The Economic Impact of the U.S. Industrial Bioeconomy

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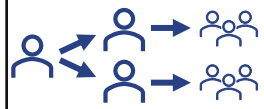
TECONOMY PARTNERS LLC

Study Objectives

- This jobs and economic impact study sets some definable and reasonable boundaries upon which to estimate the current size and impact of the **U.S. industrial bioeconomy**, thus establishing a baseline upon which to assess true progress in growing the industrial bioeconomy.
- While aiming to be inclusive, the approach is designed to focus on U.S. firms where all or a substantial majority of employment and operations are firmly within the boundaries established.
- This approach, by its very nature, yields a direct U.S. employment value that is robust, but is not driven by the inclusion of specific feedstock inputs. This is not an ethanol industry, biodiesel industry, or SAF-focused approach.
  - This allows measurement of the industrial bioeconomy to cross the boundaries between various traditional and advanced biofuels while also capturing the growing and increasingly complex arena of bioproducts.
- The specific objectives of this study are twofold.
  - First, to quantify the U.S. employment of non-biopharmaceutical component of the bioeconomy, focusing on key value-added sectors primarily within manufacturing, research, and technical services.
  - Second, to understand how the industrial bioeconomy impacts the broader U.S. economy through its purchase of raw materials (i.e., a variety of agricultural commodities) and other inputs and through additional economic multiplier effects of its employment, wages, and sales.

U.S. Industrial Bioeconomy Economic Impact Summary

	**53,302** Industrial Bioeconomy jobs in the U.S.	Includes over 43,600 manufacturing jobs and 5,950 research jobs.
	**643,992** Total supported U.S. jobs	Beyond the industry's direct 53,302 workers, the research, development, processing, and production activities of the industry support over **590,000 additional U.S. workers**, including more than **190,000 farming and agricultural commodity jobs** across the country.
	**12.08** U.S. Industrial Bioeconomy jobs multiplier	**Every direct industrial bioeconomy job generates and supports more than 11 additional U.S. jobs.**
	**$210.4 B** Total U.S. Economic Impact	The U.S. industrial bioeconomy's operations (including university and national laboratory R&D) **generate and support more than $210 billion on an annual basis in U.S. output.**
	**$133,600** Average industry employee compensation	Across the breadth of the industry, workers, on average, receive $133,600 in total compensation (including wages, salaries, and benefits).

Source: TEConomy data development and analysis using the IMPLAN economic impact model.

What Drives These Impacts?

Relative to other industrial sectors, the extended domestic supply chain of the U.S. industrial bioeconomy generates **outsized secondary economic benefits**. This is especially true of domestic employment, where each direct job supports 11.08 additional indirect and induced jobs (total employment multiplier of 12.08). For comparison, the employment multiplier for the sector that includes solar photovoltaics is 6.50 and the multiplier for the sector that includes wind turbines is 3.73.

- The U.S. industrial bioeconomy relies almost exclusively on local suppliers, often within close proximity to manufacturing facilities, for core feedstocks and commodity inputs.
  - Industrial heartland combines significant agricultural production with feedstock processing capacity to drive ethanol and biodiesel production. Southeast timber supplies are a key feedstock for other industrial bioproducts.
- The U.S. industrial bioeconomy depends on labor, biomass, other materials, goods, and services that cannot be economically sourced overseas.
  - Imports are primarily limited to some specialty production equipment. Much of current actual production relies on availability of biomass as a bulk commodity input or taps into waste streams generated by U.S. population centers.
- The U.S. industrial bioeconomy is a natural outgrowth of U.S. leadership in the sciences.
  - Significant levels of research performed and funded by U.S. national laboratories and leading U.S. academic institutions provides the scientific underpinning for continued growth and development of the U.S. industrial bioeconomy.
- The U.S. industrial bioeconomy has remained a consistent source of domestic jobs and manufacturing strength without the need for any special strategies to bring jobs back from overseas.
  - The significant jobs multiplier demonstrates this key facet of the U.S. industrial bioeconomy. The U.S. industry provides jobs, economic activity, and sustainability throughout the U.S.
  - A considerable competitive and policy advantage of these industrial bioeconomy jobs is their tie to U.S. soil, both literally and figuratively—these jobs are here and stay in the U.S.
  - U.S. industrial bioeconomy outpaces both U.S. solar PV and U.S. wind turbine production in both the number of U.S. jobs and contribution to U.S. GDP.

Developing and Assessing the Economic Impact of the U.S. Industrial Bioeconomy

Study Overview

- This jobs and economic impact analysis attempts to set some definable boundaries to focus on those firms currently operating **primarily** within (or self-specifying as being involved in) the U.S. industrial bioeconomy.
- The jobs analysis, seeks to be comprehensive by moving beyond the existing U.S. North American Industrial Classification System (NAICS) which poorly defines and handles the industrial bioeconomy.
- **The analysis is conservative in its direct U.S. employment estimation compared to other studies, in part by not including the agricultural/crop production economy (e.g., farm employment) as direct industry employment.**
  - **However, the significant role of agriculture is ultimately captured in the indirect effects of the economic impact analysis.**
- To develop this assessment, a firm and establishment database of U.S. operations was created using input data from a variety of subscription databases.

Key considerations when defining and developing the industrial bioeconomy's industry database and employment estimates

- There was a purposeful "by design" effort to eliminate biopharmaceutical firms and related biomanufacturing for the analysis. While significant and important to the U.S. for both economic and healthcare reasons, the **focus of this effort is on U.S. firms creating "industrial" bioproducts and outputs, including biofuels.**
- Other key considerations include:
  - Firms performing "bioprocessing" efforts leading to direct food or beverage products are also specifically excluded. This is to avoid overextending the definitional boundaries since bakeries and breweries are in part capturing the results of the "biological processes" of yeast. Including employment from these sectors would overwhelm and obfuscate the true picture of the expanding and emerging U.S. industrial bioeconomy. However, firms working to develop and improve these yeasts or identify as providing "ingredients" or inputs to the food and beverage industry through biomanufacturing-related processes are included on a case-by-base basis.
  - While firms producing wood (or other cellulose-based) fuel pellets are included within the Traditional Biofuels sector, other lumber, wood products, and paper production firms are not included.
- Decisions were made on a case-by-case basis regarding the inclusion or exclusion of firms or establishments that meet the industrial bioeconomy definition, but also produce items that, on their own, would be excluded from the analysis. Web-based research and other corporate information was used to determine whether most of these firms' output was directly connected to the defined industry.

Defining the U.S. Industrial Bioeconomy – Six Sectors

Sector	Description	Key Products or Components	Example Companies (U.S.-Based Operations)
Industrially Processed Biofeedstocks	This sector captures operations engaged in transforming raw biomass into a usable bio-feedstock. Many of the establishments in this sector, are specific processing sites of major "household" name multinational companies.	○ starches, crystalline and liquid glucose, dextrose ○ other bioproduct inputs or chemical components from wet corn milling ○ biofuel/bioproduct inputs or chemicals from soybean and other oilseed processing ○ algae production	ADM, Bunge, Cargill, Primient (formerly Tate & Lyle's Primary Products business)
Traditional Biofuels	This sector captures traditional (or 1st Generation) biofuels of all types, with significant employment and impacts coming from ethanol and biodiesel.	○ processed liquid biofuels (e.g., corn-based ethanol, soybean-based biodiesel, waste oil/grease-based biodiesel) ○ processed solid biofuels (e.g., wood pellets) ○ processed gas biofuels (e.g., captured landfill biogas)	POET, ADM, Green Plains, Enviva, Quad County CP, Marquis Energy, Valero Renewable Fuels Company, Atascocita Landfill (WM)
Industrial Bioproducts	This sector captures firms engaged in producing select bioproducts using direct biofeedstocks or component chemicals obtained from biofeedstocks through one of the biomass conversion approaches. Also included in this sector are yeasts and enzymes used in biorefineries.	○ biopolymers, bioplastics, and other biomaterials ○ biosolvents, bioadhesives, biocoatings, biolubricants ○ other biochemicals/bio-derived chemicals ○ biological fertilizers ○ microbes, enzymes, and biocatalysts	Novozymes/Novonesis, IFF-Danisco, ADM, Natureworks, Enzyme Solutions, Enzyme Development Corporation (EDC), Conagen, Alto Ingredients, Trillium Renewable Chemicals, Danimer Scientific, Kula Bio, Alta Ingredients

Defining the U.S. Industrial Bioeconomy – Six Sectors

Sector	Description	Key Products or Components	Example Companies (U.S. Operations)
Advanced Biofuels	This sector captures firm engaged in the development and/or production of biofuels that are produced from feedstocks other than food crops (e.g., crop waste, other cellulosic materials, plant oils or algal oils).	○ advanced liquid biofuels (e.g., 2nd-4th generation ethanol, renewable diesel, SAF, green/renewable methanol) ○ advanced gas biofuels (e.g., biomethane)	Aemetis, LanzaJet, GEVO, Oberon Fuels, Fulcrum BioEnergy, SkyNRG Pacific Northwest (PNW), Montana Renewables
Production and Processing Equipment and Development Services	This sector captures firms that provide production and processing equipment to firms operating in the above four categories. Firms that also provide their equipment to non-biofuel/bioproduct will be included if it can be determined that a significant share of their annual production is in direct support of the biofuel/bioproduct industry.	○ biomass handling and processing equipment ○ fermentation tanks, digesters, bioreactors, etc. ○ specific instrumentation companies ○ specific software companies ○ specific process design and engineering services companies ○ Industry-related biotech firms	LanzaTech, 2G Energy, Applied Chemical Technology, Inc., Wessels Company, G & F Manufacturing Co., Inc., Gulf Coast Alloy Welding, Inc., Frontline BioEnergy, LLC, Velocys
University and National Lab Research & Development	Using author information extracted from research publications and research awards a conservative estimate of the number of university and national laboratory researchers (principal investigators) engaged in biofuel, industrial bioproduct, and related research are captured in this sector to recognize and at least partially account for the important work and economic impacts of these researchers within each of their states. To ensure a conservative estimate and to recognize significant research activities, faculty member/researchers need to have five or more publications over the recent 2020-2022 period to be included.		Iowa State University, Michigan State University, North Carolina State University, University of Tennessee – Knoxville, University of Wisconsin – Madison, Argonne National Laboratory, Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory, Sandia National Laboratory

Overview of Data Development Methodology

- U.S. firms and establishments were identified using a wide variety of sources and industry lists.
- To develop this assessment, a firm and establishment database of U.S. operations was created using data from a variety of subscription corporate databases (e.g., Dun & Bradstreet).
- Initial employment for these establishments was captured through Dun & Bradstreet data. Additional information from other sources including Data Axle, Pitchbook, LinkedIn, and SEC filings as well as web-based research was then used to corroborate, update, and correct U.S. employment numbers for each record.
- Since the finalized database was developed after January 1, the employment data are referred to as 2023.
- Establishments were then further classified into industry sectors and modeling sectors as required.

U.S. Industrial Bioeconomy – Direct Employment

- U.S. industrial bioeconomy direct employment reaches 53,302 jobs.
- This employment level includes over 43,600 manufacturing jobs and 5,950 research jobs (including focused industry, university, and national laboratory research).
  - Approximately 54% of the employment (over 29,000 jobs) falls into a current U.S. industry classification within the Chemicals sector.
  - Approximately 3% of the employment (nearly 1,800 jobs) is classified as "natural gas distribution" – as current U.S. NAICS classification include renewable natural gas captured at landfills and processed for direct inclusion into the U.S. natural gas pipeline infrastructure as part of this sector.
- The distribution of industrial bioeconomy employment **touches every U.S. state**, with 17 states having 1,000+ industrial bioeconomy jobs.

Top 30 U.S. Industrial Bioeconomy Occupations – Direct Employment

The U.S. industrial bioeconomy provides a strong mix of scientific and production jobs providing varied employment opportunities across the U.S.

Occupation	# of Industry Jobs	Occupation	# of Industry Jobs
Chemical Equipment Operators and Tenders	4,663	Heavy and Tractor-Trailer Truck Drivers	774
First-Line Supervisors of Production Workers	2,247	Non-Technical Sales Representatives	774
Packaging and Filling Machine Operators	1,919	Shipping, Receiving, and Inventory Clerks	737
Industrial Machinery Mechanics	1,652	Miscellaneous Assemblers and Fabricators	723
Freight, Stock, and Material Movers, Hand	1,592	Batchmakers (Processing)	719
Mixing and Blending Machine Operators	1,373	Crushing and Grinding Machine Operators	677
Chemical Plant and System Operators	1,202	Mechanical Engineers	643
General and Operations Managers	1,191	Chemical Engineers	642
Maintenance and Repair Workers, General	1,170	Separating, Filtering, and Still Machine Operators	604
Inspectors, Testers, Samplers, and Weighers	1,078	Office Clerks, General	591
Industrial Engineers	1,004	Customer Service Representatives	553
Chemists	970	Production Workers, All Other	550
Industrial Truck and Tractor Operators	894	Accountants and Auditors	502
Chemical Technicians	893	Biochemists and Biophysicists	488
Industrial Production Managers	861	Secretaries and Administrative Assistants	456

Source: TEConomy data development and analysis using Lightcast NAICS-based occupational estimations (based upon US Bureau of Labor Statistics data).

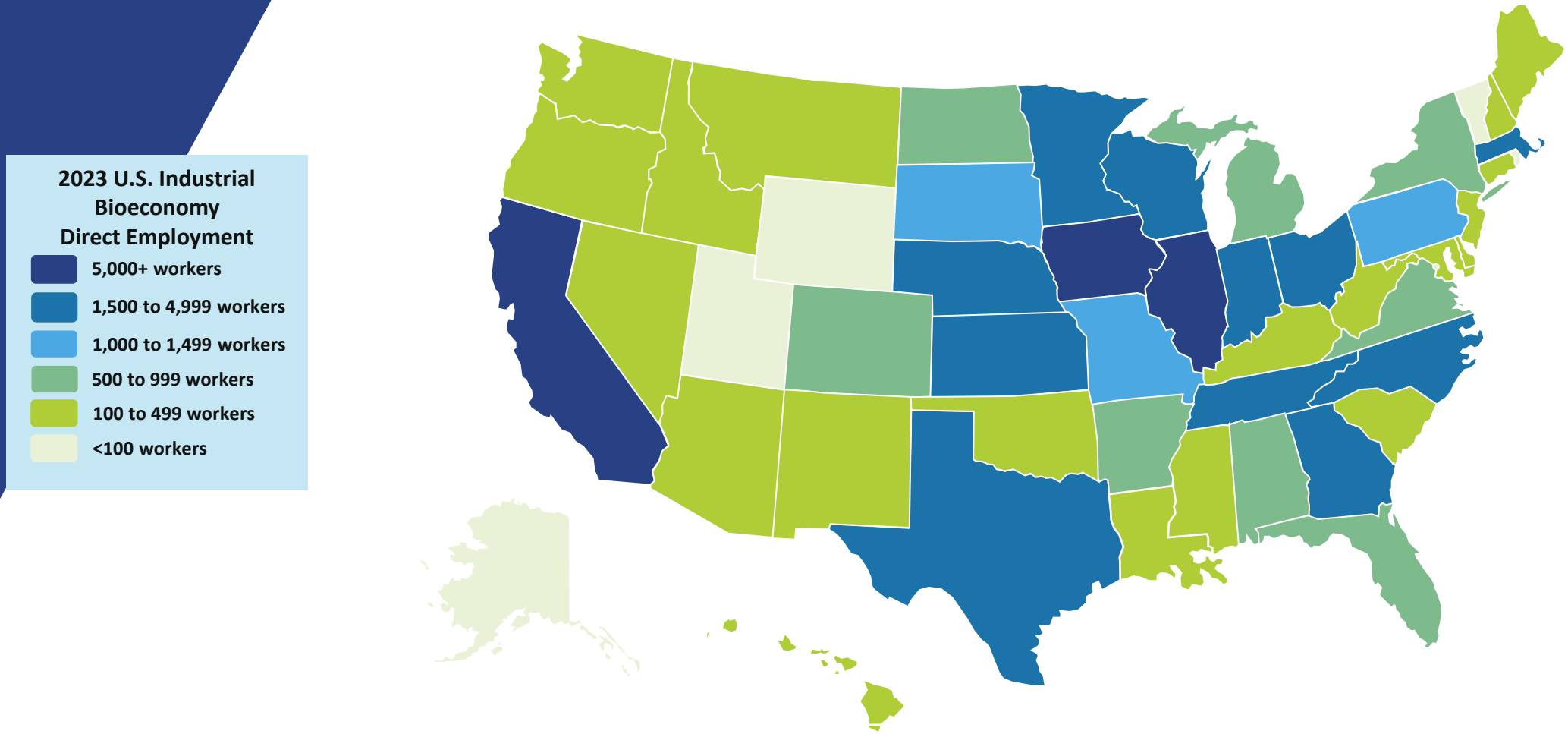
Top 10 States by Direct Employment in U.S. Industrial Bioeconomy

- Geographic distribution of direct employment driven primarily by feedstock processing and traditional biofuel locations
- Subsectors and orientation to the industry leads to a wide variety of states with important economic involvement in the U.S. industry

State	Direct Industry Employment
California	6,204
Illinois	6,102
Iowa	5,771
Nebraska	3,114
Georgia	3,004
Minnesota	2,006
Texas	1,916
Massachusetts	1,740
North Carolina	1,707
Ohio	1,673

Source: TEConomy database development.

Geographic Distribution of the Industrial Bioeconomy – Direct Employment



Traditional biofuels are currently the largest sector

- Use of first-generation feedstocks leads to significant ag-heartland presence within traditional biofuels.
- However, important distinctions emerge when examining traditional biofuel subsectors.

State	Direct Industry Sector Employment
Traditional Biofuels	**18,157**
Iowa	3,384
Nebraska	1,496
South Dakota	1,178
Texas	1,086
Minnesota	948

Source: TEConomy database development.

Iowa is a significant player in both ethanol and biodiesel; Renewable natural gas currently driven by population and presence of landfills/dairies

State	Subsector Employment
Trad. Biofuels - Ethanol	**11,395**
Iowa	2,688
Nebraska	1,452
South Dakota	1,170
Minnesota	892
Indiana	705

State	Subsector Employment
Trad. Biofuels - Biodiesel	**2,709**
Iowa	637
Texas	357
Missouri	245
California	179
Kansas	137

State	Subsector Employment
Trad. Biofuels – Wood Pellets	**2,597**
North Carolina	393
Georgia	228
Virginia	191
Maryland	160
Wisconsin	136

State	Subsector Employment
Trad. Biofuels – Renewable Natural Gas	**1,456**
California	464
Texas	406
Massachusetts	150
Pennsylvania	70
Michigan	56

Source: TEConomy database development.

Industrial bioproducts are the second largest sector; Emerging advanced biofuels employment driven by operational status and prior refining involvement

- Industrial bioproducts show the most significant geographic diversity among the sectors.
- Advanced biofuels of all types are in development, in pilot scale operations, and getting to full scale. Path and current size of operation currently most dependent on whether existing/former refining capacity is being modified for use.

State	Direct Industry Sector Employment
Industrial Bioproducts	**13,853**
California	2,049
Georgia	1,421
Illinois	1,271
North Carolina	823
Massachusetts	807

State	Direct Industry Sector Employment
Advanced Biofuels	**2,364**
California	1,135
Montana	250
North Dakota	116
Louisiana	115
Nevada	99

Source: TEConomy database development.

Processed biofeedstocks primarily based around heartland states, and corn and soybean production

- Leading states for producing processed corn and soybean biofeedstocks again show heartland orientation due to size and history.
- Other processed feedstocks have more diverse footprint reflecting other industrial bioeconomy products (e.g., wood pellet feedstock primarily drawn from southeastern U.S. forests).

State	Direct Industry Sector Employment
Industrially Processed Biofeedstocks	**9,499**
Illinois	3,487
Iowa	1,697
Nebraska	1,080
Indiana	641
Minnesota	408

Source: TEConomy database development.

Specific industry-related equipment and services show geographic breadth and diversity

- Sector includes biotech/R&D services (leading to significant presence in California and Massachusetts) and specific industry-related equipment where the dominant market for the company appears to be the industrial bioeconomy.
- Large, and important suppliers to the industry, while not captured in the direct industry database, are ultimately captured in the estimated indirect employment impacts.

State	Direct Industry Sector Employment
Production/Processing Equipment and Development Services	**8,177**
California	1,954
Massachusetts	719
Tennessee	565
Pennsylvania	464
Minnesota	450

Source: TEConomy database development.

Important contributions to industry growth and technological development comes from nation's universities and national laboratories

- California's top ranking reflects both universities and national laboratories involved in significant industrial bioeconomy research.
- Other states with key national laboratories also show significant numbers of researchers
  - Including Illinois, Colorado, Tennessee and often with strong university collaborations.
- Key federal funding leads to important research in other states
  - For example, the DoE funded Great Lakes Bioenergy Research Center (GLBRC) with researcher in Wisconsin and Michigan)

State	Direct Industry Sector Employment
University and National Laboratory Researchers	**1,252**
California	167
Illinois	105
Colorado	100
Michigan	82
Tennessee	81
Wisconsin	78
Washington	76
Georgia	64
Texas	46
Florida	35

Source: Based upon TEConomy analysis of research publications captured within the Clarivate Analytics Web of Science database published in the 2020-2022 timeframe. Data only includes researcher with five or more publications in this timeframe. Detailed examinations to ensure location and to eliminate double-counting of researchers with joint university and national laboratory appointments.

Overview of Input-Output Analysis

Input-output analysis models the interrelationships and financial transactions between economic sectors. Input-output multipliers are based on the flow of commodities between industries, consumers and institutions in a state or regional economy. This analysis used state and national input-output models developed by IMPLAN.

The IMPLAN model is the most widely used model in the nation and is based on the U.S. Bureau of Economic Analysis (BEA) national accounts data, supplemented with state level employment data from the U.S. Bureau of Labor Statistics (BLS) and other economic data from the U.S. Bureau of the Census. The analysis calculates three types of impacts:

- Direct Impacts – the specific impact of the direct employment and expenditures of the biofuel and industrial bioproducts firms within the U.S.
- Indirect Impacts – the impact of suppliers (both inputs and production equipment) to firms within the industry.
- Induced Impacts – the additional economic impact of the spending of employees and supplier employees within the analysis region.
- Total Impact = the sum of the three above impact categories.

In effect, the input-output analysis models the "ripple effect" (also known as the multiplier effect) that originates from industry employment and associated expenditures in the state and national economies. Multipliers are interpreted as "for every 1 job or $1 in direct impacts, a total of X jobs or $#.## are generated and supported (including the direct impact).

The IMPLAN input-output model is used to derive estimates for five categories of impacts:

- Employment is the total number of jobs created and includes the direct employment at industry operations.
- Labor Income is the total amount of income, including salaries, wages and benefits, received by employees and others in the related supply-chain.
- Value-Added. Contribution to state or national GDP.
- Output (also known as production, sales, or business volume) is the total value of the goods and services produced in the economy.
- Government Revenues includes estimated revenues generated for local, state, and federal governments through the economic activity measured.

Modification to Key Production Function in IMPLAN Models

A key component of the underlying data within the U.S. and state IMPLAN models are the production functions for each IMPLAN sector – specifically, how much does each sector buy from each of the other sectors represented in the economy and what share of the total value do each of these purchases account for. These production functions are based upon U.S. Bureau of Economic Analysis (BEA) 2012 national benchmark input-output data, the most recently available full U.S. input-output dataset. For the industrial bioeconomy, which in many respects has emerged over the last two decades, the production functions built from these data are significantly out-of-date.

This issue is further exacerbated as ethyl alcohol manufacturing (ethanol) has its own industry code (NAICS 325193), while other industrial bioeconomy products, including biodiesel production, are captured as a portion of the all other basic organic chemical manufacturing industry (NAICS 325199). Furthermore, within the BEA's "current" input-output structure these two industries are combined with an additional NAICS code into a broader other basic organic chemical manufacturing sector (NAICS 32519). Through this industrial aggregation, the base production functions for ethanol, biodiesel, enzymes, and other industrial bioeconomy products are considered the same as a wide variety of miscellaneous petroleum-based organic chemicals that are also included within the sector.

To improve the overall estimations of the impacts of the industrial bioeconomy, the production function for this other basic organic chemical manufacturing sector was modified within the IMPLAN models to more appropriately reflect the inputs requirements to produce the combination of ethanol, biodiesel, and other industrial bioproducts. Data and guidance for this modification came from research performed by/for the Renewable Fuels Association, Clean Fuels Alliance America, and other web-based resources.

Economic Impacts of U.S. Industrial Bioeconomy, 2023

Impact Type	Employment	$ in Millions					
		Labor Income	Value Added	Output	Local/County Tax Revenue	State Tax Revenue	Federal Tax Revenue
Direct	53,302	$7,121.8	$14,938.7	$66,265.4	$527.8	$687.4	$1,415.3
Indirect	357,911	$27,025.8	$41,230.8	$96,798.1	($959.2)	($19.0)	$6,025.1
Induced	232,780	$15,271.1	$26,872.3	$47,341.4	$1,250.9	$1,472.2	$3,015.0
Total Impacts	643,992	$49,418.7	$83,041.8	$210,404.9	$819.4	$2,140.6	$10,455.3
Multiplier	12.08	6.94	5.56	3.18			

Source: TEConomy database development and economic analysis using IMPLAN U.S. economic impact model. Note per IMPLAN: negative indirect tax revenues for local/county and state primarily reflect instances where state and local subsidies to agricultural commodity suppliers exceed the actual taxes paid. This also occurs at the federal level, but other corporate indirect (supplier) taxes exceed these subsidies by a wide margin.

Key takeaways from economic impact assessment

- This direct employment of 53,302 jobs leads to a conservative U.S. sales (output) estimate of **$66.3 billion** for 2023.
- The research, development, processing and production activities of the industry leads to the need for an additional 357,911 supplier jobs (including agricultural production) and more than **$96.8 billion** in U.S. sales.
- Including induced impacts (direct and indirect workers spending their wages) the U.S. industrial bioeconomy generates and supports nearly 644,000 U.S. workers (employment multiplier of 12.08) and total output of **$210.4 billion** (output multiplier of 3.18).
- The U.S. industrial bioeconomy, with its indirect and induced impacts, will generate an estimated **$13.4 billion in local, state, and federal tax in 2023**.

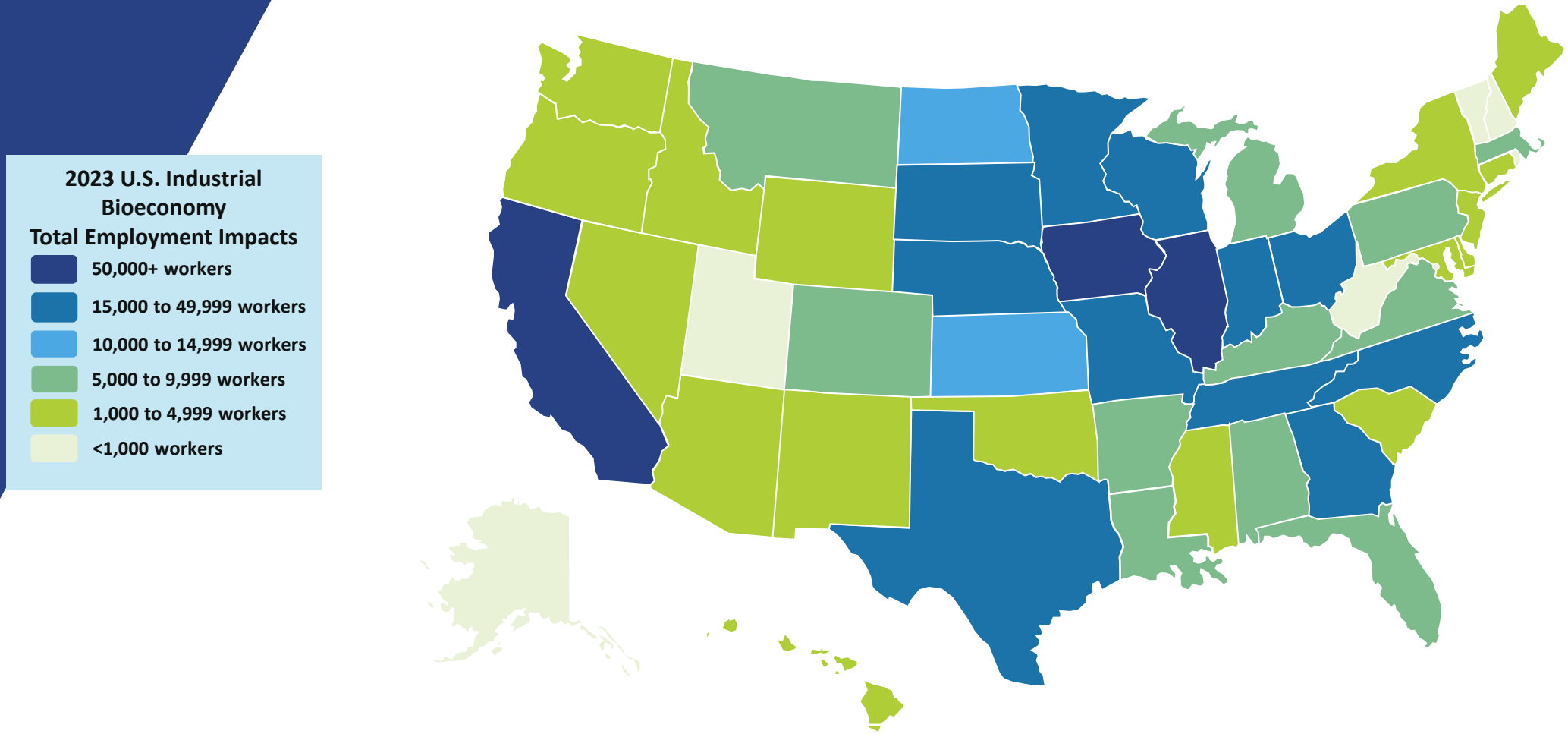
Top 10 States by Total Employment Impacts

- Illinois, while not the largest state within any single industrial bioeconomy sector, has significant presence across almost all, leading to largest single-state employment impact.
- Due to company mix and agricultural supplier role to other Midwest states, **Ohio has the largest employment multiplier** among the top 10 at 19.11.

State	Direct Employment	Total Employment	Employment Multiplier
Illinois	6,102	88,597	14.52
Iowa	5,771	66,092	11.45
California	6,204	62,972	10.15
Nebraska	3,114	39,597	12.72
Ohio	1,673	31,975	**19.11**
Texas	1,916	30,417	15.88
Georgia	3,004	26,977	8.98
Minnesota	2,006	26,904	13.41
Indiana	1,543	26,678	17.29
Wisconsin	1,621	21,141	13.04

Source: TEConomy database development and economic analysis using IMPLAN economic impact model for each state and the U.S. State impacts also include estimates on the in-state impacts generated from interstate commerce and supplier activities.

Geographic Distribution of U.S. Industrial Bioeconomy – Total Employment Impacts



Top 10 States by Indirect (Supplier) Employment Impacts

- Illinois and Iowa continue their significant roles, with substantial employment supporting their states and the overall U.S. industrial bioeconomy through a significant combination of agricultural production, processing, and logistics.
- Indiana breaks into the Top 10 Supplier states with more than 15,500 supplier jobs.

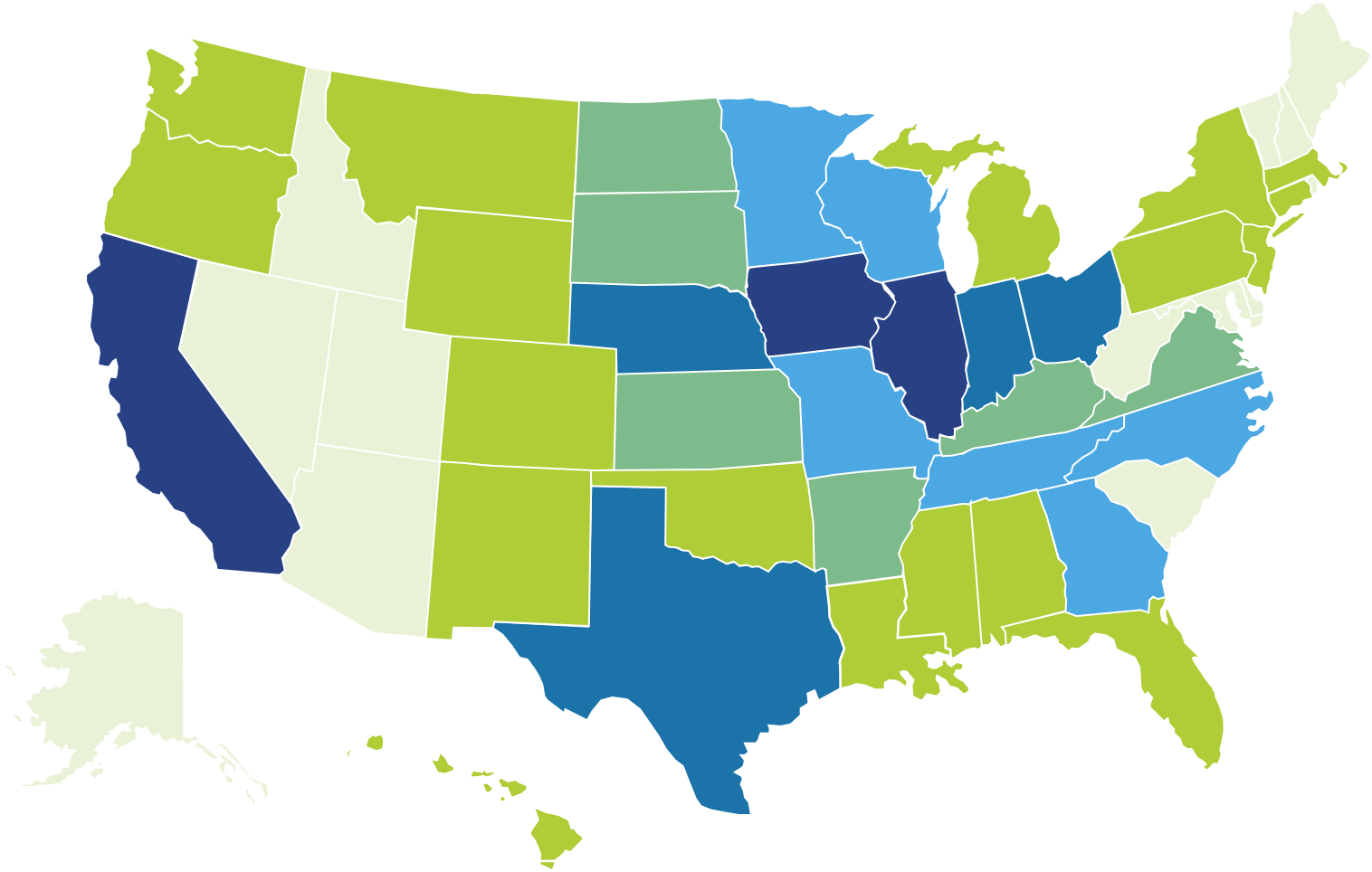
State	Indirect (Supplier) Employment
Illinois	47,445
Iowa	39,834
California	30,774
Nebraska	20,546
Ohio	20,113
Texas	17,378
Indiana	15,510
Minnesota	14,047
Georgia	13,843
Wisconsin	12,394

Source: TEConomy database development and economic analysis using IMPLAN economic impact model for each state and the U.S. State impacts also include estimates on the in-state impacts generated from interstate commerce and supplier activities.

Geographic Distribution of U.S. Industrial Bioeconomy – Indirect (Supplier) Employment Impacts

2023 U.S. Industrial Bioeconomy Indirect (Supplier) Employment Impacts

- 30,000+ workers
- 15,000 to 29,999 workers
- 10,000 to 14,999 workers
- 5,000 to 9,999 workers
- 1,000 to 4,999 workers
- <1,000 workers



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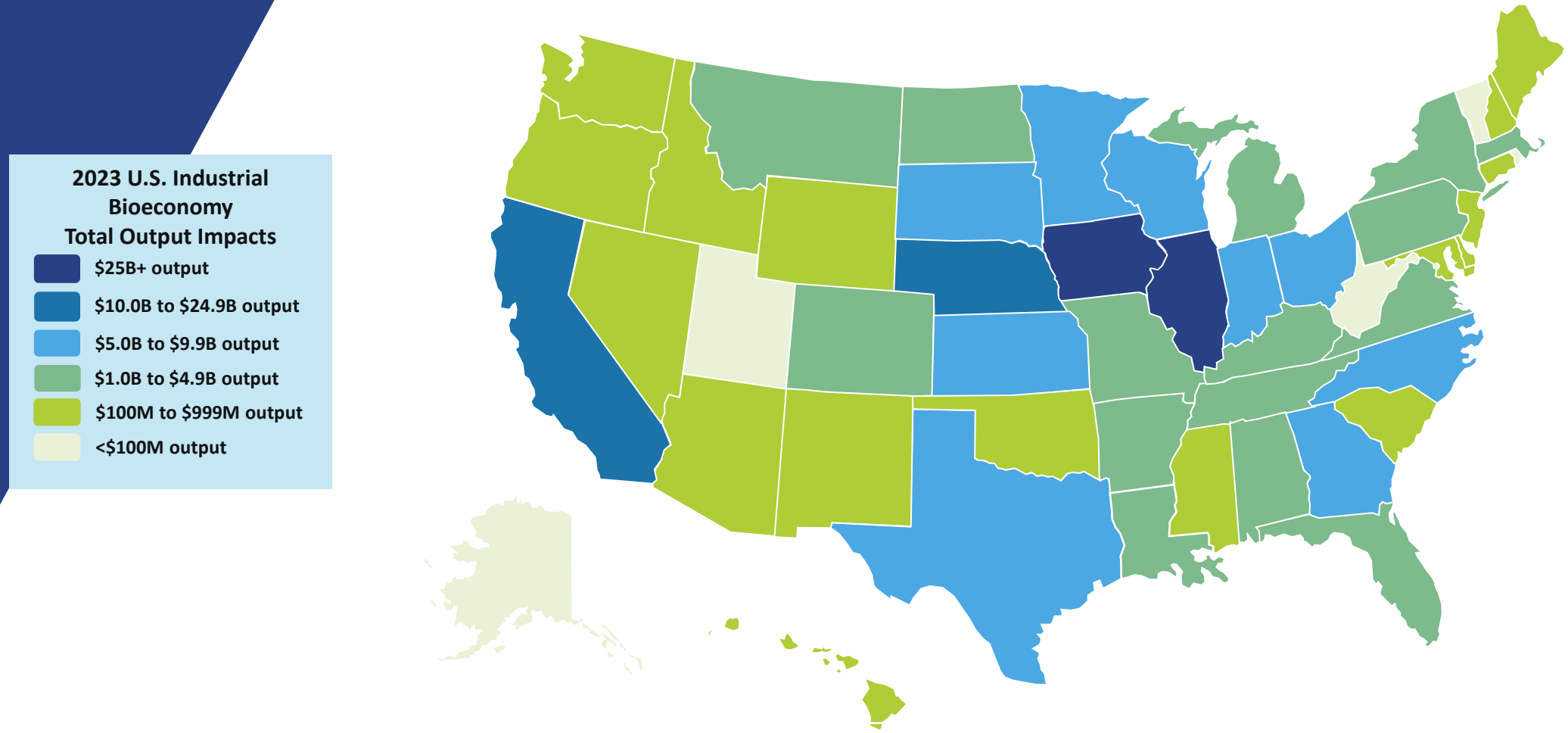
Top 10 States by Total Output (Economic) Impacts

- Through the IMPLAN model employment levels generate the economic impact estimates.
- The overall state level distribution of total output impacts is similar, though not exactly duplicative of state level employment impacts.
- South Dakota's role in ethanol production brings it into the Top 10 states for Total Economic Impact.

State	Direct Output ($M)	Total Output ($M)	Output Multiplier
Illinois	$9,199.8	$31,966.2	3.47
Iowa	$8,485.4	$26,630.0	3.14
California	$6,378.1	$21,551.3	3.38
Nebraska	$5,739.1	$16,751.7	2.92
Minnesota	$2,791.7	$9,476.2	3.39
Indiana	$3,086.8	$9,266.4	3.00
Ohio	$2,839.6	$9,167.5	3.23
Georgia	$3,196.0	$8,544.6	2.67
Texas	$2,088.6	$7,610.1	3.64
South Dakota	$1,874.7	$6,770.9	3.61

Source: TEConomy database development and economic analysis using IMPLAN economic impact model for each state and the U.S. State impacts also include estimates on the in-state impacts generated from interstate commerce and supplier activities.

Geographic Distribution of U.S. Industrial Bioeconomy – Total Output (Economic) Impacts



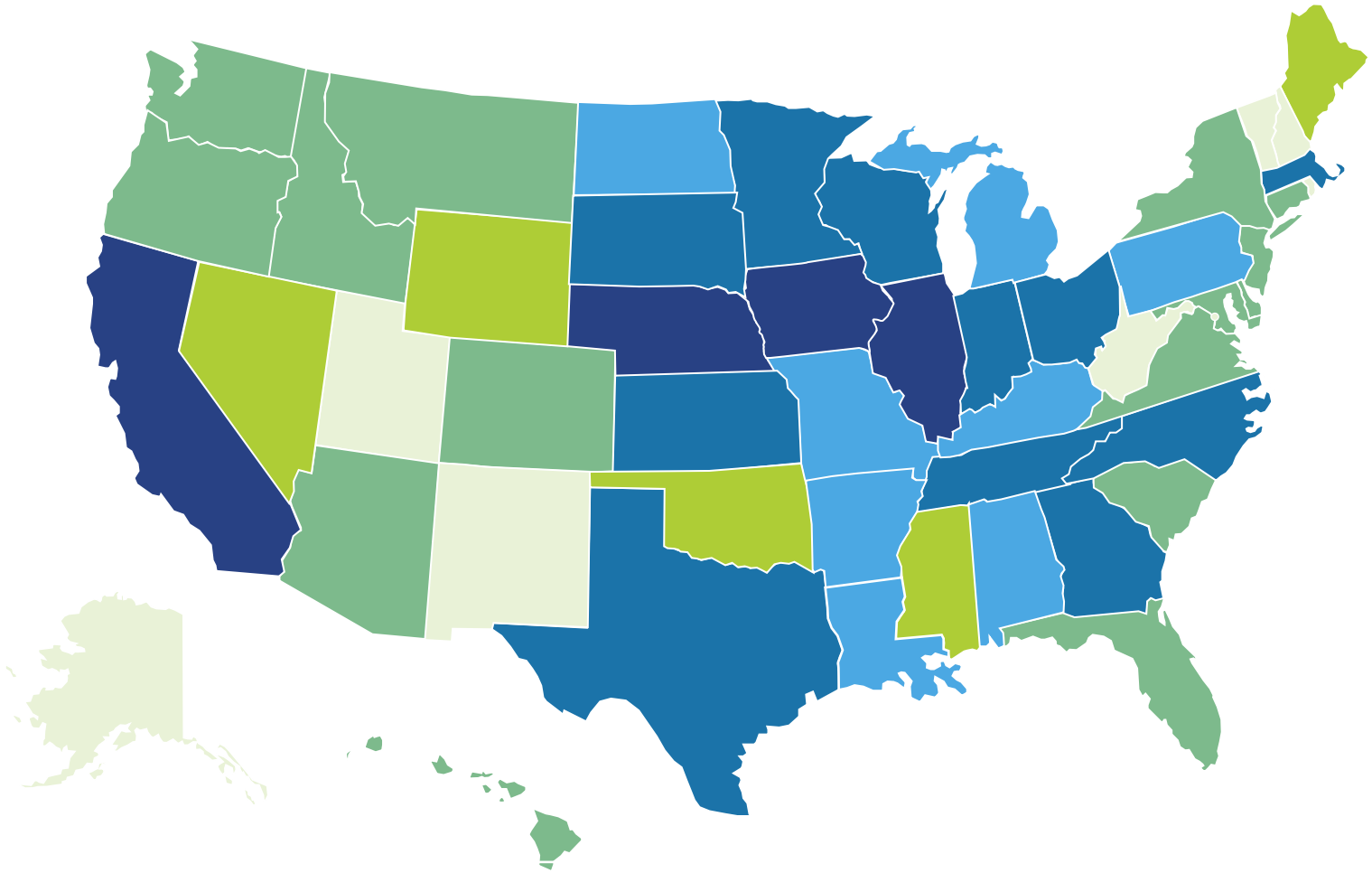
Top 10 States by Combined Direct and Indirect Value Added (Industry and Suppliers Contribution to GDP) Impacts

- Substantial levels of value added are generated through industry and suppliers.
- Industry mix and supplier requirements modify the Top 10 order compared to total output.

State	Direct and Indirect Value Added ($M)
Illinois	$8,639.9
California	$6,763.9
Iowa	$6,537.4
Nebraska	$5,065.1
Indiana	$2,528.4
Ohio	$2,473.3
Minnesota	$2,243.6
Texas	$2,147.0
Georgia	$1,870.9
South Dakota	$1,541.6

Source: TEConomy database development and economic analysis using IMPLAN economic impact model for each state and the U.S. State impacts also include estimates on the in-state impacts generated from interstate commerce and supplier activities.

Geographic Distribution of U.S. Industrial Bioeconomy – Combined Direct and Indirect Value Added (Industry and Suppliers) Impacts



Top 10 Industry Supplier Sectors by Employment

- Employment from agricultural production and related activities account for 52% of indirect employment impacts.
- Given the bulk/commodity nature of significant inputs real estate and transportation-related services are also important input suppliers.

IMPLAN Sectors	Indirect (Supplier) Employment
Support activities for agriculture and forestry	77,062
Grain farming	76,780
Real estate/facility rental and leasing	31,441
Oilseed farming	22,645
Truck transportation	10,258
Other nondurable goods wholesale distribution	9,666
All other crop farming	8,180
Employment services (incl. temp. & contract workers)	7,740
Building support services	5,332
Management of companies and enterprises	4,332

Source: TEConomy database development and economic analysis using IMPLAN U.S. economic impact model.

Top 10 Industry Supplier Sectors by Output

- Agricultural production also leads the financial value estimation of supplier inputs.
- Other energy distribution and production inputs are still significant given the transport required for many feedstocks and the energy input requirements of current industrial bioeconomy production.

IMPLAN Sectors	Indirect (Supplier) Output ($M)
Grain farming	$24,371
Oilseed farming	$14,581
Real estate/facility rental and leasing	$6,877
Other nondurable goods wholesale distribution	$3,659
Support activities for agriculture and forestry	$3,401
Natural gas distribution	$2,602
Truck transportation	$1,996
Pesticide and other ag chemical manufacturing	$1,948
Petroleum refineries	$1,767
Electric power transmission and distribution	$1,595

Source: TEConomy database development and economic analysis using IMPLAN U.S. economic impact model.

The U.S. Industrial Bioeconomy in Context

Growing, yet still evolving, the U.S. industrial bioeconomy is an emerging industry that is often compared with renewable energy industries such as wind turbines and solar photovoltaics, even though the industrial bioeconomy extends beyond energy/fuel products. To provide some context for the U.S. industrial bioeconomy impacts discussed, the following provides some relative comparisons to the U.S. operations of these two other manufacturing industries.

Industry	Estimated 2023 Employment	Estimated 2023 Employment Multiplier	Estimated 2023 Output ($M)	Direct 2023 Contribution to GDP ($M)
U.S. Industrial Bioeconomy	**53,303**	**12.08**	**$66,265.4**	**$14,938.7**
U.S. Wind Turbine Mfg.	14,999	3.73	$13,943.5	$2,038.3
U.S. Solar PV Mfg.	12,038	6.50	$9,699.3	$1,563.5

Source: Additional TEConomy analysis using IMPLAN U.S. economic impact model for estimated U.S. employment multipliers (using IMPLAN sector incorporating wind turbine and solar PV manufacturing) and IBIS World market research publications to provide estimated output and contribution to GDP (industrial value added).

Strengths and limitations of this study

Strengths

- Does not rely on existing NAICS coding structure to “define” the industry. Currently, only one NAICS code is completely within the Industrial Bioeconomy – NAICS 325193 Ethyl Alcohol Manufacturing.
- Detailed examination of firm/establishment information improves both employment values and industry/sector coding from raw data.
- The “industrial” focused approach, provides a robust, yet understandably conservative statement of the industrial bioeconomy, while providing a valuable perspective on the extent and size of its supplier base, including agricultural production, through the economic impact analysis.
- Capturing the direct employment, through the database development approach, and developing the overall economic impacts using the IMPLAN modelling system, generates employment figures that are 100% U.S.-based employment.

Limitations

- Establishment level data sources such as D&B and DataAxle can be wrong or out of date for both employment levels and industry coding. While every effort was made to correct these issues during database development, errors in values may still occur.
- Current national level data from federal sources (e.g., BEA) often collapses NAICS 325193 into the broader five-digit NAICS 32519 Other Basic Organic Chemical Manufacturing. This “coding structure” then includes ethanol, biodiesel and much of the output from industrial bioproducts, with significant levels of more petroleum-based organic chemicals and other economic activities outside of our parameters for the industrial bioeconomy. Efforts were made to account for and minimize the effects of this issue in the overall analysis, yet issues may exist on a state-by-state basis.

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