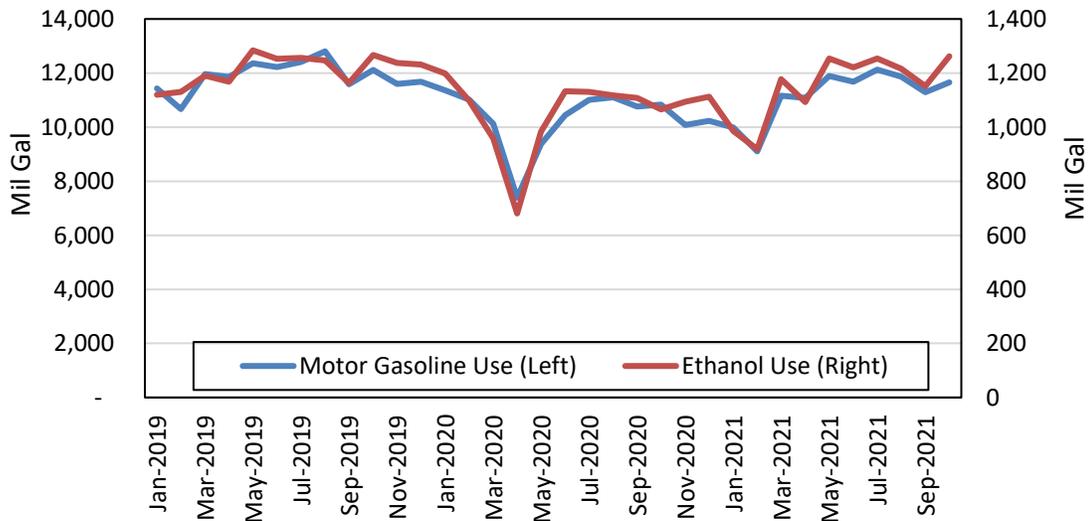


CONTRIBUTION OF THE ETHANOL INDUSTRY TO THE ECONOMY OF THE UNITED STATES IN 2021

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The U.S. ethanol industry recovered substantively in 2021 from the COVID-19 affected economy in 2020. Despite the development and spread of new COVID variants during 2021 the economy largely reopened, and consumers responded accordingly. The impact of the pandemic, particularly on the supply of goods and services and on prices, continued to overshadow most other issues facing the industry during the year. As the economy reopened people resumed driving and both gasoline and ethanol demand increased over 2020 levels. As illustrated in Figure 1, both motor gasoline and ethanol domestic use approached pre-COVID levels during the second half of the year.

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



Source: EIA

Ethanol producers responded to the recovery in demand by restoring idled capacity and increasing operating rates. At year's end, RFA reported there were 208 installed ethanol biorefineries with a capacity of nearly 17.7 billion gallons that produced 15 billion gallons in 2021. The ability to meet demand with existing capacity and questions about the stability of the economy restrained investment in new capacity.

The major factor that impacted the ethanol industry in 2021 was the sharp increase in feedstock – notably corn – prices and other input costs. Corn prices (No.2 Yellow, Central Illinois) averaged \$5.99 per bushel during 2021, 74 percent above 2020 levels despite increased production. Inflation in the overall economy reached 7 percent during the year, more than twice the rate experienced during the previous decade. This affected all other input costs. The upside of inflationary pressures in the economy was and that the prices of ethanol and principal co-products distillers dried grains (DDGS) and distiller's corn oil (DCO) also surged and outpaced the increase in total operating costs. Consequently, average industry average profitability for all of 2021 more than doubled compared to 2020 levels.

On the regulatory front, the major issues revolved around the status of EPA approval for year-round sales of E15 on a nationwide basis; implementation of RFS renewable fuel requirements at the statutory volume of 15 billion gallons; and the EPA's position on denying all pending small refinery exemption (SRE) petitions based on the 2020 decision of the Tenth Circuit Court in light of the 2021 Supreme Court ruling.

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 2021 in terms of employment, income, and Gross Domestic Product (GDP) directly and indirectly supported by the industry.

Expenditures by the Ethanol Industry in 2021

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 \$37.6 billion on raw materials, other inputs, and goods and services to produce ethanol during 2021, nearly 76 percent more than COVID depressed 2020 levels. The increase in production costs reflects the combination of a rebound in industry output and sharply higher prices for feedstocks (mostly corn) and other inputs. 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 2021.

The largest share of spending was for corn and other feedstocks used as raw material to make ethanol. The ethanol industry used 5.1 billion bushels of corn (and corn equivalent) on a gross basis in 2021, valued at \$30.8 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 about 90 percent of ethanol production costs.

¹ Expenditures for feedstock and energy were estimated using year-to-date 2021 calendar year average prices. Revenues were estimated using 2021 calendar year average prices for ethanol, distiller's grains, and distillers' corn oil. 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, 2021

Operating Costs	2020 Mil \$	2021 Mil \$	% Chg vs 2020
Feedstock (corn)	\$16,405	\$30,823	87.9%
Enzymes, yeast and chemicals	\$1,053	\$1,191	13.2%
Denaturant	\$213	\$549	157.4%
Natural Gas, electricity, water	\$2,050	\$3,164	54.3%
Direct labor	\$569	\$640	12.4%
Maintenance & Repairs	\$452	\$508	12.4%
Transportation	\$130	\$147	12.4%
GS&A	\$539	\$606	12.4%
Total Operating Costs	\$21,411	\$37,628	75.7%
\$/Gallon	\$1.57	\$2.54	

This analysis estimates both the total production effect and the crop price (farm income) effects of ethanol production on agriculture based on a structural model of U.S. agriculture maintained by the author. 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 is 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 sustainable fuels such as renewable propane and sustainable aviation fuel 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. The disruptions caused by COVID continued to exert a drag on R&D, however activity did pick up prompting a substantial increase in expenditures relative to 2020. Reflecting this we estimate that R&D outlays in the renewable fuels industry more than doubled to \$340 million in 2021.

3. Co-product value

Most ethanol is produced by dry mills that also produce valuable co-products in the form of DDGS and DCO.³ There is significant ongoing research directed at improving these co-products, notably DDGS, to increase inclusion rates in swine and poultry and enhancing suitability as a feed ingredient in markets such as aquaculture. The ethanol industry produced an estimated 35.3 million short tons of DDGS and 3.8 billion pounds of DCO in 2021 with an aggregate market value of \$9.4 billion.

Spending associated with ethanol production 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

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

³ DDGS and corn distillers 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>

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.

As in the past, we continue to treat industry earnings as an addition to the household sector since the income is paid to owners of operating ethanol plants. As a result, the impact of corporate earnings is estimated using multipliers for the household sector and incorporated into direct GDP.

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.

- 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. It is expressed in full-time equivalent jobs. Value added including labor income and employment represent the net economic benefits that accrue to the nation because of increased economic output.

There are three types of effects measured with a 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 and DCO) in the analysis. Since these are co-products the backward linkages for their production are accounted for in the expenditures for ethanol production. Consequently, the value of DDGS and DCO was treated as income and value added only, and we applied income multipliers to the employee compensation portion to avoid double counting.

As was the case in our previous studies, we incorporated 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 estimated the impact of ethanol and DDGS exports by applying USDA Agricultural Trade multipliers for output and employment to the estimated value of exports for 2021 reported by EIA and the USITC trade databases.

A major improvement in this year's analysis is the use of updated USDA Agricultural Trade Multipliers that have been expanded to include detail for ethanol and distiller's grains. Use of these multipliers

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

provides a more precise estimate of the economic contribution of exports than the broader other organic chemicals industry multipliers used previously. As before, 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 2021. The full impact of the spending for annual operations of ethanol production, co-product output, exports, and R&D is estimated to have contributed nearly \$52 billion to the nation's GDP in 2021, a 50 percent increase compared to 2020 and nearly 22 percent above pre-COVID 2019 levels. 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. The manufacturing activity of ethanol production alone contributed \$16.5 billion to the U.S. economy while agriculture accounted for \$24.3 billion.

Employment

Jobs are created from the economic activity supported by ethanol production. The ethanol production is not a labor-intensive industry (accounting for fewer than 9,000 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

⁵ The Census Bureau does not report employment in ethanol production. This analysis conservatively 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 more than 407,400 jobs in all sectors of the economy 2021.

Table 2
Economic Impact of the Ethanol Industry: 2021

	GDP (Mil 2021\$)	Jobs (FTEs)	Income (Mil 2021\$)
Ethanol Production	\$16,519	117,291	\$8,709
Direct	\$5,023	8,942	\$2,357
Indirect	\$5,645	38,245	\$3,009
Induced	\$5,850	70,104	\$3,343
Agriculture	\$24,340	258,585	\$13,993
Direct	\$5,553	62,888	\$2,854
Indirect	\$10,911	119,016	\$6,675
Induced	\$7,876	76,680	\$4,463
Construction/CAPEX	\$0	0	\$0
R&D Expenditures	\$495	4,543	\$342
Exports (Total)	\$10,712	26,998	\$5,677
Total Ethanol	\$52,065	407,416	\$28,721
Direct	\$10,768	73,193	\$5,355
Indirect	\$27,404	185,499	\$15,450
Induced	\$13,894	148,723	\$7,916

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, jobs supported by 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 a large number of sectors.

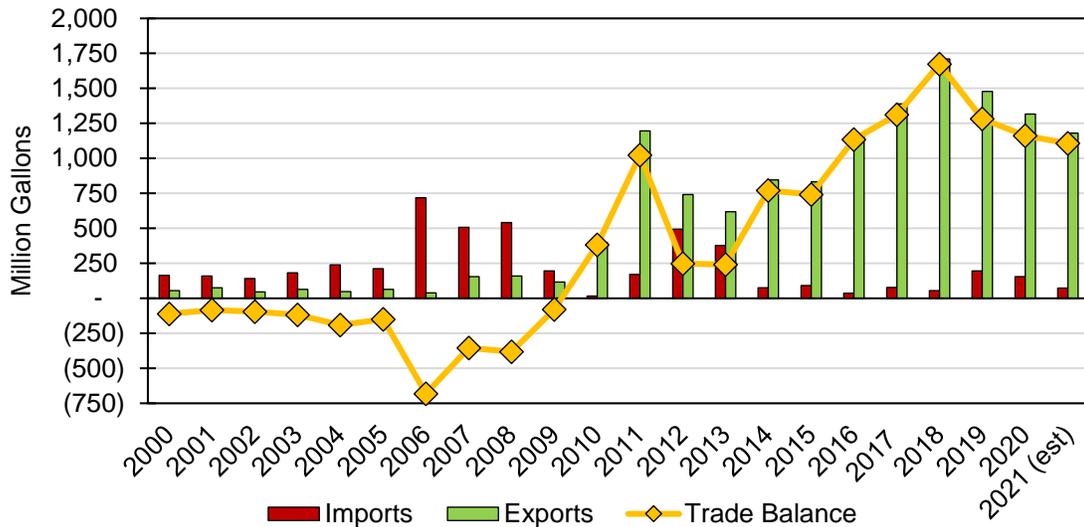
Income

Economic activity and associated jobs produce income for American households. The economic activities of the ethanol industry put nearly \$29 billion into the pockets of Americans in 2021. 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 declined throughout 2021 relative to 2020 as COVID continued to affect the economies and motor fuel use in importing countries and as a substantial tariff hindered exports to Brazil. Three markets, Canada, South Korea and India, accounted for more than half of U.S. ethanol exports in 2021. Exports rose to Canada, which accounts for nearly a third of total exports, but shipments to India fell roughly 20 percent. The only major export markets that grew significantly in 2021 were South Korea and China. Year-to-date exports of ethanol were 6 percent below 2020 levels through November and are projected to total about 1.2 billion gallons with an export value of \$2.5 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

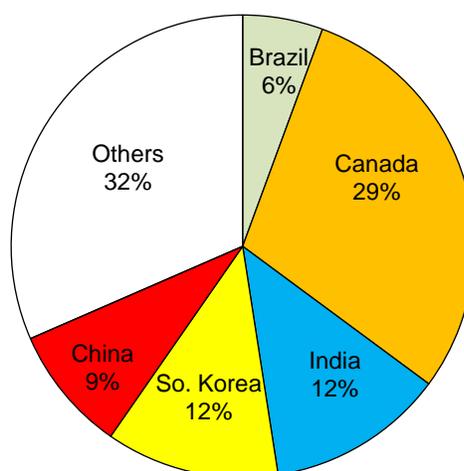


Source: Foreign Agricultural Service. Global Agricultural Trade System (GATS)

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 \$4.4 billion of export value added \$10.7 billion to GDP and supported 27,000 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, nine markets account for more than 75 percent of total U.S. ethanol exports, although the U.S. shipped ethanol to roughly 90 countries in 2021.

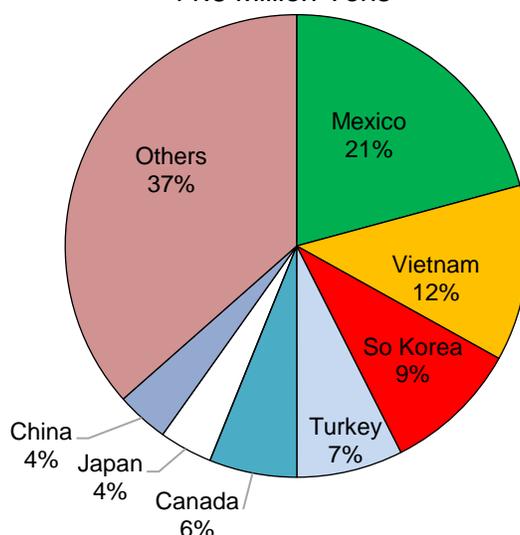
Figure 3
U.S. Ethanol Exports, Jan-Nov 2021
1,134 million gallons



Source: EIA

DDGS exports through November 2021 increased nearly 6 percent from year earlier levels and are projected to reach 12.8 million tons for all of 2021 valued at \$3 billion. Higher world prices for DDGS led to an increase of nearly 60 percent in the value of exports. Seven countries account for two-thirds of U.S. DDGS exports (Figure 4). Only two of these markets – South Korea and Japan – registered declines in imports from the U.S. while two other countries – Mexico and Canada – posted significant increases.

Figure 4
U.S DDGS Exports, Jan-Nov 2021
11.8 Million Tons



Source: USITC DataWeb

Tax revenue

The combination of GDP and household income supported by the ethanol industry contributed an estimated \$5.5 billion in tax revenue to the Federal Treasury in 2021. State and local governments also benefit from the economic activity supported by the ethanol industry, earning \$4.9 billion in 2021.

Crude oil displacement

Ethanol also 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, U.S. dependence on imported oil and refined products has dramatically declined since peaking in 2005, but the U.S. remains a significant importer of crude oil. The use of domestic biofuels (ethanol and biodiesel) continues to be a contributor to the nation's energy independence. The production of 15 billion gallons of ethanol displaced nearly 500 million barrels of crude oil needed to produce gasoline in 2021. The value of the crude oil displaced by ethanol is

estimated more than \$33 billion in 2021.⁶ Money that would have been spent on larger imports of crude oil stays in the 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 17.7 billion gallons with 208 installed ethanol plants producing 15 billion gallons at year-end 2021. 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, 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 on the basis of 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 for the Other Basic Organic Chemical Manufacturing industry to 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

⁶ Ethanol directly competes with and displaces gasoline as a motor fuel. According to the EIA, one 42-gallon barrel of crude oil produced 20 gallons of gasoline in 2021. 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 billion gallons of ethanol are the equivalent of about 10 billion gallons of gasoline. Since one barrel of crude produces 20 gallons of gasoline, it takes 497 million barrels of crude to produce 10 billion gallons of gasoline, the amount displaced by ethanol. This oil was valued at the 2021 average composite acquisition cost of crude oil by refiners reported by EIA at \$67/bbl.

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.

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, and does not reflect other supplying industries. Additionally, there are regional differences in feedstock costs, ethanol and DDGS prices, and other input costs that have not been explicitly considered. Relatively few states procure all of 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 California or Texas to the extent that the dollars spent for corn imported from other states represent income for farmers in supplying states and are not netted out of the analysis. Similarly, corporate and co-op income is generated by plants domiciled in a particular state and ownership varies from state-to-state.

Table 3
Contribution of Ethanol Production to Individual State Economies, 2021

State	Capacity (Mil Gal)	Plants	GDP (Mil \$)	Earnings (Mil \$)	Employment (Jobs)
IA	4,678	43	\$11,469	\$6,386	97,421
NE	2,351	26	\$5,013	\$2,779	47,636
IL	1,912	14	\$7,826	\$4,250	51,465
MN	1,371	19	\$4,142	\$2,331	32,247
IN	1,388	15	\$3,936	\$2,201	36,945
SD	1,253	16	\$3,671	\$2,023	25,772
OH	716	7	\$1,982	\$1,106	18,541
KS	602	14	\$3,390	\$1,812	18,288
WI	596	9	\$2,831	\$1,567	17,687
ND	547	6	\$2,069	\$1,097	11,915
TX	345	4	\$1,151	\$633	9,411
MI	350	5	\$787	\$454	8,525
MO	277	6	\$675	\$351	6,732
TN	232	3	\$699	\$378	5,575
CA	222	5	\$438	\$258	3,683
NY	165	2	\$255	\$134	1,783
CO	143	4	\$317	\$181	2,867
GA	120	1	\$247	\$139	2,382
PA	120	1	\$382	\$209	2,602
Others	267	8	\$784	\$434	5,939
U.S.	17,655	208	\$52,065	\$28,721	407,416

Conclusion

Despite the persistence of COVID-19, economic and regulatory challenges in 2021, 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. The importance of the ethanol industry to agriculture and rural economies is particularly notable. Growth and expansion of the ethanol industry through the application of new technologies and feedstocks 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.