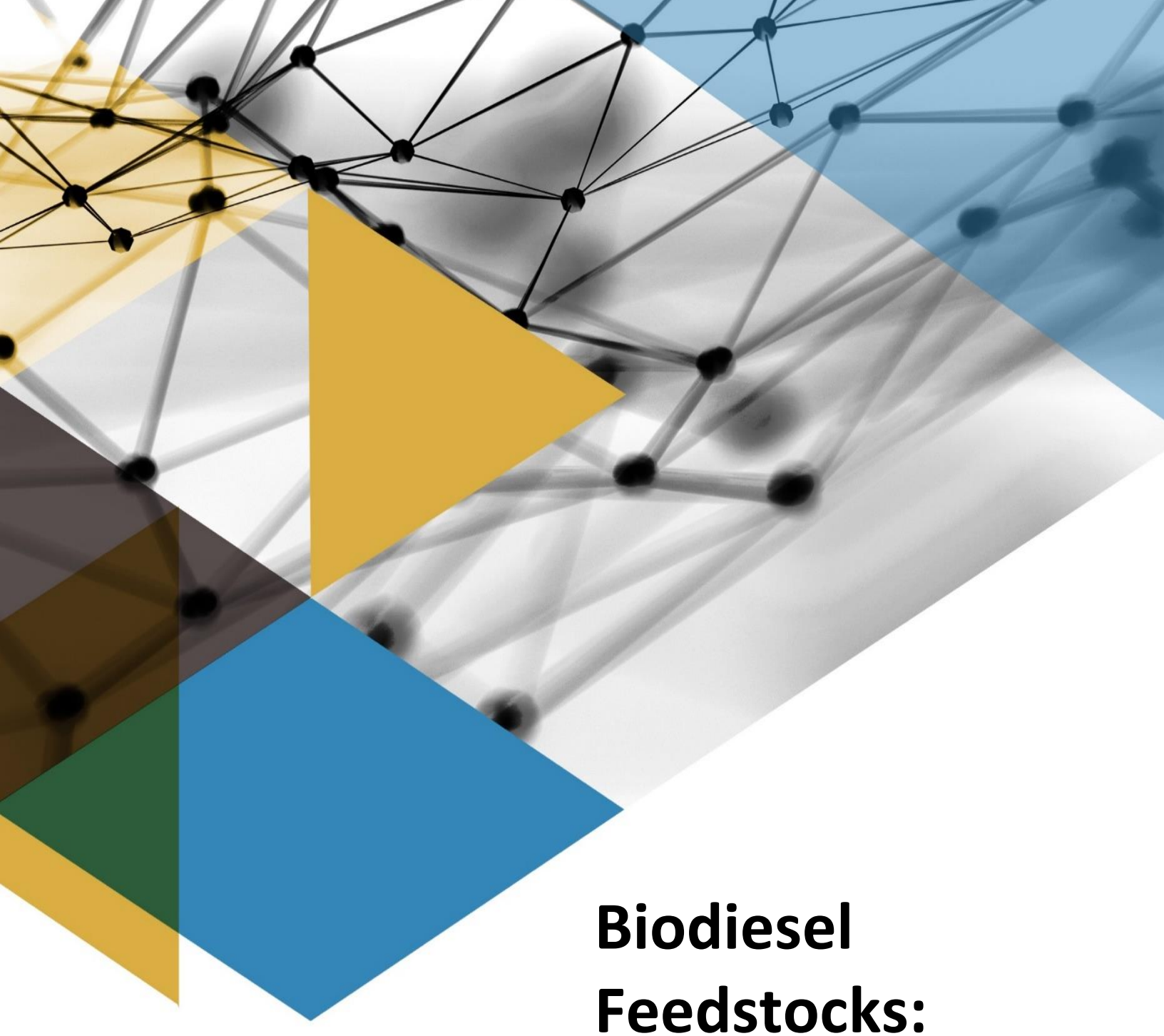

Biodiesel Feedstocks:

Technologies, Synthesis, Efficiency and Policies

February 2024

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Report Code: EGY171B

Additional segmentations and data sets are available upon request. Email custom@bccresearch.com.

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Chapter 1

Introduction

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Chapter 1: Introduction

This report, "Biodiesel Feedstocks: Technologies, Synthesis, Efficiency, and Policies," discusses the growing solid biodiesel market and segment within the broader biofuels market. The report outlines how the market is evolving and provides an overview of historical developments and their impact at a global level. The report also discusses the future directions of the market and new technologies that are changing the market's dynamics. The report further provides an in-depth financial analysis of the market and a detailed view of growth opportunities in specific geographies and market sub-segments.

Additionally, the report discusses various drivers and challenges that the market faces and analyzes trends that are having an impact. This report further discusses stakeholders in the market, including business overviews, strengths, weaknesses, and key strategies.

Study Goals and Objectives

This BCC Research report aims to provide recent market scenarios and developments in the global biodiesel market. The study aims to give readers an in-depth analysis of changes in policies, technologies, and feedstocks in the biodiesel industry and the recent trends in the industry and the market. The report will also discuss the opportunities available to stakeholders and participants in the market.

Reasons for Doing This Study

Lately, biodiesels like renewable diesel, sustainable aviation fuel, and used cooking oil or UCO-based biodiesel are gaining attention. For instance, in 2023, in the U.S., renewable diesel production capacity exceeded biodiesel production capacity. According to the United States Department of Agriculture (USDA), exports of UCO-based biodiesel increased in China in the first half of 2023. This was due to solid demand from the EU. Above all, the UCO-based biodiesel and renewable diesel satisfy the EU's and the U.S.'s biodiesel feedstocks policies' goals.

Also, developed nations like the U.S. and Europe will see more use of renewable diesel, while emerging economies like India, China, and Brazil will see more use of biodiesel. The U.S.'s new renewable fuel program and the EU's Renewable Energy Directive II (RED II) are the main drivers of the biodiesel market. Demand for low-carbon-based transportation fuel and blending rate targets drive the market in emerging economies.

Scope of Report

This BCC Research report will explore the developments in the biodiesel market. The report will detail the biodiesel market by feedstock type: vegetable oils (rapeseed, palm oil, soybean oil, sunflower oil, corn oil, and used cooking oil) and animal fats. The report will also detail the market based on applications and regions. Each segment evaluation includes market size estimates for biodiesel and a

forecast for growth to 2028. The report concludes with a competitive landscape of the global biodiesel market and company profiles of the various players in the area.

What's New in This Update?

This updated report will present the new feedstocks, i.e., used cooking oil (UCO), available in the market and its growth potential. The report also gives information on renewable diesel, a new type of biodiesel produced, and its potential market. In addition, the report is updated with new chapters, namely, the emerging technologies in biodiesel feedstocks, such as algae, and the other latest developments, such as the ESG perspective of biodiesel and patent analysis. The report is updated with the latest companies in the biodiesel market.

Research Methodology

The methodology of this report involves both primary and secondary research. Secondary sources include annual reports, company investor presentations, press releases, white papers, articles from recognized websites, etc. Primary data were obtained through LinkedIn, email, and telephone.

Based on the above secondary sources and primary data, the market size of this report was estimated. BCC calculated biodiesel revenue based on the revenue from the top 10 biodiesel manufacturers. Since renewable diesel constitutes a comparatively minimal percentage of the market, BCC calculated the market size of renewable diesel along with biodiesel. BCC selected the leading companies based on the size of the biodiesel capacity (nameplate capacity). The global demand for biodiesel in volume was calculated by combining each region/country's biodiesel consumption.

Market demand estimates are made for 2023 and projected over five years, with 2022 as the base year. Projections are made in terms of constant U.S. dollars. Growth is presented in terms of a compound annual growth rate (CAGR).

Information Sources

The research study involves the extensive usage of secondary sources, directories, and databases (including the Organisation for Economic Co-operation and Development (OECD), The Food and Agriculture Organization of the United Nations (FAO), The U.S. Department of Energy's (DOE) Energy Information Administration (EIA), The U.S. Department of Agriculture (USDA), The USDA's Foreign Agricultural Service, The Renewable Energy Policy Network for the 21st Century (REN21), The European Biodiesel Board, The European Renewable Ethanol Association (ePure), The National Renewable Energy Laboratory (NREL), European Biofuels Technology Platform, Biodiesel Magazine, Ethanol Producer Magazine, and Biofuels Review) to identify and collect information useful for this market-oriented and commercial study of the global biofuels market.

Geographic Breakdown

In this report, the geographic regions considered for market analysis include:

- North America.
    - United States.
    - Canada.
    - Mexico.

- EMEA (Europe, the Middle East and Africa).
    - Germany.
    - France.
    - Sweden.
    - Italy.
    - Spain.
    - Polan.
    - Rest of Europe.
    - The Middle East.
    - Africa.

- Asia-Pacific.
    - Indonesia.
    - Thailand.
    - Malaysia.
    - China.
    - India.
    - Rest of Asia-Pacific.

- South America.
    - Brazil.
    - Cambodia.
    - Argentina.
    - Rest of South America.

Market Segmentation

[1]*Other applications of biodiesel include heating, electricity, and industrial purposes.*

Chapter 2

Summary and Highlights

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Chapter 2: Summary and Highlights

Market Outlook

The biodiesel market is seen to grow steadily, mainly driven by stringent environmental policies and increasing demand for alternative fuel for the transport sector. With the scope to offer low-intensive carbon fuels, biodiesel is emerging as a viable option for the transport sector.

Market Size	The global market for biodiesel is expected to be valued at $43.1 billion in 2023 and reach $51.6 billion by the end of 2028.
CAGR	The global biodiesel market is expected to witness a compound annual growth rate (CAGR) of 3.7% from 2023 to 2028.
High Growth Region	Europe accounted for 34% of the global market in 2022, followed by Asia-Pacific.
Market Drivers/ Opportunities	• Environmental regulations and policies. • Energy security. • Growing demand for UCO-based biodiesel.
Restraints/ Challenges	• Feedstock availability. • Increasing feedstock cost.
ESG Development	Neste is included in the STOXX Global ESG Leaders index, which has 300 leading companies in ESG practices.
Emerging Technologies	• Renewable diesel from residue and waste. • Algae-based feedstock.
Leading Vendors	• Neste • Chevron Renewable Energy Group • ADM

Market Summary

Regarding market demand, Europe is the largest biodiesel market. However, Asia-Pacific (APAC) is expected to see the strongest growth rate in the coming years, followed by South America. North America is the second-largest market. Demand for biodiesel in EMEA is negligible and is not expected to grow significantly in the coming years. EMEA's meager market share and growth are mainly due to its large production and usage of fossil fuels, including fossil diesel.

Classification by feedstock shows that rapeseed oil is currently the major market segment. Rapeseed oil is followed by soybean oil and palm oil. However, usage of these feedstocks widely varies by region. For example, rapeseed is the most common feedstock in Europe, while soybean oil is the most common feedstock in the Americas (both North America and South America). APAC continues to use palm oil heavily for biodiesel production. In terms of growth, used cooking oils and animal fats are expected to grow gradually. Due to its low price and easy availability, the used cooking oil segment is expected to grow most robustly in the coming years in the developed world.

Transport is the significant segment by application. Transport's share was estimated at 82.8% in 2022 and is expected to increase to 85.0% by the end of 2028. Automotive fuel is expected to be the major segment within transport, followed by aviation fuel. Power generation also has a demand for biodiesel.

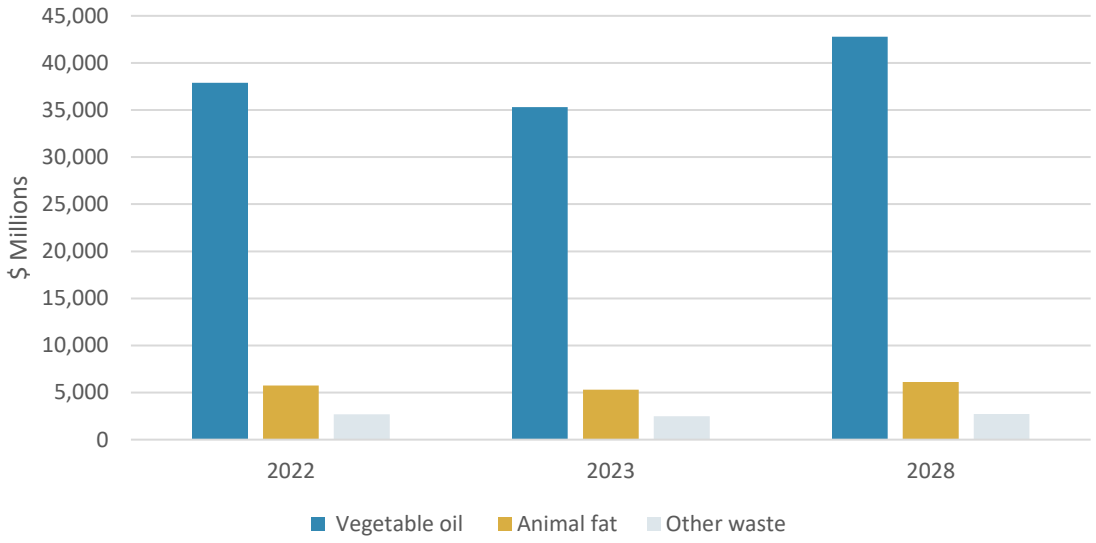
Summary Table:
Global Market for Biodiesel, by Feedstock Type, Through 2028
($ Millions)

Feedstock Type	2022	2023	2028	CAGR% 2023-2028
Vegetable oil	37,888.1	35,308.5	42,788.2	3.9
Animal fat	5,743.4	5,304.9	6,138.3	3.0
Other waste	2,707.0	2,481.4	2,718.6	1.8
Total*	46,338.5	43,094.8	51,645.1	3.7

*Note: Totals in this report's tables and figures might not match exactly because of rounding.

Source: BCC Research

Summary Figure:
Global Market for Biodiesel, by Feedstock Type, 2022-2028
($ Millions)



Source: BCC Research

Chapter 3

Market Overview

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Chapter 3: Market Overview

Introduction

Biodiesel is a form of biofuel made from vegetable oil, animal fats, or used cooking oil and consists of long-chain alkyl (methyl, ethyl, or propyl) esters. Some of the common forms of biofuels are ethanol, biodiesel, green diesel (HVO biodiesel), and biogas. All forms of biofuel are considered renewable energy sources, as they are made from organic matter or waste. Biofuels play an essential role in reducing carbon dioxide emissions and, hence, are gaining increasing popularity.

Biofuels are one of the largest sources of renewable energy in use currently. In the transportation sector, they are blended with existing fuels such as gasoline and diesel. Ethanol, FAME biodiesel, and green biodiesel are the main biofuels used in transportation. Ethanol is most commonly used in a blended form (with petroleum). Biodiesel is the second-most widely used biofuel. The use of green diesel is growing but limited compared to the other two biofuel types.

Biodiesel is also called FAME (fatty acid methyl ester) biodiesel. Pure biodiesel is also called B100 (100% pure biodiesel). However, pure biodiesel is not used in current diesel engines, as most current engines may not be suitable for pure biodiesel. Biodiesel is often used in blends such as B5, B8, and B20. The key advantage of biodiesel is that it raises the fuel's cetane number and improves fuel lubricity. A higher cetane number means the engine is easier to start and reduces ignition delay. Improved lubricity reduces friction within the moving parts, avoiding additional wear and increasing the life of various engine parts.

A complete evaluation of emission results and potential health effects by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act Section 211(b) offers the following benefits of biodiesel over fossil diesel:

- The ozone (smog) forming potential of biodiesel hydrocarbons is less than diesel fuel. The ozone-forming potential of B100 is 50% less than that of fossil diesel, while it is 10% less for B20.
- Sulfur emissions are eliminated with pure biodiesel (B100), while they are expected to be reduced by 20% with B20.
- Carbon monoxide (CO) is expected to be reduced by as much as 48% for B100 and 12% for B20.
- Particulate matter emissions are shown to be 47% lower when B100 is used, while they are 12% lower when B20 is used.
- The exhaust emissions of total hydrocarbons (a contributing factor in the localized formation of smog and ozone) are, on average, 67% lower for B100 and 20% lower for B20.

- B100 is estimated to decrease polycyclic aromatic hydrocarbons (PAH) and nitrated polycyclic aromatic hydrocarbons (nPAH) by as much as 80% to 90%, while B20 is expected to reduce the same by 13% to 50%. PAH have been identified as potential cancer-causing compounds.

The only negative of biodiesel seems to be increased nitrogen oxide (NOx) emission. Tests conducted by multiple agencies have shown that NOx emissions from using biodiesel can increase by 2-10% compared to fossil diesel.

Biodiesel Generations

First-Generation Biodiesel

First-generation biodiesel is made from edible vegetable oil like palm, soybean, sunflower, etc. First-generation biodiesels dominate the market today and are produced on an industrial scale worldwide. The advantages of first-generation biodiesel are low greenhouse gas emissions and low-cost conversion technology. However, the main disadvantage is that it causes food insecurity and direct and indirect land use issues. Also, the first-generation feedstock alone could not meet the growing demand for biodiesel.

Second-Generation Biodiesel

The second-generation biodiesel is made of non-edible oils like jatropha oil, castor oil, jojoba oil, agricultural waste, and used cooking oil or waste cooking oil. The advantages of second-generation feedstocks are that they use waste as feedstock and non-edible oil crops can be grown on non-agricultural lands. The main disadvantage of these feedstocks is that they incur high pretreatment costs and advanced technology to produce biodiesel.

Among these feedstocks, used cooking oil is gaining attention and entering into industrial-scale production in many countries. The UCO-based biodiesel is experiencing strong growth and is expected to become a significant market in the coming years.

Third-Generation Biodiesel

Third-generation biofuels offer a further improvement over second-generation biofuels, which are produced from crops specially engineered and grown for biofuel and other such uses. One example of feedstock for third-generation biofuel is algae. Algae are cultured to provide a low-cost, high-energy product and an entirely renewable feedstock. It is estimated that alga has the potential to produce more energy per acre than conventional crops. Another advantage is that algae can be grown in land and water unsuitable for food production, significantly reducing the strain on already depleted land and water sources. Algae can be used to develop a wide range of biofuels such as diesel, petrol, and jet fuel; hence, it has a market opportunity.

Types of Feedstocks

Vegetable Oil-Based Feedstocks

Biodiesel can be produced from a wide range of feedstocks. The feedstocks used can be categorized into vegetable oil and animal fats. The main types of vegetable oil feedstock that are used for biodiesel production are:

- Soybean Oil.
- Canola/Rapeseed Oil.
- Palm Oil.
- Sunflower Oil.
- Used/Waste Cooking Oil.
- Corn Oil.

Soybean Oil

Soybean oil is one of the most commonly used feedstocks for biodiesel production. Soybean oil is widely used, mainly in North America and South America, for biodiesel production. Brazil and the U.S. are the world's most significant producers of soybean crops, producing approximately 36.2% and 33.72% in 2021-2022, respectively.

Of its total soybean oil production, the U.S. is the largest producer with a 20% share, followed by Brazil with 16%. Of the total soybean oil produced, the U.S. used 39.7% for biodiesel production in 2021-2022.

North America, and especially the U.S., is a significant consumer of biodiesel, and countries in South America, such as Brazil, Argentina, and Colombia, are experiencing strong demand for biodiesel. This makes soybean oil a highly sought-after product for biodiesel production. As such, soybean oil as a feedstock is expected to see modest growth in the coming years.

One key challenge for biodiesel producers in the U.S. is that soybean oil is also used as cooking oil. Around 40% of the U.S. raw soybeans are exported, and the rest are processed or crushed at soybean processing plants. This soybean crush yields about 80% soybean meal and 20% soybean oil; this 20% yield goes into cooking and biodiesel production. Although the U.S. has a huge soybean output, using soybean oil for biodiesel must compete with cooking oil; this negatively impacts the market. Compared to this, no-food vegetable oils are mainly used for biodiesel and similar purposes and may have better growth prospects in the biodiesel production space.

Canola/Rapeseed Oil

For this report, canola and rapeseed are used interchangeably. Canola oil is a vegetable oil derived from a variety of rapeseed that is low in erucic acid, as opposed to colza oil. In some countries, rapeseed oil refers to oil for industrial use, whereas canola oil refers to edible cooking oil. In most European countries, the term rapeseed is used for both canola and rapeseed. Europe rarely uses the term canola. In the U.S., the term canola is preferred.

In Europe, canola/rapeseed oil is the primary feedstock used for biodiesel production. Globally, rapeseed/canola is the largest feedstock for biodiesel production. In 2021-2022, Europe produced

around 17.2 million tons of rapeseed oil. The harvest area is expected to increase by 7% in 2022-2023. Germany and France are the EU's largest producers of rapeseed.

One key advantage of canola oil is its low cloud point, so it gels at lower temperatures than many other feedstocks. Research published by the University of Idaho showed that canola biodiesel had a cloud point of 1°C and a pour point of -9°C. Cloud point is defined as the temperature of the fuel at which tiny, solid crystals can be observed as the fuel cools, which clog vehicle filters. The pour point refers to the lowest temperature at which the fuel is moved when the container is tipped. It is important to note that from the cloud point and pour point angles, canola only has a slight advantage over soybean oil. However, it has a huge advantage over biodiesel from animal fat, as biodiesel has much higher clouds and pour points than canola oil.

Another advantage of rapeseed/canola oil over soybean oil is its high yield. Canola/rapeseed contains about 40% oil, around double the oil yield, making it possible to obtain more biodiesel from the same amount of material.

Palm Oil

Palm oil is another prevalent source of biofuel production. It is mainly used in APAC due to the presence of large palm oil-producing nations such as Indonesia, Malaysia, and Thailand. As of November 2023, Indonesia produced more than 50% of the world's palm oil production, followed by Malaysia at 24%. These countries have a huge palm oil export business. But several factors—including the European Union's (EU) recently proposed ban on palm oil in biofuel, with a plan to eliminate it in transport fuels by 2030—have led both countries to focus on increasing domestic palm oil consumption, including increasing the biofuel blending mandate, which will boost the domestic consumption of palm oil for biodiesel production. In line with this, the two countries are also expected to become the strongest growth drivers of the biodiesel market in the coming years. Although their market sizes (dollar value) are tiny compared to the U.S. and some other Western European countries, strong growth makes them key opportunity markets. In 2023, the Indonesian government increased its biodiesel blending rate to 35% (B35), the highest among all the nations in the world. This is expected to increase Indonesia's consumption by 25%.

While the key contention behind the proposed palm oil ban in Europe is large-scale deforestation in Asian palm oil-producing countries, palm oil is undoubtedly one of the most efficient sources of biodiesel feedstock. For example, when compared to rapeseed oil, palm oil produces 4-10 times more oil per unit of land and requires less fertilizer and pesticides. Net palm oil production is more efficient than rapeseed oil. Since rapeseed yields more oil than soybean crops, palm oil is also considered more efficient.

The proposed ban by the EU is not expected to have much impact on palm oil consumption and usage in APAC and is expected to remain the major feedstock for biodiesel production in the coming years.

Sunflower Oil

While sunflower oil is also used for biodiesel production in some countries, it is not expected to grow significantly in the coming years. In the U.S., sunflower oil is priced at a premium compared to soybean oil and canola/rapeseed oil; hence, its use as a feedstock for biodiesel production is not expected to see major growth. In many countries in APAC (such as India), sunflower oil is widely and very commonly used as a cooking oil, so it is not expected to see major traction in the biodiesel production space.

However, the key benefit of sunflower is that sunflower seeds have a high oil content (often more than 40%), and average yields can produce 600 pounds of oil per acre, considerably more than soybeans.

Used/Waste Cooking Oil (Vegetable Oil)

Waste cooking oil or used cooking oil (UCO) as a source for biodiesel production is experiencing strong growth. The main advantages are easy availability, low price, and higher sustainable value (as it is already a waste product and hence involves no deforestation, etc.). In the case of waste cooking oil, the oil that should be disposed of is de-odored and purified using the appropriate solvents. This purified oil is used for biodiesel production.

Further, the fact that UCO is considered a problematic waste that is difficult to dispose of supports its use as biodiesel feedstock. UCO's inadequate disposal can harm the environment and hinder sewage treatment. It is highly toxic for natural ecosystems and, at the domestic level, can block pipes and cause odors.

The key challenge of UCO lies in collection and transportation costs. The collection is considered difficult, as collecting it from households remains challenging, and how individuals (house owners) react is yet to be seen. However, overall metrics indicate UCO could be the most efficient and inexpensive biodiesel feedstock (when environmental impacts such as deforestation are also considered), and its usage is witnessing very strong growth. UCO is expected to see strong growth in the EU and North America. Use and adoption in emerging regions are expected to be very low, mainly due to the unavailability of technology and limited knowledge of UCO's potential as biodiesel feedstock.

Corn Oil

Corn oil is another feedstock that is used for the production of biodiesel. However, the use of corn oil as a biodiesel feedstock is very low compared to soybean, canola, and palm oil. Corn oil is not considered a viable biodiesel feedstock because of its high edible value and relatively high price. However, some industrial corn processing co-products, such as corn germ and dried distillers' grains with solubles (DDGS), can produce biodiesel after the extraction of corn distillers' oil (CDO). Another sub-segment within the corn oil space is non-food-grade corn oil, which has witnessed significant growth in the past few years for biodiesel production.

The primary use of corn oil in the U.S. is for ethanol production. The corn ethanol boom of 2005-2010 saw a massive increase in the production of distillers' grains, which also helped increase the use of corn oil for biodiesel production. The strong growth of corn oil as feedstock for biodiesel production continued from 2010-2013. Corn still represents the largest feedstock used to produce ethanol. In 2022, according to USDA, around 294,900 million pounds of corn was used for ethanol production. About 38% of total corn consumption is used for ethanol production.

However, various factors, such as better availability of other feedstocks (such as soybean oil, canola oil, and palm oil), high feedstocks' yield, and the lower price of certain feedstocks, led to low traction of corn oil for biodiesel production.

The table below shows the approximate (and average) oil yield of some common crops per year in kilograms (kg) per hectare (ha).

Table 1
Approximate Oil Yield per Year of Common Crops, 2022
(kg/ha)

Crop	Oil Yield (kg/ha)
Palm	6,660–11,000
Coconut	2,260
Jatropha	540–3,200
Canola	555–1,554
Sunflower	544–1,125
Soybean	224–463
Algae	3,190–10,000

Source: BCC Research

Animal Fat-Based Biodiesel

The use of animal fat for biodiesel production, which is currently experiencing growth, is expected to become a primary feedstock in the long run. Animal fat includes beef tallow, pork lard, and chicken fat.

Animal fats are highly saturated, so the fat solidifies at a relatively high temperature. Therefore, biodiesel made from animal fat has a high cloud point. For example, biodiesel from beef tallow and pork lard has a cloud point of 12°C to 15°C.

Another key advantage of animal fat-based biodiesel is its high cetane number. The saturated fatty acids in animal fats are the source of this high cetane number; values over 60 are expected. In comparison, soybean oil-based biodiesel usually has a cetane number of about 48 to 52, while petroleum-based diesel fuel is generally between 40 and 44. This high cetane number also helps to lower NOx emissions. While biodiesel reduces all other greenhouse gas emissions compared to petroleum diesel, NOx emission increases. However, studies have shown that a high cetane number of animal fat-based biodiesel has no increase in NOx emission compared to petroleum-based biodiesel, indicating that animal-based biodiesel is better at reducing overall GHG emissions.

Renewable Diesel

Another biomass-based diesel that complies with the Renewable Fuel Standard (RFS) is renewable diesel. The feedstock for renewable diesel is also the same as biodiesel. However, there is a difference between biodiesel and renewable diesel. Biodiesel is also called FAME (fatty acid methyl ester) biodiesel. The biodiesel is produced via a transesterification process. However, renewable diesel is also known as hydrogenated vegetable oil (HVO). HVO uses many techniques, but the most common method is hydrotreating.

Renewable diesel is different from biodiesel. The processing method differs while the same feedstock is used in both fuels. The feedstock requirement for renewable diesel is more than that of FAME biodiesel.

Approximately eight pounds of feedstock produces one gallon of renewable diesel. The biodiesel production process is simple, whereas the renewable diesel production process requires an oil refinery-like setup and is costly. Renewable diesel is a drop-in fuel. That is, it can be used 100% in the vehicles as it is without any blending. Biodiesel is always blended with fossil fuel to be used in vehicles.

Neste is the largest producer of renewable biodiesel in the world. In the U.S., 11 renewable diesel plants have the capacity to produce 1,750 million gallons per year.

Renewable fuel has the following benefits compared to biodiesel:

- Renewable fuel is a drop-in fuel used directly in existing diesel engines.
- According to the California Low Carbon Fuel Standard, renewable diesel can reduce carbon intensities by 65%.
- Renewable diesel is flexible. It can be used from any feedstock, completely replace fossil diesel, and can be made in plants that also produce Sustainable Aviation Fuel (SAF).

Chapter 4

Market Dynamics

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Chapter 4: Market Dynamics

Market Trends

Growing Demand for Low-Carbon Intensive Feedstock

In recent years, the perspective on sustainability in renewable fuels has changed. Earlier, biodiesel produced from vegetable oil was considered sustainable and environmentally friendly. Still, the term sustainability is being scrutinized because of stringent policies and the world's united commitment to move towards a zero-carbon future. In this regard, countries are moving towards low-carbon intensive biodiesel feedstock that does not compete with food crops like used cooking oil, animal fat waste, and other waste materials. Among these, cooking oil is gaining more attention. The UCO industry comprises collecting, recycling, and repurposing the UCO into biodiesel. UCO has become a typical solution to waste management. The demand for UCO-based biodiesel is increasing, especially in the U.S. and Europe. The instant increase in demand for UCO is driven primarily by government mandates and incentives in these regions.

Figure 1
Biodiesel Feedstocks: Market Dynamics

Source: BCC Research

Table 2
UCO Based Biodiesel Volume in the U.S., 2021-2022
(1,000 Tons)

Category	2021	2022	% Change
Production	1,349.9	1,359.3	0.7
Consumption	1,535.2	2,273.1	48.1
Imports	129.5	395.6	205.5
Exports	761.1	489.9	-35.6

Source: North America Renders Association (NARA)

In the U.S., since the domestic production of UCO is already used, the country depends greatly on imports. Asia is the largest exporter of UCO. From January to August 2023, China exported 384,000 metric tons of UCO to the U.S.—around 65% of U.S. imports. According to Chinese customs data, in the last 12 months, U.S. imports have created $390 million worth of business for China.

According to BCC Research, the EU had around 1 to 1.2 million tons of used cooking oil in 2022. According to the USDA report, UCO was Europe's second most important feedstock in 2022, accounting for 29% of the total feedstock. Like the U.S., Europe imports large parts of UCO from Asian countries. According to Spain's Ministry of Energy Transition, Europe imported 41.73% of UCO from China in 2022. Compared to 2021, the imports in 2022 were up by 24%. Other countries that supply UCO to Europe are Malaysia, Indonesia, Saudi Arabia, and Russia. Together, these countries account for 82% of UCO imports. The European countries that produced UCO-based biodiesel were Germany, Spain, Poland, Netherlands, Italy, Spain, Finland, Portugal, France and Austria. These countries used 96% of the UCO. Other countries that produce UCO in small quantities are Hungary, the Czech Republic, Ireland, Slovakia, and Bulgaria.

The global potential of UCO will increase with the increase in vegetable oil consumption. According to USDA, global vegetable oil consumption in 2021/2022 was 202.54 million metric tons. About 57% of the oil was used for human consumption and 16% for biodiesel production. Of the total UCO generated, only 10% to 20% of the UCO has been collected and treated. The remaining 80% to 90% of the oil remains idle or wasted. This means a vast pool of UCOs is yet to be collected for biodiesel production. A proper collection infrastructure will increase the availability of UCO for biodiesel production. In addition, the per capita oil consumption will increase as people's purchasing power increases in developing countries.

Growing Demand for Renewable Diesel

As explained earlier in the Market Overview chapter, renewable diesel and biodiesel are alternatives to fossil-based fuels derived from renewable sources, but their production process, chemical composition, and properties differ. For this reason, renewable diesel is gaining more attention. According to the International Energy Agency (IEA), the demand for renewable diesel will increase by 40% from 2021 to 2022. Seventy one percent of these renewable diesels were produced from waste and residue. For the first time in the U.S. in January 2023, renewable diesel production surpassed biodiesel production. According to the Energy Information Administration (EIA), between January 2022 and January 2023, renewable diesel production increased by 71%. Since 2021, renewable diesel production has tripled in the U.S., and biodiesel production has declined by 13%.

In Europe, Neste is the largest producer of renewable diesel, with a current (2022) capacity of 1.4 million tons per year. The company is expanding its capacity with an additional 1.3 million tons annually. The new facility will start operating in 2026, and Neste will have 2.7 million tons of renewable diesel capacity per year. Other companies that are investing in renewable diesel are UPM (640 million liters) and Shell (1 billion liters).

Table 3
Largest Hydrogenation-Derived Renewable Diesel (HDRD) Producers in the EU, 2022
(Million Liters)

Company	Annual Capacity (Million Liters)
Neste	215
UPM	115
Eni	325
Preem	220
St1	250
Total Energies	640
Galp	35

Source: BCC Research (gathered and complied from USDA)

Global Growing Biodiesel Production

In biofuel consumption, ethanol fuel consumption is found to be relatively flat, while the demand for biodiesel has increased. Biodiesel will be the major contributor to biofuel growth in the future. This is due to high blending requirements, decarbonization initiatives, policies, and incentives.

- Under the Renewable Fuel Standards (RFS) program, the U.S. has increased its biomass-based diesel volume requirements for blending from 2.76 billion gallons in 2022 to 3.35 billion in 2025.
- In Europe, the percentage of biofuel in biodiesel for some of the major countries are Austria (3.4%), Belgium (6.5%), Bulgaria (6%), France (8.6%), Greece (7%), Latvia (6.5%), Lithuania (6.2%), and Slovakia (6.9).
- The Brazilian government has increased the biodiesel blending rate from 10% in 2022 to 12% in 2023, 13% in 2024, 14% in 2025 and 15% in 2026.
- Indonesia, which already has the world's largest blending mandate, increased it from 30% in 2022 to 35% in 2023.

Market Drivers

Stringent Policies

According to the IEA, over 80 countries have biofuel policies, which are the main drivers of the biofuel market. In almost every country, the policies that support biofuel growth are becoming mandates for countries to attain or achieve biofuel targets. Low Carbon Fuel Standards were formed to reduce the carbon emission intensity of liquid fuels used in transportation compared to fossil fuels. The first low-carbon fuel standard (LCFS) was authorized in California. Today, LCFS spreads across the countries and has become one of the preferred policies worldwide. Some LCFS in other countries are the RenovaBio policy in Brazil and the Clean Fuel Program (CFP). In the U.S., these LCFS programs are expected to spread nationwide by the end of 2023. The LCFS extends beyond nations where countries are shifting their policy focus consumption targets to carbon emission reduction targets.

U.S. Biodiesel Policies and Incentives

- Infrastructure Tax Credit: Fueling stations that install 20% biodiesel through December 2022 will receive a tax credit of 30% of the cost.

- Biodiesel Educational Grants: Organizations providing knowledge or awareness of the benefits of biodiesel to public, private vehicle fleet operating entities, and other interested entities will receive a competitive grant from the government.

- Income Tax Credit: A taxpayer who uses 100% biodiesel in his own vehicle, business, or trade vehicles will receive an incentive of $1 per gallon of biodiesel. The incentive can be a credit against the taxpayer's income tax liability. This incentive, planned initially to expire by the end of 2022, is now extended until 2024.

- Biodiesel Mixture Excise Tax Credit: A blender that blends at least 0.1% of renewable diesel with fossil-based diesel will get a tax credit of $1 per gallon of pure biodiesel.

- Biodiesel Infrastructure Grants: Grants are provided for the installation, upgrading, and retrofitting of biodiesel blending equipment for a blending rate of greater than 5%.

- Fuel Use Requirements for Federal Vehicles: Federal vehicles that use 20% biodiesel will receive credits toward their annual requirements.

EU Biodiesel Policies and Incentives

The EU has broad policies, incentives, and mandates for biodiesel and renewable diesel production and consumption. Some of the key aspects of the policies are:

Renewable Energy Directive II (RED II): RED sets the target for renewable energy share in total EU energy consumption. RED II sets the targets to be achieved between 2021-2030. As per RED II, all the member states should have a share of 32% renewable energy by 2030, and the transport sector should have a share of 14%. This target was again revised in 2023 as RED III but is yet to be formally announced. According to USDA, RED III might increase the transport sector target to 29%.

The Fit for 55 Package: To reduce carbon emissions by 55% by 2030 compared to 1990 levels and to attain zero carbon by 2050, the European Commission released the Fit for 55 package. Under this package, the following regulations were adopted.

- New Carbon Emission Standard: In April 2023, the commission announced a target to attain 100% carbon emission reduction by 2035 from new passenger cars and new lightweight vehicles. As a result of this regulation, by 2035, internal combustion engine cars and vans will be banned. In April 2023, a revision of carbon emission standards for heavy-duty vehicles was announced. On average, carbon dioxide emissions will be reduced by 45% from 2030, 65% from 2035, and 90% from 2040 onwards compared to 2019.

- Energy Tax Revision: Under the package, the energy tax directive was revised.

Table 4
Proposed Taxation for Motor Fuels
(Euro/Gigajoule)

Types of Fuels	Start of Transitional Period (01/01/2023)	Final Rate After Completion of the Transitional Period 01/01/2033)
Sustainable food and feed crop biofuels	5.38	10.75
Sustainable biofuels	5.38	5.38
Low-carbon fuels	0.15	5.38
Advanced sustainable biofuels and biogas	0.15	0.15
Renewable fuels of non-biological origin	0.15	0.15

Source: USDA

- Sustainable Aviation Fuel (SAF): Under the package, the European Commission set targets for SAF to be used in aviation per the following table:

Table 5
Proposed Target for SAF Regulation
(% Share)

Date of Application	Minimum Share of SAF	Minimum Share of Synthetic Fuels
January 1, 2025	2%	N/A
January 1, 2030	5%	0.7%
January 1, 2035	20%	5%
January 1, 2040	32%	8%
January 1, 2045	38%	11%
January 1, 2050	63%	28%

Source: USDA

- Biodiesel Anti-dumping (AD) and Countervailing Duties (CV) Against the U.S. Biomass-Based Diesel: In 2009, the EU imposed AD and CV duties of up to $495 per ton on the import of biodiesel and renewable diesel from the U.S. This is extended and implementing Regulation (EU) 2021/1266 imposes an anti-dumping duty rate of up to $223 per ton for both fuels.

Environmental Policies and Incentives

Globally, the biofuel market is driven by policies. None of the biofuels—ethanol, renewable diesel, or the recent sustainable aviation fuels—have been acting as per market forces. Thus, the biofuel market is not competitive. The market has been driven either by sustainability requirements or environmental concerns. The significant increase in the production and consumption of renewable diesel and sustainable aviation fuel was mainly due to biofuel policies like Low Carbon Fuel Standards (LCFS) to reduce carbon emissions. For instance, in the U.S., according to the Department of Agriculture and Consumer Economics at the University of Illinois, total renewable diesel consumption accounted for 52% in 2022. Still, just one decade ago, consumption accounted for just 8%. One of the main reasons for this tremendous change was LCFS in California.

Energy Security

The Russia-Ukraine war has led to inflation worldwide and reduced global economic growth. This also led to an energy crisis in European nations and pressured them to reduce their dependence on fossil fuels. In contrast, the U.S. is self-sufficient in fuels and exports fuels to other countries. Indigenous biodiesel production reduces the need to import fossil fuels, leading to national and economic security.

Market Challenges

Feedstock Availability

In 2022, renewable diesel and sustainable aviation fuel production and consumption will increase. If this trend continues, then the industry might face a feedstock crisis. According to IEA, between 2022 and 2027, there will be a 56% increase in demand for vegetable oil, used cooking oil, and animal fat. These feedstocks are common for producing renewable diesel and sustainable aviation fuel, and demand for these fuels is high because they satisfy low carbon-intensive fuel needs. Government incentives and grants for these kinds of fuel are high in countries like the U.S. and the EU. All these reasons might produce a feedstock crunch. Alternatively, corn-based biofuels are under less stress, and their share in biofuel production might be nearly flat, predicts the IEA.

The UCO industry Is already facing many challenges like fluctuations in the supply of UCO. The collection of used cooking oil depends on people's feeding habits, and there are always fluctuations in its supply. The changes are expected to be higher among household sectors than professional ones like restaurants, canteens, and cafes. Also, there are no standard collection networks and infrastructures. There is no official collection point network to enable efficient UCO collection. Developing countries lack the infrastructure for collecting UCO from various collection points compared to developed countries.

Fluctuating Feedstock Prices

Biodiesel is still an expensive process. Nevertheless, vegetable oil dominated the biodiesel feedstock market. The major biodiesel feedstock in the EU, the world's top biodiesel producer, is still rapeseed. In the U.S. and Brazil, the major biodiesel feedstock is soybean. These food crops highly fluctuate due to weather, war, and global commodity markets impact production costs. The production cost is also affected by the feedstock type and the region. The feedstock is responsible for around 75% of the biodiesel cost.

Strong Growth of the HVO Market

A key challenge recently disrupting the biodiesel market is the stronger growth of HVO (green or renewable diesel) in certain regions. HVO is considered the next-generation biodiesel with advantages over biodiesel, so it is gaining stronger acceptance in certain geographical regions. Further, the HVO market is witnessing a wide range of new entrants and strong venture capital funding, helping the HVO market grow. Companies such as Neste Oyj, Renewable Energy Group, Honeywell, and Valero are some companies with a presence in the renewable diesel space. These companies are active and investing strongly to boost the renewable diesel market.

In the future, the renewable diesel segment is expected to present an even more significant challenge to the growth of the biodiesel market, even in emerging regions. Although renewable diesel is unlikely to completely wipe out biodiesel from the market, BCC Research expects renewable diesel market growth to result in the biodiesel segment losing market share in the overall biodiesel market.

Cases of Fraud Biodiesel and UCO

Another recent challenge is the emergence of fraudulent biodiesel and UCO cases, which are incidentally growing biodiesel feedstocks. Cases of fraudulent biodiesel and UCO are reported from around the world. Major biodiesel fraud activities happened in the EU, which the industry players think is destabilizing the market. The amount of biodiesel imported from China has raised doubt that the country's feedstock must be restricted feedstocks. In January and February 2023, China's exports to Europe were 80% more than what it imported in January and February 2022. The German Environment Ministry has observed fraudulent cases in its biodiesel import and is investigating the claims. EU-based waste biodiesel trade associations and Dutch and German policymakers have warned the industry to take immediate action.

These cases of fraudulent biodiesel, especially from UCO, are expected to increase scrutiny of new entrants in the biodiesel market. While this will not immediately slow down market growth, it may impact new and prospective entrants, eventually affecting the growth rate in the long term.

Market Opportunities

Growing Demand for Sustainable Aviation Fuels (SAF)

An increase in the consumption and production of SAF is a sign of investors' interest in SAF that aligns with the need for low-carbon intensive fuel. Increased investment in SAF is seen in Europe and North America. Tax incentives by the U.S. and Renewable Fuel EU target boost the growth of SAF. As of the 2022 Inflation Reduction Act, the U.S. offers an SAF credit of $1.25 per gallon of qualified SAF. The EU has set a mandatory SAF target for airlines. All airlines should mandatorily use 2% SAF by 2025. The percentage will gradually increase to 6% by 2030, 20% by 2035, and 70% by 2050.

The global airline trade association, The International Air Transport Association (IATA), and its member airlines passed a resolution in October 2021 to achieve zero carbon emissions by 2050. The association focuses on SAF, innovative technologies, and other efficiency measures. However, it is estimated that SAF could reduce 65% of carbon emissions. The aviation industry is also developing other technologies like electric power and hydrogen fuels to limit carbon emissions. However, both these technologies face significant technological and infrastructural challenges. SAF is the only near-term solution for the aviation industry to attain its zero-carbon target.

UCO Market Expansion and Potential

The U.S. and the EU have established a trade market with huge demand and significant imports of UCO. The UCO supply is limited, so the need for UCO will always exist. The global potential of UCO will increase with the increase in vegetable oil consumption. According to USDA, global vegetable oil consumption in 2021/2022 was 202.54 million metric tons. About 57% of the oil was used for human consumption and 16% for biodiesel production. Of the total UCO generated, only 10-20% of the UCO has been collected and treated. The remaining 80% to 90% of the oil remains idle or wasted. This means a vast pool of UCOs is yet to be collected for biodiesel production. A proper collection infrastructure will increase the availability of UCO for biodiesel production. In addition, the per capita oil consumption will increase as people's purchasing power increases in developing countries.

Chapter 5

Emerging Technologies and Developments

HCA Publishing

Chapter 5: Emerging Technologies and Developments

Introduction

The global biodiesel market is a dynamic market with frequent new developments. These developments include research to identify new feedstocks, new production methods, biodiesel with possibly higher blends, biodiesel with higher cetane numbers, and more. One key advancement in the global biodiesel market is the introduction of algae as a feedstock for biodiesel production. As the demand for biodiesel grows, more feedstock, especially non-food crops, is needed. Hence, research is going on in this field to increase the energy from the available resources by modifying energy crops genetically and finding new feedstocks like microorganisms, algae, and other non-food crops.

Advancement in Feedstock

Algae as Feedstock

In a journey toward zero carbon, countries are more selective about the feedstock used to produce biodiesel. In this regard, more research and advancement are going on in the field of biodiesel feedstock. Of late, UCO is gaining the attention of investors as a low-carbon intensive biodiesel feedstock. Another emerging biodiesel feedstock is algae.

Biodiesel obtained from algae is third-generation biodiesel. Algae has certain advantages over food crop oil-based biodiesel. For instance, algae can be grown on land and water unsuitable for food production; algae are not used for any edible purpose, so the food versus fuel debate is moot, and the production rate of algae is faster than other crops. One significant advantage of algae over food crops is the very high annual productivity and oil content of algae. For example, soybean can produce about 450 liters of oil per hectare, canola can produce 1,200 liters per hectare, and palm can produce 6,000 liters. Algae, meanwhile, can yield 90,000 liters per hectare.

The algae used for biodiesel production is aquatic unicellular green algae (Chlorophyceae). This type of algae is a photosynthetic eukaryote characterized by high growth rates and high population densities; under favorable conditions, it can double its biomass within 24 hours. Further, while algal biomass contains three main components — carbohydrates, proteins, and lipids/natural oils — the bulk of the natural oil is triacylglycerol, the right oil for producing biodiesel. This is another reason for the intense focus on algae for biodiesel production.

The table below shows some forms of algae used as feedstock for biodiesel production and their oil content. It is important to note that while some algae have low oil content, their growth rate doubles in 24 hours, which means enormous feedstock availability. Further, it is observed that during the peak growth phase, some microalgae can double every 3.5 hours.

Table 6
Microalgae and Oil Content
(% Dry Weight)

Microalgae	Oil Content
Botryococcus braunii	25-75
Chlorella sp.	28-32
Crypthecodinium cohnii	20
Cylindrotheca sp.	16-37
Nitzschia sp.	45-47
Phaeodactylum tricornutum	20-30
Schizochytrium sp.	50-77
Tetraselmis suecia	15-23

Source: BCC Research

Research on algae as a feedstock for biofuel is not new. The U.S. government extensively researched algae as a source of biofuels in the 1970s and 1980s. However, it was deemed too expensive for maintenance and production. The period from 2005-2010 saw more developments in the algae-as-biofuel-feedstock space. This period saw the emergence of companies such as Algenol, Sapphire Energy, and Solazyme that successfully raised funding from investment bodies. These companies focused on producing algae with high oil content and low production costs. However, despite spending on research and development for several years, these companies were unsuccessful, and algae as feedstock in biofuel production remained a low traction area.

In terms of cost, major oil price declines in 2008 and 2014 did not help biodiesel competitiveness. Technical issues also proved to be major sticking points. Most of these companies that started with algae as feedstock either went out of business or shifted their focus by 2012.

However, because of its potential as a feedstock, alga has again found importance and focus, and multiple research initiatives are ongoing to develop a cost-effective production process. For example, the U.S. Department of Defense's (DOE) Bioenergy Technologies Office's (BETO) Advanced Algal Systems program supports early-stage applied research and development to lower the costs of producing algal biodiesels and bioproducts. The program works with public and private partners to develop innovative technologies and conduct analyses to expand algal biomass resource potential in the U.S. sustainably.

One of the reasons that algae have again gained interest is that microalgae are said to be the most valuable product for carbon capture. And, like any other industry, the aviation industry is also under compulsion to reduce the greenhouse gases it emits during its operation. The industry emits about 900 billion tons of CO_2 annually, which is about 3% of the total CO_2 emission globally. Also, as more people are expected to fly, the amount of CO_2 will increase. Sustainable Aviation Fuel (SAF) is the only option for airlines to decarbonize the aviation sector in the short term.

Currently, SAF fulfills less than 1% of the airline's biofuel demand. Hence, the aviation industry's main obstacle is the lack of biofuels to meet their vast demand. Algae with high productivity and yield have an

opportunity to meet the market and also reduce carbon emissions. The upcoming feedstock, like municipal solid waste and used cooking oil, has huge demand. According to EAI, using used cooking oil and animal fats exhausts nearly 100% of estimated supplies over the forecast period. Even when a broader range of wastes (such as palm oil mill effluent, tall oil, and other agribusiness waste oils) is considered, demand still swells to nearly 65% of the global supply. Thus, algae with high yield and productivity will have an opportunity to meet aviation fuel demands.

Though algae biofuel has not been able to commercialize for a more extended period, recent technological developments are keeping the algae biofuel ideas alive, including:

- Reliance Industries Limited has developed catalytic hydrothermal liquefication technology that uses wet algae biomass to produce biofuel. This technique excludes the energy-intensive drying process in the algae biofuel conversion process. This development has a significant impact on the operating cost.

- NREL is studying the feasibility of algae biorefinery conversion pathways. The NREL study focuses on achieving a modeled MFSP of $2.50/gallon gasoline equivalent (GGE) from algal biomass. Combined analysis from the 2014 and 2016 reports, which focus primarily on producing algal fuels (fermenting sugars to ethanol and upgrading lipids to diesel-range blend stocks), finds an MFSP of $5.90/GGE (2014$) when considering out-year targets.

- In February 2023, ExxonMobil withdrew from its algae-based biofuel research, which partnered with biofuel company Viridos. Viridos has gained investment from Chevron, United Airlines, and Breakthrough Energy Ventures. It raised $25 million in May 2023.

- SOCAR Türkiye R&D, an R&D center in Europe, has joined with Technip Energies, a French engineering and technology company, to produce 40,000 tons of jet fuel from algae. The partners have developed a new technology where algae are directly converted into low-temperature fuel.

- Recently, algae-based wastewater treatment has been gaining attraction. Some studies concentrate on removing pollutants and toxic material using algae, not biomass collection or biodiesel production. However, wastewater cultivation techniques for biofuel production have been developed recently. According to the U.S. Department of Energy, onshore production of PNG in the U.S. is 56 million barrels of wastewater daily. If algae could be cultured in this wastewater, it could result in 700,000 gallons of biodiesel daily, fulfilling a large part of transportation fuel needs.

Mixed Feedstock

So far, different vegetable oils have been processed separately to produce biodiesel. However, researchers are exploring methods to use mixed oils to produce biodiesel to overcome the disadvantages of using edible and non-edible oils in biodiesel production. Still, 70% of biodiesel is made from vegetable or edible oils. This is raising the food versus fuel debate and shortages of edible oil for the growing population increases vegetable oil prices. Non-edible oils are used in biodiesel products. Castor oil and jatropha are some of the non-edible oil crops used to produce biodiesel. But low yield,

high viscosity, poor oxidation, low volatility, etc. makes it less suitable for biodiesel production. Researchers have developed approaches to mixing different oils for biodiesel production to overcome the disadvantages of single-oil feedstocks. This method reduces the feedstock cost and availability, minimizing biodiesel's production cost. For instance, research studies found that mixing low-cost cooking oil with castor and other non-edible oils reduces feedstock costs. Properly combining oils gives comparatively high-quality biodiesel. Mixing high-viscosity feedstock with low-viscosity feedstock has produced biodiesel with properties comparable to ASTM standards.

FOG-based Biodiesel

FOGs are fats, oil, and greases disposed of down the drains in homes, restaurants, and food processing plants and are identified as yet another potential feedstock for biodiesel production. When not treated, the sewage or wastewater contains traces of fats, oil, and greases, leading to sewage pipe blockage and overflow. Blocking FOGs are removed and become landfills, polluting the environment.

These FOGs are treated and separated to produce biodiesel. In 2016, the EU funded BioDie2020, a project to produce biodiesel from FOG separated from wastewater. Argent Energy, a U.K.-based biodiesel company, coordinated the project. The project developed an innovative pretreatment method to treat the FOG and convert it into biodiesel in Argent Energy's pretreatment pilot plant. The produced biodiesel was also successfully used in the buses.

A South African entrepreneur developed the unique pretreatment method. The unique method of separating FOG from wastewater is patented by U.K.-based Eco Clarity founded by the South African entrepreneur Christopher Clemes. After continuous research and development, the company set up a plant at Argent Energy's site in 2023.

The company sets up Eco Clarity hubs at wastewater treatment plants where it collects FOG from wastewater before it enters the waste system. Later, the collected FOG is pretreated to produce biodiesel. The company's original 50-ton capacity plant is now doubled, and the company is also constructing new plants. The plants can commercially produce biodiesel from FOG, and the U.K. could build up to 40 such plants by 2026.

Chapter 6

Biodiesel Market by Feedstock Type

BCC Publishing

Chapter 6: Biodiesel Market by Feedstock Type

Introduction

Based on the type of feedstock, the global biodiesel market can be categorized into the following types:

- Vegetable oil.
- Animal fat.
- Other waste.

The primary biodiesel feedstock is vegetable oil (soybean oil, rapeseed oil, palm oil, used cooking oil). Vegetable oil has long been a biodiesel feedstock, and both first- and second-generation biodiesel were produced through vegetable oils. Further, the large-scale production of vegetable oil crops in several countries has led to the wide popularity of vegetable oil as a feedstock for biodiesel production. On the other hand, animal fat as feedstock has advantages, such as easy availability, no edible purpose, and low cost.

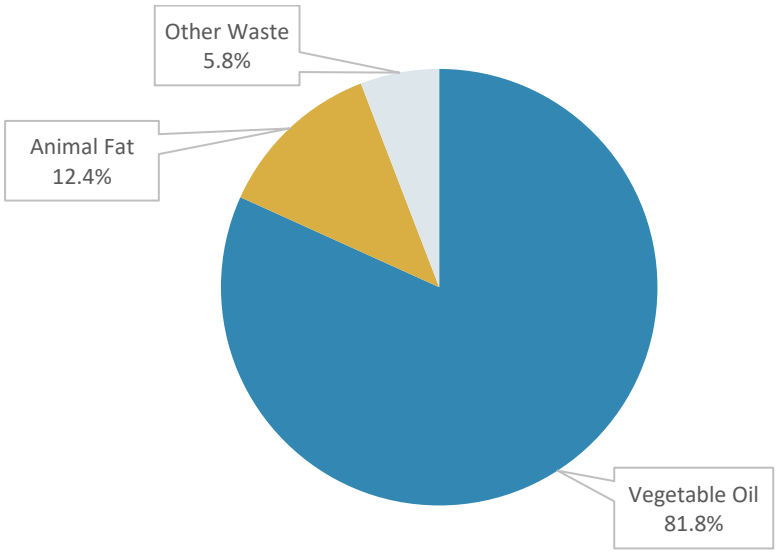
Vegetable oil constituted around 81.8% of biodiesel feedstock in 2022. For an extended period, vegetable oil has been dominating the market and will be dominating the market for the next five years. The new emerging feedstock is used cooking oil (UCO), which again, comes under vegetable oil. Animal fat has been used as a feedstock for a long time, and recently, it has been gaining attention for its low cost and mitigation of environmental pollution.

Table 7
Global Market for Biodiesel, by Feedstock Type, Through 2028
($ Millions)

Feedstock Type	2022	2023	2028	CAGR% 2023-2028
Vegetable oil	37,888.1	35,308.5	42,788.2	3.9
Animal fat	5,743.4	5,304.9	6,138.3	3.0
Other wastes	2,707.0	2,481.4	2,718.7	1.8
Total	46,338.5	43,094.8	51,645.1	3.7

Source: BCC Research

Figure 2
Global Market Shares of Biodiesel, by Feedstock Type, 2022
(%)



Source: BCC Research

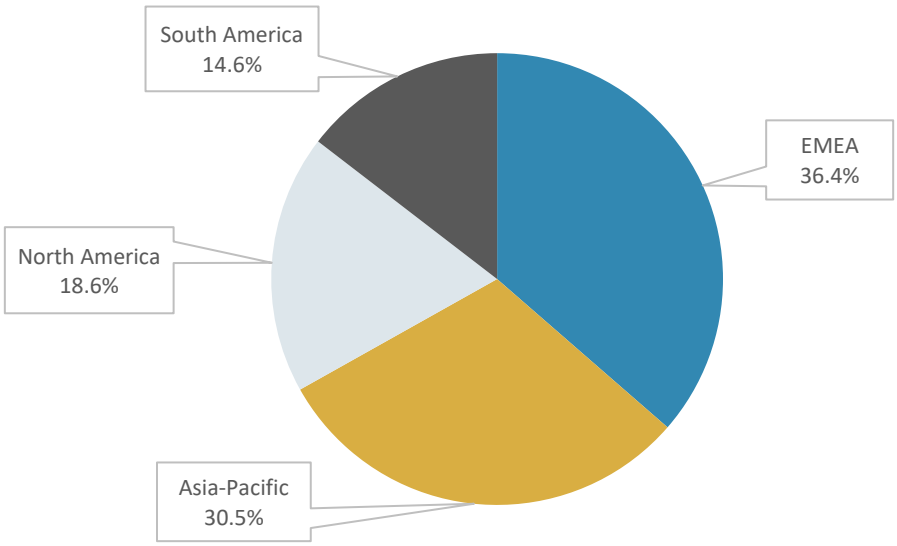
Vegetable Oil

Table 8
Global Market for Vegetable Oil-based Feedstocks, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023-2028
North America	7,034.5	6,590.3	8,223.5	4.5
EMEA	13,789.8	12,915.6	16,318.9	4.8
Asia-Pacific	11,544.3	10,708.0	12,568.4	3.3
South America	5,519.5	5,094.7	5,677.4	2.2
Total	37,888.1	35,308.5	42,788.2	3.9

Source: BCC Research

Figure 3
Global Market Shares of Vegetable Oil-based Feedstocks, by Region, 2022
(%)



Source: BCC Research

Animal Fat

Animal fat comprises poultry, tallow (beef), and white grease (pork). Waste animal fats from the meat processing industry, slaughterhouses, and other places are collected and treated to produce biodiesel.

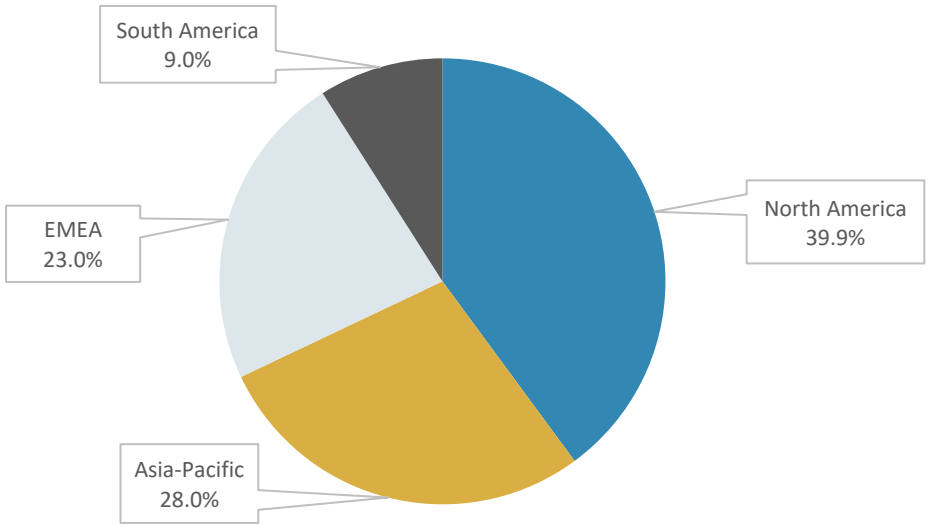
Animal fat is considered a desirable feedstock for biodiesel because of its low cost compared to vegetable oil. This is because the market for animal fat is much more limited than the market for vegetable oil, as much of the animal fat produced is not considered edible by humans. Apart from its use as feedstock for biodiesel production, animal fat is used as pet food, animal feed, and for industrial purposes such as soap making.

Table 9
Global Market for Animal Fat-based Feedstocks, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023-2028
North America	2,291.8	2,115.7	2,452.3	3.0
EMEA	1,322.3	1,226.5	1,473.0	3.7
South America	518.5	483.1	559.0	3.0
Asia-Pacific	1,610.8	1,479.6	1,654.0	2.3
Total	5,743.4	5,304.9	6,138.3	3.0

Source: BCC Research

Figure 4
Global Market Shares of Animal Fat-based Feedstocks, by Region, 2022
(%)



Source: BCC Research

Other Waste

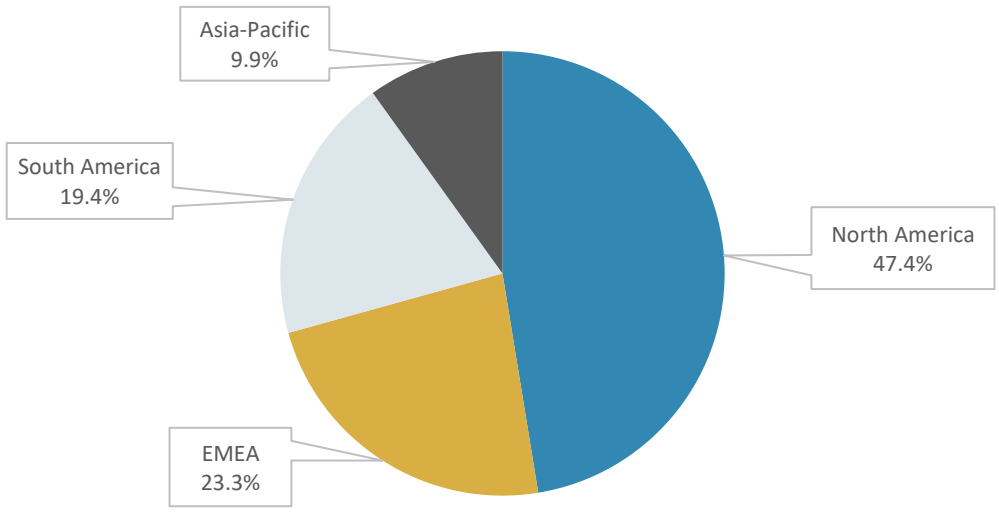
Other waste could include municipal solid waste, yard, and food waste. The RED II initiative in the EU has listed a few waste feedstocks that should be used in biofuel production: Biowaste from households, industrial waste, animal manure, and sewage sludge. The oily portion of waste can be used as feedstock for biodiesel production. Waste used for biodiesel production changes from country to country. The use of these waste-based feedstocks face many challenges due to technological restraints, mainly in pretreatment. Pretreating the waste is costly, and consistent collection and supply of this waste logistically is challenging.

Table 10
Global Market for Other Waste-based Feedstocks, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023-2028
North America	1,283.8	1,182.8	1,357.5	2.8
EMEA	629.7	574.9	606.0	1.1
South America	525.0	480.0	498.4	0.8
Asia-Pacific	268.5	243.7	256.8	1.1
Total	2,707.0	2,481.4	2,718.7	1.8

Source: BCC Research

Figure 5
Global Market Shares of Other Waste-based Feedstocks, by Region, 2022
(%)



Source: BCC Research

Chapter 7

Biodiesel Market by Application

BCC Publishing

Chapter 7: Biodiesel Market by Application

Introduction

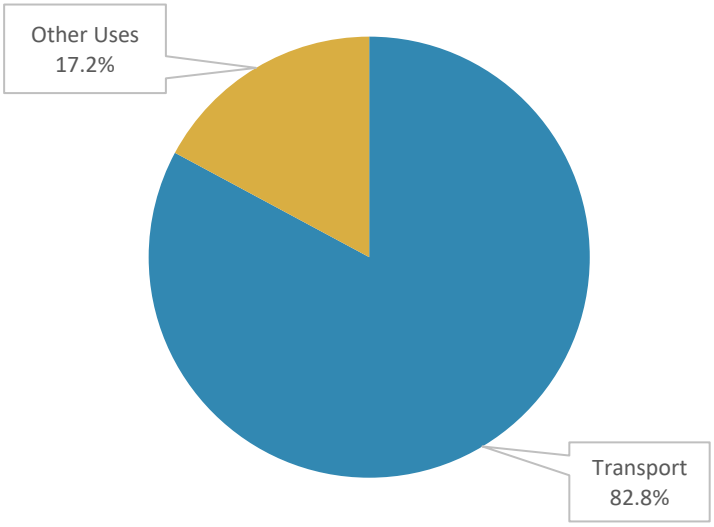
Most biodiesel, renewable diesel, and ethanol produced worldwide are used for transport. The automotive sector is the largest user, and biodiesel is used by blending biodiesel with fossil fuel. Every country has a blending mandate, and due to strict environmental policies worldwide, these mandates could turn into law worldwide. Thus, the demand for biodiesel for transport will dominate the market. Other applications of biodiesel include heating, electricity, and industrial purposes.

Table 11
Global Market for Biodiesel, by Application, Through 2028
($ Millions)

Application	2022	2023	2028	CAGR% 2023-2028
Transport	38,389.8	35,855.0	43,878.7	4.1
Other uses	7,948.7	7,239.8	7,766.5	1.4
Total	46,338.5	43,094.8	51,645.1	3.7

Source: BCC Research

Figure 6
Global Market Shares of Biodiesel, by Application, 2022
(%)



Other applications of biodiesel include heating, electricity, and industrial purposes.

Source: BCC Research

Transportation

The demand for biodiesel in the transport sector shows continuous growth, mainly due to favorable government policies. Technological advancements and increasing consumer preference for an environmentally-friendly alternative are also responsible for the constant growth of biodiesel in the transport sector. Biodiesel's growing share in the transport sector is also evident from the increase in biodiesel blending in most countries. Also, fuel policies like the U.S. Renewable Fuel Standard (RFS) program firmly increase the amount of renewable fuel that must be mixed with fossil fuel by refineries. U.S. refineries must raise their biodiesel mix by 520 million gallons in the next two years. In the long run, emerging countries are expected to lead the biodiesel transport market due to the high blending rate and more supporting policies.

Biodiesel will be used among different transport types, mainly cars, trucks, and buses. Diesel fuel can deliver more energy per unit of weight than gasoline; hence, it is the fuel of choice for heavy vehicles. For all large-scale transportation, diesel is the only fuel available; alternatives such as electric vehicles (EV), hybrid, and hydrogen cells are not currently viable. Though the EV is now on the market, from the decarbonization point of view, it may not be an option to reduce carbon emissions until it is charged using renewable power. It has a low supporting infrastructure and requires frequent charging.

The only alternative to petroleum diesel is biodiesel and similar sustainable diesel products. Hence, the biodiesel market is expected to grow strongly in the fuel application segment.

Recent developments and initiatives by automotive manufacturers mean that light-, medium-, and heavy-duty diesel vehicles are not technically alternative fuel vehicles. Currently, almost all are capable of running on biodiesel. However, pure biodiesel (B100) is rarely used on any vehicle; biodiesel blends (between B5 and B20) are commonly used in diesel vehicles. In the U.S., the most common biodiesel blend is B20, which ranges from 6-20% biodiesel blended with petroleum diesel. However, B5 is also commonly used in fleet vehicles. In the U.S., almost all original equipment manufacturers (OEMs) approve using B5. However, higher blends (such as B8, B10, B20, etc.) are subject to engine and diesel use specifications only and using higher combinations in engines that do not permit the same may result in severe damage to machines.

In the U.S., distributors are also active stakeholders in the biodiesel market, and their initiatives have led to the growth of biodiesel in the trucking sector. Biodiesel and biodiesel blends are available nationwide at more than 2,000 public locations and are generally produced and widely distributed where the vast majority of highway fuel is consumed.

In addition to the U.S., other governments and countries that have taken severe initiatives to boost domestic biodiesel markets are Indonesia, Thailand, Malaysia, Canada, Brazil, Argentina, Colombia, and some EU countries.

Aviation fuel is the second-largest segment, followed by the automotive segment. The aviation sector is also a massive greenhouse gas emitter, and many governments, organizations, and environmental bodies are working to shift the aviation sector to alternative fuels (namely biodiesel and renewable diesel). Although many operators have moved to these alternate fuels, some challenges must be addressed. A full-scale shift is not immediately possible and will take considerable time.

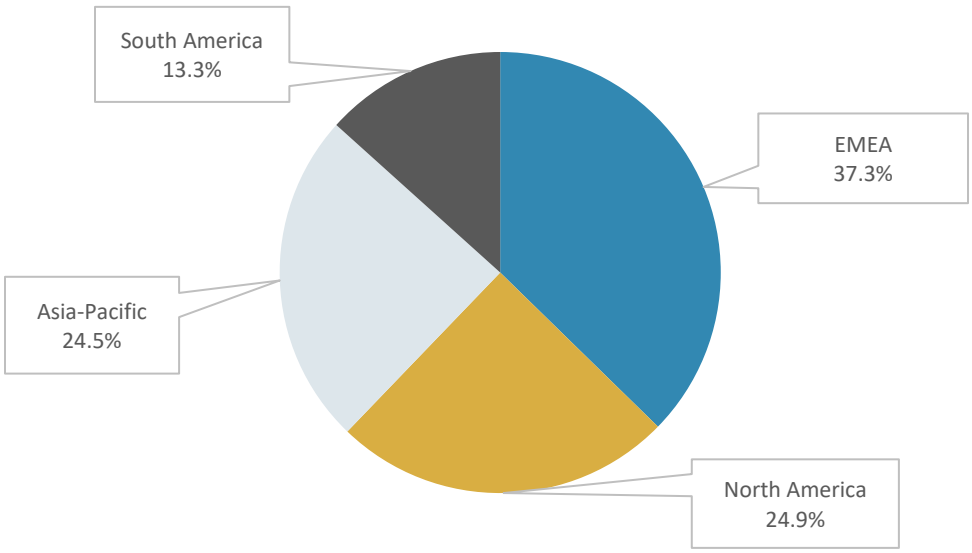
Besides aviation, rail transport, and shipping are other sectors with some biodiesel prospects. Although shipping is considered a moderately significant market for biodiesel, its share is estimated to be lower than that of aviation. Further, the aviation sector is expected to see much more substantial growth than the shipping sector, thus lowering the attractiveness of the shipping sector in the coming years. Accordingly, automotive and aviation will remain the most attractive sectors for the biodiesel market in the coming years.

Table 12
Global Market for Transportation Application of Biodiesel, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023-2028
North America	9,549.1	8,909.8	10,890.2	4.1
EMEA	14,325.0	13,426.9	16,986.1	4.8
Asia-Pacific	9,396.5	8,773.7	10,622.6	3.9
South America	5,119.2	4,744.6	5,379.8	2.5
Total	38,389.8	35,855.0	43,878.7	4.1

Source: BCC Research

Figure 7
Global Market Shares of Transportation Application of Biodiesel, by Region, 2022 (%)



Source: BCC Research

Other Uses

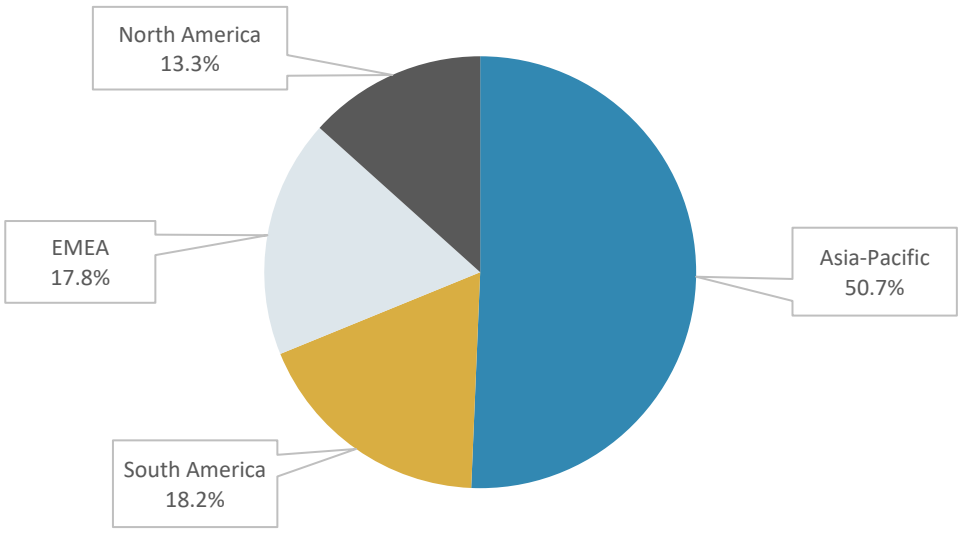
Other biodiesel uses constitute biodiesel for electricity, heating and cooling, and other industrial uses. Electricity generation is a strong, growing application segment despite being a distant second to oil and gas. The power generation segment has several benefits, such as powering diesel generators and providing emergency power supplies in oil rigs. The sub-segment of powering diesel generators (for hospitals, emergency installations, large apartment complexes, etc.) is expected to have a higher demand in emerging regions. Several countries in emerging regions have unreliable electricity supplies and often see power outages. Power outages are almost synonymous with emerging and underdeveloped areas, as developed regions rarely see large-scale or frequent power outages. Countries such as India, Pakistan, Bangladesh, Indonesia, Brazil, Paraguay, Philippines, Thailand, and Venezuela see frequent power outages in remote areas and urban city centers. While developed countries such as the U.S., Canada, and Switzerland have also seen power outages, those are primarily rare and one-off incidents. Countries such as Brazil, India, and Indonesia, otherwise witnessing moderate to strong growth in various sectors, also witness frequent electricity disruptions and are expected to be significant diesel users for power generation. The demand for power generation in emerging regions can be gauged by the fact that, currently, APAC is the largest diesel generator market (in terms of market share and dollar value) and is also expected to see the strongest growth. Frequent power outages and unreliable electricity supplies have given rise to huge demand for diesel generators in APAC.

Table 13
Global Market for Other Applications of Biodiesel, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023-2028
North America	1,061.0	979.0	1,143.2	3.1
Asia-Pacific	4,027.1	3,657.6	3,856.5	1.1
EMEA	1,416.8	1,290.0	1,411.8	1.8
South America	1,443.9	1,313.2	1,355.0	0.6
Total	7,948.8	7,239.8	7,766.5	1.4

Source: BCC Research

Figure 8
Global Market Shares of Other Applications of Biodiesel, by Region, 2022
(%)



Source: BCC Research

Chapter 8

Biodiesel Market by Region

BCC Publishing

Chapter 8: Biodiesel Market by Region

Introduction

During COVID-19, the use of biofuels as transportation fuel decreased as there were strict restrictions on movement. Among the major biofuels, the use of ethanol reduced, while the use of biodiesel increased, but at a slower pace. During the economic recovery in 2021, the biodiesel market expanded, but ethanol consumption did not return to its 2019 level. The biodiesel market grew due to government support via high blending requirements. Biodiesel will mainly contribute to global decarbonization activities in the transport sector.

Lately, biodiesels like renewable diesel, SAF, and UCO-based biodiesel are gaining attention. The shift mainly occurs in developed countries like the U.S. and the EU.

Among all the regions, Europe ranked first in the global biodiesel production and consumption worldwide in 2022. This includes renewable diesel as well. Over 80% of the biodiesel production and consumption happened in the U.S., the EU, Indonesia, and Brazil.

Table 14
Biodiesel Production & Consumption Share & Ranking by Country/Region, 2022

Country/Region	Production Share	Consumption Share
	Biodiesel in % (Rank)	Biodiesel in % (Rank)
The EU	32.2 (1)	34.3 (1)
The U.S.	18.3 (2)	24.4 (2)
Indonesia	17.6 (3)	19.8 (3)
Brazil	12.3 (4)	12.9 (4)
China	3.6 (5)	1.4 (6)
Argentina	3.3 (6)	0.5 (7)
Thailand	3.0 (7)	2.6 (5)

Note: Numbers refer to country ranking in global production; percentages refer to the production share of countries in the base period. Biodiesel includes renewable diesel.

Source: BCC Research

The global biodiesel market saw a decline in 2023 in terms of value. The Russia-Ukraine war started in 2022 and then followed Western sanctions. The war created supply chain disruptions, and Russia—one of the top exporters of food products, fertilizers, and vegetable oil—stopped exporting. These events impacted biofuel feedstock prices. Biofuel and biodiesel markets are sensitive to feedstock prices as feedstock costs constitute around 70% of the biodiesel cost. In 2022, the food crops and feedstock prices were high, leading to the high price of biodiesel. Biodiesel prices were at their peak in 2022. In

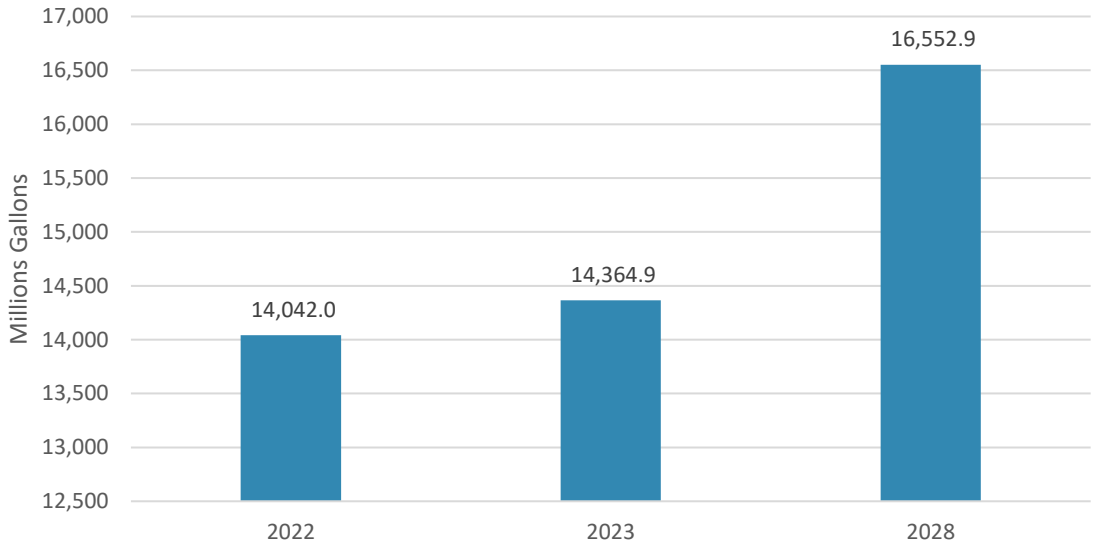
2023, the price declined and is expected to normalize in the coming years—a deep decline in prices in 2023 led to a fall in the biodiesel value.

Table 15
Global Market Volumes of Biodiesel, Through 2028
(Million Gallons)

Product	2022	2023	2028	CAGR% 2023-2028
Biodiesel	14,042.0	14,364.9	16,552.9	2.9

Source: BCC Research

Figure 9
Global Market Volumes of Biodiesel, 2022-2028
(Million Gallons)



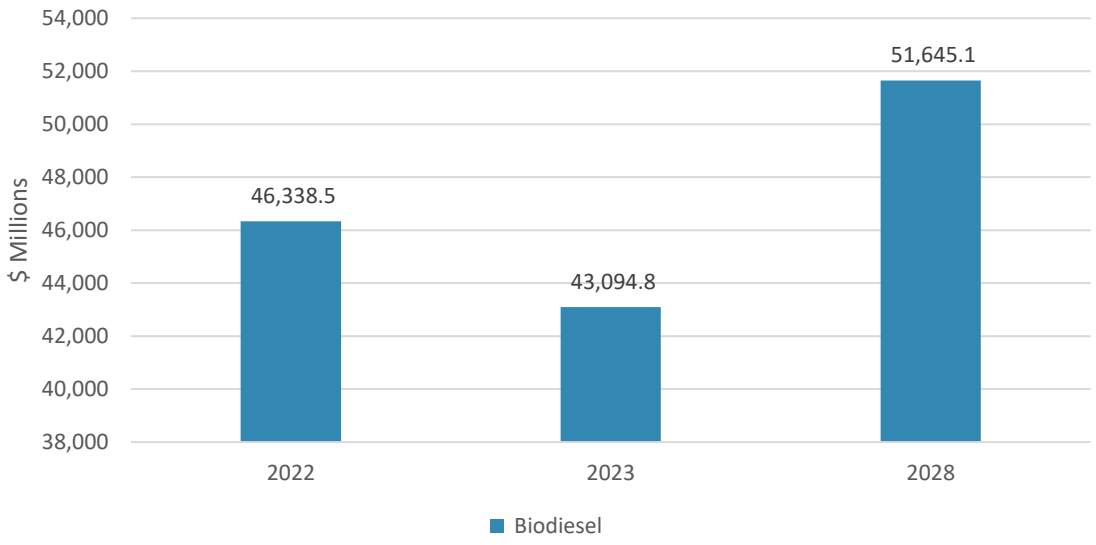
Source: BCC Research

Table 16
Global Market for Biodiesel, Through 2028
($ Millions)

Product	2022	2023	2028	CAGR% 2023-2028
Biodiesel	46,338.5	43,094.8	51,645.1	3.7

Source: BCC Research

Figure 10
Global Market for Biodiesel, 2022-2028
($ Millions)



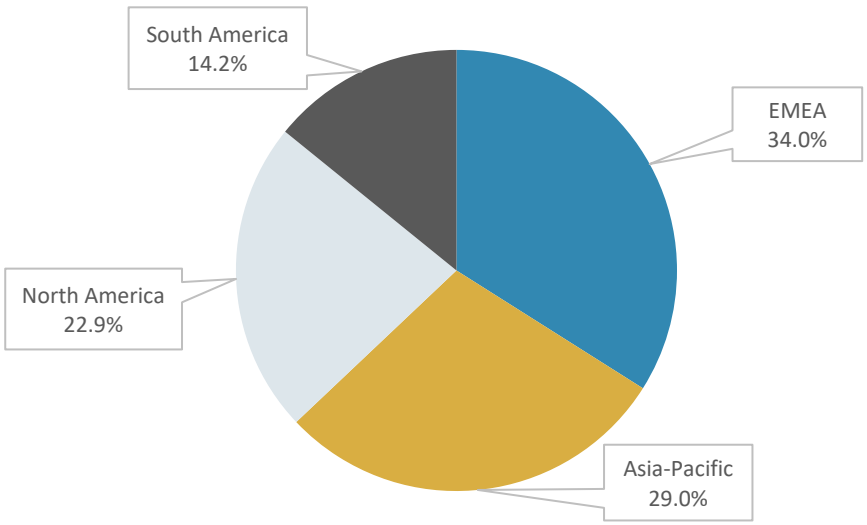
Source: BCC Research

Table 17
Global Market for Biodiesel, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023-2028
North America	10,610.1	9,888.8	12,033.3	4.0
EMEA	15,741.8	14,716.9	18,397.8	4.6
Asia-Pacific	13,423.5	12,431.3	14,479.2	3.1
South America	6,563.1	6,057.8	6,734.8	2.1
Total	46,338.5	43,094.8	51,645.1	3.7

Source: BCC Research

Figure 11
Global Market Shares of Biodiesel, by Region, 2022
(%)



Source: BCC Research

North America

The U.S.

The U.S. is the largest biodiesel market in North America, with more than 90% of the region's production and consumption. However, for the past few years, the production capacity of biodiesel has decreased. According to IEA, between Jan 1, 2022, and Jan 1, 2023, the production capacity of biodiesel fell by 169 million gallons per year. During the same period, the production capacity of renewable diesel production capacity increased by 71%. There has been a significant investment in renewable diesel. Also, according to the Energy Information Administration (EIA), 13 biodiesel plants have been closed.

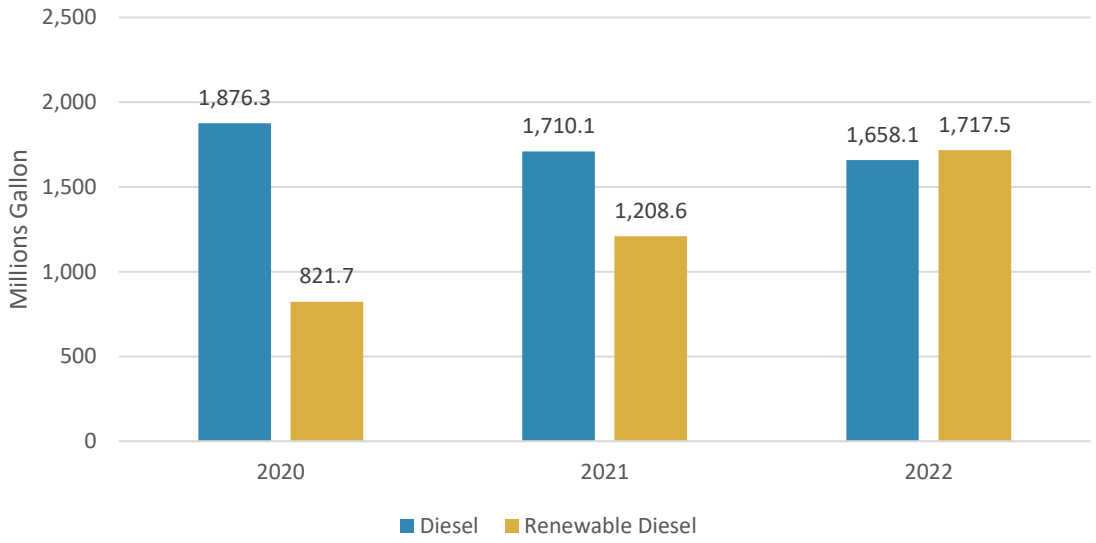
The U.S. is divided into 5 PADD (Petroleum Administration for Defense Districts). In PADD 1, located on the East Coast, the number of total biodiesel plants fell from 14 to 10; in PADD 2, in the Midwest, biodiesel plants decreased from 37 to 33; in PADD 3, in the Gulf Coast, the plants fell from 12 to 9 and in PADD 5, in West Coast, plants dropped from 9 in 2022 to 7 in 2023. The fall was also due to the impact of COVID-19 restrictions, but the most significant effect was due to high competition from renewable diesel.

A sharp decline in production capacity began in 2020, which reflects the shutdown and idling of many FAME biodiesel plants during the COVID-19 pandemic. This was followed by an even more rapid idling of capacity during 2021-2022 in the face of a boom in renewable diesel production.

Though both renewable diesel and biodiesel are produced from the same feedstocks, renewable diesel is a drop in fuel. It can completely replace fossil-based diesel, but biodiesel can only be blended with diesel at specific percentages. Renewable diesel does not affect the vehicle engine, whereas biodiesel could. Comparatively, biodiesel production can pollute the environment more than renewable diesel. Besides, biodiesel (B20) in April 2023 was around $4.02 per gallon, and B100 was $4.95 per gallon.

The average price of renewable diesel in April 2023 was $5.33 per gallon. The margin of renewable biodiesel is higher than that of biodiesel, and at the same time, renewable diesel highly satisfies the U.S. biofuel policy.

Figure 12
U.S. Volume Market for Biodiesel and Renewable Diesel Consumption, 2020-2022
(Millions Gallon)



Source: BCC Research

From the above figure, it is evident that renewable diesel consumption surpassed biodiesel consumption in 2022. From 2021-2022, there was a 40% increase in renewable diesel consumption.

Canada

In 2022, biodiesel production and consumption declined in Canada compared to the last year. Biodiesel consumption was reduced from 400 million liters in 2021 to 380 million liters in 2022. Similarly, renewable diesel consumption declined from 472 million liters in 2021 to 380 million liters in 2022. In 2021, Canada had 12 biorefineries, and in 2022, it reduced to 11 as Darling Ingredients, one of the largest biodiesel producers, closed its refinery in Canada, which could produce 12 million gallons per year. In 2022, there were no renewable diesel plants in Canada, and the renewable diesel consumed by Canada was imported from the U.S.

Table 18
Canadian Volume Market for Biodiesel and Renewable Diesel Consumption, 2019-2023
(Million Liters)

Product	2019	2020	2021	2022	2023
Biodiesel	370	340	400	380	380
Renewable Diesel	380	500	472	380	460
Total	750	840	872	760	840

Source: USDA

Besides, it is to be noted that Canada was using more renewable diesel compared to biodiesel. The consumption will recover with the same trend in the coming years. Some of the renewable diesel facilities announced to be operational soon are:

- In January 2023, ExxonMobil announced that it would build its largest renewable diesel facility in Canada, with a capacity of 20,000 barrels of renewable diesel per day. ExxonMobil will invest around $560 million via its subsidiary, Imperial Oil Limited.

- Tidewater Renewables, a Canada-based energy company, constructed a $380 million renewable diesel facility in Canada in June 2023. The facility is expected to produce 3,000 barrels of renewable biodiesel per day.

Mexico

In North America, more than 90% of the biodiesel market is reported by the U.S., and around 5% is constituted by Canada. In Mexico, biodiesel production is negligible. Comparatively, the Mexican market produces a significant amount of ethanol biofuel. However, the country has the potential to produce biodiesel, but structural challenges, lack of support from the government, and lack of proper regulations slow the market down. Mexico imports its biodiesel from the U.S. In 2022, Mexico imported $169.97 million worth of biodiesel from the U.S. However, in October 2023, the government temporarily restricted imports of fuels, including biofuels, due to alterations and adulteration in its received import of fuels.

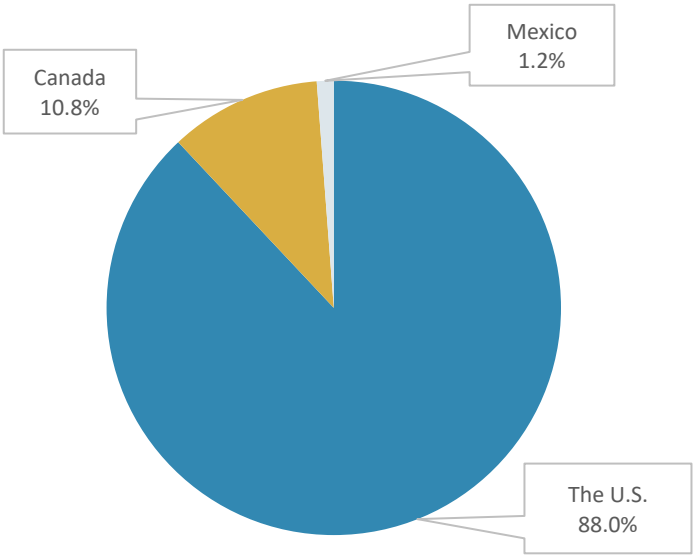
Currently, the country produces biodiesel using used cooking oil (UCO). According to Pemex, the Mexican state-owned petroleum company, UCO-based biodiesel produced is cheaper than the traditional diesel produced by the company. Thus, the opportunity to produce biodiesel is high in Mexico. The Advanced Biodiesel Cluster (BDA) of the Mexican Center for Energy Innovation – Bioenergy (CEMIE-BIO) says the country can collect 360 million liters of used oil from 100,000 dwellers. Companies collect used cooking oil and produce biodiesel, but they are entirely self-consumed as it is 40% cheaper than fossil-based diesel supplied by Pemex.

Table 19
North American Market for Biodiesel, by Country, Through 2028
($ Millions)

Country	2022	2023	2028	CAGR% 2023-2028
The U.S.	9,336.9	8,702.1	10,649.5	4.1
Canada	1,145.9	1,068.0	1,263.5	3.4
Mexico	127.3	118.7	120.3	0.3
Total	10,610.1	9,888.8	12,033.3	4.0

Source: BCC Research

Figure 13
North American Market Shares of Biodiesel, by Country, 2022
(%)



Source: BCC Research

The U.S. is the world's number one ethanol producer, with 46.7% of the world's ethanol production volume. Also, it is the world's second-largest biodiesel producer, with 18.4% of the world market. U.S. policies like low carbon fuel level standards, the Renewable Fuel Standard (RFS), and renewable fuels production and blending tax credit were the main drivers of the U.S. market.

Under the 2022 Inflation Reduction Act, the U.S. government allotted $500 million in grants to cover 75% of the cost of the biodiesel infrastructure projects. The act also extends tax credits to renewable

fuels till 2024. The policy was originally planned to end by 2022 but has been extended till December 31, 2024. A taxpayer using B100 will receive an incentive of $1 per gallon of biodiesel use. B100 and B20 are biodiesel blending rates. Biodiesel is usually used by blending it along with fossil fuels in vehicles. A B20 blending rate means 20% biodiesel and the remaining is fossil diesel. B100 uses 100% biodiesel in the vehicle. The maximum blending rate used in the U.S. is B20.

Among the North American countries, U.S. manufacturers have predominately started using used cooking oil (UCO) for biodiesel production. Hence, the percentage of UCO is given below for readers' understanding. In 2022, the U.S. consumed 15,280.56 million pounds of vegetable oil, 3,393 million pounds of used cooking oil, and 2,702 million pounds of waste oils, fats, and greases.

Table 20
U.S. Biodiesel Feedstock Share, 2021-2022
(%)

Feedstock Type	2021 Share (%)	2022 Share (%)
Vegetable Oil	55.0	66.0
Used Cooking Oil	14.6	21.6
Animal Fats	11.3	12.1
Other Waste	0.3	0.3

Note: Others include non-edible industrial, other fats, and oil.

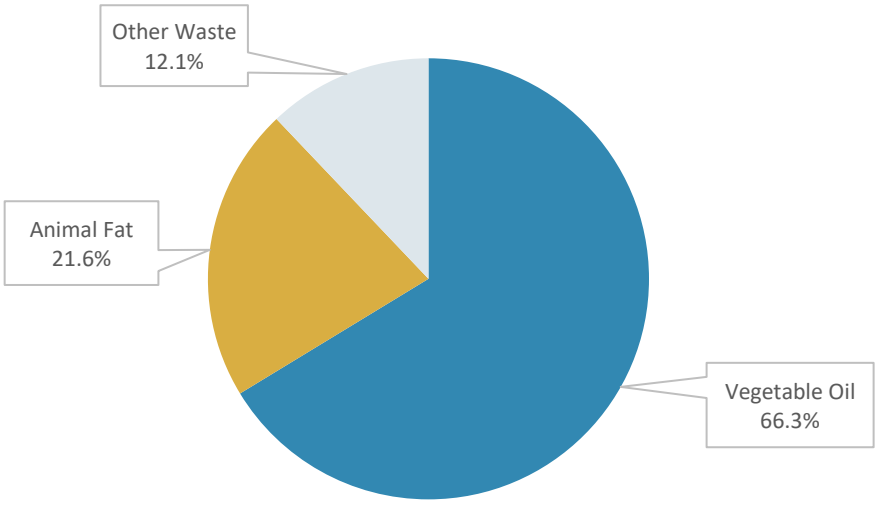
Source: BCC Research

Table 21
North American Market for Biodiesel, by Feedstock Type, Through 2028
($ Millions)

Feedstock Type	2022	2023	2028	CAGR% 2023-2028
Vegetable Oil	7,034.5	6,590.3	8,223.5	4.5
Animal Fat	2,291.8	2,115.7	2,452.3	3.0
Other Waste	1,283.8	1,182.8	1,357.5	2.8
Total	10,610.1	9,888.8	12,033.3	4.0

Source: BCC Research

Figure 14
North American Market Shares of Biodiesel, by Feedstock Type, 2022
(%)



Source: BCC Research

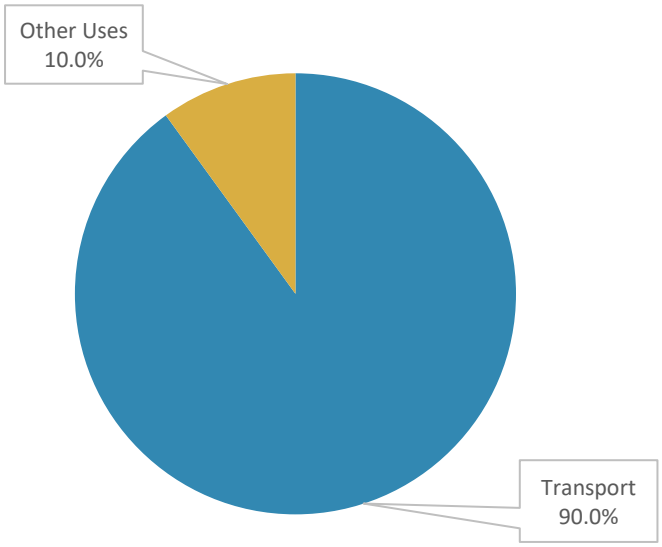
Most biodiesel produced in the region is used to transport people and goods. However, most biodiesel is blended with fossil fuels like petroleum, gasoline, diesel, and jet fuel. Light-duty vehicles like cars, vans, and buses commonly use biodiesel. These light-duty vehicles consume more than 50% of the biodiesel.

Table 22
North American Market for Biodiesel, by Application, Through 2028
($ Millions)

Application	2022	2023	2028	CAGR% 2023-2028
Transport	9,549.1	8,909.8	10,890.2	4.1
Other Uses	1,061.0	979.0	1,143.2	3.1
Total	10,610.1	9,888.8	12,033.3	4.0

Source: BCC Research

Figure 15
North American Market Shares of Biodiesel, by Application, 2022
(%)



Source: BCC Research

Asia-Pacific

Among Asia-Pacific nations, Indonesia has been the largest producer and consumer of biodiesel. It is the third-largest biodiesel producer worldwide, with a 17.6% share in global production in 2022.

In Indonesia, the country's B30 blending target, national biodiesel program, and financial support from the crude palm oil (CPO) fund are supporting the growth of biodiesel in the country. Biodiesel production and consumption will increase in 2022 and are expected to increase in 2023. However, most of the biodiesel production serves the B30 target market. The country does not produce renewable diesel.

China produces biodiesel and renewable diesel from UCO. The country's biodiesel production increased by 32% in 2022 compared to 2021. Renewable diesel production is expected to grow in 2023 due to a high demand from the European market. China's renewable diesel market is export-oriented, and it is the largest exporter of renewable diesel to Europe. Most of the biodiesel is exported to the Netherlands and Belgium.

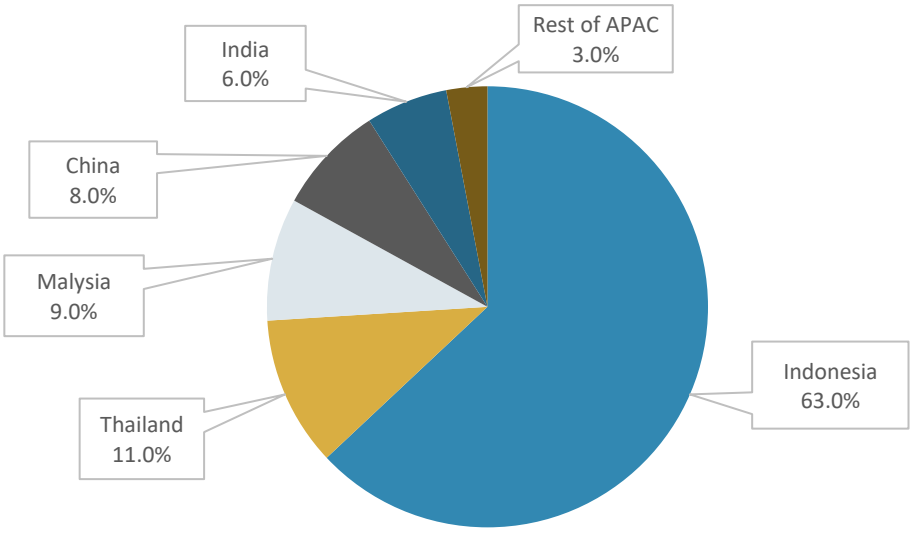
India's biodiesel market is unregulated, and the country produces minimal biodiesel, but the market has good potential. The government has 10 biodiesel plants with 600-million-liter capacity. The primary feedstocks used to make biodiesel are cooking oil, animal fats, and grease.

Table 23
Asia-Pacific Market for Biofuels, by Country, Through 2028
($ Millions)

Country	2022	2023	2028	CAGR% 2023-2028
Indonesia	8,456.8	7,806.9	9,020.5	2.9
Thailand	1,476.6	1,371.6	1,636.1	3.6
Malaysia	1,208.1	1,114.6	1,172.8	1.0
China	1,073.9	1,006.9	1,303.1	5.3
India	805.4	758.3	941.1	4.4
Rest of Asia-Pacific	402.7	373.0	405.4	1.7
Total	13,423.5	12,431.3	14,479.2	3.1

Source: BCC Research

Figure 16
Asia-Pacific Market Shares of Biodiesel, by Country, 2022
(%)



Source: BCC Research

With a 30% blending rate, Indonesia is Asia's largest biodiesel consumer. Palm oil is the only feedstock the country is using to produce biodiesel. Since 2021, the country has used palm oil to produce little renewable diesel. Malaysia also uses only palm oil as a feedstock for biodiesel production.

It is surprising to see most Asia-Pacific countries, namely China, India, Australia, Japan, etc., use non-food feedstocks like cooking oil, animal fat, and other waste oils to produce biodiesel. There is abundant used cooking oil in India and China due to population. However, the UCO collection market is not well-organized like those in the U.S. and Europe. Once collected, Asia-Pacific countries have a big opportunity for UCO-based biodiesel, which has a high market in the U.S. and Europe.

Table 24
Asia-Pacific Biodiesel Feedstock Share, 2021 and 2022
(%)

Feedstock Type	2021 Share (%)	2022 Share (%)
Vegetable Oil	90.9	89.9
Used Cooking Oil	8.3	9.3
Animal Fats	0.2	0.1
Others	0.6	0.7

Note: Others include non-edible industrial, other fats, and oil.

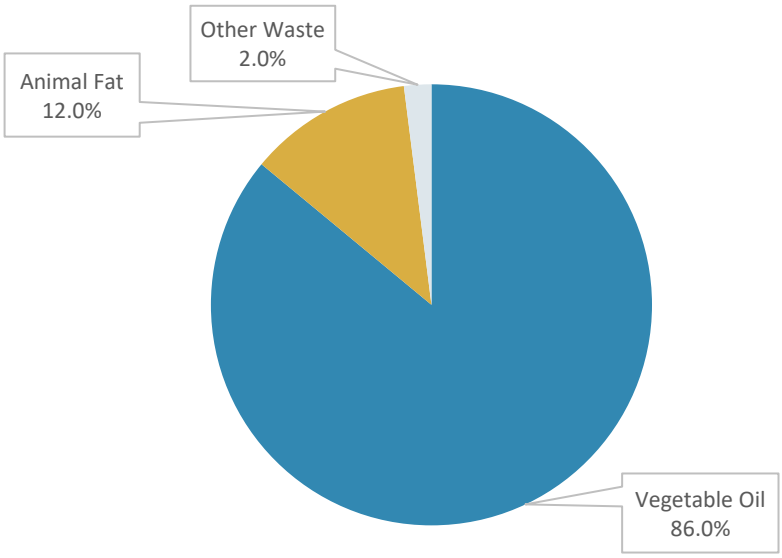
Source: BCC Research

Table 25
Asia-Pacific Market for Biodiesel, by Feedstock Type, Through 2028
($ Millions)

Feedstock Type	2022	2023	2028	CAGR% 2023-2028
Vegetable Oil	11,544.2	10,708.0	12,568.4	3.3
Animal Fat	1,610.8	1,479.6	1,654.0	2.3
Other Waste	268.5	243.7	256.8	1.1
Total	13,423.5	12,431.3	14,479.2	3.1

Source: BCC Research

Figure 17
Asia-Pacific Market Shares of Biodiesel, by Feedstock Type, 2022
(%)



Source: BCC Research

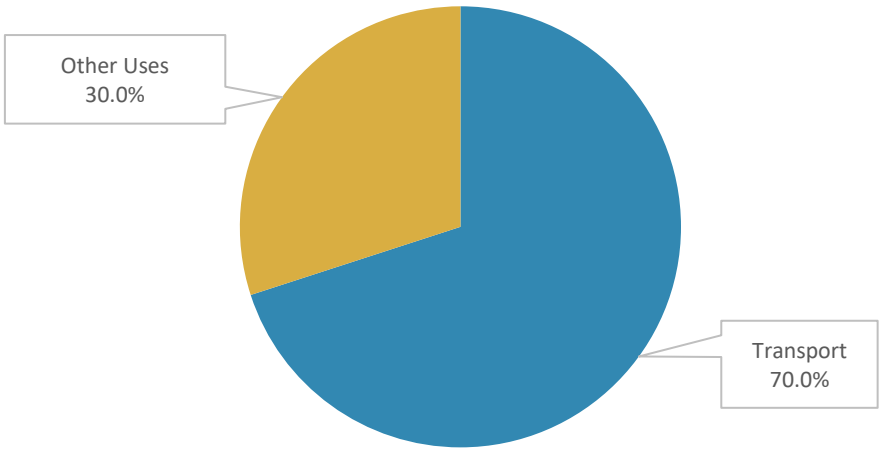
Indonesia has a high blending rate of biofuels for the transport sector. The country has increased its biodiesel blending rate from 20% in 2016 to 30% in 2025. By 2025, all vehicles must use 30% biodiesel in their cars. In terms of volume, the biodiesel for blending will increase from 2.5 billion liters to 6.9 billion liters. In China, transport accounts for over one-third of total biofuel demand. Though China has a biofuel mandate of around 10%, no solid actions or regulations exist to implement it. The biofuel market is fragmented and unregulated in most Asia-Pacific countries like India. Due to the high fuel cost, the blending rate is also low. Due to the high transportation market, biodiesel has a big market.

Table 26
Asia-Pacific Market for Biodiesel, by Application, Through 2028
($ Millions)

Application	2022	2023	2028	CAGR% 2023-2028
Transport	9,396.5	8,773.7	10,622.6	3.9
Other Uses	4,027.0	3,657.6	3,856.6	1.1
Total	13,423.5	12,431.3	14,479.2	3.1

Source: BCC Research

Figure 18
Asia-Pacific Market Shares of Biodiesel, by Application, 2022
(%)



Source: BCC Research

EMEA

The EU is the world's largest market for biodiesel. Government mandates in all EU nations drive the market. The top biodiesel consumers in Europe are France, Germany, Spain, Sweden, Poland, and Italy. These countries constituted 67% of the European biodiesel consumption. In 2023, biodiesel consumption will increase by around 2%. Alternatively, a slight demand reduction will be seen in countries like Spain, Portugal, and the Czech Republic.

In renewable diesel the EU's RED policies encourage renewable diesel production. Neste is the EU's largest producer of renewable diesel. In 2022, renewable fuel production slightly declined, but in 2023, production is expected to increase due to new plants in Finland and Sweden. Consumption will be high in Italy and the Netherlands. By 2025, the EU will likely witness double the capacity in renewable diesel, most of which will be used for SAF production.

Table 27
EU Volume Market for Biodiesel and Renewable Diesel Production, 2019-2023
(Million Liters)

Product	2019	2020	2021	2022	2023
Biodiesel	13,438	11,971	11,924	12,160	12,000
Renewable Diesel	2,842	3,629	4,120	3,960	4,200

Source: USDA

The above table shows the constant growth of renewable diesel production and a slight decline in biodiesel production. In 2022, renewable diesel constituted 22% of the total biodiesel production and is expected to increase by 23% in 2023. Thus, the growth in biodiesel in Europe will be attributed to renewable diesel from 2023 onwards. The Netherlands is the largest producer of renewable diesel in 2022, with 1,280 million liters of renewable diesel production.

Besides, additional consumption of renewable diesel and a decline in biodiesel production will lead to a demand-supply gap that is filled by import. In 2022, Europe imported 3,160 million liters of biodiesel from Argentina, China, the United Kingdom, Malaysia, South Korea, and Indonesia. In 2023, imports are expected to increase by 14%, and China will be the largest exporter of biodiesel.

Table 28
Major Renewable Diesel Producing Countries, 2019-2023
(Million Litters)

Country	2019	2020	2021	2022e	2023f
Netherlands	1,156	1,203	1,247	1,280	1,280
Finland	424	381	753	830	960
France	150	476	641	640	640
Italy	328	797	750	550	615
Sweden	208	208	312	350	370
Spain	545	535	409	300	300
Austria	-	-	-	-	30
Portugal	30	30	9	5	5
Total	2,842	3,629	4,120	3,960	4,200

Note: Renewable diesel also includes a small amount SAF; e = estimated, f = forecast

Source: USDA

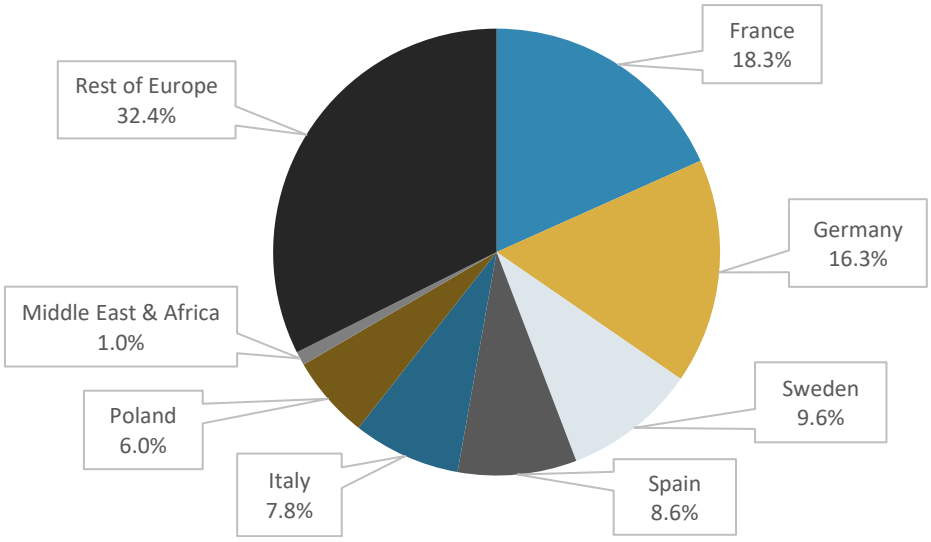
Renewable diesel production is taking place only in the above eight countries. Neste Oyj, Eni S.P.A., UPM, TotalEnergies SE, and Preem are major companies that produce renewable diesel from these countries.

Table 29
EMEA Market for Biodiesel, by Country, Through 2028
($ Millions)

Country	2022	2023	2028	CAGR% 2023-2028
Germany	2,565.9	2,479.5	3,630.7	7.9
France	2,880.7	2,705.7	3,436.8	4.9
Sweden	1,511.2	1,446.7	2,021.2	6.9
Italy	1,227.9	1,164.3	1,551.4	5.9
Spain	1,353.8	1,247.1	1,437.5	2.9
Poland	944.5	878.6	1,063.4	3.9
Middle East & Africa	157.4	142.7	152.0	1.3
Rest of Europe	5,100.4	4,652.3	5,104.8	1.9
Total	15,741.8	14,716.9	18,397.8	4.6

Source: BCC Research

Figure 19
EMEA Market Shares of Biofuels, by Country, 2022
(%)



Source: BCC Research

Europe is the world's first largest biodiesel producer, with 30.7% of the global biodiesel production share in 2022. Like the U.S., the biodiesel market is driven by existing policies in the EU nations. Blending targets in the U.K., Finland, France, and Italy and carbon emission reduction targets in Germany drive the market. Europe's ReFuelEU target of 2% for aviation by 2025 will likely boost the biodiesel market in the forecast period. However, the EU has recently set palm oil biodiesel under the high-risk indirect land use category. This will likely cause a decline in biodiesel consumption in the EU in the forecast period.

The Middle East and Africa (MEA) region produces only ethanol. The biodiesel production in the area is negligible, around 1%. However, the Middle East strongly supports carbon emission reduction like any other country. Wakund International LLC, an Omani SME, and Oman Oil Marketing Company via (OOMCO) have collaborated to market biofuels in Oman. Wakund, with a 500,000-biofuel capacity per year, started commercializing fuel at the start of 2022.

As the economy grows, the demand for biofuels increases steadily in African countries. The African government will soon set an E10 blending target in the country. Europe, Africa, and the Middle East accounted for 16% of the U.S. ethanol export in 2020-2021.

Table 30
The EU Biodiesel Feedstock Share, 2021 and 2022
(%)

Feedstock Type	2021 Share (%)	2022 Share (%)
Vegetable Oil	60.3	58.7
Used Cooking Oil	26.6	28.9
Animal Fats	7.6	6.4
Other	5.5	6.0

Source: BCC Research

Note: Other includes but is not limited to pine oil, tall oil, tall oil pitch, palm fatty acids, and free fatty acids.

Compared to 2021, the share of vegetable oil declined in 2022. This is mainly due to a 25% decline in the use of palm from 2021-2022. Rapeseed oil is the primary feedstock among vegetable oils, comprising 42% in 2022. The rapeseed oil increased by 1% in 2022 compared to 2021 and is expected to increase by 3% in 2023 to compensate for the decline in palm oil use.

Besides, the share of used cooking oil is increasing. It is the second largest feedstock by percentage, with 28.9%. Europe has implemented double counting to UCO to discourage the use of food crops and drive the use of UCO. Europe also imports large quantities of UCO from other countries, and China was the largest exporter of UCO, with a 47% share in 2022. Animal fat use decreased slightly because the feedstock does not enjoy double counting as UCO. Animal fat-based biodiesel production requires equipment changes in countries like Denmark, Finland, France, the Netherlands, and the United Kingdom. Only the latest developed plants in the EU produced animal-fat-based biodiesel.

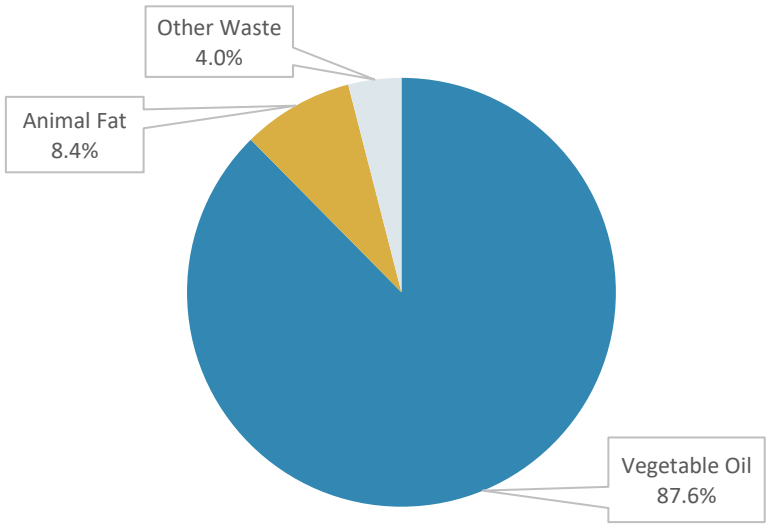
Ninety-six percent of UCO is produced in the Netherlands, Germany, Finland, Italy, Spain, Portugal, Austria, France, and Poland. Palm oil was mainly used in Spain, Italy, France, Belgium, and the Netherlands, and to a lesser extent in Germany and Romania. France, Austria, and Germany have banned the use of palm oil. Most of the soybean oil is used in Germany and Spain. Small amounts are used in Belgium, Portugal, Romania, Bulgaria, Austria, the Netherlands, Greece, and Poland. Other low-share biodiesel feedstocks like sunflower oil are used in Greece, France, Bulgaria, and Hungary, constituting 59%. Another category of feedstock is used in wood (Sweden), free fatty acids (Germany and Finland), tall oil (Finland), palm fatty acids (Finland), and cottonseed oil (Greece).

Table 31
EMEA Market for Biodiesel, by Feedstock Type, Through 2028
($ Millions)

Feedstock Type	2022	2023	2028	CAGR% 2023-2028
Vegetable Oil	13,789.8	12,915.6	16,318.8	4.8
Animal Fat	1,322.3	1,226.4	1,473.0	3.7
Other Waste	629.7	574.9	606.0	1.1
Total	15,741.8	14,716.9	18,397.8	4.6

Source: BCC Research

Figure 20
EMEA Market Shares of Biodiesel, by Feedstock Type, 2022
(%)



Source: BCC Research

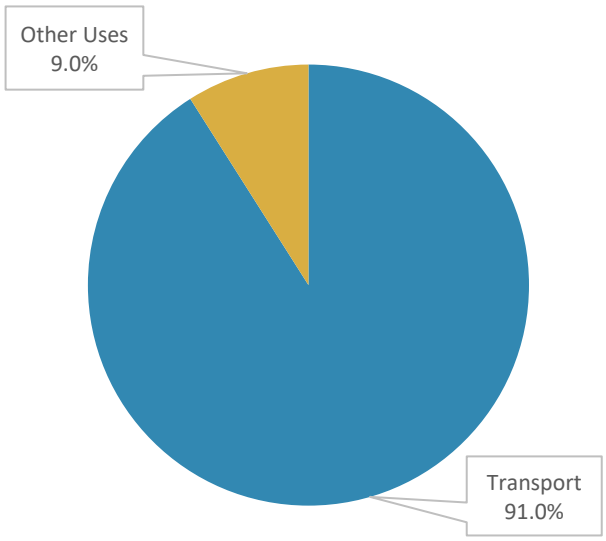
In the EU, all biodiesel accounted for 90% of renewables in transport. In 2022, crop-based biofuels will still dominate the transport sector. However, as the EU has restricted palm oil and boosted its renewable diesel consumption, biodiesel consumption in transport would increase further. Also, the blending mandate for petrol and diesel is increasing every year. The minimum percentage of blending mandate in 2022 was 6.8%, which increased to 7.2% in 2023. Under the RED II initiative, the blending rate for 2030 is set at 14% by 2030.

Table 32
EMEA Market for Biodiesel, by Application, Through 2028
($ Millions)

Application	2022	2023	2028	CAGR% 2023-2028
Transport	14,325.0	13,426.9	16,986.0	4.8
Other Uses	1,416.8	1,290.0	1,411.8	1.8
Total	15,741.8	14,716.9	18,397.8	4.6

Source: BCC Research

Figure 21
EMEA Market Shares of Biodiesel, by Application, 2022
(%)



Source: BCC Research

South America

It is a well-known fact that Brazil is the largest producer of biodiesel in the South American region and the fourth-largest producer of biodiesel in the world. Argentina, Brazil, and Colombia are responsible for 24% of global biodiesel production. Most of this production is consumed internally by these countries, except for Argentina, which exports biodiesel to Europe. So far, the South American regions have no renewable diesel plants. Only now have they started focusing on renewable diesel. Some companies

with plans to engage in renewable diesel are Brazil Biofuels (BBF), Vibra Energia, the Brazilian group ECB, and Petrobras.

Biodiesel production in Brazil declined by 7% in 2022 compared to 2021. This is because mandatory blending in the country was reduced in 2022 due to the high feedstock cost of soybeans. But, in March 2023, Brazil increased its biofuel mandate to 12% from 10%. Thus, biodiesel production is expected to increase by 5% in 2023 compared to 2022.

In Argentina, in 2022, biodiesel production and consumption increased as the country increased the blend rates. However, production and consumption in 2023 are expected to decline as the economy suffers severe drought and a decline in feedstock production.

In Colombia, biodiesel production and consumption increased in 2022 and are expected to grow in 2023, and the economy saw a reasonable recovery rate after the pandemic. Primary biodiesel production is palm oil-based, and the country has not reported production of renewable diesel. However, among 12 biodiesel plants, one plant is said to produce biodiesel using a small quantity of used cooking oil (UCO).

Table 33
South American Volume Market for Biodiesel Production and Consumption, by Leading Countries, 2019-2023
(Million Liters)

Country	2019	2020	2021	2022	2023
Brazil					
• Production	5,925	6,500	6,870	6,765	7,100
• Consumption	5,924	6,496	6,928	6,750	7,150
Argentina					
• Production	2,440	1,315	1,960	2,170	1,000
• Consumption	1,292	570	500	812	740
Colombia					
• Production	605	583	720	779	780
• Consumption	605	580	716	780	783

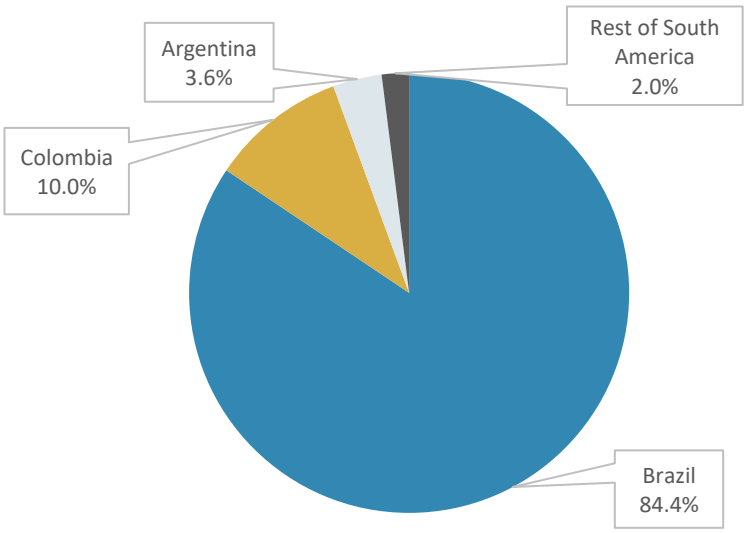
Source: IEA

Table 34
South American Market for Biodiesel, by Country, Through 2028
($ Millions)

Country	2022	2023	2028	CAGR% 2023-2028
Brazil	5,539.2	5,124.9	5,744.8	2.3
Colombia	656.3	599.7	639.8	1.3
Argentina	236.3	216.0	229.0	1.2
Rest of South America	131.3	117.2	121.2	0.7
Total	6,563.1	6,057.8	6,734.8	2.1

Source: BCC Research

Figure 22
South American Market Shares of Biodiesel, by Country, 2022
(%)



Source: BCC Research

Brazil is the fourth-largest producer of biodiesel globally (13.1% in 2022). Most of the biodiesel is produced from soybean oil. Blending requirements and incentives for biodiesel production and consumption drive the Brazilian biodiesel market. The current biodiesel blending rate is 11%. The biodiesel market is expected to increase in the forecast period due to blending targets.

Table 35
Brazilian Biodiesel Feedstock Share, 2021 and 2022
(%)

Feedstock Type	2021 Share (%)	2022 Share (%)
Vegetable Oil	68.5	67.9
Used Cooking Oil	15.9	16.2
Animal Fats	7.6	7.9
Other	7.9	8.1

Note: Other includes but is not limited to pine oil, tall oil, tall oil pitch, palm fatty acids, and free fatty acids.

Source: BCC Research

Among the vegetable oils, soybean crude oil is Brazil's most significant feedstock for biodiesel production. In 2022, soybean oil accounted for 65.8% of biodiesel production, and palm oil accounted for 2.1% of the biodiesel production. There was a slight decline of 1% in soybean oil share in 2022 compared to 2021. The region has an abundant supply of soybean oil and other feedstock. However, the country has yet to commercialize renewable diesel and just started focusing on sustainable aviation fuel.

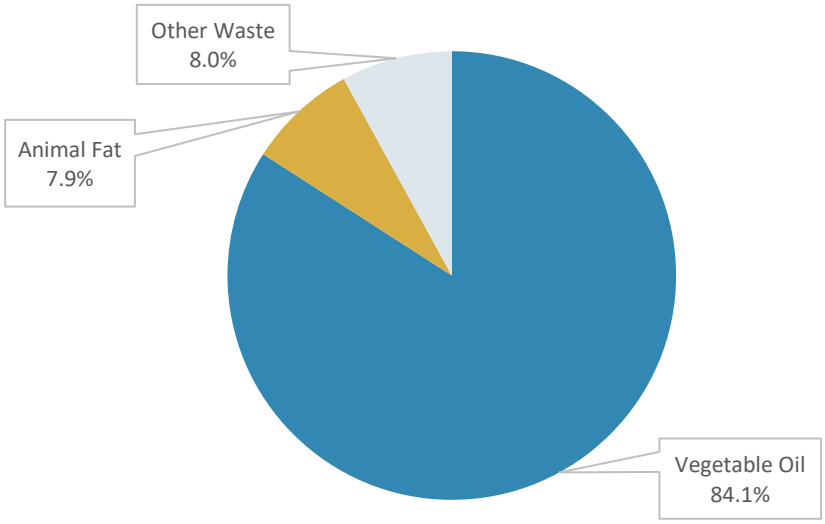
Argentina uses only soybean oil as the feedstock for biodiesel production. It is abundant in quantity as the country is one of the world's largest soybean producers.

Table 36
South American Market for Biodiesel, by Feedstock Type, Through 2028
($ Millions)

Feedstock Type	2022	2023	2028	CAGR% 2023-2028
Vegetable Oil	5,519.5	5,094.7	5,677.4	2.2
Animal Fat	518.5	483.1	559.0	3.0
Other Waste	525.0	480.0	498.4	0.8
Total	6,563.1	6,057.8	6,734.8	2.1

Source: BCC Research

Figure 23
South American Market Shares of Biodiesel, by Feedstock Type, 2022
(%)



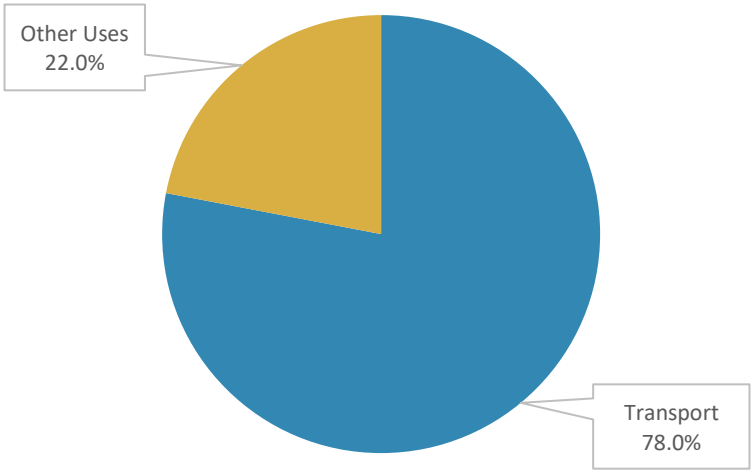
Source: BCC Research

Table 37
South American Market for Biodiesel, by Application, Through 2028
($ Millions)

Application	2022	2023	2028	CAGR% 2023-2028
Transport	5,119.2	4,744.6	5,379.8	2.5
Other Uses	1,443.9	1,313.2	1,355.0	0.6
Total	6,563.1	6,057.8	6,734.8	2.1

Source: BCC Research

Figure 24
South American Market Shares of Biodiesel, by Application, 2022
(%)



Source: BCC Research

Chapter 9

Sustainability in the Biodiesel Industry: An ESG Perspective

HCA Publishing

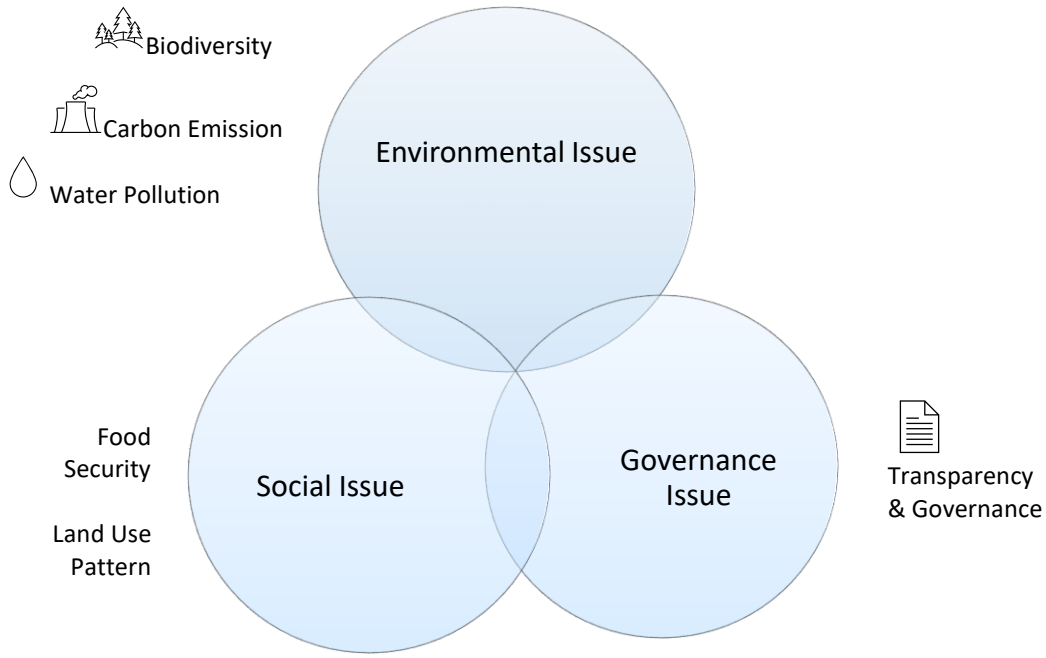
Chapter 9: Sustainability in the Biodiesel Industry: An ESG Perspective

Introduction

Today, biodiesel is seen as the primary option for the transport sector to reduce greenhouse gas emissions. Apart from road transport, the marine and aviation sector also provides an opportunity for the biodiesel industry's growth as the sector becomes more conscious about the feedstock it uses. However, a significant percentage of biodiesel is produced from vegetable oil, leading to changes in land use patterns, excess water use, biodiversity issues, etc. However, if best practices are followed, biodiesels can be used to achieve a net-zero future.

Key ESG Issues

Figure 25
ESG Issues in the Biodiesel Industry



Source: BCC Research

Environmental Issues

Though biodiesel is considered a sustainable fuel, it impacts the environment via carbon emission during its production cycle. Studies on the lifecycle assessment of biodiesel show that the biodiesel production process emits more carbon during cultivation and production. The oilseed production stage produces the most carbon emissions during biodiesel and renewable diesel production. During the farming process, the main factors responsible for greenhouse gas emissions from biodiesel are fertilizer use and nitrous oxide emission during crop farming.

In 2022, U.S. vegetable oil imports increased to $10.9 billion from $8.0 billion in 2021. In 2019, imports were $6.3 billion. The import increase was due to expanding demand for biodiesel and renewable diesel. The share of vegetable oil in biodiesel production has increased from 17.4% in 2012 to 21.6% in 2022. With the growing demand for renewable diesel, according to the Iowa Farm Bureau, the U.S. renewable

diesel capacity has to triple by 2030 to meet the demand. In 2022, the U.S. used nearly 8 million tons of vegetable oils for biodiesel, which must increase to 21 million tons by 2030. Palm oil has a higher emission intensity than other feedstocks used for biodiesel production. Globally, palm oil in food consumption has declined from 65% in 2012 to 61.7% in 2022. Similarly, the industrial use of vegetable oil has increased from 17.4% of all vegetable oils in 2012 to 21.6% in 2022. In 2022, 71.3% of palm kernel oil and 26.5% of palm oil were used for biodiesel production.

Increased demand for biodiesel leads to increased land use for biodiesel production. Clearing forest land for palm and soybean production for biofuels will increase carbon emissions by releasing carbon stocks into the air. Further, fertilizers applied during crop production emit nitrous oxide. In addition, more demand for biofuels leads to more land use by converting wasteland, grassland, and forest land into cultivable land. The increase in the cropland increases the intensity of fertilizers like nitrogen and phosphorous. These fertilizers also pollute the groundwater and surface water.

Similarly, the main factor for carbon emission in renewable diesel processes is grease, rendering high chemical and energy use for conversion processes. Also, renewable diesel production involves hydro-processing, which is highly energy-intensive.

Social Issues

Land Use

Government policies and incentives are attracting companies to drive biofuel production, but this, at the same time, has increased the land use for biofuel production. In the U.S., ethanol production increased land use by around 8% from 2008-2016. This, in turn, has increased fertilizer use and water use. The increased demand for biofuels is also changing the pattern of land use. The changes in the land use pattern can lead to deforestation, affect biodiversity, and increase greenhouse gas emissions. A study on the Environmental Outcomes of the U.S. Renewable Fuel Standard revealed that additional demand for ethanol with every billion gallons per year would boost the U.S. cropland by 0.4% and increase greenhouse gas emissions, nutrient pollution, and soil erosion. The need for more biofuel production has sometimes replaced other farming activities, like cattle ranching. Another major issue with expanding biofuel land has been the displacement of small farmers and a change in land ownership for large-scale expansion. This especially happens in the developing countries.

Governance Issues

Government policies and incentives purely drive biodiesel markets. Mandatory biofuel blending policies, tax incentives, and subsidies have created demand for these products. The world's largest biodiesel producers, the U.S. and the EU, have the most robust policies. Large biodiesel manufacturers headquartered in the U.S. and the EU have a strong presence in developing countries like Brazil and Africa. This brings in the need for international governance, which has already been established. However, biodiesel governance at the international level appears to be non-binding.

Biodiesel Industry ESG Performance Analysis

Biodiesel manufacturers are taking measures to reduce environmental, social, and governance issues. Some measures include low carbon-intensive feedstocks, research on alternative feedstock, efficient catalyst and pretreatment technologies, transparency and certification, safety, regulatory compliance, etc.

Biodiesel policies have become stricter about reducing its dependence on food-based crops. The manufacturers are slowly increasing feedstock that does not directly compete with food crops. They are moving towards feedstocks like crop residue, used cooking oil (UCO), animal fat waste, etc. According to IEA, in 2022, for the first time, renewable diesel led to the expansion of biofuels. The study also predicted that by 2027, one-third of biofuel production would come from waste and residue. Companies that make biodiesel are also exploring municipal solid waste and algae. Companies like Valero, Renewable Energy Group (REG), Neste, and more have expanded their renewable diesel capacity. Valero expanded its renewable diesel capacity to 1.2 billion gallons in 2022. REG has planned to increase its renewable diesel capacity to 100,000 barrels per day by 2030. The primary feedstock used by REG are fats, used cooking oils, and greases, which have lower lifecycle carbon emissions. The company is also developing an innovative feedstock, CoverCress, an oil seed crop that can be grown in the off-season. Also, the crop stops soil erosion, uses less water, and improves soil health.

As responsible agriculture practices, companies like Novazyme, Neste, Louis Dreyfus Company (LDC), Wilmar International, Poet, and Gevo encourage and partner with farmers for sustainable agriculture practices. Some companies like LDC and Gevo are implementing sustainability standards and codes of conduct that promote sustainable agriculture.

To align with ESG goals, most biofuel companies have conducted life cycle assessments (LCAs). These assessments help investors know how the company aligns with the ESG regarding greenhouse gas emissions, renewable fuel standards set by international associations, the impact of their products on the environment, and other social factors.

Consumer Attitudes Towards ESG

Consumer awareness of biodiesel varies among regions and countries. In general, people are less aware of biodiesel. According to a 2022 survey, only 25% of Americans were mindful of low-carbon biofuels. However, after narrating the advantages of low-carbon fuels, around 67% of respondents said they would use biodiesel if priced equal to traditional fuels. The awareness also varies depending on the age, race, and education level. Thirty-four percent of Americans between 18-29 were aware of drop-in-fuels compared to 19% of Americans aged 60+.

According to a study “A review of public opinion on liquid biofuels in the EU: current knowledge and future challenges”, 60% of people are willing to adopt biofuels derived from non-food crop-based biofuels. People are even ready to pay extra for biofuels if they are produced from non-food crops. The survey showed that there is little public knowledge of biofuels. Moreover, in Greece, the people had limited knowledge of biofuels, and 76.2% of people did not know the difference between ethanol and biodiesel. However, 90% of people had a strong belief that fossil fuels are responsible for climate change

in the world. After explaining the advantages of biodiesels, 80% of car owners are ready to use biodiesels/biofuels.

Corporations consider biofuels as the option to reduce their scope 1, 2, and 3 emissions and attain their sustainability goals. For instance, California's food and drug retailer, Albertson Companies, uses UCO-based biodiesel for its trucks in its distribution centers. With the slow increase in the use of sustainable aviation fuels, corporations are willing to pay extra for their flight tickets using sustainable aviation fuels. Companies like Google, Facebook, and Amazon use biodiesel to power their data centers wholly or partially.

In addition to the road transport sector, marine companies are also starting to use biodiesel for ships. Some maritime companies have also begun to modify their engines to use biodiesel. Aviation companies like Air France, Delta, American Airlines, and Lufthansa use sustainable aviation fuels from Neste. Neste, Europe's largest producer of renewable diesel, supplies biofuels to DHL, UPS, and Amazon Prime Air cargo companies.

ESG Practices by Companies

Environment Performances

Biodiesel companies offer low-intensive carbon fuels for the transport sectors. The biodiesel companies are now using low-carbon intensive feedstocks like used cooking oil. Large biodiesel manufacturers are committed to reducing carbon emissions using low-carbon intensity feedstocks, efficient processing methods, and waste recycling.

Table 38
Environment Performance of Biofuel Companies

ESG Metric	Example
Greenhouse Gas Emissions	HF Sinclair has committed to reducing its greenhouse gas emissions by 25% by 2030 from its 2020 level. Despite expanding its biofuel production plants, the company is making substantial progress toward its reduction goal.
Water Management	Renewable Energy Group (REG) biodiesel processes are less water-intensive. None of the company's production plants are located in a high-water stress area, and the company continuously monitors its usage and disposal of water.
Waste Management	In 2020, Eni developed Eni Rewind, a digitalization project to manage waste. Depending on the characteristics of the waste type, Eni Rewind selects recovery or disposal solutions, methods of treatment, and other criteria to reduce waste as much as possible.
Biodiversity	ADM is planning to be deforestation-free throughout its supply chain by 2025. The company plans to use a satellite monitoring system to trace deforestation throughout its supply chain. ADM has also partnered with local farmers and agronomy groups to restore soil health, maximize crop diversity, increase responsible nutrient input, and minimize soil erosion.

Source: BCC Research

Social Performance

Table 39
Social Performance of Biofuel Companies

ESG Metric	Example
Diversity and Inclusion	In Eni, more than 44% of the Board of Members are women, and more than 60% of the Board of Statutory Auditors, including the chair, are women.
Human Rights	REG is committed to international standards for human rights, and thus, the company avoids forced labor, underage labor, trafficking, and other human rights violations.
Labor Standards	HF Sinclair has a positive working relationship with local unions to form a collaborative working environment. In 2022, 26% of Sinclair's employees were represented by labor unions under collective bargaining agreements.
Employee Engagement	Neste often engages its raw material suppliers in open dialogue on sustainability issues in the supply chain. In 2022, the company engaged renewable raw material suppliers and sub-suppliers across Asia, America, and EMEA.

Source: BCC Research

Governance Performance

Governance practices in the biofuels industry typically involve ensuring transparency and accountability in the company's operations. This can include implementing ethical business practices, ensuring compliance with relevant laws and regulations, and establishing clear communication channels with customers, investors, and employees. Companies may also implement policies to ensure their supply chain's integrity and prevent corruption.

Table 40
Governance Performance of Biofuel Companies

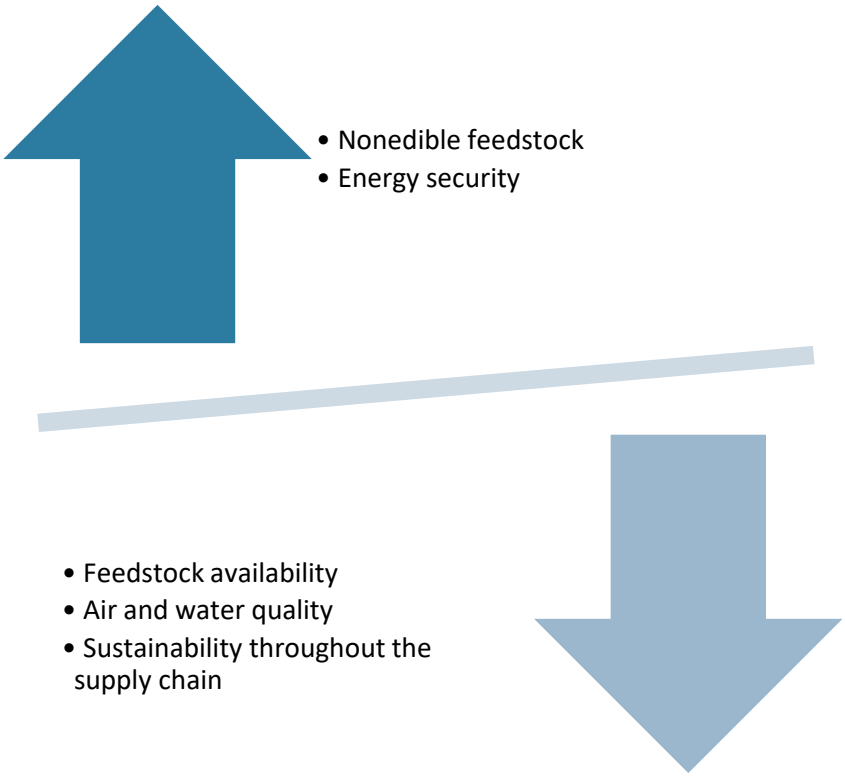
ESG Metric	Example
Board Composition	HF Sinclair has 12 board directors, with 42% representing diversity in gender and race.
Executive Compensation	REG's environment, health, and safety (EHS) are linked to executive variable pay.
Anti-corruption	ADM has an anti-corruption program aligned with a global anti-corruption policy to reduce corruption in its international business dealings. The company also trains its employees about corruption to avoid potential issues beforehand.
Shareholder Rights	ADM has developed an easy-to-access way to engage stakeholders to discuss valuable insights and topics. In 2022, it involved stakeholders via customer feedback, NGO inquiries, and shareholder dialogue.

Source: BCC Research

ESG Risks and Opportunities

Biodiesel companies have opportunities and risks in implementing ESG; the following figure depicts the risks and opportunities.

Figure 26
Opportunities and Risks in Implementing ESG



Source: BCC Research

Opportunities in Implementing ESG in Biodiesel Companies

Nonedible Feedstock

After the COVID-19 pandemic, biodiesel production increased, and most of the additional production came from renewable diesel production. According to the International Energy Agency (IEA), 70% of renewable diesel was made from waste and residue in 2021. Biodiesel production from used cooking oil is also increasing by companies. Developed countries are importing used cooking oil for biodiesel production, and China is taking advantage of the opportunities. Emerging economies have massive potential for used cooking oil, and collecting and exporting these feedstocks could be an excellent opportunity for companies.

There is an opportunity for the growth of other waste, like grease, municipal solid waste, etc., to increase. These feedstocks will not require any land, and carbon emissions will also be minimal compared to the current feedstock.

Energy Security

Biodiesel is the best alternative to reduce oil imports and attain energy security. Feedstock for biodiesel can be produced domestically, leading to increased energy independence. Once the biodiesel infrastructure and markets are well established, countries need not rely on oil imports, alleviating geopolitical risk linked with volatile regions. Also, the internally developed biodiesel sector would contribute to economic development by providing jobs and supporting local economies. Also, unlike fossil fuel resources, biodiesel feedstocks are renewable. That is, these resources will not be exhausted and can be produced again and again locally. Moreover, the biodiesel mandate and government support will result in a self-sufficient domestic market, thus reducing trade. According to the OECD, international biodiesel trade will decline from 13% to 11% by 2032.

Risks in Implementing ESG in Biofuel Companies

Feedstock Availability

Again, food crops (vegetable oils) hold the largest share as a feedstock in biodiesel production compared to waste and residue. According to BCC Research, vegetable oil will be the principal feedstock for the next five years despite the high CAGR of waste and residue-based biofuels. Other advanced biofuel feedstocks like algae and other microorganisms are yet to be commercially produced on a large scale. The availability of used cooking oil is currently limited as the market to collect and recycle UCO is yet to be developed, even in countries like the U.S. and the EU.

Air and Water Quality

In addition to increasing carbon emissions via deforestation, oilseed cultivation, crushing, pretreatment, and processing emit greenhouse gases like carbon and nitrous oxide. Also, applying nutrients and pesticides to crops during cultivation can decrease air and water quality.

Sustainability Throughout the Supply Chain

For a biofuel to be sustainable or environmentally friendly, the complete supply chain from land selection and crop cultivation to biofuel production must be sustainable, which is challenging. Despite good intentions, environmental harm can occur.

Case Study

ESG Performance of Valero: Driving Sustainable Innovation in the Biodiesel Industry

Introduction

Valero, the U.S.-based company, is an independent petroleum refiner. The company is also one of the leading producers of renewable diesel. In a joint venture with Darling Ingredients, the company formed Diamond Green Diesel Holding LLC, a renewable-diesel-producing company. The total renewable diesel capacity of the company is 1.2 billion gallons, making it the U.S.'s largest renewable diesel producer and the world's second largest. Valero has 15 refineries in the U.S., Canada, and the U.K.

Environmental Sustainability

Valero is highly committed to a zero-carbon future with high targets to reduce greenhouse gas emissions. Its initiative to reduce environmental impact includes the following:

- The company is targeted to reduce its refinery Scope 1 and 2 emissions by 100% by 2035.
- In 2021, the company invested over 70% of its growth capital in low-carbon projects.
- The company has developed a large-scale carbon capture and sequestration pipeline to store carbon from its eight ethanol plants.
- The company has so far invested $4.65 billion in low-carbon business.
- The company produces many other low-carbon fuels: Low-carbon hydrogen, renewable propane, renewable naphtha, fiber cellulosic ethanol, and sustainable aviation fuel (under development).
- Valero and Southwest Research Institute (SwRI) are developing a membrane to remove carbon dioxide from the exhaust tailpipe of a vehicle's engine. The company's tests resulted in a 90% reduction of carbon dioxide.
- Each year, the company captures around 1 million tons of carbon dioxide.
- The company uses naturally occurring bacteria to purify the wastewater before discharge. Through innovative technology, the company reuses the water 17 times before its final discharge. In 2021, 1.9 million gallons of water were repurposed.
- The company uses air readout technology and an air quality monitoring system to detect air emissions from the surroundings.
- The company uses an innovative technology, Roberoller Tankers, to increase its waste disposal efficiency. During 2010 to 2022, the company eliminated the need of around 5,700 over-the-road truck trips, disposed of 11,400 HDPE liners, and reduced the water use by more than 2.2 million gallons that would have been required for container washing.
- In 2021, the company recycled 96% of its refinery and 55% of hazardous waste.

Social initiatives

- The company maintains 99%-100% pay equity ratios for gender and minority status.
- Through a total wellness and rewards program, the company invests in employee health, well-being, and long-term financial security.
- In 2021, total people investment was $2.2 billion.
- Valero employees were allowed to voice their ideas and perspectives through virtual platforms.
- Women in executive leadership have increased from 11-15%; women as people leaders increased from 18-20%, and women as engineers have risen from 17-20%.
- The company offers supplier diversity programs and training to small businesses.

Governance and Transparency

- Valero has linked executive compensation with ESG and climate change metrics.
- The company is committed to combat money laundering. The company has accomplished this by being vigilant, looking for payment irregularities, and promptly reporting suspicious activity.

Outcomes

Valero is looking to reduce greenhouse gas emissions and create a zero-carbon society. The company produces renewable diesel using low-carbon intensive feedstock and many low-carbon fuels. The company has high carbon emission reduction targets and high investment in low-carbon fuels. The company supports research studies for innovative technologies for carbon emission reduction, and its solid filtration membrane is an excellent finding. Above all, the company believes renewable diesel is an affordable, simple, and immediate solution for carbon emission reduction.

Investments

Table 41
ESG Related Investments, by Valero

ESG-Related Investment ($ Billion)	Description
0.8	In 33 wind turbines with 50-megawatt capacity.
1.8	To produce renewable diesel in Marathon's refinery in Martinez, Calif.
4.6	Low-carbon businesses.

Source: BCC Research

Conclusion

Valero has invested more than $4 billion in many low-carbon businesses. The company has 1.2 million gallons of renewable diesel capacity produced from low-intensive carbon feedstocks like waste, residue, and used cooking oil, reducing up to 80% of carbon emissions. The company has also invested in sustainable aviation fuels (SAFs), which will begin production in 2025. Through these ethanol plants, the company reduces carbon emissions by 30%. Moreover, the company is reducing its carbon intensity via CCS projects. The company has planned to reduce carbon emissions by 100% through various measures. Thus, the company is investing in offering sustainable solutions.

Concluding Remarks from BCC

Though biodiesel is said to be a sustainable option and alternative for the transport sector, carbon emission during farming emits high carbon, and there are other environmental concerns in the biodiesel production process. In addition, maintaining sustainability throughout its supply chain is a challenging process. Amidst these concerns, companies like Valero are making efforts to become more sustainable by using waste materials for biodiesel production, increasing the use of other low-carbon fuels, and more. Using low-carbon feedstocks, the company addresses carbon emissions and other vital issues concerning biodiesel feedstocks, like food security, water pollution, soil erosion, and air pollution.

Chapter 10

Patent Analysis

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Chapter 10: Patent Analysis

Overview

A patent analysis shows companies from various segments are active in the patent space. While large companies such as Neste Oil, ExxonMobil, Shell, and Chevron have a strong presence in the market. Also, in June 2022, Chevron strengthened its position with the acquisition of Renewable Energy Group, Inc. (REG). REG is among the leading biodiesel producers, operates 12 biorefineries and feedstock processing facilities.

The top applicant for patents from 2021-2023 was Innospec Inc., an American specialty chemical company. The company has applied for 31 patents, followed by Neste with 26 patents, and The Fynder Group with 17. The Fynder Group is a food company that makes nutritional vegan protein from a microbe. Large oil companies that generally have a strong presence in the biodiesel market applied for patents are Neste, REG Synthetic Fuels, LLC, Shell, ExxonMobil, and Chevron Renewable Energy Group. Other than Innospec Inc., chemical companies that applied for patents are BASF (6 patents) and Afton Chemical (4 patents).

Table 42
Top Biodiesel Patent Applicants, by Assignee Company, 2021-2023
(Number)

Company	Number of Patents
Innospec Inc.	31
Neste Oyj	26
The Fynder Group	17
REG Synthetic Fuels, LLC	13
Iogen Corp.	10
Shell plc	9
POET, LLC	9
ICM Biofuels	9
Shell Research Ltd.	8
Auburn University	6
BASF Enzymes LLC.	6
RenFuel	5
Hull Partners Ltd.	5
ExxonMobil Corp.	5
Afton Chemical	4

Source: lens.org

Active patent documents from 2021-2023 are declined. The number of granted patents in 2021 was 1,149; in 2022, it was 846; at the time of writing, in 2023, it was around 654. In 2022, most patents were documented by the U.S. (3,186 patents) and Europe (only 439 patents).

Patents, by Major Biodiesel Companies

Some of the active patents by major companies are listed below:

Table 43
Major Active Patents on Biodiesel, 2021-2023

Patent No.	Expiration Date	Application Date	Publication Date	Patent Title	Company
US 11692148 B2	Nov. 2038	Nov. 2018	Jul. 2023	Preparation of a Fuel Blend	Neste Oyj
EP 3894523 B1	Nov. 2039	Nov. 2019	Jun. 2023	Diesel Fuel Composition	Neste Oyj
US 2023/ 0114439 A1	Jan. 2042	June 2022	Apr. 2023	Systems and Methods of Converting Renewable Feedstocks into Intermediate Hydrocarbon Blend Stocks and Renewable Transportation Fuel	Marathon Petroleum Company LP
US 11518950 B2	July 2037	Oct. 2021	Dec. 2022	Biodiesel Fuel Mixtures	Hull Partners LLC, Clean Fuels Alliance America
US 11414606 B1	Apr. 2040	Nov. 2019	Aug. 2022	System And Method For Producing Hydrothermal Renewable Diesel And Saturated Fatty Acids	Aduro Energy Inc.
US 2022/016993 4 A1	Nov. 2041	Nov. 2021	Jun. 2022	Marine Fuel Compositions	ExxonMobil Research and Engineering Co.
US 2021/037175 5 A1	Oct. 2039	Oct. 2019	Dec. 2021	Renewable Diesel	REG Synthetic Fuels LLC
US 11204271 B2	May 2039	May. 2039	Dec. 2021	Systems And Methods For Alternative Fuel Life Cycle Tracking And Validation	Immixt LLC, Gilbarco Inc
US 11162033 B2	Jun. 2038	Jun. 2018	Nov. 2021	Production Of Renewable Base Oil And Diesel By Pre-Fractionation Of Fatty Acids	Neste Oyj

US 11142701 B2	Jun. 2038	Jun. 2018	Oct. 2021	Process for the Production of Renewable Base Oil, Diesel and Naphtha	Neste Oyj
US 11365359 B2	Sept. 2040	Sept. 2018	Sept. 2021	Renewable Hydrocarbon Lighter Fluid	REG Synthetic Fuels LLC
EP 2055761 B1	Mar. 2028	Mar. 2008	Sept. 2021	Use Of Ca-Phenate In Lubricating Oil Compositions Comprising A Biodiesel Fuel	Chevron Oronite Company LLC
US 11078427 B2	May 2039	May 2019	Aug. 2021	Methods and Devices for Producing Biodiesel, Diesel-Range Hydrocarbons, and Products Obtained Therefrom	Renewable Energy Group, Inc.
US 10982159 B2	May 2038	May 2018	Apr. 2021	Method for Reducing the Content of Saturated Monoglycerides in a Raw Biodiesel	GEA Mechanical Equipment GmbH
US 10981784 B2	Apr. 2033	May 2018	Apr. 2021	Partially Renewable Transportation Fuel	Iogen Corp.
EP 2055762 B1	Mar. 2028	Mar. 2008	Apr. 2021	Lubricating Oil Compositions Comprising a Biodiesel Fuel and an Antioxidant	Chevron Oronite Company LLC
EP 3494201 B1	Aug. 2037	Aug. 2017	Mar. 2021	Purification of Feedstock by Heat Treatment	Neste Oyj
EP 3532581 B1	Oct. 2037	Oct. 2017	Jan. 2021	Lubricating Oil Compositions Comprising a Biodiesel Fuel and a Mannich Condensation Product	Chevron Oronite Tech B.V, Chevron Oronite Company LLC
US 2021/0071213 A1	Dec. 2027	Oct. 2020	Oct. 2020	Two-Stage Process for Producing Oil from Microalgae	Genifuel Corp.
US 11052379 B1	July 2040	July 2020	July 2020	Titania-Supported Mixed Metal Oxide Catalyst	King Saud University
US 11692148 B2	Nov. 2038	Nov. 2018	July 2023	Preparation of a Fuel Blend	Neste Oyj

Source: lens.org

Chapter 11

M&A and Venture Funding Outlook

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Chapter 11: M&A and Venture Funding Outlook

Mergers & Acquisitions

Oil and gas giants like BP, Shell, and Chevron participated in biodiesel merger and acquisition activities in 2022. The table below explains mergers and acquisition activities in the biodiesel market in 2022.

Table 44
PM&A Activities in Biofuel Industry, 2022 and 2023

Acquirer	Target	Industry	Capacity (MMgy)
BP p.l.c.	Green Biofuels Ltd.	Renewable Diesel	14.5
Canary Biofuels	Community fuels	Biodiesel	10
Cargill Inc.	Owensboro Grain	Biodiesel	54
CB Industrial Product Holdings Bhd (CBIP)	Gulf Lubes Malaysia Sdn Bhd (GLM)	Biodiesel	261
Chevron	REG	Renewable Diesel	470
Neste Oyj	Crimson Renewable Energy	UCO	NA
Neste Oyj	Walco Foods	Animal Fats	NA
Neste Oyj	Demeter	Renewable Diesel	NA
Shell	EcoOils Limited	Waste Oil Recycling	2.0
Motor Oil Hellas	Elin Verd	Biodiesel	2.5
St1 Nordic	Brocklesby	Renewable Diesel	NA
Community Fuels	Canary Biofuels	Biodiesel	NA
CoverCress Inc.	Bayer	Oilseed	NA
Desmet Ballestra Group N.V.	Alfa Laval	Edible Oil	NA

Note: NA=Not Applicable

Source: BCC Research (data gathered from company websites and other sites)

The major M&A deal was Chevron's acquisition of Renewable Energy Group (REG) with 470 million gallons capacity. The acquisition shows Chevron's interest in renewable diesel as it acquired REG for $3.15 billion. After acquiring REG, Chevron became one of the largest renewable diesel producers in the world.

Big oil companies like BP, Shell, Chevron, and ExxonMobil are investing in biodiesel as part of their decarbonization activity to reduce their carbon emissions. Oil companies have an advantage over non-oil and refining companies in biodiesel production, that is, easy integration of biofuel structure due to existing infrastructure. BP has a 30% stake in Green Biofuels, the U.K.'s largest renewable diesel producer. EcoOils Ltd was acquired by Shell to make low-carbon fuels, including sustainable aviation fuels. EcoOils recycles waste oil into biofuel feedstock. ExxonMobil acquired Norway-based biofuel company Biojet AS, whose share in Biojet AS was 49.9%. Biojet will produce biodiesel from wood waste and supply ExxonMobil with 3 million barrels annually.

Neste acquired a used cooking oil (UCO) aggregator from Crimson Renewable Energy Holdings LLC. Neste also acquired animal fats trader Walco Foods. In 2023, Neste acquired a 29% share of a company, Demeter B.V. Neste already holds a 59% share. Now, Neste holds 80% of the company. These three acquisitions strengthen Neste's raw material sourcing. These acquisitions have been mainly for feedstock investments.

The M&A activities in 2022 increased compared to 2021 and will likely increase further in 2023. Studies show that 2022 saw the highest number of transactions in the biodiesel industry.

Investments in Biodiesel

The International Energy Agency (IEA) reported that biofuel investments increased significantly in 2022, and the largest share of investments went to renewable diesel. Some of the major investments made in 2022-2023 are:

- Neste: In March 2022, Finland's Neste and American Marathon Petroleum developed a new project, Martinez Renewable Fuels, in California. Under this project, the companies aimed to produce 730 million gallons of renewable diesel per day by the end of 2023. Around $1.2 billion was invested in this 50-50 joint venture project.

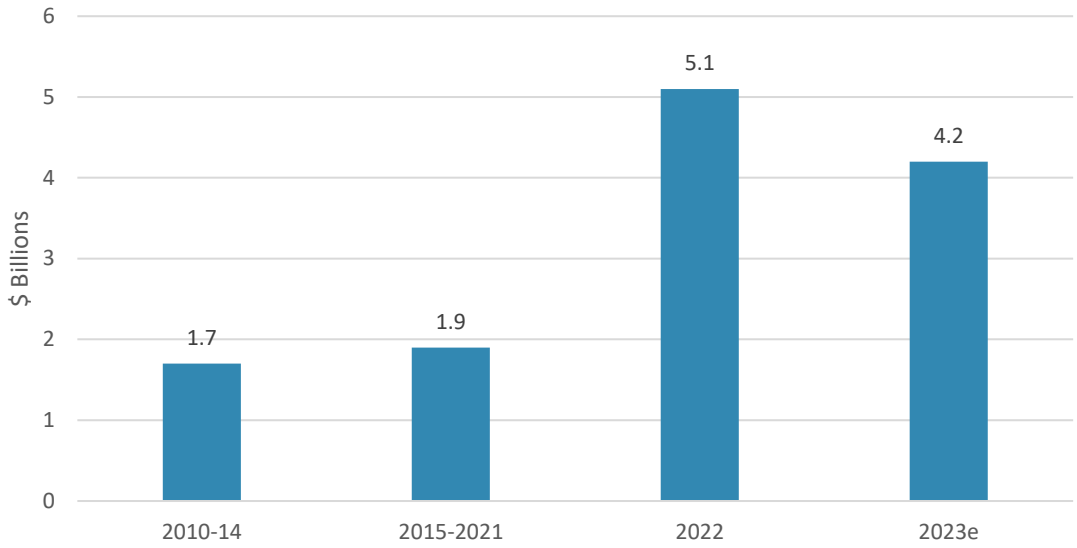
- Neste: The company invested around $1.8 billion to expand its Rotterdam renewable diesel facility, which has a total renewable diesel capacity of about 1.4 million tons annually in 2022. With the investment, the facility will get an additional capacity of 1.3 million tons per annum, totaling 2.7 million tons annually.

- Imperial Oil: In 2022, a Canadian energy company invested $0.72 billion to build Canada's largest renewable diesel facility. The facility's capacity is over 1 billion liters of renewable diesel daily. A significant portion of renewable diesel produced will be supplied to British Colombia, which supports the project.

- In September 2023, Japan-based Mitsui & Co announced that, in a joint venture with Portugal oil refining company Galp, the company agreed to invest in renewable diesel. The amount of the investment was not disclosed.

Region-wise, in 2021, the U.S. and Brazil constituted 30% of the total investment in liquid biofuels. In 2022, the U.S. will likely lead the growth in the biofuel sector due to its substantial fiscal incentives. The U.S. offers around $9.4 billion in financial support.

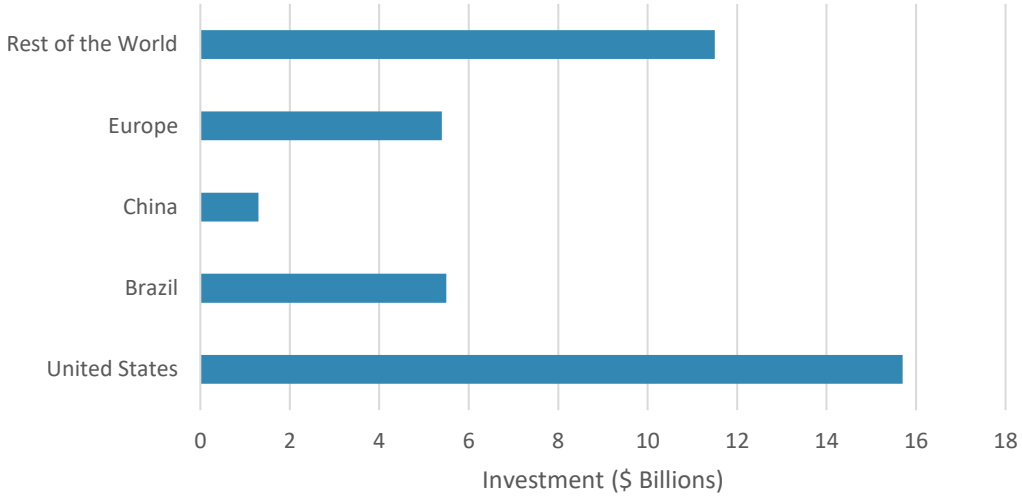
Figure 27
Average Annual Global Biodiesel Investments, 2010-2023 (Est.)
($ Billions)



Note: Values are approximate, e-estimated

Source: International Energy Agency (IEA)

Figure 28
Cumulative Investment, by Region, 2010-2022
($ Billions)



Note: Values are approximate

Source: International Energy Agency (IEA)

Investment in the biofuel market will be dominated by renewable diesel and sustainable aviation fuel. Solid policies and carbon emission reduction targets will drive these markets, especially in the airline sector.

Chapter 12

Competitive Intelligence

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Chapter 12: Competitive Intelligence

Competitive Landscape

The global biodiesel market has a large number of stakeholders. The fragmented market has many large and small players, suppliers, and distributors. The companies present in the market can be broadly segmented into the following categories:

- Biodiesel producers.
- Biofuel and renewable fuel producers.
- Large fossil fuel and diesel producers.
- Diversified producers and manufacturers.
- Key technology vendors with a presence in the biofuels space.

Large fossil fuel producers and diversified producers are expected to be the major players in the market. However, niche players in the biodiesel and biofuel space are expected to have stronger market knowledge and are often acquired by prominent players. The market also sees frequent new entrants, mainly in the biodiesel/biofuel or technology vertical.

Biodiesel Producers

These are niche companies, primarily small, with a local presence or presence in a particular continent. These companies' strong technological knowledge and customer base make them frequent acquisition targets. The companies generally are startups funded by venture capital and other financial bodies.

Some key companies in this space are:

- Ecodiesel Colombia SA.
- BIOD Energy (India) Private Ltd.
- Münzer Bioindustrie GmbH.
- Argent Energy.
- BioCube Corp.
- Crimson Renewable Energy LLC.
- Epitome Energy.
- FatHopes Energy.
- German Biofuels GmbH.
- RBF Port Neches LLC.
- Renewable Biofuels Inc.
- Western Dubuque Biodiesel LLC.

Biofuel and Renewable Fuel Producers

Biofuel and other renewable fuel producers are generally larger than the niche biodiesel producers. However, these companies are also among new companies. These companies are often characterized by their robust technology, market knowledge, and presence in multiple biofuels and alternative fuel verticals (bioethanol, biodiesel, biomass, HVO, etc.).

Some key companies in this space are:

- VERBIO Vereinigte BioEnergie AG.
- Chevron Renewable Energy Group.
- World Energy.

Large Fossil Fuel and Diesel Producers

These are generally among the largest companies in the biodiesel market. These companies are well established with a vast global presence. The companies in this space also have solid financials, which makes them capable of acquiring other companies, especially niche biodiesel and biofuel producers. Some large oil and gas companies in this space have no production facility but have partnered with biodiesel or biofuel manufacturers, including through investments.

Some key companies in this space are:

- Neste Oyj.
- Eni S.p.A.
- HF Sinclair Corp.
- Valero.
- ExxonMobil.
- BP Plc.
- Shell.
- Marathon Petroleum.

Diversified Producers and Manufacturers

These are also among the largest companies in the biodiesel market. These companies are often in adjacent industry verticals such as chemicals, metal and mining, food and food processing, agribusiness, fossil fuel, and related verticals. Like large fossil fuel companies, these companies are characterized by solid financials, vast geographic presence, and established customer bases. These companies acquire niche players to strengthen their technology presence and establish a footprint in niche verticals.

Some key companies in this space are:

- Aemetis Inc.
- The Archer-Daniels-Midland Co.
- Avril Group.
- Cargill Inc.
- China Clean Energy, Inc.
- Emami Agrotech Ltd. (EAL).
- FutureFuel Corp.
- INEOS Group Ltd.
- Louis Dreyfus Co.
- Manuelita S.A.
- Wilmar International Ltd.

Key Technology Vendors in the Biofuel Space

These companies often have a solid presence in the production technology space. These companies are characterized by their technology focus and often hold the most patents in the biodiesel and broader biofuel market.

Some key companies in this space are:

- Springboard Biodiesel.
- Alfa Laval Ageratec.
- GlobeCore GmbH.
- Ador Green Energy Pvt. Ltd.
- Biofuel Systems.
- Crown Iron Works.
- BDI-BioEnergy International GmbH.

Market Share Analysis

As of 2022, the U.S. and the EU constitute the world's biodiesel production market. Some of the largest biodiesel companies in the market are:

- Neste Oyj.
- ENI S.p.A.
- ADM.
- Chevron Renewable Energy Group.
- Cargill Inc.
- Verbio.
- HF Sinclair Corp.
- Valero.
- Marathon Petroleum.
- Aemetis Inc.

These companies comprise 60% of the global biodiesel market in revenue.

Table 45
Largest Biodiesel Producers in the U.S., as of January 2023
(Million Gallons/% Share)

Company	Annual Nameplate Capacity (Million Gallons)	% Share
Renewable Energy Group (REG)	432	21
AG Processing Inc.	193	9
Cargill Inc.	161	8
RBF Port Neches LLC	144	7
Louis Dreyfus Agricultural Industries LLC	99	5
ADM	85	4
Paseo Cargill Energy LLC	70	3
Incobrasa Industries Ltd.	62	3
FutureFuel Chemical Company	60	3
Owensboro Grain Biodiesel LLC	56	3
Deerfield Energy LLC	50	2
Mid-America Biofuels LLC	50	2
Lake Erie Biofuels LLC	45	2
Western Iowa Energy LLC	45	2

Source: BCC Research

Chevron Renewable Energy Group (REG) is the largest biodiesel producer in the U.S., with five biodiesel facilities. AG Processing has two biorefineries and is the second largest producer. The top four companies in the above list have 45% of the U.S. biodiesel production capacity share.

In biodiesel production, the EU constitutes the largest market in the world, with a 30.7% share. Europe was also the early adopter of renewable or hydrogenation-derived renewable diesel (HDRD). In the EU, Neste is the largest commercial producer of renewable diesel. UPM, Eni, Preem, etc. are other largest commercial producers. Like Neste, other companies planning to extend their renewable diesel facilities in the EU soon are UPM (640 million liters) and Shell (1 billion liters).

Table 46
Largest Renewable Diesel Producers in EU
(Million Liters)

Company	Annual Capacity (Million Liters)
Neste Oyj.	215
UPM	115
Eni S.p.A.	325
Preem	220
St1 Oy	250
TotalEnergies SE	640
Galp	35

Source: BCC Research

Strategic Analysis

Various strategies adopted by biodiesel companies are product diversification, collaboration and expansion, and technological advancements, among others.

Diversified Feedstocks

Today, vegetable oil dominates the biodiesel feedstock sector, and though this will continue for the next five years, companies are also looking to diversify their feedstocks. Most companies are shifting to waste-based feedstocks as these feedstocks cost less and are in line with the U.S. and EU biodiesel policy objectives. Companies have already started producing biodiesel from some of the wastes like used cooking oil and animal fat waste. They also explore other wastes like municipal solid waste, grease, and wastewater as long-term options. For example, Neste is investigating novel vegetable oil, acid oils, palm oil mill effluent, and brown greases (wastewater-derived greases from restaurant kitchens) as short- to mid-term feedstocks. It investigates other wastes like unused plastics, crop waste, municipal solid waste, algae, etc., as mid- to long-term options.

Technological Advancement

Companies are investing in research on algae-based biodiesels. Companies are evaluating algae-based biofuels via aerobic and anaerobic methods. Eneos and Honda Motors have joined 35 Japanese companies, including half a dozen chemical companies, in an initiative, Matsuri (Microalgae Towards Sustainable and Resilient Industry), to convert algae into sustainable aviation fuel. Under the initiative, algae are being cultivated on a 5-hectare farm in Malaysia. Companies are planning to expand the cultivation in later stages. Following feedstock cost, pretreatment cost contributes to the cost of biodiesel production. In this regard, various technological advancements are also happening in the

pretreatment process. For instance, Neste has developed a unique approach, NEXBTL, which will turn any raw material into biofuels.

Collaboration and Expansion

Prominent biofuel players are constantly involved in capacity expansion via acquisition, retrofitting, or construction. The companies also join various associations and government organizations to produce large-scale biodiesel.

Product Diversification

Biodiesel production is a cost-intensive process. Most biodiesel costs are incurred by feedstock and affect the margin of biodiesel producers. As most vegetable oils used for biodiesel production are also food crops, a massive demand for the product affects the cost. In 2022, the low supply of vegetable oils due to the Russia-Ukraine war and droughts affected the price of these feedstocks. Byproduct production, along with biodiesel, is found to increase the margin of biodiesel companies. Companies are adopting strategies to earn from biodiesel byproducts. Companies are also exploring innovative processes to produce biobased products for other industries.

Vertical Integration

Major companies producing biodiesel are agritech, chemical, and oil refining companies. Refining companies have an advantage in biodiesel production. They vertically integrate with dedicated biodiesel companies and benefit from the growing market. This strategy helps the companies take control of both the raw material supply and biofuel distribution market.

Above all, the main strategies that help biodiesel companies succeed in the market would be:

- Gaining access to an ample supply of feedstock. This will enable companies to sell biodiesel at competitive prices.
- Strong government support and relationships could be advantageous as the biodiesel market is policy-driven.
- Establishing smooth and strong relationships with local farmers, associations, and agriculture organizations will lead to smooth and continuous feedstock supply and, hence, the operation.

Chapter 13

Company Profiles

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Chapter 13: Company Profiles

Introduction

The biofuels industry includes thousands of companies ranging from the world's largest multinational corporations with broad agricultural activities to farmer-owned cooperatives that manufacture fuel and value-added byproducts for a tiny regional base. Several highly profitable companies are engaged in biodiesel production. Neste, Chevron Renewable Energy Group, Cargill, and Archer Daniels Midland are among the largest.

Food and agricultural firms are part of the biofuel supply chain. Europe is the largest biodiesel producer, and cereal and vegetable oil manufacturers are often biofuel producers. Biodiesel production worldwide is tied to growers and processors of vegetable oils—rapeseed, soybean, sunflower, and palm—and businesses and institutions that generate waste oils and fats.

Company Profiles

AG PROCESSING INC.

12700 W. Dodge Rd.
Omaha, NE 68154
United States
Tel: 1-402-496-7809
Website: www.agp.com

Company Snapshot

Table 47
Ag Processing Inc.: Company Snapshot

Parameter	Information
Ticker	0576803D:US
Founded/Incorporated Year	1983
Headquarter	The U.S.
Revenue 2022 ($ Millions)	Not available
Strongest Business Region/Country	The U.S.
Number of Employees (2022)	1,100 (as of December 2022)
Key Geographies	The U.S., International
Market Focused Business Segment	Not available
Entity Type	Private
Ownership Type	Parent

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Ag Processing Inc. (AGP), founded in 1983 and headquartered in the U.S., is a leading agribusiness company procuring, processing, marketing, and transporting oilseeds, grains, and related products, including soybean biodiesel. The company's businesses include soybean processing, vegetable oil refining, renewable fuels, and Ag products/grain marketing. The company's primary business is soybean processing, and it operates ten soybean cooperative processing plants in Iowa, Minnesota, Missouri, Nebraska, and South Dakota, as well as four soybean oil refineries and three biodiesel production facilities. The company's biodiesel product is marketed under the name SoyGold.

Key Highlights

- AGP is the second-largest FAME biodiesel producer in the U.S. and has a strong presence in the U.S., the world's largest soybean oil-based biodiesel market, and Canada.
- The company has three biodiesel production plants (Algona, Iowa; Sgt. Bluff, Iowa; and St. Joseph, Mo.) with a combined annual capacity of 175 million gallons.
- SoyGold Biodiesel has a blend rate of 2% to 20% blend.
- Although the company seems to have low soybean oil-based biodiesel export, it has international representatives (for its soybean export) in China, Taiwan, Mexico, Philippines, Slovakia, Turkey, and Vietnam, which it can capitalize on to expand its biodiesel presence.

News and Key Developments

Table 48
Ag Processing Inc.: News, 2021-2023

Year	Strategy	Development
2023	Expansion	AGP is building a new soybean processing facility in David City, Nebraska. This will expand its soybean-crushing capacity by 15%. The new plant is expected to be operational by 2025.
2022	Expansion	The company expanded and upgraded its port facilities in Aberdeen's Grays Harbor Export Terminal port. The development included an additional storage facility at Terminal 2 and the addition of a state-of-the-art ship loader in Terminal 4.
2021	Expansion	The company invested $72 million to expand its Iowa soybean crushing plant. The project was completed in 2023 fall. The state gave a $1.5 million grant for the expansion project.

Source: Company website

ESG Trends
Not available.

ARCHER DANIELS MIDLAND CO. (ADM)

2229 San Felipe St.
Houston, TX 77019
United States
Tel: 1-713-386-2600
Website: www.adm.com/en-us

Company Snapshot

Table 49
Archer Daniels Midland Co. (ADM): Company Snapshot

Parameter	Information
Ticker	NYSE: ADM
Founded/Incorporated Year	1902
Headquarter	The U.S.
Revenue 2022 ($ Millions)	101,556
Strongest Business Region/Country	The U.S.

Number of Employees (2022)	42,001 (as of December 2022)
Key Geographies	The U.S., Switzerland, Cayman Islands, Brazil, Mexico, Canada, The U.K., Other Foreign
Market Focused Business Segment	Ag Services & Oilseeds
Entity Type	Public
Ownership Type	Parent

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Founded in 1902, Archer Daniels Midland Co. (ADM) is an agricultural processor and food ingredient provider in the U.S. The company has evolved as a significant player in the biofuel industry. The company produces biodiesel and ethanol. ADM produces biodiesel using a transesterification process using vegetable oil as feedstock. Its biodiesel plants are in the U.S., the EU, Brazil, and Canada. Ethanol is made using corn as a primary feedstock. The company operates multiple ethanol production facilities in Columbus, Neb.; Cedar Rapids, Iowa; and a complex in Decatur, Ill. ADM signed an MOU with Gevo, a biofuel company, to produce Sustainable Aviation Fuel (SAF) from the ethanol produced in its facilities.

Key Highlights

- As a decarbonization initiative, the company has decided to convert 900 million gallons of ethanol into SAF. The company has also signed agreements for CO_2 pipelines for carbon capture and sequestration.
- In 2022, ADM achieved a 58% increase in operating profit in the oilseed business segment compared to 2021.
- In Q4 2022 earnings, North America's growing domestic demand for renewable diesel contributed to the company's substantial margin.
- The company's capacity to meet global biodiesel demand and the U.S. renewable diesel demand resulted in a significantly high Remaining Performance Obligation (RPO) year after year.

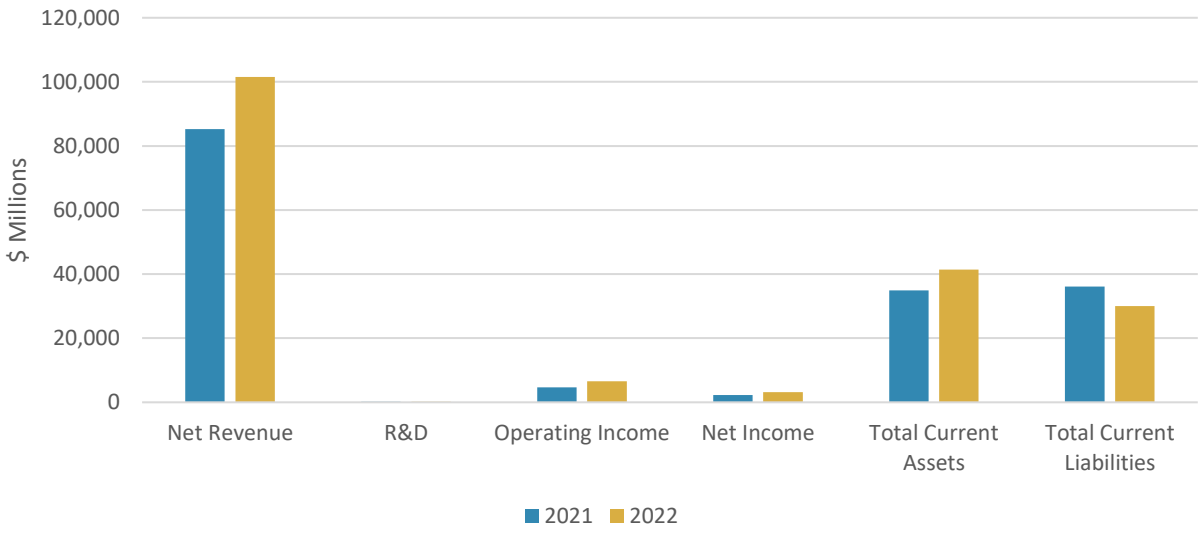
Financials: Revenue

Table 50
Archer Daniels Midland Co. (ADM): Annual Revenue, 2022
($ Millions)

Financials	Revenue ($ Millions)
Net Revenue	101,556
R&D	216
Operating Income	6,549
Net Income	3,140
Total Current Assets	41,407
Total Current Liabilities	30,002

Source: Company annual report

Figure 29
Archer Daniels Midland Co. (ADM): Annual Revenue, 2021 and 2022
($ Millions)



*Note: The bar chart of R&D for 2021 and 2022 is not visible because the number of these segments is minimal, as given in the above table.

Source: Company annual report

News and Key Developments

Table 51
Archer Daniels Midland Co. (ADM): News, 2021-2023

Year	Strategy	Development
2023	Joint Venture	ADM and Marathon Petroleum have joined together and built a new soybean crushing facility in North Dakota. The facility is expected to come online in 2023 to produce soybean oil as a feedstock for renewable diesel. The facility's capacity is 150,000 bushels per day.
2022	Product Announcement	ADM announced that by 2026, the company will commercialize sustainable aviation fuel (SAF). The company sees an opportunity to convert its 900 million gallons of ethanol into about 500 million gallons of SAF.
2021	Grants	The U.S. Department of Energy Bioenergy Technologies Office for biofuels research granted $3.4 million to the ADM company for its research on bioprocessing separation technology, a process in biofuel conversion. This grant is part of the U.S. government's total fund of $64.7 million for producing low-cost, low-carbon fuels for airplanes and ships.

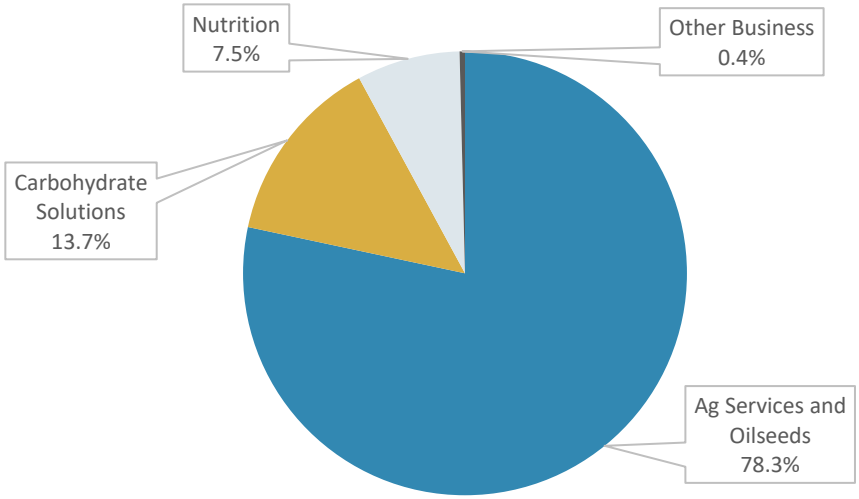
Source: Company website

ESG Trends

As per Sustainalytics, ADM's ranking in the food products group is 257 out of 624 industries, and the ESG rating is around 31.8, which is a high risk.

Product Financials: Revenue

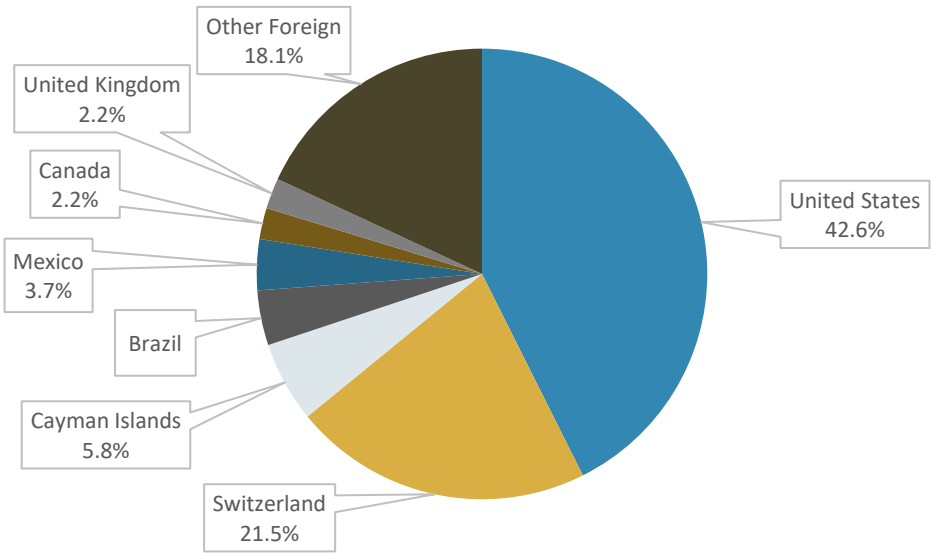
Figure 30
Archer Daniels Midland Co. (ADM): Revenue Share, by Business Unit, 2022 (%)



Source: Company annual report

Regional Financials: Revenue

Figure 31
Archer Daniels Midland Co. (ADM): Revenue Share, by Country, 2022
(%)



Source: Company annual report

ARGENT ENERGY

Alford House
Lloyd Drive
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Ellesmere Port, CH65 9HQ
United Kingdom
Tel: +44 (0) 151 318 2610
Website: www.argentenergy.com

Company Snapshot

Table 52
Argent Energy: Company Snapshot

Parameter	Information
Ticker	TSX: AET_u
Founded/Incorporated Year	2001
Headquarter	The U.K.
Revenue 2022 ($ Millions)	Not available
Strongest Business Region/Country	Europe
Number of Employees (2022)	Not available
Key Geographies	Not available
Market Focused Business Segment	Not available
Entity Type	Private
Ownership Type	Subsidiary

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Argent Energy, founded in 2001 and headquartered in the U.K., operates a multi-feedstock biodiesel plant. The company produces biodiesel from animal fat, uses cooking oil and other waste for transportation, and has an annual production capacity of around 250,000 tons. The company uses waste materials only as feedstock for biodiesel and is looking for ways to convert any waste into biodiesel. The company has three biodiesel production facilities:

- In Scotland, the company has a production capacity of 55,000 tons. The primary feedstock is animal fats.
- Stanlow has a production capacity of 95,000 tons.
- In Amsterdam, the company produces 100,000 tons of waste-based biodiesel.

Key Highlights

- Argent Energy U.K. also supplies biodiesel for blending with mineral diesel. The company delivers standard diesel, B20, and other high blends up to B100 (pure biodiesel).

- The company uses used cooking oil and animal fat as feedstock, and both these segments are witnessing strong growth relative to other segments.

- Apart from the U.K., the company has a presence in the EU and the U.S. through oil companies and fuel suppliers.

News and Key Developments

Table 53
Argent Energy: News, 2022 and 2023

Year	Strategy	Development
2023	Product Diversification	In July 2023, Argent Energy's biodiesel was successfully trialed by a Dutch maritime logistic company, VT Group. The biodiesel was used as a fuel with minimal technical adjustments. The company reported a reduction of 85% in carbon emissions with biodiesel.
2022	Feedstock Innovation	Wastewater treatment company Eco-Clarity has developed a patented technology that separates fats, oil, and greases (FOG) from wastewater and converts them into a biodiesel feedstock. Argent Energy has set up an Eco-Clarity Waste Conversion Hub in its Stanlow facility. In 2022, the company produced its first ton of biodiesel from wastewater.
2022	Joint Venture	Argent Energy signed a joint venture with Virgin Voyages, a Florida-based cruise line, to supply biodiesel as a fuel. Voyage Virgin will only use biodiesel from feedstock certified as waste by the European RED scheme. Argent Energy's biodiesel will be used as a drop-in fuel by Voyage Virgin to decarbonize the marine sector.

Source: Company website

ESG Trends
Not available.

AVRIL GROUP

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75378 Paris, Cedex 08
France
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Website: www.groupeavril.com

Company Snapshot

Table 54
Avril Group: Company Snapshot

Parameter	Information
Ticker	FR0010945360.PA
Founded/Incorporated Year	1983
Headquarter	France
Revenue 2022 ($ Millions)	9,860
Strongest Business Region/Country	Europe
Number of Employees (2022)	7,367 (as of December 2022)
Key Geographies	France, The U.S., Other European Countries
Market Focused Business Segment	Avril Oilseed Processing and Renewable Energies
Entity Type	Public
Ownership Type	Parent

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Avril Group, founded in 1983 and headquartered in France, is a sizeable agro-industrial group specializing in human nutrition, animal nutrition, renewable chemistry, and renewable energy. The company was formerly known as Sofiproteol and became Avril Group in 2015. Avril Group's subsidiaries, Expur and Saipol, produce biodiesel from rapeseed and sunflower seeds. The company's biodiesel is marketed under the brands Diester and Oleo100. Oleo100 is B100 fuel, which can completely replace fossil diesel. This is produced using rapeseed as a feedstock.

From 2010-2021, the company was involved in the BioTfueL project in partnership with Axens, CEA, IFP Énergies nouvelles, Thyssenkrupp Industrial Solutions, and TOTAL Energies. The project involved the development of technology for converting second-generation feedstocks into biodiesel. The project successfully converted 3,200 tons of plants into biodiesel.

Key Highlights

- Seven percent of Diester biodiesel is used in all diesel vehicles in France.
- The company has partnered with truck manufacturers Volvo, Scania, and Renault to use its Oleo 100 biodiesel.
- In May 2021, the company experimented with its Oleo100 with a river transport company, Sogestran Group's subsidiary, CFT.

- Since April 2021, trains on Paris-Granville have been running on Oleo100 biodiesel, and in 2023, the train covered a distance of 3.5 million kilometers. This action has reduced carbon emissions by 11,000 tons and nitrogen oxide particles by 50%. Since April 2021, trains on the Paris-Granville line have been only using Oleo100 biodiesel, the first passenger train in France to run on 100% biodiesel and avoid 11,000 tons of carbon emissions.

News and Key Developments

Table 55
Avril Group: News, 2022 and 2023

Year	Strategy	Development
2023	Expansion	In April, Avril Group plans to double the production of Oleo 100 biodiesel capacity and aims to power fleet trucks rather than cars with its Oleo 100 biodiesel. This is because the company wants to focus on higher-margin Oleo fuel instead of blending biodiesel with fossil fuel. Out of 1 million tons of biodiesel produced on average in France, the company planned to use 200,000 tons for Oleo100. In 2021, 40,000 tons of Oleo100 were used.
2022	Expansion	The company announced its plan to increase its sunflower seed crushing facility in France in April. The company planned to process more than one million tons of sunflower seed. It was decided to reduce its dependence on imports from the Black Sea.
2021	Product Launch	In July 2021, the company conducted an Oleo100 experiment with rail freight company Getlink's subsidiary, Europorte, in a natural condition. The company found that with Oleo100, 35 tons of carbon emissions could be avoided weekly.

Source: Company website

ESG Trends
Not available.

CARGILL INC.

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Website: www.cargill.com

Company Snapshot

Table 56
Cargill Inc.: Company Snapshot

Parameter	Information
Ticker	CARG.N0000:CSE
Founded/Incorporated Year	1865
Headquarter	The U.S.
Revenue 2022 ($ Millions)	177,000
Strongest Business Region/Country	Not available
Number of Employees (2022)	More than 160,000 (as of December 2023)
Key Geographies	Not available
Market Focused Business Segment	Not available
Entity Type	Public
Ownership Type	Parent

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Cargill is an American multinational corporation that engages in the processing of agricultural products, commodities trading, and provision of food products. Cargill has been involved in the production of biofuels since the early 2000s. Cargill is the third-largest FAME biodiesel manufacturer in the U.S. As of January 2022, the company's total biodiesel capacity was 146 million gallons.

The company recently completed its first advanced biodiesel plant in Ghent, Belgium. The facility converts residues and waste oils into renewable fuel. The company has invested $150 million in the facility, one of Europe's most extensive waste-to-biofuels facilities that will produce 115,000 tons of advanced biofuels annually.

Cargill's biofuel production primarily focuses on using soybean oil as a feedstock. However, the company is also exploring using other feedstocks, such as all types of waste oils, cooking oils, grease, and residues from edible oil production. Cargill is also investing in research and development to improve the efficiency and sustainability of its biofuel production processes. The company is trailing renewable fuel/fuel oil blending up to 30% in the Netherlands to reduce carbon emissions. As of June 2022, the company has conducted 16 trials.

Key Highlights

- Cargill's shipping subsidiary, Cargill Ocean Transportation, plans to increase its use of biofuels in vessels to 50,000 tons by the middle or end of 2023.
- In 2022, the company achieved a 58% increase in operating profit in the oilseed business segment compared to 2021.
- In Q4 2022 earnings, North America's growing domestic demand for renewable diesel contributed to the company's substantial margin.
- The company's capacity to meet global biodiesel demand and the U.S. renewable diesel demand resulted in a significantly high RPO year after year.

News and Key Developments

Table 57
Cargill Inc.: News, 2021-2023

Year	Strategy	Development
2023	Partnership	Since the beginning of 2022, Cargill has been testing biofuels to power its vessels. In this regard, in December 2022, Cargill partnered with a Japanese ship-building company, Mitsui and Tsuneishi, to build Kamsarmax vessels, medium-sized ships with a holding capacity between 80,000 and 85,000 DWT. Methanol produced by Cargill will power the ship.
2022	Partnership	Heartwell Renewables is a renewable diesel-producing company formed by the joint venture between Cargill and The Love's Family of Companies, a private company in the U.S. In November 2022, the two companies hosted a groundbreaking ceremony to build Hastings's renewable diesel processing facility. The facility will use beef fat and grease as feedstock to produce biodiesel. The company claims that using beef as feedstock is less carbon-intensive than soybean, its usual feedstock.
2021	Expansion	Cargill has invested $475 million to expand its soybean crushing facilities in different states in the U.S. The processing capacity in its Iowa plant will be increased by 10%, and its Sydney, Ohio facility will double its capacity. The expansion is planned to meet the increasing demand for biofuels. The projects are expected to be completed in five years.

Source: Company website

ESG Trends

As per Sustainalytics, Cargill's ranking in the food products group is 602 out of 624 industries, and the ESG rating is around 48.4, which is a high risk.

CHEVRON RENEWABLE ENERGY GROUP

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Tel: 1-515-239-8000
Website: www.regi.com

Company Snapshot

Table 58
Chevron Renewable Energy Group: Company Snapshot

Parameter	Information
Ticker	N/A
Founded/Incorporated Year	2022
Headquarter	The U.S.
Revenue 2022 ($ Millions)	246,252
Strongest Business Region/Country	The U.S.
Number of Employees (2022)	Not available
Key Geographies	The U.S. and International
Market Focused Business Segment	Upstream
Entity Type	Private
Ownership Type	Subsidiary

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Chevron, one of the world's leading oil and gas companies, acquired Renewable Energy Group (REG), a biodiesel and renewable diesel-producing company, in 2022. The REG company is now known as Chevron Renewable Energy Group. The company has 11 biorefineries in the U.S. and the EU. Ten biorefineries produce biodiesel, and one produces renewable diesel. The company's nameplate capacity is 470 million gallons per year. As of January 2022, the company had 432 gallons of FAME biodiesel. The company plans to increase its renewable fuel capacity to 100,000 barrels per day by 2030. UltraClean BlenD is the company's patented fuel that combines the company's renewable diesel and biodiesel. The company also produces other products like bio-residual oil, glycerin, renewable naphtha, and renewable propane.

The company's biofuel processing technology is unique; it uses multiple feedstocks, especially hard-to-process feedstocks like distillers, corn oil, rendered animal fat, and used cooking oil. Sixty-nine percent of feedstocks are from waste and residual streams.

Key Highlights

- The sale of its proprietary fuel UltraClean BlenD increased by 58% in 2021 compared to the previous year.
- The fuel produced by the company reduced carbon emissions to 4.1 million metric tons for the whole year.
- The company earned $3.2 billion by selling 621 million gallons in 2021.
- Seventy-eight percent of the company's feedstock was from waste and residual streams. Twenty-two percent was from vegetable oils, soybeans, or canola oil.

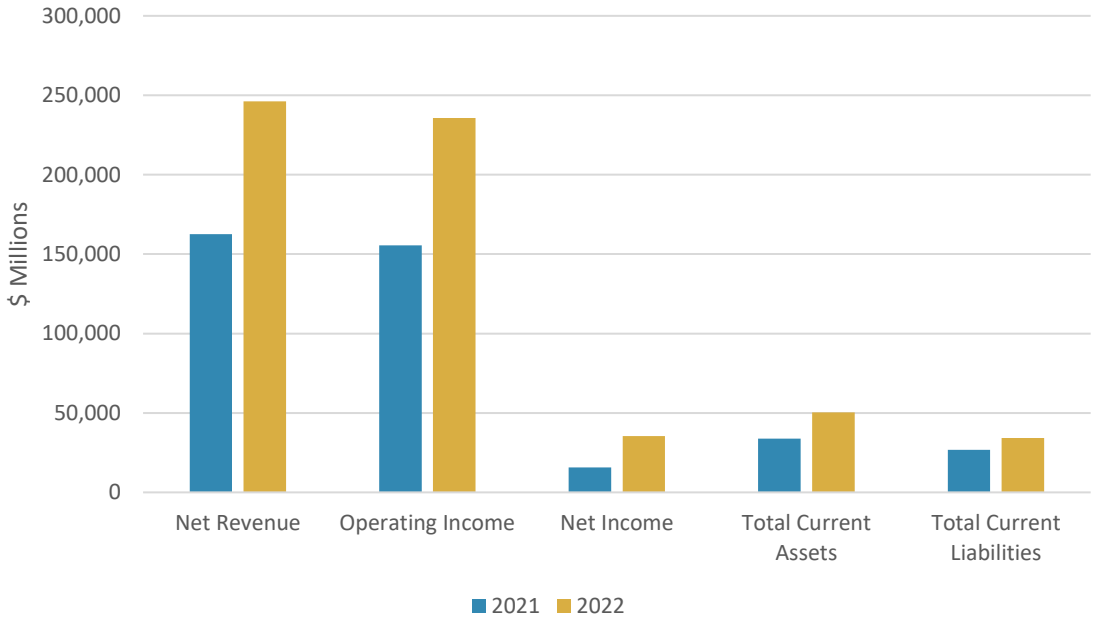
Financials: Revenue

Table 59
Chevron Renewable Energy Group: Annual Revenue, 2022
($ Millions)

Financials	Revenue ($ Millions)
Net Revenue	246,252
Operating Income	235,717
Net Income	35,465
Total Current Assets	50,343
Total Current Liabilities	34,208

Source: Company annual report

Figure 32
Chevron Renewable Energy Group: Annual Revenue, 2021 and 2022
($ Millions)



Source: Company annual report

News and Key Developments

Table 60
Chevron Renewable Energy Group: News, 2022

Year	Strategy	Development
2022	Expansion	Renewable Energy Group (REG) held a groundbreaking ceremony on August 27 for the expansion of its German biorefinery. The new facility will have a pretreatment system enabling the company to use a wider variety of feedstock for biodiesel production. The facility will be using low-carbon, third-generation feedstock.
2022	Partnership	REG collaborated with North America's leading commercial fleet fueling networks, CFN and Pacific Pride, to offer their biofuels. This collaboration will enable REG to distribute cleaner fuels for fleets across North America.
2022	Acquisition	REG acquired a fuel distributor, Dawson Oil Company, in Northern California. The Dawson Oil Company sells 24 million gallons of biofuels annually for REG. The Dawson company serves 4,500 customers and will sell REG's brand EnDura Fuels to industrial, government, and agricultural fleets across the northern California market.

Source: Company website

ESG Trends

According to Sustainalytics, Chevron Renewable Energy Group's ranking in the oil and gas producers' group is 74 out of 307 industries, and the ESG rating is around 36.8, a high risk.

Marketed Products and Offerings

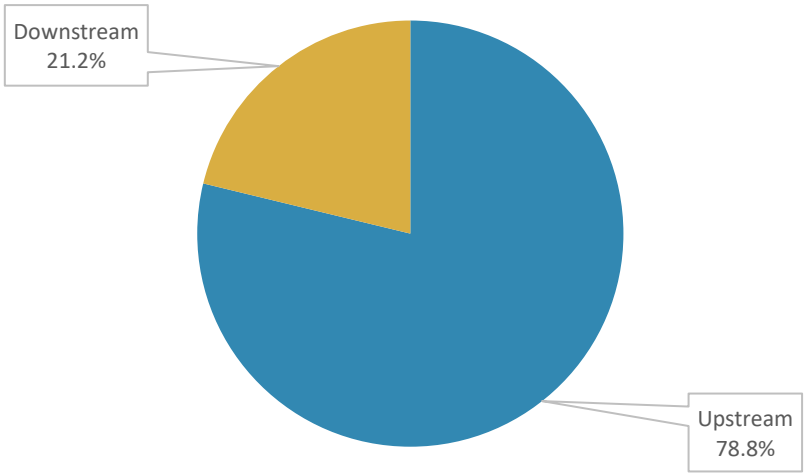
Table 61
Chevron Renewable Energy Group: Biofuel Product Portfolio

Brands	Product
Beyond	Sustainable Aviation Fuel
InfiniD	Biodiesel
PuriD	Biodiesel
VelociD	Renewable Diesel
UltraClean BlenD	Renewable Fuel

Source: Company website

Product Financials: Revenue

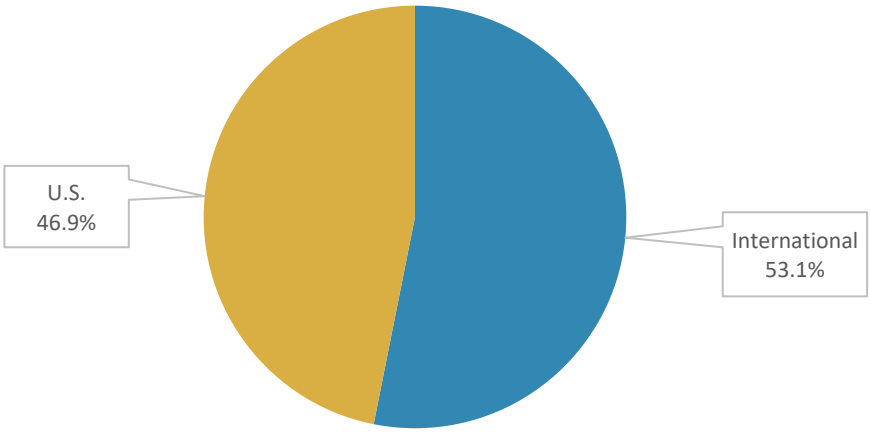
Figure 33
Chevron Renewable Energy Group: Revenue Share, by Business Unit, 2022 (%)



Source: Company annual report

Regional Financials: Revenue

Figure 34
Chevron Renewable Energy Group: Revenue Share, by Country/Region, 2022 (%)



Source: Company annual report

ENI S.P.A.
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00144 Rome
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Tel: +39-06 598 21
Website: www.eni.com

Company Snapshot

Table 62
ENI S.p.A.: Company Snapshot

Parameter	Information
Ticker	BIT:ENI
Founded/Incorporated Year	1953
Headquarter	Italy
Revenue 2022 ($ Millions)	139,541.6
Strongest Business Region/Country	Italy
Number of Employees (2022)	32,188 (as of December 2022)
Key Geographies	Italy, Other European Union, Rest of Europe, Africa, Asia, Americas, Other Areas
Market Focused Business Segment	Refining & Marketing and Chemicals
Entity Type	Public
Ownership Type	Parent

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Eni is an integrated energy company involved in oil and gas extraction, electricity generation from renewable resources and cogeneration, biorefining, and the circular economy process. The company operates in 62 countries, producing biodiesel from waste and non-food-based crops. The company stopped using palm oil for biofuel production in October 2022.

The company's biofuel capacity is reported to increase by 3 million tons per annum by 2025, driven by initiatives in Italy, Malaysia, and the U.S., with a production of biojet up to 0.2 million tons by 2026. The company has signed an agri-bio feedstock deal with Mozambique, Benin, Rwanda, Kenya, Congo, Angola, Kazakhstan, and Ivory Coast for continuous feedstock supply.

Key Highlights

- The company aims to increase its biofuel capacity by over five million by 2030.
- In 2022, the company obtained around $700 million from selling biofuels (HVO).

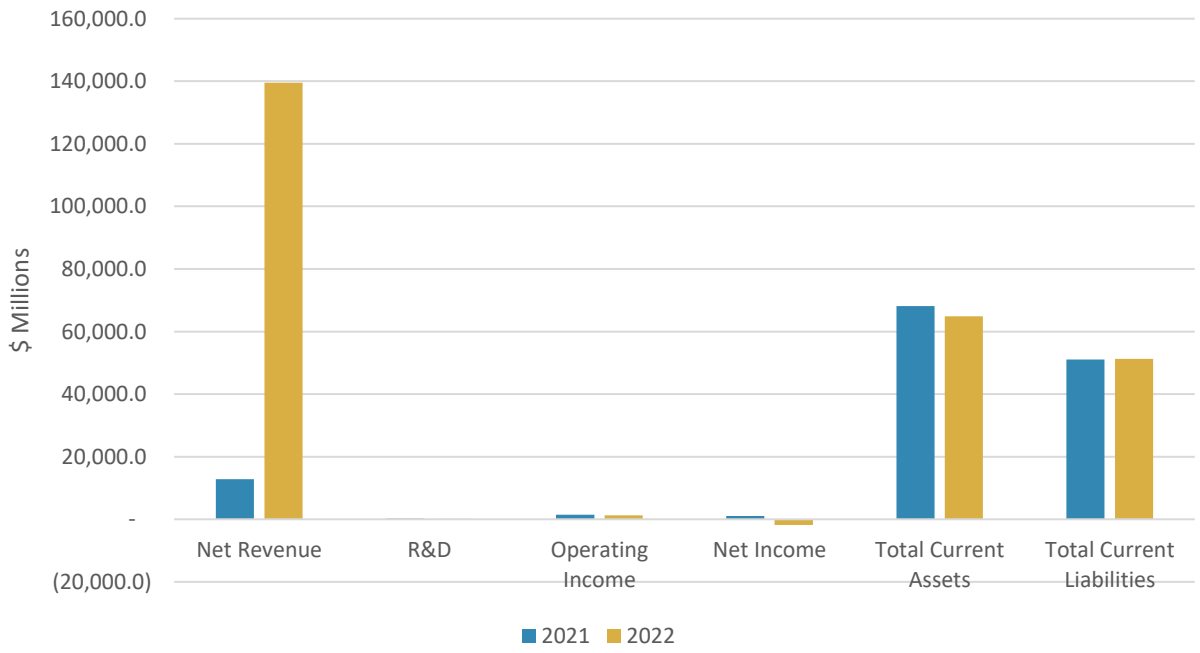
Financials: Revenue

Table 63
ENI S.p.A.: Annual Revenue, 2022
($ Millions)

Financials	Revenue ($ Millions)
Net Revenue	139,541.6
R&D	172.7
Operating Income	1,237.3
Net Income	(1,828.1)
Total Current Assets	64,864.7
Total Current Liabilities	51,301.4

Source: Company annual report

Figure 35
ENI S.p.A.: Annual Revenue, 2021 and 2022
($ Millions)



Source: Company annual report

*Note: The bar chart of R&D, Operating Income, and Net Income for 2021 and 2022 is not visible because the number of these segments is minimal, as given in the above table.

News and Key Developments

Table 64
ENI S.p.A.: News, 2023

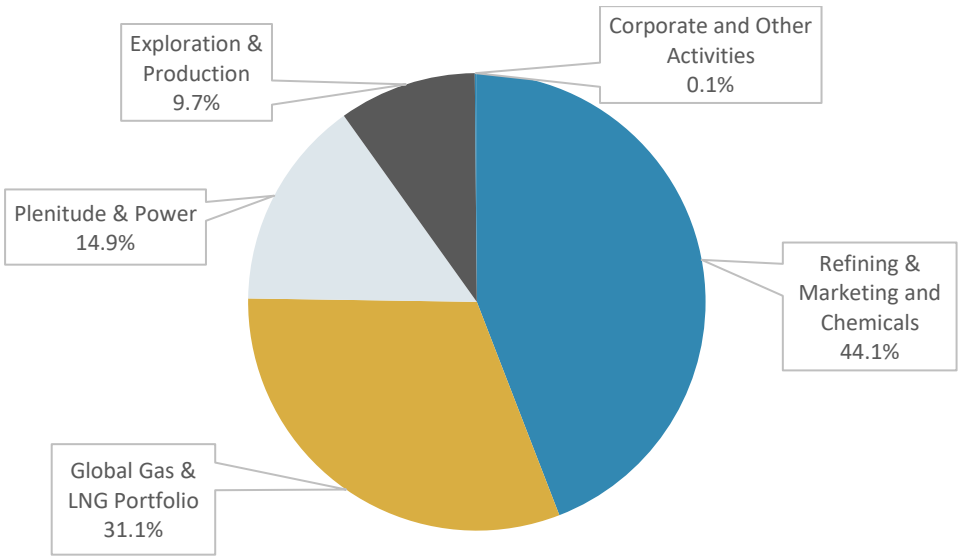
Year	Strategy	Development
2023	Product Launch	Eni is promoting its first produced renewable-based biodiesel, HVOlution, among its fuel transporters, who are its partners. The company states that the fuel is made according to European standards and uses renewable feedstock. Around 300 vehicles are transporting Eni's fuel across Italy. To date, the company's biodiesel has covered 200,000 kilometers.
2023	Business Integration	Eni Sustainable Mobility is a new company launched by Eni under which all its sustainable transport and biomethane-related operations have been integrated into one entity. Eni will own the new company, besides Eni's leading venture, Plenitude.
2023	Contract	Spinelli Group, a container management company, has contracted with Eni to use its HVO-based biodiesel for its fleets. The company has 300 heavy-duty vehicles; half of the trucks are compatible with HVO-based biodiesel.

Source: Company website

ESG Trends
According to Sustainalytics, Eni's ranking in the oil and gas group is 21 out of 307 industries, and the ESG rating is around 28.7, a medium risk.

Product Financials: Revenue

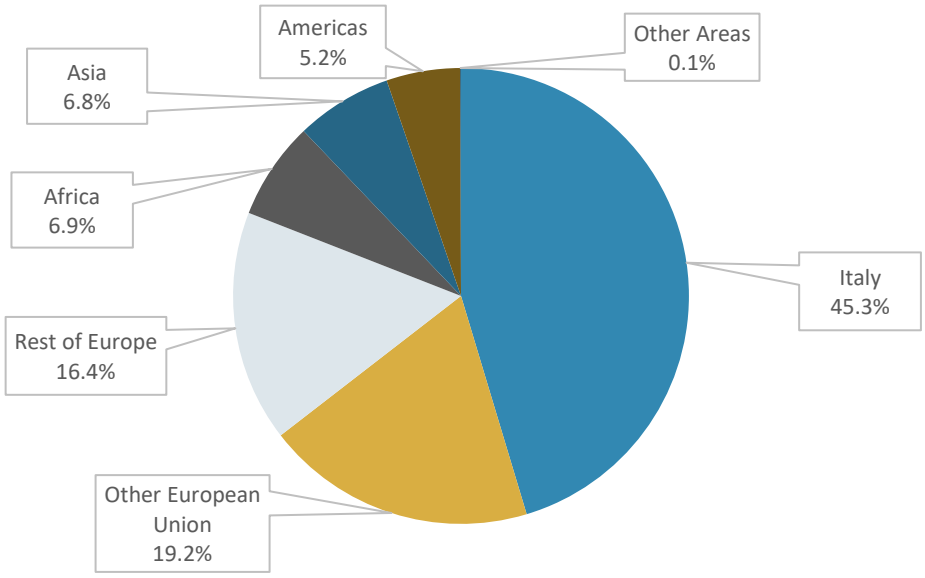
Figure 36
ENI S.p.A.: Revenue Share, by Business Unit, 2022
(%)



Source: Company annual report

Regional Financials: Revenue

Figure 37
ENI S.p.A.: Revenue Share, by Country/Region, 2022
(%)



Source: Company annual report

HF SINCLAIR CORP.
2828 N. Harwood, Suite 1300
Dallas, TX 75201
United States
Tel: 1-214-954-6510
Website: www.hfsinclair.com

Company Snapshot

Table 65
HF Sinclair Corp.: Company Snapshot

Parameter	Information
Ticker	NYSE:DINO
Founded/Incorporated Year	1947
Headquarter	The U.S.
Revenue 2022 ($ Millions)	38,204.8
Strongest Business Region/Country	The U.S.
Number of Employees (2022)	5,223 (as of December 2022)
Key Geographies	The U.S., Canada, Europe, Asia and Latin America
Market Focused Business Segment	Refining
Entity Type	Public
Ownership Type	Parent

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Founded in 1947, HF Sinclair is an energy company producing diesel, jet fuel, fuel oil, base oil, renewable diesel, gasoline, and other products. The company has seven refineries across six states: New Mexico, Kansas, Oklahoma, Wyoming, Utah, and Washington. The company's renewable diesel unit has three facilities, and the annual production capacity of renewables is 380 million gallons. The company also has a pretreatment unit that enables the company to use multiple feedstocks, like soybean oil, animal fats, and distillers' corn oil, for renewable diesel production.

Key Highlights

- In 2022, the company sold around 136 million gallons of renewable diesel.
- In 2022, the renewable diesel revenue was $654 million.
- In the first quarter of 2023, total sales from renewable fuel was 46 million gallons. In the same quarter, 2022, the sales volume was 5 million gallons.
- In terms of value, the sales of the renewable segment in the first quarter of 2023 were $298 million. In the same quarter, 2022, the sales were $47 million.

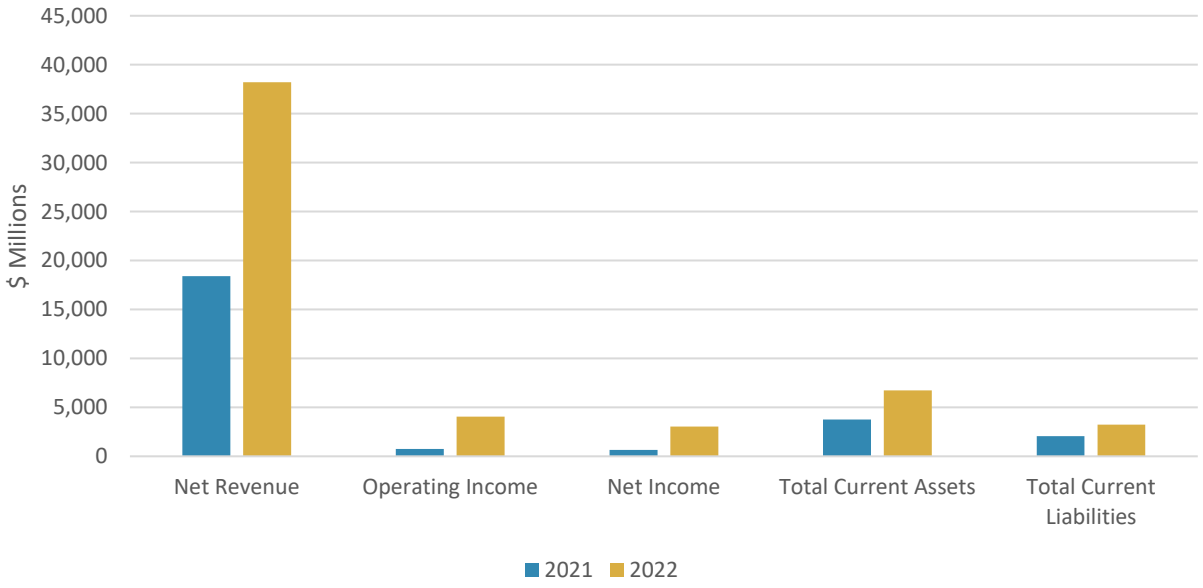
Financials: Revenue

Table 66
HF Sinclair Corp.: Annual Revenue, 2022
($ Millions)

Financials	Revenue ($ Millions)
Net Revenue	38,204.8
Operating Income	4,054.2
Net Income	3,041.1
Total Current Assets	6,748.3
Total Current Liabilities	3,245.5

Source: Company annual report

Figure 38
HF Sinclair Corp.: Annual Revenue, 2021 and 2022
($ Millions)



Source: Company annual report

News and Key Developments

Table 67
HF Sinclair Corp.: News, 2023

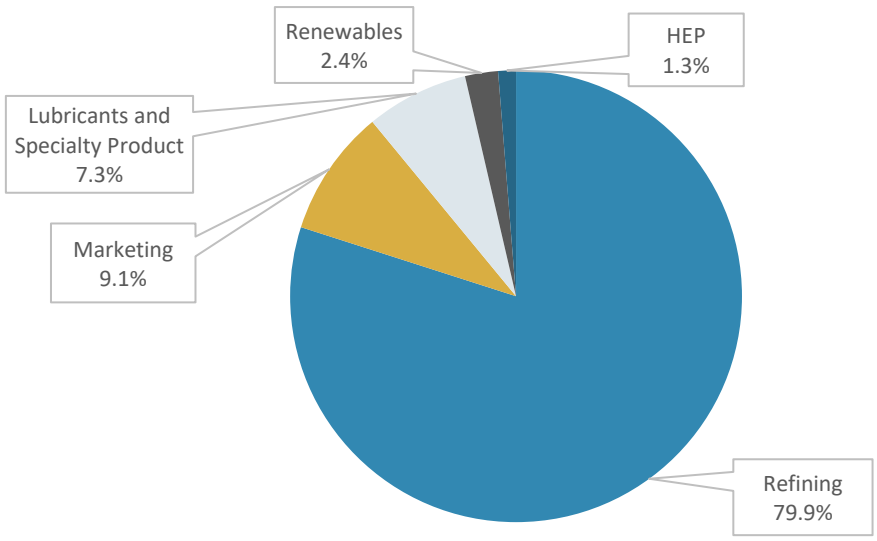
Year	Strategy	Development
2023	Biofuel Conversion Technology	HF Synclair Corp. will implement Topsoe's HrdroFlex Technology to convert waste and biomass into renewable diesel. This technology will be implemented in all three facilities: Sinclair, Wyo.; Cheyenne, Wyo.; and Artesia, N.M.
2023	Market Expansion	HF Synclair Corp. has started producing renewable diesel in its three refineries and is looking for markets. It has identified California as the most significant market and the Pacific Northwest states of Washington and Oregon as critical markets. The company is also eyeing Canada.

Source: Company website

ESG Trends
HF Synclair Corp.'s ESG rating is around 33.26, which is a high risk.

Product Financials: Revenue

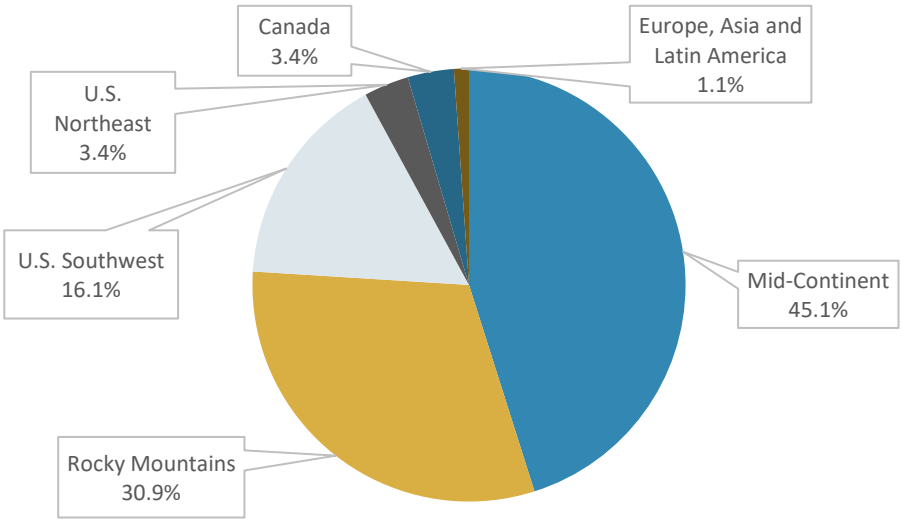
Figure 39
HF Sinclair Corp.: Revenue Share, by Business Unit, 2022
(%)



Source: Company annual report

Regional Financials: Revenue

Figure 40
HF Sinclair Corp.: Revenue Share, by Region, 2022
(%)



Source: Company annual report

NESTE OYJ

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Finland
Tel: +358 10 45811
Website: www.neste.com

Company Snapshot

Table 68
Neste Oyj: Company Snapshot

Parameter	Information
Ticker	HEL:NESTE
Founded/Incorporated Year	1948
Headquarter	Finland
Revenue 2022 ($ Millions)	25,707
Strongest Business Region/Country	Finland
Number of Employees (2022)	5,244 (as of December 2022)
Key Geographies	Finland, North and South America, Other European Countries, Other Nordic Countries, Baltic Rim, Other Countries
Market Focused Business Segment	Oil Products
Entity Type	Public
Ownership Type	Parent

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Neste is one of the leading producers of renewable diesel, sustainable aviation fuel, and renewable solutions for the polymers and chemical industry. Neste's renewable diesel is a drop-in fuel branded as Neste MY Renewable Diesel, and the fuel is currently sold in more than 500 stations in the U.S., Sweden, the Netherlands, and Belgium. It is available in 184 stations in Finland and 30 stations in the Baltic region.

The company has partnered with various industries like Coca-Cola, Rolls-Royce, Bollore, Liebherr, Mar Contracting, and LCL to supply renewable diesel. In France, the company supplies renewable diesel via pipeline.

In 2022, the company partnered with Marathon Petroleum, a petroleum refinery company, to produce renewable diesel. For this, Marathon Petroleum's refinery will be converted to produce around 2.1 million tons of renewable diesel annually. The project is to be completed by the end of 2023. Neste will have a 50% interest in the fuel project, Martinez Renewable.

Key Highlights

- In 2022, Neste's renewable diesel sales were 0.8 million tons.
- Since January 2022, Coca-Cola has used Neste renewable diesel for up to 50,000 transport routes.
- Neste produces 3.3 million tons of renewable products annually, which is projected to increase to 6.8 million tons by 2026.
- Two Japanese airports, Tokyo Haneda and Narita, have already used Neste's sustainable aviation fuel.

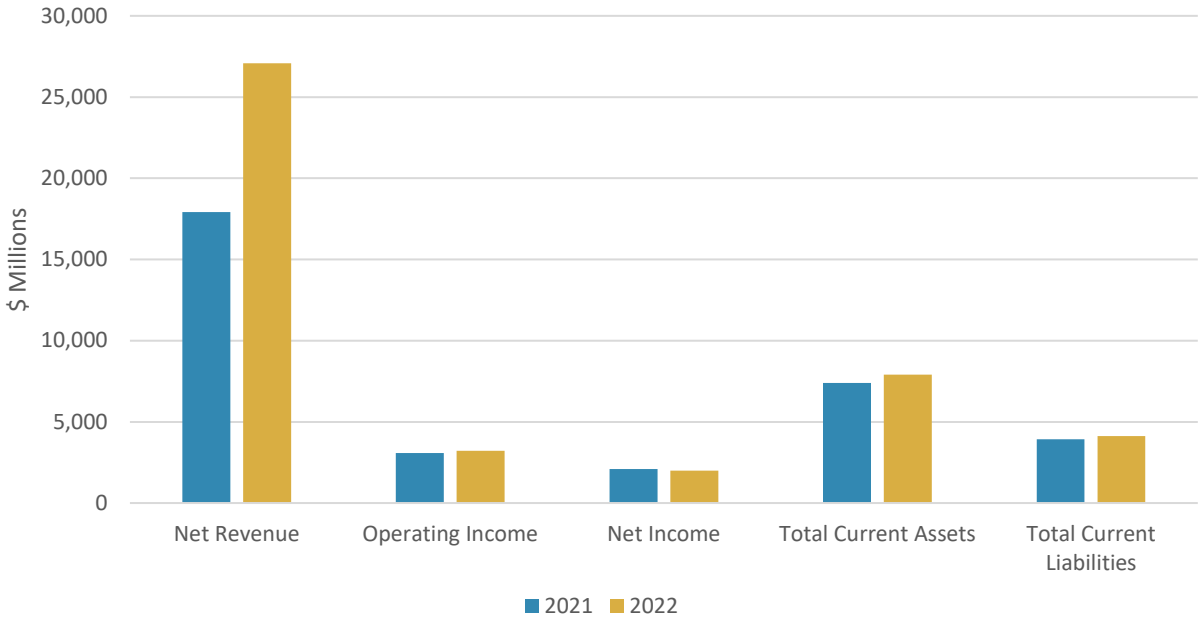
Financials: Revenue

Table 69
Neste Oyj: Annual Revenue, 2022
($ Millions)

Financials	Revenue ($ Millions)
Net Revenue	25,707
Operating Income	3,048
Net Income	1,888
Total Current Assets	7,504
Total Current Liabilities	3,916

Source: Company annual report

Figure 41
Neste Oyj: Annual Revenue, 2021 and 2022
($ Millions)



Source: Company annual report

News and Key Developments

Table 70
Neste Oyj: News, 2023

Year	Strategy	Development
2023	Collaboration	PTL Marine, a maritime fuel supplier, has collaborated with Neste to supply renewable diesel to the marine sector across California. From January 2023, commercial vessels in California were supposed to use renewable diesel instead of ultra-low sulfur diesel as per California's Commercial Harbor Craft (CHC) regulation.
2023	Collaboration	Neste tested a credit transfer system showing how much carbon reduction has been achieved jointly by airlines, logistics companies, and end customers using sustainable aviation fuel. For this, the company collaborated with ISCC, a Credit Transfer System developer, and DLH, a logistics company. This system will reduce carbon emissions along the value chain.

2023	End Use	Outokumpu, a Finland-based stainless-steel company, uses Neste's renewable diesel in its steel mills. Renewable diesel reduces carbon emissions from the operation of its heavy industries and fleet by 90%. Outokumpu has committed to becoming carbon neutral by 2025.

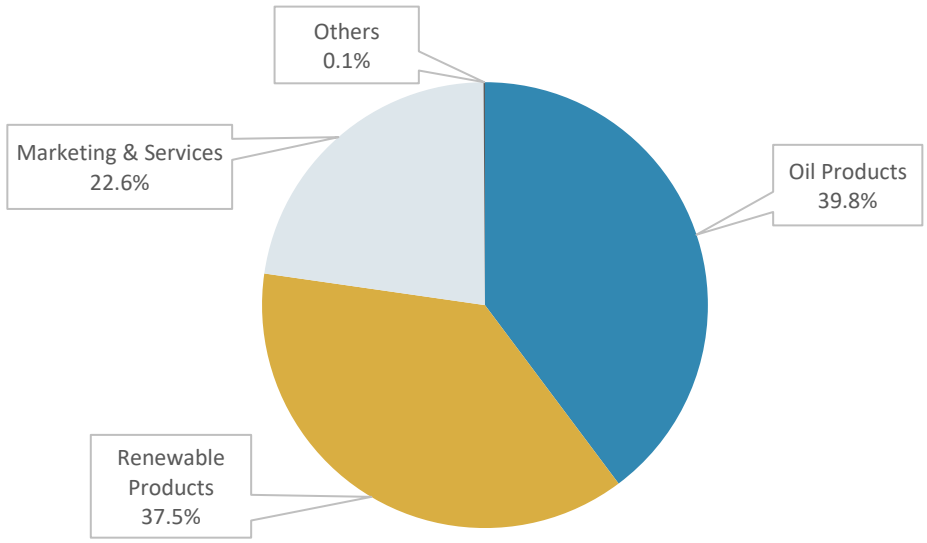
Source: Company website

ESG Trends

According to Sustainalytics, Neste's ranking in the refiners and pipeline group is 6 out of 206 industries, and the ESG rating is around 19.5, a low risk.

Product Financials: Revenue

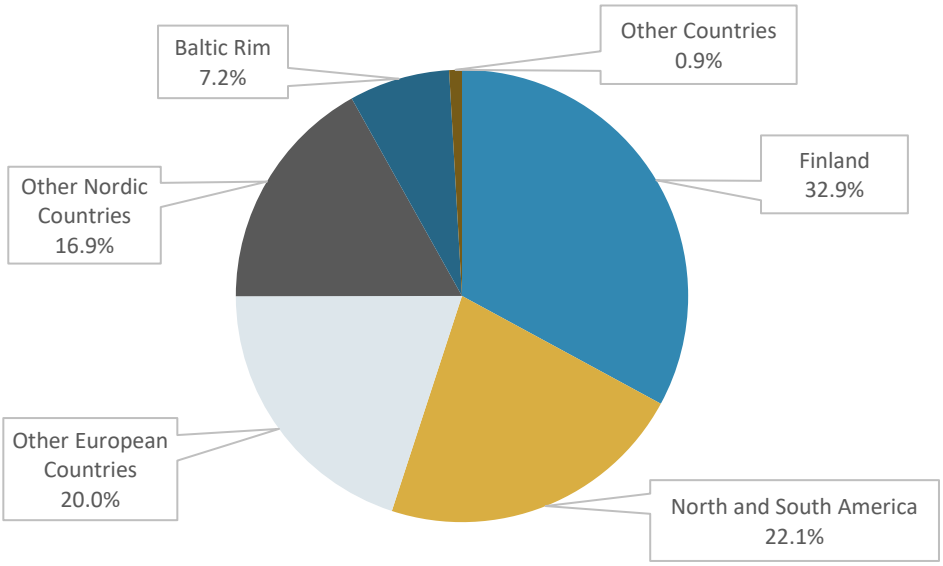
Figure 42
Neste Oyj: Revenue Share, by Business Unit, 2022
(%)



Source: Company annual report

Regional Financials: Revenue

Figure 43
Neste Oyj: Revenue Share, by Region/Country, 2022
(%)



Source: Company annual report

POET LLC.
4615 North Lewis Avenue
Sioux Falls, SD 57104
United States
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Website: http://www.poet.com

Company Snapshot

Table 71
POET LLC: Company Snapshot

Parameter	Information
Ticker	NASDAQ:PTBBU
Founded/Incorporated Year	1987
Headquarter	The U.S.
Revenue 2022 ($ Millions)	Not available
Strongest Business Region/Country	The U.S.
Number of Employees (2022)	2,400 (as of December 2022)
Key Geographies	Not available
Market Focused Business Segment	Not available
Entity Type	Private
Ownership Type	Parent

Source: Company website, annual reports, investor presentations, and press releases

Company Overview

Founded in 1987, POET is a leading company that produces biofuels and other bio-based food, feed, personal care products, and plant-based alternatives to fossil fuels. Today, the company has 33 bioprocessing facilities across eight U.S. states, which can produce 3 billion gallons of biofuel per year. In 2021, the company acquired Flint Hills Resources, the fifth-largest biofuel producer in the U.S., to reach a 3-billion-gallon capacity. The company consumes around 930 bushels of corn every year to produce 975 million pounds of corn oil and 14 billion pounds of distillers' dried grain. Corn is used as a feedstock to produce advanced biofuels.

Key Highlights

- The company has increased its biofuels yield by 8% since 2005.
- The company's Ohio bioprocessing facility produces 90 million gallons of biofuel annually.
- Compared to traditional gasoline, the company has planned to reduce its bioethanol's carbon intensity by 70% by 2030.
- POET is the 36th-largest container shipper in the U.S., exporting bioproducts to more than 25 countries worldwide.

Table 72
POET LLC: News, 2021-2023

Year	Strategy	Development
2023	Partnership	POET signed a partnership agreement with Midwest Commodities in Michigan. As a part of the agreement, Midwest Commodities will provide DDGS truck-to-container transload services. With this service, POET can serve its global customers more efficiently.
2022	Announcement	In May 2022, POET announced that it would reopen its bioprocessing facility in Indiana. The reopening of this facility will bring POET's total facilities to 34. POET would invest $30 million in this facility and upgrade it to increase the plant's production rate from 80 million to 95 million gallons of bioethanol.
2021	Acquisition	On June 1, 2021, POET acquired Flint Hills Resources, a refining company. It acquired the company's ethanol assets, two terminals, and animal feed businesses. This acquisition increased POET's production capacity by 40%.

Source: Company website

Appendix

Acronyms

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Appendix: Acronyms

Acronyms Used in the Report

Table 73
Acronyms Used in the Report

Acronym	Meaning
ADM	Archer Daniels Midland Company
BETO	Bioenergy Technologies Office
CO	Carbon Monoxide
DOE	Department Of Energy
EMEA	Europe, Middle East & Africa
FAME	Fatty Acid Methyl Ester
FOG	Fat, Oil, Grease
HDRD	Hydrogenation-Derived Renewable Diesel
HVO	Hydrotreated Vegetable Oil
NOx	Nitrogen Oxide
PAH	Polycyclic Aromatic Hydrocarbons
RED	Renewable Energy Directive
SAF	Sustainable Aviation Fuel
UCO	Used Cooking Oil
WCO	Waste Cooking Oil

Source: BCC Research

About BCC Research

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About BCC Research

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