



Office of the Chief Economist
U.S. DEPARTMENT OF AGRICULTURE



**Indicators & Trends of the U.S.
Biobased Economy 2023:
Advancing Markets for Producers**

October 2026

Prepared by:

Dr. Janire Pascual-Gonzalez

Dr. Jay S. Golden

Ms. Cecilia Flores

Dr. Anthony Radich

Executive Summary

This report provides an updated assessment of the bioindicators of the U.S. economy for calendar years 2022 and 2023. It highlights key indicators, trends, and investments showing the continued expansion of the biobased economy across energy, fuels, and manufacturing sectors. 2023 marked a year of recovery, with production and trade returning to pre-pandemic levels.

In 2023, the United States consolidated its position as the global leader in transportation biofuels, producing 19 billion gallons (38 percent of global production) and exporting 1.6 billion gallons (35 percent of global production), primarily in the form of ethanol. In marketing year 2023, 37 percent of U.S. corn and 47 percent of U.S. soybean oil was used for domestic biofuel production. ([USDA ERS Bioenergy Statistics](#)).

One of the most significant developments in 2023 was the rapid growth of renewable diesel. Renewable diesel continues to grow due to its compatibility with existing petroleum refineries, distribution infrastructure, and engines, making it an easier-to-use alternative compared to traditional biofuels such as ethanol or biodiesel.

Several government and industry initiatives drove the growth of the U.S. biobased economy and the increased reliance on agricultural feedstocks in 2022 and 2023. Consequently, investments in biofuels, biobased chemicals, and carbon capture and sequestration increased, highlighting the crucial role of federal programs and public-private collaboration in fostering innovation, advancing sustainability, and boosting rural and national economic development.

KEY UPDATES

1. THE UNITED STATES LED THE GLOBAL TRANSPORTATION BIOFUELS MARKET IN 2023

The United States was the world's largest producer, consumer and exporter of transportation biofuels in 2023. In 2023, the United States produced 19 billion gallons of biofuels, consumed, 18 billion gallons, and exported 1.6 billion gallons. Fuel ethanol accounted for the largest share of production, consumption, and exports of biofuels.

2. U.S. RENEWABLE DIESEL PRODUCTION CAPACITY SURPASSED BIODIESEL PRODUCTION CAPACITY IN 2023

Driven by the rising targets for state and federal renewable fuel programs and the renewal of biomass-based diesel tax credits, the U.S. production capacity of renewable diesel surpassed biodiesel capacity for the first time in 2023.

3. GLOBAL BIOENERGY JOBS INCREASED BY 62 PERCENT FROM 2012 THROUGH 2023

The global bioenergy industry accounted for 3.9 million direct and indirect jobs in 2023, marking a significant increase from 2.4 million in 2012. Of these jobs, 72 percent were in the liquid biofuels industry, 20 percent were in solid biomass, and 8 percent were related to biogas.

4. MAJOR OIL COMPANIES PLANNED NEW INVESTMENTS IN BIOFUELS

Major oil companies such as BP, Chevron, Shell, TotalEnergies, ExxonMobil, and Eni, increased investment in biofuels, with 43 new projects that were planned to start operations by 2030. They were focused primarily on renewable jet fuel and renewable diesel, which made up 72% of the planned capacity.

KEY UPDATE #1: THE UNITED STATES LEAD THE GLOBAL TRANSPORTATION BIOFUELS MARKET IN 2023

The United States was the leading biofuels producer, consumer, and exporter country in the world in 2023, followed by Brazil and Indonesia. Specifically, the United States accounted for 38 percent of global production (19 billion gallons), 36 percent of global consumption (18 billion gallons), and 35 percent of global exports (1.6 billion gallons) of transportation biofuels (i.e., ethanol, biodiesel, and renewable diesel) in 2023 (see Figure ES-1).

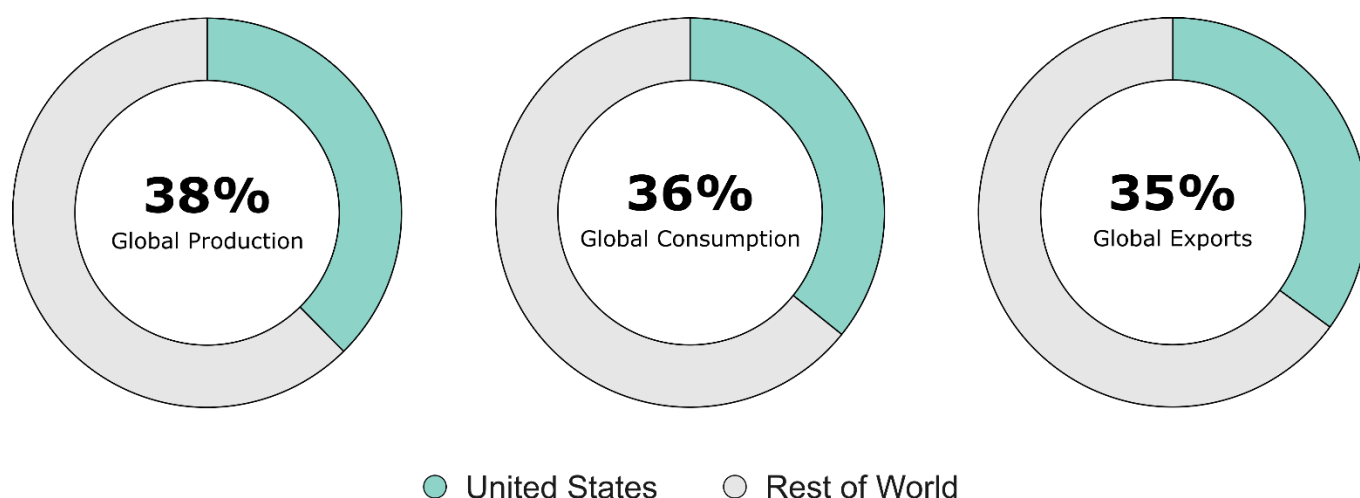


Figure ES-1. U.S. share of global production, consumption, and exports of transportation biofuels in 2023 (OECD-FAO Agricultural Outlook, 2024).

Ethanol accounted for the largest share of production, consumption, and exports of transportation biofuels with 15.9 billion gallons produced, 14.6 billion gallons consumed, and 1.4 billion gallons exported in the United States in 2023.

KEY UPDATE #2: U.S. RENEWABLE DIESEL PRODUCTION CAPACITY SURPASSED BIODIESEL PRODUCTION CAPACITY IN 2023

In 2023, the production capacity of renewable diesel in the United States reached 3 billion gallons, marking a 44 percent increase over biodiesel production capacity and surpassing it for the first time (see Figure ES-2). The drivers behind the growth in renewable diesel capacity were rising targets for state and federal renewable fuel programs, as well as the renewal of biomass-based diesel tax credits (EIA, 2024).

The production capacity of renewable diesel in the United States tripled over 3 years, from 0.8 billion gallons in 2021 to 3 billion gallons in 2023. In contrast, biodiesel production capacity declined 13

percent during the same period, falling to 2.1 billion gallons in 2023. One significant advantage of renewable diesel is that it is chemically equivalent to petroleum diesel fuel, allowing it to be used as a drop-in fuel without requiring engine modifications. This contrasts with biodiesel, which differs chemically from petroleum diesel. Warranty coverage of diesel engines for use with more than 5 percent biodiesel varies by manufacturer. The increase in renewable diesel capacity also led to production and consumption exceeding biodiesel in 2023, by 53 percent and 48 percent, respectively. Domestic renewable diesel consumption exceeded domestic biodiesel consumption for the first time in 2022. The number of states producing renewable diesel also increased in 2023 to 11 from just 5 in 2021. Louisiana and Texas with 1.6 and 0.6 billion gallons respectively, accounted for almost 60 percent of total renewable diesel production capacity in the United States. (EIA, 2024).

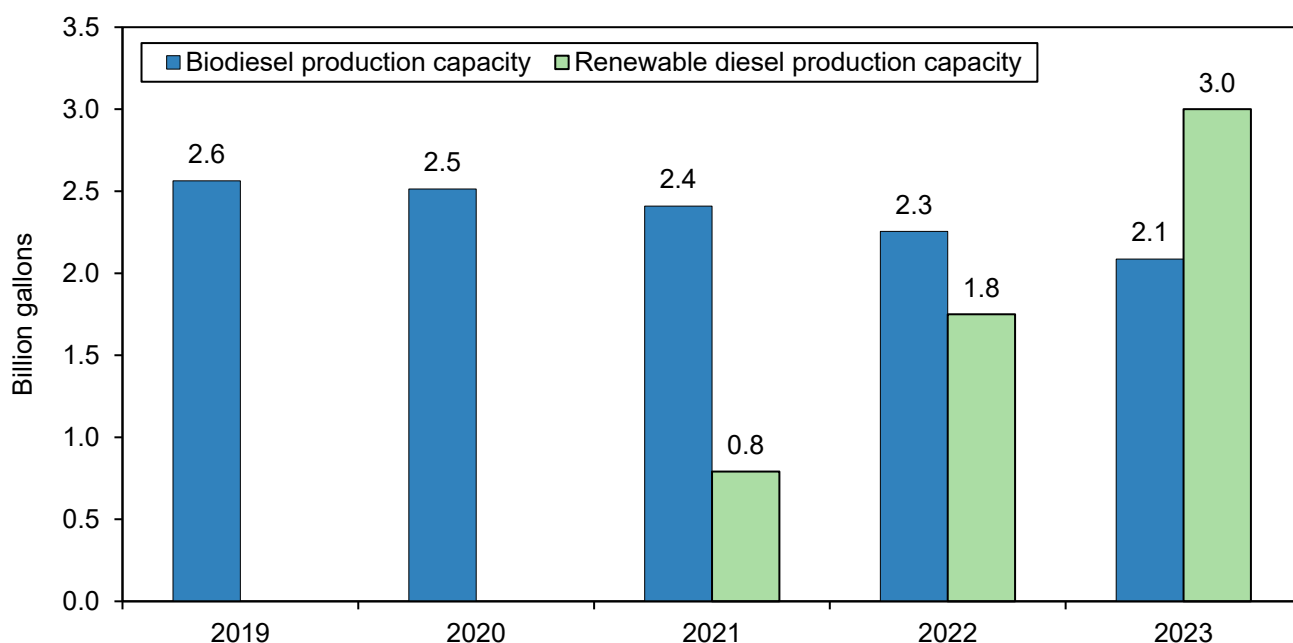


Figure ES-2. Annual biodiesel and renewable diesel production capacity in the United States from 2019 to 2023 (in billion gallons) (EIA, 2024).

KEY UPDATE #3: GLOBAL BIOENERGY JOBS HAVE INCREASED BY 62 PERCENT FROM 2012 THROUGH 2023

The global bioenergy industry accounted for 3.9 million direct and indirect jobs in 2023, marking a significant increase from 2.4 million in 2012. Of these jobs, 72 percent were in the liquid biofuels industry, 20 percent were in solid biomass, and 8 percent were related to biogas. This constant growth highlights the expanding role of the biobased economy in the global transition towards cleaner energy sources.

While the global bioenergy industry trended upward over this period, growth in the United States was lower. Between 2012 and 2023, bioenergy industry employment in the United States increased by only 6 percent, from 370,000 to 390,000 direct and indirect jobs. Eighty-eight percent of these jobs were concentrated in the biofuels sector, reflecting the country's focus on ethanol, biodiesel, and other liquid biofuels as key contributors to its renewable energy portfolio (IRENA, 2024).

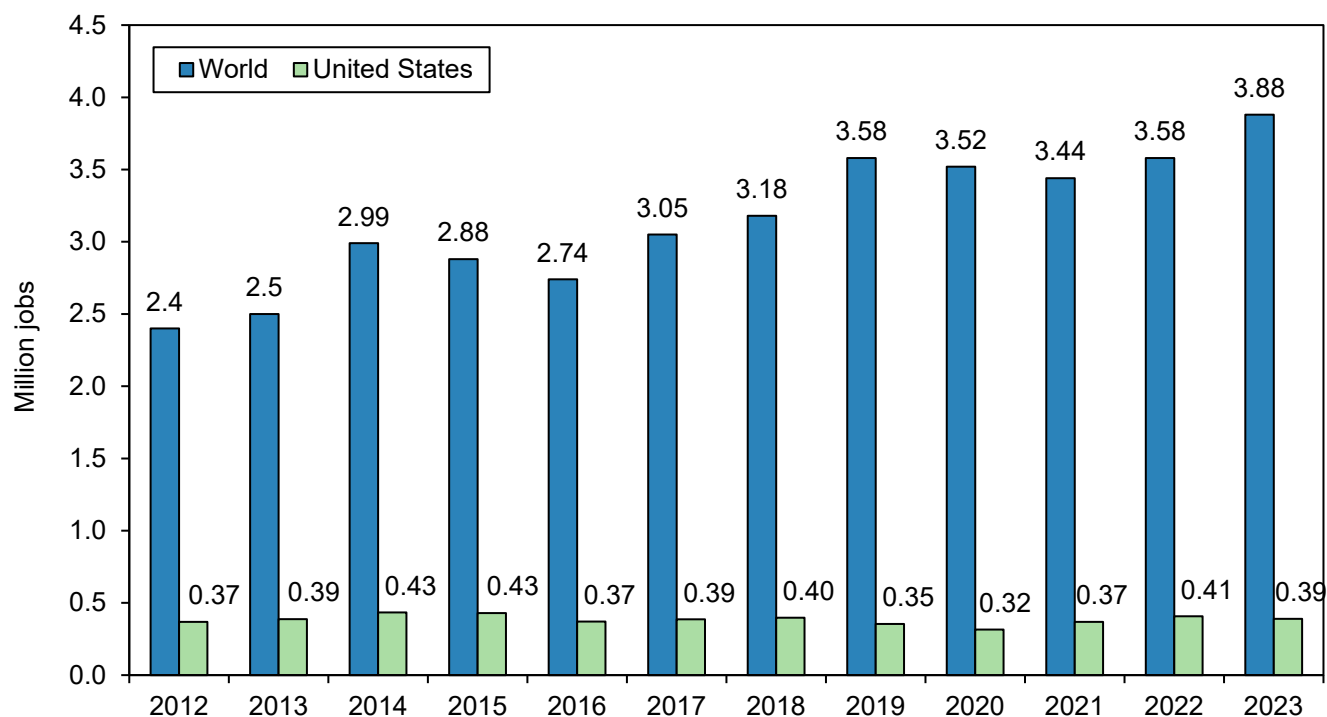


Figure ES-3. Estimated direct and indirect jobs in the bioenergy industry in 2023 (in million jobs) (IRENA, 2024).

KEY UPDATE #4: MAJOR OIL COMPANIES PLANNED NEW INVESTMENTS IN BIOFUELS

Rystad Energy reported that major oil and gas companies were significantly ramping up investments in the biofuels sector, with 43 new projects expected to become operational by 2030. Of these, 31 involved new installations, 6 integrated the co-processing of biobased feedstocks into existing refineries, and 6 aimed to fully convert refineries into exclusively biofuels facilities (RystadEnergy, 2024).

The study highlighted six major companies—BP, Chevron, Shell, TotalEnergies, ExxonMobil, and Eni—as leading this shift. These companies focused on renewable jet fuel and renewable diesel, which together represented 72 percent of the projected new capacity (see Figure ES-4). Investments in advanced biofuels were central to long-term decarbonization strategies. This momentum was derived from domestic policies such as the federal Renewable Fuels Standard and state low-carbon fuels

standards and also from international policies, such as Europe’s “ReFuel EU” initiative and increasing mandates in the Asia-Pacific region. Renewable jet fuel and renewable diesel offer a solution to reduce emissions without significant infrastructure changes (RystadEnergy, 2024).

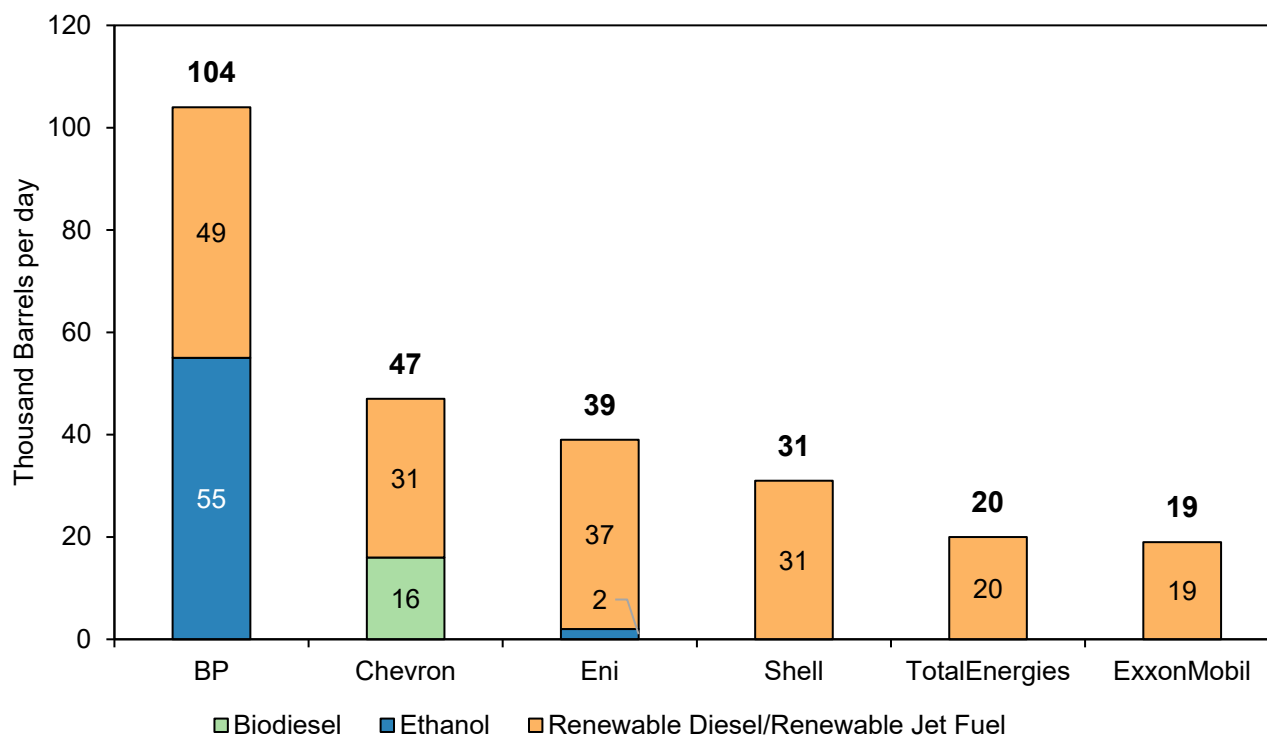


Figure ES-4. Announced biofuel capacity of oil major companies by biofuel in 2024 (in thousand barrels per day) (RystadEnergy, 2024).

This project was supported through a cooperative agreement (58-0111-23-005) issued by the Office of the Chief Economist of the United States Department of Agriculture and the Dynamic Sustainability Lab at Syracuse University.

How to Cite this Report

Pascual-Gonzalez, J., Golden, J.S., Flores, C., and A Radich (2026). Indicators & Trends of the U.S. Biobased Economy 2023: Advancing Markets for Producers. U.S. Department of Agriculture, Office of the Chief Economist.

About the Authors

Janire Pascual-Gonzalez, Ph.D.



Dr. Janire Pascual-Gonzalez is a Research Assistant Professor in the Public Administration and International Affairs department in the Maxwell School where she also is a Sr.

Project Manager of the Dynamic Sustainability Lab at Syracuse University. Prior to joining Syracuse University, she was a postdoctoral scholar in the Office of Research, Economic Development and Engagement and the Center for Sustainable Energy and Environmental Engineering at East Carolina University. Her research focuses on net-zero transitions and quantifying and evaluating the U.S. biobased economy with specific focus on chemicals, energy, fuels and consumer products, and the environmental and economic implications spanning from agriculture, climate and water to economics and job growth as well as trade. Additionally, she develops and applies state-of-the-art data science tools to analyze environmental data to find technological and policy alternatives in order to reduce the environmental impacts. Dr. Pascual-Gonzalez received her chemical engineering degree and her master's degree in chemical engineering and processes in 2011 from the Universitat Rovira i Virgili of Tarragona (Spain). In 2015, she received her Ph.D. in Chemical, Environmental and Processes Engineering at Universitat Rovira i Virgili of Tarragona (Spain). She can be reached at jpascu02@syr.edu

Jay S. Golden, Ph.D.



Dr. Jay Golden is the Pontarelli Professor of Environmental Sustainability and Finance at Syracuse University where he directs the Sustainable Dynamics Lab (www.DynamicsLab.org).

Golden's research covers sustainable dynamics and systems with a focus on the utilization of Earth resources and global commerce related to the net-zero carbon economy transition. Golden received his Ph.D. in engineering from the University of Cambridge and his master's degree in Environmental Engineering and Sustainable Development from a joint program of the Massachusetts Institute of Technology and the University of Cambridge. He also holds a Professional Mastery of Project Management Certificate from Stanford University, an MLE in Higher Education from Harvard, and has a B.A. degree in Management. He is the author of the book Dynamic Sustainability by Cambridge University Press. He can be reached at JGolde04@Syr.edu

Cecilia Flores



DYNAMIC SUSTAINABILITY LAB™
AT SYRACUSE UNIVERSITY

Cecilia Flores is a research analyst in the Dynamic Sustainability Lab at Syracuse University. She received her BS in Chemical Engineering from the Pennsylvania State University in 2021. Then, she worked in a small research company as a battery research engineer. In 2024, she started her Environmental and Ecological Engineering PhD program at Purdue University. She can be reached at: flore145@purdue.edu

Anthony F. Radich, Ph.D.



Tony Radich is an Agricultural Economist with the Office of Energy and Environmental Policy. He focuses on the biobased economy, biofuels policy and markets, and greenhouse gas lifecycle analysis. Prior to joining USDA in 2016, Tony worked for 15 years at the U.S. Energy Information Administration, where he covered fuel ethanol and biodiesel markets. He contributed to the Annual Energy Outlook, the Short-Term Energy Outlook, and helped to launch the Biodiesel Production Survey. Tony holds a PhD in Economics from Emory University, and an A.B. in Economics and Business and a BS in Mechanical Engineering from Lafayette College.

Table of Contents

Executive Summary	1
KEY UPDATE #1: THE UNITED STATES LEAD THE GLOBAL TRANSPORTATION BIOFUELS MARKET IN 2023.....	3
KEY UPDATE #2: U.S. RENEWABLE DIESEL PRODUCTION CAPACITY SURPASSED BIODIESEL PRODUCTION CAPACITY IN 2023	3
KEY UPDATE #3: GLOBAL BIOENERGY JOBS HAVE INCREASED BY 62 PERCENT FROM 2012 THROUGH 2023.....	4
KEY UPDATE #4: MAJOR OIL COMPANIES PLANNED NEW INVESTMENTS IN BIOFUELS	5
How to Cite this Report	6
About the Authors.....	7
Table of Contents.....	9
Table of Tables.....	11
Table of Figures.....	11
Glossary of Terms	15
1. THE GLOBAL BIOECONOMY.....	18
1.1. Transport Biofuels	19
1.2. Biobased Chemicals	24
1.3. Bioplastics.....	26
1.4. References.....	31
2. U.S. BIOECONOMY INVESTMENT UPDATES	34
2.1. Research & Development (R&D) Funding	35
2.2. Carbon Capture and Sequestration	38
2.3. New Biofuel Investments	40
2.4. References.....	41
3. U.S. INDUSTRY UPDATES	43
3.1. Transportation Fuels	44
3.1.1. Ethanol	44
3.1.2. Agricultural Biogas - Renewable Natural Gas.....	47
3.1.3. Biodiesel.....	48

3.1.4.	Renewable Diesel.....	51
3.1.5.	Renewable Jet Fuels.....	53
3.2.	Primary Energy	56
3.2.1.	Wood Pellets	56
3.2.2.	Waste-to -Energy	60
3.2.3.	Biogas.....	63
3.3.	Biobased Chemicals	65
3.3.1.	Biobased Plastics.....	66
3.4.	Biobased Products.....	68
3.5.	Forestry Products	70
3.6.	Apparel and Textiles	72
3.7.	References.....	74
4.	APPENDIX	79
4.1.	Bioindicators Database Structure.....	80
4.1.1.	Using the Bioindicators Database.....	80
4.1.2.	Data Overview.....	80
4.1.2.1.	Ethanol	80
4.1.2.2.	Biobutanol.....	81
4.1.2.3.	Biodiesel	81
4.1.2.4.	Animal Fats and Recycled Greases.....	81
4.1.2.5.	Renewable Diesel	82
4.1.2.6.	Renewable Jet Fuel.....	82
4.1.2.7.	Wood Pellets.....	83
4.1.2.8.	Waste to Energy.....	83
4.1.2.9.	Biogas	85
4.1.2.10.	Bioproducts.....	85
4.1.2.11.	Bioplastics	86
4.1.2.12.	Enzymes.....	87
4.1.2.13.	Apparel and Textiles	88
4.1.2.14.	Forest Products.....	88
4.1.2.15.	Funding.....	89

Table of Tables

Table 1.1.1. World policies to mitigate biofuels and feedstock price increases (IEA, 2024).	24
Table 2.2.1. CCS Facilities operating in the United States as of 2023 (Global CCS Institute, 2025).	38
Table 2.3.1. Recent biofuels investments in the U.S.	40
Table 3.1.1. Approved renewable jet fuel production pathways (ICAO, 2024).	55
Table 3.4.1. USDA BioPreferred product certifications by year and category (USDA, 2024).	69

Table of Figures

Figure 1.1.1. Total transport biofuels (i.e., ethanol, biodiesel, and renewable diesel) production (left) and consumption (right) by country or region from 2012 to 2023 (in million gallons) (OECD-FAO Agricultural Outlook, 2024).	19
Figure 1.1.2. Global transport biofuel demand, by biofuel from 2016 to 2023 (in billion liters) (IEA, 2024).	20
Figure 1.1.3. Five-year transport biofuel demand growth for advanced and emerging economies from 2016 to 2022 (in billion liters) (IEA, 2024).	21
Figure 1.1.4. Total transport biofuels (i.e., ethanol, biodiesel, and renewable diesel) imports (left) and exports (right) by country or region from 2012 to 2023 (in million gallons) (OECD-FAO Agricultural Outlook, 2024).	22
Figure 1.1.5. Total ethanol and biodiesel industries direct and indirect jobs by country or region from 2012 to 2023 (in thousand jobs) (IRENA, 2024).	22
Figure 1.1.6. World price by biofuel from 2012 to 2023 (in U.S. dollars per gallon) (OECD-FAO Agricultural Outlook, 2024).	23
Figure 1.3.1. Global bioplastics production capacities by type in 2023 (Plastics Industry Association, 2024).	27
Figure 1.3.2. 2023 Percentage of bioplastic production (green) and plastic production (purple) by region [1. European Union Member States, Norway, Switzerland, and the United Kingdom. 2. Commonwealth of Independent States: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan,	

Moldova, Russia, Tajikistan, Turkmenistan, and Uzbekistan. 3. Includes Asian countries (except China & Japan), Oceania, Turkey, and Ukraine.] (Plastics Europe, 2024).	28
Figure 1.3.3. Total bioplastics production by country or region from 2017 to 2023 (in Thousand Tons) (MarketLine Industry, 2023). Note: Values for 2023 are forecasts.	29
Figure 1.3.4. Global market segmentation by revenue from 2020 to 2023 (EuropeanBioplastics, 2023).	30
Figure 1.3.5. Total bioplastics market value by country or region from 2017 to 2023 (in million dollars) (MarketLine Industry, 2023) Note: Values for 2023 are forecasts.	30
Figure 2.1.1. Number of awards to research projects containing traditional biofuel related keywords in the United States from 2010 to 2023 by NIFA and NSF (NIFA, 2025; NSF, 2025).	35
Figure 2.1.2. Number of awards to research projects containing emergent biofuels related keywords in the United States from 2010 to 2023 by NIFA and NSF (NIFA, 2025; NSF, 2025).	36
Figure 2.1.3. Number of awards to research projects containing keywords related to biobased products in the United States from 2010 to 2023 by NIFA and NSF (NIFA, 2025; NSF, 2025).	37
Figure 2.1.4. Award amount range in dollars for Biofuels research projects and Bioproducts research projects in 2023 in the United States by NIFA and NSF (NIFA, 2025; NSF, 2025).	37
Figure 3.1.1. Ethanol production facilities in 2023 by location, capacity, and type in the United States (in million gallons) (Ethanol Producer Magazine, 2024).	45
Figure 3.1.2. Total ethanol production and consumption in the United States from 2010 to 2023 (in billion gallons) (EIA, 2024).	45
Figure 3.1.3. Exports and imports of ethanol in the United States from 2010 to 2023 (in billion gallons) (EIA, 2024).	46
Figure 3.1.4. Exports (blue line) and imports (green line) of ethanol in the United States by country in 2023 (in million gallons) (EIA,2024).	47
Figure 3.1.5. Operational projects of renewable natural gas from 2010 to 2023 in the United States (EPA, 2024).	48
Figure 3.1.6. Biodiesel production facilities location by capacity (in million gallons) in the United States in 2023 (EIA, 2024).	49

Figure 3.1.7. Total biodiesel production and total biodiesel consumption in the United States from 2010 to 2023 (in billion gallons) (EIA, 2024).	50
Figure 3.1.8. Exports and Imports of biodiesel in the United States from 2010 to 2023 (in million gallons) (EIA, 2024).	50
Figure 3.1.9. Exports (blue line) and imports (green line) of biodiesel in the United States by country in 2023 (in million gallons) (EIA, 2024).	51
Figure 3.1.10. Renewable diesel production facilities location and capacity (in million gallons) in the United States in 2023 (EIA, 2024).	52
Figure 3.1.11. Renewable diesel production, consumption, and imports in the United States from 2011 to 2023 (in million gallons) (EPA 2024; EIA, 2024).	53
Figure 3.1.12. Airports and FBOs offering renewable jet fuel in the United States in 2023 (4AIR, 2023).	54
Figure 3.1.13. Production and consumption of renewable jet fuel from 2016 to 2023 in the United States (in million gallons) (EPA, 2024).	56
Figure 3.2.1. Wood pellet production facilities in the United States in 2023, sized according to their capacity (in thousand metric tons) and colored by feedstock (Biomass Magazine, 2024).	57
Figure 3.2.2. Total wood pellet production versus total wood pellet consumption in the United States from 2012 to 2023 (in million metric tons) (FAOSTAT, 2024).	58
Figure 3.2.3. Exports and imports of wood pellets in the United States from 2012 to 2023 (in million metric tons) (FAOSTAT, 2024).	59
Figure 3.2.4. Exports (blue line) and imports (green line) of wood pellets in the United States by country in 2023 (in million metric tons) (FAOSTAT, 2024).	60
Figure 3.2.5. Waste-to-energy facilities in the United States in 2023, sizes according to capacity in MW (EIA, 2024).	61
Figure 3.2.6. Final use of the energy generated from biogenic municipal solid waste in the United States from 2010 to 2023 (in trillion British thermal units) (EIA, 2024).	62
Figure 3.2.7. Biogas facilities locations by type in the United States in 2015 (wastewater) and 2023 (landfills and anaerobic digesters) (EPA, 2024; Water Environment Federation, 2015).	64

Figure 3.2.8. Total energy generated from biogas by source from 2010 to 2023 (in trillion British Thermal Units (BTU)) (EPA,2024; EIA,2024).	65
Figure 3.3.1. Production of bioplastics in the United States from 2017 to 2022 (in Thousand Tons) (MarketLine Industry, 2023).	67
Figure 3.3.2. United States bioplastics market value from 2017 to 2022 (in million U.S. dollars) (MarketLine Industry, 2023).	67
Figure 3.4.1. A sample USDA Certified Biobased Product label (USDA, 2020).	68
Figure 3.4.2. USDA BioPreferred total products certified by year (USDA, 2024).	69
Figure 3.5.1. Production of roundwood, sawnwood, wood fuel and paper in the United States from 2010 to 2023 (in million tons) (FAOSTAT, 2025).	70
Figure 3.5.2. Production of wood pulp, wood-based panels, wood residues and wood pellets in the United States from 2010 to 2023 (in million tons) (FAOSTAT, 2025).	71
Figure 3.5.3. Exports and Imports of forest products in the United States from 2010 to 2023 (in billion U.S. dollars) (FAOSTAT, 2025).	71
Figure 3.6.1. Exports and imports of apparel in the United States from 2010 to 2023 (in billion U.S. dollars) (ITA, 2024).	73
Figure 3.6.2. Exports and imports of textiles in the United States from 2010 to 2023 (in billion U.S. dollars) (ITA, 2024).	73

Glossary of Terms

Anaerobic digestion:	Collection of processes in which organic material is broken down by microorganisms in the absence of oxygen.
Biobased chemical:	Chemical totally or partially produced from plants or renewable sources.
Biobutanol:	Type of alcohol produced through biological processes and used as a fuel or chemical feedstock.
Biodegradable:	Can be degraded by naturally occurring microorganisms in a defined environmental and timescale.
Biodiesel:	Diesel fuel derived from vegetable oils, animal fats, or recycled grease. Chemically distinct from petroleum diesel.
Bioeconomy:	As defined by the Congressional Research Service (2022), the term bioeconomy refers to the share of the economy based on products, services, and processes derived from biological resources (e.g., plants and microorganisms). The bioeconomy is crosscutting, encompassing multiple sectors, in whole or in part (e.g., agriculture, textiles, chemicals, and energy).
Bioenergy:	Form of renewable energy derived from biomass.
Biofuel:	Fuel produced from biological or renewable materials. Examples include biodiesel and ethanol.
Biogas:	Mixture of gases, primarily methane and carbon dioxide, produced by anaerobic digestion from different waste sources.
Biogenic material:	Material made by or from living organisms (i.e., plants and animals).
Bioplastic:	Type of plastic that is partially or fully biobased and/or biodegradable.
BioPreferred Program:	A program administered by the U.S. Department of Agriculture with the goal of increasing the Federal purchase and use of biobased products. The program's purpose is to spur rural economic development, create new jobs and provide new markets for farm commodities.
Bioproduct:	Products derived in whole, or in significant part, from biological or renewable materials.
British Thermal Units:	Amount of heat needed to raise one pound of water at one atmosphere of pressure through one degree Fahrenheit.
Carbon Intensity:	Carbon intensity is the ratio of carbon dioxide and carbon dioxide equivalents per unit of energy, or the amount of carbon dioxide and

carbon dioxide equivalents emitted as a result of using one unit of energy in production. Emission intensities are also used to compare the environmental impact of different fuels or activities. The related terms - emission factor and carbon intensity - are often used interchangeably.

Cellulosic material:	The world's most abundant biological material. Corn stover, switchgrass, or wood chips are some examples of cellulosic materials. Cellulose is a group of organic compounds with the formula $(C_6H_{10}O_5)_n$.
Cubic feet:	Volume of a cube with sides of one foot.
Energy density:	Amount of energy stored in a given system or substance per unit volume or mass. Often has units of joules per cubic meter or kilogram.
Enzyme:	Substance produced by living organisms that act as a catalyst on a specific biochemical reaction.
Fatty Acid Methyl Ester:	A type of biodiesel produced by chemically reacting fatty acids with methanol. Fatty acids typically are derived from vegetable oils or animal fats.
Fuel ethanol:	Motor gasoline blending component produced from fermenting biomass that is rich in starches and sugars. It is typically derived from corn and sugar cane.
Fuel blends:	Mixtures of fuel and ethanol with other additives commonly used to enhance performance or meet regulatory requirements in transportation fuels.
Greenhouse gases:	Gases, such as carbon dioxide, methane, and nitrous oxide, that contribute to global warming when released into the atmosphere.
Global warming potential:	Amount of heat a greenhouse gas traps in the atmosphere. Expressed in relation to carbon dioxide.
Gross domestic product:	Monetary value of all the finished goods and services produced within a country's borders in a specific period of time, usually a year.
Irrigation water:	Water applied to plants in controlled amounts at needed intervals.
Methane potential:	Amount of methane in the biogas produced during anaerobic digestion, expressed under normal conditions of temperature and pressure.
Non-biogenic material:	Material of nonbiological origin such as plastics and synthetic materials made from petroleum.
Noncombustible material:	Material that does not support combustion such as glass and metals.
Organic material:	Material made from living organisms (i.e., plants and animals).

Primary energy:	Energy in its original form, such as coal, crude oil, natural gas, or sunlight before any conversion process.
Renewable diesel:	Diesel fuel derived from renewable sources through hydrotreating and other refining processes.
Renewable jet fuel:	Renewable jet fuel aimed at reducing greenhouse gas emissions. Renewable feedstocks include biomass and waste oils.
Renewable natural gas:	Natural gas derived from renewable sources such as landfill gas, agricultural waste, or wastewater treatment plants.
Transesterification:	Chemical reaction in which triglycerides, typically from plant oils, are reacted with alcohol to produce biodiesel and byproduct glycerol.
Waste-to-energy:	Production of energy or heat from waste.
Waste-to-energy plant:	Facility that incinerates waste for energy recovery. In these plants the waste is burned to capture the heat from the burning process and produce steam, which is used to generate electricity or heat.

1. THE GLOBAL BIOECONOMY



1.1. Transport Biofuels

The international transport biofuel sector was strongly influenced in 2022 and 2023 by transport fuel demand and national policies. These policies were typically designed with three major goals in mind: supporting farmers, reducing greenhouse gas (GHG) emissions, and/or increasing energy supply and independence (OECD, FAO, 2024).

The International Energy Agency (IEA) noted decreasing transport biofuel demand in high-income countries but increasing transport biofuel demand in middle-income and low-income countries (IEA, 2024). The dominant transport biofuel markets continued to be the United States, Brazil, the European Union, China, and Indonesia, accounting for 85 percent of total global demand.

This section analyzes the transport biofuels industry over the last decade by country and/or region.

Production

As presented in Figure 1.1.1, transport biofuels production and consumption varied greatly by country and region. However, there were relationships between the consumption and production for each country that impacted global trade. Overall, both production and consumption of transport biofuels have increased over time, with a minor worldwide drop in 2020 and 2021 due to the COVID-19 pandemic.

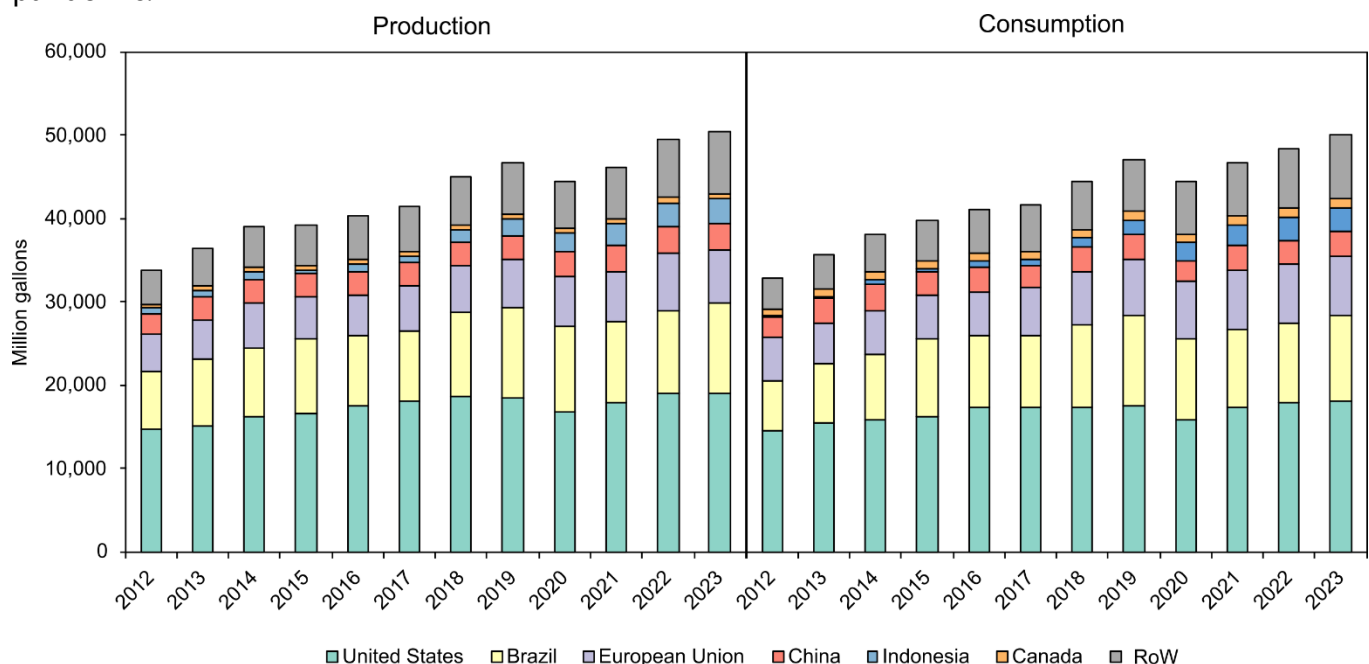


Figure 1.1.1. Total transport biofuels (i.e., ethanol, biodiesel, and renewable diesel) production (left) and consumption (right) by country or region from 2012 to 2023 (in million gallons) (OECD-FAO Agricultural Outlook, 2024).

The United States was the world’s largest producer and consumer of transport biofuels, producing 19 billion gallons and consuming 18 billion gallons in 2023. Brazil (10 billion gallons produced, 9.6 billion gallons consumed in 2023) and the European Union (6 billion gallons produced, 7 billion gallons consumed in 2023) were the other two of the top three producers and consumers of transport biofuels.

According to the IEA, global transport biofuels demand, which includes ethanol, biodiesel, renewable diesel, and renewable jet fuel, increased by 30 percent in 2023 compared to 2016 levels, reaching 175 billion liters (IEA, 2024) (see Figure 1.1.2). Biodiesel and renewable diesel each contributed 36 percent to this growth, while ethanol contributed 26 percent.

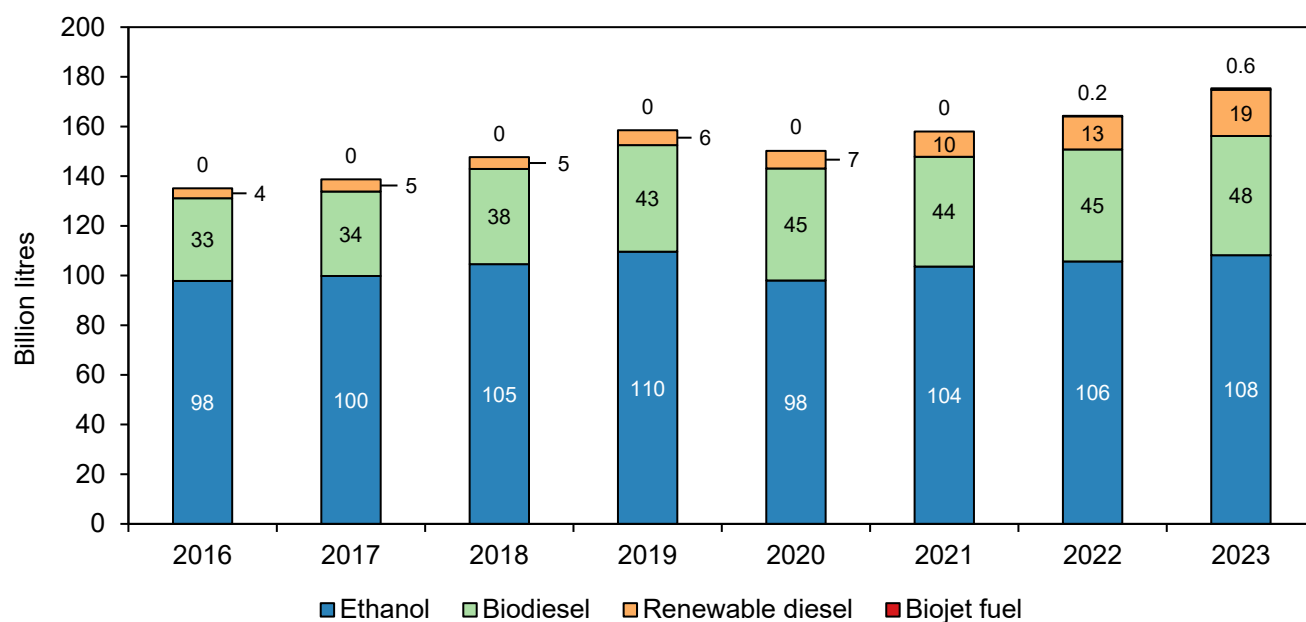


Figure 1.1.2. Global transport biofuel demand, by biofuel from 2016 to 2023 (in billion liters) (IEA, 2024).

More than 60 percent of new transport biofuel demand between 2016 and 2022 came from emerging economies (i.e., countries with low to middle per capita income) such as Brazil, Indonesia, and India (see Figure 1.1.3). This demand was driven by robust biofuels policies, rising fuel consumption, and abundant available feedstock. Among advanced economies (i.e., countries with high per capita income), led the growth, accounting for 80 percent of the increase. In advanced economies, however, the demand for transport biofuels grew more slowly due to constraints such as the rising adoption of electric vehicles (EVs), vehicle efficiency improvements, high biofuel costs, and technical limitations (IEA, 2024).

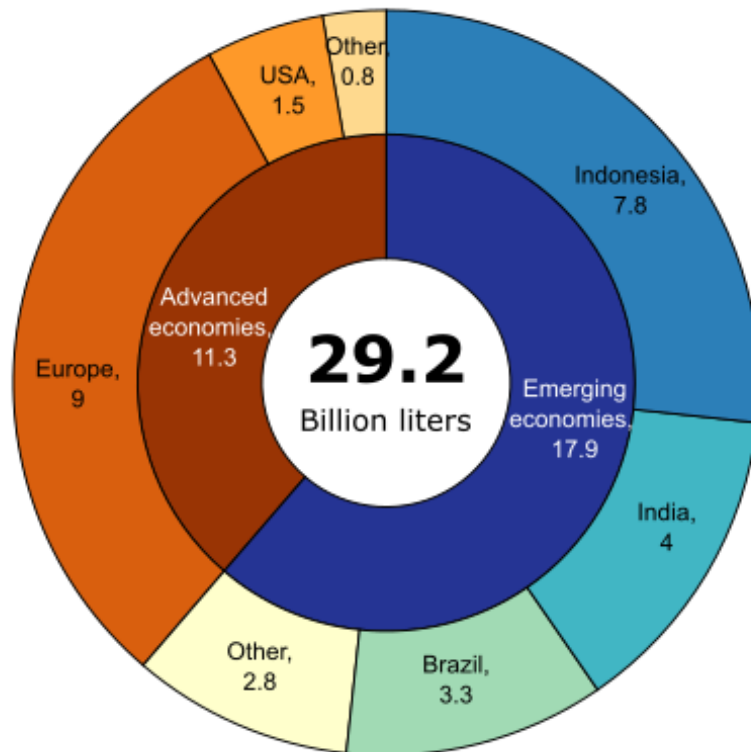


Figure 1.1.3. Five-year transport biofuel demand growth for advanced and emerging economies from 2016 to 2022 (in billion liters) (IEA, 2024).

Trade

International trade in biofuels dropped in 2020 during the COVID-19 pandemic and did not recover to pre-pandemic levels by 2023, the data year of this report. Specifically, 2023 exports were 6 percent lower, and imports were 13 percent lower than in 2019 (see Figure 1.1.4). The United States, along with Brazil, remained a net exporter of transport biofuels. (OECD-FAO, 2024).

Economic Impact

The International Renewable Energy Agency (IRENA) estimated that the worldwide ethanol and biodiesel industries directly and indirectly employed 2.8 million people in 2023, with most of the jobs concentrated in planting and harvesting feedstock (IRENA, 2024). Brazil, the largest global employer in the biofuels industry, accounted for 1 million jobs that represented 35 percent of total jobs, followed by Indonesia (0.8 million jobs, 28 percent) and the United States (0.3 million jobs, 12 percent) (see Figure 1.1.5).

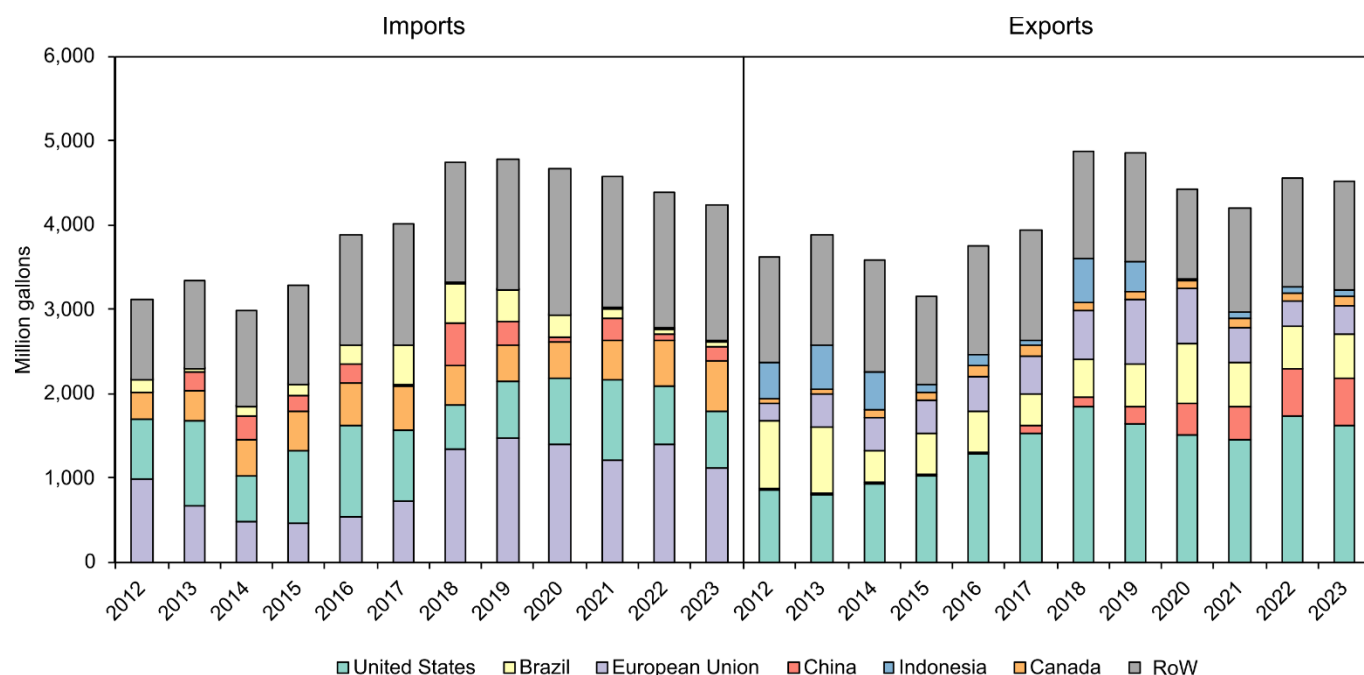


Figure 1.1.4. Total transport biofuels (i.e., ethanol, biodiesel, and renewable diesel) imports (left) and exports (right) by country or region from 2012 to 2023 (in million gallons) (OECD-FAO Agricultural Outlook, 2024).

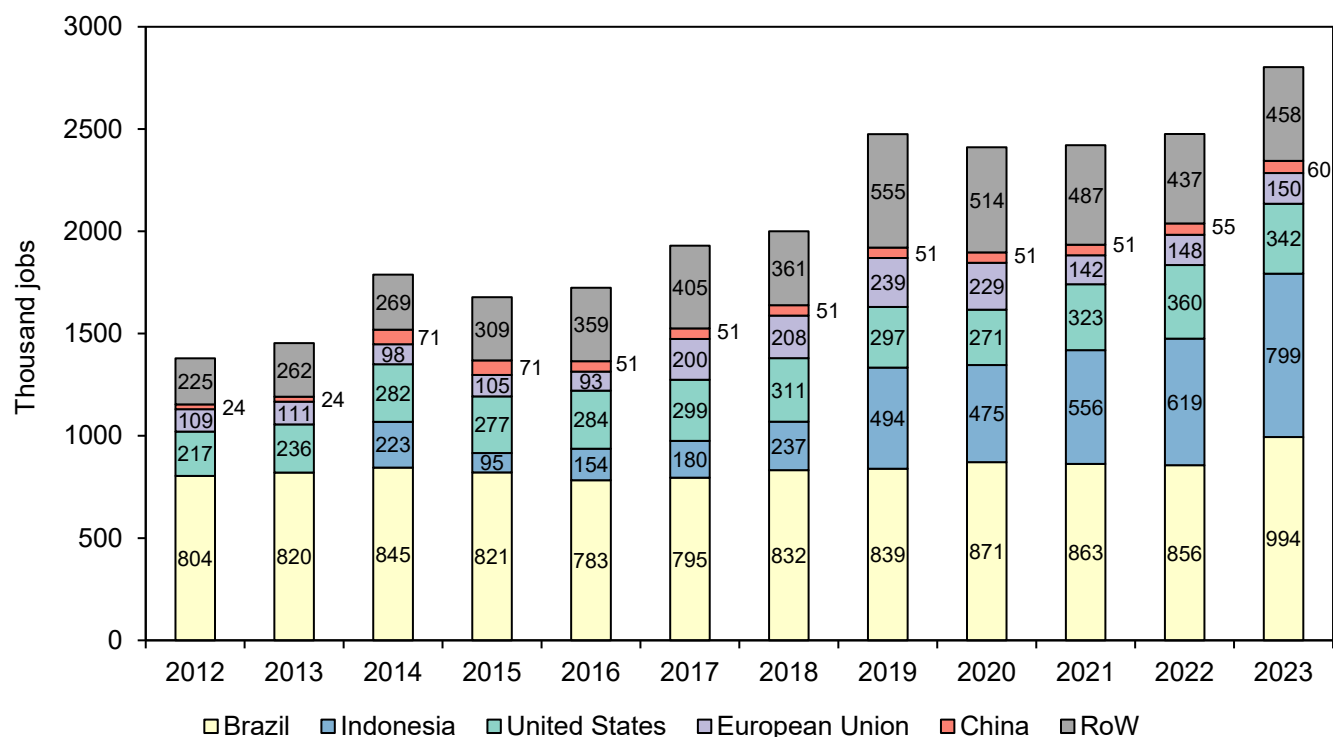


Figure 1.1.5. Total ethanol and biodiesel industries direct and indirect jobs by country or region from 2012 to 2023 (in thousand jobs) (IRENA, 2024).

World prices for ethanol, biodiesel and renewable diesel reached historic highs after the COVID-19 pandemic in 2021 and 2022, with ethanol priced at \$2.68 U.S. per gallon and biodiesel and renewable diesel priced at \$7.10 U.S. per gallon in 2022 (see Figure 1.1.6). These price increases were driven by rising feedstock costs, particularly vegetable oils, which saw price increases ranging from 65 to 164 percent since 2019 (see Figure 1.1.6). In response to these price spikes, several governments adopted new or modified policies to mitigate the impact of high biofuel and oil prices (see Table 1.1.1). As a result of these policies, global transport biofuel prices decreased by 20 percent in 2023 compared to 2022 prices.

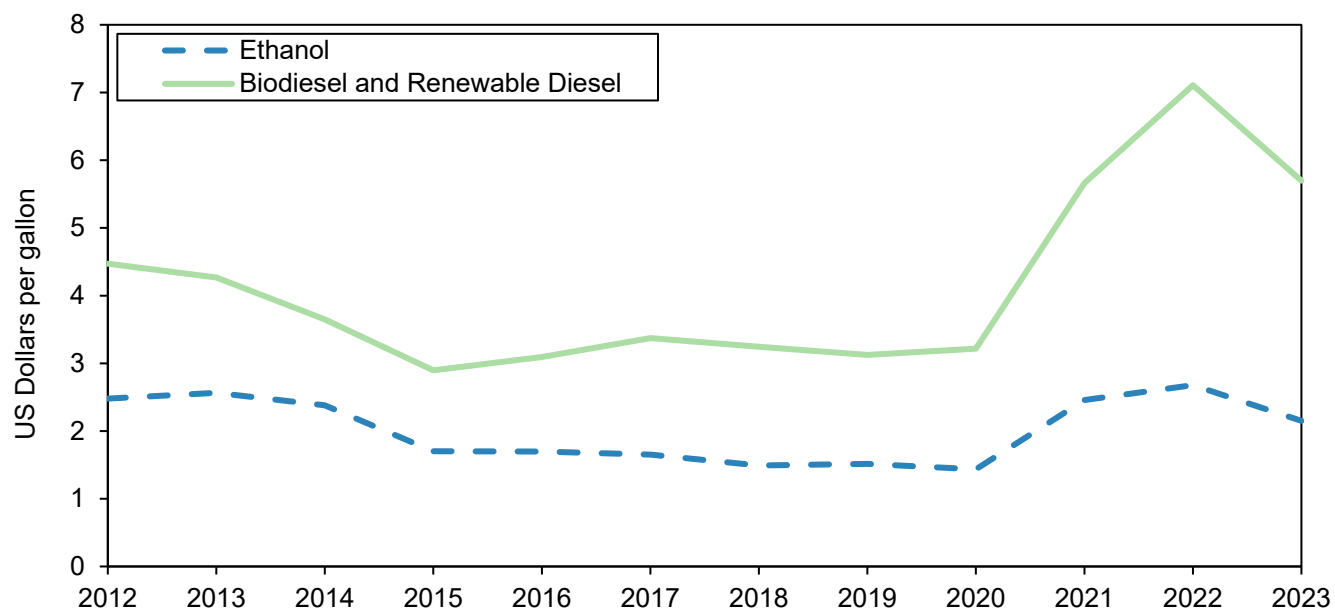


Figure 1.1.6. World price by biofuel from 2012 to 2023 (in U.S. dollars per gallon) (OECD-FAO Agricultural Outlook, 2024).

Table 1.1.1. World policies to mitigate biofuels and feedstock price increases (IEA, 2024).

Country	Policy proposal, change, or continuation
Argentina	Reduced the biodiesel blend rate from the original 10% to 5%.
Brazil	Maintained the biodiesel blending mandate at 10%, instead of the intended 15% target for 2022.
Belgium	Proposed a temporary removal of current biofuel mandates and a gradual phase-out of crop-based fuels by 2030.
Colombia	Reduced ethanol blending mandate from 10% to 4% between April 2020 and January 2022; proposed a 6% target until August 2022.
Czech Republic	Proposed the removal of blending targets (but this will not be confirmed until the end of the year), while maintaining greenhouse gas reduction requirements.
Finland	Reduced the renewable energy requirement from 20% to 12% for 2022.
Germany	Proposed reducing the use of agrofuels derived from food and feed crops, in response to high food prices.
Sweden	Proposed a pause to its GHG targets for the transport sector in 2023.
Indonesia	Plans to increase its 40% blending mandate, but not until 2023.
Croatia	Removed penalties for blenders that miss their targets.
United States	Allowed 15% ethanol blending during summer months.

1.2. Biobased Chemicals

Traditionally, the biobased chemicals sector has relied on sugar, starch, and oil crops as feedstocks. However, in recent years, new feedstocks such as residues from agriculture and forestry, as well as organic waste (i.e. food, municipal solid waste, sewage and wastewater), have gained more attention. This shift was driven by the need to avoid competition with food and ensure a sustainable supply (Jong et al., 2020).

Corporate Actions

In 2023, the biobased chemical market was valued at \$67.9 billion, representing less than 10 percent of the overall global chemical market. However, companies' investment, consumer willingness to pay for more sustainable product, and advances in technology were all drivers of growth in production and use of biobased chemicals (Polaris Market Research, 2023).

Key drivers of the biobased chemical sector include R&D investments by major chemical companies as well as by startups like Genomatica. Companies in the global biochemical market include:

- **Cargill Incorporated (U.S):** Cargill produces and distributes biochemical products such as bio-polyols, coalescing agents, dielectric fluids, and epoxy products for food, ingredients, agricultural, and industrial solutions. The company operated in 70 countries, employed 160,000 people, and earned \$177 billion in revenue in 2023 (Cargill, 2024).
- **Mitsubishi Chemical Corporation (Japan):** Mitsubishi is Japan's largest chemical corporation. Its portfolio includes biobased and biodegradable materials, renewable polymers, and sustainable processes to reduce GHG and resource consumption. The company operated in 45 countries, employed 25,000 people, and generated \$32 billion in revenue in 2023 (Mitsubishi Chemical Corporation, 2024).
- **Braskem (Brazil):** This company produces biopolymers, such as polyethylene from sugarcane, at industrial scale. Braskem operated in over 70 countries, employed 8,000 workers, and generated nearly \$14 billion in revenue in 2023 (Braskem, 2024).
- **Genomatica (U.S):** A United States company with 58.7 million dollars in revenue and 260 employees in 2023. Genomatica develops sustainable materials, such as renewable butanediol (bio-BDO) and bio-based nylon, and owned a portfolio of over 1,800 patents and patent applications as of 2023. The company employed 260 people and earned revenue of \$58.7 million in 2023 (Genomatica, 2024).

In addition, consumer brands such as Michelin, Unilever, and L'Oréal made significant commitments to increase the use of biobased chemicals (LEK, 2023). Some examples of these commitments include:

Michelin: The company set a goal to use 100 percent renewable and recycled materials in its tires by 2050, and 40 percent by 2030. To achieve this, the company began to invest in the production of biobased butadiene derived from ethanol, a key ingredient in synthetic rubber production (Michelin, 2024).

Unilever: The company's plans included (Unilever, 2024):

- **Reformulating products:** using lower-GHG and biobased chemicals.
- **Regenerative agriculture:** scaling up more sustainable farming practices in their value chain.
- **Packaging:** reducing material use and transitioning towards recycled and renewable feedstocks.

As part of this program, Unilever partnered with Evonik to produce biosurfactants for its cleaning products, replacing traditional petrochemical surfactants with plant-based options.

L'Oréal: The company set goals to use 95 percent biobased ingredients, 100 percent recycled or biobased plastics in packaging, reduce packaging by 20 percent, and recycle or reuse 100 percent of waste generated at its sites by 2030. In 2023, L'Oréal used 65 percent biobased ingredients in its

products, used 32 percent recycled or biobased plastic in packaging, and reused or recycled 97 percent of its waste (L'Oréal, 2024).

To continue growing, the biobased chemical sector must address several challenges (LEK, 2023):

- **Cost comparison to traditional chemicals:** petrochemicals are often cheaper than their biobased equivalents, although production costs can vary significantly depending on the specific chemical.
- **Product reformulation:** customers are required to reformulate products to include biobased chemicals.
- **Feedstock competition:** biobased feedstocks must not compete with food production.
- **Commercialization:** scaling up R&D projects requires significant capital and time investment.

1.3. Bioplastics

By 2023, there was a biobased plastic alternative for almost every traditional plastic material and its application. Bioplastics can display the same properties as their conventional counterparts but offer social and environmental benefits, such as reduced fossil fuel usage, lower carbon footprint, and additional waste management options.

The growth of bioplastics in products and applications drove an increase in manufacturers, converters, and end users. According to European Bioplastics, the principal factors driving this market expansion were:

- High consumer acceptance rates.
- Concerns about climate change, rising fossil materials costs, and increasing dependence on fossil materials.
- Efficiency and technological maturity of bioplastics.
- Increased biomass share of bioplastics, ensuring renewability and availability.
- Commitments from major brands such as Procter & Gamble, Puma, Lego, IKEA, Heinz, or Toyota, which enhanced consumers awareness and demand for bioplastics.

Production

Global bioplastics production accounted for 0.7 percent of total plastic production in 2023, a 150 percent increase since 2018, when bioplastic share represented just 0.3 percent of total plastic production. This growth was driven by rising demand and the emergence of new applications and products (EuropeanBioplastics, 2024).

According to European Bioplastics, the production of bioplastics in 2023 was nearly evenly divided between non-biodegradable and biodegradable polymers. The most commonly-produced and used bioplastics were Polyamide nylon (PA), Polyethylene (PE), Polylactic acid (PLA) and Polytrimethylene terephthalate (PTT) (see Figure 1.3.1.) (Plastics Industry Association, 2024).

China led both the plastic and bioplastic markets in 2023, representing 33 and 35 percent of global plastic and bioplastic production, respectively. North America and Europe were the other two large markets for plastics and bioplastics (see Figure 1.3.2). Europe's largest bioplastics producers were Germany (41 percent of EU production), Italy (34 percent), and France (10 percent) (Plastics Europe, 2024). Overall, bioplastics production was growing significantly in 2022 and 2023 (European Bioplastics, 2024).

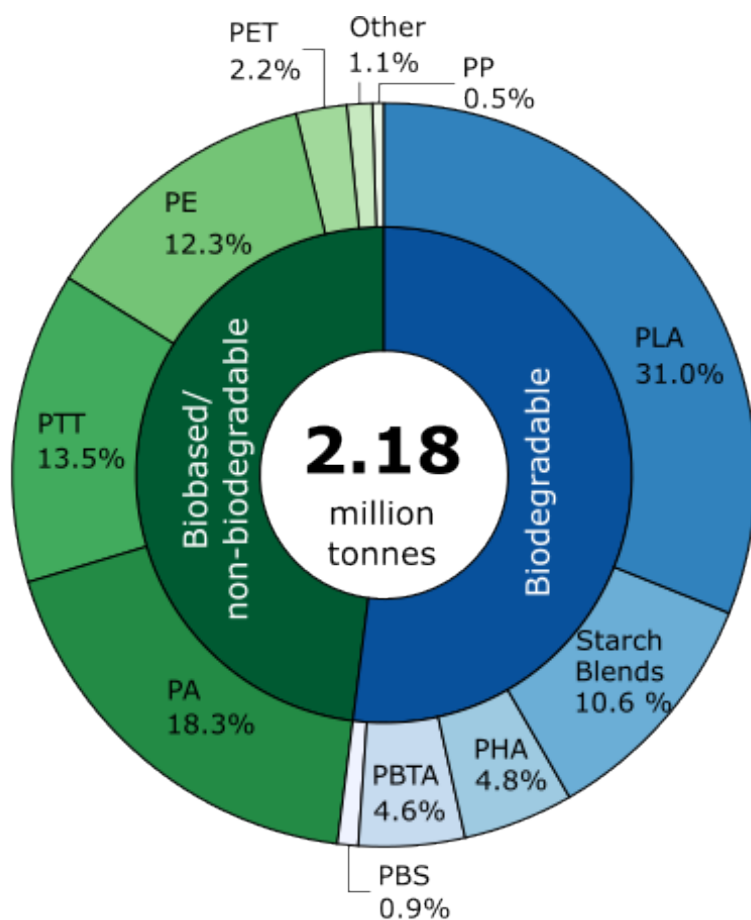


Figure 1.3.1. Global bioplastics production capacities by type in 2023 (Plastics Industry Association, 2024).

Although bioplastics are still an emerging market, a deeper look into bioplastic production over the years by region (see Figure 1.3.3) shows significant growth of 94 percent in 2023 in comparison with

2017 levels. The European Union represented the largest rise at 120 percent increase in production between 2017 and 2023, followed by the United States (97 percent increase), and Brazil (85 percent increase).

Key segments in bioplastic applications included packaging (49 percent of revenue growth) and textiles and consumer goods (29 percent), which reflected changing consumer preferences for sustainable products (see Figure 1.3.4) (Plastic Industry Association, 2024).

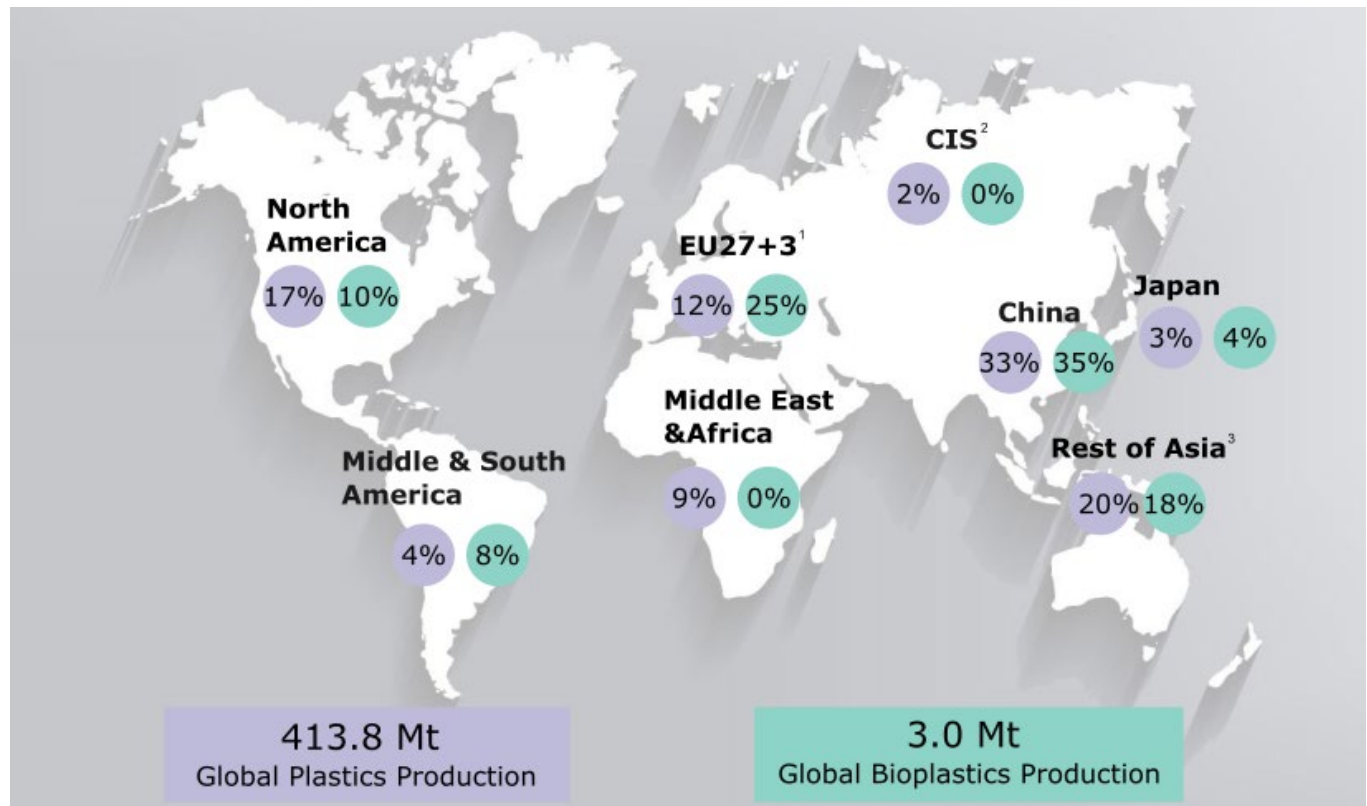


Figure 1.3.2. 2023 Percentage of bioplastic production (green) and plastic production (purple) by region [1. European Union Member States, Norway, Switzerland, and the United Kingdom. 2. Commonwealth of Independent States: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, and Uzbekistan. 3. Includes Asian countries (except China & Japan), Oceania, Turkey, and Ukraine.] (Plastics Europe, 2024).

As of 2023, the top five companies in the world bioplastic were, by revenue (Emergen Research, 2023):

- **BASF SE (Germany):** BASF offers completely compostable plastics derived from renewable sources such as Ecovio (PBTA, PLA) and Ecoflex (PBAT) (BASF, 2024).
- **Eastman Chemical Company (U.S.):** Eastman Chemical Company produces TREVA, a cellulose based engineering bioplastic (Eastman, 2024).

- **Futamura Group (Japan):** Futamura Group produces a wide range of bioplastic films, cellulose films, fibrous casing, activated carbon, and phenolic laminated sheets (Futamura, 2024).
- **NatureWorks LLC (U.S.):** NatureWorks LLC manufactures bioplastics, derived entirely from plant resources such as cornstarch. It was the first company to produce PLA at commercial scale and the largest manufacturer globally of PLA derived from corn starch (NatureWorks, 2024).
- **Plantic Technologies (Australia):** Plantic Technologies is focused on developing starch-based plastics obtained from renewable sources for packaging applications (Plantic, 2024)

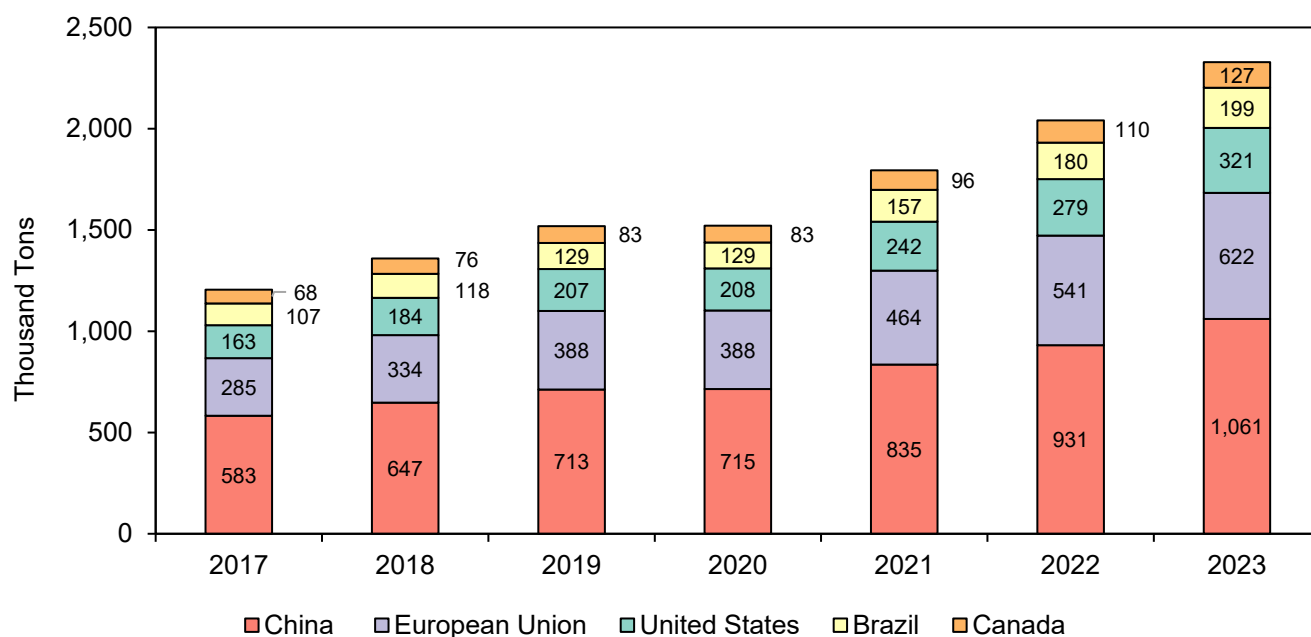


Figure 1.3.3. Total bioplastics production by country or region from 2017 to 2023 (in Thousand Tons) (MarketLine Industry, 2023). Note: Values for 2023 are forecasts.

Economic Impact

As presented below, figure 1.3.5 analyzes the bioplastics market value by country or region from 2017 to 2023. As seen, the bioplastics market value has followed a similar growth trajectory to production. However, in monetary terms, the European Union is the leader market surpassing China. In 2023, the European Union was the largest market, valued at 3 billion dollars (a 116 percent increase from 2017), followed by China at 2.8 billion dollars (a 79 percent increase from 2017), and the United States at 1.4 billion dollars (an 85 percent increase from 2017). In monetary terms, the market is projected to grow by 5.3 billion by 2027, a 61 percent increase in 5 years (MarketLine Industry, 2023)

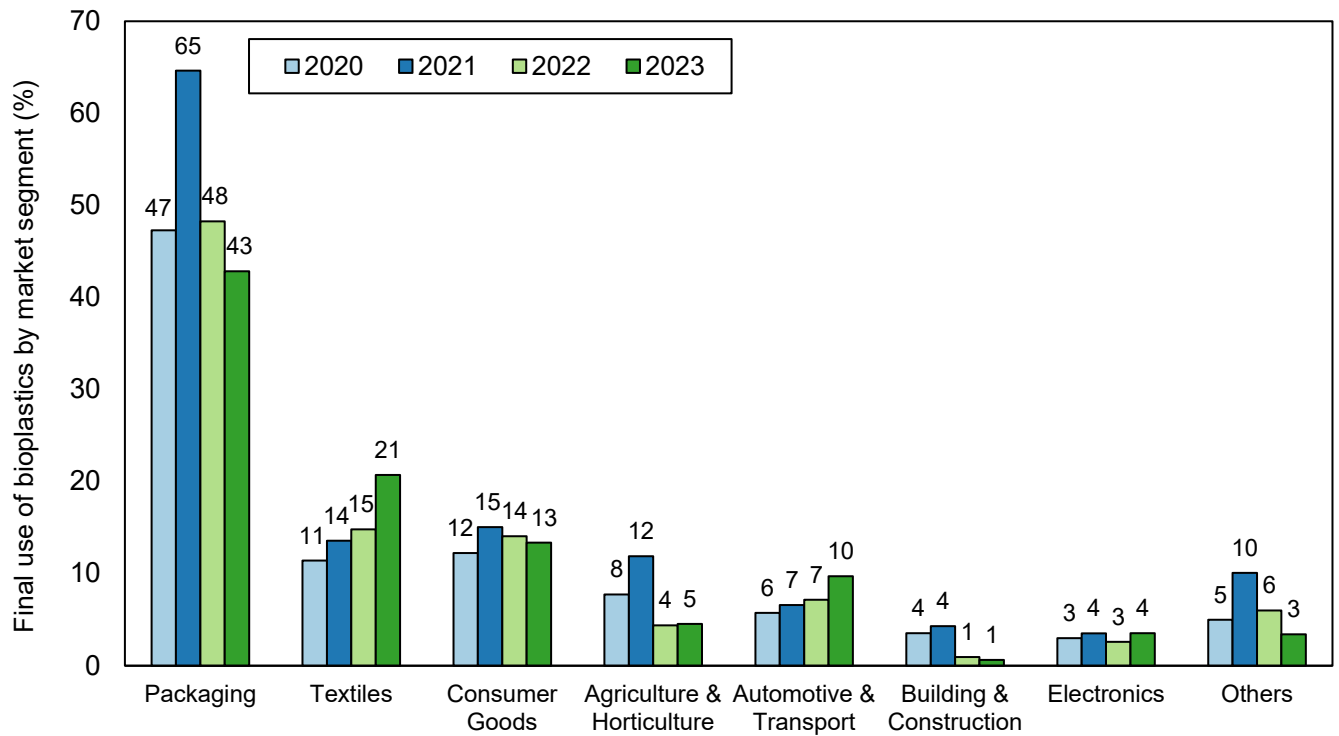


Figure 1.3.4. Global market segmentation by revenue from 2020 to 2023 (EuropeanBioplastics, 2023).

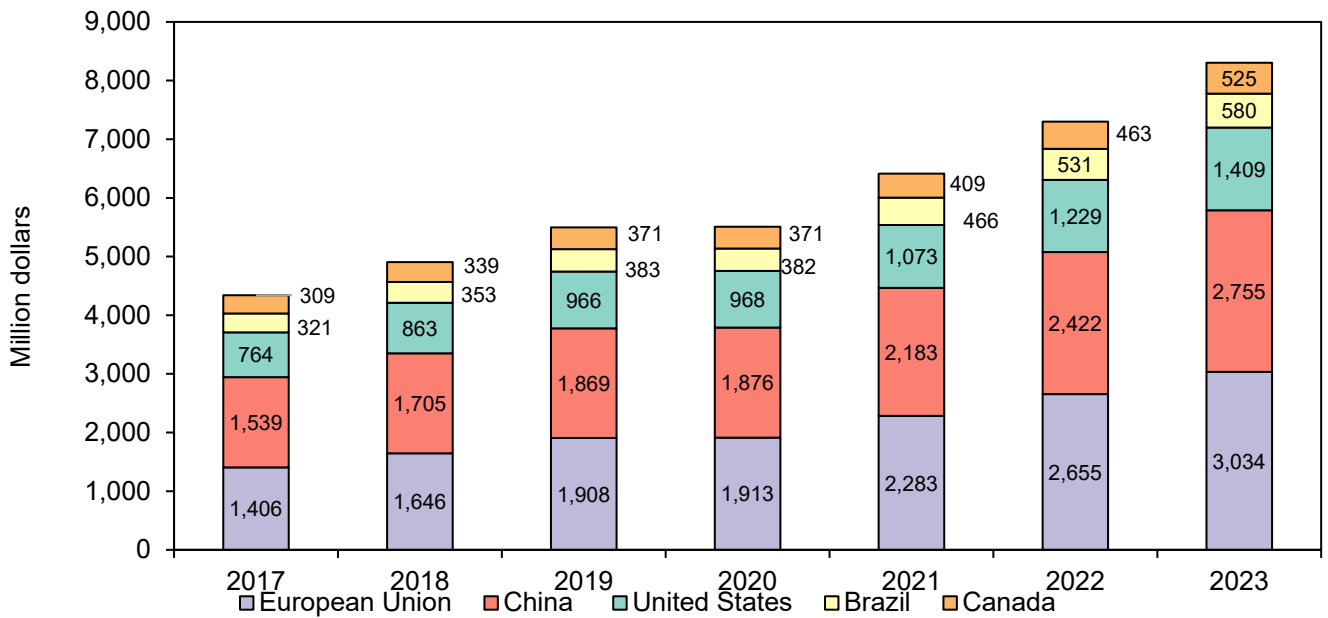


Figure 1.3.5. Total bioplastics market value by country or region from 2017 to 2023 (in million dollars) (MarketLine Industry, 2023) Note: Values for 2023 are forecasts.

1.4. References

BASF. ecovio® (PBAT, PLA) – Certified Compostable Polymer with Bio-based Content. (2024). Accessed from: https://plastics-rubber.basf.com/global/en/performance_polymers/products/ecovio/ [Accessed October 2024].

Braskem. Sustainably sourced bio-based plastic. (2024). Accessed from: <https://www.braskem.com/imgreen/my-environmental-impact> [Accessed October 2024].

Cargill. BioIndustrial Products. (2024). Accessed from: <https://www.cargill.com/bioindustrial/bioindustrial-product-categories> [Accessed October 2024].

Eastman. Products. (2024). Accessed from: <https://www.eastman.com/en/products/product-finder> [Accessed October 2024].

Emergen Research. Top 8 Bioplastic Companies Transforming the World in an Eco-friendly Way. (2023) Accessed from: <https://www.emergenresearch.com/blog/top-8-bioplastic-companies-transforming-the-world-in-an-eco-friendly-way> [Accessed April 2024].

EuropeanBioplastics. Bioplastics market development update 2023. (2023) Accessed from: <https://www.european-bioplastics.org/market/> [Accessed April 2024].

Futamura. NatureFlex™ - Compostable and renewable packaging films. (2024). Accessed from: <https://www.futamura.com/en/divisions/cellulose-films/products/natureflex/> [Accessed October 2024].

Genomatica. Our Products. (2024). Accessed from: <https://www.genomatica.com/products> [Accessed October 2024].

International Energy Agency. Renewables 2023. (2024) Accessed from: <https://www.iea.org/reports/renewables-2023> [Accessed March 2024].

International Energy Agency. Will energy security concerns drive biofuel growth in 2023 and 2024?. (2024) Accessed from: <https://www.iea.org/reports/renewable-energy-market-update-june-2023/will-energy-security-concerns-drive-biofuel-growth-in-2023-and-2024> [Accessed March 2024].

International Renewable Energy Agency -IRENA. Renewable Energy and Jobs – Annual Review 2022. (2023). Accessed from: <https://www.irena.org/publications/2022/Sep/Renewable-Energy-and-Jobs-Annual-Review-2022> [Accessed March 2024].

Jong, E., Stichnothe, H., Bell, G., Jørgensen, H. Bio-based chemicals a 2020 update. (2020). Accessed from: <https://www.ieabioenergy.com/blog/publications/new-publication-bio-based-chemicals-a-2020-update/> [Accessed April 2024]

LEK. Identifying Growth Opportunities in Bio-based Chemicals. (2023). Accessed from: <https://www.lek.com/insights/ind/us/ei/identifying-growth-opportunities-bio-based-chemicals> [Accessed April 2024]

L'Oréal. Preserving Natural Resources. (2024). Accessed from: <https://www.loreal.com/en/commitments-and-responsibilities/for-the-planet/preserving-natural-resources/> [Accessed April 2024].

MarketLine. Industry Profile. (2023) Accessed from: <https://advantage-marketline-com.libezproxy2.syr.edu/Analysis?reporttype=5914> [Accessed April 2024].

Michelin. MICHELIN, leader in sustainable mobility. (2024). Accessed from: <https://www.michelin.com/en/sustainability/mobility> [Accessed October 2024].

Mitsubishi Chemical Corporation. Products. (2024). Accessed from: <https://www.m-chemical.co.jp/en/products/index.html> [Accessed October 2024].

NatureWorks. Technology and Products. (2024). Accessed from: <https://www.natureworkslc.com/technology-and-products> [Accessed October 2024].

OECD-FAO. Agricultural Outlook. (2023). Accessed from: <https://doi.org/10.1787/agr-outl-data-en>. [Accessed March 2024].

OECD-FAO. Agricultural Outlook, Biofuels. (2024). Accessed from: <https://www.oecd-ilibrary.org/sites/cdc97c88-en/index.html?itemId=/content/component/cdc97c88-en#section-d1e24466-556a4a4157> [Accessed March 2024].

Plantic. Coles meat packaging made entirely from a combination of recycled and renewable material. (2024). Accessed from: <https://plantic.com.au/> [Accessed October 2024].

Plastics Europe. Plastics-the fast Facts 2024. (2024) Accessed from: <https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2024/> [Accessed January 2025].

Plastics Industry Association. Plastics Market Watch. Watching: Bioplastics 2024. (2024).

Polaris Market Research. Global Bio-based Chemicals Market Share, Size, Trends, Industry Analysis Report, By Type (Bio-Lubricants, Bio-Solvents, Bioplastics, Bio-Alcohols, Bio-Surfactants, Bio-Based

Acids); By End-Use; By Region; Segment Forecast, 2024 – 2032. (2023) Accessed from: <https://www.polarismarketresearch.com/industry-analysis/bio-based-chemicals-market> [Accessed April 2024].

Precedence Research. Bioplastics Market. (2024) Accessed from: <https://www.precedenceresearch.com/bioplastics-market> [Accessed March 2024].

Rahman, M.H., Bhoi, P.R., 2021. An overview of non-biodegradable bioplastics. J. Clean. Prod. 294, 126218.

Unilever. Our Climate Transition Action Plan. (2024). Accessed from: <https://www.unilever.com/sustainability/climate/our-climate-transition-action-plan/> [Accessed April 2024].

2. U.S. BIOECONOMY INVESTMENT UPDATES



2.1. Research & Development (R&D) Funding

The technologies used to produce biobased products and biofuels were relatively new compared to legacy fossil-based production methods as of 2023. As a result, these processes were still being developed and optimized, relying primarily on experimental techniques and innovative methodologies. To support the advancement of biobased products and biofuels, local, state, and federal agencies implemented various incentives programs including research grants awards for enterprises engaged in this sector.

The National Institute of Food and Agriculture (NIFA) and the National Science Foundation (NSF) maintain a database of awards granted to projects related to biobased products and biofuels (NIFA, 2025; NSF, 2025). Figures 2.1.1, 2.1.2, and 2.1.3 present the number of grants awarded to projects in three categories: traditional biofuels (i.e., ethanol, biodiesel, biogas, wood pellets, and waste to energy), emerging biofuels (i.e., renewable jet fuel, renewable diesel, recycled greases, and animal fats), and bioproducts (i.e., bioproducts, bioplastics, and biochemicals).

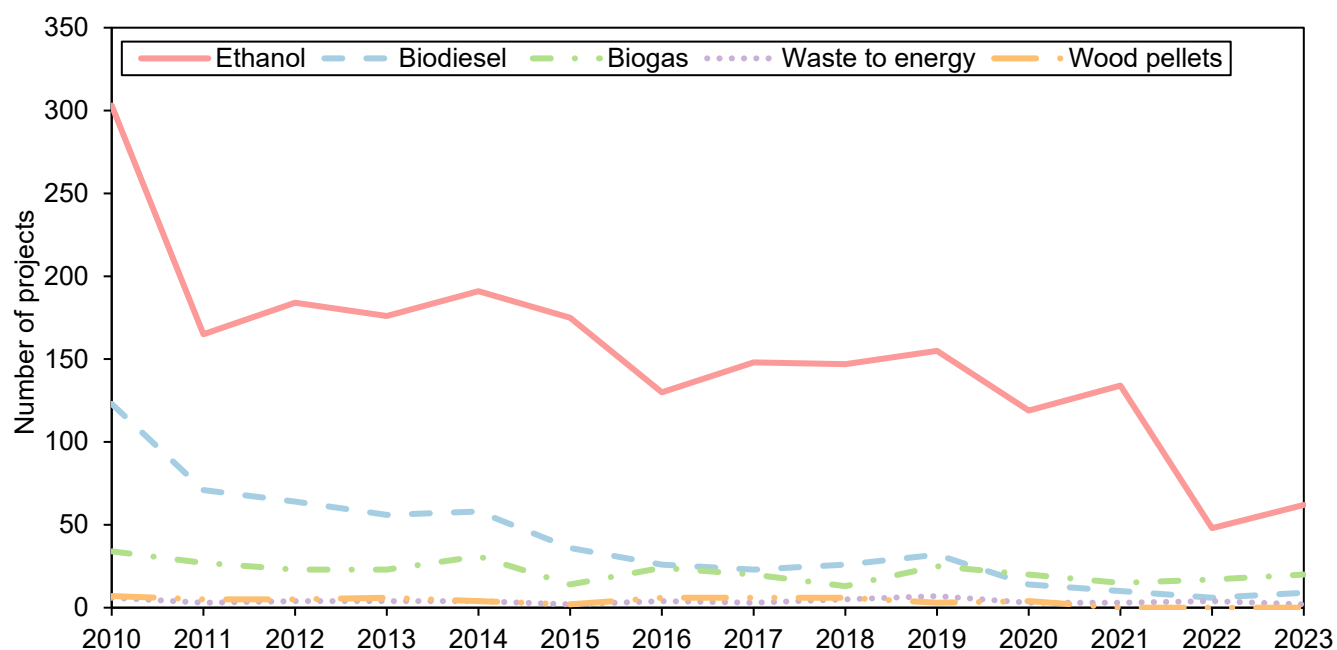


Figure 2.1.1. Number of awards to research projects containing traditional biofuel related keywords in the United States from 2010 to 2023 by NIFA and NSF (NIFA, 2025; NSF, 2025).

The number of awards for traditional biofuels projects has steadily declined since 2010, dropping from 473 research projects to just 93 in 2023. The most significant decreases were in projects related to ethanol and biodiesel (NIFA, 2025; NSF, 2025). This decline was largely driven by the fact that the

technologies associated with the production of these fuels are well-established and optimized, resulting in reduced research activity.

The decline was even more pronounced for emerging biofuels, with only seven research projects receiving funding in 2023 from both agencies combined (see Figure 2.1.2). Due to the novelty and evolving nature of these biofuels, their funding trends are more difficult to predict (NIFA, 2025; NSF, 2025).

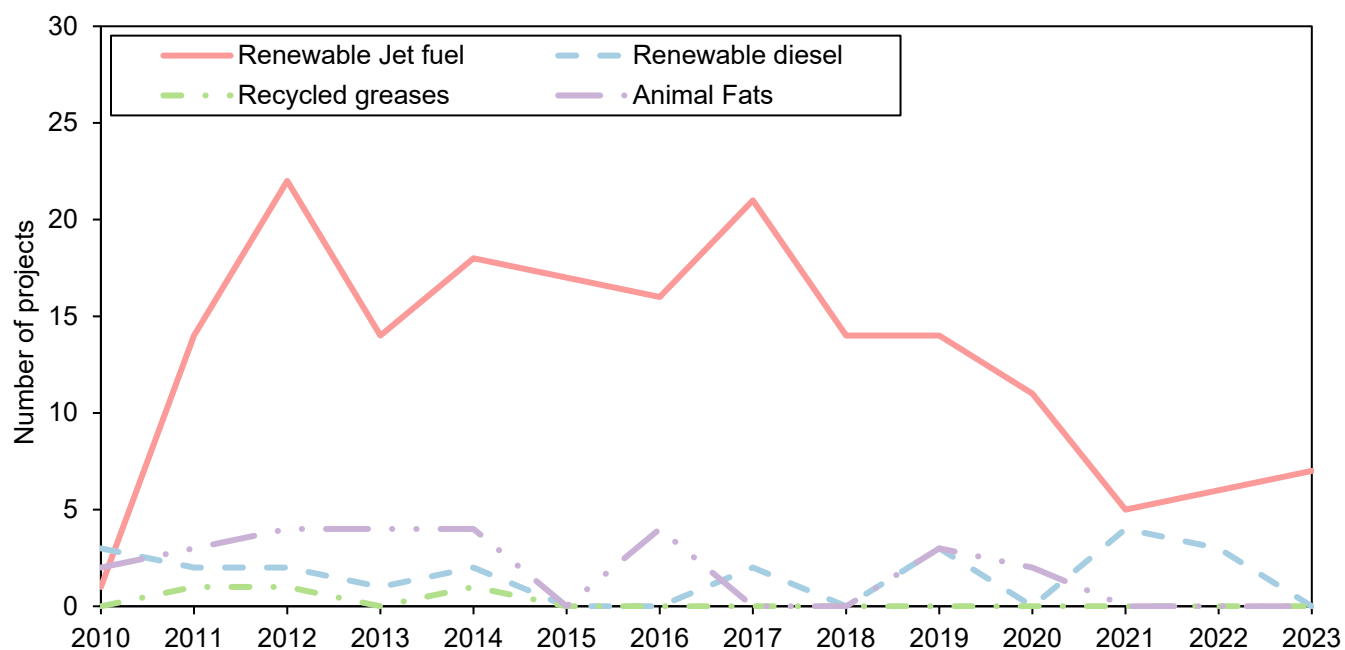


Figure 2.1.2. Number of awards to research projects containing emergent biofuels related keywords in the United States from 2010 to 2023 by NIFA and NSF (NIFA, 2025; NSF, 2025).

In contrast, the number of projects containing the keywords “bioplastics” and “biochemicals” has remained relatively stable, fluctuating between 15 and 20 research projects per year since 2010. However, projects related to the broader category of “bioproducts” have seen a significant decline, dropping from 102 awards in 2010 to 59 awards in 2023 (see Figure 2.1.3) (NIFA, 2025; NSF, 2025).

In 2023, 50 percent of NSF-funded projects received awards between \$100,000 and \$500,000, while only 15 percent were awarded over \$1 million. The funding distribution for traditional biofuels projects was even more skewed, with 77 percent of awards falling between \$100,000 and \$500,000, and only 8 percent exceeding \$1 million.

In contrast, NIFA’s award distribution was more balanced. In 2023, 29 percent of projects received less than \$250,000, 21 percent received between \$250,000 and \$500,000, 38 percent were funded between \$500,000 and \$1 million, and 12 percent received more than \$1 million. Specifically, for bioproducts

related projects, half of the awards (15) fell within the \$500,000 to \$1 million range (see Figure 2.1.4) (NIFA, 2025; NSF, 2025).

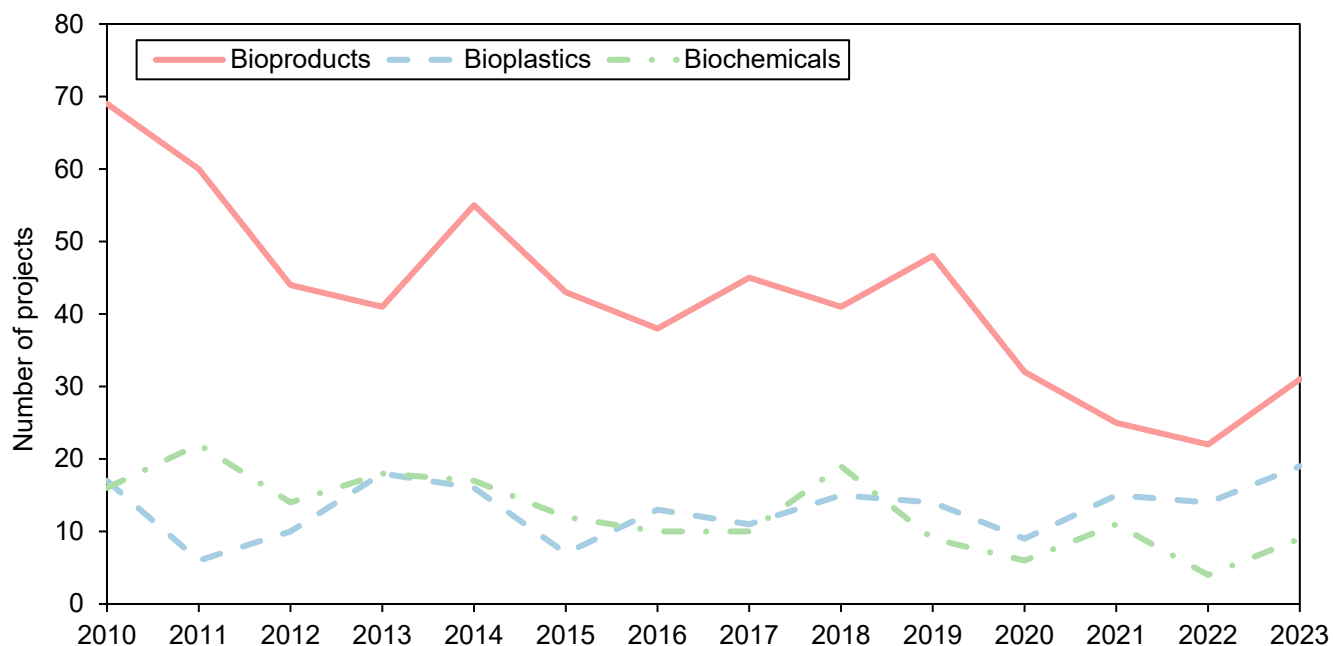


Figure 2.1.3. Number of awards to research projects containing keywords related to biobased products in the United States from 2010 to 2023 by NIFA and NSF (NIFA, 2025; NSF, 2025).

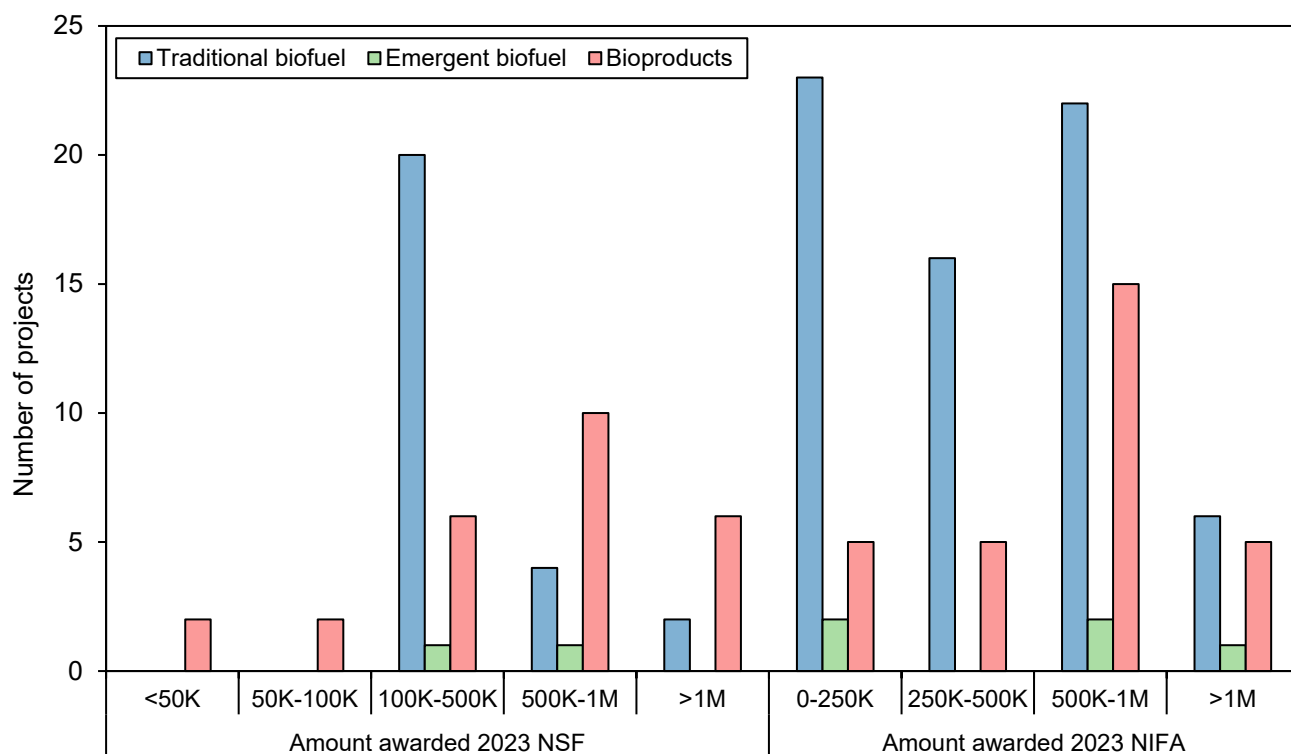


Figure 2.1.4. Award amount range in dollars for Biofuels research projects and Bioproducts research projects in 2023 in the United States by NIFA and NSF (NIFA, 2025; NSF, 2025).

2.2. Carbon Capture and Sequestration

One of the more recent developments has been American industry investment in carbon capture and sequestration (CCS) and carbon capture, utilization, and sequestration (CCUS). This presents unique opportunities for both domestically produced biofuels and bioenergy. Bioenergy with carbon capture and storage, or BECCS, involves capturing and permanently storing CO₂ from processes where biomass is converted into fuels or directly burned to generate energy. Because plants absorb CO₂ as they grow, this is a way of removing CO₂ from the atmosphere.

In the United States, there were 22 CCS facilities operating as of 2023, with a total CO₂ capture capacity of 24.2 million metric tons per year (see Table 2.2.1). Five ethanol production facilities contributed a combined 2 million metric tons of CO₂ capture capacity to the total.

The Inflation Reduction Act (IRA) of 2022 extended and modified tax credits for CCS and CCUS. Beginning in 2023, the section 45Q tax credit provided \$17 per metric ton of CO₂ captured and permanently stored in geological formations or \$12 per metric ton of CO₂ captured and utilized for enhanced oil and gas recovery or other qualifying use. If direct air capture (DAC) technology is employed, the 45Q credits are increased to \$36 per metric ton of CO₂ stored or \$26 per metric ton of CO₂ utilized. (The 45Q tax credits were subsequently increased by the One Big Beautiful Bill Act of 2025.)

In July 2023, ExxonMobil announced the acquisition of Denbury, an experienced developer of CCUS solutions, for \$4.9 Billion. The acquisition of Denbury provided ExxonMobil with the largest CO₂ pipeline network in the United States at 1,300 miles, including nearly 925 miles of CO₂ pipelines in Louisiana, Texas, and Mississippi (ExxonMobil, 2023).

Table 2.2.1. CCS Facilities operating in the United States as of 2023 (Global CCS Institute, 2025).

Name of Facility	Date	Location	Industry	CO ₂ Capture Capacity (million metric tons per year)
Occidental Terrell	1972	Texas	Natural Gas/LNG	0.5
Enid Fertilizer	1982	Oklahoma	Hydrogen/Ammonia/ Fertilizer	0.2
ExxonMobil Shute Creek Gas	1986	Wyoming	Natural Gas/LNG	7.0

Great Plains Synfuels Plant and Weyburn-Midale	2000	North Dakota	Hydrogen/Ammonia/ Fertilizer	3.0
Core Energy CO ₂ -EOR South Chester plant	2003	Michigan	Natural Gas/LNG	0.4
Arkalon CO ₂ Compression Facility	2009	Kansas	Bioenergy/Ethanol	0.5
Longfellow WTO Century Plant	2010	Texas	Natural Gas/LNG	5.0
Bonanza BioEnergy CCS	2012	Kansas	Bioenergy/Ethanol	0.1
Air Products Valero Port Arthur Refinery	2013	Texas	Hydrogen/Ammonia/ Fertilizer	0.9
Coffeyville Gasification Plant	2013	Kansas	Hydrogen/Ammonia/ Fertilizer	0.9
Contango Lost Cabin Gas Plant	2013	Wyoming	Natural Gas/LNG	0.9
Nutrien Geismar CCS	2013	Louisiana	Hydrogen/Ammonia/ Fertilizer	0.3
ADM Illinois Industrial	2017	Illinois	Bioenergy/Ethanol	1.0
Petra Nova	2017	Texas	Coal Power Generation and heat	1.4
Campo Viejo Gas Processing Plant	2018	Texas	Natural Gas/LNG	0.2
30-30 Gas Plant	2019	Texas	Natural Gas/LNG	0.1
Red Trail Energy	2022	North Dakota	Ethanol	0.2
Targa Red Hills natural gas processing complex	2022	New Mexico	Natural Gas/LNG	0.5
Barnett Zerp CCS	2023	Texas	Natural Gas/LNG	0.2
Targa Red Hills natural gas processing complex	2022	New Mexico	Natural Gas/LNG	0.5
Barnett Zerp CCS	2023	Texas	Natural Gas/LNG	0.2
Harvestone Blue Flint Ethanol	2023	North Dakota	Bioenergy/Ethanol	0.2
Total				24.2

2.3. New Biofuel Investments

With the increase commitments to decarbonize by companies and governments, biofuels are gaining increasing attention among long-established oil and gas companies. A 2024 report by RystadEnergy showed that the world’s leading oil and gas companies – BP, Chevron, Shell, TotalEnergies, ExxonMobil, and Eni – are making a significant shift towards green energy by expanding their investment in the biofuels sector with 43 new projects announced to start up by 2030. The focus of these investments is renewable diesel and renewable jet fuel, which are expected to make up 72 percent of projected capacity. BP is the leading company in the bioenergy shift with an announced new capacity of 104 thousand barrels per day of ethanol, renewable diesel and renewable jet fuel, followed by Chevron (47 thousand barrels per day), and Eni (39 thousand barrels per day) (See Figure ES-4) (RystadEnergy, 2024).

Other major investments in biofuels include the \$1.2 billion project between Marathon Petroleum Corporation and Neste to produce up to 730 million gallons per year of renewable fuels in the Martinez refinery in California (Marathon, 2022).

Additionally, Montana Renewables has invested over \$1.67 billion in biofuels through a DOE loan guarantee. Montana Renewables will expand its renewable fuels facility in Great Falls, Montana to produce renewable jet fuel, renewable diesel, and renewable naphtha. The facility currently produces about 140 million gallons per year of biofuels, mostly renewable diesel, and the expansion will produce about 315 million gallons per year, most of which will be renewable jet fuel (DOE, 2025).

Table 2.3.1. Recent biofuels investments in the U.S.

Company	State/ Region	Date	Amount	Details
Marathon Petroleum & Neste	California	August 2023	\$1.2 billion	730 MG/year renewable fuels
BP Products	Washington	September 2024	\$26.67 million	renewable jet fuel production
Crysalis	Illinois	September 2024	\$239.5 million	New renewable jet fuel facility
Brookfield	Texas	September 2024	\$1.1 billion	E-fuels production (e renewable jet fuel, eDiesel and eNaphtha)

Calumet Inc.	Montana	October 2024	\$1.67 billion DOE Loan Guarantee	Expansion for renewable jet fuel production
ExxonMobil	Texas	December 2024	NA	Developing a large-scale low-carbon hydrogen
USA BioEnergy	Texas	December 2024	\$2.8 billion	Renewable jet fuel facility in partnership with Southwest Airlines

2.4. References

ExxonMobil. ExxonMobil announces acquisition of Denbury (2023). Accessed from: https://corporate.exxonmobil.com/news/news-releases/2023/0713_exxonmobil-announces-acquisition-of-denbury [Accessed March 2025].

ExxonMobil. ExxonMobil signs carbon capture agreement with CF Industries in Mississippi (2024). Accessed from: <https://corporate.exxonmobil.com/what-we-do/delivering-industrial-solutions/carbon-capture-and-storage/exxonmobil-signs-carbon-capture-agreement-cf-industries-yazoo#:~:text=ExxonMobil%20signs%20carbon%20capture%20agreement,now%20up%20to%205.5%20MTA>. [Accessed March 2025].

Global CCS Institute. CCS Facilities Database. (2025). Accessed from: <https://www.globalccsinstitute.com/co2re/> [Accessed March 2025].

Illinois. Crysalis Biosciences Inc. Invests \$239.5 Million for Sustainable Aviation Fuel Facility in Sauget. (2024). Accessed from: <https://www.illinois.gov/news/press-release.30466.html> [Accessed March 2025].

International Energy Agency. Bioenergy with Carbon Capture and Storage. (2024) Accessed from: <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/bioenergy-with-carbon-capture-and-storage> [Accessed March 2025].

Marathon. Marathon Petroleum Corp Announces Closing of Martinez Renewables JV with Neste. (2022). Accessed from: <https://ir.marathonpetroleum.com/investor/news-releases/news-details/2022/Marathon-Petroleum-Corp-Announces-Closing-of-Martinez-Renewables-JV-with-Neste/default.aspx> [Accessed March 2025].

RystadEnergy. A major turn: Big Oil bets on biofuels with more than 40 projects planned by turn of decade. (2024). Accessed from: <https://www.rystadenergy.com/news/big-oil-bets-on-biofuels> [Accessed March 2025].

The National Institute of Food and Agriculture -NIFA- Enterprise Search. Accessed from: https://portal.nifa.usda.gov/enterprise-search/project_details [Accessed February 2025].

The National Science Foundation -NSF- Awards Advanced Search. Accessed from: <https://www.nsf.gov/awardsearch/advancedSearch.jsp> [Accessed February 2025].

TotalEnergies. United States: TotalEnergies acquires Talos Low Carbon Solutions, a pioneer in the growing American Carbon Storage industry. Accessed from: <https://totalenergies.com/media/news/press-releases/united-states-totalenergies-acquires-talos-low-carbon-solutions-pioneer> [Accessed April 2025].

United States Department of Agriculture - USDA – Partnership for Climate-Smart Commodities Projects. (2025). Accessed from: <https://www.biopreferred.gov/BioPreferred/faces/Welcome.xhtml> [Accessed February 2025].

United States Department of Energy -DOE- DOE Announces \$1.67 Billion to Montana Renewables to Significantly Expand US Sustainable Aviation Fuel Production (2025). Accessed from: <https://www.energy.gov/lpo/articles/doe-announces-167-billion-montana-renewables-significantly-expand-us-sustainable> [Accessed April 2025].

United States Steel. U. S. Steel and CarbonFree Sign Definitive Agreement to Capture Carbon Dioxide Emissions at One of the Largest North American Integrated Steel Mills. Accessed from: <https://investors.ussteel.com/news-events/news-releases/detail/672/u-s-steel-and-carbonfree-sign-definitive-agreement-to> [Accessed March 2025].

3. U.S. INDUSTRY UPDATES



3.1. Transportation Fuels

3.1.1. Ethanol

The United States was the world's largest producer of ethanol in 2023, accounting for 53 percent of global ethanol production in that year. It was followed by Brazil (28 percent) and the European Union (5 percent) (RFA, 2024).

In 2023, 134 million pounds (34 percent of total U.S. corn production) were consumed for ethanol production, accounting for 99 percent of ethanol feedstocks. The United States also led global corn production in 2023 (390 million metric tons, 32 percent of global production), followed by China (289 million metric tons, 24 percent of global production), and Brazil (122 million metric tons, 10 percent of global production) (USDA, 2024).

In 2023, the ethanol industry contributed 54.2 billion dollars to the GDP of the United States, comparable to the 68-billion-dollar contribution from the forestry and fishing industry or the 47-billion-dollar contribution from textile mills and textile product mill industry (BEA, 2024). Moreover, the ethanol industry supported nearly 350 thousand jobs, including direct, indirect and induced employment in 2023, although this represented a 6.5 percent decline compared to 2022 (RFA, 2011-2024).

While the number of ethanol production facilities in the United States remained relatively stable over the past decade, with 27 states in the United States containing at least one production facility, 2023 saw the lowest number of operational plants in this period, with 187 facilities in operation and only two under construction (see Figure 3.1.1.) (RFA, 2011-2024).

Despite this decline in plant numbers, improvements in production processes and technology optimization have driven continuous growth in ethanol output, reaching 15.6 billion gallons in 2023 as shown in figure 3.1.2. The transportation sector remained the primary domestic consumer of ethanol, followed by the industrial sector (EIA, 2024).

The United States maintained its position as a net exporter of ethanol in 2023, with production growth outpacing domestic consumption increases. Ethanol exports rose to 1.4 billion gallons, while imports fell to 27 million gallons, marking the lowest import level since 2010 (see Figure 3.1.3) (EIA, 2024).

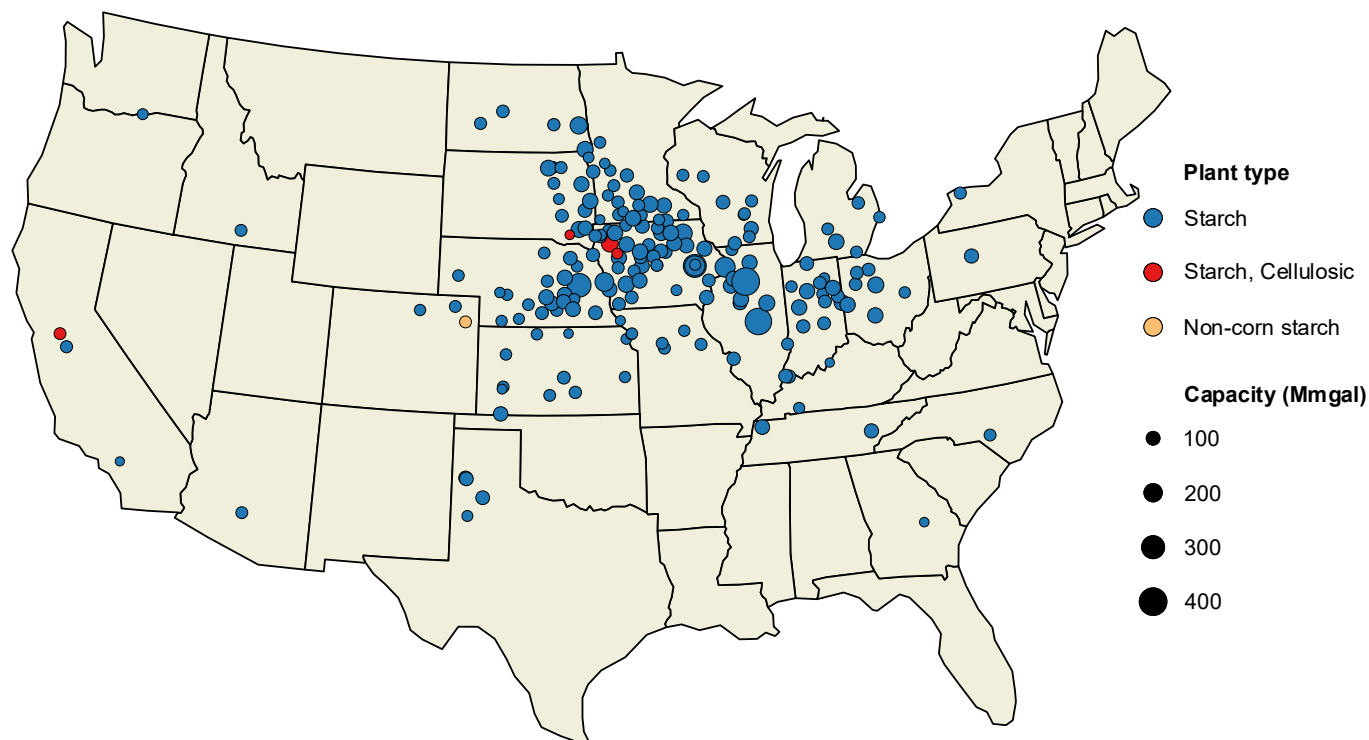


Figure 3.1.1. Ethanol production facilities in 2023 by location, capacity, and type in the United States (in million gallons) (Ethanol Producer Magazine, 2024).

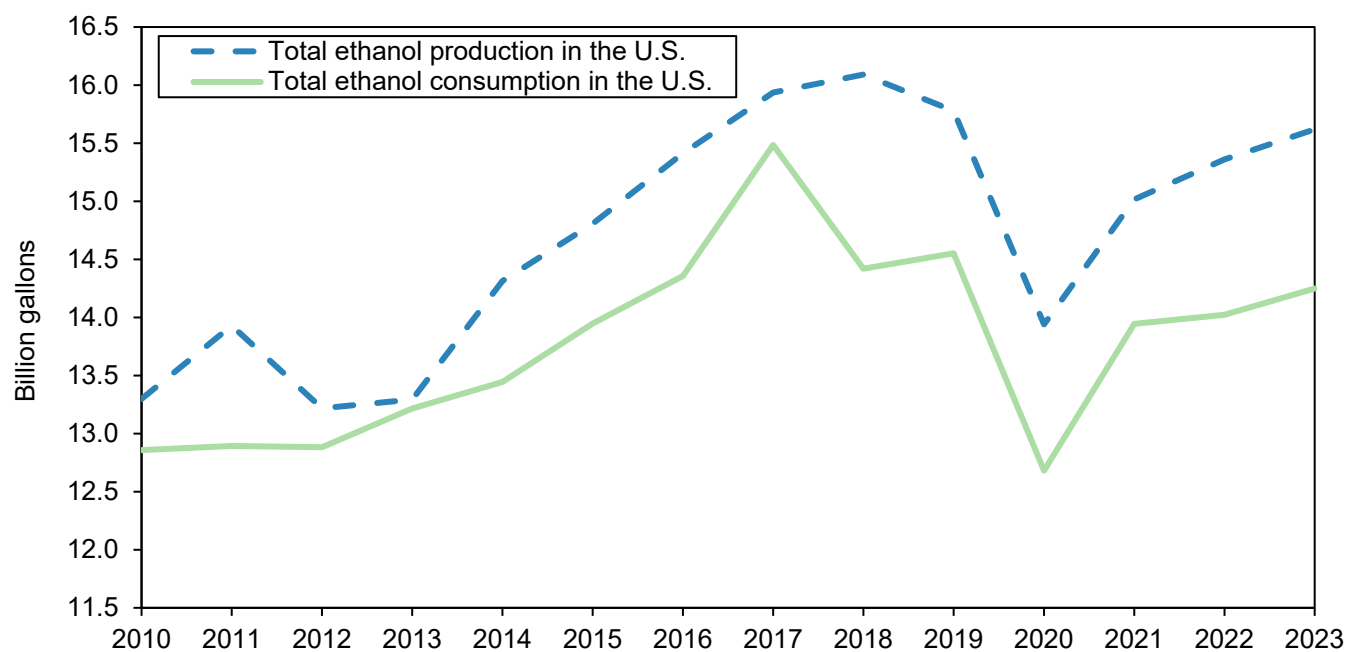


Figure 3.1.2. Total ethanol production and consumption in the United States from 2010 to 2023 (in billion gallons) (EIA, 2024).

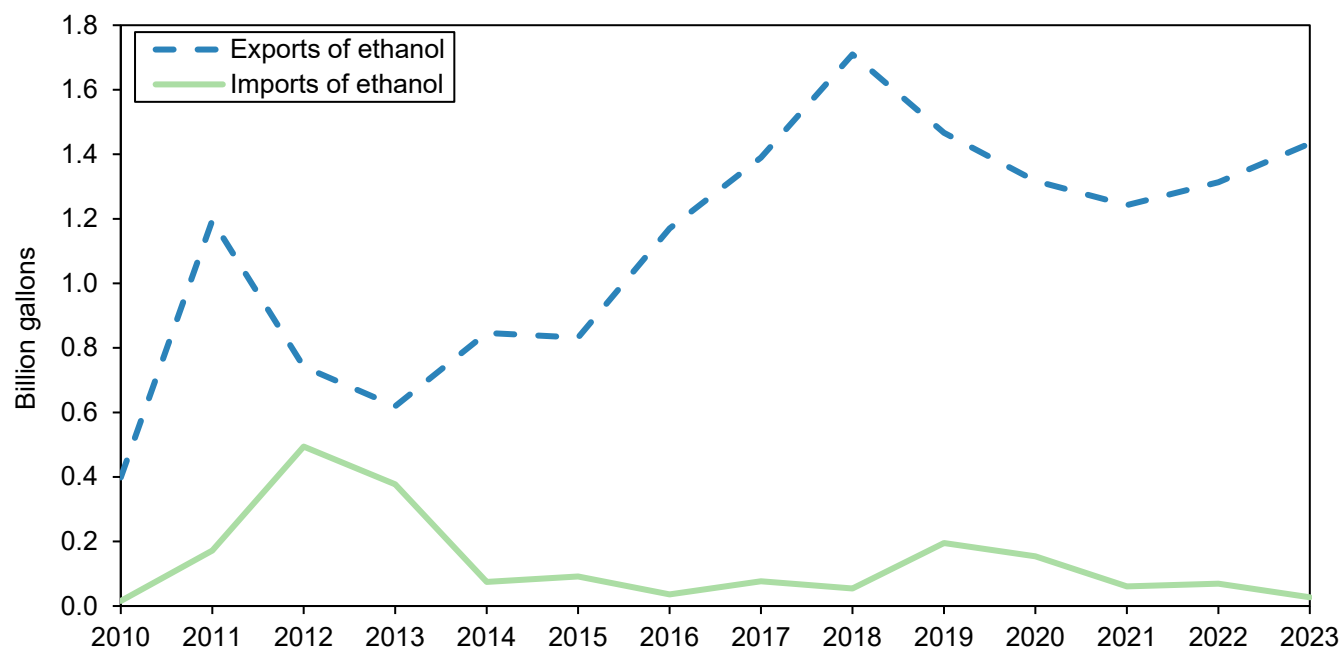


Figure 3.1.3. Exports and imports of ethanol in the United States from 2010 to 2023 (in billion gallons) (EIA, 2024).

Imports accounted for just 0.1 percent of domestic consumption, and the United States only imported ethanol from Brazil in 2023. Key export markets for U.S. ethanol included Canada, the United Kingdom, and the Netherlands (see Figure 3.1.4) (EIA, 2024).

Traditionally, ethanol has been used primarily as fuel, blended with gasoline. Since 2018, however, the use of ethanol has grown in nonfuel industrial applications, including disinfectants, solvents, and pharmaceuticals. This growing demand, especially from foreign manufacturing sectors, has contributed to the recent increase in U.S. ethanol exports (FAS, 2024).



Figure 3.1.4. Exports (blue line) and imports (green line) of ethanol in the United States by country in 2023 (in million gallons) (EIA,2024).

3.1.2. Agricultural Biogas - Renewable Natural Gas

Renewable natural gas (RNG) is derived from renewable sources such as manure from dairy or hog farms, agricultural crop residues, sludge from sewage water, municipal solid waste, and food waste. The biogas released from organic waste decomposition contains 40 to 60 percent methane (CH_4), which can be captured. Through refining processes, impurities like water, nitrogen, oxygen, hydrogen sulfide, ammonia, and carbon dioxide are removed, resulting in a gas with over 90 percent methane content. RNG can be seamlessly integrated as a "drop-in" replacement for fossil natural gas in pipelines and fueling stations and used in natural gas vehicles without engine modifications. This significantly reduces GHG emissions, particularly in cases where biogas would otherwise be released into the atmosphere, such as from waste lagoons.

Since 2017, the number of biogas production sites upgraded to produce RNG has increased dramatically in the United States, with 237 operational RNG projects at landfills or livestock waste anaerobic digesters by 2023 (see Figure 3.1.5.) (EPA, 2024).

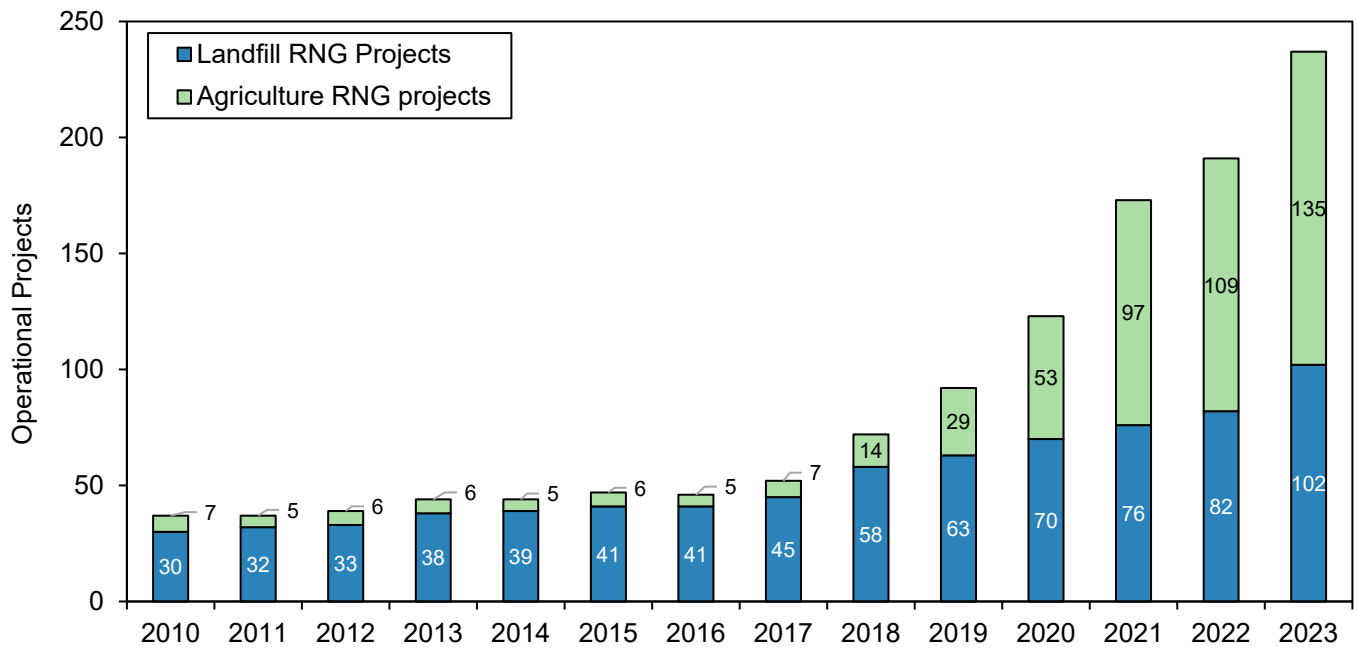


Figure 3.1.5. Operational projects of renewable natural gas from 2010 to 2023 in the United States (EPA, 2024).

3.1.3. Biodiesel

Biodiesel, also known as Fatty Acid Methyl Ester (FAME), is produced through a transesterification process using feedstocks such as vegetable oils, recycled cooking oils, or animal fats. The most common feedstocks for biodiesel production include soybean oil (57 percent), corn oil (14 percent), recycled greases (11 percent), canola oil (10 percent), and raw animal fats (8 percent). Unlike petroleum-based diesel, biodiesel is nontoxic and biodegradable (RFA, 2020; EIA, 2024).

In 2023, the number of U.S. biodiesel production facilities dropped to 59 plants, a 22 percent reduction from 2022. Despite this, U.S. biodiesel production increased by 12 percent from 1.6 billion gallons in 2022 to 1.7 billion gallons in 2023, supporting 66,261 American jobs. Biodiesel consumption also grew, reaching 1.9 billion gallons. This increase was driven by a decrease in biodiesel prices, which fell from \$6.50 per gallon in 2022 to \$5.20 per gallon in 2023 (EIA, 2024; Irena, 2023). Consequently, the number of B20 and B100 biodiesel fueling stations rose by 42 percent between 2022 and 2023 (USDA, 2024).

Iowa continued to lead the United States in biodiesel production in 2023. Even as renewable diesel production grew across the country, Iowa farmers expanded biodiesel demand beyond traditional highway fuel markets, to home heating oil, rail, and even marine applications (Iowa RFA, 2023). California, Texas, and Missouri collectively accounted for 30 percent of total U.S. biodiesel production capacity, with Illinois following closely behind in the number of biodiesel production plants in 2023.

Together, these states represented 46 percent of the total plants in the United States (see Figure 3.1.6.) (EIA, 2024).

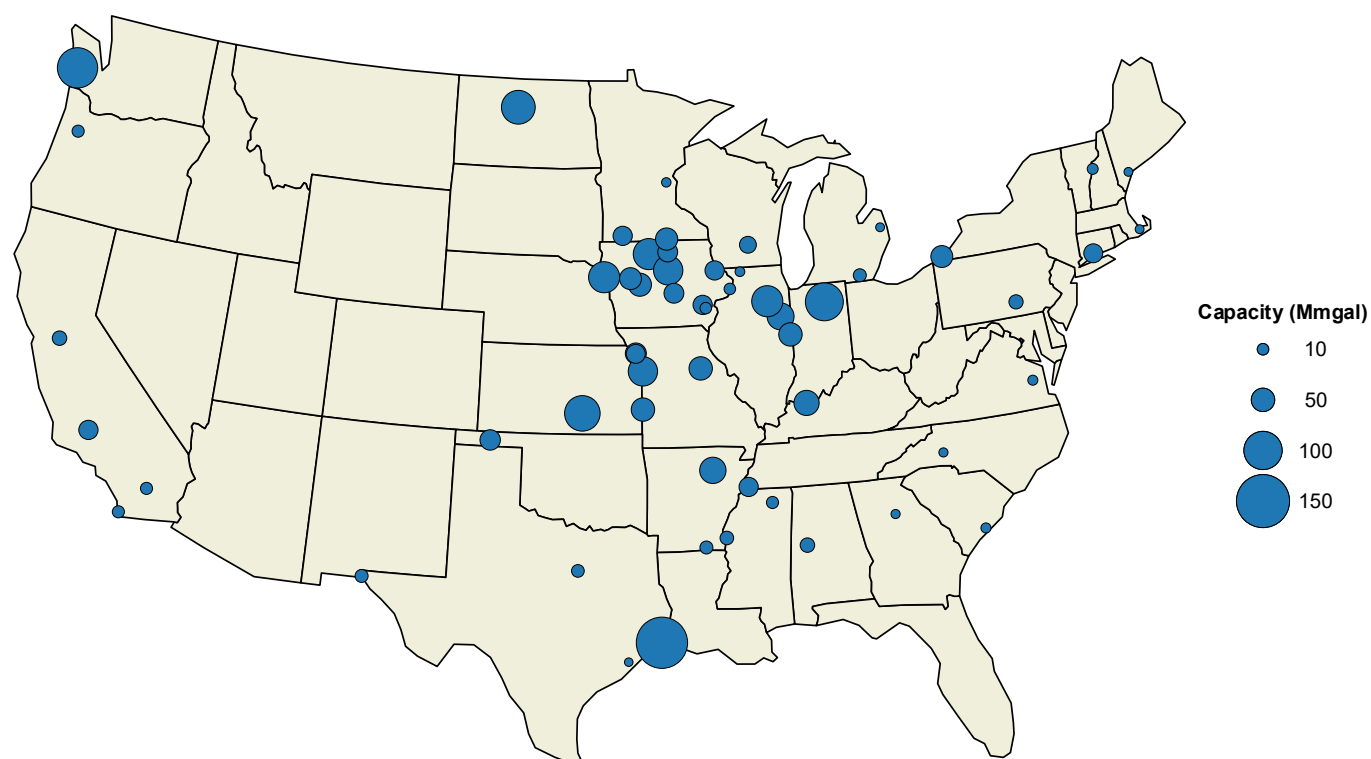


Figure 3.1.6. Biodiesel production facilities location by capacity (in million gallons) in the United States in 2023 (EIA, 2024).

In 2023, biodiesel consumption increased at a faster rate than production, making the United States a net importer of 10 million gallons of biodiesel (EIA, 2024). Production and consumption levels remained relatively stable from 2018 through 2023, with minor fluctuations (see Figure 3.1.7.). The extension of the Biodiesel Income Tax Credit incentives through December 2024 contributed to the increased consumption and production of biodiesel in the United States in 2023 relative to 2022 (AFDC, 2024).

In 2023, the United States exported a total of 251 million gallons of biodiesel, with Canada receiving 230 million gallons (92 percent of total exports), followed by Peru receiving 19 million gallons (8 percent) (EIA, 2020). At the same time, biodiesel imports rose by 100 percent compared to 2022, reaching 511 million gallons as a result of the growing demand to meet government renewable fuel programs (see Figure 3.1.8.) (EIA, 2024).

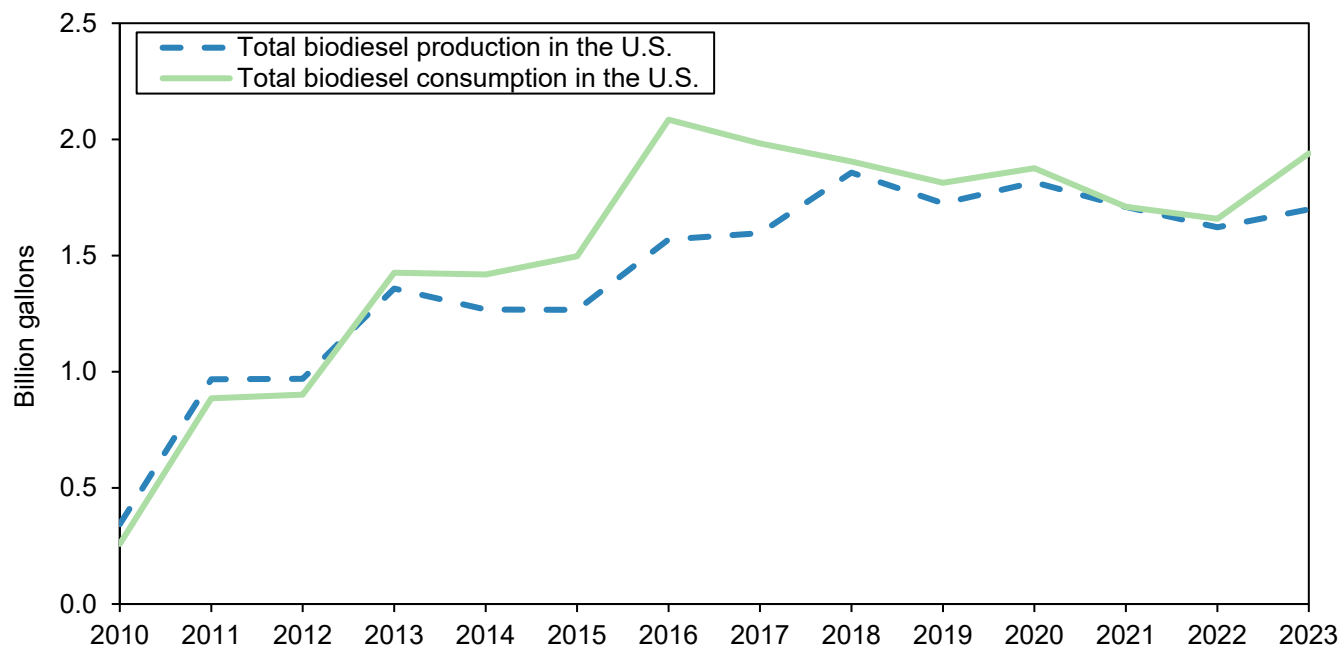


Figure 3.1.7. Total biodiesel production and total biodiesel consumption in the United States from 2010 to 2023 (in billion gallons) (EIA, 2024).

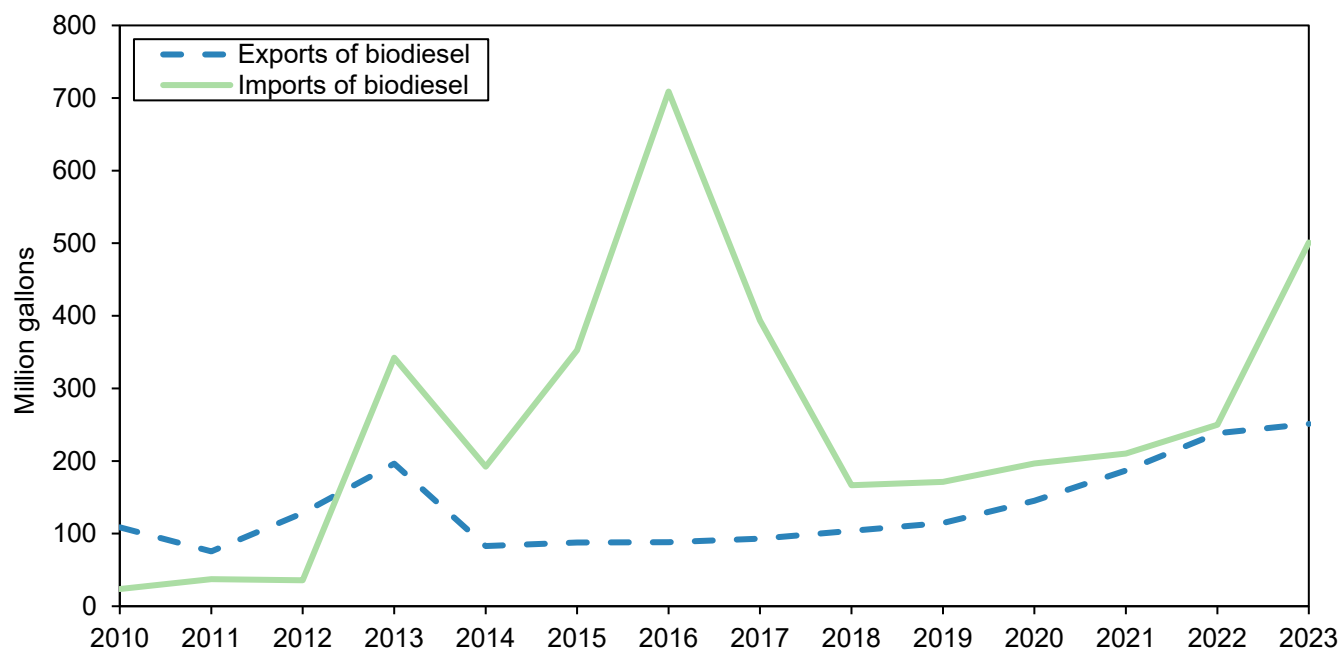


Figure 3.1.8. Exports and Imports of biodiesel in the United States from 2010 to 2023 (in million gallons) (EIA, 2024).

Germany (175 million gallons) and Canada (140 million gallons) were the primary sources of these imports, accounting for 63 percent of total U.S. biodiesel imports. The lower biodiesel prices in Europe, \$6.40 per gallon (\$1.70 per liter) in comparison to \$7.60 per gallon (\$2.00 per liter) in the United States

in 2022, made importing biodiesel from the region economically attractive (see Figure 3.1.9.) (IEA, 2022, EIA, 2024).

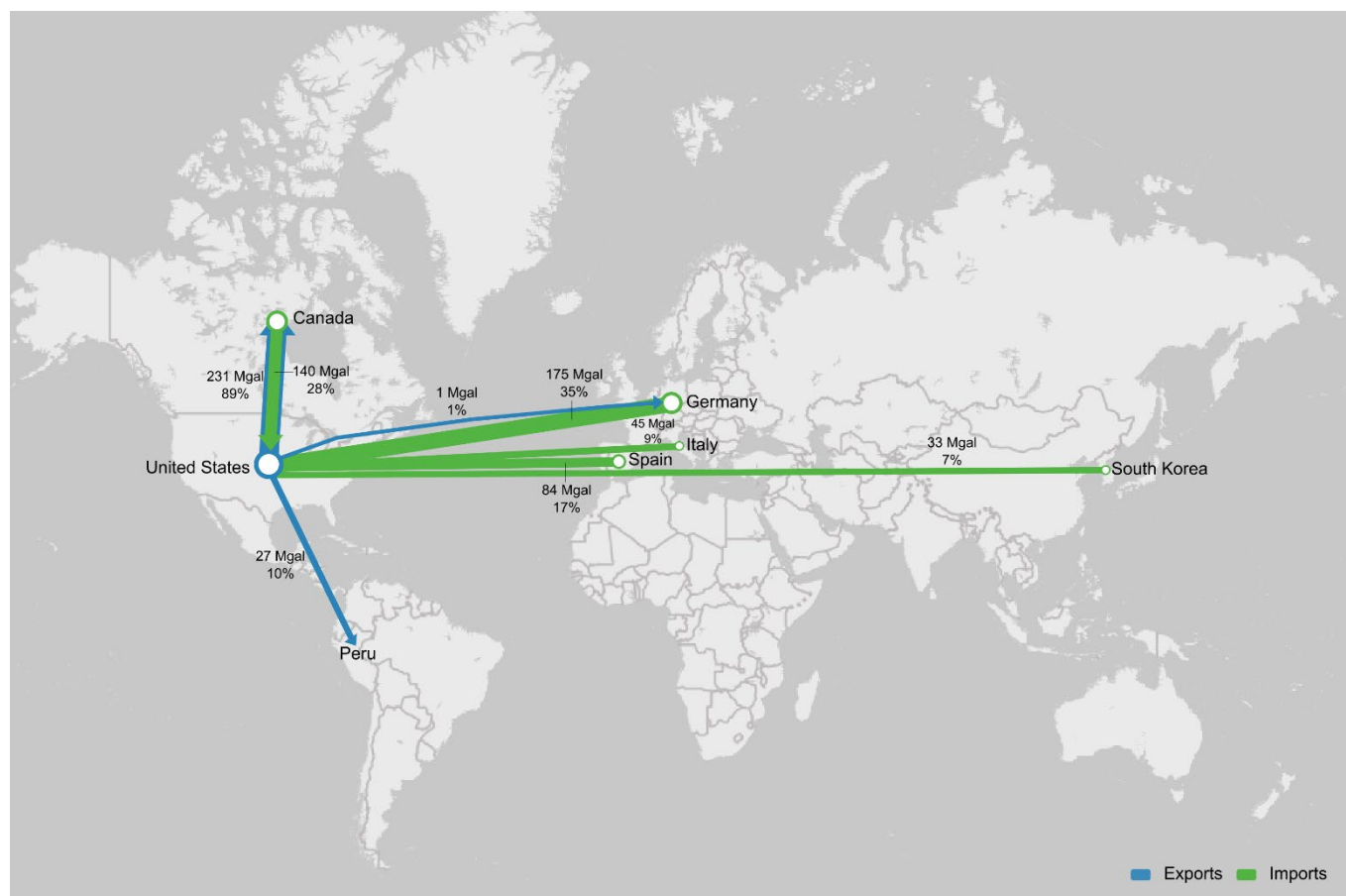


Figure 3.1.9. Exports (blue line) and imports (green line) of biodiesel in the United States by country in 2023 (in million gallons) (EIA, 2024).

From 2022 to 2023, petroleum diesel prices declined by 12 percent, and soy oil prices declined by 11 percent. As a result, the prices of B99/100 and B20 fell by 2 percent and 9 percent, respectively, in 2023 compared to 2022 (USDA, 2024; DOE, 2024).

3.1.4. Renewable Diesel

Renewable diesel, also known as Hydrotreated Esters of Fatty Acids (HEFA) or Hydrotreated Vegetable Oil (HVO), is a biomass-based diesel fuel. Unlike biodiesel, which is produced through transesterification of vegetable oils and animal fats, renewable diesel is obtained through thermochemical processes such as hydrotreatment of vegetable oils and animal fats, conversion of alcohols to hydrocarbons, or gasification and synthesis of biomass. These production methods yield renewable diesel that has no sulfur and is chemically equivalent to petroleum diesel, meeting the ASTM

D975 specification for diesel fuel. As a result, it is a drop-in replacement for conventional ultra-low sulfur diesel (ULSD), giving it a significant advantage over biodiesel.

Renewable diesel also complies with the stringent air emission regulations for California Air Resource Board (CARB) diesel fuel. Renewable diesel was found to reduce emissions of nitrogen oxides (NO_x), particulate matter (PM), unburned hydrocarbons (HC), and carbon monoxide (CO) compared to CARB's already-strict diesel fuel formulation. It is also considered an advanced biofuel since it can be derived from non-edible biomass (California Environmental Protection Agency, 2020).

The production of renewable diesel expanded rapidly in the U.S. during 2022 and 2023, with 17 production facilities reaching a combined capacity of 3 billion gallons per year (see Figure 3.1.13.). This represents a 74 percent increase from 2021 (when capacity was 0.8 billion gallons) and 42 percent from 2022 (when capacity was 7.8 billion gallons). In 2023, renewable diesel production capacity surpassed that of biodiesel for the first time. The number of states with renewable diesel production facilities increased from six in 2022 to 11 in 2023, with Texas and Louisiana emerging as the largest producers. This growth was driven by increasing state and federal renewable fuel policies, as well as the extension of biomass-based diesel tax credits (EIA, 2023).

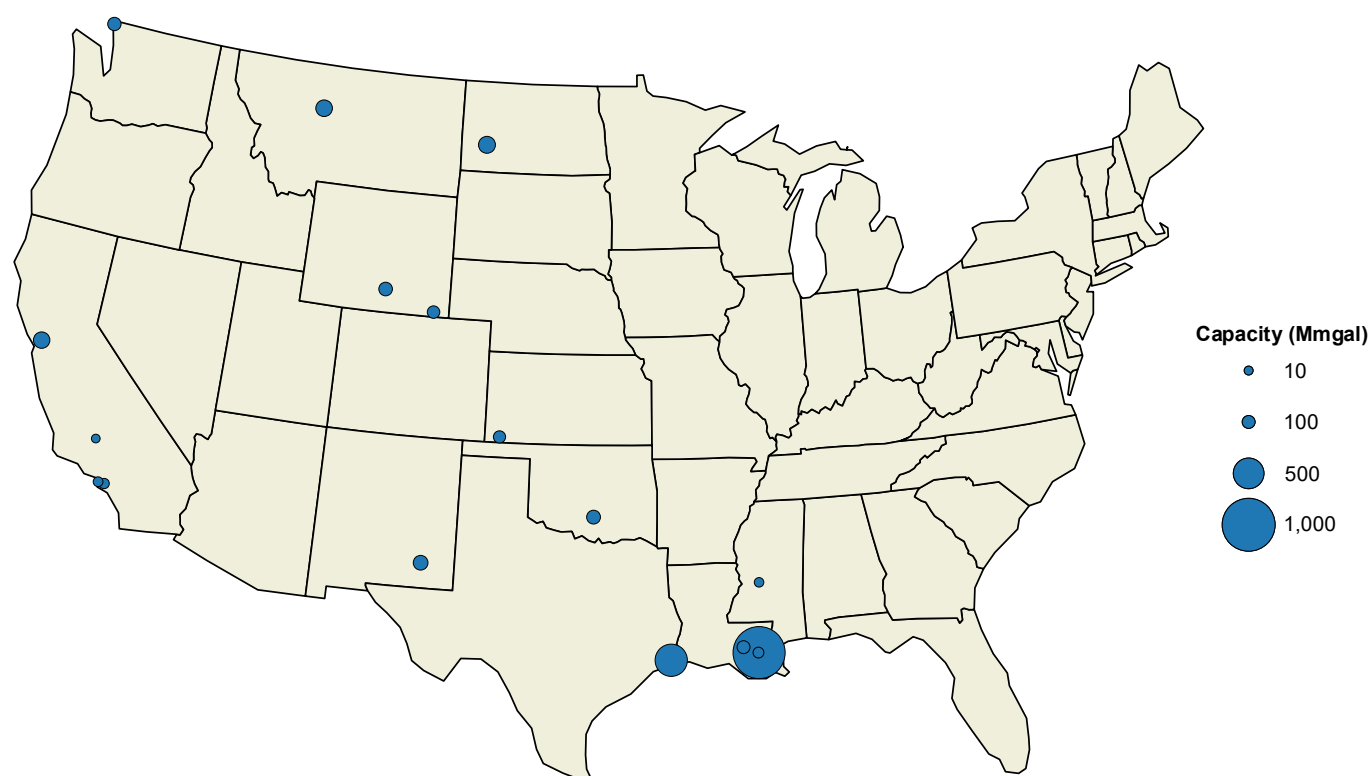


Figure 3.1.10. Renewable diesel production facilities location and capacity (in million gallons) in the United States in 2023 (EIA, 2024).

As a result of growing production capacity, renewable diesel production and consumption surged in 2022 and 2023, with a 73 percent increase in production and a 67 percent rise in consumption in 2023 compared to 2022 (see Figure 3.1.14.). Despite this increased production capacity, consumption continued to outpace production (EPA, 2024).

To bridge the gap between production and consumption in 2023, the United States imported renewable diesel primarily from Singapore (96 percent), with smaller shares from the Netherlands (3 percent) and Finland (3 percent). In 2023, renewable diesel imports increased by 38 percent compared to 2022, with most of the imported fuel being directed to the U.S. West Coast. According to the EIA, the United States did not export renewable diesel in 2022 or 2023 (EIA, 2024).

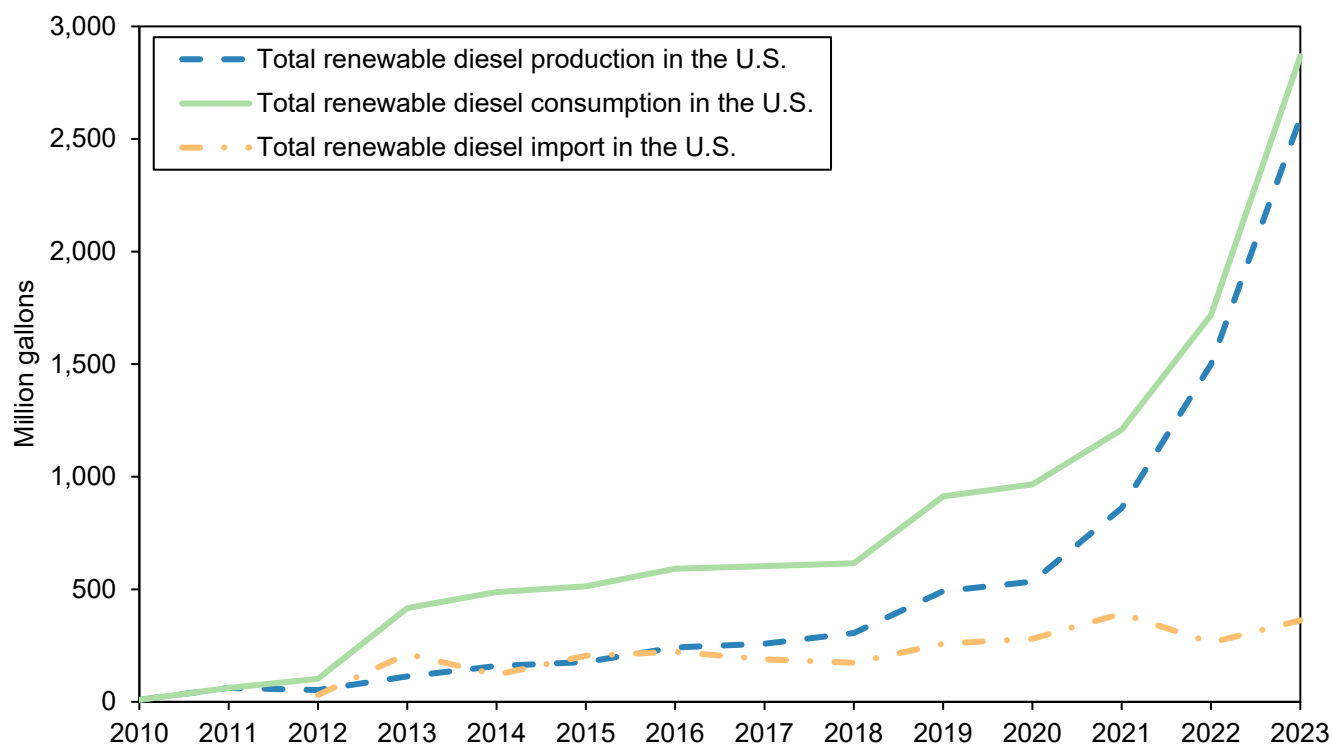


Figure 3.1.11. Renewable diesel production, consumption, and imports in the United States from 2011 to 2023 (in million gallons) (EPA 2024; EIA, 2024).

3.1.5. Renewable Jet Fuels

Renewable jet fuel is a biofuel produced from renewable feedstocks. It has similar properties to conventional jet fuel but has a smaller carbon footprint.

Renewable jet fuel has several advantages over traditional jet fuel. According to the United States Department of Energy (DOE, 2023), greenhouse gas emissions can be reduced up to 94 percent,

depending on feedstock and production process, when renewable jet fuel is used. Also, because it has a higher energy density, the fuel consumption is lower in comparison with traditional jet fuel. Finally, renewable jet fuel can be produced using multiple feedstocks and production technologies (AFDC, 2023).

Since 2016, over 50 airlines around the world have used renewable and traditional jet fuel blends, culminating in more than 450,000 commercial flights powered by renewable jet fuel by 2023, an increase from just 500 flights in 2016 (IATA, 2023). Notably, Virgin Atlantic completed the world's first transatlantic flight (London to New York) using 100 percent renewable jet fuel in November 2023.

In the United States, 36 airports or Fixed Base Operators (FBOs) supplied renewable jet fuel in 2023, with most located in California and Colorado as presented in figure 3.1.12. (4AIR, 2023).

In 2021, 60 companies made a major commitment at the World Economic Forum's Clean Skies for Tomorrow Coalition to use 10 percent renewable jet fuel by 2030. Airlines like British Airways, Delta Airlines, KLM, United Airlines, and Virgin Atlantic led this effort. By 2022, other airlines such as Alaska Airlines, American Airlines, Finnair, Japan Airlines, and Qatar Airways committed to purchasing up to 200 million gallons of renewable jet fuel annually over five years (i6 GROUP, 2024).

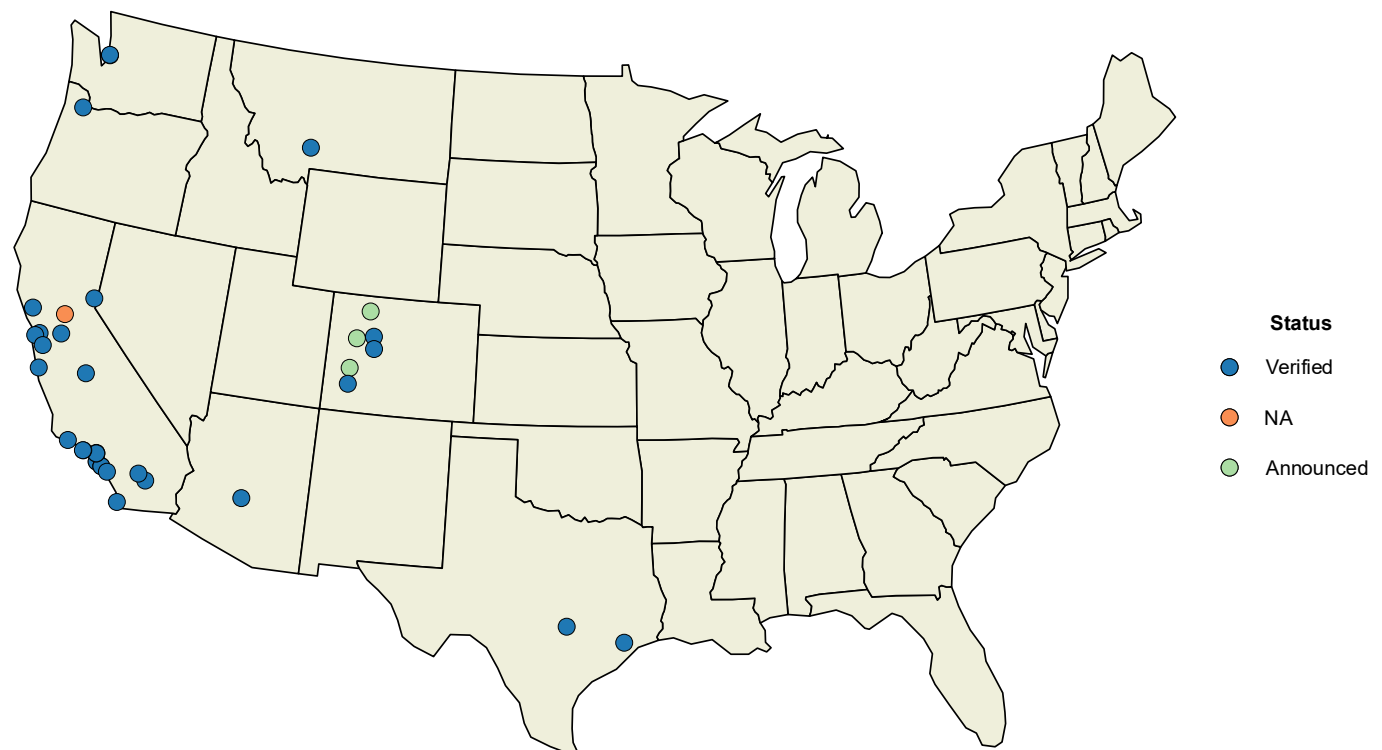


Figure 3.1.12. Airports and FBOs offering renewable jet fuel in the United States in 2023 (4AIR, 2023).

ASTM International, the international standards organization that establishes jet fuel specification requirements, has approved 11 renewable jet fuel production pathways as of July 2023 (Table 3.1.1). These pathways allow renewable jet fuel to be blended with conventional jet fuel without requiring engine or aircraft modifications. ASTM standards are continuously updated to incorporate technological advances in renewable jet fuel production (ICAO, 2024).

Table 3.1.1. Approved renewable jet fuel production pathways (ICAO, 2024).

Production Process	Possible Feedstock	Blending Limit
Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene (FT)	Coal, natural gas, biomass	Up to 50%
Synthesized paraffinic kerosene from hydroprocessed esters and fatty acids (HEFA)	Vegetable oils, animal fats, used cooking oils	Up to 50%
Synthesized iso-paraffins from hydroprocessed fermented sugars (SIP)	Biomass used for sugar production	Up to 10%
Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources (FT-SKA)	Coal, natural gas, biomass	Up to 50%
Alcohol-to-jet synthetic paraffinic kerosene (ATJ-SPK)	Ethanol, isobutanol and isobutene from biomass	Up to 30%
Catalytic hydrothermolysis jet fuel (CHJ)	Vegetable oils, animal fats, used cooking oils	Up to 50%
Synthesized paraffinic kerosene from hydrocarbon - hydroprocessed esters and fatty acids (HC-HEFA-SPK)	Algae	Up to 10%
Synthetic Paraffinic Kerosene with Aromatics	C2-C5 alcohols from biomass	NA
Co-hydroprocessing of esters and fatty acids in a conventional petroleum refinery	Vegetable oils, animal fats, used cooking oils from biomass processed with petroleum'	Up to 5%
Co-hydroprocessing of Fischer-Tropsch hydrocarbons in a conventional petroleum refinery	Fischer-Tropsch hydrocarbons co-processed with petroleum	Up to 5%
Co-Processing of HEFA	NA	Up to 10%

In 2023, the United States produced 14 million gallons of renewable jet fuel from 14 production facilities, representing a 58 percent increase from 2022. Consumption rose by 56 percent, reaching 26 million gallons (see Figure 3.1.16.) (EPA, 2024). However, the United States remained a net importer of renewable jet fuel, with consumption consistently outpacing production in 2021, 2023 and 2023. Despite the growth in production and consumption, renewable jet fuel made up less than 0.1 percent of the total jet fuel used by major U.S. airlines in 2023 (GAO, 2023). The high cost of renewable jet fuel, from 50 percent to 200 percent more expensive than traditional jet fuel, was the primary reason for its limited use (i6 GROUP, 2024).

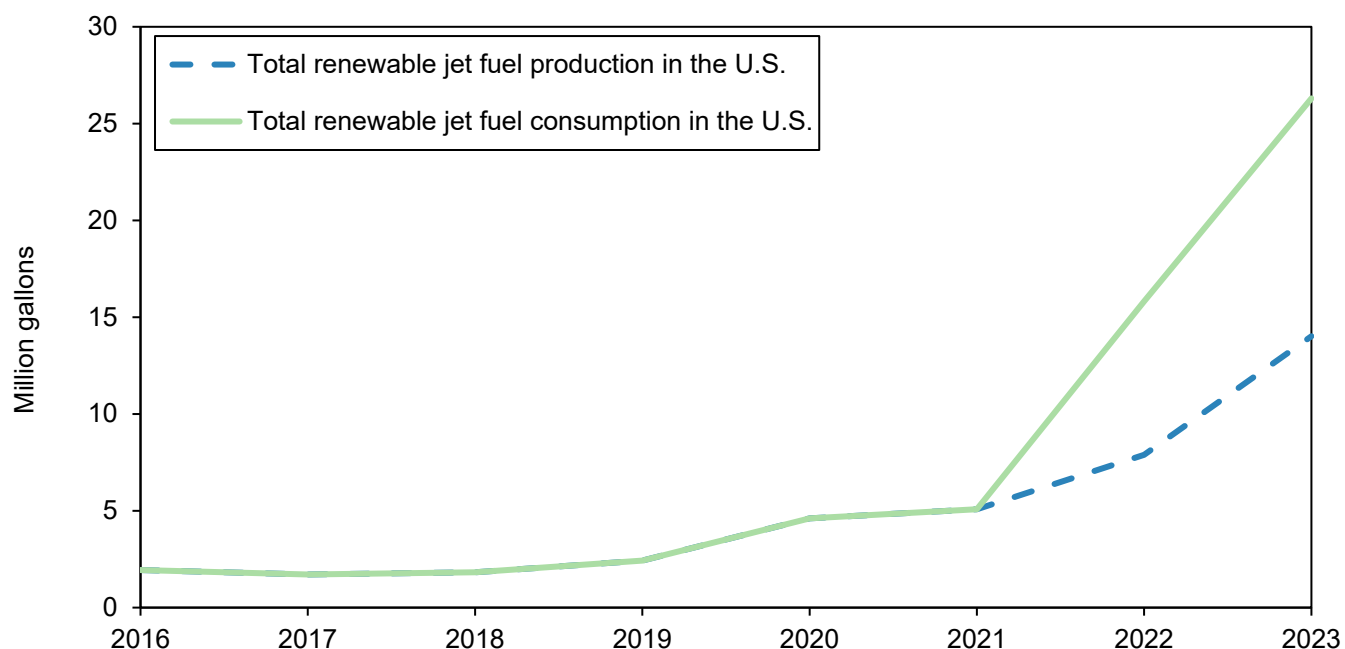


Figure 3.1.13. Production and consumption of renewable jet fuel from 2016 to 2023 in the United States (in million gallons) (EPA, 2024).

3.2. Primary Energy

3.2.1. Wood Pellets

Wood pellets, a popular form of biomass energy, are used as a sustainable fuel option. They are primarily made from compacted sawdust, dried wood chips, and industrial waste generated during wood product production. Due to their higher density and lower moisture content compared to cordwood, wood pellets are more efficient to burn, producing more heat per unit of volume. Additionally, wood pellets burn more cleanly and produce lower particulate emissions compared to coal. These characteristics make wood pellets ideal for heating systems and electricity generation (Biomass Magazine, 2010).

As presented in figure 3.2.1., there were 118 wood pellet production facilities in the United States in 2023, a decrease of 5 from 2022. Despite this reduction, total operational capacity increased by 8 percent, reaching 13.9 million metric tons per year. Five new plants were proposed, with one currently under construction.

Notably, 80 percent of nation's wood pellet production capacity is concentrated in the southeastern area of the United States, primarily using softwood and/or hardwood as feedstock (Biomass Magazine, 2024).

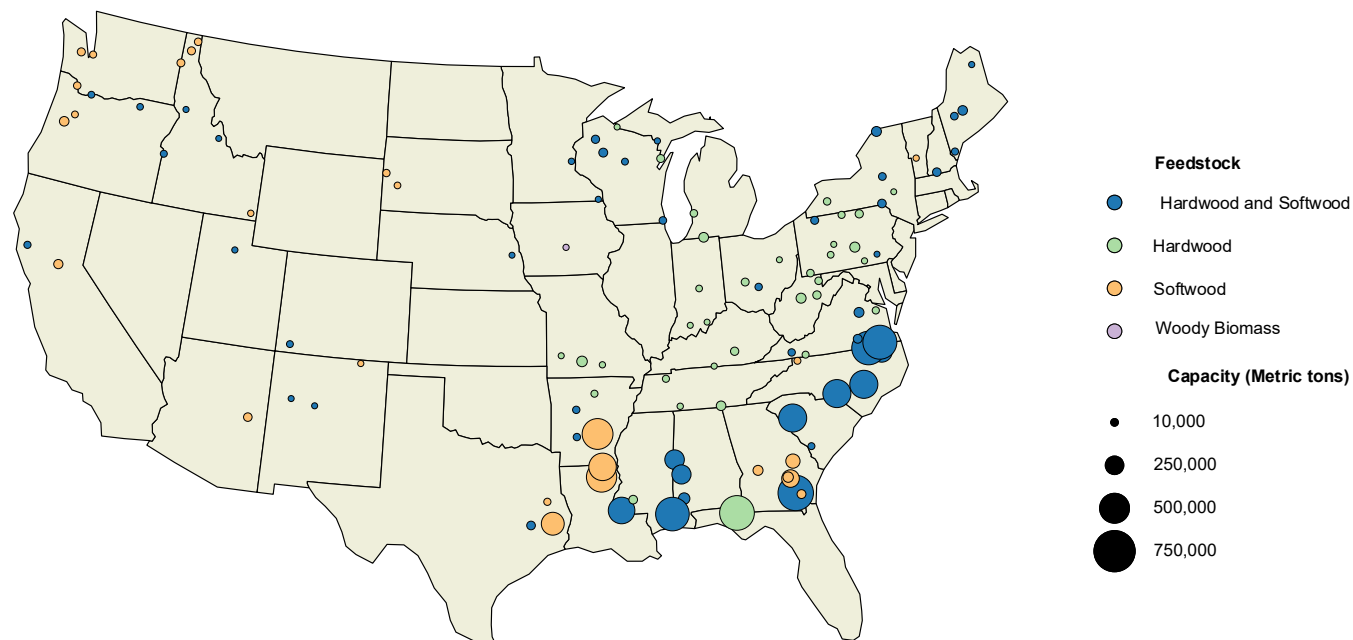


Figure 3.2.1. Wood pellet production facilities in the United States in 2023, sized according to their capacity (in thousand metric tons) and colored by feedstock (Biomass Magazine, 2024).

The United States continued to be the world's leading producer and exporter of wood pellets, accounting for 20 percent of total global production and 32 percent of total global exports in 2023. Total production reached a record high of 9.8 million metric tons in 2023, representing a 3 percent increase from 2022 (see Figure 3.2.2.) (FAOSTAT, 2024).

In contrast, only about 5% of the wood pellets produced in the United States were consumed in the United States. In 2023, consumption dropped to 0.5 million metric tons, a 40 percent decrease from the previous year (FAOSTAT, 2024).

In 2023, the primary use of wood pellets in the United States was for heating, with 94 percent of total energy consumption from wood dedicated to this purpose, while the remaining 6 percent was used for

electricity generation. Over the past decade, wood pellet consumption for heating has remained steady at approximately 2,000 trillion BTUs. Additionally, in 2023, the industrial sector accounted for 64 percent of total energy consumption from wood, followed by the residential sector at 23 percent, the electric power sector at 8 percent, and the commercial sector at 4 percent (EIA, 2024).

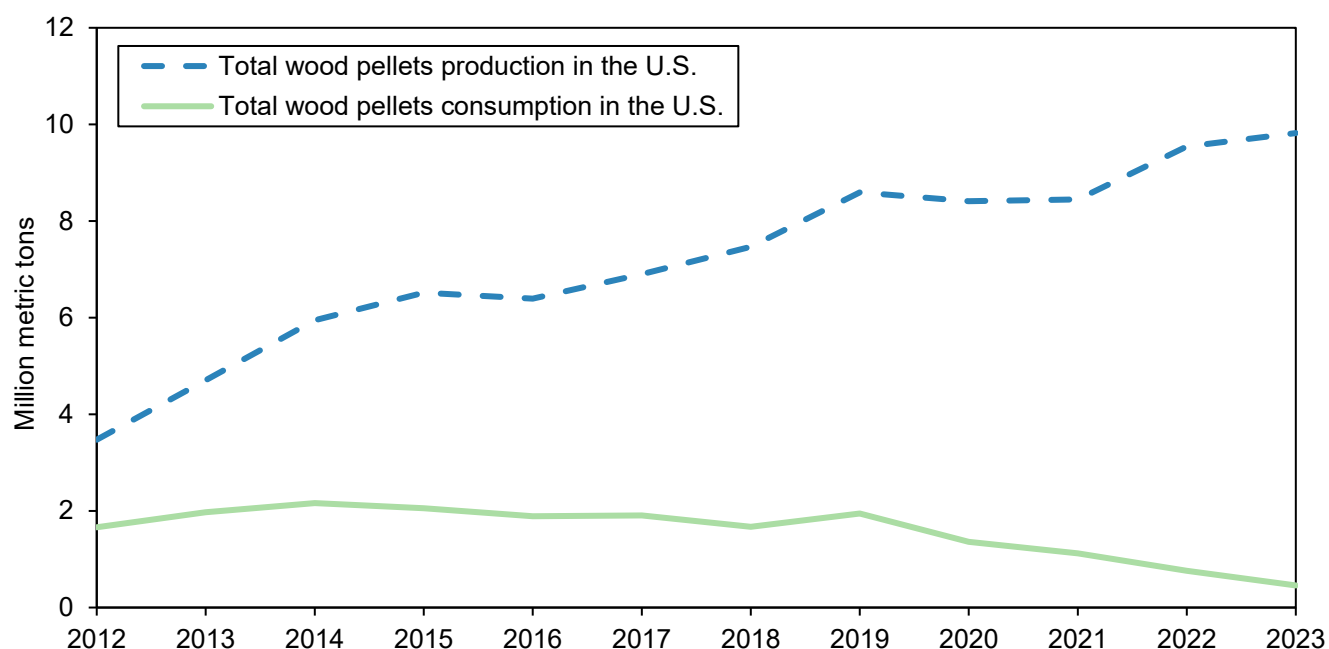


Figure 3.2.2. Total wood pellet production versus total wood pellet consumption in the United States from 2012 to 2023 (in million metric tons) (FAOSTAT, 2024).

In 2023, U.S. wood pellet exports reached a peak of 9.5 million metric tons, almost a 30 percent increase from 2021 (see Figure 3.2.3.). The United Kingdom was the largest importer of U.S. wood pellets, accounting for 55 percent of total U.S. wood pellets production, which amounted to 5.3 million metric tons. The Netherlands and Denmark also saw significant increases in their imports of U.S. wood pellets in 2023, rising by 22 percent and 212 percent, respectively, compared to 2021. This resulted in import quantities of 1.4 million metric tons for the Netherlands and Denmark (UN Comtrade, 2024).

Domestically, wood pellets are primarily used for heating, while exported wood pellets are used primarily for electricity generation (EIA, 2015). The global demand for clean energy alternatives is projected to increase significantly as key environmental deadlines and goals are approaching in 2030 and 2045, which is expected to drive growth in the wood pellet industry. The United Kingdom, for example, plans to achieve its environmental goals by using wood pellets in cofiring (combustion of two different fuels) or in dedicated biomass power plants.

The Drax power station, located east of Leeds in the United Kingdom, is one of the largest thermo-electric power facilities that has switched from coal to wood pellets, achieving 75 percent of its power output through biomass. As of 2023, its capacity had increased to 2.6 GW from biomass up from its 1.29 GW capacity when operating from coal. Nearly 60 percent of Drax’s biomass feedstock mix came from the United States, and the station consumed 97 percent of total U.S. wood pellet exports to the United Kingdom in 2023 (Drax, 2024).

Through 2023, the volume of wood pellets imported into the United States remained significantly lower than the volume exported, consistently holding at 200 thousand metric tons per year since 2013 (see Figure 3.2.3.). In 2023, 99 percent of these imports originated from Canada (see Figure 3.2.4.) (UN Comtrade, 2024).

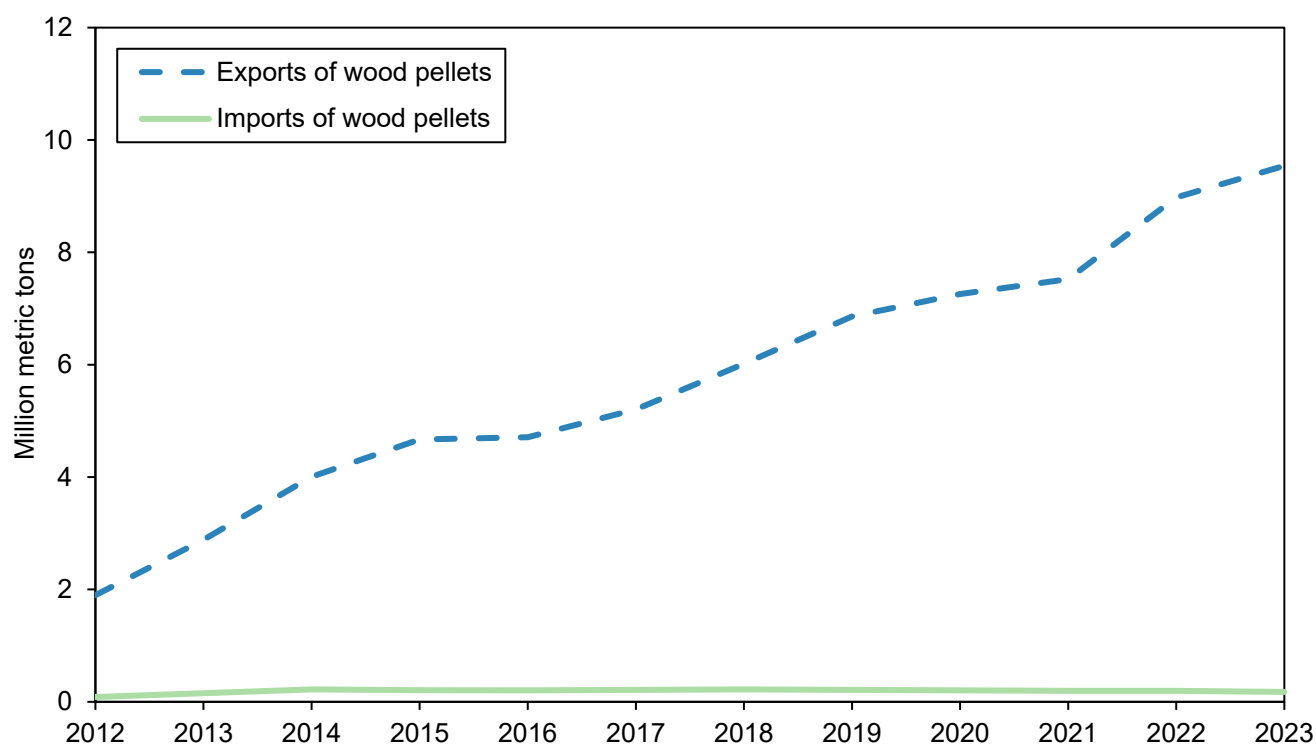


Figure 3.2.3. Exports and imports of wood pellets in the United States from 2012 to 2023 (in million metric tons) (FAOSTAT, 2024).

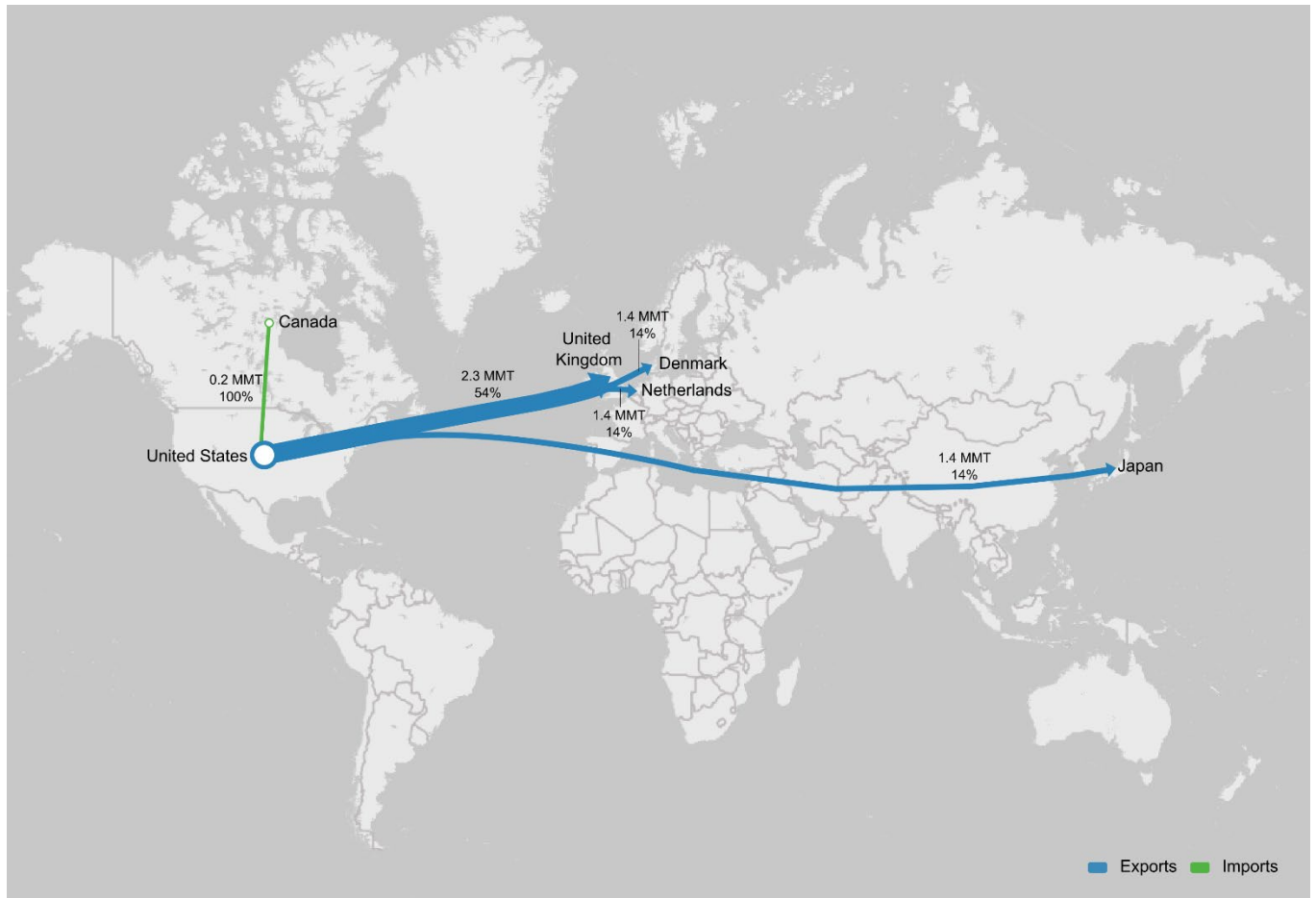


Figure 3.2.4. Exports (blue line) and imports (green line) of wood pellets in the United States by country in 2023 (in million metric tons) (FAOSTAT, 2024).

In 2023, the number of direct jobs in the economic sector encompassing the wood pellet industry reached an all-time high, with 27,000 direct jobs created—an increase of 7 percent from 2021 (U.S. BLS, 2024).

3.2.2. Waste-to -Energy

Waste-to-energy (WTE) involves combusting municipal solid waste (MSW), which would otherwise be sent to landfills, into electricity. WTE plants provide a sustainable solution for both waste management and energy production, reducing the volumes of material sent to landfills by up to 90 percent and, in turn, reducing potential environmental impacts from landfills such as water contamination. It is estimated that 12 percent of all MSW in the United States is processed in WTE plants to produce electricity, with 66 percent of that waste being biomass. This reduction is particularly beneficial in densely populated urban areas where space for landfills is limited (EIA, 2023).

In 2023, the number of WTE facilities in the United States that incinerate MSW for energy recovery decreased to 61. These facilities are mainly concentrated in two geographic clusters: one in Florida, which hosts 10 waste-to-energy plants, and another in the northeastern part of the United States, with 34 plants (see Figure 3.2.5.) (EIA, 2024).

In 2023, WTE facilities processed 94,000 metric tons of waste per day, generating enough energy to power approximately 2.3 million U.S. households. The industry was valued at \$10 billion and provided employment for about 6,000 American workers (Waste Management World, 2023).

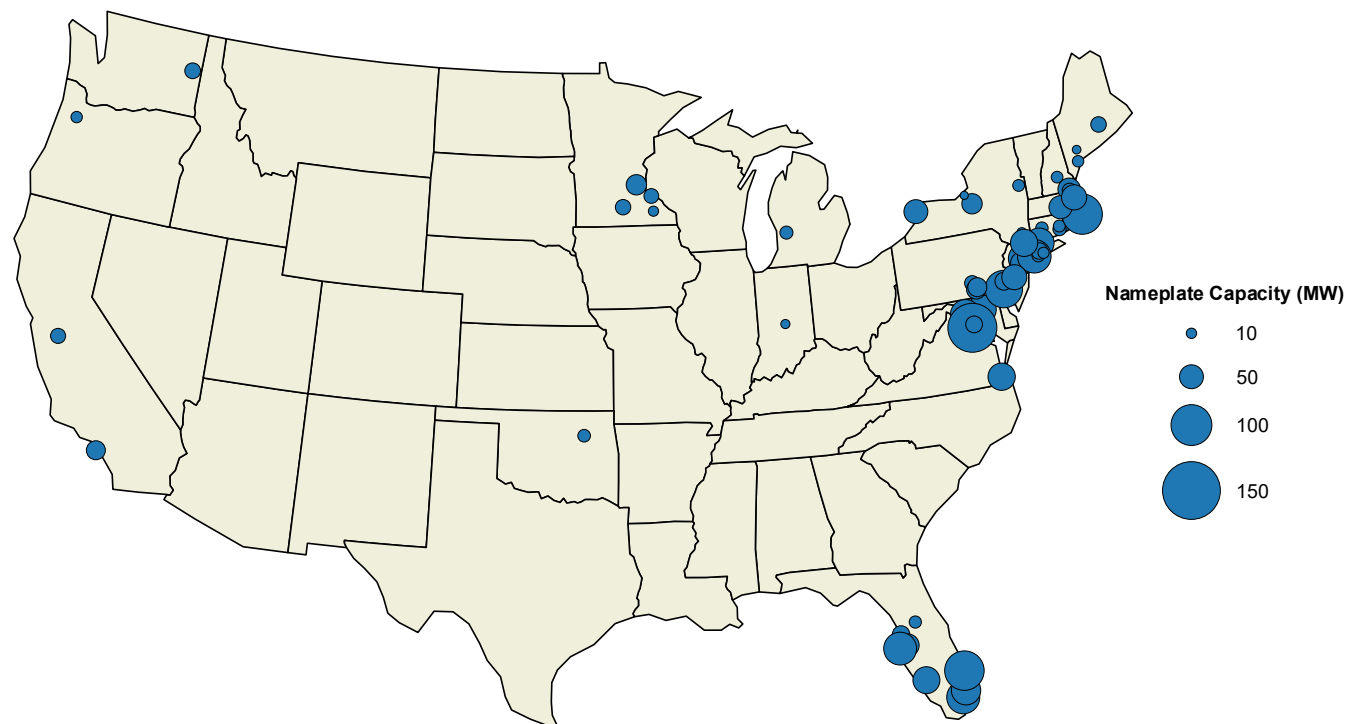


Figure 3.2.5. Waste-to-energy facilities in the United States in 2023, sizes according to capacity in MW (EIA, 2024).

The concentration of waste-to-energy facilities in the northeastern United States was driven by the region's high population density, large urban areas, and limited landfill space. Similarly, the cluster of plants in Florida supported the state's solid waste management goals. Florida's rapid population growth, the second-highest in the nation, has contributed to increasing MSW volumes that would otherwise be landfilled.

The number of WTE plants in the United States decreased by 35 percent in 2023 compared to 2020. This reduction was largely driven by public opposition, due to concerns about toxic air emissions and the contribution of these facilities to climate change (EIA, 2022; EPA, 2024). Consequently, companies turned to utilizing MSW in co-incineration plants, which primarily produce material products or

generate energy, rather than constructing new waste-to-energy plants (EPA, 2020). Moreover, urban areas began adopting zero waste policies, sustainability incentives, and renewable energy targets, leading to a gradual shift away from incineration plants.

Between 2010 and 2023, MSW consumption for WTE remained relatively constant. In 2023, 15 million metric tons of biomass MSW were incinerated, generating 116 trillion BTUs of energy (see Figure 3.2.6.). 90 percent of the total energy generated from biomass MSW is used for electricity generation, primarily consumed by the commercial sector (50 percent) and the independent power producers (48 percent). The remaining 10 percent was utilized as steam, which some WTE facilities sent to nearby industrial plants and institutions (EIA, 2023).

Compared to 2021, consumption of MSW by independent power producers decreased by 45 percent (6 million metric tons), while consumption of energy from MSW by the commercial sector increased by 143 percent (5 million metric tons) in 2023 (EIA, 2024). The commercial sector's increased use of MSW for energy production was due to technological advancements that made these fuels more cost-effective and efficient, prompting wider adoption by businesses.

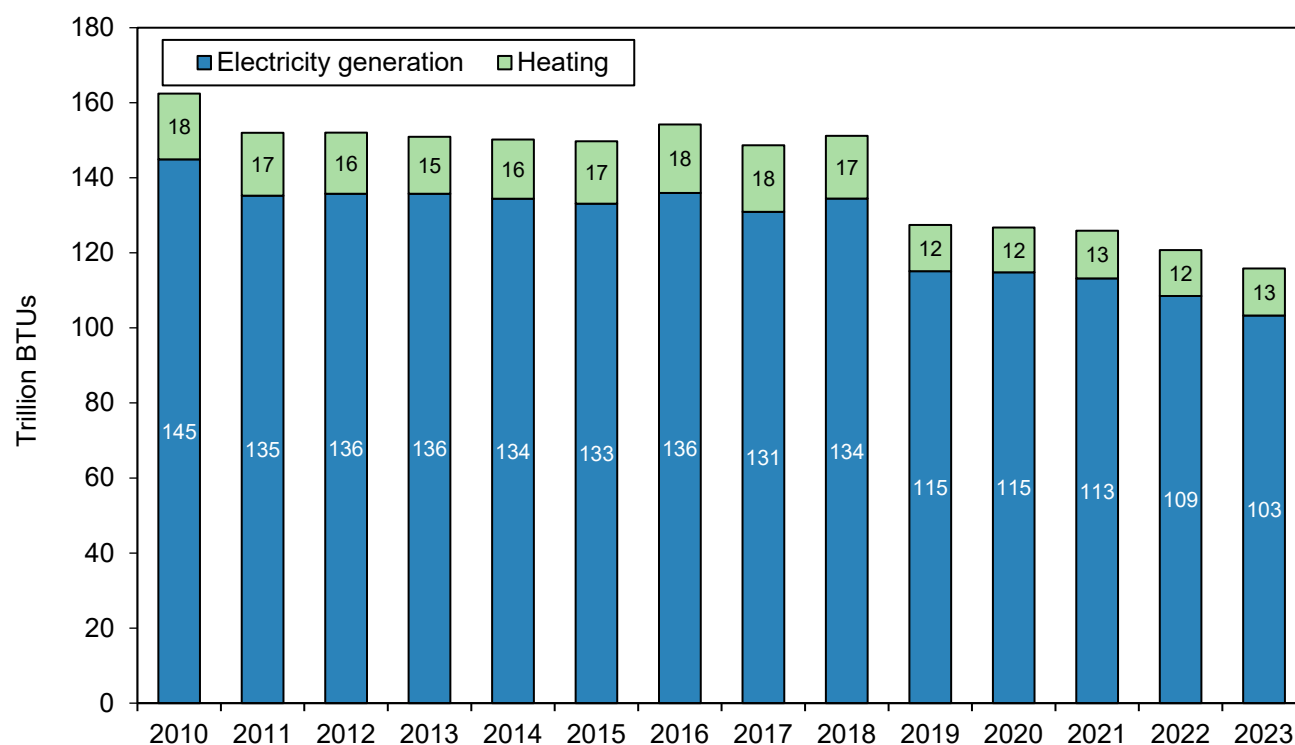


Figure 3.2.6. Final use of the energy generated from biogenic municipal solid waste in the United States from 2010 to 2023 (in trillion British thermal units) (EIA, 2024).

3.2.3. Biogas

Biogas, a renewable energy source produced through the anaerobic digestion of organic matter by microorganisms in oxygen-deprived conditions, represents a key advancement in sustainable energy solutions. This natural process occurs in various environments, including landfills and controlled settings equipped with anaerobic digesters.

Sources of organic matter for biogas production include landfills, wastewater treatment plants, animal manure, and organic waste. Methane content varies depending on the source: landfill biogas typically contains 40 to 60 percent methane, while biogas from farms and wastewater treatment plants can range from 55 to 70 percent methane. Biogas can be refined into RNG through processing and purification, reaching methane concentrations of 96 to 98 percent. This upgraded biogas can be seamlessly integrated into natural gas pipelines, providing a sustainable alternative to traditional fossil fuels (EPA, 2023).

Biogas systems are versatile, with applications in electricity generation, heating, and transportation fuel. The growing adoption of biogas technologies enhances waste management strategies while mitigating greenhouse gas emissions. Additionally, these systems contribute to a circular economy by converting waste into valuable energy resources, highlighting their critical role in promoting environmental stewardship and energy sustainability.

As presented in figure 3.2.7., in 2023, the United States saw significant growth in biogas production, with over 2,400 active sites, including 598 anaerobic digesters on farms, 1,120 wastewater treatment facilities, and 532 landfill gas (LFG) projects. The majority of these facilities were concentrated in the midwestern and northeastern regions of the United States. California emerged as the leading biogas producer due to substantial investments in LFG projects and state policies, such as the Low Carbon Fuel Standard (LCFS), which encourage the use of biogas and renewable natural gas. According to the American Biogas Council, California had 82 LFG operational projects in 2023, which represented a significant share of the biogas production capacity in the United States in 2023 (EPA, 2024; Water Environment Federation, 2024).

The biogas industry in the United States experienced substantial growth between 2021 and 2023. Potential biogas production from landfills increased from 345 billion cubic feet in 2021 to 436 billion cubic feet in 2023, driven by advancements in methane capture technologies, increased organic waste diversion, and supportive government policies aimed at reducing greenhouse gas emissions (EPA, 2023). In contrast, potential biogas production from wastewater treatment remained stable at 147 billion cubic feet during the same period, indicating a focus on optimizing existing facilities. Meanwhile,

potential biogas production from animal manure increased from 1,157 billion cubic feet in 2021 to 1,278 billion cubic feet in 2023, owing to the adoption of anaerobic digesters on farms, government support for sustainable agriculture, and cost-effective cluster projects.

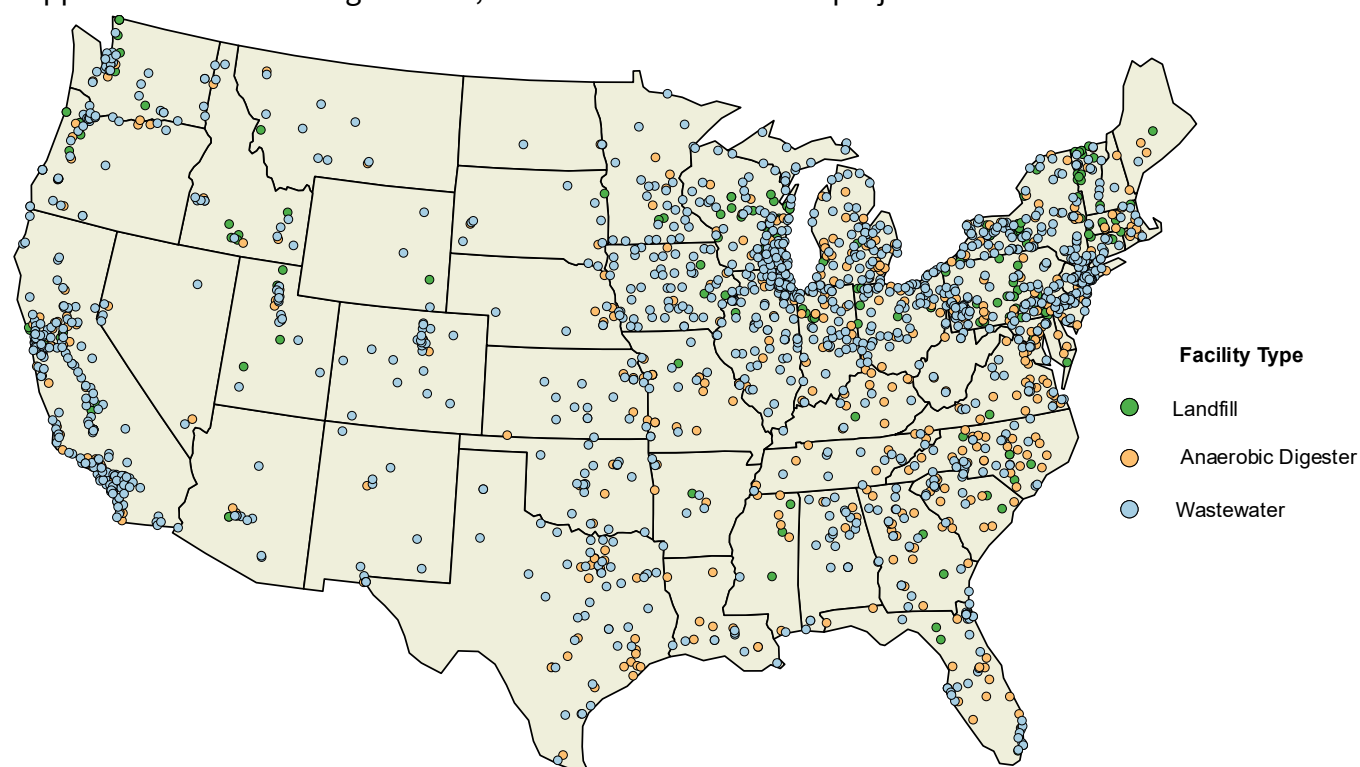


Figure 3.2.7. Biogas facilities locations by type in the United States in 2015 (wastewater) and 2023 (landfills and anaerobic digesters) (EPA, 2024; Water Environment Federation, 2015).

Although farms have the highest potential for biogas generation, the amount of biogas captured on farms is significantly lower than that captured at landfills. In 2023, biogas captured from farms remained stable at 2.4 trillion BTUs (see Figure 3.2.8), maintaining 2019 levels. In contrast, biogas captured from landfills decreased by 8 percent compared to 2022 (see Figure 3.2.8). This reduction in landfill biogas production contributed to a decrease in total energy generated from biogas in 2023 (EPA, 2024; EIA, 2024).

The agricultural biogas industry saw growth from a small base, particularly through the development of anaerobic digestion systems using livestock manure. The number of new digester systems on livestock farms increased from 10 in 2017 to 65 in 2023. Similarly, the number of RNG projects, including those for pipeline injection and compressed natural gas (CNG) for transportation fuel, saw a sharp rise, growing from 7 in 2017 to 109 in 2022 (EPA, 2023).

This growth in agricultural biogas and RNG projects was largely due to federal and state incentives, such as the Renewable Fuel Standard (RFS) and Low-Carbon Fuel Standard (LCFS) programs, which promote the development and use of renewable, low-carbon energy sources (EPA, 2022; Federal Register, 2022). However, the number of other biogas projects, such as those for combined heat and power or electricity generation, has either decreased or remained constant between 2010 and 2023 (EPA, 2024).

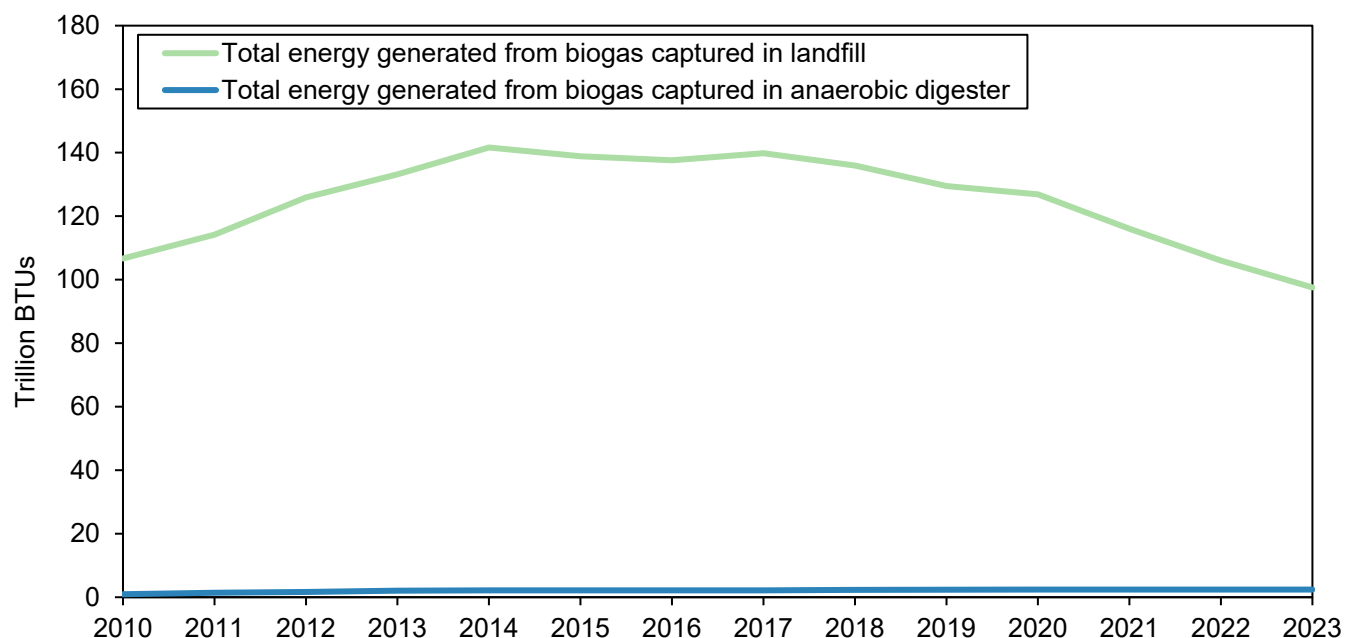


Figure 3.2.8. Total energy generated from biogas by source from 2010 to 2023 (in trillion British Thermal Units (BTU)) (EPA,2024; EIA,2024).

The American Biogas Council estimated that at the end of 2023 the U.S. had the potential to develop more than 15,000 new biogas systems, which could generate at least 45 billion dollars in capital investment, resulting in 375,000 short-term construction jobs and 25,000 permanent jobs (American Biogas Council, 2024).

3.3. Biobased Chemicals

Biobased chemicals, also known as renewable chemicals, are derived from renewable sources such as plants, crops, and biomass, in contrast to traditional chemicals produced from fossil fuels. The demand for biobased chemicals is rising due to their potential to reduce environmental impacts, lower carbon emissions, and contribute to a circular economy (Polaris Market Research, 2023).

Biobased chemicals are utilized in a wide range of applications across various industries, including automotive, packaging, agriculture, consumer goods, and construction. Key types of biobased chemicals include:

- **Biobased plastics:** Derived from renewable feedstocks such as sugarcane, or cellulose, bioplastics are used in applications such as packaging, automotive parts, films, textiles, and consumer goods.
- **Biobased solvents:** Known by their low toxicity, reduced volatiles organic compound emissions, and recyclability, biosolvents are used in coatings, adhesives, paints, and cleaners.
- **Biobased pesticides:** Derived from plant extracts or microorganisms, biopesticides are used for pest control without leaving harmful residues.
- **Biobased fertilizers:** Produced by converting waste into nutrient-rich products, biofertilizers provide essential nutrients to plants.
- **Biobased personal care and household products:** Biobased ingredients derived from vegetable oils are used in products such as cosmetics, detergents, and cleaning agents.
- **Biobased chemicals in construction materials:** Biobased adhesives, coatings, and insulation materials are used in construction to reduce carbon emissions, improve air quality, and minimize environmental impacts.

In 2023, the global biobased chemical market was valued at \$67.9 billion, accounting for less than 10 percent of the overall global chemical market. (Polaris Market Research, 2023).

3.3.1. Biobased Plastics

Bioplastics, or biobased plastics, are either made from renewable resources (biobased), designed to break down naturally (biodegradable), or both.

Bioplastics production (both biobased and biodegradable) in the United States, which accounted for 12 percent of global production, grew by 51 percent between 2017 and 2022, increasing from 184 thousand tons in 2017 to 279 thousand tons in 2022 (see Figure 3.3.1.) (MarketLine Industry, 2023). Despite this significant growth, bioplastics still represented only 0.6 percent of total plastic production (European Bioplastics, 2023).

The value of the United States bioplastics market mirrored the rise in production. In 2022 the market was valued at 1.2 billion dollars, representing a 61 percent increase from 2017 (see Figure 3.3.2.) (MarketLine Industry, 2023).

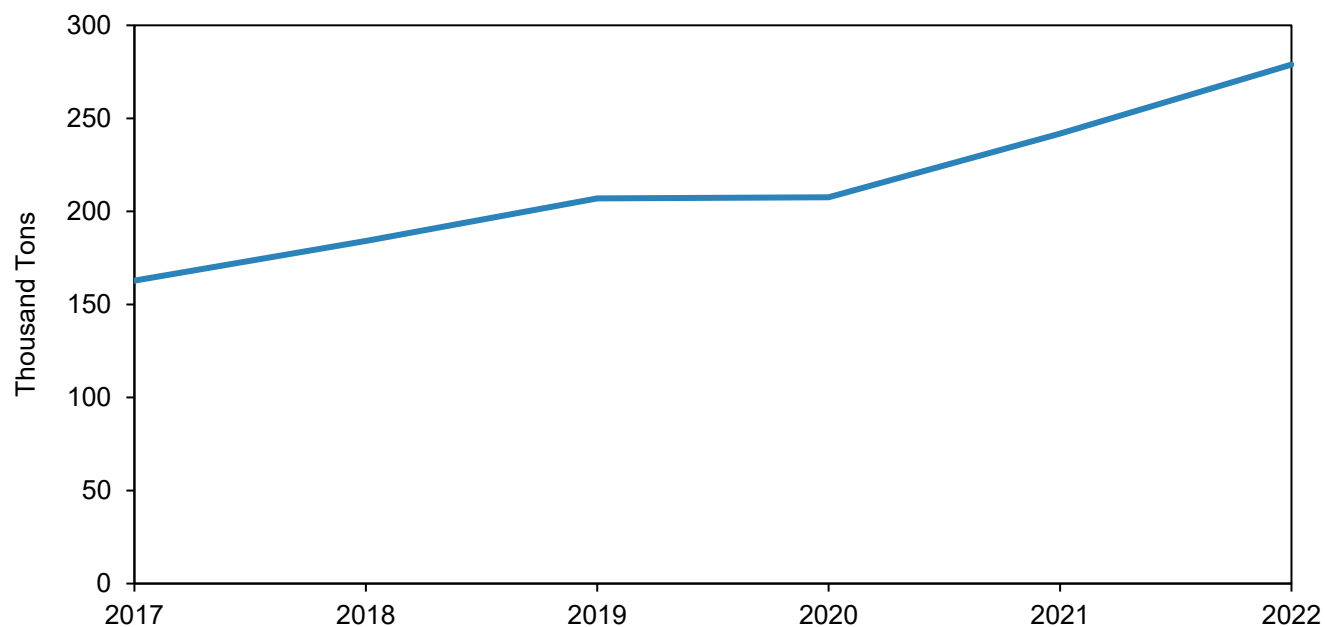


Figure 3.3.1. Production of bioplastics in the United States from 2017 to 2022 (in Thousand Tons) (MarketLine Industry, 2023).

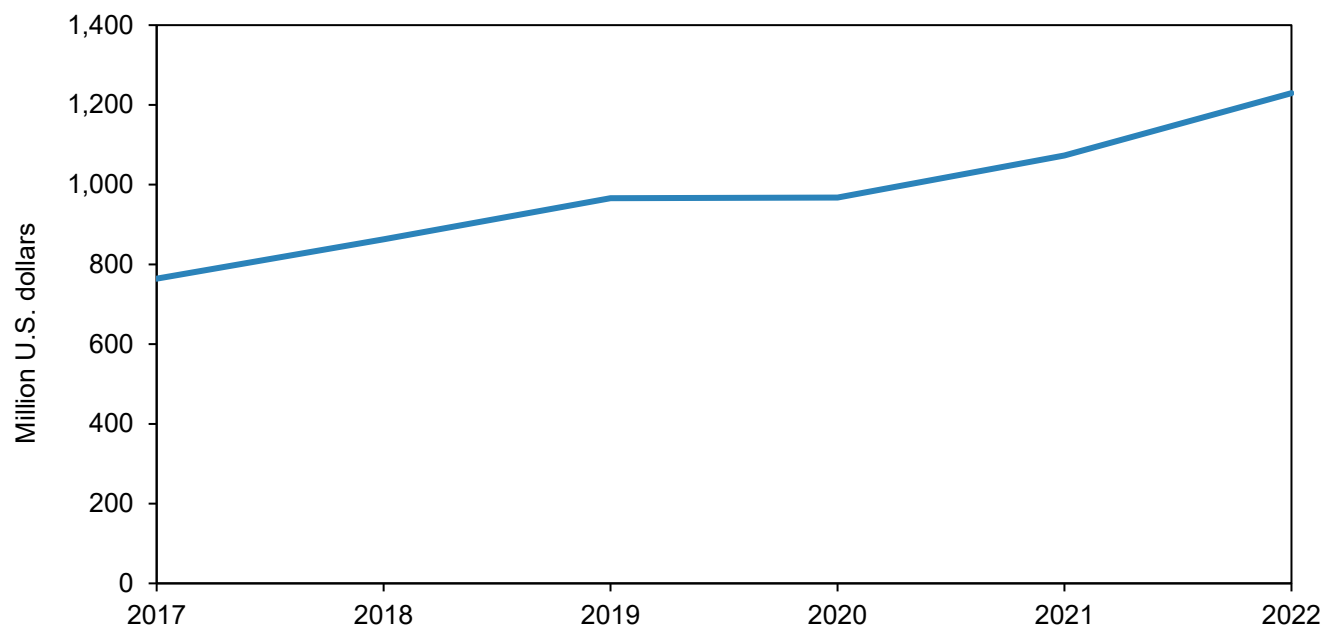


Figure 3.3.2. United States bioplastics market value from 2017 to 2022 (in million U.S. dollars) (MarketLine Industry, 2023).

3.4. Biobased Products

The U.S. Department of Agriculture (USDA) defines a biobased product as a commercial or industrial product (other than food or feed) that is either: a) composed, in whole or significant part, of biological products, such as renewable domestic agricultural materials, renewable chemicals, and forestry materials; or b) an intermediate ingredient or feedstock. These products provide alternatives to conventional petroleum-derived goods, such as lubricants, detergents, inks, fertilizers, and plastics. In 2002, USDA established the U.S. BioPreferred Program as part of the Farm Bill to promote the purchase and use of biobased products. This program was reauthorized and expanded in the Agriculture Improvement Act of 2018 (2018 Farm Bill) (USDA, 2024).

The BioPreferred Program has two major components:

- **Mandatory purchasing requirements** for biobased products by federal agencies and their contractors.
- A **voluntary labeling initiative** to raise consumer awareness of the benefits of biobased products (see Figure 3.4.1).

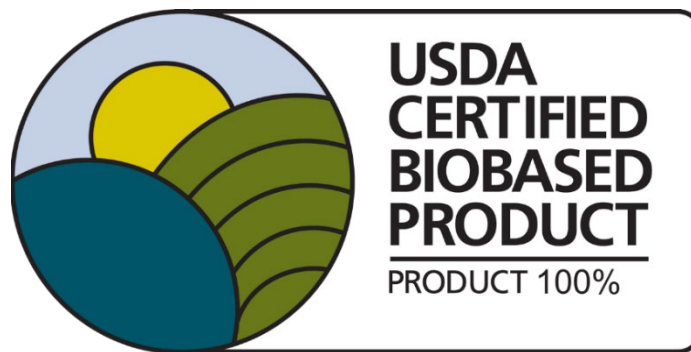


Figure 3.4.1. A sample USDA Certified Biobased Product label (USDA, 2020).

USDA's BioPreferred Program provides businesses with resources, including voluntary labeling process, a catalog of biobased products, training, and information on marketing of biobased products to the federal government (USDA, 2024). More than 3,000 companies across all 50 states, spanning from agricultural producers to manufacturers, participate in the BioPreferred Program (USDA, 2022).

In 2023, the number of products certified through the USDA BioPreferred Program continued to rise, marking a 115 percent increase since 2021 (see Figure 3.4.2.). The categories with more certified products include intermediate products, household supplies, and personal care and toiletries (see Table 3.4.1.) (USDA, 2024).

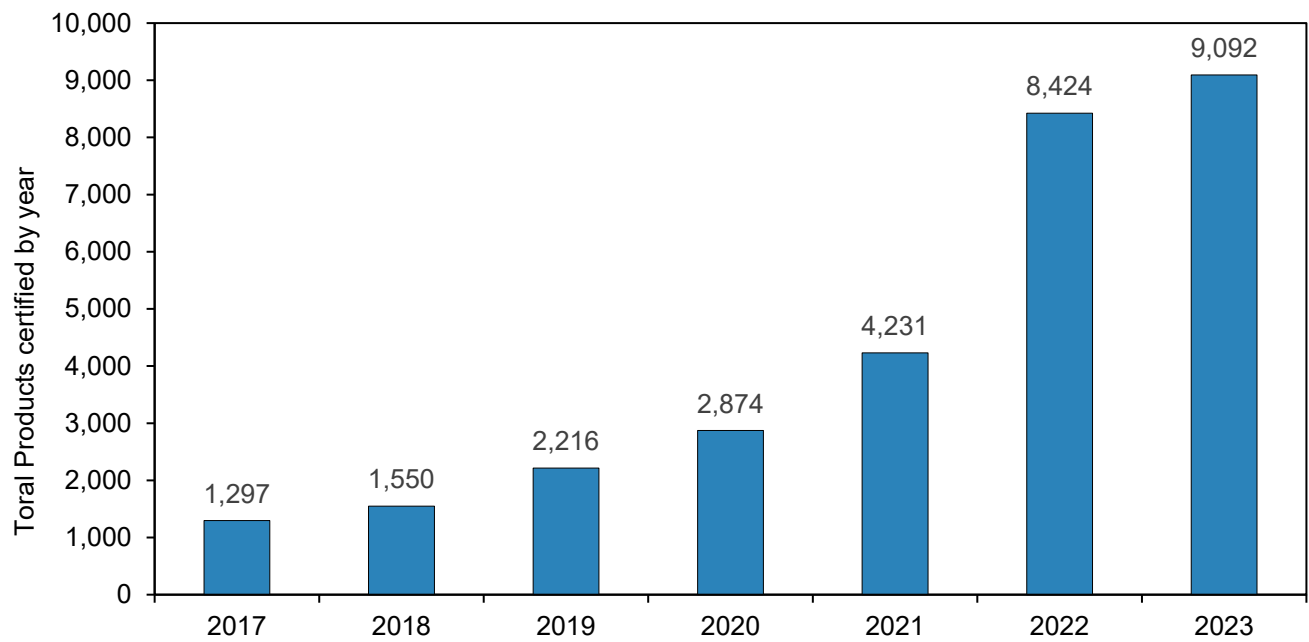


Figure 3.4.2. USDA BioPreferred total products certified by year (USDA, 2024).

Table 3.4.1. USDA BioPreferred product certifications by year and category (USDA, 2024).

Catalog Category	2017	2018	2019	2020	2022	2023
Baby and Kids	53	46	58	52	238	277
Construction	57	106	116	74	562	748
Custodial Services	148	176	341	212	821	927
Films and Packaging	85	106	60	95	378	413
Food Services/Cafeteria	68	88	138	351	601	682
Grounds Maintenance	110	72	82	48	414	486
Household Supplies	218	207	404	375	1,130	1,269
Intermediates	157	373	345	330	2,074	3,230
Miscellaneous	63	43	114	84	223	263
Office Supplies	9	21	16	20	103	114
Operations and Maintenance	164	121	113	62	783	928
Personal Care and Toiletries	160	186	423	209	1,041	1,042
Safety Equipment	1	0	0	0	20	31
Vehicles and Equipment Maintenance	4	5	6	2	36	59
Total Products Certified by Year	1,297	1,550	2,216	2,874	8,424	9,092

3.5. Forestry Products

The potential applications of forest products as both a material and energy source are extensive. These products can be used to produce high-performance biomaterials and high-value chemicals (USDA, 2024).

In 2023, the production of forest products in the United States decreased to 1 billion metric tons. Roundwood accounted for the largest share, comprising 59 percent of total production, followed by sawnwood (14 percent), and wood fuel (9 percent). Wood pellets, however, increased by 3 percent compared to 2022 (see Figures 3.5.1-3.5.2.) (FAOSTAT, 2025).

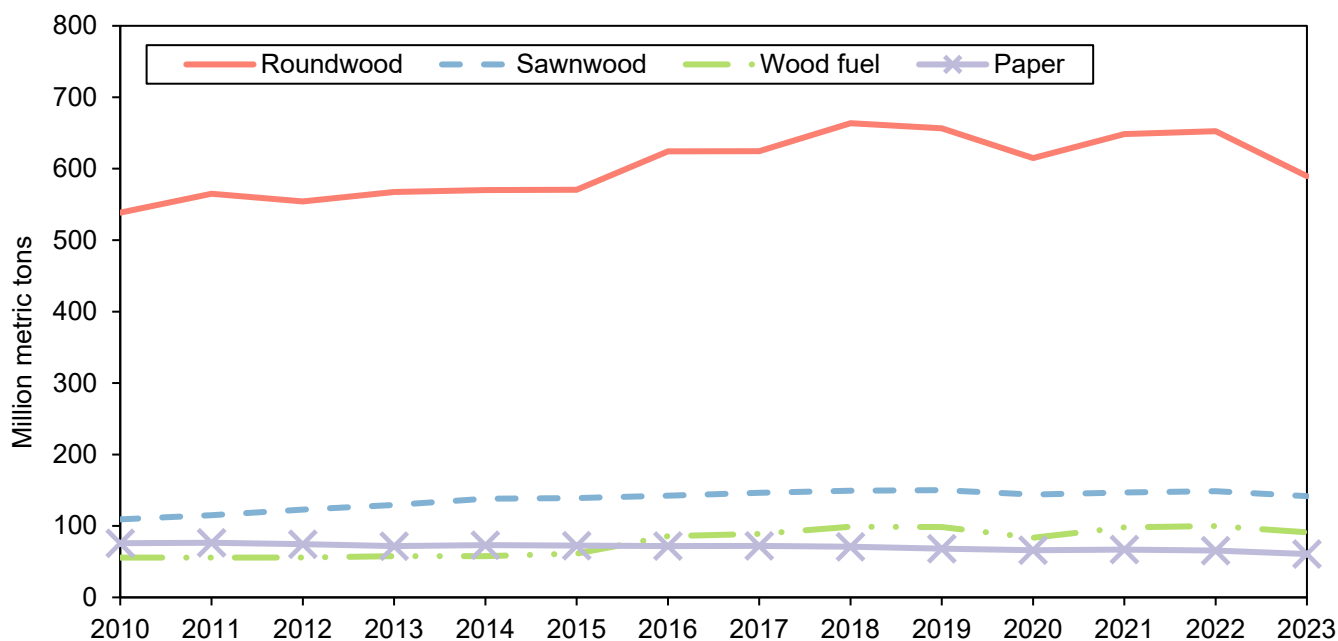


Figure 3.5.1. Production of roundwood, sawnwood, wood fuel and paper in the United States from 2010 to 2023 (in million tons) (FAOSTAT, 2025).

Exports of American forest products decreased from \$30 billion in 2022 to \$25 billion in 2023, and imports of forest products decreased from \$39 billion to \$27 billion. Despite the decrease in trade, the United States remained a net importer of forest products, with 2 billion dollars of net imports in 2023 (see Figure 3.5.3.) (FAOSTAT, 2025).

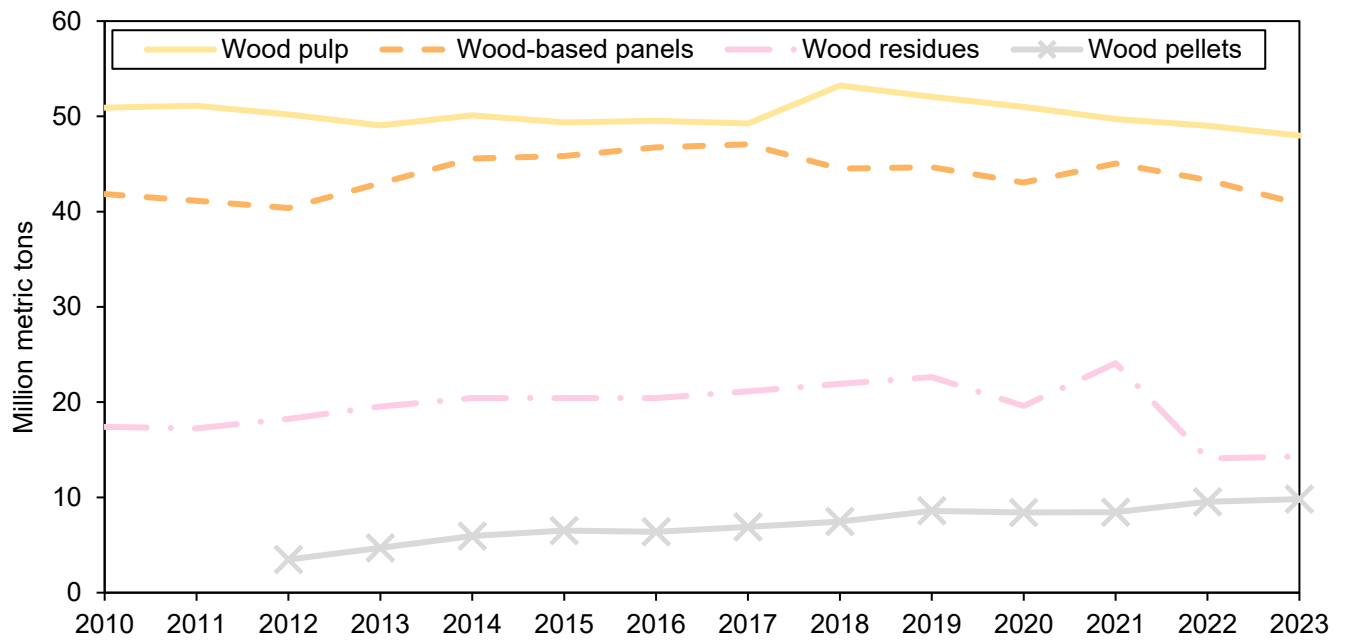


Figure 3.5.2. Production of wood pulp, wood-based panels, wood residues and wood pellets in the United States from 2010 to 2023 (in million tons) (FAOSTAT, 2025).

In 2023, wood and paper products in the United States contributed 0.5 percent to the U.S. gross domestic product. These industries generated a value added of 93 billion dollars and employed nearly 800,000 full and part time workers (BEA, 2024).

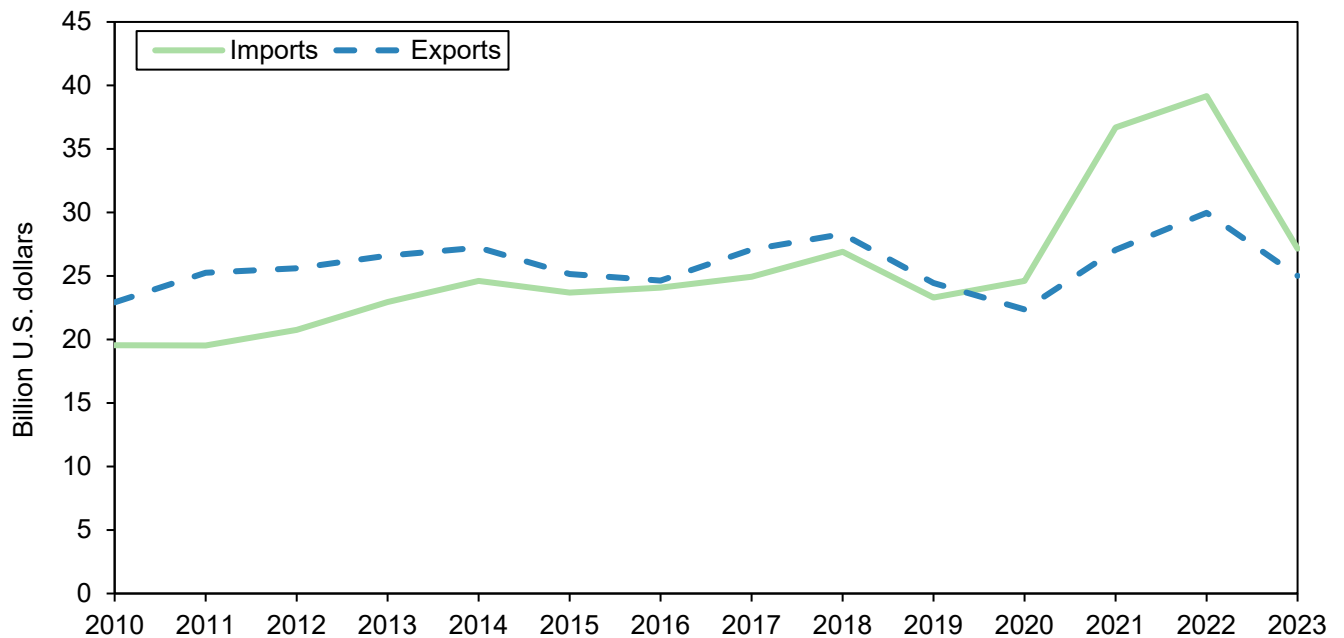


Figure 3.5.3. Exports and Imports of forest products in the United States from 2010 to 2023 (in billion U.S. dollars) (FAOSTAT, 2025).

3.6. Apparel and Textiles

Biodegradable fabrics are made from natural materials, such as hemp, linen, cotton, jute, and silk, or synthetic polymers like polylactic acid (PLA) and polyhydroxyalkanoates (PHA), which can decompose naturally in the environment.

The global market for biodegradable fabrics was \$5.9 billion in 2023. North America led the market in 2023, accounting for over 40 percent of the market share, followed by Europe (30 percent), and the Asia-Pacific region (20 percent) (Coherent Market Insights, 2024).

In 2023, the United States apparel and textiles industries contributed 0.1 percent to the country's gross domestic product, generating a value added of \$28 billion and employing more than 300,000 full and part time workers (BEA, 2024).

The United States remained a net importer of apparel in 2023, with imports that were 10 times higher than exports. In 2023, U.S. apparel imports declined by 22 percent compared to 2022, reaching \$82 billion. This was largely due to global supply chain disruptions, high inflation, and rising material costs. Additionally, 72 percent of these imports came from Asia, the lowest share in 5 years, as companies sought to diversify their sourcing due to growing geopolitical concerns (Sheng Lu, 2024). Meanwhile, United States apparel exports continued to increase, reaching \$7 billion in 2023 (see Figure 3.6.1.) (ITA, 2024).

Traditionally, the United States was a net exporter of textiles. However, following the COVID-19 pandemic in 2020, it became a net importer. This trend persisted in 2023, with \$9 billion in textile imports and \$8 billion in textile exports (see Figure 3.6.2.). Like the apparel industry, the textile trade was impacted by challenging macroeconomic conditions, contributing to the overall decline in 2023 (ITA, 2024).

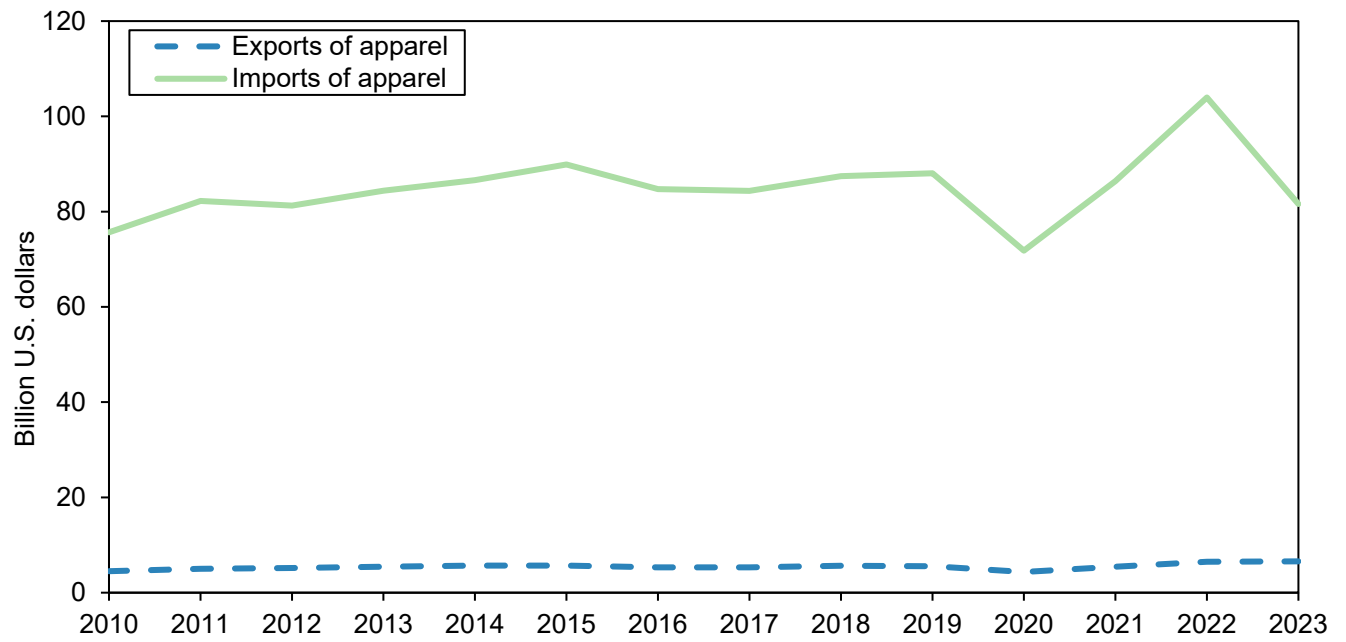


Figure 3.6.1. Exports and imports of apparel in the United States from 2010 to 2023 (in billion U.S. dollars) (ITA, 2024).

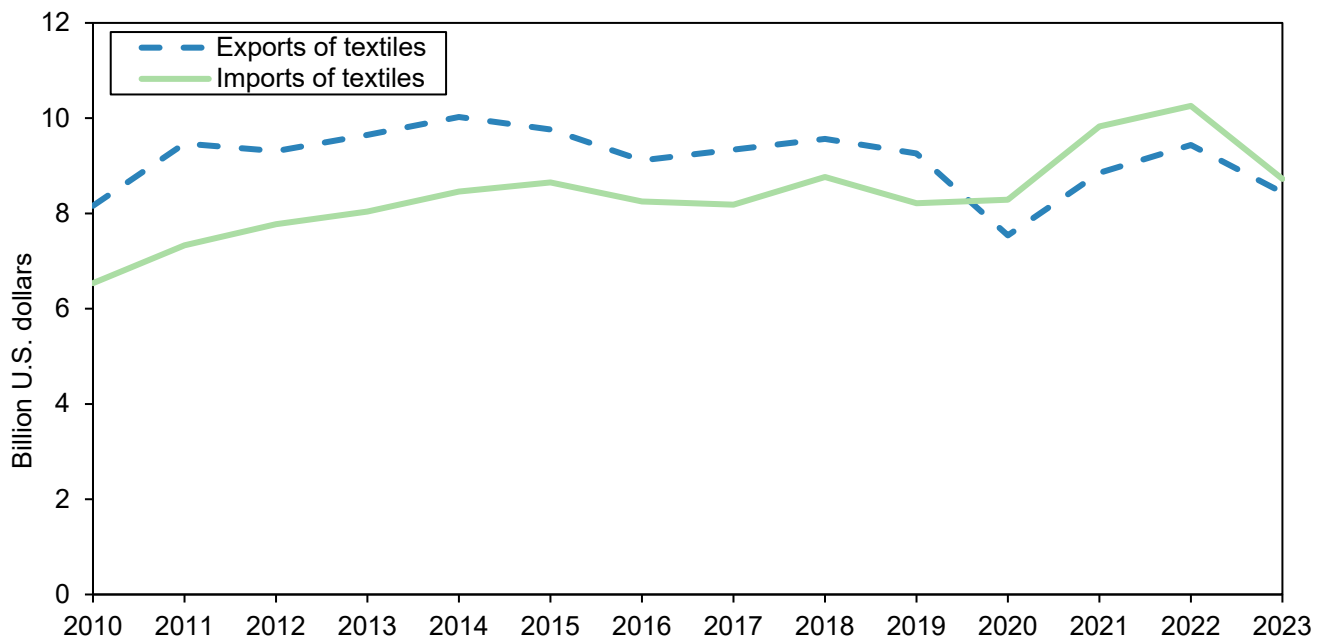


Figure 3.6.2. Exports and imports of textiles in the United States from 2010 to 2023 (in billion U.S. dollars) (ITA, 2024).

3.7. References

American Biogas Council. Third year of record growth for U.S. biogas industry; Expected to continue in 2024. (2024). Accessed from: <https://americanbiogascouncil.org/third-year-of-record-growth-for-u-s-biogas-industry-expected-to-continue-in-2024-2/> [Accessed May 2024].

AviationPROs. Climate-Friendlier Flights Are Taking Off From Southern California. (2023). Accessed from: <https://www.aviationpros.com/ground-handling/fuel-distributors-suppliers-manufacturers/sustainable-aviation-fuel/news/21293969/climate-friendlier-flights-are-taking-off-from-southern-california> [Accessed November 2024].

Biomass Magazine. Pellet Mill List. (2024). Accessed from: <https://biomassmagazine.com/plants/list/pellet-mill> [Accessed August 2024].

Bureau of Economic Analysis. Gross Domestic Product by Industry and Input-Output Statistics. (2024). Accessed from: <https://www.bea.gov/itable/gdp-by-industry> [Accessed August 2024].

California Environmental Protection Agency. Biodiesel and Renewable Diesel Multimedia Evaluations. Accessed from: <https://ww2.arb.ca.gov/resources/documents/biodiesel-and-renewable-diesel-multimedia-evaluations> [Accessed August 2024].

Coherent Market Insights. Global Biodegradable fabrics market size and share analysis. (2024). Accessed from: <https://www.coherentmarketinsights.com/industry-reports/global-biodegradable-fabrics-market> [Accessed September 2024].

Drax. About us. Accessed from: <https://www.drax.com/about-us/> [Accessed August 2024].

Ethanol Producer Magazine. The Latest News and Data About Ethanol Production. (2024). Accessed from: <http://ethanolproducer.com/plants/list/ethanol> [Accessed August 2024].

EuropeanBioplastics. Bioplastics market development update 2023. (2023) Accessed from: <https://www.european-bioplastics.org/market/> [Accessed April 2024].

Federal Register. Renewable Fuel Standard (RFS) Program: Standards for 2023-2025 and Other Changes. (2022). Accessed from: <https://www.federalregister.gov/documents/2022/12/30/2022-26499/renewable-fuel-standard-rfs-program-standards-for-2023-2025-and-other-changes> [Accessed May 2023].

Food and Agriculture Organization of the United States - FAOSTAT - Forestry production and trade. (2024). Accessed from: <http://www.fao.org/faostat/en/#data/FO> [Accessed February 2025].

International Air Transport Association -IATA- Net-Zero Carbon Emissions by 2050. (2021). Accessed from: <https://www.iata.org/en/pressroom/pressroom-archive/2021-releases/2021-10-04-03/> [Accessed August 2024].

ICAO. Conversion processes (2024). Accessed from: <https://www.icao.int/environmental-protection/GFAAF/Pages/Conversion-processes.aspx> [Accessed August 2024].

International Energy Agency – IEA - Renewable Energy Market Update-May 2022-Transport biofuels. (2022). Accessed from: <https://www.iea.org/reports/renewable-energy-market-update-may-2022/transport-biofuels>

Intergovernmental panel on climate change – IPCC – Direct global warming potentials. Accessed from: https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html [Accessed December 2020].

International Renewable Energy Agency -IRENA- Renewable Energy and Jobs – Annual Review. Accessed from: <https://www.irena.org/Publications/2023/Sep/Renewable-energy-and-jobs-Annual-review-2023> [Accessed August 2024].

Iowa Renewable Fuels Association. Contribution of the Renewable Fuels Industry to the Economy of Iowa. (2023). Accessed from: <https://iowarfa.org/economicimpactstudy/> [Accessed August 2024].

I6GROUP. Which Airlines Are Embracing SAF?. (2024). Accessed from: <https://www.i6.io/blog/which-airlines-are-embracing-saf> [Accessed August 2024].

International Trade Administration – ITA - TradeStats Express - U.S. Trade by Product. (2024). Accessed from: <https://www.trade.gov/data-visualization/tradestats-express-us-trade-product> [Accessed September 2024].

MarketLine. Industry Profile. (2023) Accessed from: <https://advantage-marketline-com.libezproxy2.syr.edu/Analysis?reporttype=5914> [Accessed April 2024].

Plastics Industry Association. Plastics Market Watch. Watching: Bioplastics 2024. (2024).

Renewable Fuels Association -RFA- Annual Ethanol Production. (2024). Accessed from: <https://ethanolrfa.org/markets-and-statistics/annual-ethanol-production> [Accessed August 2024].

Renewable Fuels Association -RFA- Biodiesel. (2020). Accessed from: <https://www.afdc.energy.gov/fuels/biodiesel.html> [Accessed August 2024].

Renewable Fuels Association -RFA- Pocket guide to ethanol. (2011-2024). Accessed from: <https://ethanolrfa.org/publications/outlook/> [Accessed August 2024].

Sheng Lu. Patterns of US Apparel Imports in 2023 and Critical Sourcing Trends to Watch in 2024. (2024). Accessed from: <https://shenglufashion.com/2024/02/12/patterns-of-us-apparel-sourcing-and-imports-in-2023/> [Accessed August 2024].

The International Magazine of Rendering – Render – US Market Report. April 2024. Accessed from: <https://rendermagazine.com/past-issues/> [Accessed August 2024].

U.S. Bureau of Labor Statistics Census of Employment and Wages. (2024). Accessed from: https://data.bls.gov/cew/apps/data_views/data_views.htm#tab=Tables [Accessed August 2024].

United States Department of Agriculture - USDA - BioPreferred|Site Map. (2024). Accessed from: <https://www.biopreferred.gov/BioPreferred/faces/Welcome.xhtml> [Accessed September 2024].

United States Department of Agriculture - USDA - Economic Research Service U.S. Bioenergy Statistics. Accessed from: <https://www.ers.usda.gov/data-products/u-s-bioenergy-statistics/> [Accessed August 2024].

United States Department of Agriculture - USDA - Economic Research Service U.S. imports of animal fats, greases, and processed oils surge to meet demand from biomass-based diesel production. Accessed from: <https://www.ers.usda.gov/data-products/chart-gallery/> [Accessed August 2024].

United States Department of Agriculture - USDA – Forest Service. Bioeconomy. (2024). Accessed from: <https://fas.usda.gov/data/production/commodity/0440000> [Accessed August 2024].

United States Department of Agriculture - USDA – Foreign Agricultural Service. (2024). Accessed from: <https://research.fs.usda.gov/forestproducts/bioeconomy> [Accessed August 2024].

United States Department of Agriculture - USDA – The growing importance of U.S. ethanol exports for industrial uses. USDA Foreign Agricultural Service. (2024). Accessed from: <https://fas.usda.gov/data/growing-importance-us-ethanol-exports-industrial-uses> [Accessed April 2024].

United States Department of Agriculture - USDA – World Agricultural Supply and Demand Estimates, April 11, 2024. (2024). Accessed from: <https://esmis.nal.usda.gov/sites/default/release-files/3t945q76s/0g3563734/0c4856877/wasde0424.pdf>

United States Department of Energy -DOE- Alternative Fuels Data Center: Biodiesel Income Tax Credit. Accessed from: <https://afdc.energy.gov/laws/396> [Accessed August 2024].

United States Department of Energy -DOE- Alternative Fuels Data Center: Fuel Prices. Accessed from: <https://www.afdc.energy.gov/fuels/prices.html> [Accessed August 2024].

United States Department of Energy -DOE- Alternative Fuels Data Center: Sustainable Aviation Fuel. Accessed from: <https://afdc.energy.gov/fuels/sustainable-aviation-fuel> [Accessed August 2024].

U.S. Energy Information Administration – EIA - In 2023, U.S. renewable diesel production capacity surpassed biodiesel production capacity. (2023). Accessed from: <https://www.eia.gov/todayinenergy/detail.php?id=60281> [Accessed August 2023].

United States Energy Information Administration - EIA - Monthly Energy Review. (2024). doi: DOE/EIA-0035(2024/8).

U.S. Energy Information Administration – EIA - Petroleum & Other Liquids. Accessed from: https://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_EPOORDO_im0_mbbbl_a.htm [Accessed August 2024].

United States Energy Information Administration - EIA - U.S. biodiesel imports have doubled since 2022 due to low prices in Europe. (2024). Accessed from: <https://www.eia.gov/todayinenergy/detail.php?id=62123>

United States Energy Information Administration - EIA - U.S. capacity to convert waste to energy declines after remaining steady since 1994. (2022). Accessed from: <https://www.eia.gov/todayinenergy/detail.php?id=53639> [Accessed November 2024].

United States Energy Information Administration - EIA - U.S. Energy Atlas. (2024). Accessed from: <https://atlas.eia.gov/datasets/79dad60ce89c47519452a2959d49acd8/explore> [Accessed August 2024].

United States Energy Information Administration - EIA - U.S. Exports of Fuel Ethanol (Thousand Barrels). (2024). Accessed from: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=m_epooxe_eex_nus-z00_mbbbl&f=a [Accessed August 2024].

United States Energy Information Administration - EIA - U.S. Imports of Fuel Ethanol (Thousand Barrels). (2024). Accessed from: <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MFEIMUS1&f=A> [Accessed August 2024].

U.S. Environmental Protection Agency - EPA - Energy recovery from the combustion of municipal solid waste (MSW). (2024). Accessed from: <https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw> [Accessed April 2024].

U.S. Environmental Protection Agency - EPA - Landfill Gas Energy Project Data. (2024). Accessed from: <https://www.epa.gov/lmop/landfill-gas-energy-project-data> [Accessed September 2024].

U.S. Environmental Protection Agency - EPA - Livestock Anaerobic Digester Database. (2024). Accessed from: <https://www.epa.gov/agstar/livestock-anaerobic-digester-database> [Accessed September 2024].

U.S. Environmental Protection Agency - EPA - Renewable Natural Gas. (2024). Accessed from: <https://www.epa.gov/lmop/renewable-natural-gas> [Accessed August 2024].

United States Environmental Protection Agency – EPA - RINs Generated Transactions. (2024). Accessed from: <https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rins-generated-transactions> [Accessed August 2024].

United States Government Accountability Office - GAO - Sustainable Aviation Fuel:

Agencies Should Track Progress Toward Ambitious Federal Goals. (2023). Accessed from: <https://www.gao.gov/products/gao-23-105300> [Accessed August 2024].

Waste Management World. The state of waste-to-energy in the US. (2023). Accessed from: <https://waste-management-world.com/resource-use/the-state-of-waste-to-energy-in-the-us/> [Accessed June 2024].

4AIR. Where can I find Sustainable Aviation Fuel (SAF)? (2023). Accessed from: <https://www.4air.aero/saf-map> [Accessed August 2024].

4.APPENDIX



4.1. Bioindicators Database Structure

The database compiled for this report is presented in additional detail in an accompanying spreadsheet, [USDA_Bioindicators_2023.xlsx](#). This file includes physical, production, trade, and economic data from 2010 through 2023.

4.1.1. Using the Bioindicators Database

The file has a Table of Contents where the major categories are listed. Each category's name is hyperlinked to the corresponding sheet with the data. When clicking on the hyperlink for the desired category, the sheet with the data for that category is opened. Each data sheet contains the name of the variable, the values of the variable for different years, source name, the link to the reference from which the data was retrieved, and the date of retrieval.

4.1.2. Data Overview

A list of the data included in the database is provided below.

4.1.2.1. Ethanol

Number of ethanol plants installed in the United States [2010-2023]

Number ethanol plants in the United States-Starch [2016-2023]

Number ethanol plants in the United States-Cellulosic [2016-2023]

Number ethanol plants in the United States-Corn [2018-2023]

Number ethanol plants in the United States-Sorghum [2018-2023]

Number ethanol plants in the United States-Other (Tobacco, crop residue, waste stream) [2018-2023]

Number of ethanol plants operational in the United States [2011-2023]

Number of existing plants under construction [2013-2023]

Number proposed ethanol plants in the United States [2017-2019, 2022-2023]

Number of States which have an ethanol production facility [2010-2023]

Ethanol plant capacities (billion gallons) [2010-2023]

Total volume of ethanol produced in U.S. (billion gallons) [2010-2023]

Total volume of ethanol consumed (billion gallons) [2010-2023]

Total volume of ethanol consumed: Transportation (billion gallons) [2010-2023]

Total volume of ethanol consumed: Industrial sector (billion gallons) [2010-2023]

Total volume of ethanol imported into the U.S. (billion gallons) [2010-2023]

Total volume of ethanol exported from the U.S. (billion gallons) [2010-2023]

Total corn used for fuel ethanol use (million metric tons) [2010-2023]

Price for ethanol per gallon (dollar per gallon) [2010-2023]

Price for ethanol per gallon (dollar per gge) [2010-2023]

Price for E85 per gallon (dollar per gge) [2010-2023]
Price for gasoline per gallon (dollar per gge) [2010-2023]
Number of direct jobs working with ethanol production [2010-2023]
Number of indirect and induced jobs working with ethanol production [2010-2023]
GDP influence (billion dollars) [2010-2023]
Household income from industry (billion dollars) [2010-2023]
Tax revenue (billion dollars) [2012-2023]
Crude oil (dollar per barrel) [2010-2023]
Ethanol facilities location by capacity (million gallons) [2023]

4.1.2.2. Biobutanol

Total volume of biobutanol entering the commercial market in the U.S. (thousand gallons) [2013-2023]
Biobutanol production estimation (million liters) [2023]

4.1.2.3. Biodiesel

Number of biodiesel plants in the United States [2011-2023]
Number of proposed biodiesel plants [2016-2019, 2021,2023]
Number of existing plants under construction [2016-2019, 2021,2023]
Number of States which have a biodiesel production facility [2011-2023]
Total production of biodiesel in U.S. (billion gallons) [2010-2023]
Total volume of biodiesel consumed for transportation (billion gallons) [2010-2023]
Total volume of biodiesel imported into the U.S. (million gallons) [2010-2023]
Total volume of biodiesel exported from the U.S. (million gallons) [2010-2023]
Number of biodiesel stations [2010-2023]
Price per gallon of biodiesel (dollar per gallon) [2010-2023]
Price per gallon of B99/100 (dollar per gge) [2010-2023]
Price per gallon of B20 (dollar per gge) [2010-2023]
Price per gallon of diesel (dollar per gge) [2010-2023]
Average soy price (dollar per metric tons) [2010-2023]
Number of direct jobs working with biodiesel production [2014-2023]
Biodiesel facilities location by capacity (million gallons) [2023]

4.1.2.4. Animal Fats and Recycled Greases

Total production of poultry fat (Thousand metric tons) [2011-2023]
Total production of tallow (Thousand metric tons) [2011-2023]
Total production of white grease (Thousand metric tons) [2011-2023]
Total production of yellow grease (Thousand metric tons) [2011-2022]
Total production of other fats (Thousand metric tons) [2011-2023]

Total consumption of poultry fat for feed and food (Thousand metric tons) [2011-2022]
 Total consumption of tallow for feed and food (Thousand metric tons) [2011-2022]
 Total consumption of white grease for feed and food (Thousand metric tons) [2011-2022]
 Total consumption of yellow grease for feed and food (Thousand metric tons) [2011-2022]
 Total consumption of poultry going to biodiesel (Thousand metric tons) [2009-2023]
 Total consumption of tallow going to biodiesel (Thousand metric tons) [2009-2023]
 Total consumption of white grease going to biodiesel (Thousand metric tons) [2009-2023]
 Total consumption of yellow grease to biodiesel (Thousand metric tons) [2009-2023]
 Total consumption of other fats going to biodiesel (Thousand metric tons) [2009-2023]
 Total exports of poultry fat (Thousand metric tons) [2012-2023]
 Total exports of tallow (Thousand metric tons) [2011-2023]
 Total exports of white grease (Thousand metric tons) [2011-2023]
 Total exports of yellow grease (Thousand metric tons) [2011-2023]
 Total imports of poultry fat (Thousand metric tons) [2012-2023]
 Total imports of tallow (Thousand metric tons) [2012-2023]
 Total imports of white grease (Thousand metric tons) [2012-2023]
 Total imports of yellow grease (Thousand metric tons) [2012-2023]
 Price for poultry fat (dollar per metric ton) [2011-2023]
 Price for tallow (dollar per metric ton) [2011-2023]
 Price for white grease (dollar per metric ton) [2011-2023]
 Price for yellow grease (dollar per metric ton) [2011-2023]

4.1.2.5. Renewable Diesel

Number of renewable diesel plants installed in the United States [2021-2023]
 Number of States which have renewable diesel plants in the United States [2021-2023]
 Renewable diesel plant capacities (billion gallons) [2021-2023]
 Total production of renewable diesel in the U.S. (million gallons) [2010-2023]
 Total consumption of renewable diesel in the U.S. (million gallons) [2010-2023]
 Total volume of renewable diesel exported from the U.S. (million gallons) [2016-2023]
 Total volume of renewable diesel imported into the U.S. (million gallons) [2012-2023]
 Renewable Diesel plants location by capacity (million gallons) [2023]

4.1.2.6. Renewable Jet Fuel

Total production of renewable jet fuel (million gallons) [2016-2023]
 Total consumption of renewable jet fuel (million gallons) [2016-2023]
 Total consumption of jet fuel by Airlines (million gallons) [2016-2022]
 Airline off-take agreement (thousand gallons) [2013-2023]
 Number of eligible renewable jet fuel producers [2012-2023]

Number of renewable jet fuel facilities in service [2012-2023]
Number of airports with renewable jet fuel [2023]
Number of States with renewable jet fuel available at airports [2015-2023]
Domestic CO₂ emissions from aviation sector (Million metric tons) [2010-2022]
International CO₂ emissions form aviation sector (Million metric tons) [2010-2022]
Airports and FBOs offering renewable jet fuel [2023]

4.1.2.7. Wood Pellets

Total operational capacity of pellet mill facilities (million metric tons) [2015-2023]
Number of wood pellets plants in the United States [2013-2023]
Number of proposed wood pellets plants [2013-2023]
Number of existing wood pellets plants under construction [2013-2023]
Number of existing wood pellets plants that were put on standby [2016-2023]
Number of States which have a wood pellets production facility [2013-2023]
Wood pellets production (million metric tons) [2012-2023]
Wood pellets imports (Thousand metric tons) [2012-2023]
Wood pellets exports (million metric tons) [2012-2023]
Wood pellets consumption (million metric tons) [2012-2023]
Electricity net generation from wood (trillion BTUs) [2010-2023]
Electricity net generation from wood (trillion BTUs): Industrial sector [2010-2023]
Electricity net generation from wood (trillion BTUs): Electric power sector [2010-2023]
Heating from wood in the U.S. (trillion BTUs) [2010-2023]
Energy consumption from wood in U.S. (trillion BTUs) [2010-2023]
Energy consumption from wood in U.S. (trillion BTUs): Residential sector [2010-2023]
Energy consumption from wood in U.S. (trillion BTUs): Commercial sector [2010-2023]
Energy consumption from wood in U.S. (trillion BTUs): Industrial sector [2010-2023]
Energy consumption from wood in U.S. (trillion BTUs): Electric power sector [2010-2023]
Wood pellet production worldwide (million metric tons) [2010-2023]
Average annual densified biomass capacity (million metric tons) [2016-2023]
Wood pellets exported from U.S. (in million \$) [2012-2023]
Wood pellets imported from U.S. (in million \$) [2012-2023]
Total jobs created in the wood pellet industry [2010-2023]
Wood pellets facilities location by capacity (metric tons) [2023]
Wood pellets production by country (metric tons) [2023]

4.1.2.8. Waste to Energy

Number of WTE plants in the United States [2010-2023]
Number of WTE plants proposed in the United States [2010-2023]

Number of WTE existing plants that were put on standby in the United States [2010-2023]

Number of WTE existing plants that were closed-shut down in the United States [2010-2023]

Number of WTE fuel switching plants in the United States [2010-2023]

Number of States which have an WTE fuel switching production facility in the United States [2010-2023]

Municipal solid waste generation in the United States (million metric tons) [2010-2018]

Municipal solid waste generation in the United States (million metric tons): Recycled and composted [2010-2018]

Municipal solid waste generation in the United States (million metric tons): Combusted with energy recovery [2010-2018]

Municipal solid waste generation in the United States (million metric tons): Landfilled [2010-2018]

Biogenic Municipal Solid Waste: Consumption for electricity generation (million metric tons) [2010-2023]

Biogenic Municipal Solid Waste: Consumption for heating generation (million metric tons) [2010-2023]

Biogenic Municipal Solid Waste: Consumption for energy generation (million metric tons) [2010-2023]

Biogenic Municipal Solid Waste: Consumption for energy generation (million metric tons): Electric utilities [2010-2023]

Biogenic Municipal Solid Waste: Consumption for energy generation (million metric tons): Independent power producers [2010-2023]

Biogenic Municipal Solid Waste: Consumption for energy generation (million metric tons): Commercial sector [2010-2023]

Biogenic Municipal Solid Waste: Consumption for energy generation (million metric tons): Industrial sector [2010-2023]

Biogenic Municipal Solid Waste: Consumption for electricity generation (Trillion BTUs) [2010-2022]

Biogenic Municipal Solid Waste: Consumption for heating generation (Trillion BTUs) [2010-2022]

Biogenic Municipal Solid Waste: Consumption for energy generation (Trillion BTUs) [2010-2022]

Biogenic Municipal Solid Waste: Consumption for energy generation (Trillion BTUs): Electric utilities [2010-2022]

Biogenic Municipal Solid Waste: Consumption for energy generation (Trillion BTUs): Independent power producers [2010-2022]

Biogenic Municipal Solid Waste: Consumption for energy generation (Trillion BTUs): Commercial sector [2010-2022]

Biogenic Municipal Solid Waste: Consumption for energy generation (Trillion BTUs): Industrial sector [2010-2022]

Revenue from waste electricity generation in the U.S. (million dollars) [2011-2022]

Jobs in WTE facilities [2013-2014, 2016, 2018-2019]

Total jobs (direct, indirect, and induced) created by WTE [2013-2014, 2016, 2018]

Total economic output by WTE (million dollars) [2013-2014, 2016, 2018]

Waste-to-energy facilities location by net generation (MWh) [2023]

4.1.2.9. Biogas

Number of anaerobic digestion (AD) plants [2010-2023]

Number of anaerobic digestion (AD) plants used for electricity [2010-2023]

Number of anaerobic digestion (AD) plants used for boiler/furnace [2010-2023]

Number of anaerobic digestion (AD) plants used for "flare full time" [2010-2023]

Number of anaerobic digestion (AD) plants used for cogeneration [2010-2023]

Number of Existing AD plants under construction [2010-2023]

Number of New AD plants that went online from livestock [2010-2023]

Number of AD plants that shut down [2010-2020,2022]

Number of States which have an AD production facility [2010-2023]

Number of landfill plants [2010-2023]

Number of States which have a landfill facility [2010-2023]

Biogas potential from landfills (billion cubic feet) [2018, 2020-2023]

Biogas potential from wastewater (billion cubic feet) [2018, 2020,2023]

Biogas potential from animal manure (billion cubic feet) [2018, 2020,2023]

Anaerobic digestion: Biogas generated (trillion BTU) [2010-2023]

Anaerobic digestion: Biogas generated (billion cubic feet) [2010-2023]

Anaerobic digestion: Total methane emission reductions (million metric tons of CO₂) [2010-2023]

Agriculture: Total methane emissions (million metric tons of CO₂) [2010-2022]

Landfill gas: Energy consumption (trillion BTU) [2010-2022]

Landfill gas: Energy consumption (billion cubic feet) [2010-2022]

Landfill gas: Total methane emission reductions (million metric tons of CO₂) [2010-2023]

Waste: total methane emissions (million metric tons of CO₂) [2010-2022]

Agriculture renewable natural gas projects [2010-2023]

Landfill renewable natural gas projects [2010-2023]

Anaerobic digesters in farms location [2023]

Landfills location [2023]

Wastewater treatment facilities location [2015]

Biomethane production (thousand metric tons) [2023]

4.1.2.10. Bioproducts

USDA BioPreferred product certifications: Total [2017-2023]

USDA BioPreferred product certifications: Baby and kids [2017-2020, 2022-2023]

USDA BioPreferred product certifications: Construction [2017-2020, 2022-2023]

USDA BioPreferred product certifications: Custodial services [2017-2020, 2022-2023]

USDA BioPreferred product certifications: Films and packaging [2017-2020, 2022-2023]

USDA BioPreferred product certifications: Food services/cafeteria [2017-2020, 2022-2023]

USDA BioPreferred product certifications: Grounds maintenance [2017-2020, 2022-2023]
USDA BioPreferred product certifications: Household supplies [2017-2020, 2022-2023]
USDA BioPreferred product certifications: Intermediates [2017-2020, 2022-2023]
USDA BioPreferred product certifications: Miscellaneous [2017-2020, 2022-2023]
USDA BioPreferred product certifications: Office supplies [2017-2020, 2022-2023]
USDA BioPreferred product certifications: Operations and maintenance [2017-2020, 2022-2023]
USDA BioPreferred product certifications: Personal care and toiletries [2017-2020, 2022-2023]
USDA BioPreferred product certifications: Safety Equipment [2017-2020, 2022-2023]
USDA BioPreferred product certifications: Vehicles and equipment maintenance [2017-2020, 2022-2023]

4.1.2.11. Bioplastics

U.S. plastic and rubber products value added (billion dollars) [2008-2023]
Value added of manufacturing U.S. plastic and rubber products as percentage of GDP (percent) [2008-2023]
Gross output of U.S. plastic and rubber products (billion dollars) [2008-2023]
Compensation of employees, value added of plastics and rubber products (billion dollars) [2008-2022]
Taxes on production and imports, less subsidies of U.S. plastics and rubber products (billion dollars) [2008-2022]
Gross operating surplus of plastics and rubber product products (billion dollars) [2008-2022]
Full and part time employees (thousands) [2008-2022]
Global plastic production (million metric tons) [2008-2022]
Global production capacity of biodegradable bioplastics (million metric tons) [2008-2023]
Global production capacity of non-biodegradable bioplastics (million metric tons) [2008-2023]
Global production capacities of biodegradable and non-biodegradable bioplastics: Total (million metric tons) [2008-2023]
Global production capacities of biodegradable and non-biodegradable bioplastics: Packaging (flexible & rigid) (percent) [2017-2023]
Global production capacities of biodegradable and non-biodegradable bioplastics: Textiles (percent) [2017-2023]
Global production capacities of biodegradable and non-biodegradable bioplastics: Consumer goods (percent) [2017-2023]
Global production capacities of biodegradable and non-biodegradable bioplastics: Agriculture & horticulture (percent) [2017-2023]
Global production capacities of biodegradable and non-biodegradable bioplastics: Automotive & transport (percent) [2017-2023]
Global production capacities of biodegradable and non-biodegradable bioplastics: Building & construction (percent) [2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Electronics (percent) [2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Others (percent) [2017-2023]

Percentage of bioplastic in total global plastic consumption [2008-2022]

Land Used for bioplastics (million ha) [2013-2019]

Land Used for bioplastics/total amount of arable land (%) [2013-2019]

Global production capacities of biodegradable and non-biodegradable bioplastics: Starch blends (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Polylactic acid (PLA) (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Poly (butylene adipate-co-terephthalate) (PBAT) (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Polyethylene (PE) (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Polyamides (PA) (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Terephthalate (PET) (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Polytrimethylene Terephthalate (PTT) (percent) [2014, 2018-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Polybutylene Succinate (PBS) (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Other (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Polyhydroxyalkanoates (PHA) (percent) [2014, 2017-2023]

Global production capacities of biodegradable and non-biodegradable bioplastics: Polypropylene (PP) (percent) [2014, 2017-2023]

4.1.2.12. Enzymes

Global industrial enzyme market (billion dollars): Total [2008-2021]

Global industrial enzyme market (billion dollars): Food (billion dollars) [2011-2017]

Global industrial enzyme market (billion dollars): Feed (billion dollars) [2011-2013, 2016-2017]

Global industrial enzyme market (billion dollars): Technical (billion dollars) [2011-2013, 2016-2017]

Global industrial enzyme market (billion dollars): Biofuel (billion dollars) [2017,2021]

Global industrial enzyme market (billion dollars): Other (billion dollars) [2017]

Global industrial enzyme market (billion dollars): Detergent (billion dollars) [2011-2013, 2016]

4.1.2.13. Apparel and Textiles

U.S. textile mills and textile product mills value added (billion dollars) [2008-2023]

Value added of manufacturing U.S. textile mills and textile product mills as a percentage of GDP (%) [2008-2023]

Gross output of U.S. textile mills and textile product mills (billion dollars) [2008-2023]

Compensation of employees, value added of textile mills & textile product mills (billion dollars) [2008-2022]

Taxes of production and imports, less subsidies of U.S. textile mills & textile product mills (billion dollars) [2008-2022]

Gross operating surplus of textile mills & textile product mills products (billion dollars) [2008-2022]

Full and part time employees (thousands) [2008-2022]

Apparel and leather and allied products value added (billion dollars) [2008-2023]

Value added of manufacturing U.S. apparel and leather and allied products as a percentage of GDP (%) [2008-2023]

Gross output of U.S. apparel and leather and allied products (billion dollars) [2008-2023]

Compensation of employees, value added of apparel and leather and allied products (billion dollars) [2008-2022]

Taxes of production and imports, less subsidies of U.S. apparel and leather and allied products (billion dollars) [2008-2022]

Gross operating surplus of apparel and leather and allied products products (billion dollars) [2008-2022]

Full and part time employees (thousands) [2008-2022]

Value of the U.S. apparel exports worldwide (billion dollars) [2009-2023]

Value of the U.S. apparel imports worldwide (billion dollars) [2009-2023]

Value of the U.S. textiles exports worldwide (billion dollars) [2009-2023]

Value of the U.S. textiles imports worldwide (billion dollars) [2009-2023]

4.1.2.14. Forest Products

U.S. wood products value added (billion dollars) [2008-2023]

Value added of manufacturing U.S. wood products as percentage of GDP (percent) [2008-2023]

Gross output of U.S. wood products (billion dollars) [2008-2023]

Compensation of employees, value added of wood products (billion dollars) [2008-2022]

Taxes of production and imports, less subsidies of U.S. wood products (billion dollars) [2008-2022]

Gross operating surplus of wood products (billion dollars) [2008-2022]

Full and part time employees of U.S. wood products (thousands) [2008-2022]

U.S. paper products value added (billion dollars) [2008-2023]

Value added of manufacturing U.S. paper products as percentage of GDP (percent) [2008-2023]

Gross output of U.S. paper products (billion dollars) [2008-2023]
 Compensation of employees, value added of paper products (billion dollars) [2008-2022]
 Taxes of production and imports, less subsidies of U.S. paper products (billion dollars) [2008-2022]
 Gross operating surplus of paper products (billion dollars) [2008-2022]
 Full and part time employees of U.S. paper products (thousands) [2008-2022]
 Total production of wood fuel (million m³) [2008-2023]
 Total production of wood residues (million m³) [2008-2023]
 Total production of roundwood (million m³) [2008-2023]
 Total production of sawnwood (million m³) [2008-2023]
 Total production of wood-based panels (million m³) [2008-2023]
 Total production of wood pulp (million metric tons) [2008-2023]
 Total production of paper and paperboard (million metric tons) [2008-2023]
 Total production of wood pellets (million metric tons) [2012-2023]
 Total production of forest products imports (billion dollars) [2008-2023]
 Total production of forest products exports (billion dollars) [2008-2023]

4.1.2.15. Funding

Number of awards granted by the NIFA to research projects involving ethanol [2008-2023]
 Number of awards granted by the NIFA to research projects involving biobutanol [2008-2023]
 Number of awards granted by the NIFA to research projects involving biodiesel [2008-2023]
 Number of awards granted by the NIFA to research projects involving renewable diesel [2008-2023]
 Number of awards granted by the NIFA to research projects involving renewable jet fuel [2008-2023]
 Number of awards granted by the NIFA to research projects involving recycled greases [2008-2023]
 Number of awards granted by the NIFA to research projects involving animal fats [2008-2023]
 Number of awards granted by the NIFA to research projects involving wood pellets [2008-2023]
 Number of awards granted by the NIFA to research projects involving waste to energy [2008-2023]
 Number of awards granted by the NIFA to research projects involving biogas [2008-2023]
 Number of awards granted by the NIFA to research projects involving bioproducts [2008-2023]
 Number of awards granted by the NIFA to research projects involving bioplastics [2008-2023]
 Number of awards granted by the NIFA to research projects involving biochemicals [2008-2023]
 Number of awards granted by the NIFA to research projects involving biofuels [2008-2023]
 Number of awards granted by the NIFA to research projects involving enzymes [2008-2023]
 Number of awards granted by the NSF to research projects involving ethanol [2008-2023]
 Number of awards granted by the NSF to research projects involving biobutanol [2008-2023]
 Number of awards granted by the NSF to research projects involving biodiesel [2008-2023]
 Number of awards granted by the NSF to research projects involving renewable diesel [2008-2023]
 Number of awards granted by the NSF to research projects involving renewable jet fuel [2008-2023]
 Number of awards granted by the NSF to research projects involving recycled greases [2008-2023]

Number of awards granted by the NSF to research projects involving animal fats [2008-2023]
Number of awards granted by the NSF to research projects involving wood pellets [2008-2023]
Number of awards granted by the NSF to research projects involving waste to energy [2008-2023]
Number of awards granted by the NSF to research projects involving biogas [2008-2023]
Number of awards granted by the NSF to research projects involving bioproducts [2008-2023]
Number of awards granted by the NSF to research projects involving bioplastics [2008-2023]
Number of awards granted by the NSF to research projects involving biochemicals [2008-2023]
Number of awards granted by the NSF to research projects involving biofuels [2008-2023]
Number of awards granted by the NSF to research projects involving enzymes [2008-2023]
Award amount range by the NIFA for biofuels and bioproducts projects (dollars) [2022-2023]
Award amount range by the NSF for biofuels and bioproducts projects (dollars) [2022-2023]