WORLD BIOENERGY ASSOCIATION

2024 | 11th Edition

GLOBAL BIOENERGY STATISTICS REPORT

ABOUT US

Founded in 2008 in Stockholm, Sweden, the World Bioenergy Association (WBA) is a leading international NGO and non-profit association committed to advancing sustainable bioenergy development worldwide.

Through the publication of insightful reports and the organization of and support to impactful events, WBA shares insights on the latest bioenergy developments, encompassing markets, policies, technologies, and finance. It also offers a vibrant platform for stakeholders in the bioenergy sector to showcase their offerings, encompassing a diverse membership including national and regional associations, equipment manufacturers, fuel producers, traders, CHP facilities, utilities, and more from over 40 countries.

Additionally, WBA actively engages in strategic partnerships and international collaborations, such as the REN Alliance, the Global Bioenergy Partnership, and the IRENA Coalition for Action. For more information about the World Bioenergy Association, visit www.worldbioenergy.org.

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SUMMARY

In 2022, fossil fuels still provided 80% of the global energy supply, while biofuels maintained a steady 9% share. Renewable energy sources, including biofuels, continued their rise, contributing 89 EJ of the total 622 EJ global energy supply, marking a 30% increase over the past decade.

In 2021, the global biomass supply reached 54 EJ, with solid biomass like wood chips and pellets accounting for 85% of the total. Europe remained the largest producer and consumer of wood pellets, driven by strong policy support, while Vietnam saw a 33% increase in production, becoming a major exporter to Japan and South Korea. Agricultural residues, such as bagasse and straw, also played a significant role in bioenergy supply, particularly in Latin America and Asia.

Bioenergy plays an important role in electricity generation, transport, and heat production. In 2023, global bioenergy electricity generation reached 697 TWh, 8% of total renewable electricity generation. Asia was the leading producer of bioenergy-based electricity, with 51% of the global output. However, wind and solar have grown more rapidly than bioenergy in recent years.

Bioenergy also dominated heat production in 2021, contributing 96% of renewable heat, with Europe producing nearly 80% of global renewable heat, driven largely by bioenergy. Biomass-based heat remains a significant contributor to energy needs, particularly in Europe.

In the transport sector, biofuels provided 3.94 EJ in 2022, accounting for 93% of renewable energy used in transport. Following a dip during the pandemic, biofuel use rebounded by 3.2%, reaching pre-pandemic levels. Notably, biofuel mandates remained crucial in 64 countries to promote renewable energy in transport, with the U.S. and Brazil being the largest producers of biofuels.

In liquid biofuels, ethanol remained the dominant biofuel in 2023, with production reaching 116 billion liters globally. The U.S. and Brazil together accounted for 80% of this output. India also made significant strides, becoming the third-largest producer with 6.4 billion liters. Biodiesel production approached 50 billion liters, with Indonesia, the EU, Brazil, and the U.S. leading global production.

Bioenergy capacity has grown steadily, reaching 150.3 GW globally by 2023. Asia led this expansion, with capacity nearly tripling since 2014, particularly in China. However, growth slowed to 3% in 2023, the slowest in a decade, underscoring the need for further investments and policy support to maintain momentum in bioenergy development.

In 2023, the bioenergy sector created 3.9 million jobs globally, with liquid biofuels accounting for over 70%. Investments in bioenergy are rising, with global funding reaching USD 9 billion in 2022, driven by projects in biofuels and solid biomass.

DISCLAIMER

WBA publishes the Global Bioenergy Statistics reports annually to increase awareness of the role of bioenergy in the global energy mix. The reports are prepared with the extreme care and due diligence. Even though every effort is made to ensure the highest quality in data presented in the report, WBA cannot be held liable for the accuracy of the information presented.

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INTRODUCTION

The Global Bioenergy Statistics report, published annually by the World Bioenergy Association (WBA), stands as a key resource in understanding the evolution of the bioenergy sector. First introduced in 2014, this report has consistently provided insights into the developments within the bioenergy field. The 2024 edition marks the 11th issue in this series, reflecting significant changes in both data sources and report structure.

Bioenergy, derived from biological materials (biomass), plays a pivotal role in the global energy mix. It encompasses a diverse range of feedstocks, technology pathways, and end products, making it a versatile and essential component of renewable energy systems. As the largest renewable energy source globally, bioenergy's importance is underscored by its capacity to provide sustainable energy solutions across various sectors, including electricity, heat, and transportation.

This year's report covers data from 2021 to 2023, offering the most recent and relevant insights into bioenergy trends. We have expanded our data sources to include governmental portals, think tanks, renewable energy network organizations, as well as other data platforms. This broadening of sources ensures a more comprehensive and nuanced view of the global bioenergy landscape.

The structure of the 2024 report has been redesigned to provide a deeper understanding of the sector's impact and potential. It now includes updated sections on Bioenergy Installed Capacity and Bioenergy Generation, highlighting where capacity has been added and detailing advancements in various bioenergy technologies like liquid biofuels. New to this edition are sections focusing on socio-economic factors, such as job creation and investments, as well as emerging technologies like Sustainable Aviation Fuel (SAF) and Bioenergy with Carbon Capture and Storage (BECCS).

As you explore this report, you will find practical case studies and updates on specific countries and continents, enriching the analysis with real-world examples. This approach provides valuable context and illustrates the diverse applications and impacts of bioenergy across different regions.

By presenting the latest data and insights, the 2024 Global Bioenergy Statistics report aims to support stakeholders in making informed decisions and driving forward the development of sustainable bioenergy solutions. We hope this report will serve as a valuable tool for policymakers, industry leaders, and researchers engaged in the bioenergy sector.

To get in touch with WBA, please send an email to info@worldbioenergy.org.

World Bioenergy Association

WORLD ENERGY MIX

Total Energy Supply

In 2022, the global energy supply reached 622 EJ, with fossil fuels continuing to dominate, providing 80% of the total supply. Coal, oil, and gas remained the primary sources of energy. Renewable energy sources, however, continued their steady rise, supplying 89 EJ, which marked an almost 30% increase over the past decade. Bioenergy accounted for 9% of the total energy supply, maintaining a stable share.

Table 1. World's Total Energy Supply by Source

Year	Total	Coal	Oil	Gas	Nuclear	Renewables	Bioenergy (%)
2013	556	163	177	121	27	67	8.43
2014	563	165	180	121	28	69	8.41
2015	564	161	182	122	28	70	8.44
2016	569	156	185	127	28	72	8.51
2017	581	159	188	130	29	75	8.50
2018	595	162	189	136	30	78	8.55
2019	602	162	191	139	30	81	8.58
2020	580	158	173	138	29	83	8.97
2021	614	169	183	146	31	86	8.75
2022	622	172	188	144	29	89	8.76

All values in EJ

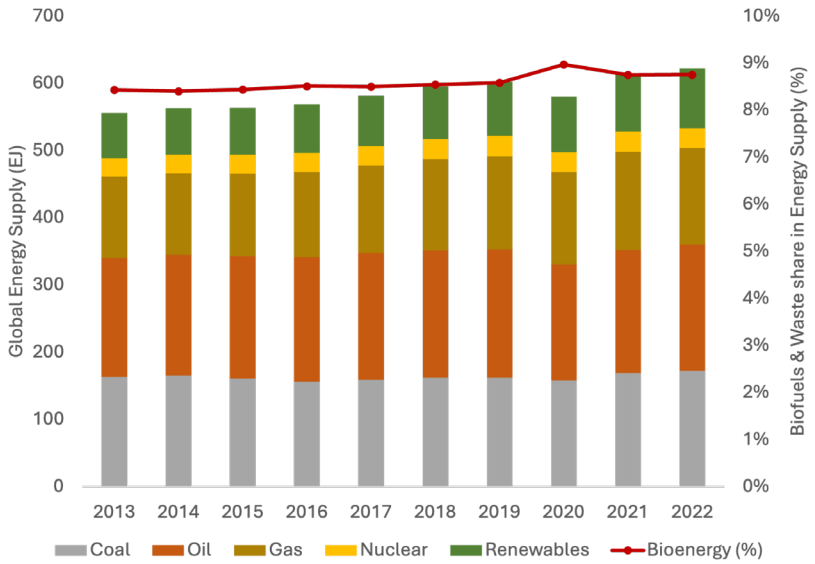


Figure 1. Total Energy Supply globally and share of bioenergy

Total Final Energy Consumption

In 2022, the total final energy consumption reached 422 EJ, with fossil fuels continuing to dominate and contributing over 82% of the total. Oil products remained the largest single energy source at 168 EJ, followed by electricity and heat at 104 EJ, showing a continuous increase over the last decade.

However, the share of renewable energy, excluding bioenergy, continued its steady rise, reaching 2.87 EJ, more than doubling since 2012. Bioenergy also remained a significant component, providing 39 EJ, though their growth has plateaued over the decade.

Table 2. World's Total Final Energy Consumption by Source

Year	Coal	Oil Products	Natural Gas	Other Renewables	Biofuels	Electricity & Heat	Total
2013	47	155	59	1.48	42	82	386
2014	47	157	59	1.59	42	84	391
2015	46	161	59	1.73	42	84	394
2016	44	164	61	1.88	42	87	399
2017	42	168	63	2.02	42	90	407
2018	40	170	67	2.21	43	94	417
2019	39	171	68	2.33	44	95	419
2020	38	155	67	2.50	43	95	402
2021	38	164	72	2.68	44	101	422
2022	37	168	71	2.87	37	104	422

All values in EJ

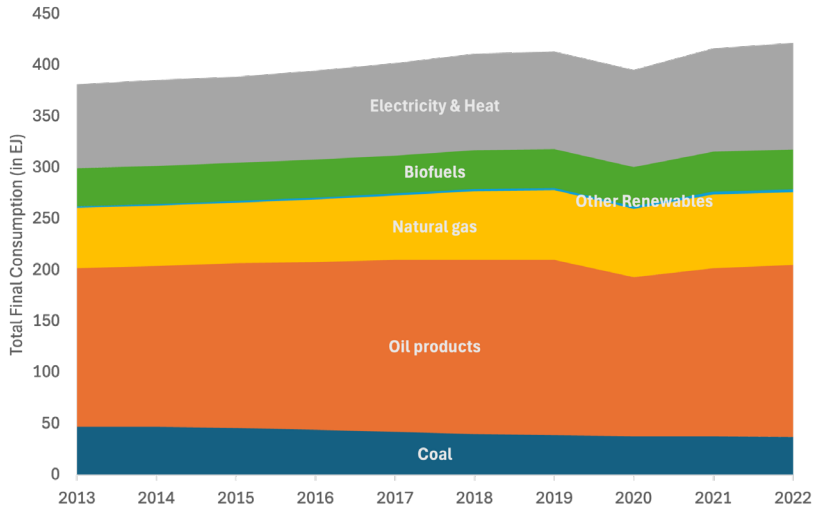


Figure 2. Total Final Energy Consumption by Source

RENEWABLE ENERGY STATUS

Electricity

In 2023, global renewable electricity generation reached 8 931 TWh, with hydropower leading at 47% and wind at 26%. Bioenergy, the fourth largest source, contributed 697 TWh, maintaining an 8% share. While bioenergy has grown, its relative share has remained stable compared to wind and solar, which have expanded more rapidly in the past decade.

Table 3. Renewable power generation globally. Source: Ember

Year	Total	Bioenergy	Hydro	Solar	Wind	Other Renewables	Bioenergy Share (%)
2000	2858	154	2629	1	31	44	5
2005	3280	211	2 912	4	104	49	6
2010	4192	325	3 428	32	346	60	8
2015	5519	477	3 884	256	830	73	9
2020	7484	609	4 344	853	1 591	86	8
2021	7927	659	4 276	1 056	1 849	87	8
2022	8485	676	4 298	1 323	2 099	89	8
2023	8931	697	4 210	1 631	2 304	90	8

All values in TWh

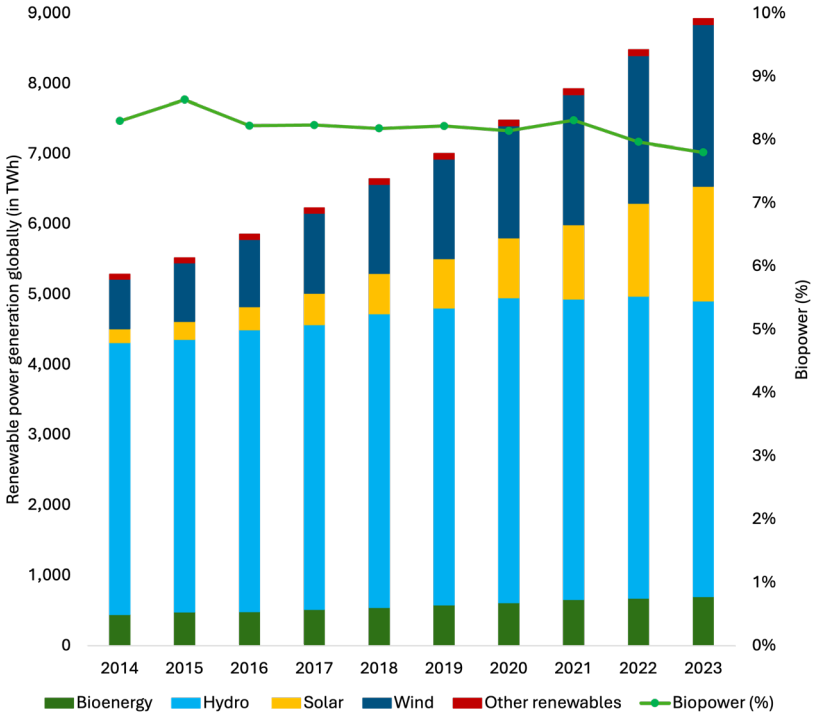


Figure 3. Renewable power generation and share of bioenergy

In 2023, Asia led global renewable electricity generation with 46% (4 087 TWh), followed by the Americas at 28% (2 505 TWh) and Europe at 22% (1942 TWh).
For bioenergy, Asia was also the largest contributor with 51% (357 TWh). Europe followed with 28% (198 TWh), and the Americas provided 19% (133 TWh). Africa and Oceania had minimal contributions in both categories. This distribution highlights Asia's significant role in both renewable energy and bioenergy production, reflecting varying regional capacities and energy profiles.

Table 4. Renewable power generation in continents in 2023. Source: Ember

Continent	Total	Bioenergy	Hydro	Solar	Wind	Other Renewables	Biopower (%)
Africa	214	3	151	27	27	6	1
Americas	2 505	133	1382	348	619	23	5
Asia	4 087	357	1797	895	1009	29	9
Europe	1 942	198	818	292	610	24	10
Oceania	141	5	44	48	37	8	4

All values in TWh

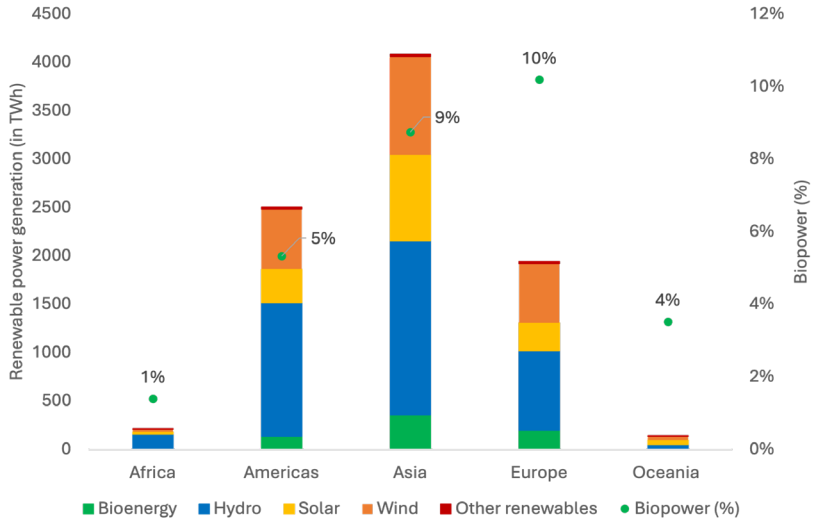


Figure 4. Renewable power generation in continents in 2023

Heat

In 2022, 1.33 EJ of renewable heat was produced in both heat-only plants and combined heat and power plants. Biomass contributed to 96% of all renewable heat produced. Geothermal and solar thermal technologies had minor contributions. Regionally, Europe produces almost 80% of the global renewable heat, with bioenergy covering 95% of it.

Table 5. Renewable heat production globally

Year	Total	Bioenergy	Geothermal	Solar Thermal	Bioenergy (%)
2000	0.43	0.41	0.02	-	96%
2005	0.55	0.53	0.02	-	96
2010	0.81	0.78	0.03	-	96
2015	0.99	0.95	0.04	0.001	96
2020	1.26	1.20	0.05	0.003	96
2021	1.37	1.32	0.05	0.002	96
2022	1.33	1.28	0.05	0.003	96

All values in EJ

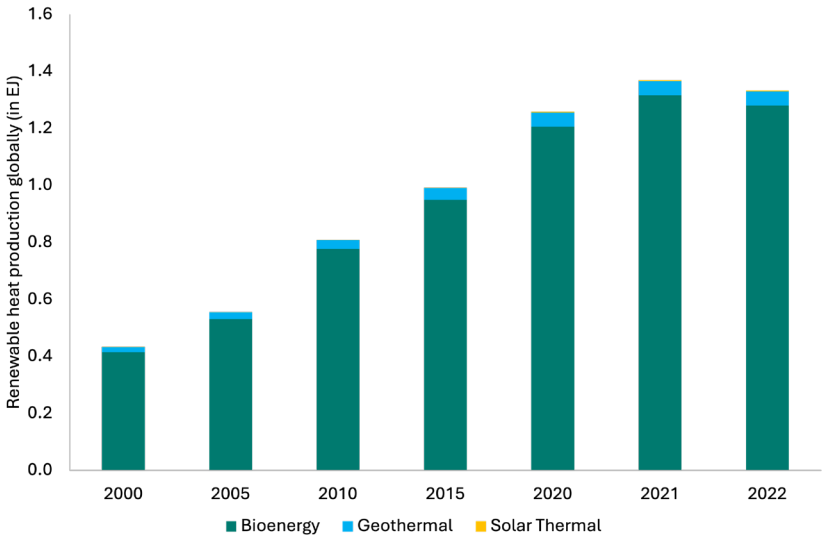


Figure 5. Renewable heat production globally

Transport

In 2022, energy consumption in the road transport sector reached around 90.6 EJ, a 3.4% increase from the previous year[1], returning to pre-pandemic levels – with fossil fuels still heavily dominated. Biofuels were the largest renewable source, contributing 3.94 EJ, which is 93% of all renewable alternatives and 4.3% of total transport energy in 2022[1]. After a decline during the pandemic, biofuel use rebounded by 3.2% from 2021 to 2022, matching levels seen in 2019. Renewable electricity contributed 0.3% of total transport energy use in 2022. Biofuel mandates remained a critical tool for promoting renewable energy in transport, with 64 countries having mandates in place in 2023[2].

Table 6. Renewable energy use in transport

Year	Total	Biofuels	Renewable Electricity	Biofuels (%)
2000	0.56	0.42	0.15	74%
2005	0.98	0.81	0.17	82%
2010	2.59	2.37	0.21	92%
2015	3.57	3.29	0.28	92%
2020	4.23	3.81	0.42	90%
2021	4.36	3.94	0.43	90%
2022	4.23	3.94	0.29	93%

All values in EJ

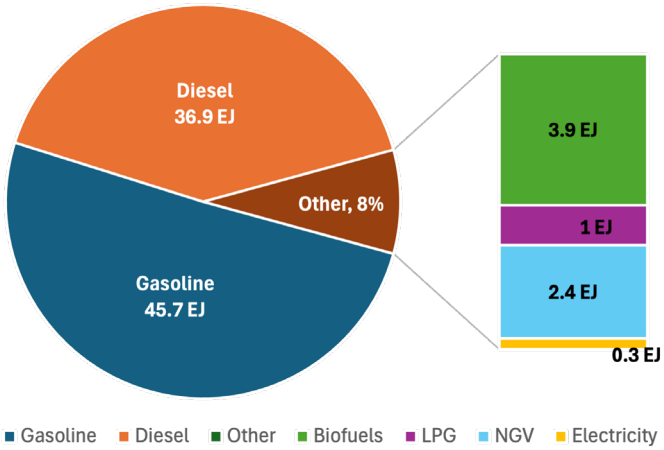


Figure 6. Global energy consumption in the road transport sector in 2022. Source: IFPEN

In 2022, the EU used 0.72 EJ of biofuels for transport, with France, Germany, and Italy leading consumption. Additionally, 25.9 TWh of renewable electricity powered the transport sector. Together, these renewable sources accounted for nearly 10% of the total energy used in EU transport that year.[3]

In the Americas, the United States and Brazil are key players in renewable energy for transport. In 2023, 6% of the energy used in U.S. transport came from renewable sources, with biofuels making up the entire share[4]. In Brazil, renewable energy made up 22.5% of transport energy consumption, primarily driven by ethanol and biodiesel in the same period[5].

BIOMASS SUPPLY

In 2021, the domestic supply of biomass reached almost 54 EJ globally. 85% of the domestic supply was from solid biomass sources including wood chips, pellets, and traditional biomass. Liquid biofuels accounted for 7%, municipal and industrial waste sectors accounted for 2 - 3% followed by biogas at 2%.

Table 7. Global domestic supply of biomass

Year	Total	Municipal Waste	Industrial Waste	Solid Biomass	Biogas	Liquid Biofuels
2000	42	0.74	0.50	40	0.29	0.44
2005	45	0.96	0.45	42	0.54	0.88
2010	49	1.17	0.79	44	0.89	2.54
2015	53	1.38	0.92	46	1.34	3.46
2020	57	1.47	1.19	49	1.50	3.94
2021	54	1.51	1.21	45	1.61	4.22

All values in EJ

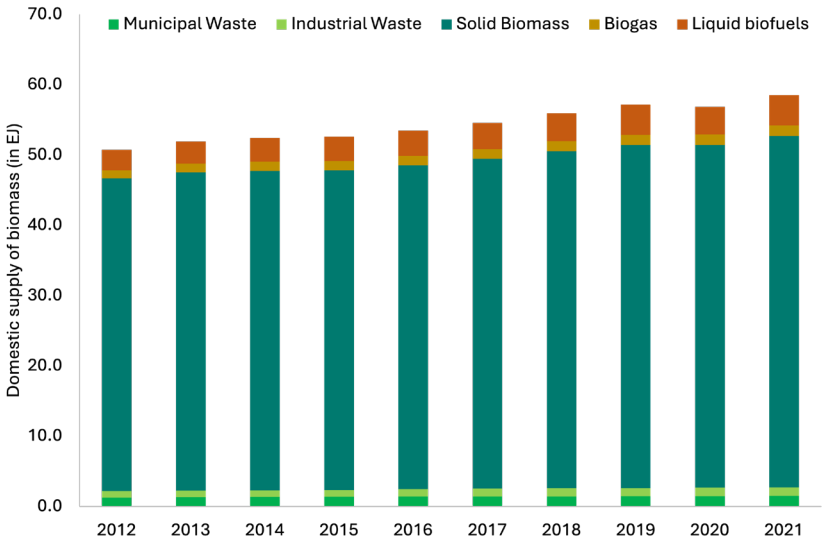


Figure 7. Global Supply of biomass.

Woodfuel

In 2022, more than 1.9 billion m^3 of wood fuel was produced globally. Africa and Asia led the global production with shares of 37% and 35% respectively. Americas with 18%, concentrated mainly in South America; and Europe followed with 9%.

Table 8 Woodfuel production globally

Year	World	Africa	Americas	Asia	Europe	Oceania
2000	1 795	551	314	808	109	13
2005	1 825	600	300	792	123	11
2010	1 864	644	290	764	155	11
2015	1 901	679	307	735	169	10
2020	1 927	713	327	708	169	10
2021	1 950	720	345	698	176	10
2022	1 967	728	355	695	180	10

All values in million m^3

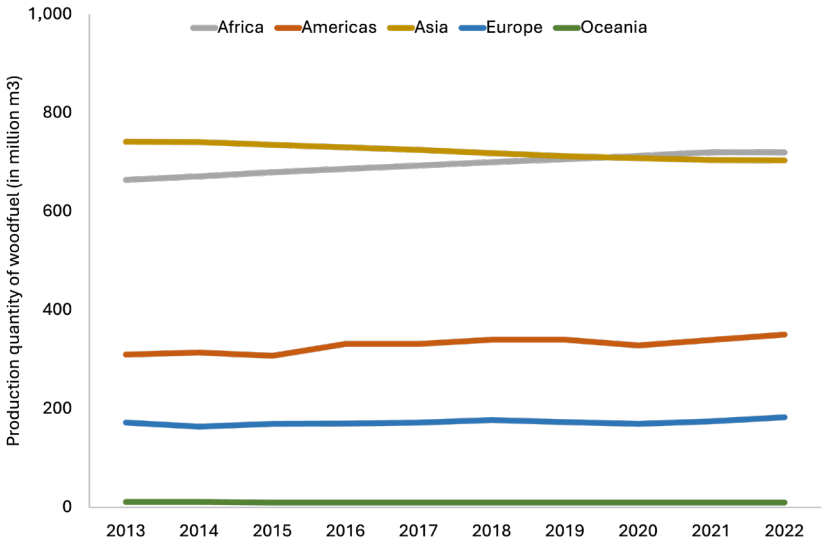


Figure 8. Woodfuel production globally

Wood Charcoal

Wood charcoal, a solid energy carrier derived from the carbonization of woody biomass, continues to play a significant role in the global energy mix. In 2022, global wood charcoal production surpassed 57 million tonnes, with Africa emerging as the dominant producer, contributing 65% of the total output. Ethiopia and Nigeria are the leading producers within the region.

Since the start of the millennium, global wood charcoal production has seen a substantial increase of over 50%. Notably, African countries have driven this growth, accounting for more than 80% of the total increase in production.

Table 9. Wood charcoal production globally

Year	World	Africa	Americas	Asia	Europe	Oceania
2000	37	20	10	7	0.30	0.04
2005	44	24	11	8	0.51	0.03
2010	46	28	9	9	0.57	0.04
2015	51	32	9	9	0.58	0.04
2020	54	35	9	9	0.63	0.04
2021	56	36	10	9	0.61	0.04
2022	57	37	10	9	0.57	0.04

All values in million tonnes

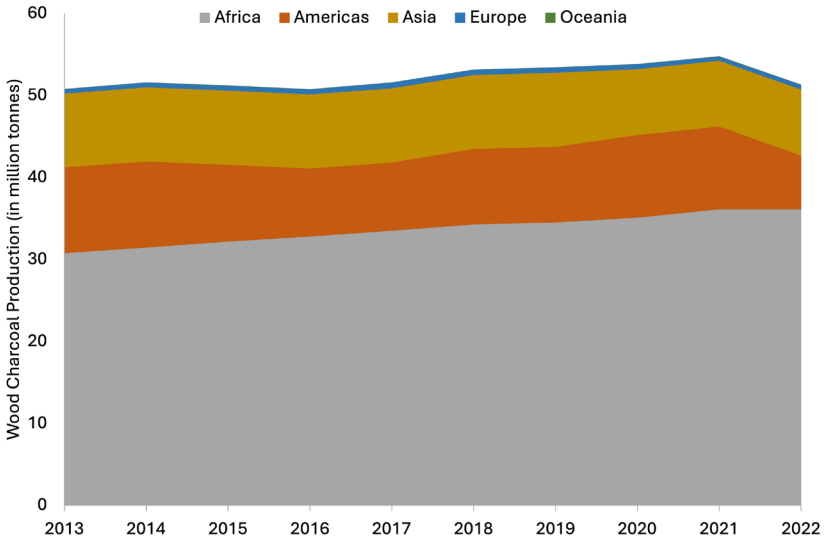


Figure 9. Wood Charcoal production by continent

Wood Pellets

In 2022, global wood pellet production reached nearly 48 million tons, with Europe leading the production by contributing about 25 million tons, or 52% of the total. Germany remained the top producer in Europe, responsible for nearly 20% of the region's output.

The Americas produced 32% of the global total, with the United States and Canada dominating the region's production. Together, they accounted for over 90% of the Americas' pellet output, positioning the U.S. as the leading global producer.

In Asia, Vietnam saw a significant increase in pellet production, rising by 33% and moving into the second spot globally. This boost made Vietnam responsible for nearly 60% of Asia's pellet production.

Table 10. Wood pellets production

Year	World	Americas	Asia	Europe	Rest of the World
2013	21	7	0.62	14	0.12
2014	25	8	2	15	0.07
2015	27	9	2	16	0.17
2016	29	10	3	17	0.19
2017	33	10	4	19	0.20
2018	38	11	6	21	0.31
2019	42	13	6	24	0.27
2020	43	13	6	24	0.20
2021	45	14	6	25	0.22
2022	48	15	8	25	0.24

All values in million tonnes

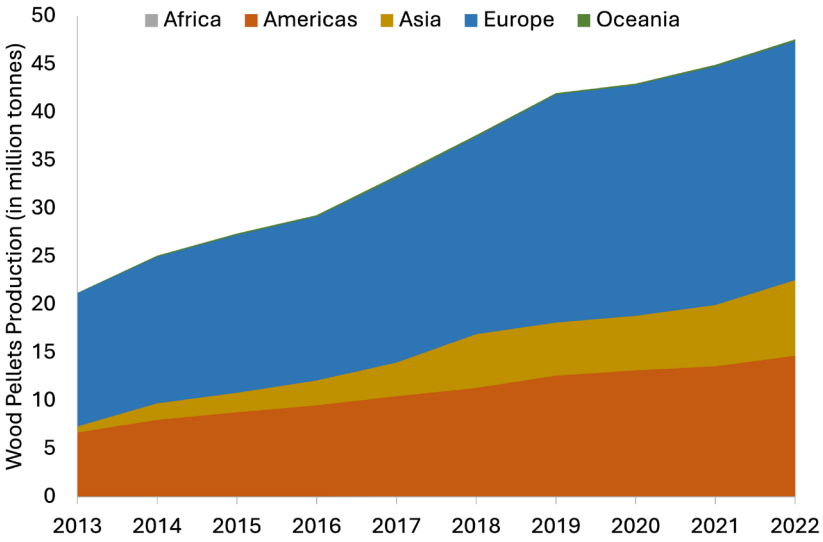
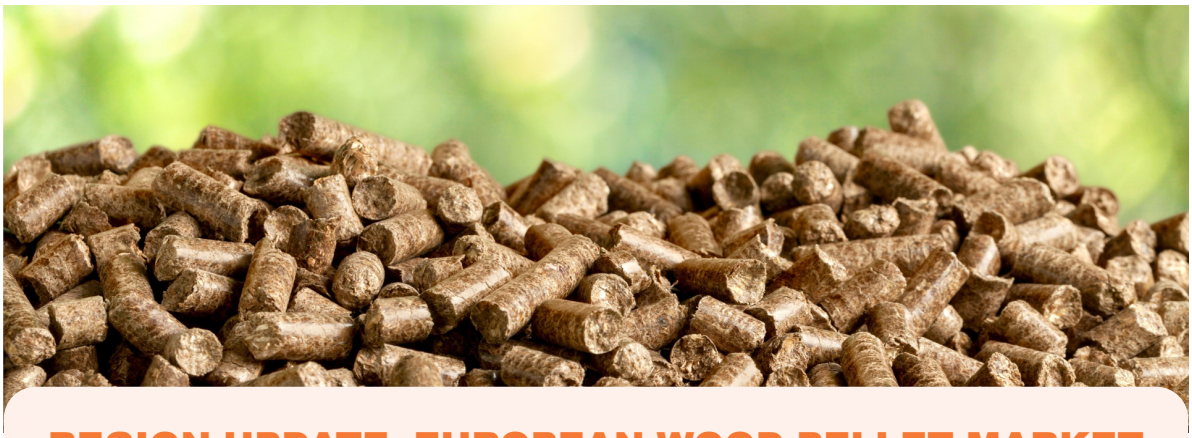


Figure 10. World pellets production by continent



REGION UPDATE: EUROPEAN WOOD PELLET MARKET

The European Union's wood pellet market has been a key driver of solid biofuel energy growth, particularly in residential and commercial sectors. In 2022, these sectors accounted for 56% of the EU's total wood pellet consumption, up from 51% in 2021, marking the highest share since 2014[6]. However, overall **wood pellet consumption** in the EU-27 saw a slight decline of 1.6% between 2021 and 2022, dropping from 24.5 to **24.2 million tonnes**. This decline contrasts with the rise in production, which grew by 3.2% to 20.4 million tonnes in 2022, driven by the expansion of production capacity through the net addition of **63 new production sites** across the region.

In 2023, **Germany** produced 3.71 million metric tons (MMT) of pellets across 50 production facilities operated by 40 companies - making it the largest producer in the EU. The total production capacity in Germany is 4.1 MMT annually, with 90% of the pellets being derived from timber industry residues. **France** has also shown robust growth in wood pellet production, being the second largest within the region, reaching 2.25 MMT in 2023. France has around 70 operational pellet plants, and recent expansions have added 270,000 metric tons (MT) of production capacity.

In the Baltic region, countries like **Latvia** and **Estonia** are key players. Latvia's production has slightly decreased to 1.95 MMT in 2023, while Estonia's production remains stable at 650,000 MT. The region has historically been a major exporter, but domestic demand has

increased significantly due to the ban on Russian gas, leading to a reduction in exports. In 2023, combined Baltic exports dropped to 2.87 MMT from a peak of 4.69 MMT in 2021.

The Nordic region, particularly **Sweden**, contributes significantly to the EU's wood pellet output, with 56 plants and a total capacity of about 2.4 MMT. Sweden's production hovers around 1.8 MMT, while **Finland** plans to expand its production capacity by an additional 300,000 MT through 2025, responding to increased residential and industrial demand.

Despite the growth across these regions, the **EU wood pellet market** faces challenges, including rising input costs and limited availability of woody biomass. The competition for sawdust resources is intensifying, leading to a growing interest in alternative biomass sources, such as agricultural residues. However, even with these additional feedstocks, it is anticipated that production may struggle to keep pace with increasing demand, particularly from the residential heating sector.

Overall, the EU pellet market remains a dynamic and expanding sector, with significant production capacity and ongoing investments to meet both domestic and export demands.

Agricultural Crops

Agricultural residues play a crucial role in bioenergy production, providing essential feedstocks for various bioenergy applications. As the demand for renewable energy grows, agro residues are increasingly recognized for their potential to contribute to climate and energy goals.

In recent years, the production of major energy crops has been crucial in meeting bioenergy needs. For instance, sugar cane remains a key feedstock for ethanol production, while crops like maize and soybeans are important for biofuel production and other agricultural residues for biomass pellet production. Understanding their availability and trends helps estimate the feasibility of bioenergy pathways and their contribution to renewable energy.

Wheat

Over the past five years, global wheat production has experienced a modest increase, primarily driven by improved yields rather than expansion in harvested area, which has remained relatively stable. While the overall consumption of wheat has risen, the use of wheat for biofuels has decreased compared to the average levels observed between 2016 and 2019. Despite the rise in wheat consumption, biofuel use has not returned to pre-COVID-19 levels and is not expected to recover to those levels.

Table 11. Overview of global wheat production, consumption, and biofuel usage. Source: OECD-FAO

Wheat	Unit	2016-2018	2019	2020	2021	2022	2023	2024
Production	Mt	752	766	765	776	785	796	798
Area	Mha	219	221	217	223	225	224	223
Yield	t/ha	3	3	4	3	4	4	4
Consumption	Mt	741	752	761	765	786	794	797
Biofuel Use	Mt	12	13	9	9	9	9	9

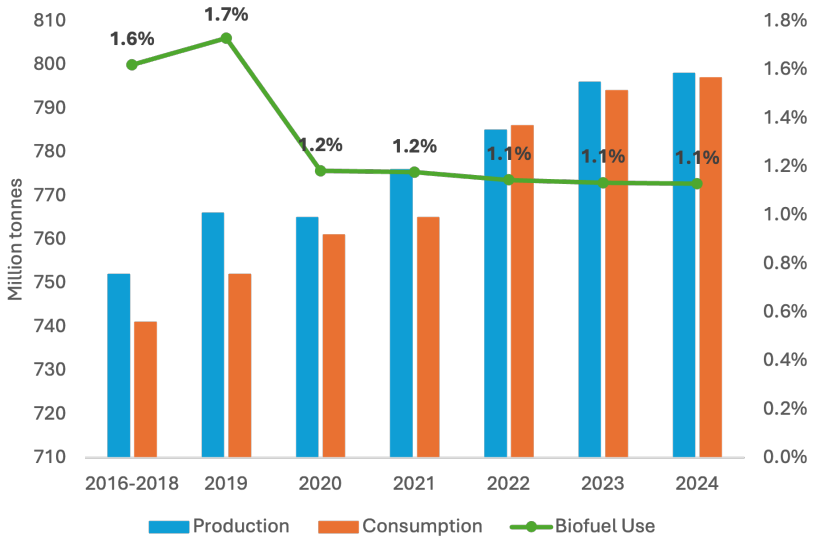


Figure 11. Global wheat production, consumption and biofuel use's share

Maize

In major maize-producing countries such as the United States and China, maize is the primary feedstock for ethanol production. Similarly, in the European Union, corn kernels are the main feedstock for ethanol. Over recent years, both maize production and consumption have seen notable increases. Despite this growth, the yield has remained stable, and there has been only a modest expansion in the harvested area. This is a positive trend, as it indicates that the rising demand for maize, driven by both food and fuel needs, has been met without requiring significant increases in agricultural land.

Table 12. Overview of global maize production, consumption, and biofuel usage. Source: OECD-FAO

Maize	Unit	2016-2018	2019	2020	2021	2022	2023	2024
Production	Mt	1128	1152	1160	1183	1207	1220	1262
Area	Mha	190	190	191	194	204	205	210
Yield	t/ha	6	6	6	6	6	6	6
Consumption	Mt	1112	1159	1173	1183	1217	1225	1258
Biofuel Use	Mt	179	182	186	186	190	192	193

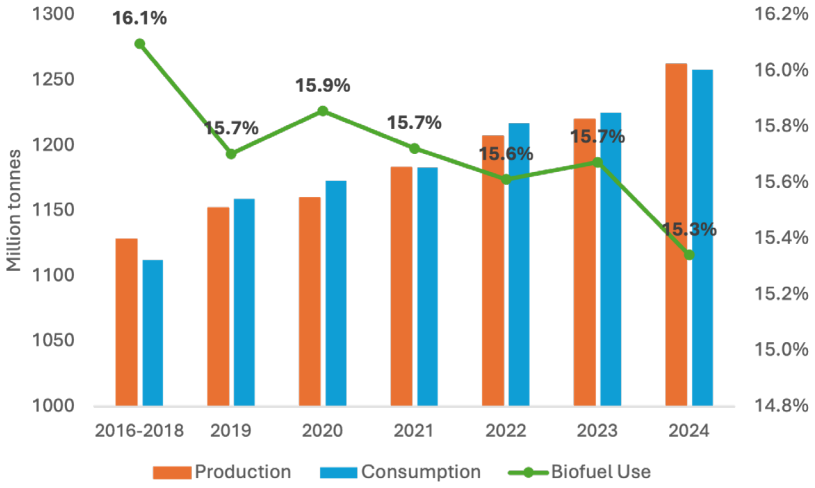


Figure 12. Global maize production, consumption and biofuel use's share

Other Coarse Grains

Coarse grains, such as barley, rye, sorghum, and other mixed grains, play a relatively small but notable role in biofuel production, particularly for ethanol in the European Union. However, the global share of biofuel use from coarse grains has decreased compared to pre-COVID-19 levels.

Over the past few years, while the production of coarse grains has fluctuated, there has been a notable increase in 2022. Despite this, the harvested area has contracted slightly, with yields remaining constant. Consumption patterns reflect a slight decrease, and biofuel usage has experienced a reduction from its previous highs, although there is a modest increase projected for 2024.

Table 13. Overview of global coarse grains production, consumption, and biofuel usage. Source: OECD-FAO

Coarse Grains	Unit	2016-2018	2019	2020	2021	2022	2023	2024
Production	Mt	292	299	297	305	399	309	308
Area	Mha	154	156	154	155	150	150	148
Yield	t/ha	2	2	2	2	2	2	2
Consumption	Mt	291	293	290	299	305	304	301
Biofuel Use	Mt	9	10	9	5	5	5	6

All values in million tonnes

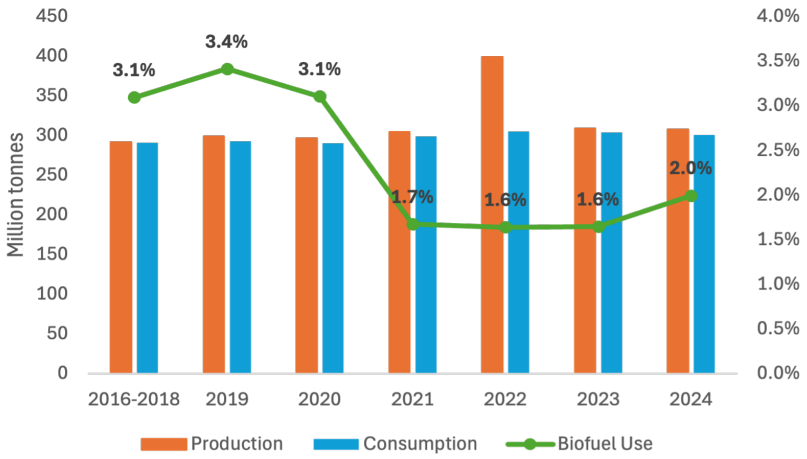


Figure 13. Global coarse grains production, consumption and biofuel use's share

Vegetable Oils

Vegetable oils, including palm oil, soybean oil, and rapeseed oil, are crucial for biofuel production. Over recent years, the use of vegetable oils for biofuels has increased significantly, rising by nearly 60% from the average values observed between 2016 and 2018. This increase in biofuel use is matched by a corresponding rise in production.

Under the Renewable Energy Directive (RED) III, aiming to enhance sustainability along the entire supply chain, the consumption of palm oil for biofuel production is expected to decline. However, this directive will likely lead to a rise in biofuel production from used cooking oils. In Indonesia, the major global producer of palm oil, the introduction of B35 and B40 biodiesel mandates will drive up the demand for palm oil, which remains the primary feedstock for biodiesel in the country.

Table 14. Overview of global vegetable oils production, consumption, and biofuel usage. Source: OECD-FAO

Vegetable Oils	Unit	2016-2018	2019	2020	2021	2022	2023	2024
Production	Mt	203	211	217	220	224	225	234
Of which Palm Oil	Mt	71	75	81	80	82	82	83
Consumption	Mt	201	211	218	219	224	225	234
Biofuel Use	Mt	26	30	32	33	36	37	41

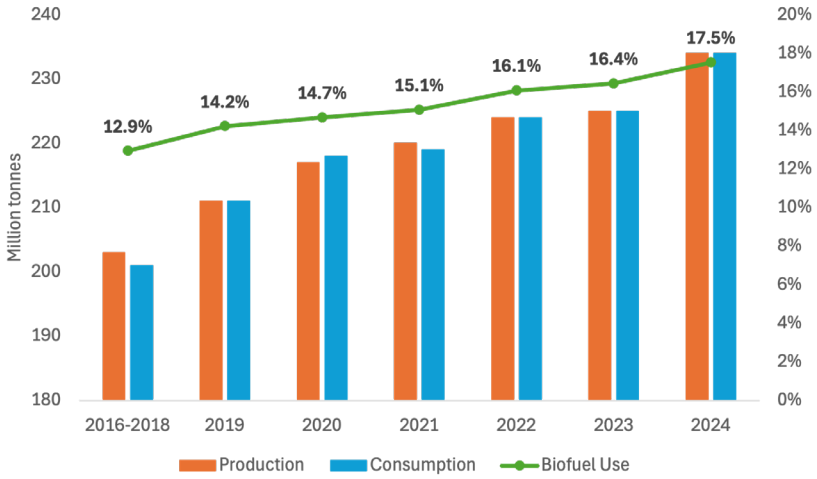


Figure 14. Global vegetable oils production, consumption and biofuel use's share

Sugar Cane

Sugar cane plays a critical role in global ethanol production, with Brazil, as the world's largest producer, using it as the primary feedstock. Brazil contributes nearly 30% to global ethanol production. India, the second-largest sugarcane producer, has tripled its ethanol production in the last 5 years by enhancing its use of sugar cane, along with other alternative crops like corn and grains. These trends highlight the vital role of sugar cane in biofuel production.

Globally, sugar cane continues to be a key feedstock for biofuels, although its role in meeting food and feed demands remains predominant, with consumption for these purposes accounting for almost 80%. Despite the rise in biofuel use, the area harvested for sugar cane has not seen substantial changes, indicating that the increase in biofuel production has not significantly impacted the land dedicated to sugar cane cultivation.

Table 15.Overview of global sugar cane production, consumption, and biofuel usage. Source: OECD-FAO

Sugar Cane	Unit	2016-2018	2019	2020	2021	2022	2023	2024
Production	Mt	1758	1731	1737	1774	1773	1735	1857
Area	Mha	25	25	25	24	24	24	26
Yield	t/ha	69	69	71	73	73	72	72
Biofuel Use	Mt	361	377	427	365	380	402	412

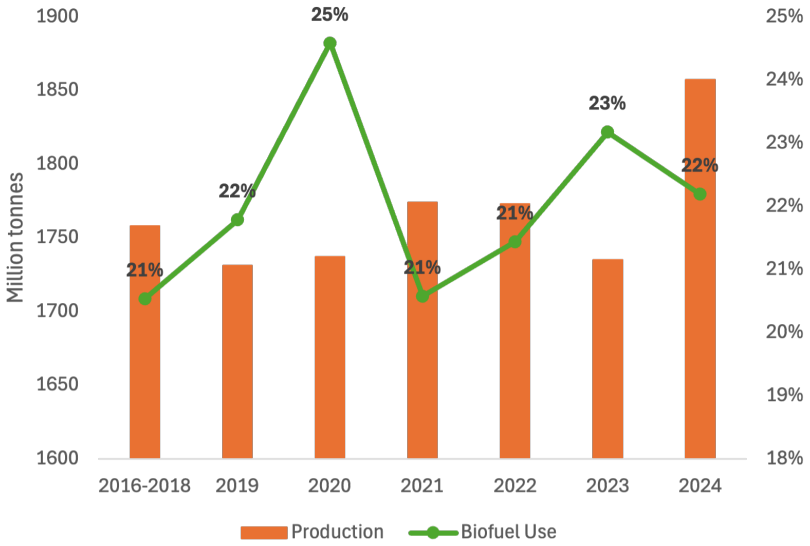


Figure 15. Overview of global sugar cane production and biofuel usage. Source: OECD-FAO

Waste to Energy

In 2021, the domestic supply of energy from municipal and industrial waste was 2.7 EJ with 56% from municipal waste and the remaining from industrial waste.

Table 16. Domestic supply of energy from waste

Year	Total Waste	Municipal Waste	Industrial Waste
2000	1.24	0.74	0.50
2005	1.41	0.96	0.45
2010	1.96	1.17	0.79
2015	2.30	1.38	0.92
2020	2.66	1.47	1.19
2021	2.70	1.50	1.20

All values in EJ

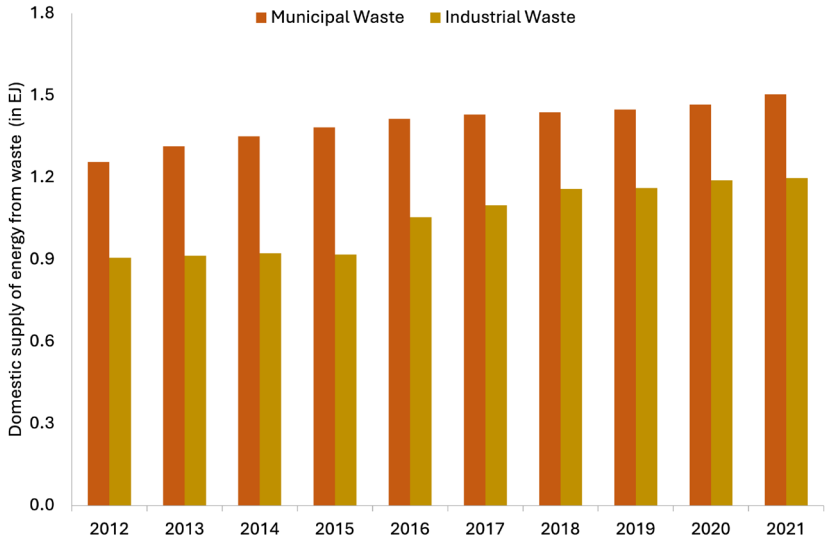


Figure 16. Global supply of energy from waste

REGIONAL UPDATE - EUROPE

According to the Confederation of European Waste-to-Energy Plants[7], as of **2021**, nearly **500 WtE plants** were operational across Europe, processing approximately **103 million tonnes** of household and similar types of waste. The energy generated from this process is substantial, providing electricity to about 21 million Europeans and supplying heat to around 17 million citizens.

Waste-to-energy technology is recognized for its potential to mitigate environmental impacts, particularly in terms of reducing CO_2 emissions. By using waste as a fuel source, WtE plants can displace the need for conventional fossil fuels in power generation. Depending on the specific type of fossil fuel replaced, the a**doption of WtE could prevent the use of 10 to 56 million tonnes of fossil fuels**, leading to a reduction in CO_2 emissions ranging from 22 to 44 million tonnes.

By converting waste into energy, WtE plants help reduce the dependency on landfills, conserving valuable land resources and reducing methane emissions associated with waste decomposition.

BIOENERGY INSTALLED CAPACITY

Global biopower capacity has grown steadily over the past decade, increasing from 88 GW in 2014 to 150.3 GW in 2023, a 71% rise. However, the growth rate slowed to 3% in 2023, marking the slowest annual increase in ten years.

Asia led this expansion, with capacity nearly tripling from 21 GW in 2014 to 63 GW in 2023, driven by significant investments in China and Japan. Europe, while initially growing steadily, plateaued from 2019 onward, maintaining around 42-43 GW. The Americas saw modest growth, reaching 38 GW in 2023, primarily due to Brazil's additions. Meanwhile, Africa and Oceania's biopower capacity has remained stagnant at 3 GW since 2016, highlighting regional disparities in biopower development.

Table 17. Bioenergy Installed Capacity by continent

Year	Asia	Europe	Americas	Africa + Oceania
2014	21	35	32	2
2016	30	37	35	3
2018	38	42	36	3
2020	49	44	37	3
2022	60	46	37	3
2023	63	46	38	3

All values in GW

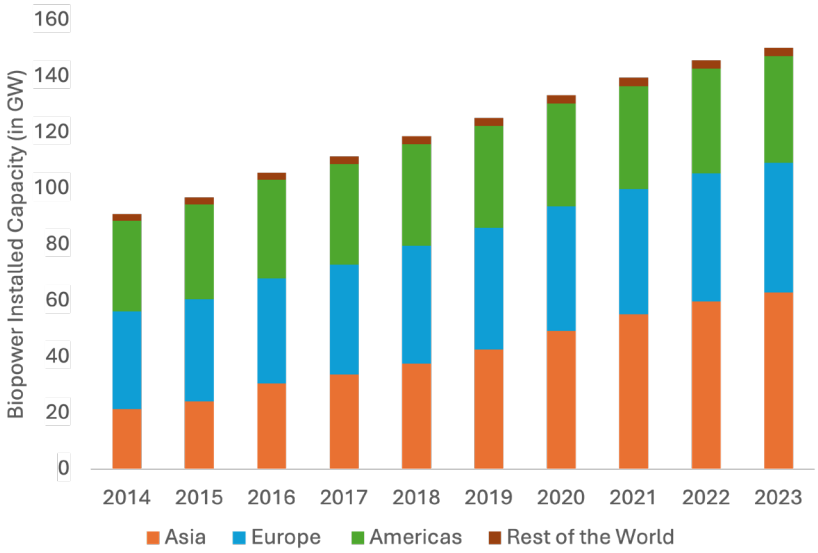


Figure 17. Global Biopower Installed Capacity.

Over the past decade, **China**'s bioenergy capacity surged from 7 GW in 2014 to 31 GW in 2023, overtaking Brazil and the United States between 2018 and 2020 to become the global leader. By 2023, China held the largest capacity at 31 GW, while **Japan** recorded the highest annual growth rate of 18%.

Brazil, the second-largest contributor, increased its capacity from 12 GW in 2014 to 18 GW in 2023, with sugarcane bagasse accounting for 8% of its electricity generation. The **United States** contributed 11 GW, ranking third in global biopower capacity. Similarly, **India**'s biopower capacity reached 11 GW in 2023, maintaining a steady increase since 2014, driven by its agricultural sector's biomass potential and policy support.

Table 18. Top 5 countries with the greatest Biopower Installed Capacity

Year	China	Brazil	USA	India	Germany
2014	7	12	12	5	8
2016	9	14	13	9	9
2018	13	15	13	10	10
2020	22	16	12	11	10
2022	29	17	11	11	10
2023	31	18	11	11	10

All values in GW

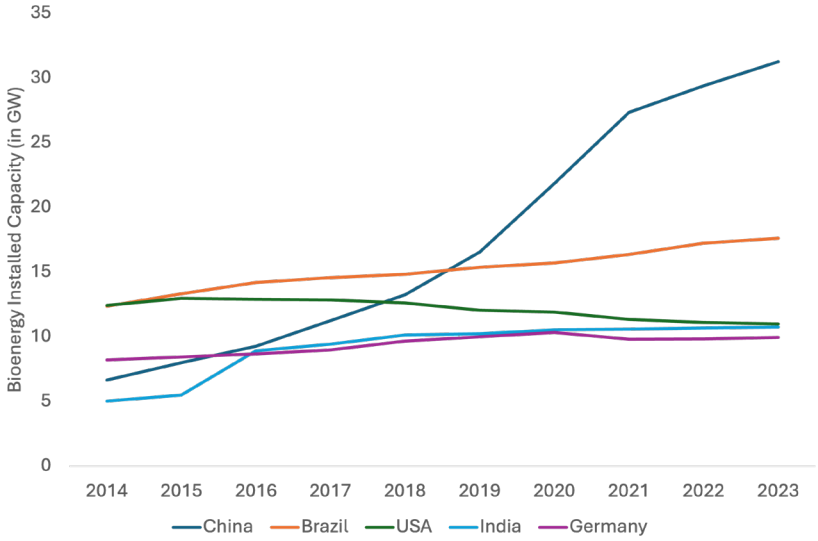


Figure 18. Bioenergy installed capacity in China, Brazil, USA, India, and Germany

Where was capacity added?

1. Yufutsu Biomass Power Plant, Hokkaido, Japan

The Yufutsu biomass-fired power generation plant, with a capacity of 75 MW, began commercial operations on February 2, 2023, in Hokkaido, Japan's northernmost prefecture. This project is a collaboration between Nippon Paper, which owns 51% of the plant, and the trading house Sojitz, leveraging Nippon Paper's robust biomass supply chain.

Feedstock and Technology: The plant utilizes a mix of imported wood chips, palm kernel shells (PKS), and unused wood material sourced locally within Hokkaido. This combination of feedstocks ensures a steady supply while contributing to local resource utilization.

Impact and Operation: The electricity generated at Yufutsu will be sold exclusively to the Hokkaido Electric Power Network over the next 20 years under Japan's feed-in-tariff (FIT) scheme. This project is part of Nippon Paper's broader strategy, which also includes the operation of the 149 MW Ishinomaki Hibarino biomass plant and the 6 MW Yatsushiro biomass plant, as well as a proposed 112 MW biomass project at Iwakuni. Japan's commitment to

bioenergy is reflected in its increasing importation of PKS, which rose by 14% in 2022 to 2.9 million tons, indicating a growing reliance on biomass for energy production.

2. Morinomiyako Biomass Power Plant, Japan

The Morinomiyako Biomass Power Plant, with a capacity of 75 MW, commenced operations in November 2023. This plant is operated by Morinomiyako Biomass Energy G.K., a collaboration between RENOVA, Inc., United Purpose Management, Inc., and Sumitomo Forestry Co., Ltd.

Feedstock and Technology: The plant uses wood pellets and palm kernel shells (PKS) as its primary fuels. These sustainable feedstocks are integral to the plant's annual power production of approximately 553 million kWh.

Impact and Operation: The electricity generated by the Morinomiyako plant is sufficient to meet the annual power needs of around 170,000 households. This contribution to the energy grid reinforces Japan's strategy to enhance renewable energy production through biomass

3. Paiton Coal-Fired Power Plant, East Java, Indonesia

Indonesia's largest power generation facility, the 4.71 GW Paiton coal-fired power plant, is integrating biomass to reduce emissions. The state-owned utility PLN's fuel procurement subsidiary, PLN EPI, has set ambitious biomass delivery targets for the plant's biomass co-firing operations.

Feedstock and Technology: The plant primarily uses wood sawdust as its biomass feedstock. Biomass consumption at the Paiton plant is projected to increase significantly, with a 10% increase for the 800 MW No.1 and No.2 units, and a fourfold increase for the 600 MW No.9 unit in 2024.

Impact and Operation: Currently, the biomass co-firing is only implemented in the units owned by PLN, with plans to increase the biomass percentage from 5% to 10% in the coming years. The project also aims to source biomass locally to reduce transportation costs and support the development of a biomass economy in the surrounding areas.

BIOENERGY GENERATION

BioPower

Biopower generation has grown steadily from 439 TWh in 2014 to 697 TWh in 2023 – with Asia leading this growth. Within the decade, Asia's share rose from 28% to 51% of global biopower, reaching 357 TWh, surpassing Europe. The Americas saw a slight decline from 146 TWh to 133 TWh, while Africa & Oceania remained relatively stable, averaging around 7-8 TWh.

Table 19. Global biopower generation

Year	World	Americas	Asia	Europe	Africa & Oceania
2014	439	139	122	170	7.36
2016	482	146	143	184	7.92
2018	544	148	193	195	7.80
2020	609	146	246	210	7.08
2022	676	136	320	212	7.91
2023	697	133	357	198	7.95

All values in TWh

In 2023, China generated more than a quarter of the world's biopower at 204 TWh. Brazil saw a record generation of 54TWh, with 637 biomass-powered projects across the country. The third largest contributor was Japan, recording the highest increase rate of 18% from 2022 values, contributing with 49TWh[8].

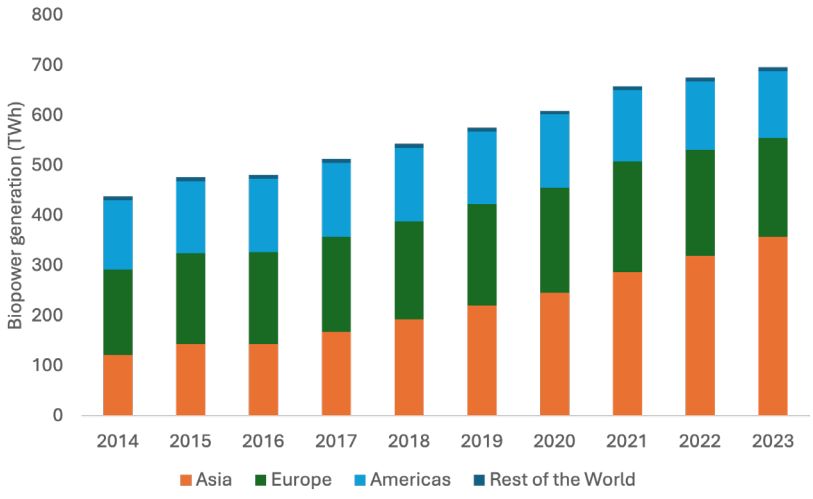


Figure 19. Global electricity generation from biomass

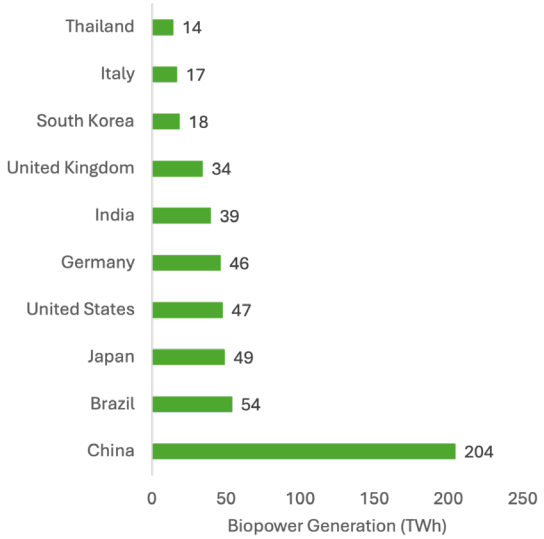


Figure 20. Top 10 countries with the highest biopower generation in 2023. Source: Ember

In 2023, Bioenergy largely contributed to countries' electricity generation. For example, in Denmark, bioenergy made up more than 20% of total electricity generation. In Finland and the United Kingdom, bioenergy accounted for 14% and 12% of their electricity generation, respectively[8].

Electricity only and CHP plants

Electricity-only plants are designed to produce electricity only. They do not produce any heat from biomass and have an average conversion efficiency of about 30%. In 2021, almost 6 EJ of biomass was used in electricity-only plants for power generation.

Table 20. Use of biomass in electricity-only plants

Year	Total	Municipal Waste	Industrial Waste	Solid Biomass	Biogas	Liquid Biofuels
2000	1.03	0.36	0.06	0.48	0.12	-
2005	1.54	0.47	0.03	0.86	0.19	0.0004
2010	2.55	0.57	0.23	1.43	0.31	0.0005
2015	3.55	0.62	0.27	2.20	0.45	0.0014
2020	5.32	0.65	0.29	3.93	0.44	0.002
2021	5.96	0.66	0.27	4.60	0.42	0.002

All values in EJ

Asia accounted for 66% of the biopower generated in electricity-only plants. Europe leads in the use of municipal waste and biogas having a share of 46% on each category of the global use. Meanwhile, Asia leads in using industrial waste, solid biomass, and liquid biofuels for electricity with a global share of 89%, 76%, and 48% respectively.

Table 21. Use of biomass in electricity-only plants in continents - 2021

Continents	Municipal Waste	Industrial Waste	Solid Biomass	Biogas	Liquid Biofuels
Africa	-	-	0.03	0.0003	-
Americas	0.24	0.02	0.56	0.14	0.0002
Asia	0.12	0.24	3.51	0.07	0.001
Europe	0.30	0.01	0.49	0.19	0.001
Oceania	-	1	0.01	0.01	-

All values in EJ

Combined Heat and Power plants (CHP) or cogeneration facilities refer to those plants designed to produce both heat and electricity. Their efficiency varies widely among the CHP facilities, considering factors such as the type of feedstocks used, and technology implemented, among others. In 2021, 3.6 EJ of biomass was used to produce energy and heat in CHP plants. Solid biomass was the major contributor, accounting for almost 70% of all the energy produced in CHP facilities, followed by municipal waste at 17%.

Table 22. Global use of biomass in CHP plants

Year	Total	Municipal Waste	Industrial Waste	Solid Biomass	Biogas	Liquid Biofuels
2000	1.09	0.21	0.14	0.71	0.03	-
2005	1.47	0.33	0.12	0.96	0.05	0.0002
2010	1.94	0.41	0.14	1.24	0.15	0.0006
2015	2.70	0.54	0.14	1.70	0.32	0.0006
2020	3.46	0.58	0.16	2.32	0.40	0.0006
2021	3.55	0.60	0.17	2.40	0.38	0.0005

All values in EJ

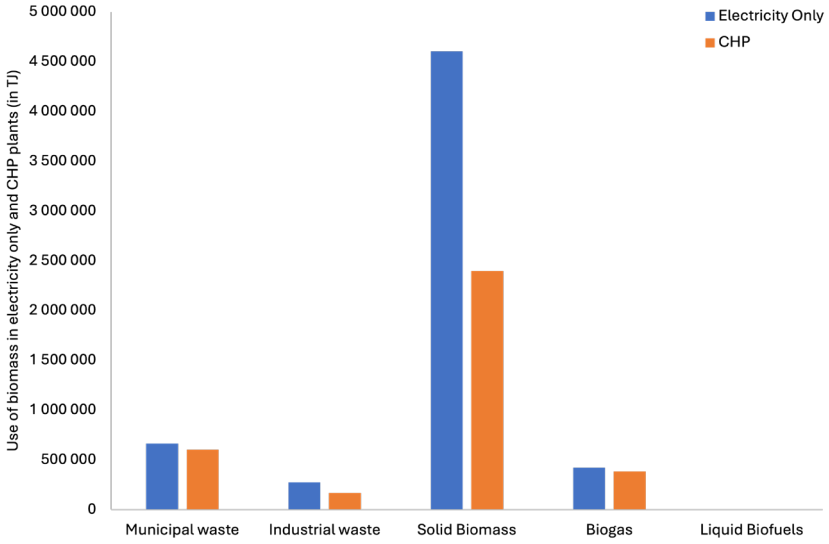


Figure 21. Use of biomass in electricity-only and CHP plants in 2021

COUNTRY UPDATE: CHINA

China's biopower generation is gaining momentum as part of the country's broader strategy to reduce its reliance on coal and lower greenhouse gas emissions. Biomass power, which involves generating electricity from organic materials like plants, wood, and waste, is considered a cleaner alternative to fossil fuels. The Chinese government is actively promoting the development of biomass energy, as outlined in the **14th Five-Year Plans for the Bioeconomy and Renewable Energy**, which both emphasize the expansion of biomass power production for electricity and heating.

China's largest biomass energy company, National Bio Energy, currently has an installed capacity of **1.13 million kilowatts** and is now jointly managed by the State Grid Corporation of China and the State Power Investment Corporation[9]. Despite its potential, **biomass energy** only accounted for about **3.6%** of China's total installed renewable power generation capacity by the end of 2021, largely due to challenges in commercializing the technology. However, with government backing and ongoing research, there is optimism that biomass energy could become a significant part of China's renewable energy mix, helping the country meet its **"double carbon" goals** of peak carbon use by 2030 and carbon neutrality by 2060.

BioHeat

In 2022, 1.28 EJ of heat was produced from biomass-based sources – 51% from solid biomass sources and 28% from municipal solid waste.

Table 23. Biomass used for heat production

Year	Total	Municipal Waste	Industrial Waste	Solid Biomass	Biogas	Liquid Biofuels
2000	0.41	0.13	0.07	0.21	0.00	0.000
2005	0.53	0.15	0.08	0.28	0.01	0.004
2010	0.78	0.21	0.13	0.42	0.01	0.010
2015	0.95	0.26	0.14	0.51	0.03	0.004
2020	1.21	0.30	0.23	0.62	0.05	0.004
2021	1.32	0.31	0.24	0.70	0.05	0.007
2022	1.28	0.36	0.23	0.65	0.04	0.005

All values in EJ

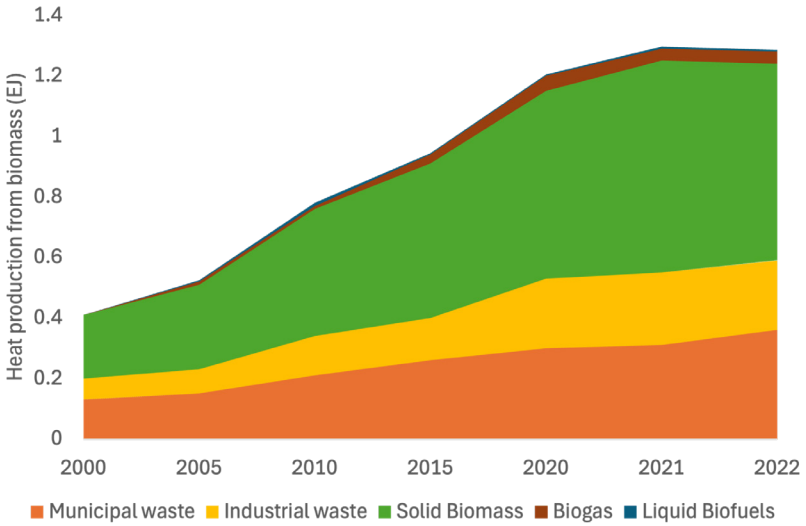


Figure 22. Global heat production from biomass

Heat only and CHP

Bioheat is produced either via heat-only plants or CHP plants. Heat-only plants are specifically designed to produce heat only and sold to a third party – e.g., residential, commercial, or industrial consumers. In 2021, 0.64 EJ of biomass was used in heat-only plants.

Table 24. Use of biomass in heat-only plants

Year	Total	Municipal Waste	Industrial Waste	Solid Biomass	Biogas	Liquid Biofuels
2000	0.24	0.05	0.04	0.15	0.001	-
2005	0.31	0.07	0.05	0.19	0.003	0.00008
2010	0.44	0.10	0.10	0.23	0.006	0.0003
2015	0.48	0.08	0.12	0.27	0.006	0.00006
2020	0.57	0.08	0.17	0.32	0.006	0.00004
2021	0.64	0.08	0.18	0.38	0.005	0.00013

All values in EJ

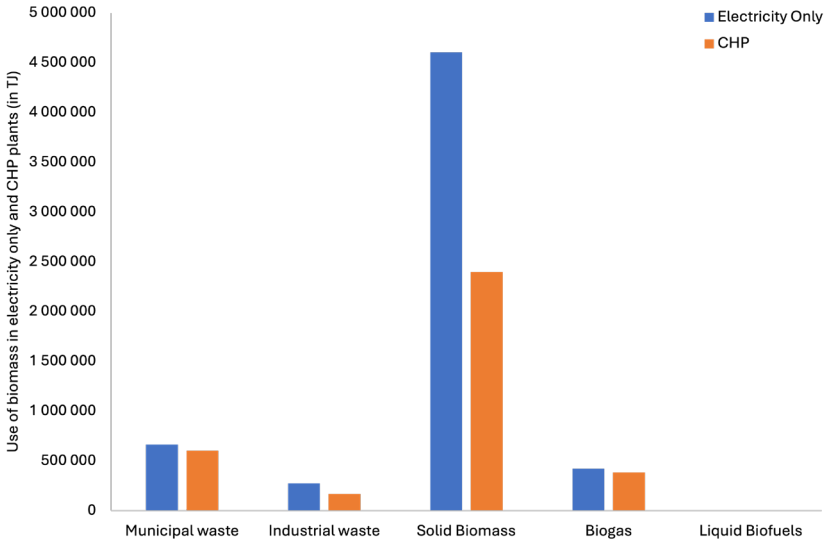


Figure 23. Global use of biomass in heat-only and CHP plants in 2021

BIOHEAT PRODUCTION FROM SOLID BIOFUELS IN THE EU

Currently, the **European heating sector accounts for nearly 40% of global pellet usage**. In 2022, a total of **0.51 EJ** was produced from solid biofuels only in all EU. The Nordic countries are at the front line of production, with Sweden, Finland, and Denmark accounting for half of the total production in 2022.

Table 25. Gross heat production from Solid Biofuels in the EU, 2021 and 2022. Source: Eurobserver

Country	2021			2022		
	Heat Only Plants	CHP Plants	Total	Heat Only Plants	CHP Plants	Total
Sweden	0.032	0.083	0.12	0.030	0.080	0.11
Finland	0.043	0.044	0.087	0.040	0.042	0.083
Denmark	0.022	0.049	0.072	0.021	0.043	0.064
France	0.029	0.026	0.054	0.028	0.026	0.054
Austria	0.028	0.015	0.043	0.025	0.015	0.040
Rest of EU	0.060	0.12	0.18	0.056	0.11	0.16
Total EU	0.21	0.34	0.55	0.20	0.31	0.51

All values in EJ

BioFuels

Liquid Biofuels

The global production of liquid biofuels has increased within the last decade, with global output reaching approximately **160 billion liters in 2022**. The highest recorded increase has been in the production of renewable diesel, which has increased from 2.6 in 2013 to more than 13 billion liters in 2022, more than 5 times higher. Additionally, biodiesel production increased almost 60% from 2013 values. Since 2019, the production of biojet has increased over 5 times higher.

A good example of the increase in the production of liquid biofuels is the **United States**. In 2023, **biomass-based diesel production** – including biodiesel, renewable diesel, sustain-

able aviation fuel (SAF), and heating oil – in the United States **reached 15 billion liters**. Both national production and consumption of advanced biomass-based diesel grew by 4 billion liters in 2023, compared to 2022 values.

Table 26. Liquid biofuels production globally

Year	Biodiesel (FAME)	Biojet	Bioethanol	Renewable Diesel
2016	33	0.00	101	4.1
2017	35	0.00	105	4.4
2018	41	0.00	111	5.1
2019	45	0.04	113	5.9
2020	44	0.07	104	6.7
2021	46	0.14	106	9.6
2022	45	0.2	116	13

All values in billion litters. Source: IEA Renewables 2022, 2023.

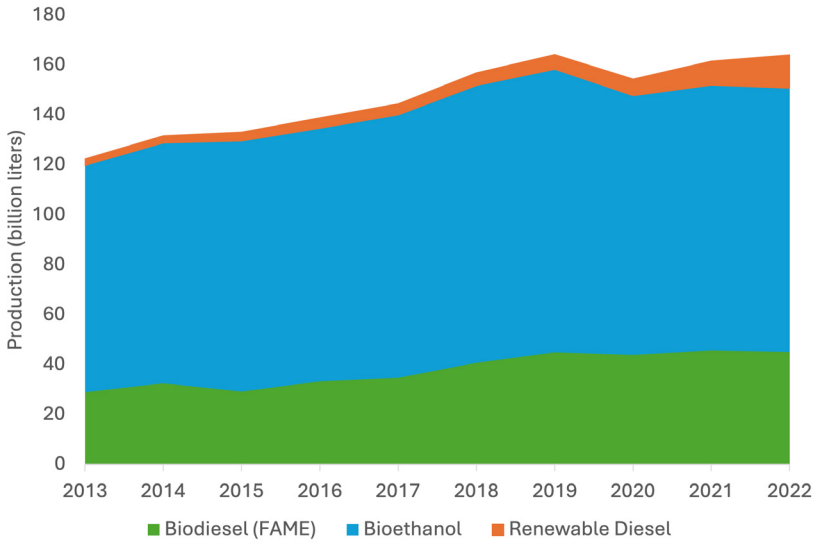


Figure 24. Global production of Biodiesel, Bioethanol, and Renewable Diesel, 2013-2022. Source: IEA Renewables 2022, 2023.

Ethanol

In 2023, ethanol remained the leading liquid biofuel globally, with **production reaching 116 billion liters**, accounting for roughly 70% of the global production of liquid biofuels. The United States and Brazil dominated the market, together accounting for approximately 80% of global production. The U**.S. produced 59 billion liter**s, while **Brazil contributed 35 billion liters**. In the U.S., maize is the primary feedstock for ethanol, whereas Brazil relies on sugarcane.

Brazil's production increased by 16% from 2022, driven by a higher yield of sugarcane for the 2023/24 crop. This boost is expected to continue into 2024, with anticipated growth in corn ethanol also contributing to a larger overall ethanol output.

India surpassed the European Union to become the third-largest producer of fuel ethanol, with **6.4 billion liters in 2023**, reflecting a 28% increase from the previous year. This growth is largely attributed to the country's Ethanol Blended Petrol Programme (EBP), which

has driven demand and achieved a 12% blending rate in 2023, with a target of E20 by 2025. The EU followed with an output of 5.3 billion liters, with France leading the region, accounting for 20% of European production.

Table 27. Top 5 largest ethanol producers

Year	U.S.	Brazil	EU	China	India
2016	58	29	5	3	0.5
2017	60	29	5	3	1
2018	61	33	5	3	2
2019	60	35	5	4	2
2020	53	33	5	4	2
2021	57	30	5	3	4
2022	58	31	5	4	5
2023	59	35	5	4	6

All values in billion liters

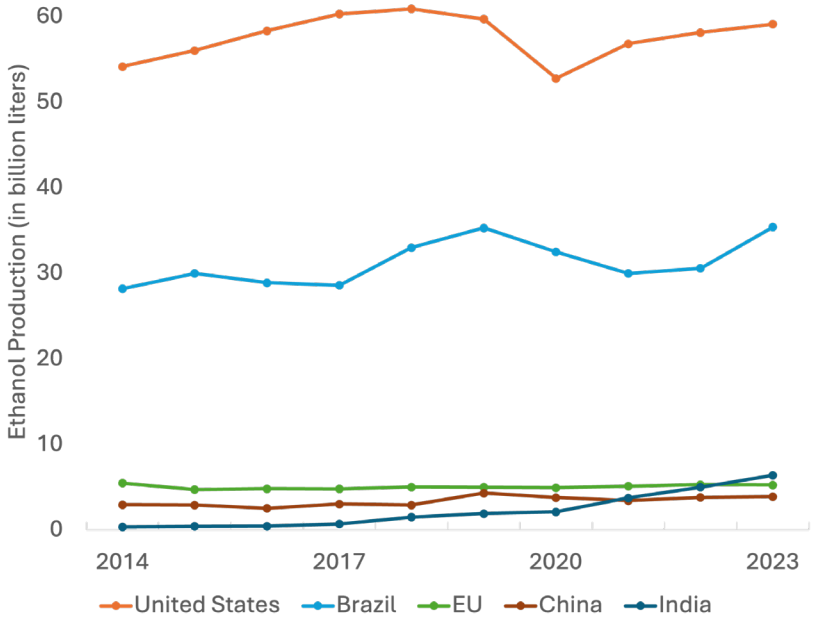


Figure 25. Ethanol production of the 5 largest producers. Source: USDA GAIN Reports

COUNTRY UPDATE: INDIA

India's ethanol market has rapidly expanded, driven by the need to reduce fossil fuel dependence, curb air pollution, and manage high oil import costs. The country is now the **world's third-largest ethanol producer and consumer**, nearly tripling its production over the past five years.

Between 2014 and 2022, India's Ethanol Blending Program (EBP) cut greenhouse gas emissions by 31.8 million metric tons. By the end of 2023, **ethanol production** capacity reached **13.8 billion liters** (BL), split between molasses-based (**8.75 BL**) and grain-based (**5.05 BL**) feedstocks[10]. Despite this growth, domestic consumption continues to outpace production, though the country hit a **blending record of 11.6%** in early 2023, moving closer to its 20% blending target by 2025.

Maharashtra, Uttar Pradesh, and Karnataka lead in ethanol production due to abundant sugarcane supplies and strong distillery infrastructure. To support the ambitious blending target, the Indian government has rolled out subsidies for new distilleries and promoted alternative feedstocks like surplus grains and corn, with corn production expected to rise by 10 million metric tons over the next five years.

Challenges for the bioethanol industry include rising feedstock prices, low prices for distillers' dried grains with solubles (DDGS) from corn ethanol, and recent bans on rice supply from the Food Corporation of India. Additionally, below-normal monsoon rains have impacted the availability of key crops like rice and sugarcane, potentially jeopardizing the **20% blending goal by 2025**[11].

Nevertheless, significant growth opportunities exist, especially through the **Global Biofuels Alliance**, formed at the 2023 G20 Summit. This alliance aims to triple global biofuel use in five years, positioning India to further expand its ethanol production and influence. Technological advancements, such as high-gravity fermentation, are also being explored to boost production efficiency and minimize environmental impact.

Biodiesel

In 2023, global production of fatty acid methyl ester (FAME) biodiesel approached **50 billion liters**. **Indonesia** led the production with nearly 14 billion liters, primarily utilizing palm oil as its main feedstock. The **European Union** (EU) followed with 13 billion liters, produced mainly from rapeseed oil and used cooking oil, with Germany, Spain, and France contributing more than half of the EU's total output. **Brazil** generated almost 8 billion liters of biodiesel, using soybeans as the primary feedstock. The United States and China were next in line, producing 6 billion liters and 3 billion liters, respectively.

Over the last decade, **Indonesia's production** has seen a significant increase, from 4 billion liters in 2014 to 14 billion liters in 2023. The EU's output has remained relatively stable at around 12 to 13 billion liters annually. Brazil's production has also grown, rising from 3 billion liters in 2014 to 8 billion liters in 2023. Meanwhile, the United States has consistently produced around 6 billion liters annually, while China has increased its output from 1 billion liters in 2014 to 3 billion liters in 2023.

Table 28. Top 5 largest biodiesel producers. Source: USDA GAIN Reports

Year	Indonesia	EU	Brazil	U.S.	China
2014	4	12	3	5	1
2015	1	11	4	5	1
2016	4	11	4	6	1
2017	3	12	4	6	1
2018	6	12	5	7	1
2019	8	13	6	7	1
2020	9	12	6	7	1
2021	10	12	7	6	2
2022	11	13	6	6	2
2023	14	13	8	6	3

All values in billion liters.

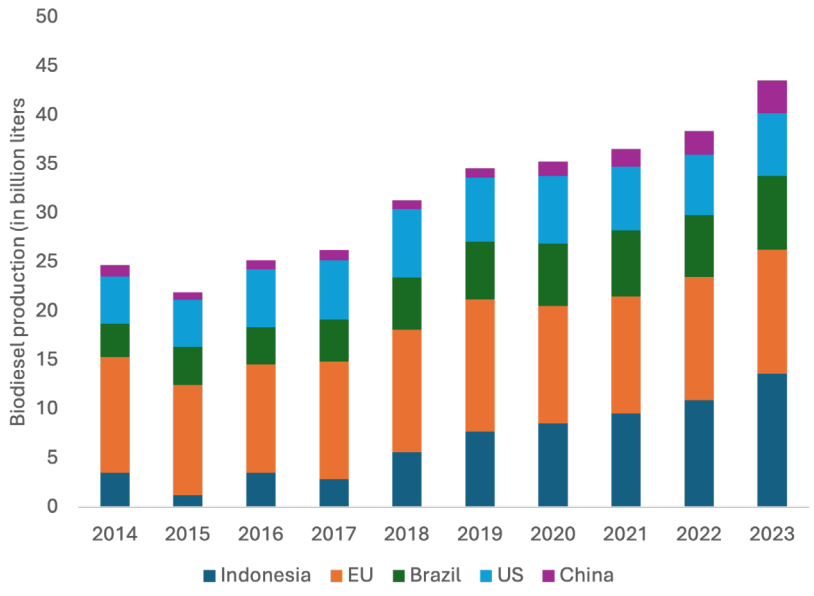


Figure 26. The top largest biodiesel producers. Source: USDA Gain Reports

Renewable Diesel

Hydrotreated vegetable oil (HVO), also known as renewable diesel, emerged as a significant bio-based diesel option, compatible with existing diesel engines either in pure form or as a blend. In 2023, the **United States** led global production with approximately **11 billion liters**, marking a dramatic increase from the previous year, almost doubling it. The European Union followed with nearly 4 billion liters of HVO production.

Since 2014, the United States has seen substantial growth in HVO production, rising from 1 billion liters to 11 billion liters by 2023. This represents a significant expansion, nearly doubling the output from the previous year. The **EU's production has also increased**, though more modestly, from 2 billion liters in 2014 to **4 billion liters** in 2023. China, a newer player in the HVO market, produced 1.4 billion liters in 2023, up from just 0.04 billion liters in 2017.

Table 29. Renewable diesel production in the United States, European Union, and China. Source: USDA GAIN Reports

Year	U.S.	EU	China
2014	1	2	-
2015	1	2	-
2016	1	2	-
2017	1	2	0.04
2018	1	3	0.15
2019	2	3	0.33
2020	2	4	0.30
2021	4	4	0.62
2022	6	3	0.94
2023	11	4	1.40

All values in billion liters

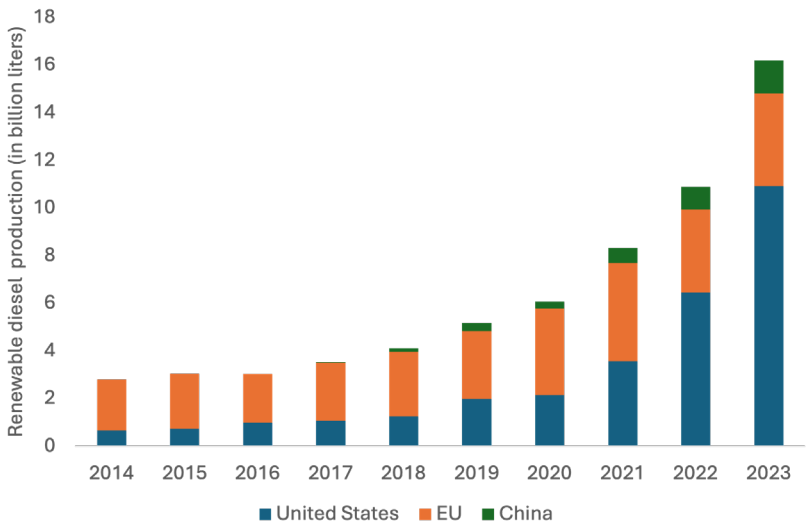


Figure 27. Renewable diesel production in the United States, the European Union, and China

COUNTRY UPDATE: UNITED STATES

The **U.S. renewable diesel market** has experienced rapid growth in recent years, driven by federal and state policies aimed at reducing carbon emissions. This expansion has led to significant **shifts** in both **domestic and global feedstock markets**, particularly in the increased demand for vegetable oils and animal fats used in renewable diesel production[12].
The **California Low-Carbon Fuel Standard** (LCFS) has been a major catalyst for this growth, creating a strong financial incentive that has positioned California as the leading market for renewable diesel. This demand surge has led to a decrease in U.S. soybean oil exports as domestic supplies are increasingly diverted to renewable diesel production, making the U.S. a net importer of soybean oil for the first time in 2023.

The growth of renewable diesel has also stimulated an **increase** in U.S. soybean crush operations to meet the rising **demand for soybean oil**, which is essential for producing renewable diesel. This has resulted in record levels of soybean meal production, leading to an export boom in this byproduct. However, the future growth of the U.S. renewable diesel market may be constrained by the **availability of feedstocks** and the **global demand for soybean meal**, as overproduction could limit the sustainability of continued expansion. Policy decisions at both federal and state levels will be crucial in determining the future trajectory of this market.

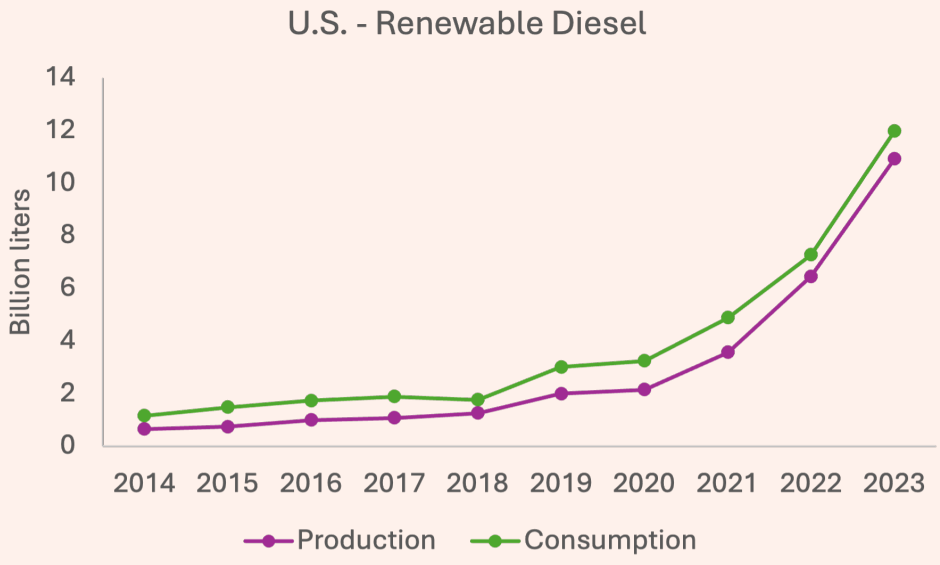


Figure 28. Renewable Diesel Overview for the United States[13].
Source: U.S Energy Information Administration

Biogases

Biogas is produced by anaerobic fermentation of different forms of organic matter and is composed mainly of methane (CH_4) and carbon dioxide (CO_2). In 2021, almost 40 billion m^3 of biogas was produced globally with an equivalent energy content of 1.5 EJ.

Table 30. Global biogas production

Year	Production (TJ)	Production (bcm)
2000	285 631	7
2005	538 590	14
2010	891 701	23
2020	1 458 785	38
2021	1 523 257	40

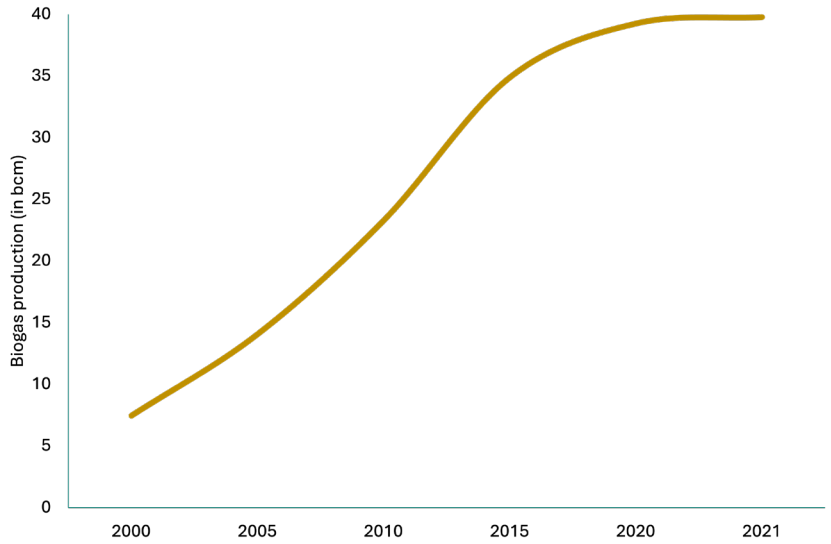


Figure 29. Global biogas production

NATIONAL AND REGIONAL UPDATES:

- In **India**, a mandatory blending of compressed biogas (**CBG**) will be introduced in April 2025. The **blending mandate** will start at **1%** and will increase gradually **to 5% by 2028-29**. With this initiative, the Indian government aims to reduce the reliance on the import of gas and to promote investment in CBG production in the country, which expects to establish **750 CBG projects by 2028-29**.

- In **Brazil**, biomethane has also shown significant growth. In **2023**, production was nearly **75 million m^3**, an increase of more than 12% on the previous year, and more than double since 2022.

- **Europe** has seen an increase in the production of biogases, especially in **biomethane**. The production in 2022 has doubled since 2018, with France, Italy, Denmark, and the UK as the fastest-growing countries. In 2022, Europe produced **21 bcm**.[14]

OTHER TECHNOLOGIES

Sustainable Aviation Fuel (SAF)

SAF, an alternative to conventional petroleum jet fuel, is made from agricultural and waste feedstocks and is typically blended with petroleum jet fuel.

UNITED STATES

The **production capacity** of sustainable aviation fuel (SAF) in the United States could experience significant growth, potentially increasing from around **2,000 barrels per day** (b/d) to nearly **30,000 b/d by 2024**, assuming all planned capacity expansions materialize[15]. Key projects contributing to this growth include **Phillips 66's Rodeo Renewed project**, which is expected to produce up to 10,000 b/d of SAF starting in the summer of 2024, and **Diamond Green Diesel's Port Arthur SAF project**, projected to deliver around 15,000 b/d by the year's end.

The rise in **investments** in SAF is driven by the U.S. Environmental Protection Agency's Renewable Fuel Standard (**RFS**), along with federal and state incentives, including tax credits, aimed at promoting the use of SAF. The U.S. government has set an ambitious **target** to meet 100% of the nation's aviation fuel demand with SAF by **2050**. As of 2023, the United States consumed approximately 1.6 million b/d of petroleum jet fuel, with projections indicating that demand could exceed 2.0 million b/d by 2050.

At the start of 2024, the U.S. SAF production capacity was still around 2,000 b/d, with only two plants—World Energy's facility in Paramount, California, and Montana Renewables' plant in Great Falls, Montana—capable of producing SAF.

JAPAN

Japan is focusing on advancing sustainable aviation fuel (SAF) as part of its broader strategy to reduce greenhouse gas emissions from aviation. By **2030**, Japan aims to cut aviation-related GHG emissions by at least 5% compared to 2019 levels. To support this goal, the country is working on **new SAF regulations**, which are expected to be implemented from 2030 to 2034. These regulations will target jet fuel producers supplying over **100 million liters** annually and will require SAF to achieve a **50% reduction in GHG** emissions compared to conventional fossil-based jet fuels[16].

The Japanese government and industry are also working to establish a competitive SAF supply chain, to r**eplace 10% of jet fuel with SAF by 2030**. This initiative includes a focus on domestic SAF production, with **bioethanol** identified as a promising feedstock. Additionally, Japan plans to set specific volume targets for SAF as part of its strategy to meet CORSIA goals and support the country's decarbonization efforts in aviation.

INDIA

India is making significant strides in the field of Sustainable Aviation Fuel (SAF) as part of its broader effort to reduce greenhouse gas emissions from the aviation sector. The National Biofuels Coordination Committee has set ambitious targets for SAF blending with jet fuel:

- **1% SAF Blending by 2027:** Starting with international flights, India aims to blend 1% SAF with jet fuel.
- **2% SAF Blending by 2028:** The target will increase to 2% for international flights.

India had originally aimed to **blend 1% SAF** into domestic commercial flights by **2025**, necessitating approximately **140 million liters of SAF** annually. Should the target increase to a 5% blend, the requirement would rise to around 700 million liters per year. India's SAF production utilizes **sugarcane molasses** as feedstock, supported by indigenous technology.

In 2019, India consumed about 8 million tonnes of aviation turbine fuel (ATF). The country has the **potential** to produce 19-24 million tonnes of SAF annually, while the estimated maximum requirement, assuming a 50% blend, is about 8-10 million tonnes/year by 2030[17]. The **cost** of producing SAF in Southeast Asia was assessed at **$1545.07/mt** as of the end of 2023, reflecting a slight daily decrease of 1.11%, according to S&P Global Commodity Insights[17].

Bioenergy with Carbon Capture and Storage (BECCS)

Bioenergy with carbon capture and storage (BECCS) is a process that combines the generation of energy from biomass with the capture and permanent storage of carbon dioxide (CO_2).

National and Regional developments:

Europe: On 10 April 2024, the European Parliament approved the Carbon Removals and Carbon Farming (**CRCF**) Regulation, establishing the **first EU-wide voluntary framework for certifying carbon removals**, carbon farming, and carbon storage in products. This regulation sets EU quality criteria, monitoring, and reporting processes, promoting investment in innovative carbon removal technologies and sustainable carbon farming while addressing greenwashing concerns. It mandates third-party **verification**, public **certification**-related information in an EU-wide registry, and introduces group certification, easing certification processes for small farmers and foresters.

Denmark: In May 2023, the Danish Energy Agency (DEA) awarded contracts for two combined heat and power plants capable of **capturing over 0.4 million tonnes of CO_2 annually** by 2026, as part of a carbon capture, utilization, and storage (CCUS) subsidy scheme. Construction has begun on these projects. In **April 2024**, the DEA expanded its efforts by awarding contracts for three additional BECCS projects through the Negative Emissions CCS (NECCS) fund, backed by a DKK 2.6 billion (EUR 350 million) subsidy aimed at achieving negative emissions.

Sweden: The **BECCS Stockholm project** will convert Stockholm Exergi's biomass co-generation plant into a full-scale BECCS facility, using forestry residues to produce energy while capturing and permanently storing biogenic CO_2. This pioneering project has the potential to **avoid around seven million tonnes of CO_2** over its first ten years, equivalent to nearly 20% of Sweden's total CO_2 emissions in 2022. In addition to enhancing the local district heating network, the project is expected to create up to 20 permanent local jobs and 1,500 jobs per year during the design and construction phase. **Construction** is set to begin in the second quarter of 2025, with **CO_2 capture** expected to start by late 2028.

United States: In North Dakota, a new carbon capture facility was commissioned at the Blue Flint bioethanol plant. Additionally, the federal government launched a carbon dioxide removal (CDR) pilot purchasing program, which includes BECCS, by entering into offtake agreements with CDR providers.

SOCIO-ECONOMIC UPDATES

Job Creation

The bioenergy sector continues to be a significant source of employment globally, driven by increased blending targets in liquid and gaseous biofuels and the adoption of biomass in energy production. This section provides an overview of employment trends across bioenergy sub-sectors—liquid biofuels, solid biomass, and biogas—focusing on the countries with the highest job creation and regional trends.

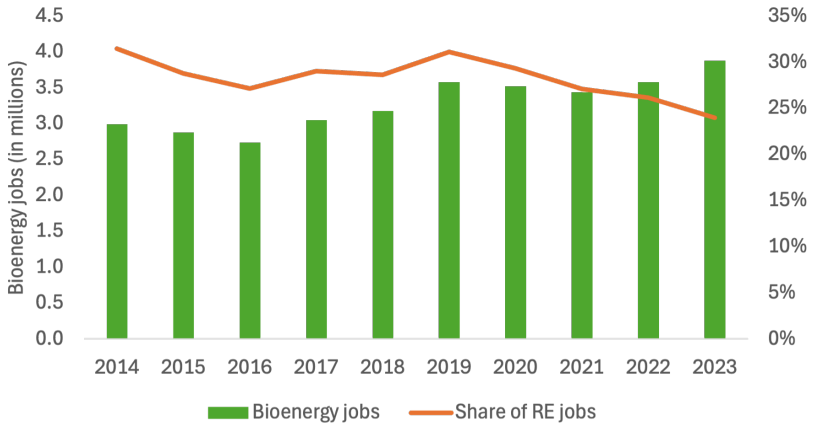


Figure 30. Overview of global bioenergy-related jobs and its share within Renewable Energy jobs

In **2023**, the global bioenergy sector generated approximately **3.9 million jobs**. Of these, **liquid biofuels** accounted for the largest share, with more than **2.8 million jobs**, representing more than 70% of the total bioenergy workforce. Even though total bioenergy jobs were raised in 2023 and are the highest number, bioenergy jobs share within renewable energy-related jobs made up 24%, marking the lowest share in the decade.

Table 31. Global Bioenergy Employment by Sector in 2023

Bioenergy Type	Approximate Number of Jobs
Liquid Biofuels	2 803
Solid Biomass	765
Biogas	316
Total	3 884

All values in thousands. Source: IRENA 2024

In **Europe**, the bioenergy sector employed **530 700 people in 2022**. The solid biofuels subsector was the largest employer, accounting for 63% of these jobs, followed by liquid biofuels at 28% and biogas at 9%[18].

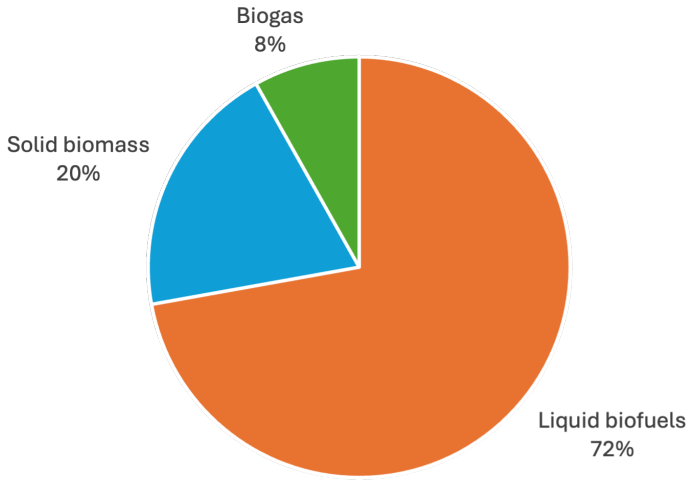


Figure 31. Global Bioenergy Employment by Sector in 2023

Additionally, while not included in total employment estimates, the **charcoal trade** supports nearly **7 million jobs in sub-Saharan Africa**, covering informal roles in harvesting, processing, and distribution[19]. As the sector evolves with increasing policy targets and investments, job creation is anticipated to expand, particularly in regions rich in feedstock resources and supportive policies.

Liquid Biofuels

According to IRENA's latest renewable energy and jobs report, the global liquid biofuel industry employed about **2.8 million people in 2023**, representing 17% of all renewable energy jobs. Within this figure, **Latin America** is a major contributor, with 43% of these jobs concentrated in the region.

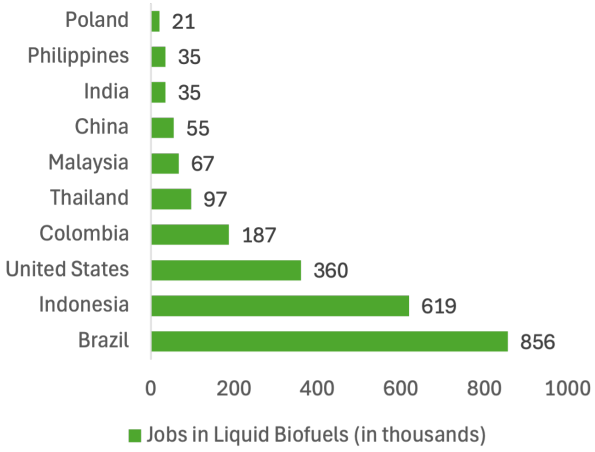


Figure 32. Top 10 Countries with the Highest Employment in Liquid Biofuels (2022)

In **2023**, in the **United States**, the liquid biofuel sector employed **342 260 people** in both direct and indirect roles related to feedstock and processing. The 27 **EU** Member States saw an estimated 150,000 biofuel-related jobs in 2022, a slight increase from 148,000 in 2021. **Brazil** remains the **largest employer** in this sector, with approximately **994 350 jobs**—35% of the global total—despite being the second-largest producer of biofuels after the United States. Labor-intensive feedstock operations in Latin America and Southeast Asia often involve informal and seasonal work.

Solid Biofuels

The solid biofuels sector employed approximately **765 000** people in 2023 – for power and heat applications. China was the biggest player, generating a quarter of those jobs, followed by India (7%) and the United States (6%).

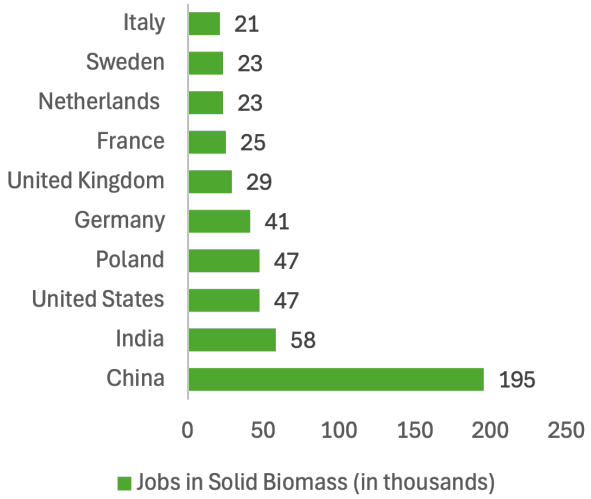


Figure 33. Top 10 Countries with the Highest Employment in Solid Biomass (2022)

Biogas

The biogas sector saw significant job creation in 2023, driven by the completion of new facilities—over 120 in the United States and around 300 in Europe. The sector created a proximately **316 000 jobs globally**. China led with more than half of these jobs, while India, supported by biogas-oriented policies, accounted for 85 000 jobs. In the EU, Germany was the largest employer, with 24 000 jobs created.

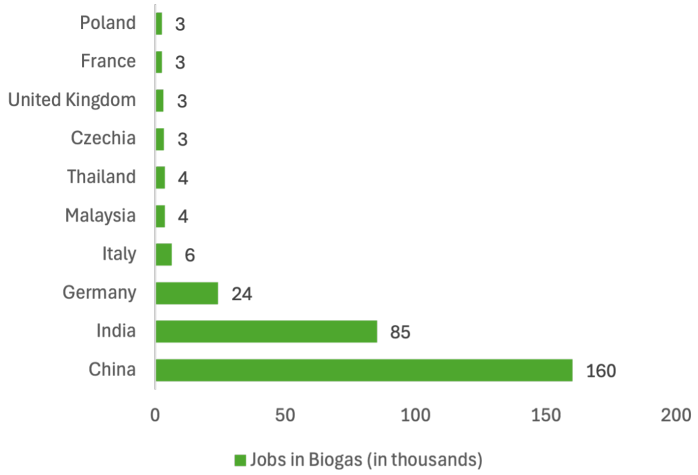


Figure 34. Top 10 Countries with the Highest Employment in Biogas (2022)

Investments

Bioenergy is currently a **market** valued at approximately **USD 44 billion**, and the sector is poised for significant growth[20]. McKinsey estimates that over **USD 150 billion in investments** have already been planned for **sustainable fuel production**, encompassing more than 200 projects related to hydrotreated fuels (HVO/HEFA), alcohol-to-jet, and biomethanol, among others.[21]

In 2022, global investment in bioenergy reached nearly **USD 9 billion**, with 66% directed towards biofuels and the remaining portion toward solid biomass[22]. The year also saw a record level of capacity additions in biofuels, spurring substantial investments in the sector. Notable examples include the USD 1.2 billion Marathon-Neste joint venture for renewable diesel production in California and Neste's USD 2.2 billion expansion of its renewable fuels plant in Rotterdam, both of which reflect the growing demand for sustainable aviation fuels.

The **United States** has played a pivotal role in this growth, driven by the **Inflation Reduction Act**, which provides approximately USD 9.4 billion in tax credits and financial incentives for new production capacities and biofuel infrastructure[23]. Additionally, in 2022, oil and gas companies increased their **bioenergy investments to USD 11 billion**, representing over half of their clean energy spending. This investment primarily focused on acquiring biomethane and biodiesel producers. Canada has also made significant strides, with its Clean Fuels Regulation allocating USD 1.5 billion to the **Clean Fuels Fund**, which supports domestic production and adoption of low-carbon fuels, including hydrogen and biofuels.

Investment trends over the past decade have shown considerable fluctuation. However, the recent surge in biofuel investments, driven by evolving policies and increasing global demand, highlights the sector's growing importance and potential.

Table 32. Global investment in Bioenergy in the last 10 years. Source: IRENA

Year	Investment in USD billion	
	Biofuels	Biomass
2013	1.89	8.62
2014	1.92	8.57
2015	1.65	7.37
2016	0.23	5.05
2017	0.21	4.63
2018	0.18	10.95
2019	1.77	8.69
2020	1.82	4.46
2021	6.03	10.86
2022	5.84	3.05

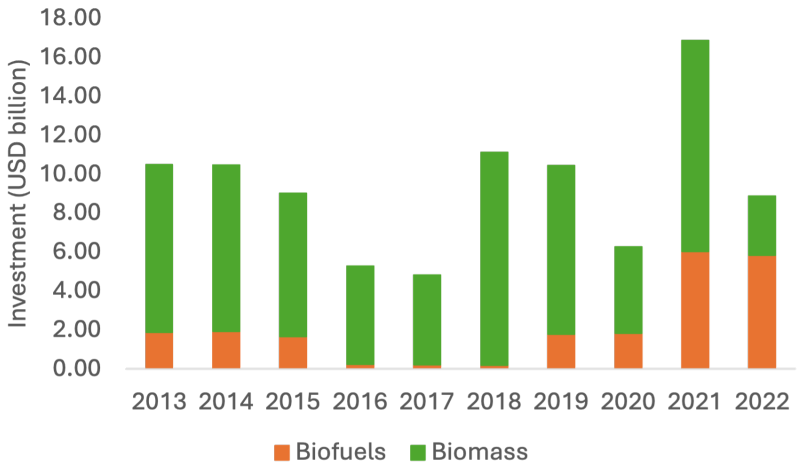


Figure 35. Global investment in Bioenergy*. Source: IRENA

**Note: Investment drops don't immediately affect capacity due to cost changes and a typical 1.7-year funding-to-completion lag*

APPENDIX

Geographical Coverage

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Guinea – Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal , Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swazi-land, Togo, Tunisia, Uganda, United Republic of Tanzania, Western Sahara, Zambia, Zimbabwe.

Americas: Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Canada, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falklands Islands , French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and the Grenadines, Suriname, Turks and Caicos Islands, United States of America, Uruguay, Venezuela.

Asia: Afghanistan, Bahrain, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, China, Hong Kong SAR, China, Macao SAR, Democratic People's Republic of Korea, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Korea Democratic Republic, Kuwait, Lao People's Democratic Republic, Lebanon, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, Sri Lanka, Syrian Arab Republic, Thailand, Turkey, United Arab Emirates, Viet Nam, Yemen.

Europe: Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, The Former Yugoslav Republic of Macedonia, Ukraine, United Kingdom.

Oceania: Australia, New Zealand

Glossary

Bioenergy: Bioenergy is equal to the sum of industrial waste, municipal waste, primary solid biofuels, biogas, bioethanol, biodiesel, other liquid biofuels, charcoal, etc.

Geothermal: Geothermal energy is the energy available as heat emitted from within the earth's crust, usually in the form of hot water or steam.

Municipal Waste: Municipal waste consists of products that are combusted directly to produce heat and/or power and comprises wastes produced by households, industry, hospitals, and the tertiary sector that are collected by local authorities for incineration at specific installations. Municipal waste is split into renewable and non-renewable.

Industrial Waste: Industrial waste of non-renewable origin consists of solid and liquid products (e.g. tyres) combusted directly, usually in specialized plants, to produce heat and/or power. Renewable industrial waste is not included here but with solid biofuels, biogases or liquid biofuels.

Solid Biofuels: Primary solid biofuels are defined as any plant matter used directly as fuel or converted into other forms before combustion. This covers a multitude of woody materials generated by industrial process or provided directly by forestry and agriculture (firewood, wood chips, bark,sawdust, shavings, chips, sulphite lye also known as black liquor, animal materials/wastes and other solid biofuels).

Biogases: Biogases are gases arising from the anaerobic fermentation of biomass and the gasification of solid biomass (including biomass in wastes). The biogases from anaerobic fermentation are composed principally of methane and carbon dioxide and comprise landfill gas, sewage sludge gas and other biogases from anaerobic fermentation.

Liquid Biofuels: Liquid biofuels are a sum of Biogasoline, biodiesel, and other liquid biofuels.

Wood Fuel: Roundwood that will be used as fuel for purposes such as cooking, heating, or power production. It includes wood harvested from main stems, branches, and other parts of trees (where these are harvested for fuel) and wood that will be used for the production of charcoal (e.g. in pit kilns and portable ovens), wood pellets, and other agglomerates. The volume of roundwood used in charcoal production is estimated by using a factor of 6.0 to convert from the weight (mt) of charcoal produced to the solid volume (m3) of roundwood used in production. It also includes wood chips to be used for fuel that are made directly (i.e. in the forest) from roundwood. It excludes wood charcoal, pellets and other agglomerates. It is reported in cubic metres solid volume underbark (i.e. excluding bark)

Wood Pellets: Agglomerates produced either directly by compression or by the addition of a binder in a proportion not exceeding 3% by weight. Such pellets are cylindrical, with a diameter not exceeding 25 mm and a length not exceeding 100 mm. It is reported in metric tonnes. Wood Charcoal: It covers the solid residue of the destructive distillation and pyrolysis of wood and other vegetal material.

Electricity Only: Refers to plants which are designed to produce electricity only. If one or more units of the plant are a CHP unit (and the inputs and outputs cannot be distinguished on a unit basis) then the whole plant is designated as a CHP plant.

Heat Only: Refers to plants (including heat pumps and electric boilers) designed to produce heat only and that sell heat to a third party (e.g. residential, commercial or industrial consumers) under the provisions of a contract.

CHP: Refers to plants that are designed to produce both heat and electricity (sometimes referred to as co-generation power stations). If possible, fuel inputs and electricity/heat outputs should be on a unit basis rather than on a plant basis.

LIST OF FIGURES

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