

Global Ethanol Production

Subjects: Area Studies

Contributor: Dung Hoang

Ethanol (C₂H₆O) is a simple liquid alcohol that is formed from the fermentation of sugars in their natural occurrences or being derived from starch-rich grains or lignocellulosic feedstocks. Ethanol is also called ethyl alcohol, grain alcohol, or simply alcohol, and is used as a disinfectant, an organic solvent, a chemical feedstock, and a transportation liquid fuel.

Keywords: fuel ethanol ; production ; feedstocks ; biomass ; fermentation ; climate change ; environmental security

1. Background

Ethanol is produced in various countries in the world and its global quantity has changed from 110 billion liters in 2019 to 98.6 billion liters in 2020 due to the pandemic ^{[1][2]}. When ethanol is blended with 95% gasoline it can reduce about 90% CO₂ and 60–80% SO₂ ^[3]. This helps the world to solve some of the problems of air pollution, reduces the levels of greenhouse gases that are causing climate change and maintains environmental security. Currently, ethanol is produced commercially from a variety of feedstocks via fermentation where the yeast *Saccharomyces cerevisiae* is utilized to ferment the sugars derived from the starch in corn and other grains or those that already are present in sugar cane and sugar beets ^[4].

2. Global Ethanol Production

It is estimated that currently 60% ethanol is produced from corn, 25% from sugar cane, 3% from wheat, 2% from molasses, and the rest from other grains, cassava and sugar beets. The annual world fuel ethanol production in the last three years together with the production by the individual countries that contributed to at least 1% of the total production are summarized in **Table 1**. As indicated in **Table 1**, the top five ethanol producers before the COVID-19 pandemic were the United States, Brazil, the European Union (EU), China, and Canada. In 2020, India produced slightly more ethanol than Canada but the ranking of the top four ethanol producers did not change.

Table 1. Annual world fuel ethanol production (Mil. L) (Source: Renewable Fuels Association analysis of public and private data sources ^[5]).

| Region | 2018 | 2019 | 2020 | % of 2020 World Production |
|---------------------|--------|--------|--------|----------------------------|
| United States | 16,091 | 15,778 | 13,926 | 53% |
| Brazil | 7990 | 8590 | 7930 | 30% |
| European Union (EU) | 1450 | 1370 | 1250 | 5% |
| China | 770 | 1000 | 880 | 3% |
| Canada | 460 | 520 | 428 | 2% |
| India | 430 | 510 | 515 | 2% |
| Thailand | 390 | 430 | 400 | 2% |
| Argentina | 290 | 280 | 230 | 1% |
| Rest of the world | 529 | 522 | 500 | 2% |
| Total | 28,400 | 29,000 | 26,059 | |

Note: The EU in this review refers to the union of 28 members, i.e., before the exit of the United Kingdom.

The number of production plants, plant type, feedstocks, and co-products of the ethanol industry in the top five ethanol-producing countries/regions are summarized in **Table 2**. In this table, all the data are for 2020. The case of the United

States needs an explanation. Several corn dry-grind ethanol plants in the United States used a bolt-on process such as the D3MAX or QCCP process discussed previously to convert the corn fibers, i.e., a biomass feedstock, and the non-converted corn starch to additional ethanol. The quantities of ethanol produced from each feedstock in these processes could not be determined separately. Therefore, all the ethanol produced in these plants are listed under corn ethanol production. In addition, some plants occasionally used small amounts of sorghum grains to mix with corn. The quantities of sorghum grains used were not known. Therefore, all the starch-based feedstock is listed under corn.

Table 2. The number of ethanol plants, plant type, feedstocks, and co-products in the top five ethanol-producing countries/regions ^{[6][7][8][9][10]}.

| Country/Region | USA | Brazil | EU | China | India |
|--|----------------|----------------|-------------|-------------|----------------|
| Number of 1st-generation plants | 208 | 360 | 57 | 18 | 220 |
| Nameplate capacity (Bil L) | 65.8 | 42.8 | 8.15 | 6.58 | 3.50 |
| Capacity used (%) | 80 | 67 | 58 | 49 | 85 |
| Number of 2nd-generation plants | 3 | 3 | 3 | 1 | 0 |
| Nameplate capacity (Bil L) | 0.21 | 0.13 | 0.09 | 0.07 | |
| Capacity used (%) | n/a | 25 | 28 | 0 | |
| Feedstocks (1000 MT) | | | | | |
| Corn | 123,465 | 5995 | 6350 | 7100 | 0 |
| Other grains | 0 | 0 | 4300 | 900 | 0 |
| Cassava | 0 | 0 | 0 | 1000 | 0 |
| Sugarcane | 0 | 326,630 | 0 | 0 | 0 |
| Sugar beets | 0 | 0 | 7450 | 0 | 0 |
| Molasses | 0 | 0 | 0 | 0 | 6407 |
| Biomass | 0 | 0.178 | 200 | 200 | 0 |
| Co-products (1000 MT) | | | | | |
| Bagasse | 0 | 120,077 | 0 | 0 | 118,374 |
| Distillers grains | 29,437 | 1876 | 3332 | 2348 | 0 |
| Corn gluten feed | 3087 | 0 | 0 | 0 | 0 |
| Corn gluten meal | 605 | 0 | 0 | 0 | 0 |
| Corn Oil | 27.9 | 108.0 | 184 | 0 | 0 |

Note: n/a: Not available.

Ethanol production from the individual nations with significant annual ethanol outputs are reviewed in the following sections.

2.1. North America

2.1.1. The United States

In the United States, ethanol produced from corn reached 6.5 billion gallons (24.6 billion L) in 2007 and in 2012 this total doubled to approximately 13.2 billion gallons (50.0 billion L). In 2018 the United States exported a total of 6.5 billion L of ethanol, expanding the share of world exports of ethanol to 61%. Most ethanol produced in the United States is from starch-based crops by dry or wet-mill processing technologies. In 2020, there were 208 ethanol production plants in the United States with a total installed capacity of 17.44 billion gallons per year (66.0 billion L per year). The total production in 2020 was 13.8 billion gallons (52.2 billion L), which represented a 12.7% decrease from the production total of 15.8 billion gallons (59.8 billion L) in the previous year ^{[11][12]}. The decrease in ethanol production was mainly caused by the reduction in transportation fuel demand, which was the direct consequence of the COVID-19 pandemic. Whereas a number of plants were shut down, some plants modified the production process to produce an ethanol product which is suitable for use in hand sanitizers to cope with the economic downturn. It is expected that production of ethanol will go back up in

2021. The ethanol co-products generated in 2020 included 29.4 million metric tons (MT) distillers grains, 3.1 million MT corn gluten feed, 0.6 million MT corn gluten meal, 1.5 million MT corn oil and 2.1 million MT captured CO₂. Corn was the major feedstock, which accounted for 93.2% of the total ethanol production in 2020. Other feedstocks included sorghum, corn fiber, waste sugars, waste starch and lignocellulosic biomass. The interest in biomass as a potential feedstock for ethanol production continued to be strong. Despite previous failures by large corporations such as Poet and DuPont, New Energy Blue announced in July 2021 the plan to construct a full-scale ethanol biorefinery, which would consume 250,000 MT per year agricultural residues generated locally for ethanol production. The proposed plant would use the Inbicon process, which would also produce a lignin co-product for use as a solid biofuel and a natural binder and possibly xylitol as a specialty chemical with potential food applications ^{[13][14]}.

2.1.2. Canada

Canada is a net importer of ethanol since the volume consumed in Canada generally exceeded the ethanol this country produced. In 1980, Canadian produced merely 8000 L but in 2010 the annual ethanol production of Canada reached 1.9 billion L. In 2019, ethanol consumption in Canada reached 3.33 billion L compared to 2 billion L in production. However, ethanol production in Canada has grown in recent years largely due to changes in feedstocks and increased capacity at existing ethanol facilities in Canada.

In 2020, Canada was ranked as the sixth largest ethanol producer in the world. The ethanol production in Canada represented 1.6% of the total global production. The two major feedstocks used for ethanol production were corn and wheat, which contributed 1534.3 million L and 360.7 million L, respectively ^[12]. Winter barley has been considered as a potential feedstock for ethanol production. However, this grain has not been used in any commercial ethanol production plant.

2.2. South America

2.2.1. Brazil

Brazil continued to be the second largest ethanol producer in the world. In 2019, Brazil ethanol production including anhydrous and hydrous ethanol amounted to more than 35.3 million M³, an increase of nearly seven percent in comparison to a year of 2018. This is the highest volume of fuel ethanol that Brazil has produced in the decade. In Brazil, sugarcane bagasse is commonly used as boiler fuel to produce energy to supply sugar mills. This is practiced to minimize the energy costs and also as an alternative to the utilization of the biomass left over.

In 2020, the ethanol production in Brazil represented 26.7% of the total global ethanol production ^[5]. There were 360 first-generation (sugar cane, corn) ethanol plants in Brazil in 2020 with a total nameplate capacity of 42,800 million L. However, only 67% of the capacity was used. There were three plants that used lignocellulosic feedstock with a total nameplate capacity of 127 million L. In 2020, these second-generation ethanol plants only operated at 25% capacity. The feedstocks included sugar cane (326.6 million MT), corn (6.0 million MT) and bagasse (178,000 MT). The total ethanol production in 2020 was 31.35 billion L, which included 32 million L produced from lignocellulosic feedstock (bagasse). The 2020 ethanol production was about 16% lower compared to the previous year (37.38 billion L). The decrease in ethanol production in 2020 was mainly caused by the diversion of sugar cane juice toward more sugar production in sugar-ethanol plants. The co-products included 120.1 million MT bagasse, 1.88 million MT DDGS and 108,000 MT corn oil. The traditional feedstock for first-generation ethanol production in Brazil is sugar cane. However, corn has become an important feedstock and its use for ethanol production has steadily gained ground. In 2020, 2.5 billion L ethanol was produced from corn, which was 1.17 million L higher than the previous year. The Corn Ethanol National Union (UNEM) predicted that corn ethanol production would reach 8 billion L by 2028. There currently are 11 corn ethanol plants, which include nine full-plant types (corn only) and 2 flex-plant types (corn and sugarcane). Two full-plants and one flex-plant are currently under construction ^[7].

2.2.2. Argentina

In 2020, Argentina was ranked 8th in the world with a contribution of 1.0% toward the total global ethanol production ^[5]. There were 22 ethanol plants with a total nameplate capacity of 1580 million L per year. The ethanol plants, however, were operated only at 55.1% capacity. Corn and molasses were used as feedstocks at 1.09 million MT and 1.70 million MT, respectively. The total ethanol production was 870 million liters, which was significantly lower than the total production in the previous year (1073 million L). The DDGS co-product was also produced at 345,000 MT ^[15].

2.2.3. Colombia

Colombia was ranked 13th in the world in 2020 with a contribution of 0.44% toward the total global ethanol production ^[13]. The country had six ethanol plants, which used sugar cane as the only feedstock. The total nameplate capacity of the plants was 540 million liters. These plants were run at only 73.1% capacity in 2020. The total ethanol production in 2020 was 395 million liters with 1.34 million MT bagasse co-product. Five of the six ethanol plants were directly linked to the sugar production plants. The bagasse obtained after juice extraction was used to generate energy for internal use in these plants. Most ethanol plants in Colombia were energy self-sufficient and even generated surplus energy to sell to the national grid ^[16].

2.3. Europe

The European Union

The total ethanol production in the EU in 2020 was 4.8% of the total global production ^[5]. The major feedstocks used for ethanol production were sugar beets (7.45 million MT), corn (6.35 million MT), and wheat (2.64 million MT). Other first-generation feedstocks were triticale (1.04 million MT), rye (520,000 MT) and barley (450,000 million MT). Wheat was predominantly used in Belgium, Germany, France and the UK. Corn was the preferred feedstock in Hungary, where corn was abundantly available, and in the Netherlands, Spain, and the UK, where the majority of corn came from the Ukraine to provide the feedstock for ethanol plants, which are located near seaports. The inland ethanol plants in Spain used a combination of corn and barley as the feedstock. Sugar beets and their derivatives were used for ethanol production in France, Germany, the UK, the Czech Republic, Belgium and Austria. The usage of lignocellulosic feedstocks in 2020 was doubled to 200,000 MT compared to the previous year. There were 57 first-generation ethanol plants with a total nameplate capacity of 8.15 billion L, which were operated at 58% capacity. There were also 3 lignocellulosic ethanol plants with a total nameplate capacity of 90 million L. However, these second-generation ethanol plants were operated at only 28% capacity. Five other lignocellulosic ethanol plants were under construction in Finland (sawdust, 10 million L per year), Italy (biomass, 28 million L per year), Austria (wood sugars, 30 million L per year), Romania (wheat straw, 65 million L per year) and Bulgaria (corn stover, 50 million L per year). All of these plants are expected to be in operation soon. The ethanol production in the EU in 2020 was 5.47 billion L. Due to the COVID-19 pandemic, ethanol consumption in the EU has decreased by 10.1%. However, this number was still slightly lower than the 13.0% decrease in gasoline consumption. According to the 2021 European Union Biofuels Annual Report, the co-products included 3.33 million MT DDGS and 188,000 MT corn oil ^[8].

2.4. Asia and Rest of the World

2.4.1. Vietnam

Vietnam is an agriculture-based country and has abundant natural resources for renewable power development. However, the pace of renewable energy development including ethanol production is not yet rapid due to barriers such as the small size of the country's economy, the lack of financial capacity, advanced technologies and human resources. Institutional barriers such as market-controlled mechanisms and unstable supporting policies also limit the development of renewable power sectors ^[17].

In terms of ethanol development, due to the economic development, Vietnam has consumed lots of gasoline in recent years. The United States Department of Agriculture (USDA) estimated gasoline consumption of Vietnam in recent years has grown approximately 4–5 percent per year. In the first quarter of 2020, Vietnam spent about \$2.5 billion on importing crude oil and petroleum products, including ethanol, in addition to its production ^[18]. Since 2007 ethanol supporting regulations have gradually increased, however, the commercialization and sales of five percent ethanol blended gasoline (E5) was pushed back to 2018 due to a lack of understanding of the environmental benefits of ethanol blended gasoline by consumers, together with some persistent rumors and myths that usage of ethanol might harm vehicle engines.

2.4.2. Korea

Korea is the 7th ranked CO₂ emitter in the world and similar to other countries is concerned about its high CO₂ emissions and its dependence on imported crude oil. All of the oil Korea consumes is imported from foreign countries. South Korea is a main importer of United States ethanol, with a total volume of 263.84 million L (24.7 million bushels in corn equivalent) in 2017–2018. In the mid-1990s, production of ethanol for fuel use in Korea using imported cassava as a feedstock was initiated. The Korea Ministry of Knowledge Economy (KMKE) announced an action plan to increase the use of biofuels in the transport sector from 0.2 billion L in 2008 to 5 billion L by 2030 ^[19].

2.4.3. China

From 2004 to 2016, China produced ethanol with an average annual increase in production rate of 16.8 percent. In 2017, China had an ethanol production of 2.8 million MT. In 2018, China produced 6.6 million MT, making it the fourth-largest ethanol producing country/region in the world, after the United States, Brazil, and the EU. China set a policy that gasoline supplies across the country were required to be blended with ethanol by 2020. According to a news source, China aimed to have 15 million MT by 2020, which is almost triple its current ethanol production capacity, in order to keep up with growing demands for cleaner fuels ^[9]. The target would exceed the estimated domestic production capacity of China and the country would need to import ethanol from foreign countries such as the United States and Brazil. Corn is China's main feedstock, which is currently accounting for 64 percent of total output for China's ethanol production ^[20].

2.4.4. India

India ranked 6th among the leading ethanol producers in the world. In 2020, India still remained one of the biggest importers of the United States ethanol, with a market share of 99 percent. With Modi's "self-resilient" strategies, India sets its ambitious goal of E-20 by 2025 while retaining its immediate goal of E-10 by 2022. India has a total installed ethanol capacity of 5 billion L, of which molasses-based distilleries constitute 4.2 billion L, or 85 percent of the overall production capacity, while grain-based distilleries constitute 750 million L (equivalent to 15 percent).

Formerly, ethanol in India could only be produced from molasses or sugar juice. However, India's existing ethanol is produced from a variety of feedstocks such as cereals (rice, wheat, barley, maize, and sorghum). In 2020, an estimated 2.98 billion L of ethanol was produced from molasses. In 2021, India's ethanol production was forecast at 3.17 billion L, 7% above 2020 due to surplus sugarcane production, and 2021 average ethanol blending rate in gasoline of India was estimated at 7.5 percent, due to accelerated government efforts to divert more feedstock toward ethanol ^[21].

2.4.5. Thailand

Thailand is the 7th largest ethanol producer in the world. Thailand consumed 1500 million L of ethanol in 2020. Thailand's 20-year Alternative Energy Development Plan (AEDP) for 2018–2037 targeted 2.0 billion L for ethanol in 2021 and 2.7 billion L for ethanol consumption in 2037. Molasses is the primary feedstock for ethanol production in Thailand. Molasses supplies in Thailand have been tight due to reduced sugarcane production for two consecutive years. Ethanol demand is primarily expected to be fulfilled by cassava-based ethanol in Thailand ^[22].

2.4.6. Australia

Australia's ethanol consumption is forecast to remain stable in 2020 at only 1.4% of gasoline consumption. Ethanol in Australia is primarily produced as a biofuel for passenger and commercial vehicles and also for alcoholic beverage, industrial chemicals, and solvents used in pharmaceutical and cosmetic applications. In spite of large feedstock availability, Australia's ethanol production volumes remain small because there is no nationwide fuel ethanol program. In Australia only two states, which are New South Wales and Queensland, have mandates with a fuel ethanol program, and have the highest consumption of ethanol blended fuel.

In New South Wales, Manildra is the largest ethanol producer with a capacity of over 300 million L. In this plant wheat starch is processed through an integrated process which separates the gluten and processes the remaining starch into a range of food and industrial-grade starches, glucose syrups, and ethanol products. In Queensland, a plant at Dalby producing ethanol from starch-based feedstock is operated by United Petroleum. This biorefinery with a capacity of 80 million L fuel-grade ethanol is located in a sorghum growing region in the Darling Downs and processes up to 0.2 million MT of sorghum grain a year from local growers. At full capacity, the biorefinery can also produce 830,000 MT of wet distillers grain, which is used for animal feed supplements ^[23].

2.4.7. Zimbabwe and Other African countries

Zimbabwe has adopted ethanol petrol blending regulations. Two ethanol plants in Zimbabwe, namely Triangle Sugar and Hippo Valley, were installed. In 2010, the Triangle plant resumed ethanol production after refurbishing its ethanol plant with a capacity of 27 million L per year. The government of Zimbabwe also initiated the Chisumbanje sugar/bioethanol project with an aim of using 10,000 hectares of sugarcane for this project. In March 2012, owners of this project halted production because the plant was running out of storage space. In Zimbabwe, some oil companies were only selling E10 at a few of their filling stations ^[24].

In other African countries, lead additives are still heavily used in gasoline and where sugarcane production cost is high, ethanol can be a cheap source of octane in gasoline. It is estimated that in Africa, to replace all the lead used in African gasoline, this would require Africa to produce about 20% of the amount of ethanol currently produced in Brazil, and would require the shift of some sugar production to ethanol production. African countries that could replace lead with ethanol

using primarily their by-product molasses production include Zimbabwe, Kenya, Egypt, Zaire, Zambia, Sudan, Swaziland, and Mauritius at a more modest scale ^[25].

References

1. Global Ethanol Production by Country or Region. Available online: <https://afdc.energy.gov/data/10331/> (accessed on 19 September 2021).
2. The Future of Biofuels: A Global Perspective. Available online: <https://www.ers.usda.gov/amber-waves/2007/november/the-future-of-biofuels-a-global-perspective/> (accessed on 19 September 2021).
3. Halde, P.; Azad, K.; Shah, S.; Sarker, E. Prospects and technological advancement of cellulosic bioethanol ecofuel production. *Adv. Eco-Fuels Sustain. Environ.* **2019**, *211*–236.
4. U.S. Energy Information Administration. Biofuels Explained, Ethanol. Available online: <https://www.eia.gov/energyexplained/biofuels/ethanol.php> (accessed on 1 December 2021).
5. Renewable Fuels Association Analysis of Public and Private Data. Available online: <https://ethanolrfa.org/markets-and-statistics/annual-ethanol-production> (accessed on 1 December 2021).
6. OECD-FAO Agricultural Outlook 2021–2030. Available online: <https://www.fao.org/publications/oecd-fao-agricultural-outlook/2021-2030/en/> (accessed on 12 October 2021).
7. Brazil Biofuels Annual Report 2020, Global Agricultural Information Network; GAIN Report Number BR2020-0032; Foreign Agricultural Service, U.S. Department of Agriculture: Washington, DC, USA, 2020.
8. European Union Biofuels Annual Report 2021, Global Agricultural Information Network; GAIN Report Number E42021-0053; Foreign Agricultural Service, U.S. Department of Agriculture: Washington, DC, USA, 2021.
9. China Biofuels Annual Report 2020, Global Agricultural Information Network; GAIN Report Number CH2020-0105; Foreign Agricultural Service, U.S. Department of Agriculture: Washington, DC, USA, 2020.
10. U.S. Bioenergy Statistics. Available online: <https://www.ers.usda.gov/data-products/u-s-bioenergy-statistics/> (accessed on 22 November 2021).
11. Renewable Fuels Association. 2021 Ethanol Industry Outlook. Available online: https://ethanolrfa.org/wp-content/uploads/2021/02/RFA_Outlook_2021_fin_low.pdf/ (accessed on 22 September 2021).
12. Renewable Fuels Association. 2020 Ethanol Industry Outlook. Available online: <https://ethanolrfa.org/file/21/2020-Outlook-Final-for-Website.pdf/> (accessed on 12 October 2021).
13. New Energy Blue to Construct Cellulosic Biorefinery in Iowa. Available online: <http://biomassmagazine.com/articles/18180/new-energy-blue-to-construct-cellulosic-biorefinery-in-iowa/> (accessed on 12 October 2021).
14. Inbicon Biomass Refinery. Available online: https://www.eia.gov/biofuels/workshop/pdf/paul_kamp.pdf/ (accessed on 12 October 2021).
15. Argentina Biofuels Annual Report 2020, Global Agricultural Information Network; GAIN Report Number AR2020-0027; Foreign Agricultural Service, U.S. Department of Agriculture: Washington, DC, USA, 2020.
16. Colombia Biofuels Annual Report 2021, Global Agricultural Information Network; GAIN Report Number CO2021-0012; Foreign Agricultural Service, U.S. Department of Agriculture: Washington, DC, USA, 2021.
17. Nong, D.; Wang, C.; QuasemAl-Aminde, A. A critical review of energy resources, policies and scientific studies towards a cleaner and more sustainable economy in Vietnam. *Renew. Sustain. Energy Rev.* **2020**, *134*, 110117.
18. USDA Foreign Agricultural Service. Vietnam Ethanol Background Report. 11 August 2020. Available online: <https://www.fas.usda.gov/data/vietnam-vietnam-ethanol-background-report> (accessed on 18 May 2021).
19. Kima, J.-S. Production of bioethanol from lignocellulose: Status and perspectives in Korea. *Bioresour. Technol.* **2010**, *101*, 4801–4805.
20. Reuter's Report, China Set to Triple Its Ethanol Production Capacity: Government Researcher. Available online: <https://www.reuters.com/article/us-china-ethanol/china-set-to-triple-its-ethanol-production-capacity-government-researcher-idUSKBN1OA0FH> (accessed on 21 May 2021).
21. India Biofuels Annual Report 2020, Global Agricultural Information Network; GAIN Report Number IN2021-0072; Foreign Agricultural Service, U.S. Department of Agriculture: Washington, DC, USA, 2020.
22. Thailand Biofuels Annual Report 2020, Global Agricultural Information Network; GAIN Report Number TH2021-0040; Foreign Agricultural Service, U.S. Department of Agriculture: Washington, DC, USA, 2020.

23. Australia Biofuels Annual Report 2020, Global Agricultural Information Network; GAIN Report Number AS2020-0020; Foreign Agricultural Service, U.S. Department of Agriculture: Washington, DC, USA, 2020.
 24. Bioethanol in Africa: The Case for Technology Transfer and South-South Cooperation. 2016. Available online: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Bioethanol_in_Africa_2016.pdf (accessed on 1 December 2021).
 25. Thomas, V.; Kwong, A. Ethanol as a lead replacement: Phasing out leaded gasoline in Africa. *Energy Policy* 2001, 29, 1133–1143.
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