

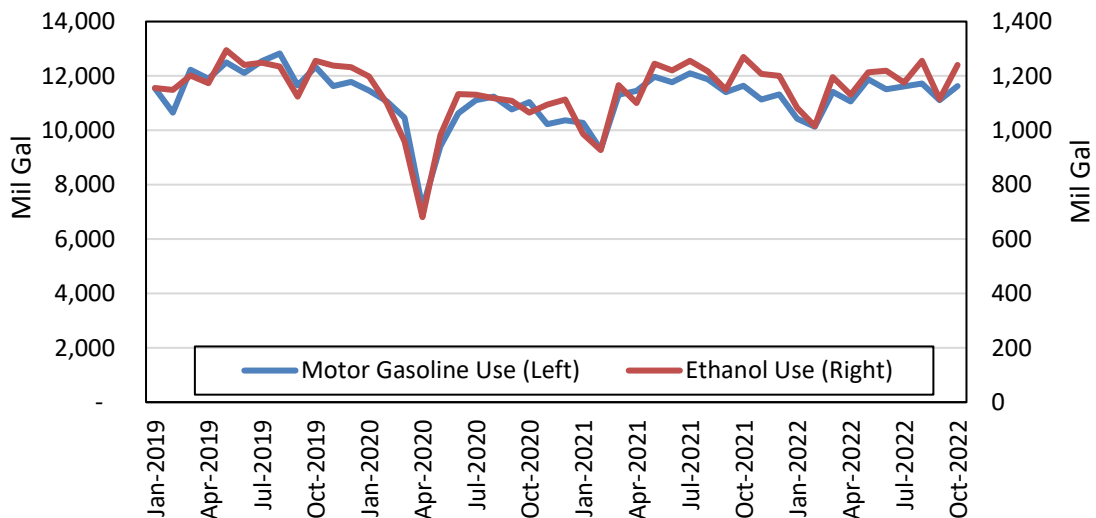
**CONTRIBUTION OF THE ETHANOL INDUSTRY TO
 THE ECONOMY OF THE UNITED STATES IN 2022**

Prepared for the Renewable Fuels Association by
 John M. Urbanchuk
 Managing Partner, ABF Economics

February 14, 2023

The U.S. ethanol industry posted growth in 2022 as it continues to recover from the economy-wide effects of the COVID pandemic and dealt with a weak economic environment and rampant inflation. The economy rebounded in the second half from recessionary levels and posted a modest 2.2 percent real growth for all of 2022. Growth in real output was accompanied by modest gains in real disposable income. These factors supported small increases in both gasoline and ethanol demand during the year. Despite a recovering economy, motor fuel demand was restrained by sharply higher crude oil and gasoline prices. This is illustrated in Figure 1 which displays finished motor gasoline and ethanol domestic use. It is important to note that growth in ethanol demand outpaced gasoline demand during 2022.

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



At year's end, RFA reported 199 installed ethanol biorefineries with a capacity of nearly 17.9 billion gallons that produced nearly 15.5 billion gallons in 2022. The ability to meet demand with existing capacity and concerns over interest rates and inflation restrained investment in new capacity.

The most significant economic problem facing ethanol producers and consumers during 2022 was inflation, which reached a 40-year high of 8 percent for the full year of 2022. The impact of this on the ethanol industry was the sharp increase in feedstock (notably corn), natural gas, and other input costs. Corn prices (No. 2 Yellow, Central Illinois) averaged \$7.10 per bushel during 2022, an 18.3 percent increase despite a larger harvest in the fall of 2021, while the price of industrial natural gas was up 48 percent for the year. Consumers faced gasoline prices that increased nearly 32 percent over year earlier levels.

The upside of inflationary pressures in the economy was that the prices of ethanol, dry mill co-products distillers dried grains (DDGS) and distiller's corn oil (DCO), and wet mill co-products corn gluten feed (CGF) and corn gluten meal (CGM) also surged. Consequently, However, returns over operating costs for the ethanol industry averaged an estimated \$0.21 per gallon, just over half that of 2021.

On the regulatory front, one of the major positives for the ethanol industry was a series of emergency waivers to allow year-round use of E15 by the U.S. Environmental Protection Agency starting in May 2022. This has been accompanied by introduction of legislation in the House of Representatives (the Consumer and Fuel Retailer Choice Act of 2022) and companion legislation in the Senate to make the waiver permanent.

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 2022 in terms of employment, income, and Gross Domestic Product (GDP) directly and indirectly supported by the industry.

Expenditures by the Ethanol Industry in 2022

Ethanol producers are part of a manufacturing sector 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 \$46.8 billion on raw materials, other inputs, and goods and services to produce ethanol during 2022, 24 percent more than year earlier. The increase in production costs reflects sharply higher prices for feedstocks (mostly corn) and other inputs, notably natural gas. 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 2022.

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 2022, valued at \$38.2 billion. Reflecting this, the ethanol industry continues to be a major source of support for agricultural output and farm income. Together, feedstock and energy accounts for more than 80 percent of ethanol production costs.

¹ Expenditures for feedstock and energy were estimated using year-to-date 2022 calendar year average prices. Revenues were estimated using 2022 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, 2022

Operating Costs	2021 Mil \$	2022 Mil \$	% Chg vs 2020
Feedstock (corn)	\$30,908	\$38,191	23.6%
Enzymes, yeast and chemicals	\$1,141	\$1,231	7.9%
Denaturant	\$505	\$577	14.3%
Natural Gas, electricity, water	\$3,358	\$4,828	43.8%
Direct labor	\$571	\$667	16.8%
Maintenance & Repairs	\$477	\$540	13.2%
Transportation	\$138	\$156	13.2%
GS&A	\$569	\$644	13.2%
Total Operating Costs	\$37,666	\$46,833	24.3%
\$/Gallon	\$2.51	\$3.02	20.3%

This analysis estimates both the total production effect and the crop price (farm income) effects of ethanol production on agriculture. The impact of demand for corn to produce ethanol on farm income was 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.

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 \$360 million in 2022.

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 37.1 million short tons of DDGS, 4.6 billion pounds of DCO, 2.5 million tons of corn gluten feed and 500 thousand tons of corn gluten meal in 2022 with an aggregate market value of \$12.6 billion.

4. Construction

As pointed out earlier the ethanol industry operated at an 87 percent capacity utilization rate in 2022. Reflecting this, relatively little new construction activity was undertaken in 2022. The RFA estimates 114 million gallons of capacity under construction or expansion 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.

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>

Methodology

The impact of the ethanol industry on the American economy was estimated by applying expenditures by the 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, in the renewable fuels production sector, the ethanol industry buys corn from the agriculture sector, which in turn, buys inputs from other suppliers such as fertilizer and pesticide producers that also purchase products from a range of other industries. These are referred to as backward linkages. Grain production is linked through both forward and backward linkages to other economic sectors in each state's economy.

The household sector is linked to all sectors as it provides the labor and management resources. In turn, changes that affect incomes of the household sector typically have significant impacts compared to a change in the sales 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 current 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. As such the imbedded multipliers reflect the post-COVID economy.

The treatment of industry net earnings marks a departure from previous years. In the past, we treated industry earnings as an addition to the household sector since the income is paid to owners of

operating ethanol plants. This year we separated revenue 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 ethanol (other basic organic chemicals) and wet corn mill industries.

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 also continue to reflect the additional value of output of 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 expenditures for ethanol production.

As was the case in our previous studies, we 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.⁴ 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 2022 reported by EIA and U.S. Census Bureau trade databases.

Use of these multipliers provides a more precise estimate of the economic contribution of exports. The USDA 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, to avoid double counting impacts we only applied the margins for transportation and trade to the value of exports. This represents the post-production (or ex-plant) impacts from exports.

Results

Table 2 summarizes the impact of ethanol industry production and exports on the U.S. economy in 2022. The full impact of the spending for annual operations of ethanol production, co-product output, exports, and R&D is estimated to have contributed \$57 billion to the nation's GDP in 2022, nine percent more than 2021. The primary reason for the increased GDP impact can be traced to the combination of higher input prices that boosted operating expenditures and 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. Agriculture contributed an estimated \$31 billion to the U.S. economy while the manufacturing activity of ethanol production accounted for \$13.8 billion.

Employment

Jobs are created from the economic activity supported by ethanol production. Ethanol production is not a labor-intensive industry (accounting for fewer than 10,000 full time equivalent direct jobs nationwide)⁵. 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

⁴<https://www.ers.usda.gov/data-products/agricultural-trade-multipliers/>

⁵ The Census Bureau does not report employment in ethanol production. This analysis assumes the average ethanol plant employs approximately 50 full-time equivalent employees.

production, construction activity, agriculture, exports, and R&D are included, the ethanol industry supported nearly 421,700 jobs in all sectors of the economy 2022.

Table 2
Economic Impact of the Ethanol Industry: 2022

	2022 GDP	2022 Employment	2022 Income
	(Mil 2022\$)	FTEs	(Mil 2022\$)
Ethanol Production	\$13,817	91,995	\$6,986
Direct	\$2,383	11,635	\$1,017
Indirect	\$7,282	44,854	\$3,751
Induced	\$4,152	35,506	\$2,217
Agriculture	\$30,957	293,307	\$21,168
Direct	\$3,478	64,677	\$4,580
Indirect	\$15,857	141,542	\$9,985
Induced	\$11,621	87,088	\$6,603
Construction	\$258	2,493	\$187
Direct	\$92	1,210	\$91
Indirect	\$63	428	\$38
Induced	\$103	856	\$58
R&D	\$560	4,033	\$376
Direct	\$215	1,280	\$164
Indirect	\$139	1,054	\$94
Induced	\$207	1,699	\$117
Exports (Total)	\$11,430	29,849	\$6,058
Total Ethanol	\$57,022	421,678	\$34,774
Direct	\$6,168	78,802	\$5,853
Indirect	\$34,770	217,727	\$19,925
Induced	\$16,083	125,149	\$8,996

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.

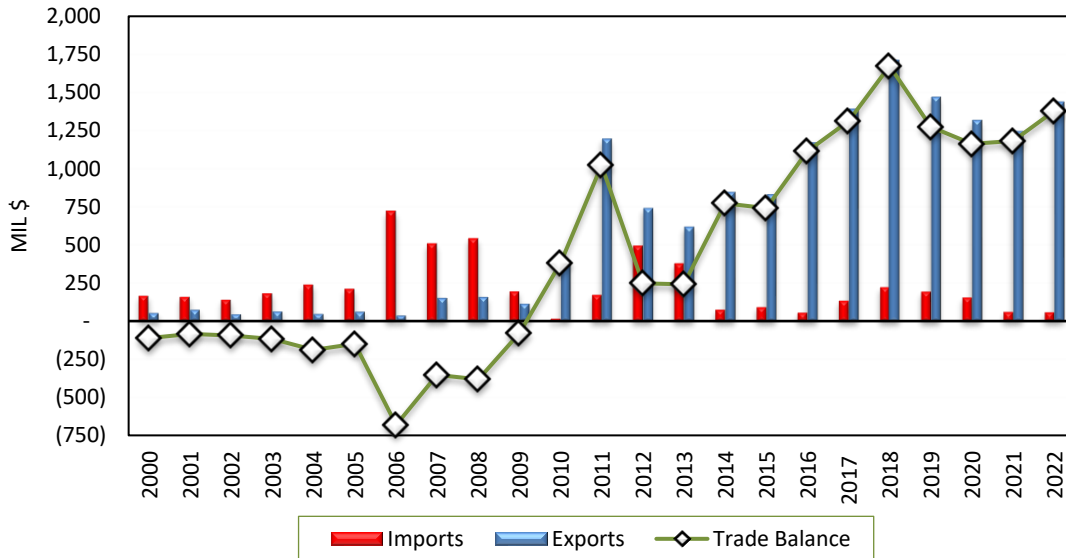
Income

Economic activity and associated jobs produce income for American households. The economic activities of the ethanol industry put \$34.8 billion into the pockets of Americans in 2022. 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

Ethanol exports recovered in 2022 posting the first year-over-year increase in four years. Three markets, Canada, South Korea and the Netherlands, accounted for more than half of U.S. ethanol exports in 2022. Exports rose to Canada, which accounts for more than a third of total exports, but shipments to India fell 40 percent. Ethanol exports to Brazil also declined during 2022 for the fourth straight year. The largest gains in exports to major markets were to the UK and the Netherlands which is a gateway to the EU. Exports of ethanol in 2022 increased 9.2 percent over 2021 levels to nearly 1.4 billion gallons with an export value of \$3.8 billion. Moreover, 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.

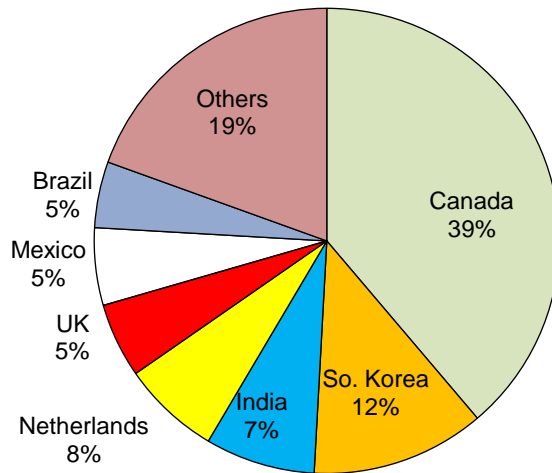
Figure 2
U.S. Ethanol Trade



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

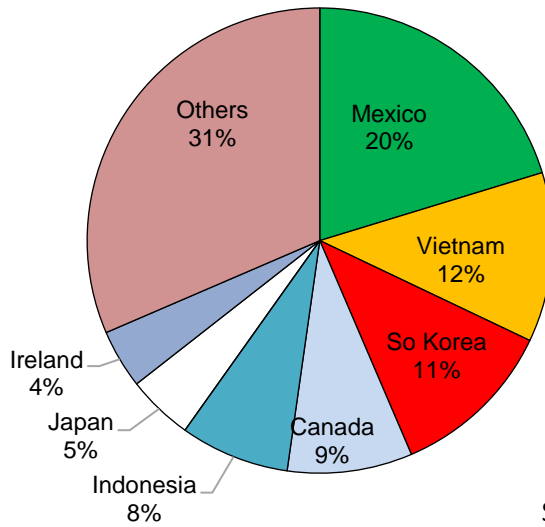
DDGS exports in 2022 totaled 11 million metric tons, 4.7 percent below year earlier levels. However, higher world prices for DDGS resulted in a 13.3 percent increase in export value. The most significant increases in DDGS exports among major markets were to Canada, South Korea, Colombia, Ireland and Japan. Seven countries account for two-thirds of U.S. DDGS exports (Figure 4).

Figure 3
U.S. Ethanol Exports, 2022
1,349 million gallons



Source: USA Trade Online

Figure 4
U.S DDGS Exports, 2022
11.0 Million Metric Tons



Source: USA Trade Online

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 updated USDA Trade Multipliers suggests that the \$7.4 billion of export value accounted for \$11.4 billion to GDP and supported nearly 30,000 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 75 percent of total U.S. ethanol exports, although the U.S. shipped ethanol to nearly 90 countries in 2022.

Tax revenue

The combination of GDP and household income supported by the ethanol industry contributed an estimated \$7.2 billion in tax revenue to the Federal Treasury in 2022. State and local governments also benefit from the economic activity supported by the ethanol industry, earning \$5.1 billion in 2022.

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 15.5 billion gallons of ethanol displaced nearly 530 million barrels of crude oil needed to produce gasoline in 2022. The value of the crude oil displaced by ethanol is estimated more than \$51 billion in 2022.⁶ Money that would have been spent on larger imports of crude oil stays in the

⁶ Ethanol directly competes with and displaces gasoline as a motor fuel. According to the EIA, one 42-gallon barrel of crude oil produced 19.4 gallons of gasoline in 2022. 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 19.4 gallons of gasoline, it takes 529 million barrels of crude to produce 10.2 billion gallons of gasoline, the amount displaced by ethanol. This oil was valued at the 2022 average composite acquisition cost of crude oil by refiners reported by EIA at \$96.84/bbl.

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

State Level Impacts of Ethanol Production

The ethanol industry has diversified geographically in recent years. RFA reports aggregate industry capacity of 17.9 billion gallons with 199 installed ethanol plants producing an estimated 15.5 billion gallons at year-end 2022. Each of these plants is a biorefinery that is an integral part of the other basic organic chemicals industry in the U.S. manufacturing sector. As such, the 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 other basic organic chemical manufacturing industry (of which ethanol is a part) 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 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, 2022

State	Capacity (Mil gal)	Plants	GDP (Mil \$)	Earnings (Mil \$)	Employment Jobs
IA	4,724	41	\$14,203	\$8,674	106,904
NE	2,280	24	\$6,912	\$4,179	52,736
IL	1,856	13	\$6,733	\$4,084	44,338
SD	1,442	16	\$4,087	\$2,464	29,430
IN	1,421	15	\$4,808	\$2,981	41,498
MN	1,414	19	\$4,636	\$2,909	33,108
OH	732	7	\$2,685	\$1,647	19,641
KS	602	12	\$2,080	\$1,213	14,460
WI	596	9	\$1,889	\$1,178	15,224
ND	555	6	\$1,766	\$1,000	11,134
TX	420	4	\$1,741	\$1,061	10,338
MI	382	5	\$1,150	\$732	10,520
MO	316	6	\$1,041	\$596	8,827
TN	232	3	\$757	\$454	5,519
CA	227	5	\$578	\$386	3,931
CO	143	4	\$404	\$258	2,912
GA	120	1	\$314	\$199	2,353
PA	120	1	\$355	\$216	2,376
Others	327	8	\$884	\$544	6,429
U.S.	17,909	199	\$57,022	\$34,774	421,678

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, other basic chemicals manufacturing. 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 2022. 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.