27,839,160	68,001,749	10,794,802	351,193	117,478	737,258,057
MN50	70,185,185	1,228,240,741	115,310,415	776,089,054	12,776,516	66,759,471	94,259,136	17,255,717	34,099,646	54,358,555	57,332,230
MN60	-	-	11,773,997	78,065,673	7,695,855	12,793,483	1,726,865	626,489	168,584	146,041	(112,996,985)
MN70	74,444,444	1,302,777,778	226,696,165	107,547,921	8,292,447	47,724,564	287,359,760	38,157,446	2,236,830	68,845	584,693,799
MN80	178,518,519	3,124,074,074	82,044,201	149,072,215	4,077,808	23,809,430	392,068,826	60,653,942	664,269	181,133	2,411,502,250
MN90	33,703,704	589,814,815	90,080,422	485,003,753	12,025,964	46,732,318	107,705,770	16,415,263	608,978	399,565	(169,157,218)

Missouri

	Inventory hd									
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
MO10	100,096,500	70,000,000	8,792	5,222	198,233	227,553	42,901	10,064	202,437	126,106
MO20	43,702,500	101,000,000	4,018	3,322	201,333	200,327	608,016	9,887	97,165	64,555
MO30	58,842,000	50,000,000	9,262	6,422	93,933	132,883	604,440	81,684	97,847	568,308
MO40	28,845,000	-	5,888	5,522	215,933	222,057	102,660	30,543	96,465	192,802
MO50	43,997,000	50,000,000	6,216	20,122	432,733	454,429	702,144	132,329	8,692,143	2,302,150
MO60	22,036,000	-	7,039	5,722	128,533	130,606	183,909	36,861	96,328	99,166
MO70	4,985,000	-	1,510	19,822	297,833	259,835	129,170	39,902	30,096,868	3,735,473
MO80	1,581,000	-	3,905	25,822	254,533	292,440	13,406	12,069	97,067	325,972
MO90	48,469,000	-	3,370	3,022	41,933	19,875	8,354	1,661	5,703,876	18,467

	Feed Grain Demand bu										
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
MO10	100,096,500	25,925,926	638,161	676,411	1,829,234	3,653,000	729,677	246,187	142,082	99,894	66,155,926
MO20	43,702,500	37,407,407	291,655	430,302	1,857,840	3,215,927	10,341,444	241,844	68,196	51,136	(10,203,251)
MO30	58,842,000	18,518,519	672,259	831,849	866,785	2,133,229	10,280,626	1,998,083	68,675	450,181	23,021,795
MO40	28,845,000	-	427,352	715,271	1,992,564	3,564,775	1,746,096	747,109	67,705	152,727	19,431,402
MO50	43,997,000	18,518,519	451,220	2,606,424	3,993,129	7,295,121	11,942,409	3,236,936	6,100,658	1,823,632	(11,971,048)
MO60	22,036,000	-	510,964	741,177	1,186,064	2,096,662	3,128,009	901,659	67,608	78,553	13,325,304
MO70	4,985,000	-	109,605	2,567,565	2,748,313	4,171,233	2,196,993	976,062	21,123,755	2,959,029	(31,867,555)
MO80	1,581,000	-	283,452	3,344,751	2,348,753	4,694,653	228,019	295,229	68,127	258,216	(9,940,200)
MO90	48,469,000	-	244,610	391,443	386,945	319,062	142,086	40,634	4,003,316	14,629	42,926,275

	DDGS Demand lbs										
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
MO10	25,925,926	453,703,704	16,430,991	21,683,986	38,149,800	46,079,289	5,653,707	2,595,319	932,258	666,541	321,511,812
MO20	37,407,407	654,629,630	7,509,347	13,794,370	38,746,393	40,566,004	80,127,920	2,549,528	447,463	341,206	470,547,397
MO30	18,518,519	324,074,074	17,308,905	26,666,902	18,077,339	26,908,757	79,656,688	21,063,885	450,603	3,003,817	130,937,179
MO40	-	-	11,003,191	22,929,715	41,556,153	44,966,414	13,529,156	7,876,061	444,239	1,019,065	(143,323,993)
MO50	18,518,519	324,074,074	11,617,731	83,555,184	83,279,159	92,021,348	92,532,569	34,123,937	40,028,811	12,168,119	(125,252,783)
MO60	-	-	13,155,989	23,760,201	24,736,085	26,447,491	24,236,545	9,505,337	443,606	524,145	(122,809,397)
MO70	-	-	2,822,049	82,309,455	57,317,749	52,616,329	17,022,813	10,289,693	138,601,237	19,744,012	(380,723,338)
MO80	-	-	7,298,139	107,224,032	48,984,695	59,218,799	1,766,743	3,112,315	447,008	1,722,939	(229,774,669)
MO90	-	-	6,298,080	12,548,642	8,069,976	4,024,676	1,100,913	428,368	26,267,327	97,611	(58,835,593)

Nebraska

	Inventory hd									
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
NE10	63,210,000	54,000,000	300,265	209	287,625	216,701	817	140	91,523	5,512
NE20	75,996,000	44,000,000	190,834	4,337	390,225	581,104	160,390	32,607	91,771	4,159
NE30	298,277,000	280,000,000	664,194	27,298	266,725	145,683	1,031,696	131,490	96,008	5,026
NE50	201,656,000	298,000,000	460,406	6,527	267,025	194,542	154,011	22,427	91,876	37,440
NE60	350,943,000	838,000,000	411,385	10,542	150,925	127,348	871,312	127,585	98,720	9,313,266
NE70	152,086,000	109,000,000	201,163	189	128,225	306,924	16,246	6,032	94,288	2,901
NE80	170,673,000	219,000,000	236,256	572	101,925	167,748	6,927	158	91,623	2,553
NE90	229,909,000	160,000,000	85,497	8,328	179,325	79,950	523,602	64,561	92,713	5,141

	Feed Grain Demand bu										
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
NE10	63,210,000	20,000,000	21,794,898	27,032	2,654,116	3,478,791	13,891	3,427	64,237	4,367	15,169,243
NE20	75,996,000	16,296,296	13,851,800	561,743	3,600,878	9,328,692	2,727,988	797,617	64,411	3,294	28,763,281
NE30	298,277,000	103,703,704	48,210,854	3,535,981	2,461,257	2,338,706	17,547,595	3,216,415	67,384	3,981	117,191,122
NE50	201,656,000	110,370,370	33,418,843	845,392	2,464,026	3,123,060	2,619,490	548,585	64,484	29,658	48,172,091
NE60	350,943,000	310,370,370	29,860,632	1,365,476	1,392,690	2,044,366	14,819,710	3,120,879	69,287	7,377,438	(19,477,848)
NE70	152,086,000	40,370,370	14,601,488	24,440	1,183,221	4,927,169	276,326	147,551	66,177	2,298	90,486,960
NE80	170,673,000	81,111,111	17,148,740	74,060	940,533	2,692,919	117,813	3,866	64,307	2,023	68,517,629
NE90	229,909,000	59,259,259	6,205,862	1,078,680	1,654,757	1,283,472	8,905,688	1,579,242	65,071	4,073	149,872,896

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
NE10	20,000,000	350,000,000	561,161,828	866,569	55,353,227	43,881,797	107,630	36,124	421,481	29,136	(311,857,792)
NE20	16,296,296	285,185,185	356,647,754	18,008,017	75,098,524	117,673,009	21,137,089	8,408,512	422,623	21,982	(312,232,325)
NE30	103,703,704	1,814,814,815	1,241,303,871	113,354,354	51,331,037	29,500,664	135,962,860	33,907,603	442,134	26,563	208,985,729
NE50	110,370,370	1,931,481,481	860,448,136	27,101,057	51,388,772	39,394,579	20,296,424	5,783,207	423,105	197,893	926,448,310
NE60	310,370,370	5,431,481,481	768,833,465	43,773,608	29,045,409	25,787,821	114,826,573	32,900,458	454,621	49,225,687	4,366,633,839
NE70	40,370,370	706,481,481	375,950,269	783,473	24,676,810	62,151,772	2,141,041	1,555,485	434,214	15,336	238,773,080
NE80	81,111,111	1,419,444,444	441,535,361	2,374,162	19,615,394	33,968,733	912,846	40,755	421,941	13,496	920,561,757
NE90	59,259,259	1,037,037,037	159,784,770	34,579,666	34,510,969	16,189,837	69,003,349	16,648,447	426,958	27,175	705,865,866

North Dakota

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
ND10	576,000	-	1,150	678	57,633	62,739	7,609	12,254	1,655	81,640
ND20	7,908,000	-	8,515	2,178	97,533	63,274	2,268	230	1,201	92,850
ND30	16,675,000	10,000,000	396	678	11,733	48,993	-	17,459	1,733	82,716
ND40	4,902,000	50,000,000	12,963	2,578	152,733	87,226	4,083	267	1,394	87,415
ND50	26,500,000	-	7,544	2,178	99,233	86,145	470	249	2,100	84,301
ND60	51,870,000	150,000,000	3,352	778	39,733	16,037	14,707	4,373	1,201	57,748
ND70	3,555,000	50,000,000	8,456	2,278	119,833	112,433	911	111	1,845	79,941
ND80	19,089,000	-	5,839	6,678	180,933	124,050	3,116	501	2,375	69,411
ND90	85,225,000	110,000,000	11,785	1,978	120,633	139,104	77,835	4,555	1,803	85,433

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
ND10	576,000	-	83,481	87,822	531,820	1,007,172	129,421	299,760	1,162	64,671	(1,629,309)
ND20	7,908,000	-	618,063	282,119	900,005	1,015,763	38,576	5,622	843	73,550	4,973,459
ND30	16,675,000	3,703,704	28,772	87,822	108,269	786,498	-	427,075	1,217	65,523	11,466,121
ND40	4,902,000	18,518,519	940,897	333,931	1,409,374	1,400,280	69,449	6,542	979	69,245	(17,847,215)
ND50	26,500,000	-	547,592	282,119	915,692	1,382,918	7,994	6,082	1,474	66,778	23,289,350
ND60	51,870,000	55,555,556	243,272	100,775	366,644	257,456	250,150	106,973	843	45,745	(5,057,414)
ND70	3,555,000	18,518,519	613,810	295,072	1,105,783	1,804,925	15,494	2,709	1,295	63,325	(18,865,931)
ND80	19,089,000	-	423,829	865,008	1,669,595	1,991,423	52,995	12,266	1,667	54,983	14,017,233
ND90	85,225,000	40,740,741	855,414	256,212	1,113,165	2,233,093	1,323,863	111,420	1,266	67,675	38,522,152

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
ND10	-	-	2,149,431	2,815,347	11,091,430	12,704,563	1,002,785	3,160,086	7,622	431,512	(33,362,776)
ND20	-	-	15,913,520	9,043,991	18,770,157	12,812,930	298,898	59,268	5,530	490,762	(57,395,057)
ND30	3,703,704	64,814,815	740,813	2,815,347	2,258,008	9,920,955	-	4,502,247	7,983	437,197	44,132,265
ND40	18,518,519	324,074,074	24,225,655	10,704,963	29,393,357	17,663,260	538,107	68,967	6,422	462,035	241,011,308
ND50	-	-	14,099,065	9,043,991	19,097,320	17,444,259	61,942	64,118	9,673	445,576	(60,265,945)
ND60	55,555,556	972,222,222	6,263,627	3,230,590	7,646,588	3,247,573	1,938,222	1,127,717	5,530	305,230	948,457,146
ND70	18,518,519	324,074,074	15,804,008	9,459,234	23,061,776	22,767,498	120,055	28,557	8,496	422,534	252,401,917
ND80	-	-	10,912,496	27,729,924	34,820,427	25,119,997	410,619	129,313	10,935	366,875	(99,500,586)
ND90	40,740,741	712,962,963	22,024,689	8,213,505	23,215,735	28,168,441	10,257,598	1,174,593	8,304	451,561	619,448,536

South Dakota

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
SD10	6,650,833	-	3,241	1,422	183,300	223,537	4,854	908	10,550	153,520
SD20	124,217,833	266,000,000	52,666	4,722	162,300	227,312	165,530	24,932	10,550	354,150
SD30	106,860,833	199,000,000	61,470	30,522	161,100	206,408	154,151	28,916	10,857	400,843
SD40	4,159,000	-	664	1,422	210,300	117,014	159	20	10,588	205,756
SD50	87,232,833	32,000,000	45,077	3,422	199,200	273,301	115,567	18,647	10,550	220,235
SD60	154,996,833	238,000,000	93,660	32,522	190,700	194,118	291,296	36,491	13,101	467,350
SD70	2,645,833	-	115	1,422	95,300	58,163	39	18	10,550	148,117
SD80	27,885,000	-	28,561	2,322	237,600	159,017	27,854	4,024	10,994	117,288
SD90	144,021,000	287,000,000	114,545	12,222	170,200	141,133	470,550	56,044	11,252	316,740

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
SD10	6,650,833	-	235,222	184,193	1,691,437	3,588,533	82,562	22,207	7,404	121,610	717,664
SD20	124,217,833	98,518,519	3,822,767	611,646	1,497,655	3,649,134	2,815,417	609,867	7,404	280,537	12,404,887
SD30	106,860,833	73,703,704	4,461,808	3,953,547	1,486,582	3,313,554	2,621,885	707,311	7,620	317,525	16,287,297
SD40	4,159,000	-	48,223	184,193	1,940,585	1,878,466	2,700	495	7,431	162,988	(66,081)
SD50	87,232,833	11,851,852	3,271,972	443,255	1,838,157	4,387,401	1,965,616	456,134	7,404	174,458	62,836,583
SD60	154,996,833	88,148,148	6,798,358	4,212,610	1,759,722	3,116,253	4,954,514	892,623	9,195	370,208	44,735,202
SD70	2,645,833	-	8,381	184,193	879,399	933,706	659	437	7,404	117,330	514,323
SD80	27,885,000	-	2,073,148	300,771	2,192,501	2,552,755	473,751	98,433	7,716	92,909	20,093,016
SD90	144,021,000	106,296,296	8,314,335	1,583,129	1,570,554	2,265,658	8,003,351	1,370,906	7,897	250,903	14,357,971

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
SD10	-	-	6,056,353	5,904,755	35,275,955	45,266,100	639,713	234,109	48,583	811,439	(94,237,007)
SD20	98,518,519	1,724,074,074	98,426,291	19,607,772	31,234,520	46,030,520	21,814,504	6,429,248	48,583	1,871,875	1,498,610,760
SD30	73,703,704	1,289,814,815	114,879,930	126,740,450	31,003,581	41,797,487	20,314,975	7,456,504	49,997	2,118,676	945,453,214
SD40	-	-	1,241,607	5,904,755	40,472,086	23,695,148	20,923	5,216	48,757	1,087,533	(72,476,025)
SD50	11,851,852	207,407,407	84,244,761	14,209,613	38,335,899	55,343,089	15,230,053	4,808,589	48,583	1,164,063	(5,977,244)
SD60	88,148,148	1,542,592,593	175,040,016	135,045,309	36,700,080	39,308,712	38,388,730	9,410,071	60,330	2,470,202	1,106,169,143
SD70	-	-	215,796	5,904,755	18,340,417	11,777,856	5,107	4,602	48,583	782,877	(37,079,994)
SD80	-	-	53,378,159	9,641,941	45,725,951	32,200,696	3,670,732	1,037,688	50,630	619,931	(146,325,728)
SD90	106,296,296	1,860,185,185	214,072,452	50,750,992	32,754,869	28,579,226	62,011,829	14,452,155	51,817	1,674,142	1,455,837,703

Wisconsin

Inventory hd										
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
WI10	38,460,000	-	7,782	92,422	31,892	136,215	6,424	781	9,167	78,902
WI20	22,160,000	41,000,000	6,370	158,922	22,628	181,192	6,482	1,326	14,051	87,260
WI30	16,670,000	-	9,858	76,822	10,254	103,277	2,883	648	4,151	80,754
WI40	92,700,000	40,000,000	42,687	165,622	54,013	240,389	43,330	5,949	6,693,118	1,164,151
WI50	42,100,000	90,000,000	16,581	87,422	18,038	115,370	5,208	1,094	41,668	85,964
WI60	51,500,000	48,000,000	26,746	301,522	14,202	321,741	18,008	3,106	9,023	166,852
WI70	91,700,000	-	63,467	172,522	81,661	298,061	122,210	15,832	26,715	2,123,927
WI80	125,500,000	285,000,000	64,605	164,422	25,868	216,816	72,756	10,548	35,250	939,560
WI90	37,130,000	-	11,904	45,322	6,445	56,940	19,700	3,716	4,065	28,630

Feed Grain Demand bu											
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
WI10	38,460,000	-	564,825	11,971,521	294,290	2,186,720	109,256	19,109	6,434	62,501	23,245,344
WI20	22,160,000	15,185,185	462,344	20,585,337	208,802	2,908,740	110,241	32,431	9,861	69,123	(17,412,064)
WI30	16,670,000	-	715,537	9,950,836	94,620	1,657,950	49,030	15,857	2,913	63,969	4,119,289
WI40	92,700,000	14,814,815	3,098,455	21,453,195	498,412	3,859,066	736,973	145,514	4,697,625	922,174	42,473,772
WI50	42,100,000	33,333,333	1,203,533	11,323,865	166,451	1,852,078	88,581	26,757	29,245	68,096	(5,991,940)
WI60	51,500,000	17,777,778	1,941,385	39,056,468	131,048	5,165,039	306,292	75,986	6,333	132,170	(13,092,499)
WI70	91,700,000	-	4,606,815	22,346,960	753,541	4,784,887	2,078,611	387,266	18,750	1,682,454	55,040,717
WI80	125,500,000	105,555,556	4,689,402	21,297,758	238,703	3,480,628	1,237,473	258,013	24,740	744,266	(12,026,538)
WI90	37,130,000	-	864,089	5,870,607	59,472	914,074	335,068	90,901	2,853	22,679	28,970,257

DDGS Demand lbs											
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
WI10	-	-	14,542,771	383,775,830	6,137,602	27,583,494	846,543	201,445	42,215	417,039	(433,546,938)
WI20	15,185,185	265,740,741	11,904,145	659,912,384	4,354,697	36,691,121	854,171	341,890	64,705	461,219	(448,843,591)
WI30	-	-	18,423,202	318,997,931	1,973,359	20,913,541	379,898	167,162	19,114	426,829	(361,301,035)
WI40	14,814,815	259,259,259	79,777,148	687,733,661	10,394,689	48,678,625	5,710,239	1,534,011	30,822,956	6,153,173	(611,545,243)
WI50	33,333,333	583,333,333	30,987,846	363,013,683	3,471,442	23,362,289	686,345	282,071	191,890	454,366	160,883,403
WI60	17,777,778	311,111,111	49,985,614	1,252,048,816	2,733,076	65,152,294	2,373,218	801,053	41,551	881,902	(1,062,906,414)
WI70	-	-	118,613,473	716,385,424	15,715,571	60,357,013	16,105,561	4,082,579	123,028	11,226,113	(942,608,762)
WI80	105,555,556	1,847,222,222	120,739,875	682,750,746	4,978,294	43,904,974	9,588,229	2,719,986	162,331	4,966,088	977,411,700
WI90	-	-	22,248,030	188,196,405	1,240,332	11,530,214	2,596,188	958,284	18,722	151,323	(226,939,496)

Subregions

					Inventory hd					
District	Total Grain bu	Ethanol mgy	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers
Colorado	180,420,000	122,000,000	1,100,000	123,000	727,000	700,000	570,000	150,000	10,704	3,681,000
Oklahoma	30,100,000	-	380,000	54,000	2,016,000	2,650,000	1,890,000	410,000	42,914,275	3,320,000
Texas	142,610,000	470,000,000	2,850,000	425,000	5,025,000	5,000,000	730,000	90,000	114,864,107	18,561,000
Northwest	(290,571,000)	208,000,000	636,000	967,000	3,398,000	3,439,000	2,865,000	471,000	8,493,389	10,129,455
Northeast	1,066,041,000	970,000,000	360,954	1,930,100	2,882,500	4,699,346	11,724,900	1,181,000	398,063,105	90,955,820
Southwest	49,911,000	326,500,000	766,106	2,372,000	1,838,000	3,893,894	942,100	106,400	42,997,287	25,107,365
Southeast	(630,928,000)	379,000,000	45,636	315,000	5,145,000	4,169,364	999,000	171,000	875,410,080	62,403,000

					Feed Grain Demand bu						
District	Total Grain bu	Ethanol	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
Colorado	180,420,000	45,185,185	79,844,089	15,932,322	6,708,535	11,237,375	9,694,845	3,669,188	7,513	2,915,878	5,225,071
Oklahoma	30,100,000	-	27,582,504	6,994,678	18,603,036	42,541,491	32,146,065	10,029,113	30,119,767	2,629,914	(140,546,567)
Texas	142,610,000	174,074,074	206,868,777	55,050,705	46,369,175	80,266,964	12,416,205	2,201,513	80,618,399	14,702,964	(529,958,775)
Northwest	(290,571,000)	77,037,037	46,164,401	125,256,546	31,355,712	55,207,618	48,729,353	11,521,249	5,961,161	8,023,975	(699,828,052)
Northeast	1,066,041,000	359,259,259	26,200,039	250,007,921	26,598,835	75,440,448	199,422,962	28,888,736	279,384,145	72,050,003	(251,211,348)
Southwest	49,911,000	120,925,926	55,608,214	307,247,701	16,960,506	62,510,210	16,023,708	2,602,677	30,178,030	19,888,620	(582,034,593)
Southeast	(630,928,000)	140,370,370	3,312,514	40,802,288	47,476,498	66,932,438	16,991,492	4,182,874	614,414,380	49,432,091	(1,614,842,944)

					DDGS Demand lbs						
District	Grain for Ethanol bu	DDGS production	Cattle on Feed	Dairy Cows	Beef Cows	Other Cattle	Mkt. Hogs	Breeding Swine	Broilers	Layers	Surplus
Colorado	45,185,185	790,740,741	2,055,777,255	510,748,816	139,910,634	141,749,313	75,117,921	38,680,750	49,292	19,456,090	(2,190,749,330)
Oklahoma	-	-	710,177,597	224,231,187	387,977,768	536,622,398	249,075,213	105,727,383	197,627,595	17,548,009	(2,428,987,151)
Texas	174,074,074	3,043,965,793	5,326,331,978	1,764,782,493	967,057,682	1,012,495,091	96,203,654	23,208,450	528,968,907	98,104,997	(6,773,187,459)
Northwest	77,037,037	1,345,328,500	1,188,613,031	4,015,399,225	653,942,687	696,394,124	377,566,394	121,457,555	39,113,513	53,539,688	(5,800,697,717)
Northeast	359,259,259	6,285,932,871	674,582,748	8,014,603,976	554,735,078	951,612,951	1,545,175,641	304,546,438	1,833,148,855	480,751,060	(8,073,223,876)
Southwest	120,925,926	2,115,889,954	1,431,766,627	9,849,562,526	353,721,795	788,509,712	124,155,427	27,437,545	198,009,881	132,706,102	(10,789,979,661)
Southeast	140,370,370	2,454,864,259	85,288,592	1,308,015,260	990,151,596	844,292,117	131,654,041	44,096,055	4,031,413,519	329,833,851	(5,309,880,771)

Appendix B

Yearly per head feedstock consumption estimates for each livestock class were determined using ration and DDGS substitution ratios from ERS research by Linwood Hoffman. The general method of calculating the amounts is as follows:

(Daily Ration Total Dry Matter (TDM) lbs/hd * Ration Feedstock %) /Dry Matter % of Corn= Daily Feedstock Consumption in lbs.

Daily Feedstock Consumption in lbs * Livestock Class Days on Feed = Annual Feedstock Consumption in lbs.

These annual feedstock figures are for a strictly grain ration, and need to be adjusted to reflect the pounds of DDGS being fed in the calculations. The ERS research gives substitution ratios of DDGS for corn for various livestock classes. The annual DDGS consumption estimates for each livestock class are multiplied by their corresponding substitution ratio, to determine the amount of grain displaced from the ration. The annual feedstock consumption in pounds is then reduced by the amount of DDGS corn displacement in pounds.. The general method is shown below, followed by the entire calculation for each class of livestock in table A.2.

Annual DDGS Consumption in lbs * DDGS substitution rate= Pounds of Corn Substituted

Annual Feedstock Consumption lbs- Pounds Corn Substituted = Annual Feedstock Consumption per Head in lbs

Table A.2 Annual Feedstock Consumption Estimation
Cattle on Feed

[(22.1 * 0.85) / 0.88] * 365 = 7,791.51 lbs annual feedstock

3,105.6 * 1.2 = 3,726.72 lbs corn substituted

7,791.51 – 3,726.72 = 4,064.79 lbs grain/hd/yr

Beef Cows

{[((22.3 * 0.7) +2) /2] / 0.88} * 90 = 900.51 lbs annual feedstock

319.8 * 1.2 = 383.76 lbs corn substituted

900.51 – 383.76 = 516.75 lbs grain/hd/yr

Other Cattle

[((16.6 * 0.75 * 0.489) + (10 * 0.75 * 0.511)) / 0.88] * 120 = 1,302.79 lbs annual feedstock

336.5 * 1.2 = 403.8 lbs corn substituted

1,302.79 –403.8 = 898.99 lbs grain/hd/yr

Dairy Cows

[((52 * 0.5 * 0.84) + (27 * 0.5 * 0.16)) / 0.88] * 365 = 9,931.82 lbs annual feedstock

3,668.6 * 0.73 = 2,678 lbs corn substituted

9,931.82 – 2,678 = 7,253.74 lbs grain/hd/yr

Market Hogs

[(2 * 0.7 * 0.37) + (4.2 * 0.7 * 0.25) + (6.9 * 0.7 * 0.28)] * 365 = 1,127.27 lbs annual feedstock

249.7 * 0.7 = 174.79 lbs corn substituted

1,127.27 – 174.79 = 952.476 lbs grain/hd/yr

Breeding Swine

[(4.2 * 0.7 * 0.75) + (11.7 * 0.7 * 0.25)] * 365 = 1,711.85 lbs annual feedstock

488.6 * 0.7 = 342.02 lbs corn substituted

1,711.85 – 342.02 = 1,369.83 lbs grain/hd/yr

Laying Hens

[(0.2357 * 0.64 * 0.833) + (0.1442 * 0.64 * 0.125)] * 365 = 50.09 lbs annual feedstock

9.4 * 0.61 = 5.734 lbs corn substituted

50.09 – 5.734 = 44.36 lbs grain/hd/yr

Broilers

(0.2167 * 0.56) * 365 = 44.3 lbs annual feedstock

8.19 * 0.61 = 4.996 lbs corn substituted

44.3 – 4.996 = 39.3 lbs grain/hd/yr