Chapter 9

Transportation and Logistics in Distillers Grain Markets

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In 2008, ethanol production continues its rapid expansion in capacity that began in 2002. The U.S. Department of Energy forecasts that 2009 ethanol production will reach 11 billion gallons, up from 2.1 billion gallons in 2002 (Energy Information Administration, 2008). Plant-level data, as tracked by *Ethanol Producer Magazine* (2008), suggest that industry capacity may reach as much as 13.2 billion gallons by the end of 2009. Further expansion is possible because the Renewable Fuels Standards of the Energy Independence and Security Act of 2007 mandates the use of 15 billion gallons of starch-based ethanol (largely to come from corn) by 2015. As a co-product of ethanol, distillers grain production tracks the explosive growth in ethanol capacity.

From 2004 to 2007, 88% of the U.S. corn production and 97% of ethanol production capacity, as well as 40% of U.S. beef and dairy production, were found in the Corn Belt (Table 9.1). In the nascent days of the U.S. ethanol industry, most of the distillers grains produced were consumed by the local feed market. Thus, distillers grain transportation movements were heavily dependent on trucks.

With the continued expansion of the U.S. ethanol industry, ethanol plants can now be described as origin mills because their production capacity is heavily concentrated in the same geographic area as the corn. The local market for distillers grains in the Corn Belt has been saturated and now requires that distillers grains be shipped to other regions of the United States or exported. Serving more distant markets leads ethanol producers to reconsider their shipping alternatives to include rail, containers, or barge. Transportation has become the third-highest ethanol plant expense, after feedstock

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Table 9.1. Distribution of corn, ethanol, livestock production, by census region, 2004 to 2007

Census Region	States	Corn Production[a]	Ethanol Production[b]	Beef and Dairy[a]	Hogs and Poultry[a]
			Percent		
1	CT, MA, ME, NH, RI, VT	0.0	0.0	0.5	0.0
2	NJ, NY, PA	1.7	0.0	3.0	1.9
3	IL, IN, MI, OH, WI	34.4	24.2	8.1	2.2
4	IA, KS, MN, MO, ND, NE, SD	53.3	72.8	32.3	5.1
5	DE, FL, GA, MD, NC, SC, VA, WV	2.4	0.0	6.1	36.9
6	AL, KY, MS, TN	2.9	0.7	6.5	25.2
7	AR, LA, OK, TX	3.3	0.2	22.8	24.6
8	AZ, CO, ID, MT, NM, NV, UT, WY	1.5	1.2	12.9	0.1
9	CA, OR, WA	0.4	0.9	7.7	3.9
	USA	100.0	100.0	100.0	100.0

Sources: [a]USDA-ERS, 2008; [b]*Ethanol Producer Magazine*, 2008.

and energy costs, further emphasizing the economic importance of finding low-cost transportation alternatives (Denicoff, 2007).

Transportation concerns for distillers grains can be characterized as being at either the plant or industry level. Examples of plant- or micro-level transportation issues include concerns about product shipping characteristics, equipment availability, rail car ownership, and rates. Industry- or macro-level issues center on modal share (or how much traffic is hauled by the different modes of truck, rail, and barge) as the geographic markets for distillers grains expand. In this chapter, plant-level issues will be addressed, and then transportation requirements for U.S. distillers grains will be estimated by identifying sources of production and points of consumption for distillers grains. In turn, inferences will be drawn about how distillers grains will be shipped, as well as when specific markets will be saturated.

Shipping Characteristics of Distillers Grains

Attributes such as moisture content, shelf life, and product density are key characteristics related to product shipment. As part of the dry-grind process, distillers grains are produced with a dry matter content of 30% to 35%, or conversely, a moisture content of 65% to 70%. This high-moisture-content product is known as wet distillers grains with solubles (WDGS), and it accounted for 37% of the total distillers grains marketed from ethanol plants in 2006 (Wu, 2008). With a shelf life of less than a week, WDGS must be shipped to users in close proximity to the ethanol plant (Elliott, Magnuson, and Wend, 2006). The high moisture content also means that 1,300 pounds per ton of the feed is water content, which adds to the transportation cost and thereby limits the market area. Additionally, flowability can be an issue with wet co-products.

Because of these characteristics, virtually all WDGS are shipped by truck to local feedlots; the average shipping distance was 61 miles in 2003 (USDA-NASS, 2006). Some ethanol plants located adjacent to feedlots use conveyors to transport the feed to cattle feedlots.

Despite these limitations, WDGS are popular for two reasons. First, an ethanol plant can lower its energy costs by avoiding the drying cost of the distillers grains. “Natural gas expenditures frequently represent

30% of the operating budget of dry mill plants" (Tiffany and Eidman, 2003).Second, WDGS provide a low-cost feed for farmers near the ethanol plant.

Most ethanol plants dry some of their distillers grains because the local demand is insufficient to consume the daily production of distillers grains in the wet format. Distillers dried grains with solubles (DDGS) have a dry matter content of approximately 90%, which extends the shelf life of the co-product. However, if the grains are not carefully manufactured, flowability issues can also occur with DDGS (Markham, 2005). Unless the moisture content of DDGS is under 11%, the grains can cake or solidify during shipment (Shurson, 2005). As a result, "workers sometimes hammer the car sides and hopper bottoms in order to induce flow. This can lead to severe damage to the rail cars themselves and can also pose worker safety issues" (Denicoff, 2007). Because of these problems, the Burlington Northern Santa Fe and Union Pacific railroads require that DDGS be shipped in hopper cars owned or leased by the shipper, rather than using carrier-owned equipment (Cooper, 2005).

A second key transportation attribute is co-product bulk density, which is measured as pounds per cubic foot. The density of DDGS averages 32 pounds per cubic foot, which means that the 4,500-cubic-foot capacity of a conventional grain hopper car is filled at a weight of 72 tons. However, the weight limit for traditional grain hopper cars is 100 tons, which means that DDGS "cubes out" or fills the volume of the car before the car reaches its maximum weight threshold.

To alleviate this bulk density problem, shippers are investing in jumbo hoppers, or rail cars with volumes of 6,300 cubic feet, which can haul 100 tons of DDGS. The nation's fleet of jumbo hopper cars increased by 11,000 in 2005 and 2006, with additional orders made for 14,000 cars (Dennison, 2007). These rail cars also have wider unloading chutes that facilitate faster unloading and improve flowability. Five-year lease rates for jumbo hopper cars range from $450 to $630 per month (Markham, 2005). The number of hopper cars leased depends on the location of destination markets for a particular ethanol plant and the plant's reliance on rail as a shipping mode.

Alternative Modes of Transportation for Distillers Dried Grains with Solubles

A 100-million-gallon plant operating 354 days per year produces 6,200 tons of DDGS per week. Storage capacity for DDGS at the ethanol plant is generally limited to two weeks. Thus, ethanol plants are highly dependent upon reliable transportation providers. DDGS are shipped by truck, rail, barge, or container. Modal choice is a function of the volume shipped, distance, rates, and the receiving capability at the destination.

Transportation rates can be extremely volatile, competitive, and reflective of local market conditions. Trucks are the most cost-effective mode for short-distance movements (up to 250 miles), while rail and barge are the preferred modes for longer distances and larger volume movements. In addition, rates can vary by season, as well as being subject to weather-related disruptions. Thus, any comparison of rates among transportation modes should be viewed with extreme trepidation. Nevertheless, examples of rates to haul DDGS are provided for August 2008 (Table 9.2). The rates are reflective of the normal shipment size and equipment configuration for a typical distance or length of haul for a particular mode.

A 100-million-gallon ethanol plant could ship 248 truckloads of DDGS per week, at a payload of 24 tons per truck (Table 9.2). The average length of haul for a movement of DDGS in 2003 was 80 miles at a cost of $4.00 per ton (USDA-NASS, 2006). Updated to 2008, the truck cost per ton mile would be $9.25 per ton, with each additional mile adding 10¢ per ton to the cost.[1] Truckers may be able to deliver two loads per day for round trip distances of up to 120 miles.

Rail rates are quoted from origins to destinations and differ by the number of cars shipped at one time, the number of origins per shipment, the distance traveled, and the type of equipment. Additional expenses related to hauling DDGS by rail include car ownership and applicable fuel surcharges. Rate quotes were obtained for DDGS from the Burlington Northern Santa Fe Railroad Web page (2008), for movements from

[1]The Iowa State Grain Truck Transportation Calculator is an interactive spreadsheet model found at http://www.extension.iastate.edu/agdmg/crops/xls/a3-29graintransportation.xls.

Table 9.2. Equipment payload, loads per week, and rates per ton, by mode, August 2008

Mode	Equipment Capacity Payload (tons)	Loads per Week for 100 Million Gallon Plant	Typical Trip One-Way Distance (miles)	Estimated Rate for Typical Trip ($ per load)	Cost per Ton per Mile
Containers	19	326	2,100 plus ocean crossing	$2,000	$0.050
Truck	24	258	80	$220	$0.115
Jumbo hopper, single car rate	100	62	800 1,900	$4,200 $4,900	$0.052 $0.025
Jumbo hopper, 100 car rate	100	62	800 1,900	$3,200 $3,900	$0.039 $0.020
Barge	1,500	4	1,400	$37,740	$0.018

southwest Iowa to Friona, Texas, and Swanson, California, at a distance of roughly 800 and 1,900 miles, respectively. For long-distance shipments, transit time can range from twelve days for unit trains to thirty days for single car shipments. Thus, the utilization of rail equipment is much less than that of truck transport, at 12 to 30 turns per year (Denicoff, 2007).

Since deregulation, the rail industry has steadily shifted traffic to trainload consignments of 80 to 100 rail cars depending upon the carrier. While trainload rates are published, relatively few feedlots have the ability to accept and store 10,000 tons of DDGS at one time. In addition, it would take eleven days for a 100-million-gallon ethanol plant to fill a train with DDGS.

Rates are quoted for a unit train loaded from one origin consisting of 95 to 100 jumbo hopper cars at $32 per ton to Friona, Texas, and $39 per ton to Swanson, California (Table 9.2). The rate per ton is $4.00 per ton higher if the 100-car train is loaded from three origins instead of one. Ethanol plants shipping at a single car rate pay an additional $10.00 per ton than the unit train rate. Shipping by jumbo hoppers lowers rates by $4.00 per ton relative to grain hopper cars.

DDGS can also be shipped by barge from the Upper Mississippi River to New Orleans and then transloaded onto an ocean-going vessel. The weekly USDA *Grain Transportation Report* provides barge rates for seven origins along the Mississippi River. The mid-Mississippi rate, applicable for ethanol plants in Northeast Iowa, was $25.16 per ton on August 12, 2008. The distance to Baton Rouge, Louisiana, is 1,450 miles and would take close to forty days to traverse (Vachal, Hough, and Griffin, 2005). Each barge can hold 1,500 tons, or the equivalent of 15 jumbo hopper cars. Barges are shipped as part of a tow of up to 15 separate barges. A 100-million-gallon ethanol plant can load four barges per week.

Despite their much smaller payload of 18 tons, containers are also being used to ship DDGS to Asia. Inland container ports near Chicago, Kansas City, Memphis, and Columbus are loading DDGS into containers as a backhaul to Asian markets (U.S. Grains Council, 2007). The August 2008 rate for shipping a 20-foot container to Asia is $2,000 per container (USDA-AMS, 2008). The time needed to deliver a container to Asia from

Chicago would be approximately ten days from Chicago to Long Beach, California, and an additional sixteen to eighteen days from Long Beach to Asia (U.S. Grains Council, 2007).

A comparison of rates would suggest that ethanol plants should always opt for jumbo hopper 100-car rates or barge rates because of the lower costs per ton per mile (Table 9.2). Yet, the northern portions of the Upper Mississippi River are closed to navigation from late November until late March in most years. Similarly, while most ethanol plants can load unit trains of DDGS, relatively few feedlots can receive that much feed at one time. Furthermore, the rail rate does not reflect an additional fixed cost of $500 per month for a rail hopper car lease. Finally, the equipment utilization is much lower for rail and barge compared with that of trucks. Instead of at least 1 load per day, trains haul 8 to 40 loads per year, while barges from the Upper Mississippi make four or five trips per year.

Modal Share for Distillers Grains

The remainder of this chapter considers the effect of the growth of the ethanol industry on the transportation for DDGS. Two prior analyses have estimated modal shares for truck, rail, and barge movements of distillers grains (Table 9.3). The initial work by Denicoff (2007) suggested that most DDGS would move by truck in 2005. Pentland (2008) argued that shippers will be dependent on truck transportation to move DDGS to markets because of capacity constraints for rail and barge traffic. Results from the most recent survey of ethanol plants showed that railroads' market share grew from 14% in 2005 to 57% in 2007 (Wu, 2008).

Given the continued growth of the U.S. ethanol industry, a transportation flow model was developed to provide additional perspectives about the shifts in distillers grain movements. By comparing results over time, the model

Table 9.3. Modal shares for dried distillers grain, 2005 and 2007

Mode	2005[a]	2007[b]
Truck	84%	43.5%
Rail	14%	56.5%
Barge	2%	0%
Total	100%	100%

Sources: [a]Denicoff, 2007; [b]Wu, 2008.

considers the magnitude of the new traffic upon the existing network, as well as providing consideration as to the geographic locations for corn, ethanol, and distillers grain production and consumption. In turn, effects on transportation requirements are inferred based upon whether the consumption of the distillers grains is within a state's borders. Distillers grains produced and consumed within a state are assumed to be transported by truck, while surplus production from a state is assumed to be shipped by rail or barge.

The model captures the flow of corn to two end uses, ethanol and livestock feed, as well as the flow of distillers grains for livestock feed (Figure 9.1). Secondary data represent state-level activity for the years 2004 through 2010. The 2004 model provides a baseline that reflects the market before the recent expansion of the ethanol industry. The 2007 model captures the effect of the first wave of ethanol construction, with the 2010 model anticipating the further expansion of ethanol capacity. Results are presented by census region (Figure 9.2).

Corn production data are from the USDA's Economic Research Service (USDA-ERS, 2008). Data for 2004 to 2007 are the reported state levels of corn production. For 2008 to 2010, corn production is forecast by determining the state proportion of average U.S. production for the period 2001 to 2007, and multiplying that value times the long-term USDA forecast (Westcott, 2008). Corn production is heavily concentrated in the Midwest states, with Census Regions 3 and 4 accounting for 87.6% of all corn production (Table 9.4). Five states—Illinois, Indiana, Iowa, Minnesota, and Nebraska—account for 65% of U.S. corn production.

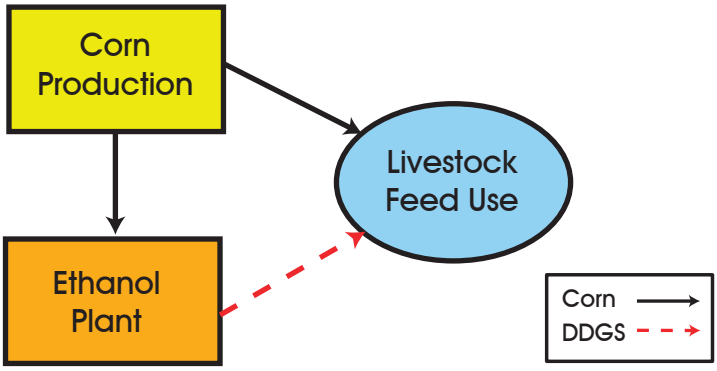

Figure 9.1. Transportation flows of corn and distillers grains

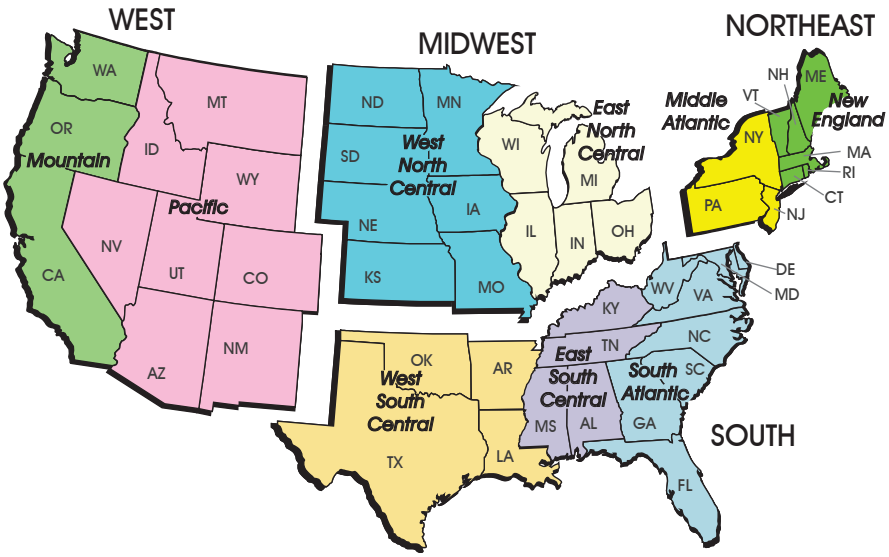

Figure 9.2. U.S. states by census regions

Ethanol plant capacities for plants operating and under construction by location are provided monthly from January 2005 through July 2008 by the Nebraska Energy Statistics Web site (2008). The yearly snapshot in this analysis uses the production capacity for July of each year. Three modifications were made to the data. First, the interest in this analysis is limited to dry-grind ethanol production because wet corn milling produces different co-products. Thus, all corn wet mills were excluded from the Nebraska data. Second, to obtain data for 2004, the Web sites for plants operating in 2005 were visited to determine a start-up date for each plant. Third, the plant data for 2009 assume that all plants under construction in 2008 will open in 2009. Data for 2010 include the capacities of an additional 11 dry-grind plants that currently have suspended operations, according to the *Ethanol Producer Magazine* (2008) Web site.

In 2004, 59 corn dry-grind plants operated at 2.6 billion gallons of capacity (Table 9.5). As of July 2008, 144 dry-grind ethanol plants were in operation with 8.2 billion gallons of capacity. By 2010, 189 dry-grind plants will be in operation with a capacity of 12.4 billion gallons. Almost 90% of the ethanol productive capacity is found in Census Regions 3 and 4. In 2008, Iowa, Nebraska, Minnesota, and Indiana accounted for 50% of industry capacity. While the U.S. Corn Belt is the region where most of the ethanol production capacity is located, ethanol production is steadily expanding to

Table 9.4. Historic and assumed corn production and region share, by year

Census Region	States	2004	2005	2006	2007	2008	2009	2010	Region Share
		million bushels							
1	CT, MA, ME, NH, RI, VT	0	0	0	0	0	0	0	0.0%
2	NJ, NY, PA	208	182	187	206	216	216	224	1.7%
3	IL, IN, MI, OH, WI	4,119	3,779	3,821	4,547	4,135	4,599	4,768	34.8%
4	IA, KS, MN, MO, ND, NE, SD	6,244	6,045	5,507	6,776	6,560	6,921	7,176	52.8%
5	DE, FL, GA, MD, NC, SC, VA, WV	300	271	285	303	252	314	326	2.4%
6	AL, KY, MS, TN	343	304	262	422	366	389	403	2.9%
7	AR, LA, OK, TX	362	315	265	555	477	441	458	3.4%
8	AZ, CO, ID, MT, NM, NV, UT, WY	179	176	168	198	220	212	220	1.6%
9	CA, OR, WA	52	43	39	68	60	58	60	0.4%
	USA	11,807	11,114	10,535	13,074	12,285	13,150	13,635	100.0%

Source: USDA-ERS, 2008.

Table 9.5. Historic and assumed dry-mill ethanol production and region share, by year

Census Region	States	2004	2005	2006	2007	2008	2009	2010	Region Share
		million gallons							
1	CT, MA, ME, NH, RI, VT	0	0	0	0	0	0	0	0.0%
2	NJ, NY, PA	0	0	0	0	50	274	274	1.7%
3	IL, IN, MI, OH, WI	670	710	736	1,291	2,300	3,126	3,163	26.0%
4	IA, KS, MN, MO, ND, NE, SD	1,887	2,013	2,782	3,729	5,158	7,225	7,647	63.0%
5	DE, FL, GA, MD, NC, SC, VA, WV	0	0	0	0	0	100	100	0.6%
6	AL, KY, MS, TN	23	23	33	33	33	133	133	0.9%
7	AR, LA, OK, TX	0	0	0	0	240	355	355	2.5%
8	AZ, CO, ID, MT, NM, NV, UT, WY	15	20	117	172	262	262	282	2.4%
9	CA, OR, WA	0	0	25	60	112	430	430	2.8%
	USA	2,595	2,766	3,693	5,285	8,154	11,904	12,384	100.0%
Number of plants		59	69	82	107	144	180	189	
Number of states		13	14	16	17	22	26	26	

Source: Nebraska Energy Statistics, 2008.

other regions across the country. The number of states with operating dry-grind ethanol plants doubled, from 13 in 2004 to 26 in 2010.

The amount of distillers grain production is a direct result of ethanol production. Each bushel of corn is assumed to produce 2.79 gallons of denatured ethanol and 17.5 pounds of DDGS. Thus, the distribution of ethanol by-products is identical to the distribution of dry-grind ethanol plants. As ethanol production expands, the volume of DDGS produced will rise almost fivefold between 2004 and 2010, from 8.14 to 38.84 million tons (Table 9.6).

Unlike the case of corn and ethanol production information, data for ethanol by-products consumption are not available at a national level, let alone a state level. Thus, livestock feed demand for ethanol by-products in this chapter are estimates obtained from a variety of sources. As such, the validity of the assumptions becomes critical. This analysis is based upon establishing an upper threshold for ethanol by-product consumption at the state level. This value is determined as the product of the state-level herd sizes for 10 classes of livestock and poultry and dietary inclusion rates, or the level of DDGS in their respective diets. Two adjustments were made over time. First, not all farms will feed DDGS as part of their animal diets. Thus, a market penetration rate is calculated to reflect the share of a particular class of livestock consuming DDGS as part of their diet. Second, animal populations are adjusted on an annual basis, based upon National Agricultural Statistics Service data (USDA-NASS, 2008).

State-level animal populations were obtained from the 2002 Census of Agriculture (USDA-NASS, 2004) for 10 classes of animals (cattle on feed, beef cows, milk cows, other cattle, breeding swine, market swine, layers, pullets, turkeys, and broilers). Adjustments to animal numbers are made based upon annual state-level updates as published by the National Agricultural Statistics Service. Southern states in Census Regions 5, 6, and 7 are where most of the nation's poultry is produced, while cattle production is concentrated in the Plains states in Regions 4 and 7, and pork production is concentrated in Regions 3, 4, and 5 (Table 9.7).

Annual feed consumption rates in pounds per head were adopted for the 10 classes of livestock and poultry from a variety of reports and conversations with animal nutrition experts (Table 9.8). A great deal of variation can be found

Table 9.6. Historic and assumed distillers grain production and region share, by year

Census Region	States	2004	2005	2006	2007	2008	2009	2010	Region Share
		million tons							
1	CT, MA, ME, NH, RI, VT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
2	NJ, NY, PA	0.00	0.00	0.00	0.00	0.16	0.86	0.86	1.7%
3	IL, IN, MI, OH, WI	2.10	2.23	2.31	4.05	7.21	9.80	9.92	26.0%
4	IA, KS, MN, MO, ND, NE, SD	5.92	6.31	8.72	11.69	16.17	22.66	23.98	63.0%
5	DE, FL, GA, MD, NC, SC, VA, WV	0.00	0.00	0.00	0.00	0.00	0.31	0.31	0.6%
6	AL, KY, MS, TN	0.07	0.07	0.10	0.10	0.10	0.42	0.42	0.9%
7	AR, LA, OK, TX	0.00	0.00	0.00	0.00	0.75	1.11	1.11	2.5%
8	AZ, CO, ID, MT, NM, NV, UT, WY	0.05	0.06	0.37	0.54	0.82	0.82	0.88	2.4%
9	CA, OR, WA	0.00	0.00	0.08	0.19	0.35	1.35	1.35	2.8%
	USA	8.14	8.67	11.58	16.57	25.57	37.33	38.84	100.0%

Source: USDA-ERS, 2008.

Table 9.7. Distribution of cattle, hogs, and chickens, and feed, by census region

Census Region	States	Region % of cattle	Region % of hogs	Region % of poultry	Region % of U.S. Feed Use
1	CT, MA, ME, NH, RI, VT	0.5	0.0	0.0	0.6
2	NJ, NY, PA	3.1	2.2	2.2	4.4
3	IL, IN, MI, OH, WI	8.3	17.4	2.3	11.3
4	IA, KS, MN, MO, ND, NE, SD	32.8	51.2	5.4	30.8
5	DE, FL, GA, MD, NC, SC, VA, WV	6.1	18.3	42.0	11.9
6	AL, KY, MS, TN	5.3	1.5	15.4	6.6
7	AR, LA, OK, TX	23.1	5.9	28.1	17.2
8	AZ, CO, ID, MT, NM, NV, UT, WY	13.0	3.1	0.1	9.1
9	CA, OR, WA	7.8	0.4	4.4	8.2
	USA	100.0	100.0	100.0	100.0

Source: USDA, 2004.

Table 9.8. Assumed corn and distillers grain intake per head, by class of livestock

Class of Livestock	Corn (lbs/head /yr)	Maximum Inclusion Rate of Distillers Grain	Distillers Grain (lbs/head/yr)[a]	Total Tons of Distillers Grain Fed Per Year
Beef cows	1,111.0	25%	277.8	4,625,661
Cattle on feed	6,151.6	25%	1,537.9	11,461,619
Milk cows	5,824.0	25%	1,456.0	6,627,682
Other cattle	862.9	20%	172.6	4,573,004
Breeding swine	1,299.2	10%	129.9	401,092
Market swine	574.0	10%	57.4	1,556,420
Layers	56.0	10%	5.6	934,910
Pullets	56.0	10%	5.6	265,479
Turkeys	59.4	10%	5.9	276,106
Broilers	6.3	10%	1.0	4,249,714
Total				34,971,687

Source: [a]Quear, 2008.

in recommended feeding rates from study to study. Based upon the animal population numbers and consumption rates, an upper limit for DDGS consumption is calculated to be 34.9 million tons. In contrast, Cooper (2005) estimated a national maximum threshold of 42 million tons. Cooper's value is much higher than our estimate because he assumed dietary inclusion rates of 40% for dairy and cattle rather than 20%, and 20% for hogs instead of 10%.

The projection of the Interagency Agricultural Projections Committee (IAPC) provides a short feature on DDGS as part of the report on *USDA Agricultural Projections to 2016*. The projections assume that only 75% of DDGS is used in the domestic livestock and poultry sectors, with 10% being exported and the remaining 15% going to domestic non-feed uses. Other uses of ethanol by-products include fertilizer, pet litter, and packaging materials. "Of the portion of distillers grains used for domestic livestock feeding, 80% is assumed to be used for beef cattle, 10% for dairy, and 5% each for poultry and hogs" (IAPC, 2007).

Cooper (2005) and the Renewable Fuels Association (2008) reported the distribution of distillers grain consumption among beef, dairy, swine, and poultry for the years 2001 to 2007 (Table 9.9). Consistent with IPAC, beef and dairy cattle consume most of the distillers grains on an annual basis (approximately 85%), while hogs consume around 11% and poultry consume the remaining 4%.

Using these values, one is able to calculate the tonnage of DDGS consumed by class of livestock and poultry following a three-step process. First, the Renewable Fuels Association (2008) also reports annual production levels of DDGS from 2001 to 2007, with production increasing from 3.4 to 16.1 million tons over that time period (Table 9.9). Exports are subtracted from production to arrive at net production available for domestic consumption. Export data for brewers or distillers spent grain are reported as part of the ERS Feed Grains Database in the Custom Queries section for the years 2001 to 2006. Over that time period, exports doubled, increasing from 0.94 to 1.96 million tons (Table 9.9). In 2006, exports accounted for 15% of U.S. DDGS production.

The second step is to multiply the allocation of DDGS by the net production available for domestic consumption, to arrive at the tons of

Table 9.9. Calculation of penetration rates of distillers grain consumption, by class of livestock, by year

DATA AVAILABLE	Distribution of Distillers Grain Consumption (%), by Class[a]						
Class of livestock	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Dairy	60	45	46	44	45	46	42
Cattle	36	35	39	37	37	42	42
Swine	2	15	11	16	13	9	11
Poultry	2	5	4	3	5	3	5
Total	100	100	100	100	100	100	100
	Distillers Grains Available for Consumption (million tons)						
STEP 1	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Total production[a]	3.42	3.97	6.39	8.05	9.92	13.23	16.09
Exports[b]	0.94	0.83	0.81	1.07	1.36	1.96	2.39
Exports as % of production	27.6	20.9	12.7	13.3	13.7	14.8	14.8
Net for domestic use	2.47	3.14	5.58	6.98	8.57	11.27	13.71
STEP 2	**Tons of Distillers Grains Consumed, By Class**						
Class of livestock	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Dairy (max tons = 6.6)	1.48	1.41	2.57	3.07	3.85	5.18	5.76
Cattle (max tons = 20.6)	0.89	1.10	2.18	2.58	3.17	4.73	5.76
Swine (max tons = 2.5)	0.05	0.47	0.61	1.12	1.11	1.01	1.51
Poultry (max tons = 5.2)	0.05	0.16	0.22	0.21	0.43	0.34	0.69
STEP 3	**Market Penetration for Distillers Grain Consumption (%), By Class**						
Class of livestock	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Dairy	22.4	21.3	38.8	46.4	58.2	78.3	86.9
Cattle	4.3	5.3	10.5	12.5	15.4	22.9	27.9
Swine	2.0	18.9	24.6	44.8	44.7	40.7	60.5
Poultry	1.0	3.0	4.3	4.0	8.2	6.5	13.2

Sources: [a]Renewable Fuels Association, 2008; [b]USDA-ERS, 2008 (http://www.ers.usda.gov/data/feedgrains/FeedGrainsQueriable.aspx).

DDGS consumed annually by dairy cattle, beef cattle, swine, and poultry. For example, in 2007, dairy cattle consumed 42% of the 13.71 million tons available for consumption (Table 9.9). This means that dairy cattle consumed 5.76 million tons.

The final step is to determine the market penetration of DDGS among the different classes of livestock and poultry. Based on the assumed dietary inclusion rates of DDGS in the diets of the respective classes of livestock and poultry, the maximum tonnage of DDGS that can be consumed by dairy cattle, beef cattle, swine, and poultry is assumed to be 6.6, 20.6., 2.5, and 5.2 million tons, respectively (Table 9.9). Dividing the estimated tons consumed from step 2 by the maximum tons that can be consumed, an estimate of the market penetration rate can be determined, or the proportion of the animal population that is consuming DDGS.

Use of DDGS is approaching a 90% market penetration rate in dairy cattle diets, while 60% of the potential consumption has been achieved in the swine industry (Table 9.9). In both cases, typical farms are quite large, allowing the farming operation to utilize truckload quantities of DDGS in the diet. In contrast, only 28% and 13% of potential consumption of DDGS has been realized for beef cattle and poultry, respectively. To complete the model, market penetration rates were forecast for 2008, 2009, and 2010, using a trend projection (Figure 9.3). These rates were then used in the model to determine the level of DDGS consumption by state and by year. Total consumption was forecast to increase by approximately one million tons per year, from 13.7 million tons in 2007 to 14.8, 15.8, and 16.9 million tons in 2008, 2009, and 2010, respectively.

After all data calculations were completed, state-level consumption was subtracted from state-level production for DDGS for each year, or

$$Net\ DDGS_{i,t} = Distillers\ Grain\ Production_{i,t} - Distillers\ Grain\ for\ Livestock_{i,t}$$

where i is a state among the 48 continental U.S. states, and t is the time period (2004 to 2010). This calculation determined whether a state had a surplus or deficit position. The changes were compared over time to identify the effects of shifts in DDGS and ethanol production. If *Net DDGS* was greater than zero, the state had a surplus of DDGS after all of the animals in that state had been fed DDGS given the assumed dietary inclusion

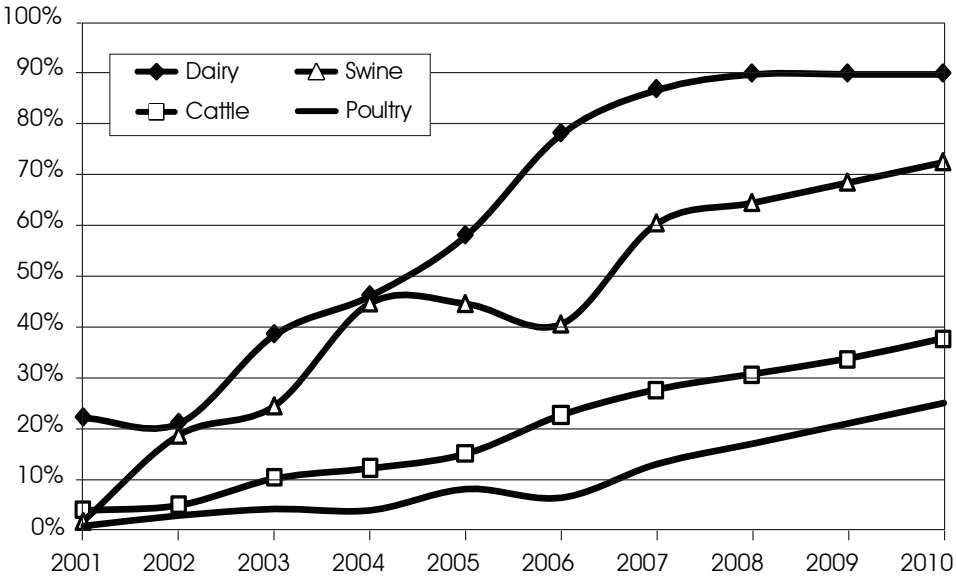

Figure 9.3. Forecast market penetration rates for distillers grain consumption rate, by class of animal

rates and market penetration rates. The remaining DDGS could then be either shipped to other states with a deficit or exported. In contrast, states with a negative *Net DDGS* balance were assumed to acquire DDGS from other states to meet livestock feed demands, given the livestock population, dietary inclusion rates, and market penetration rates.

The results of the model were validated by comparing predicted production and exports of DDGS with available data from the Renewable Fuels Association (2008) and the Economic Research Service (USDA-ERS, 2008) for the years 2004 to 2007. The model results were consistent with reported values for DDGS production and exports, especially for 2004 and 2007 (Table 9.10). Thus, the assumptions for dietary inclusion rates of DDGS in livestock feeds and market penetration rates of DDGS seem reasonable.

Model Results for Distillers Dried Grains with Solubles

In 2004, ethanol plants were present in 13 states, with a total production of 8.14 million tons of DDGS (Table 9.10). Nine states had surplus production, which was a result of the local demand for DDGS being saturated. The surplus was used to supply DDGS to other states and export

Table 9.10. Model validation and results for distillers grain production, consumption, and exports, 2004 to 2010

	Year						
Item	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
RFA and USDA reports							
RFA production (M tons)	8.05	9.92	13.23	16.09			
RFA consumption (M tons)	6.98	8.57	11.27	13.71			
USDA exports (M tons)	1.07	1.35	1.96	2.38			
Model results							
Production (M tons)	8.14	8.67	11.58	16.57	25.57	37.33	38.84
Consumption (M tons)	7.29	8.88	11.65	14.56	15.80	16.84	17.97
Exports (M tons)	0.85	-0.21	-0.07	2.02	9.77	20.49	20.86
Number of states:							
Producing distillers grains	13	14	16	17	22	26	26
With surplus distillers grains	9	8	7	8	11	15	14

Sources: Renewable Fuels Association, 2008; and USDA-ERS, 2008 (http://www.ers.usda.gov/data/feedgrains/FeedGrainsQueriable.aspx).

0.85 million tons from the United States to foreign markets. By 2007, production had doubled to 16.6 million tons of DDGS, with production in 17 states, and surplus in 8 states. Over this time period, consumption was generally in balance with production. The model suggests, however, that the continued rapid expansion in ethanol capacity will accelerate production of DDGS relative to consumption over the next three years. Thus, exports will increase dramatically, growing tenfold, from 2.0 million tons in 2007 to 20.9 million tons by the year 2010.

In 2004, the nine states with surplus production of DDGS consumed 3.21 million tons and shipped 4.47 million tons elsewhere, of which 850,000 tons were exported (Table 9.11). The 39 deficit states produced only 450,000 tons of DDGS while consuming 4.08 million tons. With the expansion of ethanol production to 26 states by 2009, DDGS production is projected to increase to 37.3 million tons. Thus, over time, DDGS will become more geographically disperse, thereby reducing the distance to transport DDGS from surplus to deficit states. The number of states with saturated markets will increase to 14 of the 26 states producing DDGS in 2010. Those states will consume 7.54 million tons and export 25.06 million tons to other states or export markets. The other 34 states will produce 6.23 million tons but will still require an additional 10.43 million tons of DDGS to satisfy the assumed demand for feed.

States with the greatest surplus of DDGS are concentrated in the Corn Belt region (Figure 9.4). By 2010, Iowa, Nebraska, Indiana, Minnesota, South Dakota, and Illinois will all have surplus production of 2.0 million or more tons (Table 9.12). States with the largest deficits in 2010 are projected to be California, Texas, Oklahoma, and North Carolina. The Burlington Northern Santa Fe and Union Pacific railroads require that DDGS be shipped in hopper cars owned or leased by the shipper. However, both carriers apparently anticipate additional growth in traffic, because unit train rates have been implemented for DDGS from ethanol plants in the Midwest to cattle feed lots in Texas, New Mexico, and other locations.

A tenfold increase in exports in three years seems extreme. Thus, the assumptions in this study merit further consideration about the level of ethanol production, dietary inclusion rates, and market penetration rates.

Table 9.11. Net distillers grain position, by year

Census Region	States	Net Distillers Grain Position						
		2004	2005	2006	2007	2008	2009	2010
1	CT, MA, ME, NH, RI, VT	-0.08	-0.10	-0.14	-0.15	-0.15	-0.16	-0.16
2	NJ, NY, PA	-0.51	-0.63	-0.82	-0.93	-0.82	-0.14	-0.17
3	IL, IN, MI, OH, WI	1.03	0.92	0.59	1.98	5.02	7.54	7.57
4	IA, KS, MN, MO, ND, NE, SD	3.63	3.70	5.34	7.23	11.31	17.42	18.30
5	DE, FL, GA, MD, NC, SC, VA, WV	-0.53	-0.68	-0.72	-1.01	-1.12	-0.94	-1.05
6	AL, KY, MS, TN	-0.18	-0.27	-0.30	-0.45	-0.51	-0.27	-0.35
7	AR, LA, OK, TX	-0.90	-1.11	-1.53	-1.93	-1.39	-1.23	-1.48
8	AZ, CO, ID, MT, NM, NV, UT, WY	-0.70	-0.88	-1.00	-1.11	-0.97	-1.08	-1.10
9	CA, OR, WA	-0.91	-1.15	-1.49	-1.62	-1.58	-0.66	-0.70
	U.S. Exports	0.85	-0.21	-0.07	2.02	9.77	20.49	20.86
Number of States with Distillers Grain Surplus		9	8	7	8	11	15	14
	Distillers grains production	7.69	8.10	10.59	15.85	21.96	30.85	32.60
	Distillers grains consumption	3.21	3.76	4.79	7.00	6.65	6.91	7.54
	Available for export	4.47	4.34	5.80	8.85	15.31	23.93	25.06
Number of States with Distillers Grain Deficit		39	40	41	40	37	33	34
	Distillers grains production	0.45	0.58	0.99	0.73	3.61	6.49	6.23
	Distillers grains for livestock	4.08	5.12	6.86	7.56	9.15	9.93	10.43
	Imported distillers grains	(3.63)	(4.55)	(5.87)	(6.83)	(5.54)	(3.45)	(4.20)

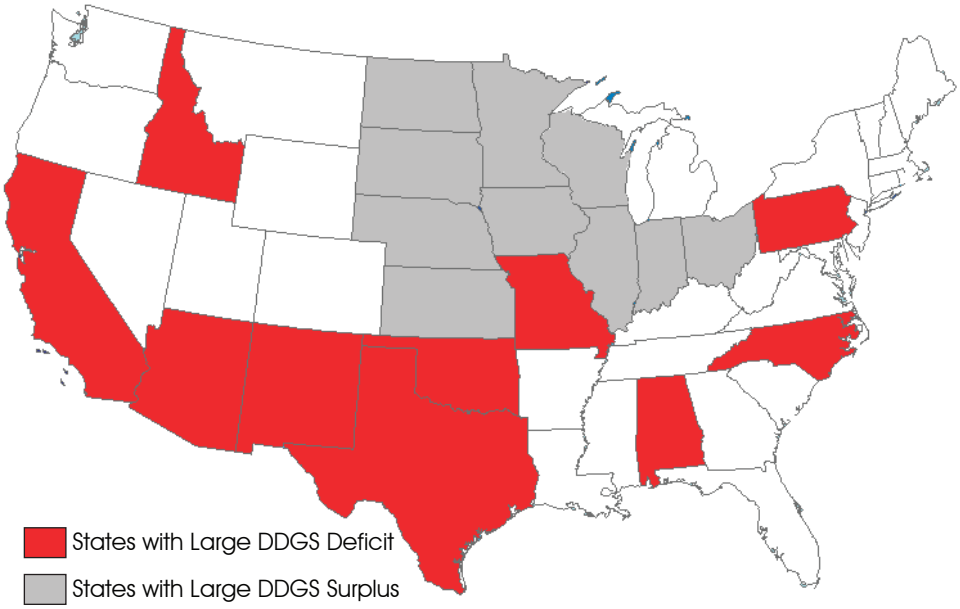

Figure 9.4. States with largest projected surpluses and deficits of distillers grains by 2010

First, the assumption of 12.4 billion gallons of dry-grind ethanol production capacity by 2010 is not unreasonable. This amount of ethanol production is consistent with the Renewable Fuels Standard as established by the Energy Independence and Security Act of 2007, which calls for 12 billion gallons of ethanol by 2010. Thus, it is likely that the DDGS will be produced in much higher volumes. As such, the volume of exports can be reduced by greater animal consumption.

Second, Cooper (2005) assumed much higher dietary inclusion rates for DDGS in the diets of dairy and beef cattle (40% versus 25%) and hogs (20% versus 10%). If his assumptions for inclusion rates are correct, the upper limit for DDGS consumption would be 20% higher, at 42 instead of 35 million tons. This would reduce exports by 4 million tons. It is difficult to judge the validity of this assumption given the rapid pace of adjustment in the industry.

Finally, the authors are unaware of other estimates of market penetration rates for different classes of livestock and poultry. One additional consider-

Table 9.12. Top surplus and deficit states for distillers grains

	2004	2005	2006	2007	2008	2009	2010
Surplus states				million tons			
Iowa	1.40	1.02	2.81	3.61	4.28	7.55	7.99
Nebraska	0.75	0.67	0.54	1.08	2.43	3.71	4.02
Indiana	0.18	0.16	0.12	0.65	1.54	3.07	3.05
Minnesota	0.53	0.86	1.08	1.16	1.45	2.30	2.61
South Dakota	1.24	1.27	1.26	1.62	2.43	2.46	2.43
Illinois	1.09	1.07	1.06	1.34	1.81	2.11	2.20
Ohio	-0.18	-0.22	-0.28	-0.35	0.71	1.27	1.25
North Dakota	0.07	0.06	0.04	0.33	0.29	0.95	0.97
Kansas	0.04	0.07	-0.11	-0.10	0.65	0.76	0.66
Wisconsin	-0.07	-0.06	-0.21	-0.02	0.62	0.61	0.59
Deficit states							
California	-0.71	-0.91	-1.16	-1.25	-1.31	-0.85	-0.90
Texas	-0.61	-0.75	-1.09	-1.35	-0.72	-0.48	-0.64
Oklahoma	-0.17	-0.21	-0.28	-0.34	-0.39	-0.42	-0.47
North Carolina	-0.18	-0.20	-0.19	-0.30	-0.34	-0.37	-0.41
Missouri	-0.38	-0.25	-0.27	-0.47	-0.23	-0.30	-0.38
Idaho	-0.20	-0.26	-0.38	-0.45	-0.34	-0.35	-0.31
Arizona	-0.09	-0.12	-0.12	-0.18	-0.22	-0.25	-0.29
New Mexico	-0.10	-0.13	-0.17	-0.22	-0.22	-0.22	-0.23
Alabama	-0.06	-0.09	-0.09	-0.14	-0.17	-0.20	-0.23
Pennsylvania	-0.27	-0.33	-0.41	-0.49	-0.52	-0.19	-0.20

ation is the length of time that a truckload of DDGS will last, given the herd size. Distributions of herd sizes are available for dairy cattle, beef cattle, and swine, which are assumed to consume 8 pounds, 4 pounds, and 1 pound of DDGS per day, respectively. Thus, at a feeding rate of one truckload per month (48,000 pounds), one could feed 200 dairy cows, 400 beef cattle, or 1,600 hogs.

Over 81% of the dairy cows are on farms greater than 100 head (Table 9.13). Thus, the penetration rate of 86.9% for the dairy sector seems reasonable, and further growth of DDGS for this class of livestock is probably limited (Table 9.9). While beef cattle and calves have a distribution similar to that of dairy cattle, their daily dietary inclusion rate is less: a truckload of DDGS feed will last twice as long. It seems reasonable that herds with at least 500 head of beef cattle, or 44% of the beef cattle inventory, will include DDGS in their diets. Thus, the market penetration rate for beef cattle could increase. With the low dietary inclusion rate of DDGS for hogs, it is likely that sizes of herds that consume it will be at least 1,500 head. Therefore, this assumed penetration rate of 72% seems reasonable. Comparable data on farm size were unavailable for poultry.

Modal Shares: Truck versus Rail

Results for DDGS production and consumption from Table 9.11 can be used to generate estimates of modal shares for truck versus rail/barge

Table 9.13. Distribution and days of feed from one truckload for dairy, cattle and calves, and hogs, by herd size, 2007

	Cumulative Distribution of Animals by Herd Size (%)			Days Fed with One Truckload of Distillers Grains		
Herd Size	**Dairy**	**Cattle & Calves**	**Hogs**	**Dairy**	**Cattle & Calves**	**Hogs**
Over 2000 head	25.7	23.3	56.0	1	2	10
1000-1999 head	41.8	31.4	81.5	4	8	32
500-999 head	54.1	44.2	91.0	8	16	64
100-499 head	81.2	78.2	95.5	20	40	160
50-99 head	94.3	89.4	99.0	80	160	640
1-49 head	100.0	100.0	100.0	240	480	1920
Penetration rate	86.9	27.9	60.5			

transportation, as well as the number of truckloads and rail carloads. DDGS produced and consumed within the boundaries of a particular state are assumed to be transported by truck. All production available for export from the surplus states is assumed to be shipped by rail. While values are reported as rail modal share or carloads, barge transportation would be competitive for many of the rail movements, primarily because much of the production of DDGS originates from states found along the Mississippi River system. Truckload capacities are 24 tons, while railcar capacities for jumbo hoppers are 100 tons (Table 9.2).

The predicted truck modal share for DDGS of 46.6% in 2007 is comparable to Wu's estimate (Tables 9.3 and 9.14). As U.S. demand for DDGS in livestock and poultry diets becomes saturated, more of the market will shift to rail and barge transportation to move the by-products to export markets. Thus, the modal share for truck transportation is expected to decline to 35% by 2010. Despite the decrease in truck modal share, the absolute number of truckloads will increase from 322,000 truckloads in 2007 to 574,000 by 2010, simply because of the much greater production of DDGS over time. Rail shipments are expected to almost triple, rising from 88,000 to 251,000 carloads over the same time period.

Future Expectations for Transportation of Distillers Dried Grains with Solubles

After 15 years of relative calm, transportation is once again emerging as an issue of concern for agricultural shippers and receivers, transportation firms, and public policymakers. The pace of change caused by the growth in ethanol production is rapid. Four observations are made with respect to the transportation of DDGS.

First, the effects of the production of ethanol and related products on transportation equipment and infrastructure are large in magnitude. In the short run, ethanol firms, truckers, and railroads are experiencing backlogs in orders for new hopper and tanker cars and difficulties in shipping DDGS. While challenging, these problems likely reflect short-term adjustments as opposed to long-term concerns. The railroads seemingly have the ability to manage this change. Continued increases in truck traffic will likely create greater equipment and infrastructure challenges, especially at the local level.

Table 9.14. Modal share and loads generated for distillers grains, by year

	2004	2005	2006	2007	2008	2009	2010
Modal share							
Truck	45.0%	50.0%	49.9%	46.6%	40.1%	35.9%	35.5%
Rail/barge	55.0%	50.0%	50.1%	53.4%	59.9%	64.1%	64.5%
Million tons of traffic	8.14	8.67	11.58	16.57	25.57	37.33	38.84
Loads of distillers grains (000)							
Truckloads	153	181	241	322	428	558	574
Railcars	45	43	58	88	153	239	251

Second, the effects of increased truck traffic will be experienced most in the communities and surrounding areas where new ethanol plants are located. An ethanol plant that produces 100 million gallons per year requires 110 truckloads of corn per day, while generating 35 truckloads each of ethanol and DDGS. While the economic development associated with new ethanol plants is welcome in rural communities, the increase in truck traffic may strain local highway maintenance budgets. The problem may be more serious in regions with bridges that are in poor condition.

Third, compared to the traditional grain sector, many ethanol plants have relatively little storage for corn and outputs. With as little as ten days to two weeks of storage capacity, these plants are heavily reliant on dependable providers of transportation service. As a corollary, railroads might increase their equipment utilization when shipping ethanol and DDGS as compared to corn. The predictable, steady nature of shipments from ethanol plants stands in sharp contrast to the seasonality associated with shipping corn.

Finally, while transportation challenges in the rapidly expanding ethanol industry certainly exist, there are also several examples of innovative responses to the challenges by entrepreneurs. For example, terminal facilities like Manly Terminal LLC in Manly, Iowa, and Gateway Terminals LLC in Sauget, Illinois, are poised to capture advantages of volume shipping for ethanol and DDGS. Finally, in Kankakee, Illinois, and elsewhere, shippers are loading DDGS in containers for shipment to Asia.

Overall, the prognosis for DDGS seems positive. As an industry in the midst of rapid expansion, uncertainty is high. Additional investment in transportation infrastructure and equipment will be required, especially for trucks and local highways. However, if the U.S. market for utilizing DDGS is saturated as soon as 2009, equipment concerns will shift to modes of transportation necessary for moving the by-product to export markets.

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