

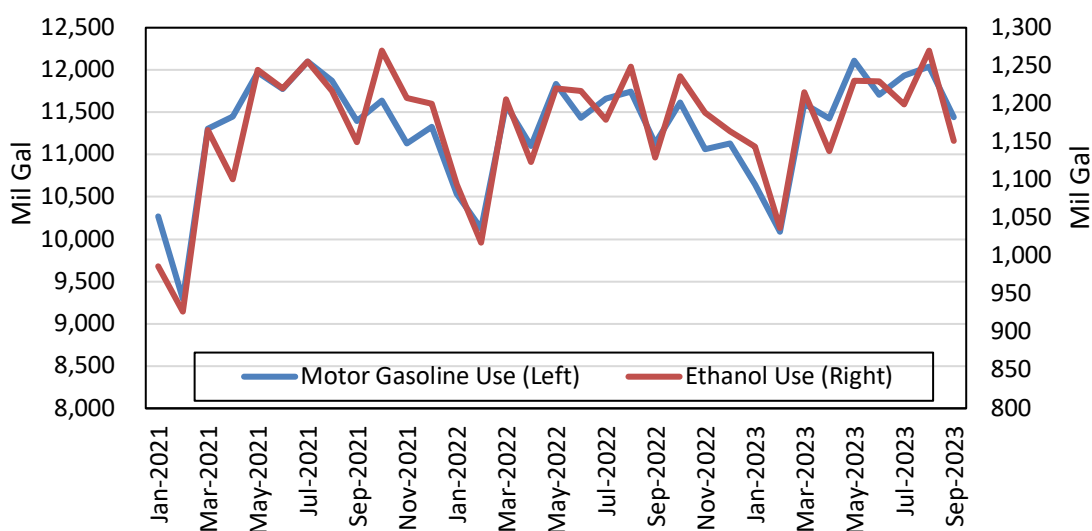
CONTRIBUTION OF THE ETHANOL INDUSTRY TO THE ECONOMY OF THE UNITED STATES IN 2023

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The U.S. ethanol industry continued to grow in 2023 as the economy improved and the regulatory environment was relatively benign. Growth in real output was accompanied by gains in employment and a recovery in real disposable income. Led in large part by lower crude oil and gasoline prices, the inflation rate fell from the 40-year high record set in 2022. These developments supported gains in both gasoline and ethanol demand during the year. This is illustrated in Figure 1 which displays finished motor gasoline and ethanol domestic use. Motor gasoline and ethanol use each increased nearly two percent over year earlier levels during the first ten months of 2023.

Figure 1
U.S. Motor Gasoline and Domestic Ethanol Demand



The most significant economic development experienced by the ethanol industry during 2023 was a significant improvement in feedstock (notably corn), natural gas, and other input costs. Corn prices (No. 2 Yellow, Central Illinois) averaged \$5.87 per bushel during 2023, 17.3 percent below 2022 levels while industrial natural gas prices fell nearly 42 percent. These two inputs alone account for about 80 percent of operating costs.

While input costs declined in 2023 so too did the prices of ethanol and co-products, distillers dried grains (DDGS) and distiller's corn oil (DCO) from dry mills and wet mill co-products corn gluten feed (CGF) and corn gluten meal (CGM), but not by as much. Reflecting this, ethanol industry returns over operating costs averaged an estimated \$0.47 per gallon, nearly twice that of 2022.

At year's end, RFA reported 198 installed ethanol biorefineries with a capacity of about 17.8 billion gallons that produced nearly 15.6 billion gallons in 2023. The ability to meet demand with existing capacity and concerns over interest rates continued to restrain investment in new capacity.

The ethanol industry continues to make a substantial positive contribution to the American economy. This study estimates the contribution of the ethanol industry to the American economy in 2023 in terms of employment, income, and Gross Domestic Product (GDP) directly and indirectly supported by the industry.

Expenditures by the Ethanol Industry in 2023

Ethanol producers are part of a manufacturing sector industry that adds substantial value to agricultural commodities produced in the United States and makes a significant contribution to the American economy.

Expenditures by the ethanol industry for raw materials, other goods, and services represent the purchase of output of other industries. The spending for these purchases circulates through the local and national economy, generating additional value-added output, household income, and employment

in all sectors of the economy.¹ Ethanol industry expenditures can be broken into ongoing production operations and research and development.

1. Ongoing production operations

The industry spent \$38.9 billion on raw materials, other inputs, and goods and services to produce ethanol during 2023, 14.5 percent less than a year earlier. The most significant declines in operating costs were attributable to sharply lower feedstock (mostly corn) and natural gas prices. These two inputs alone account for more than 80 percent of expenditures to produce ethanol. Production costs were based on a model of dry mill ethanol production maintained by the author of this report. These estimates are consistent with generic dry mill ethanol costs, such as those published by Iowa State University.² Table 1 details the expenditures by the ethanol industry in 2023.

The largest share of spending was for corn and other feedstocks used as raw material to make ethanol. The ethanol industry used 5.3 billion bushels of corn (and corn equivalent) on a gross basis in 2023, valued at \$31.8 billion. Reflecting this, the ethanol industry continues to be a major source of support for agricultural output and farm income.

This analysis estimates both the total production effect and the farm income effects of ethanol production on agriculture. The impact of demand for corn to produce ethanol on farm income is adjusted to avoid overstating the impact of ethanol demand on revenue for the corn sector. The remainder of spending by the ethanol industry for ongoing operations is for a range of inputs such as enzymes, yeast, and chemicals; electricity, natural gas, and water; labor; transportation; and services such as maintenance, insurance, and general overhead.

¹ Expenditures for feedstocks and energy were estimated using year-to-date 2023 calendar year average prices. Revenues were estimated using 2023 calendar year average prices for ethanol, distiller's grains, distillers' corn oil, corn gluten feed and corn gluten meal. Prices were provided by USDA/ERS and AMS, and EIA.

² See the Ethanol profitability spreadsheet maintained by Don Hofstrand "AgDecision Maker D1-10 Ethanol Profitability" available at <http://www.extension.iastate.edu/agdm/energy/xls/d1-10ethanolprofitability.xlsx>

Table 1
Estimated Ethanol Production Expenditures, 2023

	2022	2023	% Chg vs
Operating Costs	Mil \$	Mil \$	2022
Feedstock (corn)	\$37,479	\$31,790	-15.2%
Enzymes, yeast and chemicals	\$1,167	\$1,217	4.2%
Denaturant	\$565	\$569	0.7%
Natural Gas, electricity, water	\$4,434	\$3,193	-28.0%
Direct labor	\$584	\$697	19.4%
Maintenance & Repairs	\$488	\$565	15.7%
Transportation	\$141	\$163	15.7%
GS&A	\$582	\$674	15.7%
Total Operating Costs	\$45,441	\$38,868	-14.5%
\$/Gallon	\$2.87	\$2.50	-13.0%

2. Research and development

The renewable fuels industry continues to be a significant engine for research and development (R&D) both in the public and private sectors. Much of the R&D activity in the biofuels industry is aimed at discovering and developing advanced biofuels feedstock, refining the technology needed to meet RFS2 targets for cellulosic and advanced biofuels, and the development of new fuels such as sustainable aviation fuel (SAF) from renewable ethanol.

The primary public-sector agencies underwriting R&D in biofuels are the U.S. Departments of Energy (USDOE) and Agriculture (USDA). In addition to the federal government, many states are funding R&D in feedstock development as well as infrastructure. These public funds are being increasingly leveraged by private sector firms undertaking research in a wide range of biofuels activities. We estimate that R&D outlays in the renewable fuels industry increased at the general rate of inflation reaching more than \$380 million in 2023.

3. Co-product value

Most ethanol (more than 90 percent) is produced by dry mills that produce valuable co-products in the form of DDGS and DCO.³ The majority of the remaining ethanol is produced by wet corn mills that also produce corn gluten meal, corn gluten feed and edible corn oil as co-products. The ethanol industry produced an estimated 35.4 million short tons of DDGS, 4.3 billion pounds of DCO, 2.7 million tons of corn gluten feed and 530 thousand tons of corn gluten meal in 2023 with an aggregate co-product market value of \$11.5 billion.

4. Construction

The ethanol industry operated at an estimated 87 percent capacity utilization rate in 2023. Reflecting this, relatively little new construction activity was undertaken during the year. The RFA estimates about 50 million gallons of capacity under construction or expansion in 2023 with most of that directed at new technology.

Spending associated with ethanol production, construction activity and R&D circulates and re-circulates throughout the entire economy several-fold, stimulating aggregate demand, and supporting jobs and household income. The economic activity associated with export activity adds to this impact. In addition, expanded economic activity generates tax revenue for government at all levels.

Methodology

The impact of the ethanol industry on the American economy was estimated by applying expenditures by relevant supplying industry to the appropriate final demand multipliers for value added output, earnings, and employment.

To understand how the economy is affected by an industry such as ethanol production, it is necessary to understand how different sectors or industries in the economy are linked. For example, ethanol producers, members of the manufacturing sector, buy corn from farmers who are in the agriculture sector. Corn farmers in turn, purchase inputs from suppliers in other industries such as fertilizer and

³ DDGS and distillers corn oil production is reported monthly in the USDA Grain Crushings and Co-Products Production report. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1899>

crop protection producers that also purchase inputs from a range of other industries. These are referred to as backward linkages. Ethanol feedstock production is linked through both forward and backward linkages to other economic sectors in each state's economy.

Households are linked to all other sectors as they provide labor and management resources. Changes that affect incomes of the household sector typically have significant impacts compared to a change in the sales or output of other sectors. This is because households typically spend most of their income on both retail goods and services and this is a critical component of the national economy.

This study uses the IMPLAN (Impact Analysis for Planning) multiplier database to develop a model of the national economy, including sectors that support the ethanol industry, the links between them, and the level of national economic activity. IMPLAN is a commonly used economic input-output (I-O) model. I-O models are constructed based on the concept that all industries in an economy are linked together; and the output (i.e., sales) of one industry becomes the input of another industry until all final goods and services are produced. I-O models can be used both to analyze the structure of the economy and to estimate the total economic impact of projects or policies. For this analysis, a model for the U.S. economy was constructed using IMPLAN software and data. These data are based on the most current available benchmark input-output data and 2021 regional data published by the U.S. Bureau of Economic Analysis.

IMPLAN models provide three economic measures that describe the economy: value added, income, and employment.

- Value added is the total value of the goods and services produced by businesses in the country and is generally referred to as GDP. Value added represents the net economic benefits that accrue to the nation because of increased economic output.
- Labor income is the sum of employee compensation (including all payroll and benefits) and proprietor income (income for self-employed work). In the case of this analysis, demand for corn and other feedstock to produce ethanol supports farm income through higher crop receipts than would be the case without ethanol production.

- Employment represents the annual average number of employees, whether full or part-time, of businesses producing output, expressed in full-time equivalent jobs.

Three types of effects are measured with an economic multiplier: direct, indirect, and induced effects. Direct effects are the known or predicted changes in the economy associated with the industry directly involved (in this case, ethanol). Indirect effects are the business-to-business transactions required to produce direct effects (i.e., increased output from businesses providing intermediate inputs). Finally, induced effects are derived from spending on goods and services by people working to satisfy direct and indirect effects (i.e., increased household spending resulting from higher personal income).

We account for the additional value of output of ethanol co-products (DDGS, DCO, CGM and CGF) in the analysis. Since these are co-products, the expenditures (backward linkages) for their production are accounted for in the operating costs of ethanol production. This was done by separating costs and revenue for ethanol plants by the share of ethanol and co-products accounted for by dry and wet mills and estimated the impact of net industry earnings using multipliers for the non-beverage ethanol manufacturing and wet corn mill industries.⁴

We also incorporate the explicit impact of ethanol and DDGS exports in the economic impact analysis. The methodology for estimating the impact of trade differs from that used for industry output.⁵ We estimate the impact of ethanol and DDGS exports by applying USDA Agricultural Trade multipliers for output and employment to the estimated value of exports for 2023 reported by EIA and U.S. Census Bureau trade databases.⁶

The USDA multipliers provides a more precise estimate of the economic contribution of exports. The multipliers have three major components (or margins): production, transportation and warehousing, and wholesale/retail trade. Since IMPLAN already incorporates the impact of ethanol and DDGS production,

⁴ The Non-beverage Ethyl Alcohol Manufacturing industry is NAICS code 325193 and Wet Corn Milling and Starch Manufacturing is NAICS 311221

⁵<https://www.ers.usda.gov/data-products/agricultural-trade-multipliers/>

⁶ The estimated value of exports is based on 11 months of data

we only applied the margins for transportation and trade to the value of exports in order to avoid double counting. This represents the post-production (or ex-plant) impacts from exports.

Results

Output

Table 2 summarizes the impact of ethanol industry production and exports on the U.S. economy in 2023. The full impact of the spending for annual operations of ethanol production, co-product output, exports, and R&D is estimated to have contributed \$54.2 billion to the nation's GDP in 2023, 3.7 percent less than in 2022. The primary reason for the smaller GDP impact in 2023 can be traced to the combination of lower input prices that reduced operating expenditures and a 7.4 percent decline in the value of industry output.

Because of the importance of feedstocks, agriculture continues to be a significant source of industry economic impact. This reflects the importance of ethanol demand to total corn utilization, the aggregate value of crop production, and crop receipts and farm income. USDA reports that ethanol accounts for nearly 40 percent of total corn utilization. Feedstock (mostly corn) production contributed nearly \$28 billion to the U.S. economy while the manufacturing activity of ethanol production accounted for \$14.6 billion.

Employment

Jobs are created from the economic activity supported by ethanol production. Ethanol production is not a labor-intensive industry (accounting for nearly 12,000 full time equivalent direct jobs nation-wide)⁷. However, the economic activity of supporting industries generates a substantial number of jobs in all sectors of the national economy. When the direct, indirect, and induced jobs supported by ethanol production, construction activity, agriculture, exports, and R&D are included, the ethanol industry supported nearly 395,000 jobs in all sectors of the economy 2023.

⁷ The Census Bureau does not report employment in ethanol production. This analysis assumes the average ethanol plant employs approximately 50 full-time equivalent employees.

Table 2
Economic Impact of the Ethanol Industry: 2023

	2023 GDP	2023 Employment	2023 Income
	(Mil 2023\$)	FTEs	(Mil 2023\$)
Ethanol Production	\$14,602	95,166	\$7,057
Direct	\$2,602	11,781	\$1,037
Indirect	\$7,394	46,014	\$3,736
Induced	\$4,606	37,372	\$2,284
Agriculture	\$27,916	264,494	\$19,089
Direct	\$3,137	58,324	\$4,130
Indirect	\$14,299	127,638	\$9,004
Induced	\$10,480	78,533	\$5,954
Construction	\$217	2,093	\$157
Direct	\$78	1,015	\$76
Indirect	\$53	359	\$32
Induced	\$86	718	\$49
R&D	\$588	4,230	\$394
Direct	\$225	1,343	\$172
Indirect	\$146	1,105	\$98
Induced	\$217	1,782	\$123
Exports (Total)	\$10,904	28,480	\$5,779
Total Ethanol	\$54,226	394,464	\$32,476
Direct	\$6,042	72,463	\$5,416
Indirect	\$32,795	203,597	\$18,649
Induced	\$15,389	118,405	\$8,411

Since ethanol production is more capital intensive than labor intensive, the number of direct jobs supported by the ethanol industry is relatively small and is concentrated primarily in manufacturing and agriculture. Most agriculture jobs supported by the ethanol industry are jobs in support activities related to crop production, ranging from producers and distributors of crop protection products, fertilizer, and farm equipment to farm service providers. In addition, income generated and spent by employees

supports a significant number of jobs in seemingly unrelated sectors such as retailers and service sectors. In general, as the impact of the direct spending by the ethanol industry expands throughout the economy, the employment impact also expands and is spread over many sectors.

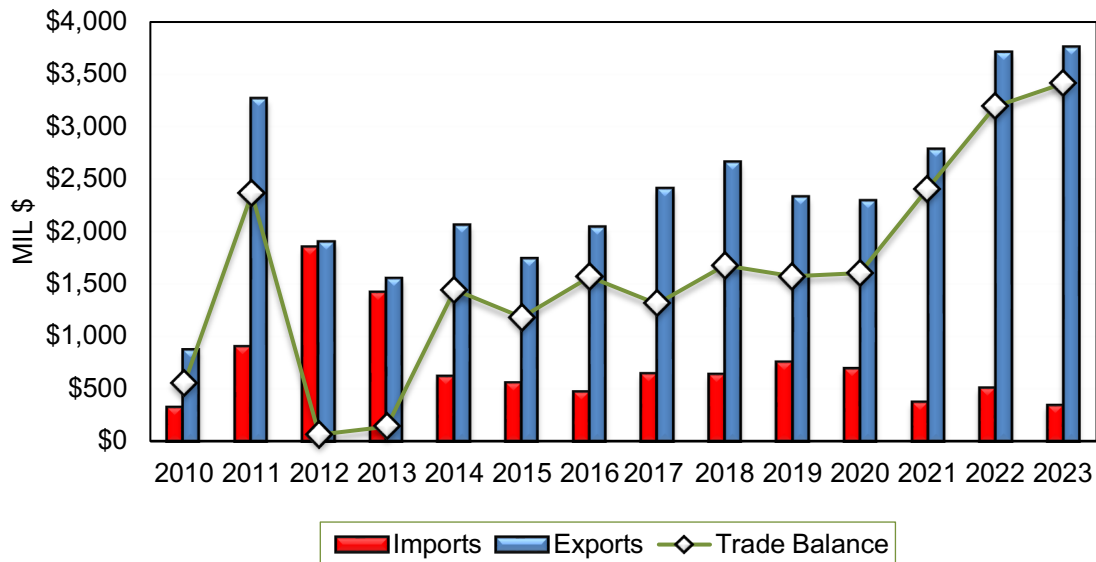
Income

Economic activity and associated jobs produce income for American households. The economic activities of the ethanol industry put \$32.5 billion into the pockets of Americans in 2023. As is the case with employment, the direct impact on income by the ethanol industry is largely concentrated in manufacturing and services. In many respects, this mirrors the employment structure of the American economy. The most significant impact of the ethanol industry continues to be increased income to farmers who benefit from the demand for feedstock, which leads to both increased production and increased prices, as well as earnings from locally owned ethanol plants.

Exports

The export markets for ethanol continued to grow in 2023. Exports of ethanol in 2023 increased six percent over 2022 levels to nearly 1.4 billion gallons with an export value of nearly \$3.8 billion. Three markets, Canada, the UK and the Netherlands, accounted for approximately two-thirds of U.S. ethanol exports. Exports rose to Canada, which accounts for nearly half of total exports, but shipments to South Korea, a major market in 2022, fell 36 percent. The largest gains in exports to major markets were to the UK, Canada and Colombia which emerged as a top ten market in 2023. The ethanol industry continues to generate a trade surplus that helps reduce the nation's trade deficit. Figure 2 illustrates the growth in ethanol exports, imports, and trade balance.

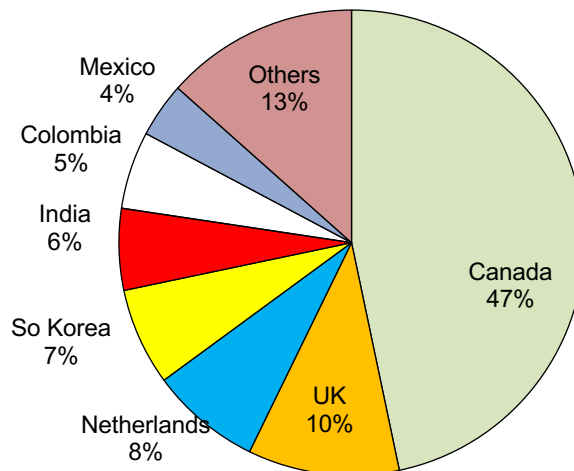
Figure 2
U.S. Ethanol Trade



Source: Foreign Agricultural Service. Global Agricultural Trade System (GATS)

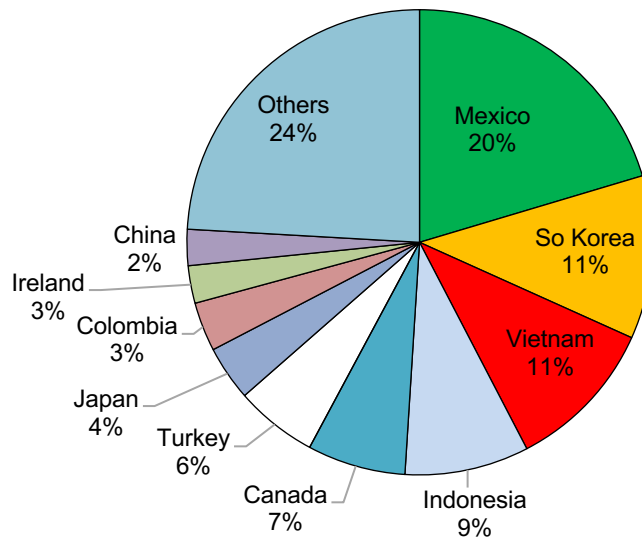
DDGS exports in 2023 totaled an estimated 10.7 million metric tons, 2.4 percent below year earlier levels. However, lower volumes combined with lower world prices for DDGS resulted in a 2.8 percent decline in export value. The most significant increases in DDGS exports among major markets were to Turkey, Indonesia and China (although China was the smallest of the top ten export markets). Exports to Canada, Ireland, Japan and Vietnam were down substantially. Ten countries accounted for nearly three-quarters of U.S. DDGS exports in 2023. (Figure 4).

Figure 3
U.S. Ethanol Exports, 2023
1,390 million gallons



Source: USA Trade Online
Data through November

Figure 4
U.S DDGS Exports, 2023
10.7 Million Metric Tons



Source: USA Trade Online
Data through November

Exports of ethanol and distillers' grains generate economic activity largely through the requirements to transport output from plants to ports and final destinations. This largely involves truck, rail, barge, and ocean shipping. Additional impacts are generated by labor, administrative and financial requirements necessary to support export activity. These impacts are categorized as indirect since they are subordinate to production. Using the USDA Trade Multipliers indicated that the \$7.1 billion of ethanol and co-product export value accounted for \$10.9 billion to GDP and supported more than 28,000 jobs in all sectors of the economy. Most of these jobs are concentrated in transportation and export trade related administrative and financial industries. As shown in Figure 3, seven markets account for more than 85 percent of total U.S. ethanol exports, although the U.S. shipped ethanol to nearly 90 countries in 2023.

Tax revenue

The combination of GDP and household income supported by the ethanol industry contributed an estimated \$5.6 billion in tax revenue to the Federal Treasury in 2023. State and local governments also benefit from the economic activity supported by the ethanol industry, earning \$4.8 billion in 2023.

Crude oil displacement

Ethanol plays a positive role in reducing our dependence on imported oil, expands the supply of motor gasoline, reduces the U.S. trade deficit, and reduces greenhouse gas emissions relative to conventional gasoline.

Ethanol displaces crude oil needed to manufacture gasoline and expands the volume of motor gasoline available to consumers. According to the EIA, the U.S. remains a significant importer of crude oil. The use of domestic ethanol continues to be a contributor to the nation's energy independence. The production of nearly 15.6 billion gallons of ethanol displaced nearly 525 million barrels of crude oil needed to produce gasoline in 2023. The value of the crude oil displaced by ethanol is estimated at \$41 billion in 2023.⁸ Money that would have been spent on larger imports of crude oil stays in the American

⁸ Ethanol directly competes with and displaces gasoline as a motor fuel. According to the EIA, one 42-gallon barrel of crude oil produced 19.5 gallons of gasoline in 2023. Ethanol has a lower energy content (76,700 btu per gallon LHV) than gasoline (114,000 btu per gallon LHV), and thus it takes 1.5 gallons of ethanol to provide the same energy as one gallon of gasoline. Therefore, 15.5 billion gallons of ethanol are the equivalent of about 10.2 billion gallons of gasoline. Since one barrel of crude produces 19.5 gallons of gasoline, it takes 525 million barrels of crude to produce 10.2 billion gallons of gasoline, the amount

economy and, when combined with the GDP generated by ethanol production, is helping keep America strong.

State Level Impacts of Ethanol Production

The U.S. ethanol industry consists of 198 operating plants in 24 states with aggregate industry capacity of 17.8 billion gallons and production of nearly 15.6 billion gallons at year-end 2023. The top six ethanol producing states (Iowa, Nebraska, Illinois, South Dakota, Indiana and Minnesota) account for nearly three-quarters of U.S. production. Not surprising, these states are the nation's leading corn producers accounting for nearly 70 percent of production of the leading ethanol feedstock. Each of these plants is a biorefinery that is an integral part of the non-beverage ethanol manufacturing industry . As such, expenditures on feed grains and other feedstocks and inputs generates economic activity and income and supports job creation.

The calculation of state-level economic activity generated by ethanol production used state-specific economic impact multipliers for the non-beverage ethanol manufacturing industry provided by the Bureau of Economic Analysis Regional RIMS II system. After identifying the multipliers for GDP, employment, and income we estimated state-level output based on year-end capacity provided by RFA. Expenditures were calculated by multiplying the national average per gallon cost of production by adjusted output. Estimates of GDP, income and employment were calculated by multiplying the appropriate state-level RIMS II multipliers by the estimated operating expenditures by state.

Since two different multiplier systems were used, the RIMS results were allocated over the national economic impacts based on state shares. The results represent only the impact of ethanol production and agriculture and exclude new construction activity, exports and R&D. The economic impacts are rough estimates for several reasons. Chief among these is that the state-level analyses used multipliers for only one industry, other basic organic chemicals, and does not reflect other supplying industries. As might be expected, the impact on a state's economy is generally proportional to ethanol

displaced by ethanol. This oil was valued at the 2023 average composite acquisition cost of crude oil by refiners reported by EIA at \$78.10/bbl.

production. Table 3 details these results for states with at least 100 million gallons of production capacity.

Table 3
Contribution of Ethanol Production to Individual State Economies, 2023

State	Capacity (Mil gal)	Plants	GDP (Mil \$)	Earnings (Mil \$)	Employment Jobs
IA	4,809	42	\$13,228	\$7,996	100,077
NE	2,305	24	\$6,368	\$3,804	47,947
IL	1,886	13	\$6,869	\$4,040	44,249
SD	1,442	16	\$3,685	\$2,216	27,205
MN	1,427	19	\$4,511	\$2,764	31,109
IN	1,426	15	\$4,650	\$2,815	35,236
OH	732	7	\$2,713	\$1,626	19,712
WI	644	9	\$1,938	\$1,190	15,510
ND	550	6	\$1,542	\$870	9,653
KS	540	11	\$1,737	\$994	12,203
TX	420	4	\$1,801	\$1,067	12,246
MI	382	5	\$1,162	\$718	9,523
MO	335	6	\$1,070	\$599	8,654
TN	235	3	\$780	\$455	5,672
CA	227	5	\$565	\$360	3,691
CO	143	4	\$406	\$249	3,160
PA	120	1	\$365	\$213	2,459
Others	327	8	\$837	\$500	6,158
U.S.	17,950	198	\$54,226	\$32,476	394,464

The results in Table 3 are generalized impacts. The impacts of comprehensive analysis of any individual state will differ from these results. The reason for this is complex. First, the structure of each state economy is unique, economic impact multipliers reflect this and will differ from national-level multipliers for any given industry. This analysis uses multipliers for only one industry, non-beverage ethanol manufacturing (NAICS 325193). Additionally, there are regional differences in feedstock costs, ethanol and co-product prices, and other input costs that have not been explicitly considered. Relatively few states procure all their feedstock and other inputs locally. Consequently, the analysis

does not factor in leakages (spending that takes place out-of-state for inputs imported from a neighboring state). This means, for example, that the impacts may be overstated for a corn-deficient state like Pennsylvania to the extent that the dollars spent for corn imported from other states such as Ohio or Indiana represent income for farmers in the supplying states and are not netted out of the analysis.

Conclusion

The ethanol industry continued to make a significant contribution to the economy in terms of GDP, job creation, generation of tax revenue, and displacement of crude oil and petroleum products in 2023. The importance of the ethanol industry to agriculture and rural economies is particularly notable. Growth and expansion of the ethanol industry as it applies new technologies and addresses new markets will enhance the industry's position as the original creator of green jobs and will enable America to make further strides toward reducing greenhouse gas emissions and positively dealing with climate change.