

Impact of 45Z on the Corn Supply Chain

Prepared for

RENEWABLE FUELS ASSOCIATION



July 2024

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Acronyms



CI – Carbon Intensity



CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation



CME – Chicago Mercantile Exchange



CSA – Climate Smart Agriculture



CIF – Cost, Insurance and Freight



DDGS – Distillers Dried Grains with Solubles



FOB – Free On Board



GMO – Genetically Modified Organism



GREET – Greenhouse gases, Regulated Emissions, and Energy use in Technologies



HFCS – High Fructose Corn Syrup



IRA – Inflation Reduction Act of 2022



IRS – Internal Revenue Service



PNW – Pacific Northwest



PAC – Polaris Analytics and Consulting



SAF – Sustainable Aviation Fuel



Treasury – U.S. Department of Treasury



USDA – U.S. Department of Agriculture



USDA-AMS – Agriculture Marketing Service



USDA-NASS – National Agricultural Statistics Service



USDA-WAOB – World Agricultural Outlook Board



USGSA – U.S. Grain Standards Act

Units of Measure



One corn bushel = 56 pounds



One metric ton = 2,204.62 pounds



One metric ton = 39.4 corn bushels



One short ton = 2000 pounds

Introduction and Description

As part of the Inflation Reduction Act of 2022 (IRA), Section 40B provides a tax credit for sustainable aviation fuel (SAF) included in qualified fuel mixtures produced by taxpayers and used or sold between 2022 and 2025. The credit is \$1.25 per gallon of SAF. A provision of 40B is that SAF must have a baseline lifecycle greenhouse gas emissions reduction percentage of 50%. There is an extra \$0.01 per gallon added for each percentage point by which the emissions reduction percentage exceeds 50%, up to a maximum of \$0.50 per gallon.

Fuel producers or importers must register with the U.S. Department of Treasury (Treasury) and provide certification demonstrating compliance with sustainability requirements. Certification can be based on CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) or a similar methodology.

Section 40B will be superseded by Section 45Z after 2024, which closely mirrors the assessment of SAF carbon intensity (CI) of Section 40B. The key difference is that 45Z requires CI to be based on Argonne GREET (Greenhouse gases, Regulated Emissions, and Energy use in Technologies) or a successor model determined by the Secretary of the Treasury for other fuels. The Internal Revenue Service (IRS) oversees the implementation and administration of 45Z.

Both programs incentivize SAF production, but Section 45Z introduces flexibility for other fuels' carbon intensity assessment.

However, the CI requirement could disrupt commodity flows, specifically corn flows, to fulfill the requirements of 45Z. For example, there could be challenges in supply chain management, logistics and tracking of Climate Smart Agriculture (CSA) feedstock. Other challenges include verification, recordkeeping and auditing of CSA practices, dealing with the impacts of natural variability (weather / climate impacts, etc.) on CI from season to season, issues with long-term soil carbon measurement and validation, and the possibility of creating feedstock winners and losers based on uncontrollable factors (e.g., soil C capacity, suitability for cover crops, etc.).

The bottom line is that to accommodate CI requirements, physical corn flows will not move in traditional market patterns and instead could disrupt market fundamentals as a result. This report describes the grain supply chain with a focus on corn, while evaluating scenarios of how corn flows can be disrupted to meet the provisions of 45Z.

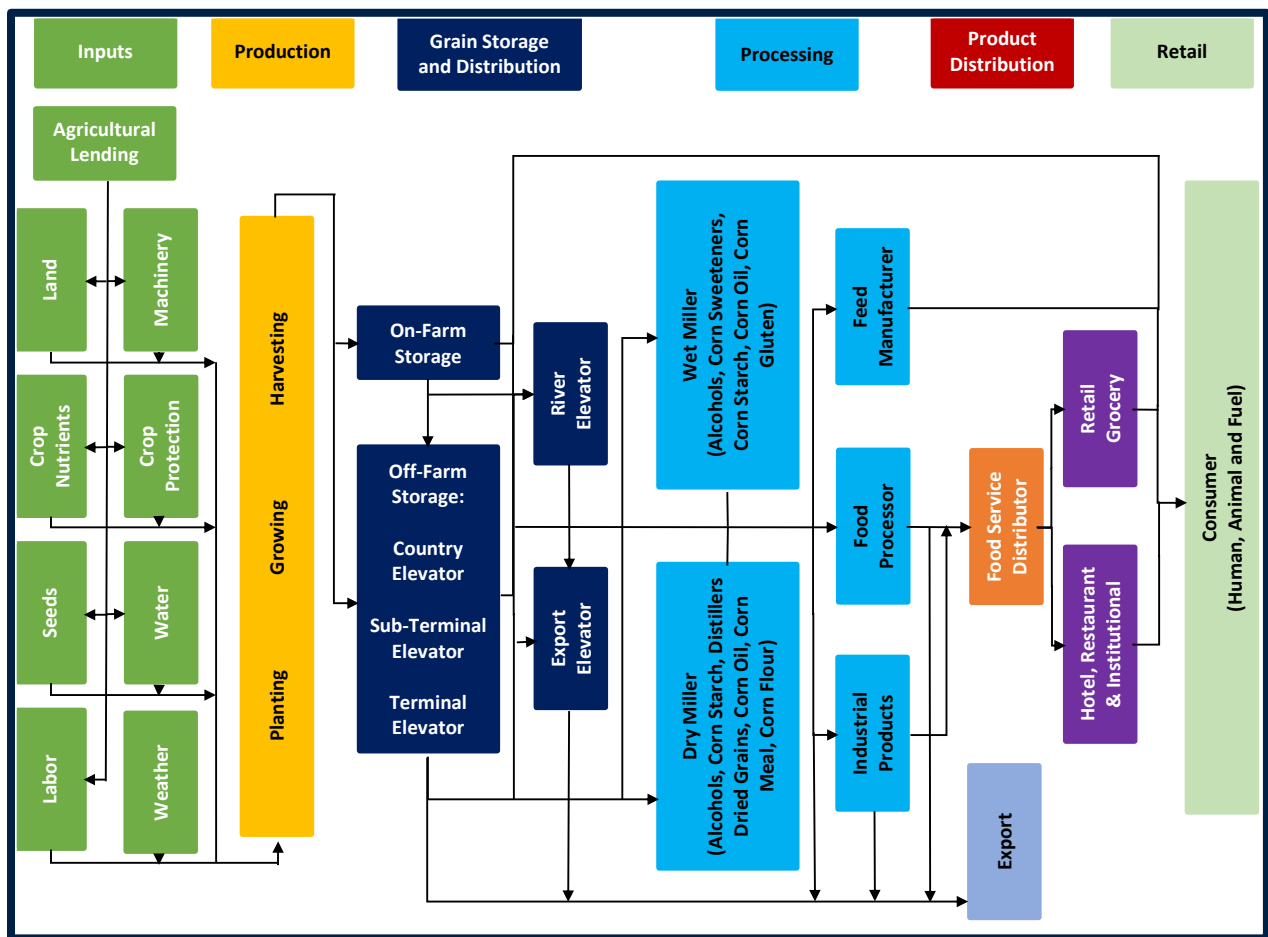
The first section of this report describes the corn supply chain, followed by a review of the modes moving corn to market position, and the next section considers price and costs. The last section introduces scenarios on the impact of CI on the corn supply chain.

Corn Supply Chain

Grain and soybean crops produced and used in the United States and around the world have intricate supply chains. Each crop then has its own nuanced supply chain given its characteristics and uses. The principal crops include barley, corn, oats, sorghum, soybeans and wheat. Yet, each crop also shares various pathways of their respective supply chains with the other crops.

The corn supply chain shown in Figure 1 includes six major tasks (inputs, production, grain storage and distribution, processing, product distribution and retail). The first task is related to getting a crop in the ground, which considers lending costs, land, labor and weather.

Figure 1: U.S. Corn Value Supply Chain



Source: Polaris Analytics and Consulting

Corn Inputs

Unlike any other commodity or resource, crop production is an annual event. Each year farmers plan, plant, treat, wait and harvest their grains and soybeans. The planning for what will be planted starts during harvest of the previous crop. Farmers have several considerations as to what crop they plant such as crop rotation

patterns, financial returns of one crop over another, tax planning and contract farming commitments as examples. Once a crop is selected to be planted the farmer then considers the type of hybrid or plant characteristic to plant. For example, does the farmer choose a genetically modified organism (GMO) or non-GMO seed variant, plant yellow corn or white corn, etc. That planning continues until planting occurs as weather, seed availability and type, and market prices influence what ultimately is planted.

Corn Production

While crop production is an annual event, by comparison, other commodities such as crude oil, coal, natural gas or livestock production are flow commodities in that they are continuously produced or harvested while grain and soybeans are harvested and stored for use throughout the crop marketing year. And none of the annual events are guaranteed to happen, given all the variables farmers encounter, especially with weather, raining at the wrong time or not at all, combined with high heat or not enough.

Once the crop is planted farmers treat their crops with nutrients and protection and rely on the weather to mature the crops to harvest.

Grain Storage and Distribution

Grain is like water in that it flows on the path of least resistance. At harvest, farmers have two options: take their crops to a storage bin on their farm or haul them to an off-farm location to be stored or to a position of consumption. The core crop harvest windows in the U.S. are June and July for the small grains (barley, oats and wheat) and October and November for the heavy grains (corn, sorghum and soybeans).

An important point is that only one crop and its class or attributes is stored in a bin. The grain storage system has been developed over decades to store grain at harvest until it is needed elsewhere. The system has been designed to be efficient where field carts and trucks hauling the harvested grain from the field are quickly unloaded. In some cases, the grain needs to be conditioned such as being dried down by mechanical means because its moisture content is too high. Putting grain through a drier slows down the operation, however. At harvest, speed matters and being able to unload into bins that can hold sizeable volumes of grain is important.

Farmers have on-farm storage bins to hold their harvested grain until the timing is right to send their grain to the next market position. On-farm storage allows farmers to have flexibility managing their harvest schedule while executing their grain marketing program. The harvest window can be quite narrow and once it starts it is difficult to stop. The on-farm option allows farmers to take the harvested grain from the field to a bin and not travel to an off-farm location and most likely wait in line to “dump” or deliver their grain. Many farmers have enough storage capacity to store an entire harvest.

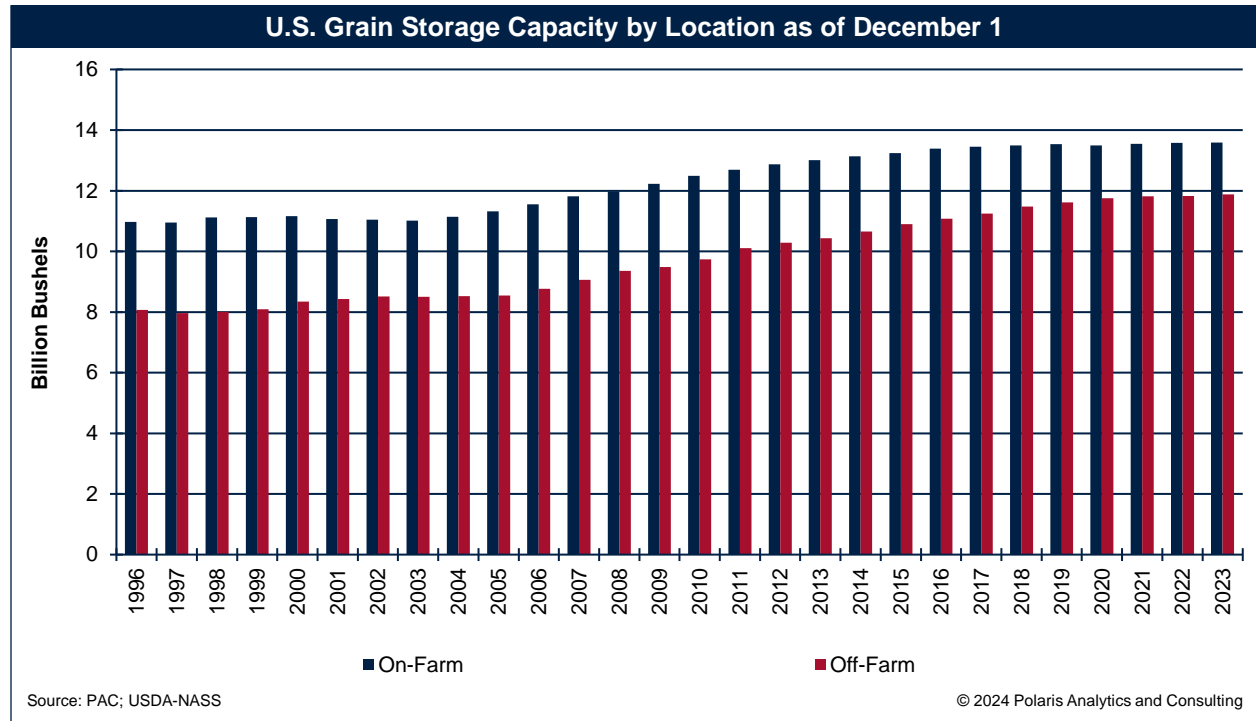
Farmers do deliver grain to off farm locations during harvest, with the bulk of it moving from the farm after harvest. Off-farm storage is located at commercial grain locations where grain merchandisers buy, market or store the grain for the farmer. In some regions around the grain growing areas of the U.S. there is not enough available grain storage and grain will temporarily be stored on the ground. Grain may remain in off-farm storage for days, weeks and even months.

Grain storage capacity is compiled by the U.S. Department of Agriculture’s (USDA) National Agricultural Statistics Service (NASS). NASS reports grain storage capacity for on-farm and off-farm as of Dec. 1. On

Dec.1, 2023, grain storage capacity in the U.S. totaled a record 25,468 million bushels. Over the past decade, storage capacity has expanded by about 1% per year.

By location, on-farm storage represented 53% of all capacity. However, off-farm storage has been gaining ground with on-farm storage, increasing from a market share of 43% in 2000 to 45% in 2016 and 47% in 2023. Grain storage capacity by location is shown Figure 2.

Figure 2: U.S. Grain Storage Capacity by Location as of December 1



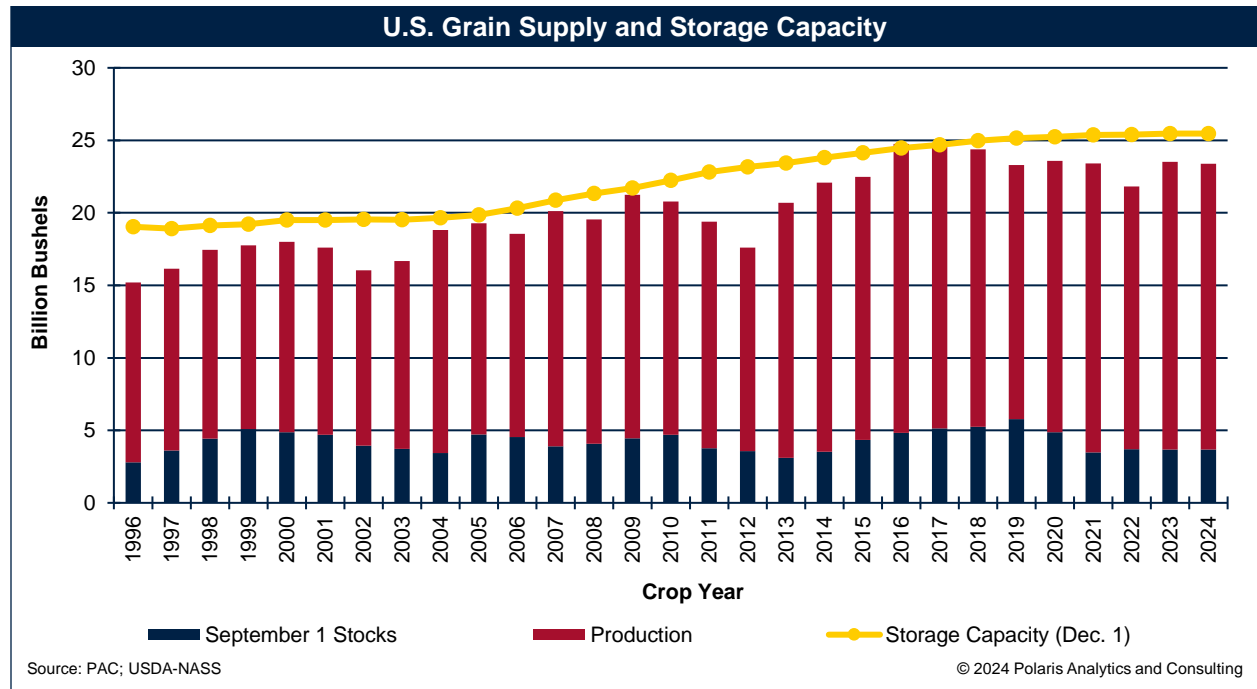
Constructing and erecting grain storage facilities has become more costly with persistent inflation and supply chain disruptions in the past few years. For example, the main construction costs include stainless steel (that are up 46% from 2019 to a purchase price index of 140.1 in April 2024) and concrete (up 43% from 2019 to a purchase price index of 247.8 in April 2024), let alone labor and finance charges.

During Sept. through Dec. 2023, grain storage utilization tightened to 92% from 85% in 2022 as crop supplies (Sept. 1 grain stocks plus corn, sorghum and soybean production) grew 8% or 1,700 million bushels to 23,513 million while capacity expanded by 65 million bushels as shown in Figure 3. A storage utilization rate of 92% is not extremely tight, especially given that one-third of the grain that is in storage on Dec. 1 will be moved into the supply chain by March 1 of the following calendar year. The volume moved out of storage and consumed is equivalent to about 5,200 million bushels. Storage becomes an issue when utilization rates are higher than 97% and increasing, if there is a carry in the market (a market carry is a higher price for corn in a deferred futures contract, e.g., the price of the December futures contract is less than the March futures contract) that slows the movement of grain into the supply chain and if grain is not fully removed from storage before the next harvest.

If on Sept. 1, 2024, grain inventories mirror last year’s, and adding USDA’s 2024 fall production (corn, sorghum and wheat) forecast to that, crop supply during September through November will total 23,386 million bushels, or 126 million less than supplies during 2023. And if grain storage capacity is unchanged, storage utilization will relax below 91%, softening the pressure on the grain storage market. Crop supply and storage capacity are shown in Figure 3.

This supply is what is used for the rest of the crop marketing year for domestic consumption and exports.

Figure 3: U.S. Grain Supply and Storage Capacity

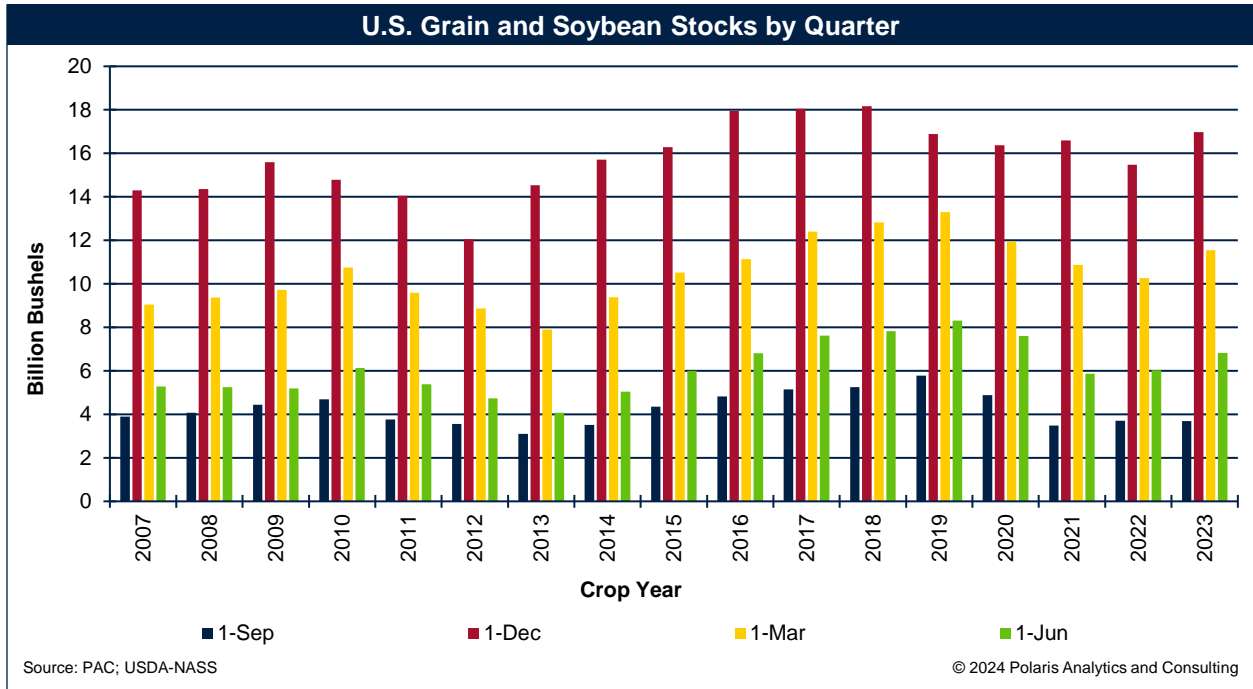


Grain stocks are largest for the year on Dec. 1 following the harvest of the fall crops (corn, sorghum and soybeans). From Dec. 1 grain is moved from or pulled out of storage to follow the “path of least resistance” to the next market position.

About two-fifths of the crop volume in storage on Dec. 1 moves through supply chain by March 1 of the following calendar year to be consumed. From March 1 to June 1 nearly one-half of the remaining volume is then transported for consumption. This phenomenon is illustrated in Figure 4 for all crops and depicts the movement and use of crops from one quarter to the next, where each quarter after Dec. 1 has less volume. During the June-August quarter of the crop marketing year (based on a September through August year), the last quarter of the marketing year, farmers will “clear” their storage bins of grain to make room for the fall harvest.

The four quarters of the crop marketing year for corn, sorghum and soybeans include September through November, December through February, March through May, and June through August. The small grains, barley, oats and wheat, have a June through May crop marketing year.

Figure 4: U.S. Grain and Soybean Stocks by Quarter



Corn Balance Table

The U.S. corn supply and demand balance table helps to understand the fundamentals of a corn crop, as shown in Figure 5 and sourced through the World Agriculture Outlook Board (WAOB) at USDA. Taken together, the Corn Inputs and Corn Production sections represent the supply side of the balance table. In this section the consumption or demand side of the balance table is presented. For the purposes of this report, corn exports will be discussed in this section even though they appear in the “storage and distribution” part of the corn marketing supply chain.

As a reminder, total corn supply equals the sum of beginning stocks (Sept. 1), production and imports. Corn demand or consumption or total use equals the sum of feed and residual, food, seed and industrial (including corn for ethanol) and exports. Ending stocks equals total corn supply less total corn usage.

Total corn usage has averaged 14,460 million bushels over the past five years, ranging from 13,706 million in 2022/23 to a record 14,956 million in 2021/22. Corn used for domestic consumption has averaged 12,283 million bushels over the past five years, representing 85% of total corn consumption. Corn exports have averaged 2,177 million bushels over the past five years, ranging from 1,662 million in 2022/23 to a record 2,747 million in 2020/21, and representing 15% of total corn consumption.

Figure 5: U.S. Corn Supply and Demand (million acres, million bushels, Sep/Aug)

| | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 |
|--------------------------|---------|---------|---------|---------|---------------|---------------|
| Planted acres | 89.7 | 90.7 | 93.3 | 88.2 | 94.6 | 91.5 |
| Harvested acres | 81.3 | 82.3 | 85.3 | 78.7 | 86.5 | 83.4 |
| Yield (bu./ac.) | 167.5 | 171.4 | 176.7 | 173.4 | 177.3 | 181.0 |
| Beginning stocks | 2,221 | 1,919 | 1,235 | 1,377 | 1,360 | 1,877 |
| Production | 13,620 | 14,111 | 15,074 | 13,651 | 15,342 | 15,100 |
| Imports | 42 | 24 | 24 | 39 | 30 | 25 |
| Total Supply | 15,883 | 16,055 | 16,333 | 15,067 | 16,732 | 17,002 |
| Feed & residual | 5,900 | 5,602 | 5,726 | 5,486 | 5,775 | 5,825 |
| Food, seed, & industrial | 6,286 | 6,472 | 6,757 | 6,558 | 6,855 | 6,855 |
| Ethanol and by-products | 4,857 | 5,033 | 5,320 | 5,176 | 5,450 | 5,450 |
| Domestic Use | 12,186 | 12,074 | 12,483 | 12,044 | 12,630 | 12,680 |
| Exports | 1,777 | 2,747 | 2,472 | 1,662 | 2,225 | 2,225 |
| Total Use | 13,963 | 14,821 | 14,956 | 13,706 | 14,855 | 14,905 |
| Ending stocks | 1,919 | 1,235 | 1,377 | 1,360 | 1,877 | 2,097 |
| Stocks-to-use ratio | 13.7% | 8.3% | 9.2% | 9.9% | 12.6% | 14.1% |

Source: USDA-WAOB

Note: Forecast shown as **bold**

Corn Feed and Residual

The corn feed and residual component of the demand table does not have “hard” data that precisely accounts for how much corn was used. The feed aspect represents corn fed to livestock including beef cattle, dairy cows, hogs and poultry (broilers, egg layers and turkeys). It is an estimated amount based on various techniques that use a grain animal consumption unit for each type of animal fed times the number of reported livestock or amount of production by animal type. The corn is moved from an elevator whether on-farm or an off-farm location directly to a feed manufacturer or processor. The manufacturer or processor may crack the corn and feed it directly to livestock or mix it with other feed components to make a compound feed ration.

Residual on the other hand is the unexplained disappearance of corn through the supply chain. This could be slippage or loss of volume as it moves from one component of the supply chain to the next.

Taken together these two items are the “adjusters” to have the balance table tie together given the known volumes used in the other parts of demand. The feeding portion is an attempt to quantify the volume fed while the residual is the balancer. Over the past five years corn volumes estimated to be used for feed and residual have ranged from 5,486 million bushels in 2022/23 and 5,900 million in 2019/20. Corn accounted as feed and residual represents about 45% of domestic consumption.

Corn Food, Seed and Industrial

This section looks at corn food, seed and industrial demand of the corn balance table. The food portion is for human consumption such cereals, popcorn and snack foods.

The seed portion represents corn grown specifically to be used for planting a future corn crop. Corn seed companies' contract with farmers to produce and harvest the required seed type (e.g., brand, hybrid, characteristic, etc.).

Corn for industrial use is sent to ethanol plants, wet and dry millers. The millers will use corn to manufacture high fructose corn syrup (HFCS), corn oil, alcohols and starches. An ethanol plant will produce ethanol, distiller dried grain with solubles (DDGs) and corn oil.

Corn Exports

The United States grows an abundant supply of corn each year with more than adequate supplies to meet domestic consumption requirements (feed, food, seed and industrial) of the U.S. A certain portion of the remaining volume is available to the global export market.

Over the past five years, the U.S. exported corn to nearly 100 countries, with about four out of five bushels going to five countries, in order of largest to least (including market share), Mexico (30.6%), China (18.8%), Japan (17.4%), Colombia (7.7%) and Canada (5.3%).

Corn sent to the export market is inspected to assure it meets the requirements of the U.S. Grain Standards Act (USGSA). The USGSA ensures corn is inspected for official certification of official weighing and to meet established standards. The inspection process verifies moisture content, foreign material, protein and overall corn quality.

Depending on the buyer, they may have purchased number two yellow corn where the corn will have to be less than 2% foreign material. Other buyers might require non-GMO corn.

U.S. corn exports are strongest during the peak harvest season (Oct. and Nov.), taking five months for one-half the annual export program to be wrapped up through Jan.

Corn Ending Stocks

At the end of each crop year there are supplies of corn that were not consumed or exported that are called ending stocks. The size of the ending stocks has been a key variable in the price of corn. If corn stocks are low relative to total usage the price of corn tends to be higher. Conversely if corn stocks are plentiful relative total usage, corn price is generally more subdued.

The U.S. has experienced low or tight corn ending stocks in the past, but it has never been zero. Traders, buyers and sellers in the market use corn price to ration demand, cutting usage to avoid running out of corn, or increase corn imports to meet consumption requirements. The corn ending stocks at the end of a marketing year, then becomes the beginning stocks for the new marketing year.

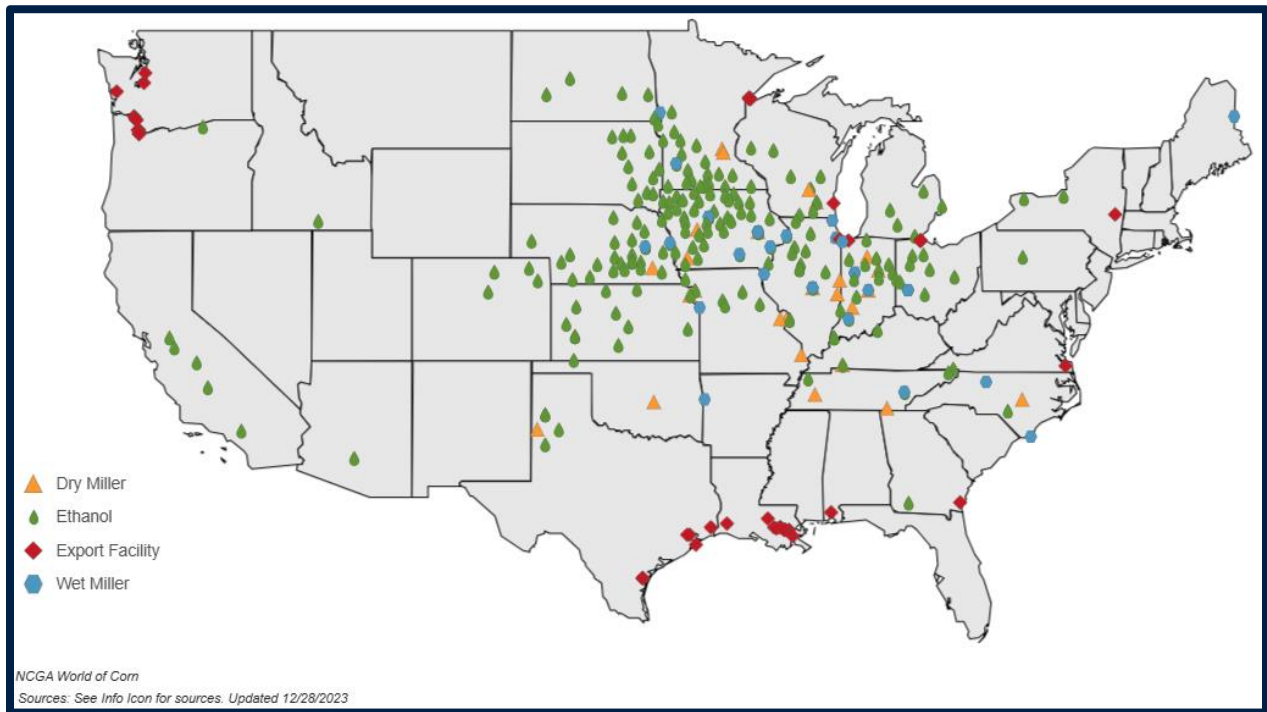
Modal Usage moving Corn to Market Position

The movement of grain from field to market position flows in a variety of directions, depending on local consumption requirements and market opportunities elsewhere. This section reviews the movement of corn to market position by transportation mode.

Corn Facilities in the Supply Chain

The location of facilities where corn is transformed, consumed or exported from are shown in value supply chain by facility in Figure 6. The top five corn growing states include (listed in order of largest to smallest production) Iowa (2.5 billion), Illinois (2.3 billion), Nebraska (1.7 billion), Minnesota (1.5 billion) and Indiana (1.1 billion). Given that corn production is largely in the U.S. Midwest and appropriately named the Corn Belt, there is a high concentration of facilities that use corn for feeding, consumption and transformation into ethanol, DDGs, corn oil, HFCS, etc., including rail and barge loading locations. These locations are readily served by the proximity of corn production to their facilities. Missing from this map is the shuttle train (that includes more than 600 shuttle train facilities) and river barge loaders and feeding locations.

Figure 6: U.S. Corn Value Supply Chain by Facility Type (2022/23)



Source: National Corn Growers Association (<https://ncga.com/world-of-corn/dashboard/us-corn-value-chain-map>)

Corn Modal Options

As indicated in the production section, harvested grain is moved from the field to an on-farm grain storage bin or an off-farm location by field cart or truck. Essentially all corn moved from an on-farm storage location to an off-farm storage location or position of consumption (e.g., ethanol plant, grain shuttle train or river barge loading location) moves by truck. The distance moved from the farm varies from a few miles, say five

miles, to as many as 75 miles, if not longer. However, the average distance is about 35 miles. The movement of corn by rail exceeds 500 miles while by barge averages over 1,000 miles. Each mode offers unique capabilities and cost considerations moving corn to a market position.

Since 2008 when ethanol production expanded rapidly, corn market shares to final domestic market position (e.g., ethanol plant, feeding position, wet or dry mill) have ranged between 80% and 90%. To final export position within the U.S. (e.g., to an export elevator) the market share has been below 20% since 2008.

The modal usage to each market position varies. For example, 84% of corn that is moved to a domestic consumption position is by truck, 15% by rail and a nominal amount by barge, according to the Agriculture Marketing Service (AMS) of USDA. Trucks are an important option to not only move corn off the farm to an off-farm location, grain shuttle train or barge loading position, but also to final market position before being transformed into semi-finished or finished products (e.g., feed, ethanol, corn oil, DDGs, etc.).

To final export position within the U.S. (an export elevator in Great Lakes, Atlantic Coast, Center Gulf, Texas Gulf, Pacific Northwest (PNW), cross-border into Mexico or Canada, or container), the highest volumes of corn exported out of the U.S. is through the Center Gulf (e.g., Lower Mississippi River from Baton Rouge through New Orleans and Myrtle Grove, LA). The Center Gulf handles about 60% of U.S. corn export inspections while export elevators in the PNW handle about 20% and interior cross border moves into Mexico and Canada about 20%. These are long haul moves outside the Corn Belt or key growing areas of the corn crop.

Because so much corn is exported through the Center Gulf, and more than 95% of the volume exported through the Center Gulf arrives by barge, the modal share of corn barge movements to export position exceeds 50%. The rail share moving corn to export position in the PNW, cross border into Mexico or Canada and to the Center Gulf averages about 35%.

The modal shares of corn moved to market position are shown in Figure 7.

Transportation Pricing

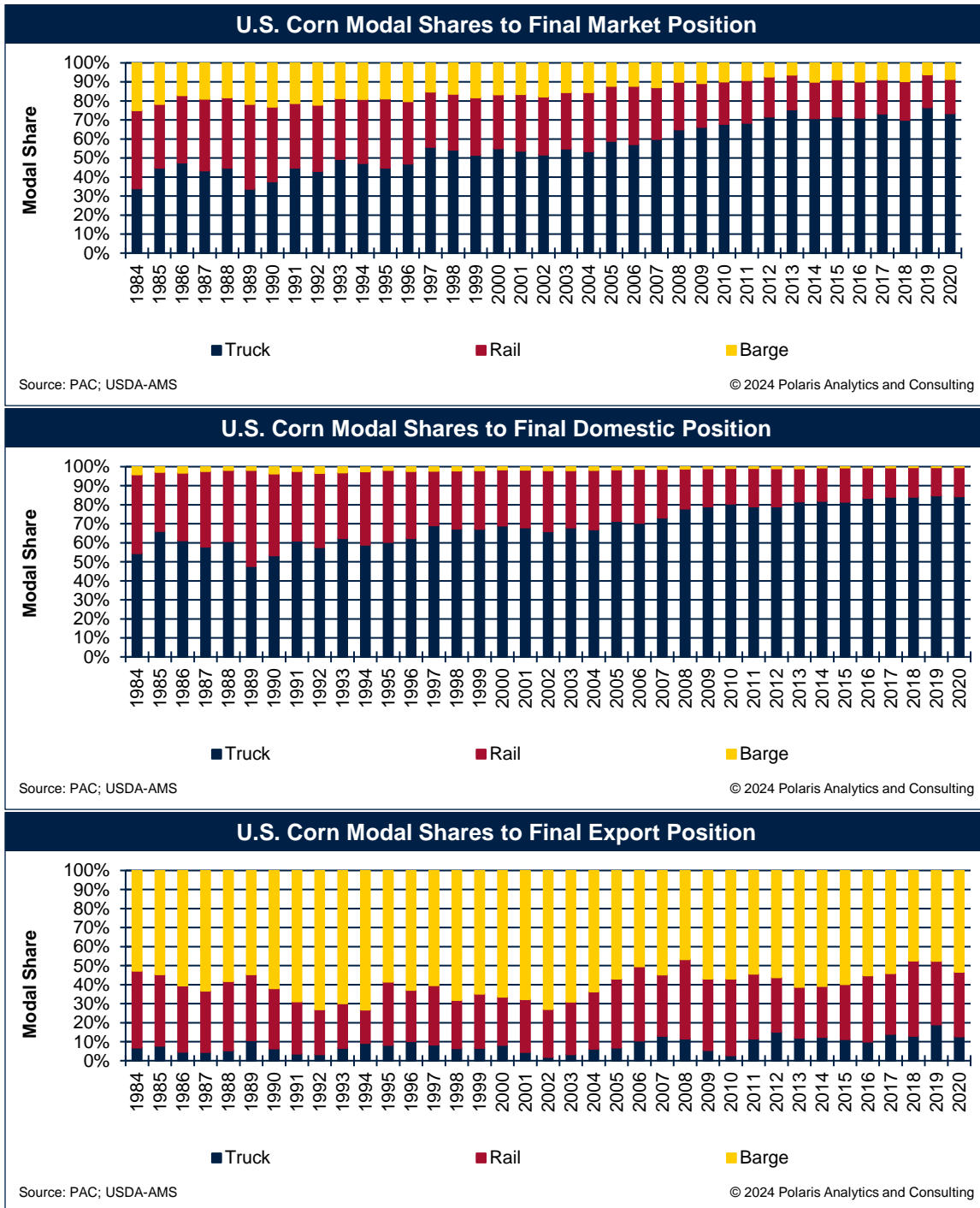
Transportation pricing or rates vary by mode and are impacted by several factors. Among shared factors is the origin and destination markets and the distance between those markets, operating costs such as fuel, available fleet capacity including the covered hopper barges or covered hopper railcars, the respective towing and locomotive power equipment, demand for service and seasonality.

Rail

Railroads establish rail freight rates in the form of a rail tariff, an amount per carload. A rail tariff includes detailed terms and conditions to move corn, for example from one area to another. A rail tariff for corn might offer a tariff using a rail owned car or a privately owned car. There are terms for train size, e.g., the number of cars moved at one time (a shuttle train includes 110 cars and dedicated locomotive equipment, and each car carrying upwards of 4,000 corn bushels), whether the corn is GMO or non-GMO. On top of the tariff there could be various surcharges for fuel as an example, or fees to switch to another railroad. The tariffs are supposed to be publicly available and can be changed at any time. If a privately owned car is used there is a lease rate or fee to use those cars.

There are secondary rail markets where cars are made available to the market at a premium or discount to the market. The value of the secondary rail market is in addition to the rail tariff. If rail cars are being offered and traded at a premium that implies there is strong demand for railcars in the marketplace. Conversely, a discount suggests demand is weak and cars are available to be traded at a discount to the rail tariff.

Figure 7: U.S. Corn Modal Shares by Final Market Position



Barge

Barge freight rates on the Mississippi River System and its connecting waterways are based on a benchmark from 1977. Each location along the river system has a tariff rate, e.g., St. Louis, MO is \$3.99 per short ton to New Orleans, LA. Tariffs are assigned to river segments that have market determined barge freight rates represented as a “percent of tariff.” At 100 percent of tariff the St. Louis rate is \$3.99 per ton, at 400 percent is \$15.96 per short ton, and so forth. Barge freight rates change frequently, reflecting market supply (number of barges and towboats) and demand (the rate of demand, seasonal patterns, and type of barge demand), navigation conditions, market demand, etc. Depending on the river segment, the number of barges in a tow could be 9 on the locking areas of the system to as many as 40 or more in the non-locking areas such as the Lower Mississippi River. Each barge can hold up to 2,200 short tons, depending on the river segment and available river draft.

Truck

Truck freight rates are local and often priced in dollars per mile. Farmers have their own trucks to move grain to market position throughout the year and there are private haulers as well. The truck sector faces seasonal pressure during the peak of grain harvest, around holidays and availability of drivers.

Modal Fuel Consumption and Emissions

Each mode has different fuel consumption capabilities and resulting emission levels. Based on research conducted by the National Waterways Foundation, average barge loadings total 1,750 short tons, which is equivalent to 16 rail hopper cars or 70 trucks. For one gallon of fuel, barges move cargo 675 ton-miles, rail 472 ton-miles and truck 151 ton-miles. As far as emissions, movements by barge generate 15.1 tons of CO₂ per million ton-miles, rail emits 21.6 tons of CO₂ per million ton-miles and truck produces 140.7 tons of CO₂ per million ton-miles.

Corn Price and Cost Considerations

Corn pricing is often associated with the Chicago Mercantile Exchange (CME) futures market where nearby and future, or forward or deferred contract months are priced and traded. A corn future is a contract for delivery of a commodity at a specific date in the future. A person can sell something they do not own, or conversely, buy something they do not want to own. The contract does not need to be fulfilled until due, even though people liquidate the contracts before then. The markets allow a person to buy or sell anytime they want (perfectly liquid) so they can always liquidate their position. The futures markets are used as a reference point for transactions all over the world. An exchange traded corn futures contract is an obligation to buy or sell a fixed quantity of a well-defined commodity at a predetermined time in the future and predetermined location(s).

While the corn futures market is based in Chicago, there are cash price locations across the U.S. whether at the farm gate, a commercial elevator, an ethanol plant, cattle feedlot or export position. Those local prices are signaling a need to buy supplies. The difference between the local cash price and the futures market is known as basis. The movement of corn responds to basis values, depending on the direction it is moving and how strong or weak it is.

Several factors influence corn basis, including:



Location



Grade



Transportation Costs



Rate of Demand



Transportation Availability



Time (e.g., October versus September)



Storage Cost



Government Actions



Storage Availability



Weather



Available Grain Supply



Interest Rates



Crop Quality

Grain merchandisers trade basis and use it as a tool to attract grain flows or to slow flows down. For example, if corn is perceived to be short or running out relative to what is required, merchandisers may offer stronger or firmer basis levels to attract corn to move from a farm into a market position. Conversely, if there are plentiful supplies in a region the basis may weaken or fall in value.

In other instances, there could be an impediment to the movement of corn, such as a slowdown or stoppage in the transportation sectors such as low or high water on the navigable waterways. If water levels are low,

then waterborne equipment such as barges might be required to be light loaded because there is not enough water depth to accommodate the maximum draft of the barge. When this happens less volume is loaded and the size of the tows (number of barges being towed) could be reduced while the velocity of the tow could be slowed. The next impact is that additional barge capacity is required to move the same volume, except there usually is not enough additional capacity. As a result, barge freight rates rise to cover the higher costs and to ration barge demand.

Those higher freight costs work backwards upstream through the barge loading locations, past the commercial elevator networks to the farm gate in the form of weakened basis. The objective is to signal to the market that by lowering basis at the farm gate farmers will not ship corn to the market. This is a mechanism to ration barge demand associated with a low water disruption moving corn. Ultimately and in this scenario, the farmer is the one who pays the price of higher freight. They do so by not sending corn to the market or if they do send corn to the market they accept a lower price in the form of weakened basis.

The following framework best illustrates the impact of an impediment to the corn supply chain. An impediment could be a transportation issue (such as the low water example), a natural disaster (e.g., a hurricane), a policy decision (unintended consequences of implementing a new program such as 45Z that can be long lasting), disputes between countries (a trade war for example that can be long lasting), etc.



Quite simply, basis represents the price of transportation between markets, such as a farm and a barge loading operation.

Impact of Carbon Intensity Scoring Scenarios on Grain Supply Chain

The previous sections provided an overview of the corn supply chain, the pathways that corn takes to market position and the modes used to move that corn. As a reminder, the flow of grain, and corn specifically, to market position moves along a path of least resistance. As outlined in the Corn Price and Cost Considerations section, impediments block, restrict or constrain the flow of corn. Unlike other impediments such as low water in a navigable waterway that is generally short-lived (less than one year) policy, regulation and trade disputes can have lasting, unintended consequences.

If 45Z guidelines require that CSA attributes remain connected to physical grain delivered to biofuel facilities, this will impact the flow of corn through the supply chain. One specific impediment is the incentive to scale farm operations according to the reduction of CI achieved. Several farm practices have demonstrated to reduce CI depending on the farm's location, climate, soil type and crops grown. But just because there are farm practices to use does not mean that all farms are created equal. For example, there could be a drag on yield, the number of bushels per acre, or less of a response in adjoining county, state or across geographies for a host of reasons. And quite frankly, the CI score on a farm can change from one year to the next.

If farmers switch from conventional corn production to no-till and cover crops, does not mean they will equally share in market opportunities for their corn. For example, some farms will have better CI results than other farms, despite efforts to reduce CI. Instead, this type of approach depicts winners and losers, and not just among farmers. If CI scoring is done at a sub-state level, some farmers that could be highly advantaged due to geography, while others are disadvantaged. Other market participants who transform corn into livestock feed or move it to the export market could lose out too and will have to increase the price of corn to compete with the ethanol plant, buy corn from other locations or modify their operations.

Deploying various farm practices to reduce CI is commendable, but what then? Conceivably the approach is to grow corn in areas where a favorable CI score or level can be achieved and transport it as feedstock to an ethanol plant to meet the required GREET levels. However, there is an unintended consequence of putting an impediment or dam in the supply chain moving corn to market.

If for example a state like Nebraska had a CI score 20 points lower than a nearby state such as Iowa, the corn in Nebraska would be attractive to ethanol plants in Iowa. If CI scoring is done at a sub-state level and CSA attributes are connected to physical grain, a lower CI score would equate to a favorable and even substantial premium (not accounting for verification, traceability requirements, etc.) to attract and buy corn from Nebraska.

In 2023, Nebraska's corn yield was 182 bushels per acre, one bushel better than the national average, and depending on the CI score that can be achieved in Nebraska the value could be a significant opportunity for an ethanol plant to attract corn from Nebraska farmers who adopt a CSA plan for their farm.

Nebraska is the third leading corn producer state in the U.S., harvesting between 1.5 billion bushels and 1.9 billion bushels per year over the past five years, producing a surplus amount of corn to fulfill consumption needs within the state of Nebraska while shipping to other states and export position.

According to the Nebraska Corn Growers Association 16% of Nebraska's corn production is used for livestock feed, 28% for ethanol and 34% is shipped out of Nebraska to other states and to export position in Galveston-Houston, the PNW or into Mexico. The remaining amount of Nebraska's corn supplies goes to other components of food, seed and industrials beyond ethanol and to ending stocks.

The volume that is moved out of state to other states or export position averaged 585 million bushels over the past five years. The price of corn in Nebraska in mid-July 2024 was \$3.98 per bushel and \$4.12 per bushel in Iowa according to USDA-AMS. The lower price in Nebraska reflects a high surplus level and higher freight costs to move to market position (e.g., weaker basis as discussed in the Corn Price and Cost Considerations section). By adding the per bushel CI premium to the Iowa price at an ethanol plant, the price in Iowa improves by that much. If the price with the premium is high enough, then it can attract corn from longer distances and other geographies such as corn from Nebraska.

For exporters in the PNW for example, the value of FOB corn was \$5.47 per bushel during mid-July based on the U.S. Grains Council *Market Perspectives* report. The PNW FOB price reflects the global market price through the PNW, while compensating for export elevator margins and the CIF (cost, insurance and freight) price at the export elevator. The CIF price greatly reflects interior freight costs such as the rail freight rate from a shuttle train loader in Nebraska to a PNW export elevator.

If the CI premium added to the Iowa price exceeds the PNW value, corn would divert away from shuttle loaders shipping to export position and move in the opposite direction to ethanol plants in Iowa. And it is not just the export market that will suffer. The livestock sector in Nebraska will see corn they historically accessed be diverted to Iowa as well.

Ethanol plants in Iowa will be able to pay a substantial premium to attract Nebraska's flow of the lower CI scored corn. This would be an unconventional move in that the transportation network, especially rail that is not designed or structured to move corn from Nebraska to Iowa on short moves (railroads prefer to move railcars long distances between origins and destinations as discussed in Modal Usage moving Corn to Market Position section of this paper). Without being able to adequately rail corn from Nebraska, corn will be trucked to Iowa.

A railcar can be loaded with 110 short tons of corn (or about 4,000 bushels) while a truck can haul 25 short tons (or about 900 bushels), roughly 4.4 trucks per railcar. One 110 railcar shuttle train of corn (approximately 440,000 bushels of corn) would then require 484 trucks. If an ethanol plant in Iowa uses about 36 million bushels of corn annually, that would be the equivalent of about 82 shuttle trains.

Rail will not be able to adequately move the lower CI scored corn from Nebraska to Iowa. The corn will have to be moved by truck, a lot of trucks, nearly 39,600 truckloads. The additional cost of moving lower CI scored corn from Nebraska to Iowa would be substantial. For example, instead of delivering corn 25 miles to a feedlot or shuttle train loader, a farmer in eastern Nebraska could be shipping corn upwards of 125 miles to an ethanol plant in western Iowa, if not further. The net difference would be an additional 100 miles.

USDA-AMS publishes quarterly grain truck rates, with the most recent rates from the fourth quarter of 2023. Truck rates are further reported by region. For the North Central region where Nebraska and Iowa are located the representative truck rate was \$4.16 per mile per truck load, or \$416 per truck moving corn a net 100 miles to an ethanol plant in Iowa. While an ethanol plant in Iowa requires about 39,600 truckloads of corn,

not all its corn needs would necessarily be sourced from Nebraska. Consider if that ethanol plant sourced one half of its corn needs from Nebraska. The additional cost of 19,800 trucks hauling lower CI scored corn from Nebraska to an ethanol plant in Iowa, traveling a net 100 miles further, exceeds \$8.2 million for one ethanol plant. And this does not consider the impact increased truck traffic will have on the roads, highways and communities using the new route to the ethanol plant in Iowa, let alone the increased volume of emissions.

In addition to the higher truck costs, the unintended consequences of 45Z rewarding lower CI scored corn at the ethanol plant will be disruptive, negatively impacting the shuttle train network of grain handlers, exporters and railroads, livestock feeders, and other food, seed and industrial companies who invested in Nebraska for a specific purpose. One of the purposes was to be near a surplus supply of corn that Nebraska has to offer. Under 45Z and with a substantial premium available from ethanol plants in Iowa, that purpose to be near surplus corn in Nebraska will be turned upside down.

How does the supply chain overcome the premium of Nebraska's lower CI scored corn? The export sector will either improve its price to attract corn from Nebraska, seek corn supplies from other domestic markets, surrender market share to other U.S. port ranges or lose out to competitors in other countries. Nebraska's livestock sector would have to pay up to attract corn to their operations. If the livestock producers could not bid the price of corn high enough to keep corn flowing to their operations, they would have to consider alternative feeds or restructure their operations. It will be similar for the other food, seed and industrial users of corn in Nebraska.

The problem is exacerbated elsewhere. In Iowa, corn that had a higher CI score than Nebraska, and that historically went to an ethanol plant will be disadvantaged by the lower CI scored corn from Nebraska. Iowa's corn must then find its own market pathway. But those pathways are not established as they are in Nebraska and would require substantial investment by grain handlers, transportation providers such as railroads, exporters and livestock feeders. A lower CI score is commendable and if the premium is paid out through an ethanol plant will promulgate the disruption of the 45Z impact on the corn supply chain.

This type of scenario will have unintended consequences of disrupting the corn supply chain that is set up to handle large volumes through a high output network that was planned, invested in, developed and operated over years and decades. A battle for the lowest CI corn would create winners and losers, and given the framework described in the Corn Price and Cost Considerations section, competition for corn will be bolstered elsewhere whether in the U.S. or a global competitor, and over the longer run negatively impact local communities and economies.

A feasible option will be to decouple CSA from the physical corn bushel under a book and claim approach. The CSA plan is certified at the farm. The farmer then offers the CSA certificate to claim the feedstock CI while the physical feedstock from the farm flows on the path of least resistance to market position. This option maintains the integrity of the established corn supply chain while incentivizing farmers to adopt farm practices to lower CI.

Summary

The corn supply chain is intricate while sharing nuances of it with other crops. Farmers make business decisions on what they will plant and grow based on their unique location, market options, crop history and financial considerations.

The corn supply chain has been built over decades to handle large volumes through a high output system of elevators, livestock feeding operations, corn grind facilities and high-speed rail shuttle loaders and barge loading operations to feed and fuel the economy of the U.S. and globally.

Impediments to the supply chain occur regularly and depending on the situation impacts basis values that farmers take as signals to move their grain. Prolonged impediments such as policy, regulations and trade wars have unintended consequences. The 45Z portion as it is in the current IRA seeks to incentivize SAF production, will create winners and losers among farmers and supply chain participants. The costs could be substantial. If one ethanol plant in Iowa received half their corn needs using lower CI scored corn from Nebraska, they would need about 19,800 trucks. The trucks would travel a net 100 additional miles, and the cost of using trucks would be \$8.2 million more. And this does not consider the impact increased truck traffic will have on the roads, highways and communities using the new route to the ethanol plant in Iowa, and the increased volume of emissions.

Instituting a decoupling of the physical corn bushel under a book and claim approach will preserve the integrity of the corn supply chain while incentivizing SAF production through certified CSA plans at the farm level.

Before 45Z is fully implemented, further research and industry engagement is needed to properly define what is at stake, who are the winners and losers, and how SAF can fully maximize the opportunities available.



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