IEA BIOENERGY T39
BIOFUEL NEWS

Issue 65
June 2024

Upcoming Events

BBEST & IEA Bioenergy Conference
22 Oct - 24 Oct, 2024
Sao Paulo, Brazil

In this issue

Biofuels production and development in the United States

IEA Bioenergy
Technology Collaboration Programme

IEA BIOENERGY TCP TASK 39

IEA Bioenergy is a Technology Collaboration Programme (TCP) set up in 1978 by the International Energy Agency (IEA) with the aim of improving cooperation and information exchange between countries that have national programmes in bioenergy research, development and deployment. Twenty five countries plus the European Commission currently participate in IEA Bioenergy.

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SWEDISH BIOENERGY ASSOCIATION

While Tomas Ekbom is Task Leader for IEA Bioenergy TCP Task 39, he also works for the Swedish Bioenergy Association (Svebio). Svebio is a environmental organisation for companies and individuals. We are strongly rooted in our values, and believe in renewable energy, entrepreneurship and a free market economy.

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Online & E-magazine

BC-SMART Low Carbon Fuels Consortium
Newsletter

ISSN 2004-7002

ELECTROFUELS MAY BECOME THE NEW GREEN LITTLE BLACK DRESS

What do you wear as a woman to the party? Since the days of the famous French designer Coco Chanel in the mid-1920s the LBD – the Little Black Dress has been an ever-favourite piece of garment. Biofuels have been the rising star for many years and the most popular choice to replace fossil fuels in the transport sector. With the risen over-concern for deforestation and human starvation, the introduction of strict sustainability criteria and the categorizing of feedstocks down to almost every type of biomass have hindered technology and business development to just a trickle in commercialization of new advanced biomass-to-liquids technologies.

Drop-in fuels like HVO became a success a decade ago almost overnight with feedstocks like fats and greases (fogs) with little value and oil refineries searched for new supply with a haste similar to the gold rush in USA some 130 years ago. HVO is now turned into SAF, Sustainable Aviation Fuels but those over-concerns have resurfaced in this area as well. As onion on the salmon, the EU ban on the internal combustion engine (ICE) in the wake of discussions of electrification of every part of the transport sector, the music is turned down somewhat.

In comes electrofuels, which are carbon-based fuels made from hydrogen and carbon dioxide, where the hydrogen has been made by electrolysis of water – and where the carbon atom may be of biomass origin, making the elwectrofuels biomass-based. Electrofuels are sometimes referred to as e-fuels and biomass variants could be called biomass e-fuels (i.e. biofuels). Wind has many times been given as answer for the new electricity needed. In this way, electrofuels have been preliminarily accepted as a bridge in the European Union future legislation to prolong the manufacturing and sales of ICE. The new black dress.

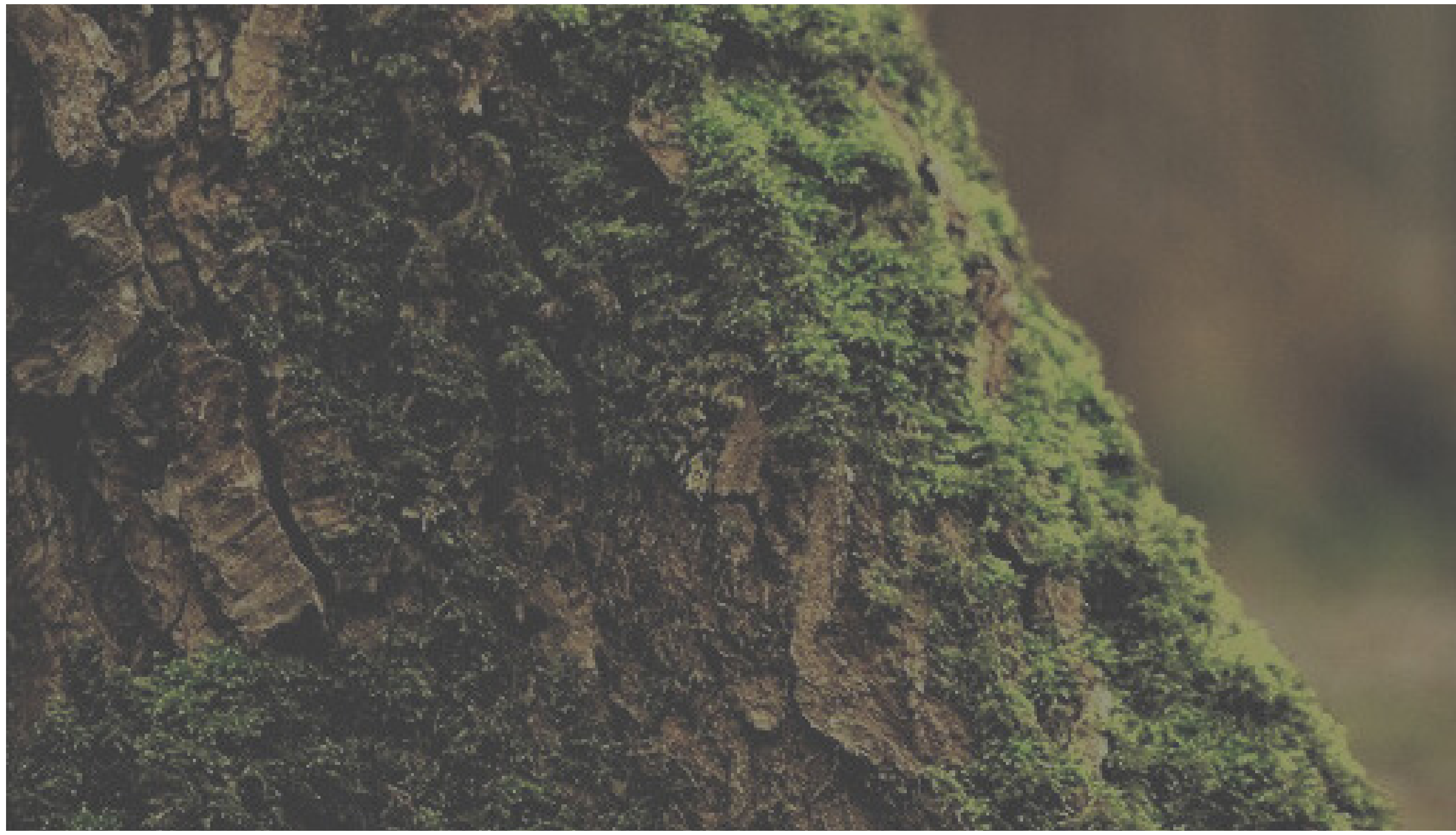
Sweden was for a number of years the leading country in the EU and among leading countries in the world of blending of biofuels and sales of pure biofuels in the transport sector. With the last year's surge in fuel prices and global inflation, Sweden and a few other countries turned down the blending development. Electrofuels are essentially a class of synthetic fuels, which are not as price sensitive to feedstocks as biofuels but rely on cheap electricity. In areas with either low prices or a large potential of renewable electricity this business is booming, it is a bonanza for e-fuels.

In northern Sweden, as one example, there are currently six e-fuels projects for methanol (e-methanol) which all have biomass as origin for the carbon. One e-fuel plant is already under construction and one more has gotten the environmental permit. Another plant is planned for in the south for a chemical complex as base chemical for production of renewable special chemicals. In total there are almost 800,000 tonnes of methanol in planned annual production. On top of that, there are additional hydrogen and SAF projects in Sweden planned for additional 500,000 tonnes of methanol equivalents.

Will this new route to biofuels displace or complement other biofuel technologies. How will biofuels from food and feed develop in the world to replace fossil fuels? Will a possible oil price peak in the future lead to changes in the commercialization of biofuels? Will electrification led by mass-produced battery-vehicle cars in China disrupt the global vehicle industry and lead to decoupling of oil demand in many countries? These are some interesting questions to be answered in the next period.

"In northern Sweden, as one example, there are currently six e-fuels projects for methanol (e-methanol) which all have biomass as origin for the carbon"

Tomas Ekbom,
Task Leader IEA Bioenergy TCP T39



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Task 39 Information

During the current triennium, the IEA TCP Bioenergy Task 39 has had eight Business meetings (two physical) with monitoring of ongoing projects and discussions on inter-task cooperation and new projects. In addition, a special Project Meeting has been held. Material is available on our website with projects, reports, publications, and a calendar with events.

Planned activities include the joint IEA Bioenergy BBEST conference in October in Brazil where many of the task's projects will be presented and the last Task 39 Business meeting for the triennium. We all wish to see you there and you can find out more on the program in this edition of the magazine. See you in Brazil!

A new program of work is now drafted for another triennium period 2025-2027 with new projects for sustainable biofuels for internal combustion engines.

Recent publications include Implementation Agendas: Compare-and-Contrast Transport Biofuels Policies (Saddler et al., 2023), Biofuels in Emerging Markets (Souza et al., 2023) and Biofuel technologies: Lessons learned and pathways to decarbonisation (Cantarella et al., 2023). These are available at the IEA Bioenergy website.

Task 39 continues to actively organize and participate in other webinars and conferences with the goal of sharing the networks insights on how decarbonization of the transport sector can contribute to a "green economic recovery".

As of 2024 fifteen countries participates in Task 39: Austria, Belgium, Brazil, Canada, China, Denmark, European Commission, Germany, Ireland, Japan, The Netherlands, New Zealand, South Korea, Sweden, and the USA. In addition, US Grains Council participates as a Limited Sponsor. Task 39 welcomes interest from other countries to participate in the Task group.

With the collaboration among these countries, Task 39 is set to deliver cooperative research projects to address and assess policy, markets, and sustainable biofuel implementation issues. T39 welcomes international contact from industry and academia and authority to our group to work on common ground for further use and commercialization of biofuels to replace fossil fuels.

Programme of work

The mission of Task 39 is to facilitate and advance development and deployment of sustainable, lower carbon intensity biofuels to decarbonize the transport sector. Our method is to assist member countries transport biofuels stakeholders in their efforts to develop and deploy sustainable, lower carbon intensive biofuels through a coordinated focus on technology, commercialization, sustainability, policy, markets, and implementation.

The task leads and coordinates activities in three main program areas:

Technology and Commercialization (T-projects)

Technical/commercial aspects of producing and using low carbon intensity (CI) liquid and gaseous biofuels for transport, including both "conventional" and "advanced" biofuels.

Sustainability (P-projects)

Sustainability and carbon intensity metrics are playing an ever-increasing role in the policies used to develop and use biofuels. Biofuels sustainability/LCA assessment will stay a priority for the Task.

Policy (P-projects)

Policy analysis, the "right" policies (such as LCFSs) significantly influence the rate and extent of development, deployment, and use of biofuels (e.g., bioethanol, biodiesel, renewable diesel, drop-in biofuels, etc).

T39-T1
Ongoing progress in the commercialization of SAF/biojet fuel

T39-T2
Progress in the commercialization of drop-in biofuels and co-processing to produce low-CI transport fuels

T39-T3
"Extend assessment of decarbonisation of the marine transport sector and evaluate the commercial production and use of biofuels"

T39-T4
Assessment of demonstration plants and commercialisation progress

T39-T6
Inter-Task project 'Synergies of green hydrogen and bio-based value chains deployment'

T39-P1
Implementation Agendas compare-and-contrast report of each member country's biofuels policies that have been/are being used to develop, deploy and expand biofuels production and use

T39-P2(2)
Assessment of the Sustainability of Biofuels Pathways, Including Social and Environmental Aspects of Sustainability — A Case Study of Industrial Exhaust Gas-Bioethanol in China and Brazil

T39-P3
Improvement opportunities for policies and certification schemes promoting sustainable biofuels with low GHG emissions. Part 2: Robustness of GHG emission certification and verification – a case study of selected biofuel value chains and policies

T39-P4
Biofuel's production and use status in "emerging" economies.

Task 39 members

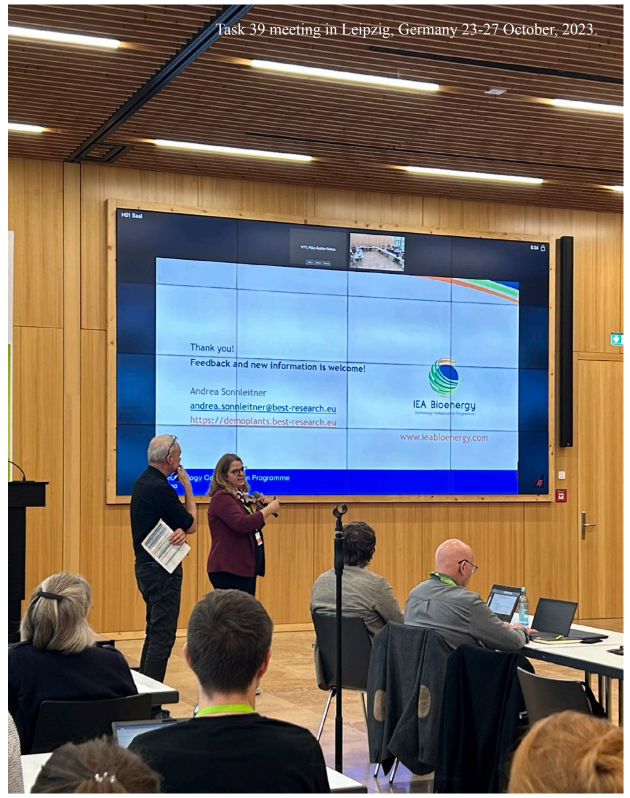
Starting from 2024 Task 39 will have 15 member countries participating as listed per below. Each country is represented by a National Team Leader (NTL) and additional representatives as well as an ExCo member. Furthermore, external experts may be involved as well. In addition, US Grains Council participates as a Limited Sponsor making the total number of members to 16.

Task 39 meeting in Leipzig, Germany 23-27 October, 2023.

Member Country	Task Representative	Organisation	ExCo Member
Austria	Andrea Sonnleitner (NTL) Dina Bacovsky	BEST BEST	Hannes Bauer
Belgium	Robert Malina	Hasselt University	Thibaut Masy
Brazil	Glaucia Mendes Souza (NTL) Rubens Maciel Filho Luiz A Horta Noguiera	BIOEN FAPESP BIOEN FAPESP BIOEN FAPESP	Marlon Arraes
Canada	Jack Saddler (NTL) Hana Mohamadi Allison Simmons	UBC UBC NRC	Oshada Mendis
China	Fuli Li (NTL)	QIBEBT	Dou Kejun
Denmark	Sune Tjalfe Thomsen (NTL)	UCPH	Katharina Paarup Meyer
European Commission	Nicolae Scarlat (NTL) Marco Buffi	EC EC	Maria Georgidaou
Germany	Franziska Mueller-Langer (NTL) Nicolaus Dahmen	DBFZ KIT	Birger Kerckow
Ireland	Tom Walsh (NTL)	Renetech	Luiz Gay-Tarazona
Japan	Yuta Shibahara (NTL)	NEDO	Takahisa Yano
New Zeeland	Paul Bennett (NTL)	Scion	Paul Bennett
South Korea	Kyungsu Na (NTL)	CNU	Jin-Suk Lee
Sweden	Tomas Ekbom (NTL Hannah Edgren	Svebio Svebio	Anna Malmström
The Netherlands	Paul Sinnige (NTL) José Muisers Stephan Janbroers	RVO RVO TNO	Kees Kwant
United States	Ling Tao (NTL)	NREL	Jim Spaeth

Current IEA Bioenergy Task 39 Limited sponsor(s)

Organisation	Task Representative	Alternative
U.S Grains Council	Linda Schmid	Mackenzie Boubin



Task 39 meeting in Leipzig, Germany 23-27 October, 2023.

A centennial T-Ford runs on ethanol - first time in five decades

Just in time for an annual veteran car show during a sunny May weekend in Stockholm, the Swedish National Museum of Science and Technology brought out from the collection a historic (black, but of course) T-Ford automobile from 1920.

This T-Ford 1920 model is part of the museum's collection and the last time it was driven was in a 1974 vintage car rally. From there on it has only been displayed and never driven. Now, fifty years later, when it premiered again, it ran on ethanol (E85) fuel. It is largely thanks to the ethanol's high octane number that it runs so smoothly and I myself can attest to that the 20 horsepower engine ran very quietly and nicely.

However, the car had firstly to be restored and a group of motor enthusiasts carefully did this to its original condition. The goal was to get it mechanically perfect, and technically correct, with purchased original parts and specially manufactured spare parts, only when there was no other way.

The car is owned by The Foundation of the National Museum of Science and Technology and in collaboration with the association "Tekniska Muséets Vänner" and the Swedish T-Ford club, it has been renovated since the fall of 2022 under the warm hand of leadership of Göran Flank, who himself is a private owner of another T-Ford, and Håkan Löfdahl. The car body and paint were in such good condition that it only needed to be polished.

Göran told me that the car was of such high quality in material and despite some problems such as a cracked piston valve and a hundred small things, it has gone very well. Under the hood sits a 2.9-liter four-stroke engine with a combined gearbox that uses same motor oil. Total weight is 750 kg and a top speed of 60 km/h. Headlights are electric, but turn signals are done with your arm. Henry Ford made himself the world's largest car manufacturer through the series of cars with the model names N, R, S and finally T, which was the crown of series production. Some of the unique innovations were left-hand steering and a top-mounted cylinder head, both of which were world firsts. Left-hand drive was a life saver because it allowed passengers to be dropped off on the right side and avoid accidents.

Of the 15 million manufactured T-Ford cars in total, it is estimated that some 500,000 remain today. The T-Ford's precise construction and high quality materials have contributed to the parts lasting over time, but also made it possible to restore the car to drivable condition more than 100 years after it was manufactured.

Today there are over 21 million modern ethanol cars (Fuel-Flexible Vehicles) in the United States that can run on pure gasoline or E85 and it can be said that ethanol as a fuel was introduced in the United States more than 100 years ago with the quote by Henry Ford that "There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the field for a hundred years". So right he was!

Text and photo: Tomas Ekbom

US GRAINS COUNCIL VISITS NORDIC REGION TO DISCUSS ETHANOL BLENDING'S ROLE IN GREENHOUSE GAS REDUCTION POLICIES

The U.S. Grains Council organized a mission to Finland, Norway and Sweden in May to discuss the countries' sustainability policies and how U.S. producers can help them meet their greenhouse gas reduction targets. Photo: Hannah Edgren

Participants left to right:

Bharadwaj Kummamuru, Executive Director, WBA
Johnny Kjellström, Director of Public Affairs, Svebio
Doug Berven,Vice President, POET
Cary Sifferath, Vice President, U.S. Grains Council
Alberto Camona, EU Ethanol Consultant U.S. Grains Council
Dorota Natucka, Director of Sales and Marketing, Bioenergy International
Alarik Sandrup, Director of Public Affairs, Lantmännen
Hagan Rose, Director, Sales & Marketing Eco-Energy
Kjell Andersson, National Team Leader, IEA Bioenergy Task 44
Fredrik Thörnqvist, Board Member, Colabit
Anna Törner, CEO, Svebio
Tomas Ekbom, Task Leader, IEA Bioenergy T39 / Program Director, Svebio

The European Union (EU) has committed to ambitious carbon-reduction goals centred around E10 blending across its member states, and the U.S. Grains Council (USGC) recently sent a delegation to the region to build relationships with industry stakeholders and policymakers to further support the EU's climate initiatives.

USGC Vice President Cary Sifferath was joined by Doug Berven, Vice President of Corporate Affairs at POET, Hagan Rose, Director of Sales and International Marketing at Eco-Energy and Alberto Carmona, USGC Regional Ethanol Consultant in Europe.

"The EU is already one of the largest export markets for U.S. ethanol and there is still so much opportunity for growth as its greenhouse gas (GHG) reduction policies continue to develop," Sifferath said. "Ethanol uses like sustainable aviation fuel SAF) will make a massive impact on reducing the transportation sector's carbon footprint and these countries deserve recognition for their forward-thinking mindset on creating a cleaner, safer environment for us all."

The team arrived in Oslo, Norway and met with advisors from the Norwegian Ministry of Climate and Environment on May 13. The day's docket also featured a meeting with ZERO, a non-profit leader in carbon emission reduction strategies in Europe. Norway implemented an E10 gasoline blend to consumers in 2023 and in 2020 became the first country to mandate sustainable aviation fuel (SAF) blending. The government plans to blend SAF at 30% by 2030.

Sifferath and company traveled to Stockholm, Sweden on May 14 to participate in a roundtable with representatives from several organizations and companies. The meeting was hosted and organized by the Swedish Bioenergy Association and IEA Bioenergy Task 39 who had invited ePURE an association that represents 85% of the EU's ethanol production and World Bioenergy Association, Colabit, Lantmännen Agroetanol, Renetech and the magazines Bioenergy International and Tidningen Bioenergi (in Swedish).

Sweden raised its SAF blending mandate to 1.7% in 2022 and in 2023, its Trollhättan-Vänersborg airport became the first in the world to exclusively offer blended SAF for all aircraft refueling. Sweden also has a high demand for biofuel-blended diesel fuel, presenting several major opportunities for ethanol growth in the country. The government plans to blend SAF at 30% by 2030.

The busy agenda continued in Helsinki, Finland with meetings with the Bioenergy Association of Finland and the renewable energy policy unit at the Finnish Ministry of Economy and Employment. Finland is aiming to have the majority of its energy come from renewable sources and reduce GHG emissions from the aviation sector by 30% by 2030. The government also provides financial incentives for consumers to purchase E85-compatible vehicles.

"Our meetings in Finland, Norway and Sweden were a great opportunity to better understand the sustainability objectives of the countries and to explain how U.S. producers are well positioned to assist them on their journey to GHG reduction," Berven said.

Text: Tomas Ekbom

Visit Task 39's website

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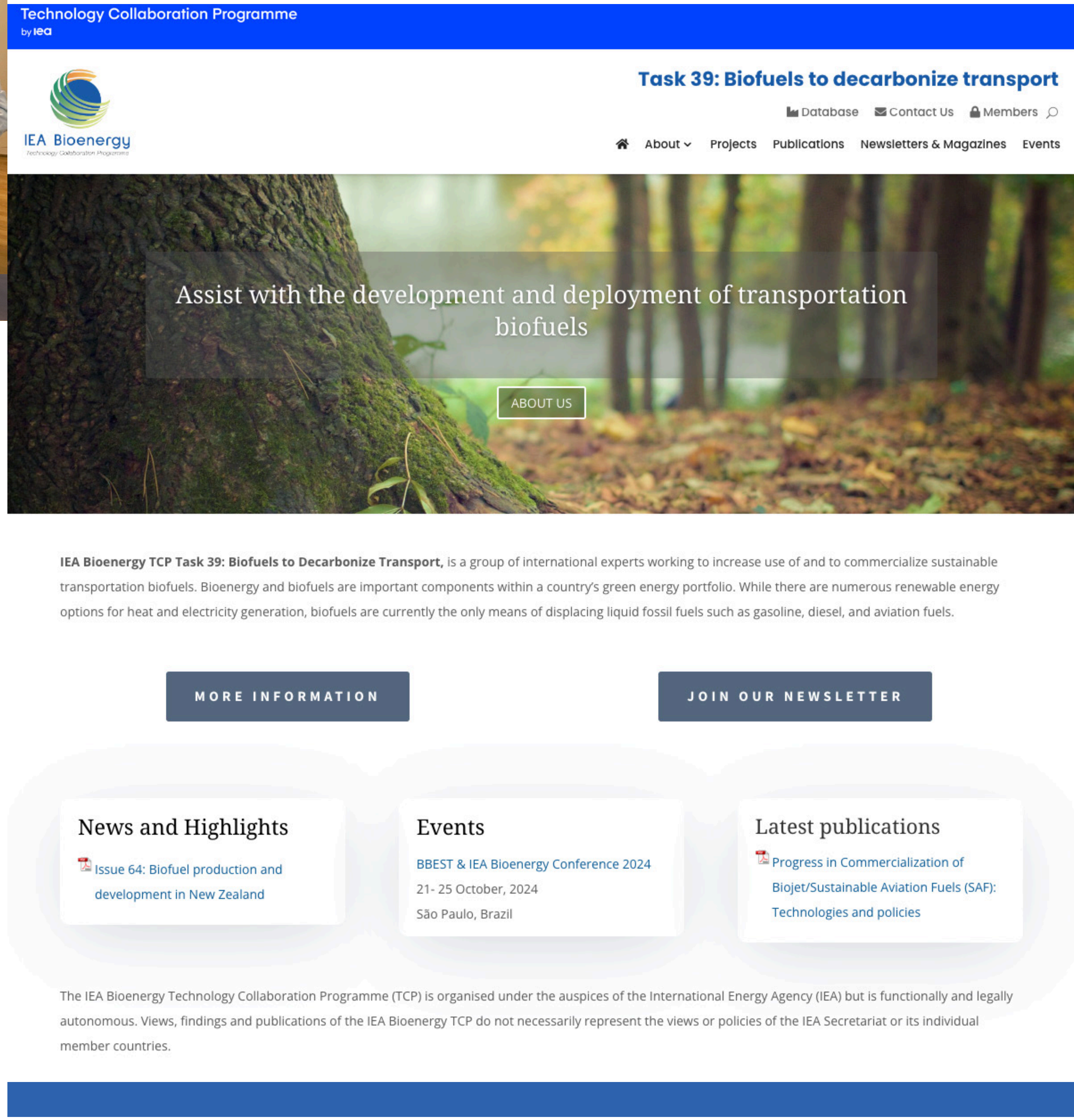


BIOFUELS PRODUCTION AND DEVELOPMENT IN THE UNITED STATES

By Neha Shakelly, Oscar Rosales Calderon,
Sharon Smolinski and Ling Tao

Highlights

• Addressing transportation emissions will require a combination of policy interventions, technological innovations, and behavioral changes.

• To decrease transportation-related carbon emissions, we recommend transitioning to cleaner and more efficient transport, expanding public transportation, and promoting sustainable urban planning.

• Transitioning to biofuels in the transport sector in the United States (U.S.) presents a host of environmental, economic, and strategic advantages.

• Environmentally, biofuels offer a promising avenue for reducing greenhouse gas emissions compared to conventional fossil fuels.
• Biofuels produce fewer harmful emissions, such as particulate matter and nitrogen oxides, compared to conventional fuels, thereby improving local air quality and reducing health risks associated with air pollution.

• The U.S. government issued a "Sustainable Aviation Fuel (SAF) Grand Challenge" to promote the development of SAF and address the decarbonization of the commercial aviation.

• The targets are to expand current domestic SAF production to 3 billion gallons per year by 2030, and then to 35 billion gallons by 2050, while achieving life cycle GHG reduction of at least 50% relative to fossil Jet A.

• The U.S.' biofuel production capacity rose to 23.8 billion gallons per year in 2023, a growth of over 1.7 billion gallons compared to 2022. Ethanol production has reached 17.8 billion gallons per year since 2023, while biodiesel production capacity stands at 2.1 billion gallons and renewable diesel capacity is now 3.9 billion gallons.

• This newsletter keeps you informed on the state of biofuels in the U.S., policy and regulations, technology advancements, and environmental and social impacts.

Introduction

Overview of transportation sector emissions

Over the past few decades, emissions from transportation have steadily risen, increasing by roughly 19% from 1990 to 2021. The transportation sector stands as the largest contributor to greenhouse gas emissions in the U.S., constituting 29% of total emissions in 2021 according to data from the Environmental Protection Agency (EPA), see Figure 1.

Within this sector, road vehicles, including passenger cars and light-duty trucks, dominate as the primary sources of carbon emissions, collectively accounting for about 58% of transportation-related CO2 emissions in 2021 (Figure 1). Additionally, heavy-duty trucks, such as freight trucks and buses, contribute significantly, making up around 23% of transportation-related CO2 emissions. Aviation, despite constituting a smaller share compared to road transportation, is a rapidly growing source of emissions, contributing approximately 8% of transportation-related CO2 emissions in 2021. Maritime shipping also plays a role in transportation emissions, estimated to contribute around 3-4% of transportation-related CO2 emissions in the U.S.. These emissions vary by region, with urban areas experiencing higher emissions per capita due to dense populations and heavy traffic.

The transportation sector has experienced shifts in modes of transport over time. For instance, there has been a gradual increase in the share of light-duty vehicles powered by gasoline-electric hybrid systems and all-electric vehicles (EVs). For the hard-to-electrify section, such as marine and jet, clean and renewable liquid fuel is an important climate solution.

Biofuels adoption

By utilizing renewable organic materials such as crops and waste biomass, biofuels can substantially lower the carbon footprint of the transportation sector, contributing significantly to mitigating climate change. The biofuels industry encompasses a wide range of economic activities, including farming, biofuel production, distribution, and research and development.

Strategically, biofuels offer several benefits, including enhanced energy security and reduced geopolitical risks. By diversifying the sources of transportation fuels and reducing reliance on imported oil, the U.S. can strengthen its energy independence and resilience to supply disruptions and price fluctuations in the global oil market. Investing in domestic biofuel production not only mitigates geopolitical risks associated with oil imports but also fosters technological innovation and leadership. Transitioning to biofuels can create new employment opportunities, particularly in rural areas where biofuel feedstocks are cultivated and processed, thereby fostering economic development and revitalizing rural communities (Figure 2).

Moreover, biofuel production creates an extra market for farmers to sell agricultural commodities and biomass feedstocks, providing them with additional revenue sources and income stability. Embracing biofuels helps advance international climate goals, promoting cooperation and climate diplomacy.

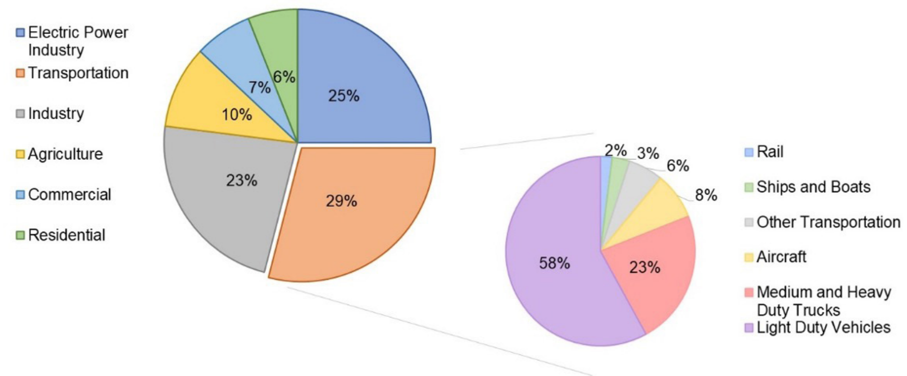


Figure 1: Share of U.S. GHG emissions by economic sector with a focus on the transportation sector [1]

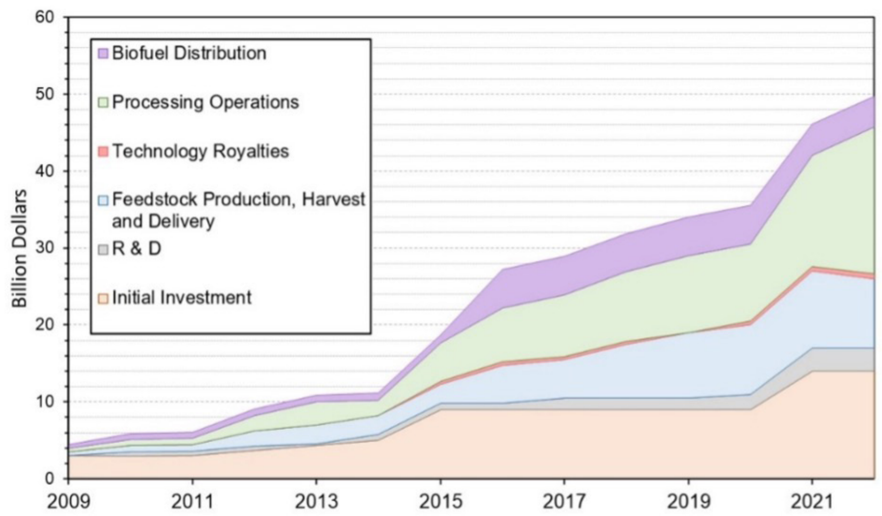


Figure 2: Economic output from biofuel production in the United States [3]

Current state of Biofuels in the United States

Ethanol

Ethanol has a long history as a domestically produced biofuel in the U.S.

Ethanol production, consumption, and capcity

In 2023, there are 187 fuel ethanol plants in 28 states, with an installed capacity of 1,152 million barrels per day, as shown in Figure 3 and Figure 4. Boosted by higher domestic consumption and experts, ethanol production increased to 15.6 billion gallons (1,018 million barrels per day).

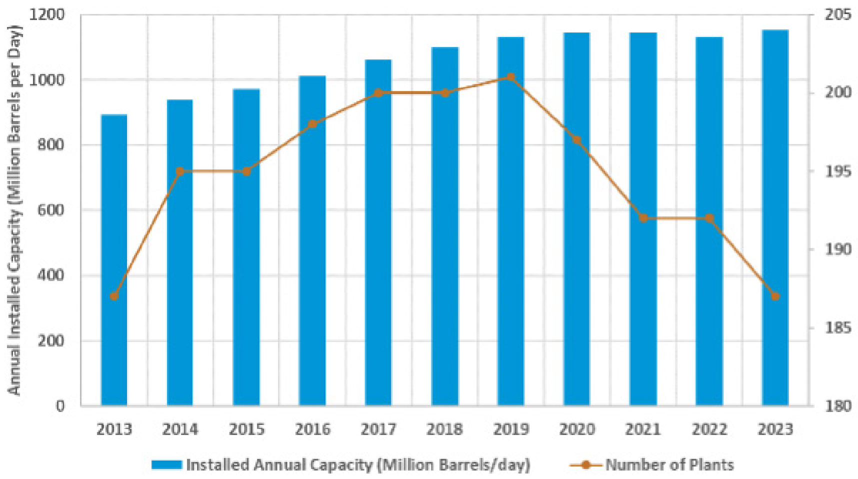


Figure 3: U.S. ethanol plants and annual nameplate capacity by the end of 2023 [5]

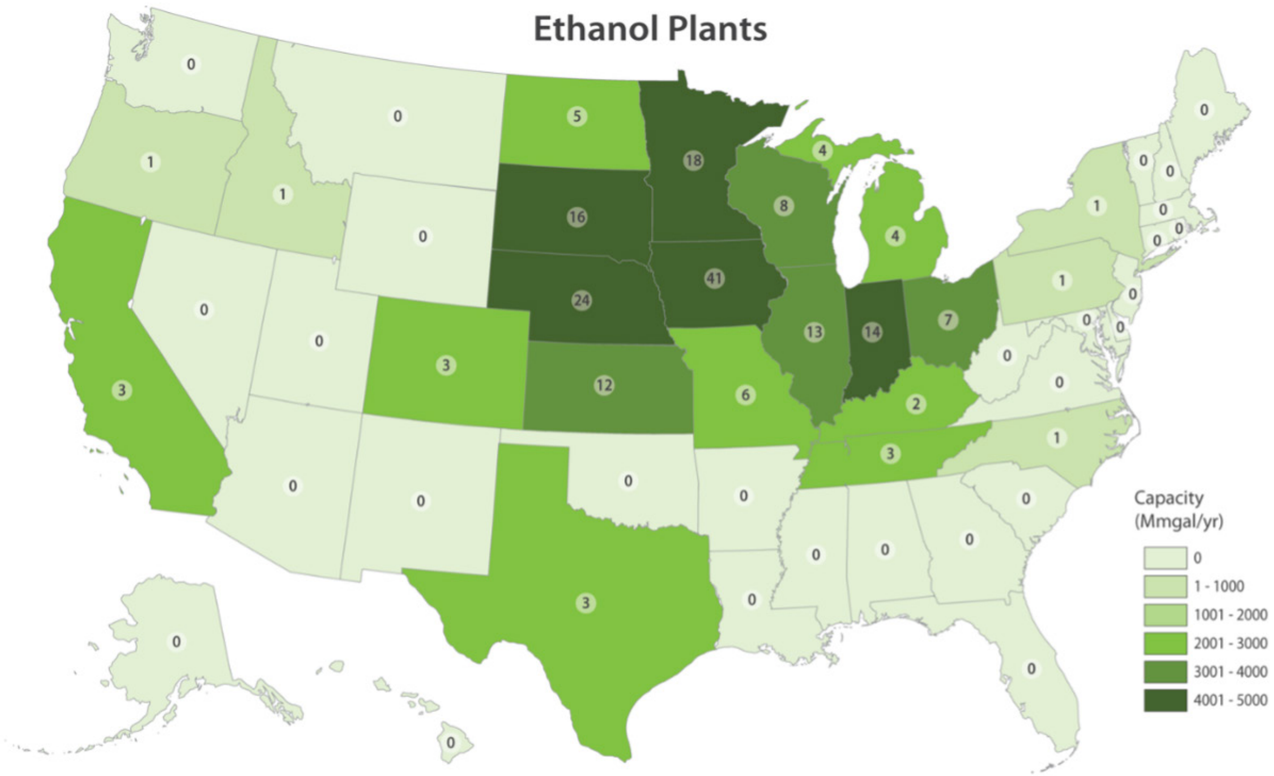


Figure 4: Ethanol plants by state, 2023 [5]

Consumption pattern

Most gasoline (98%) sold in the U.S. contains ethanol, and nearly all ethanol is sold as E10 (EIA 2022), a blend of 10% ethanol and 90% gasoline. In 2011, EPA approved E15 (10.5%–15% ethanol blended with gasoline) for use in vehicles model year 2001 and newer. Another long-available blend is E85—containing 51% to 83% ethanol, depending on geography and season—which can be used in flex fuel vehicles (FFVs). FFVs can operate on any gasoline-ethanol blended fuel between E0 and E85, and there were nearly 21 million FFVs on U.S. roads at the end of 2022 [5]. As shown in Figure 5, the U.S. ethanol industry fired on all cylinders in 2023. Operating margins hit their highest levels in nearly a decade as the cost of production fell, which also allowed ethanol to maintain its competitiveness against gasoline.

The U.S. has led the world in ethanol output for close to two decades. The U.S. exported 1.4 billion gallons of American ethanol, valued at $3.9 billion in 2023, exported to 50 nations (Figure 6) [7].

Market dynamics

The primary drivers of ethanol prices are the cost of corn grain and the gasoline prices for which ethanol serves as a substitute product. Figure 6 compares ethanol and gasoline futures prices with corn grain prices.

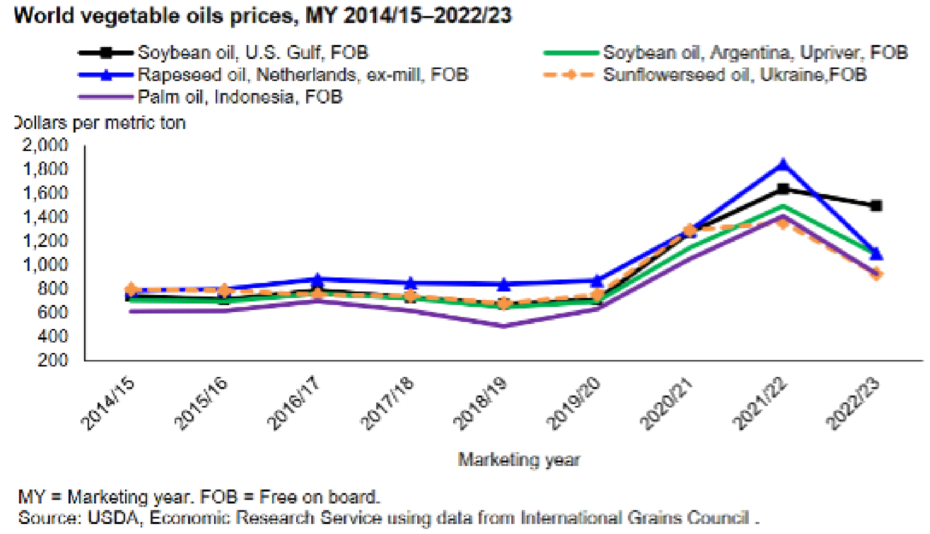


Figure 5: U.S. Annual ethanol blend rate by percentage [6, 7].

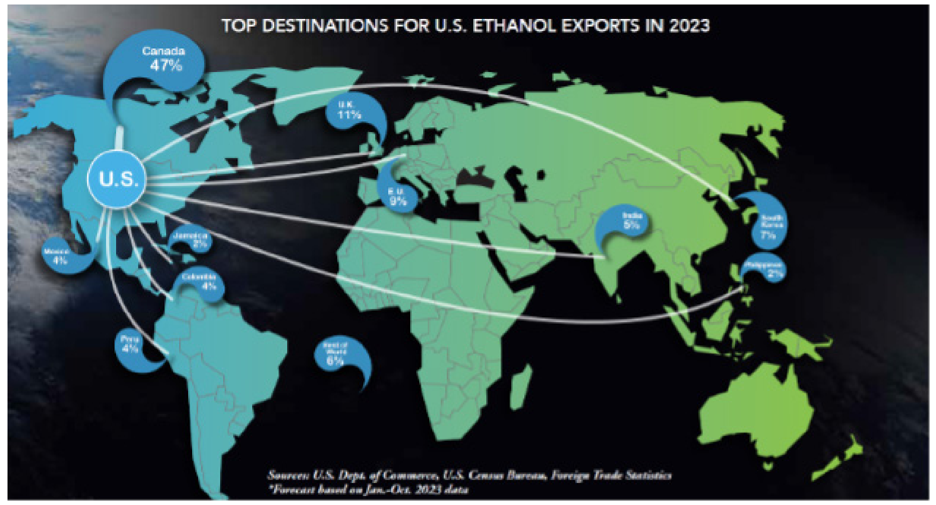


Figure 6: U.S. ethanol exports in 2023 [7].

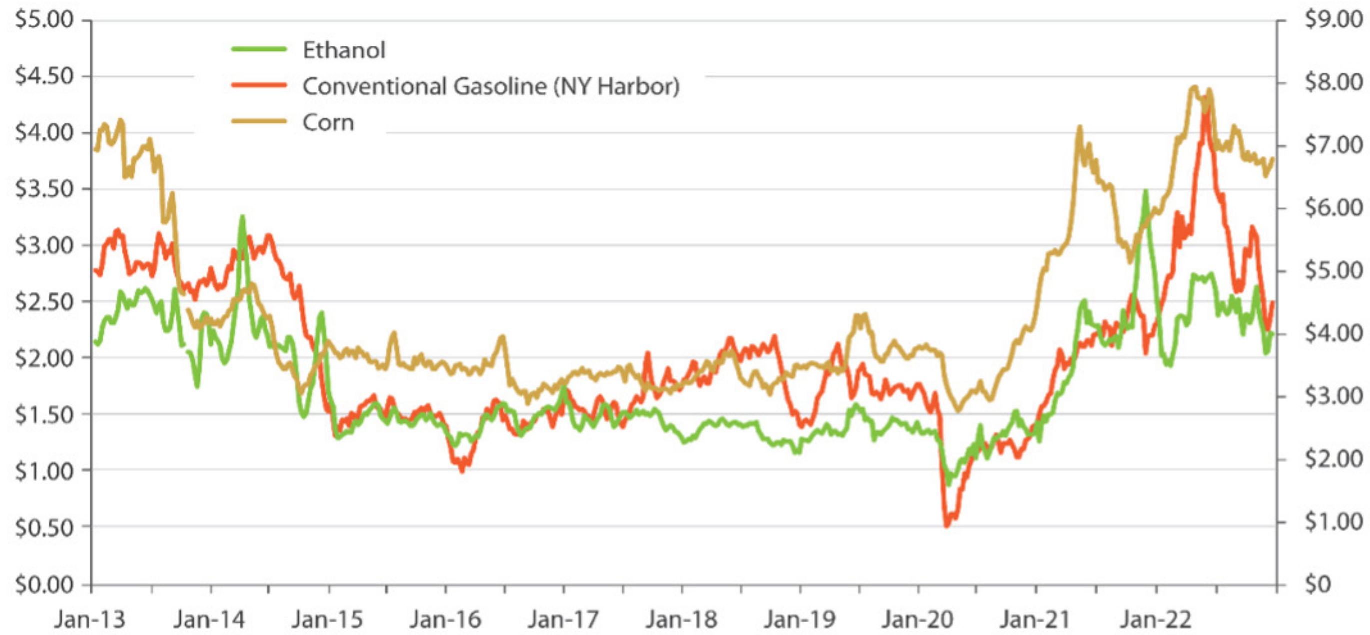


Figure 7: U.S. corn, ethanol, and gasoline prices [5].

Infrastructure

Regulations have long accommodated the use of E10 in existing infrastructure. Blends above E10 require approvals and some specialized equipment to meet the patchwork of regulations that cover refueling infrastructure. As of the end of 2022, E85 was available at 4,426 stations in 44 states. The largest ethanol markets are located on the east and west coasts of the U.S., outside of the primary corn grain production region. Most ethanol produced in the U.S. is shipped on trains to those markets because ethanol is not shipped by pipeline due to fuel properties. Ethanol prices are typically lowest in the Midwest and increase as a function of transportation costs when shipped to other domestic markets [5].

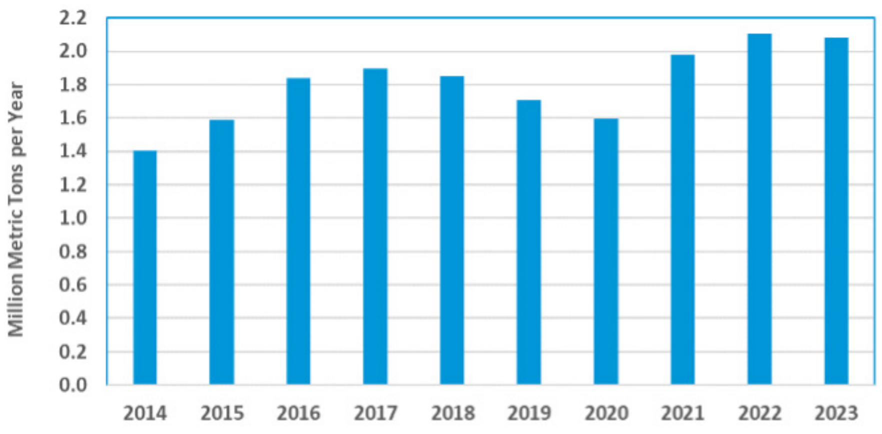


Figure 8: U.S. starch ethanol corn distillers oil (DCO) [7].

Co-products

More than 91% of the United States fuel ethanol is produced using dry mill process, with the remaining 9% coming from wet mills. Dry milling is a process that grinds corn grain into flour and ferments only the starch component into ethanol with coproducts of distillers grains (an animal feed substitute) and carbon dioxide. Roughly 80% of distiller's grains was consumed by beef or dairy. When distiller's grains are used as a partial replacement for grain in cattle diets, the nitrogen, phosphorus and sulfur contents of the diets are higher than the animals' nutrient requirements [8]. Thus, cattle consume more of these nutrients than they can utilize, and excess nitrogen, phosphorus, and sulfur are excreted in feces and urine, creating some environmental considerations when distiller's grains are fed [9]. The environmental impacts of DDGS will need to be properly addressed. Wet-mill plants primarily produce corn grain sweeteners, along with ethanol and several other coproducts (such as corn oil and starch).

In 2023, U.S.' corn ethanol facilities generated 35 million metric tons of distillers grains and corn gluten feed/meal, over 2 million metric tons of distillers corn oil (DCO, Figure 8) with 2.8 million tons of CO_2 captured [7]. DCO has become an important co-product from corn ethanol and is now used to produce biodiesel, renewable diesel (RD) and SAF. Biodiesel, RD, SAF, and renewable heating oil produced from DCO are approved pathways for biomass-based diesel (D4) or advanced biofuel (D5) under the Renewable Fuel Standard (RFS) program [10].

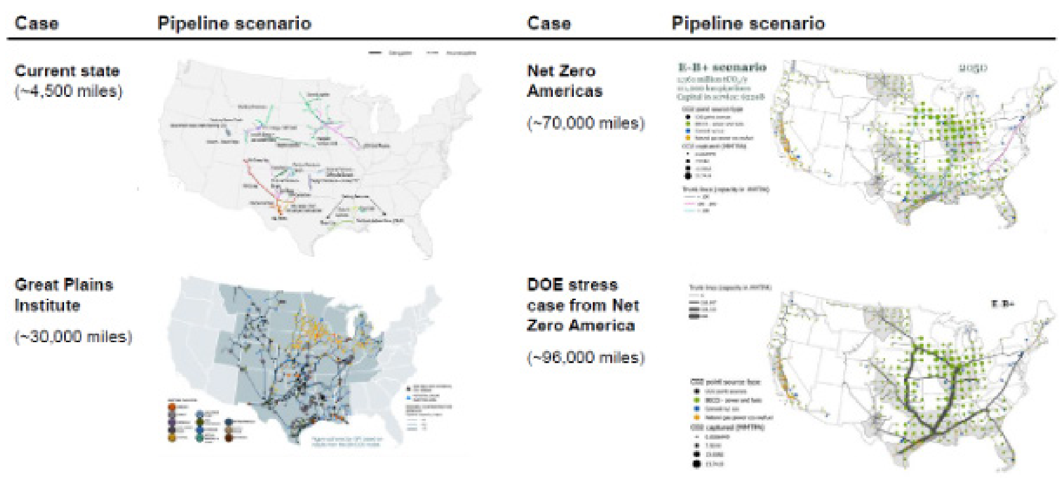
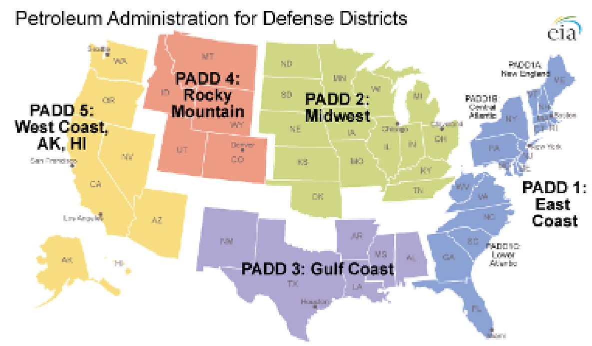


Figure 9. Different pipeline network analysis proposed by various studies with 30,000 miles to 96,000 miles https://carboncaptureready.better-energy.org/analysis/CO2 pipeline expected for near to medium term carbon capture [11-14].

Renewable Diesel and Biodiesel

The renewable diesel (RD) and other biofuels production capacity in U.S. has significantly increased in the last three years, surpassing the biodiesel production capacity in 2022, Figure 10.

The RD capacity is expected to keep growing because of the rising targets for state and federal renewable fuel programs and renewal of the biomass-based diesel tax credit through 2024 [16]. From 2024 until 2027, the clean fuel production credit (CFPC) under the Inflation Reduction Act (IRA) section 45V will support RD and other qualifying transportation fuels. As of 2023, the total production capacity of RD fuel and other biofuels amounted to 3,000 MGPY with a total of 17 plants, see Figure 11, [17]. Planned hydroprocessing facilities and expansions, along with those under construction, are expected to contribute to a projected capacity of around 5.6 BGPY for RD and other biofuels by 2027.



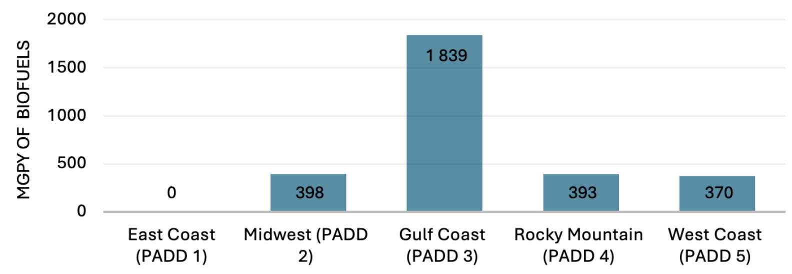


Figure 11: RD fuel and other biofuels plant capacity as of January 1st, 2023 [17, 18]

Consumption Patterns

RD, which is chemically identical to petroleum diesel, can be used as a drop-in fuel in its pure form known as R100. It can be combined with petroleum diesel or biodiesel in varying quantities. Pure biodiesel has limited direct-use applications and has supply logistics challenges due to its solvent nature, which can degrade rubber or dissolve varnish and sediments. Biodiesel is approved for blending with petroleum diesel (distillate) under ASTM D6751. Biodiesel in the U.S. is mostly consumed as blends with petroleum diesel in ratios of B2, B5, or B20. Up to 1% biodiesel is added to most petroleum diesel fuel in the U.S. to enhance engine component longevity.

In 2022, U.S. RD consumption (1.72 billion gallons) surpassed for the first time the consumption of biodiesel (1.6 billion gallons), see Figure 12. About 1.7 billion gallons of biodiesel were consumed in 2022, nearly all in blends up to B20, Figure 13.

Although the majority of RD production capacity is in the Gulf Coast, California is responsible for almost all RD consumption in the U.S, as shown in Figure 13.

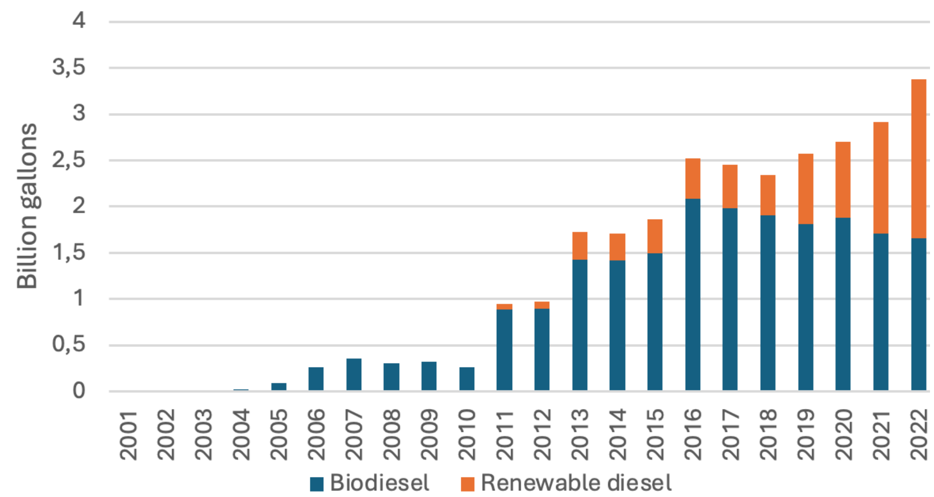


Figure 12. U.S. biodiesel, RD consumption, 2001-2022 [19]

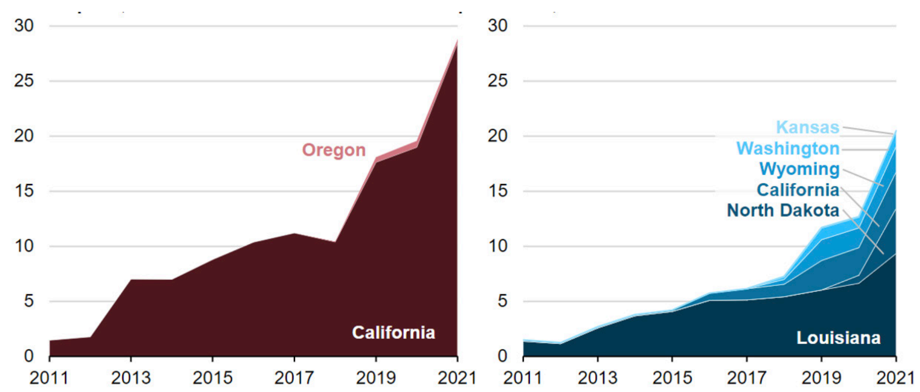


Figure 13. Annual U.S. RD consumption and production, by state (2011-2021), million barrels [20]

Market Dynamics

Soybean oil is the main feedstock used for biodiesel and RD production in U.S. Other feedstocks include palm oil, corn oil, yellow grease, canola, tallow, used cooking oil, and others. The implementation of biofuel policies has led to a notable surge in the demand for vegetable oils, animal fats, and waste greases, particularly for RD production. The vegetable oil consumption for biofuel has hit a record high of 19.1 billion pounds in the marketing year 2022/23, as shown in Figure 14. Soybean oil was primarily responsible for the increase. In addition, the U.S. EPA's approval of canola oil as a viable source for RD production in December 2022 led to a more than twofold increase in its use for biofuels from 2021/22 to 2022/23.

Vegetable oil prices in the U.S. reached a record high in 2021/22 because of domestic biofuels policy and limited global supply, as shown in Figure 15. While global vegetable oil prices dropped in 2022/23, U.S. prices remained higher than the global average. The average export price of soybean oil in 2022/23 was $1,495.00 per metric ton, $139.00 lower than 2021/22 but still above the 5-year average.

In 2022, biodiesel and RD prices saw a notable increase (Figure 16 and Figure 17) because of rising feedstock costs, as discussed above. The U.S. biodiesel (B20) prices tended to be slightly higher than fossil diesel prices since 2018, see Figure 17 left. In contrast, the biodiesel (B99/B100) blends prices have been historically higher than fossil diesel.

Figure 18 shows the historical renewable and fossil diesel prices in California from 2017 to 2024. The average diesel price in California in 2023 was $5.51 per gallon, with the average RD prices being $0.06 per gallon higher than the average fossil diesel prices in California.

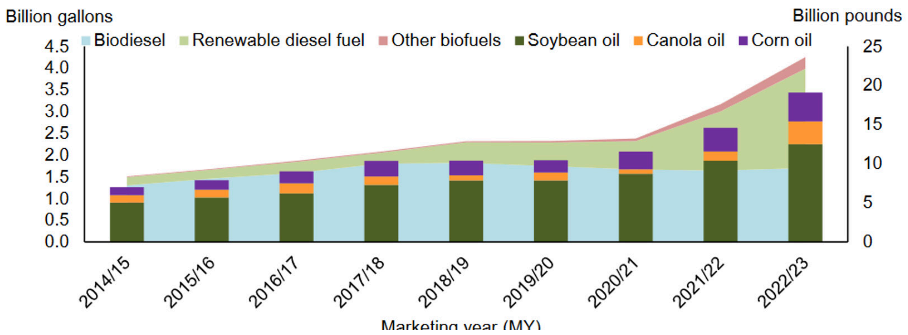


Figure 14: Biomass-based fuel production and vegetable oils use. [21]

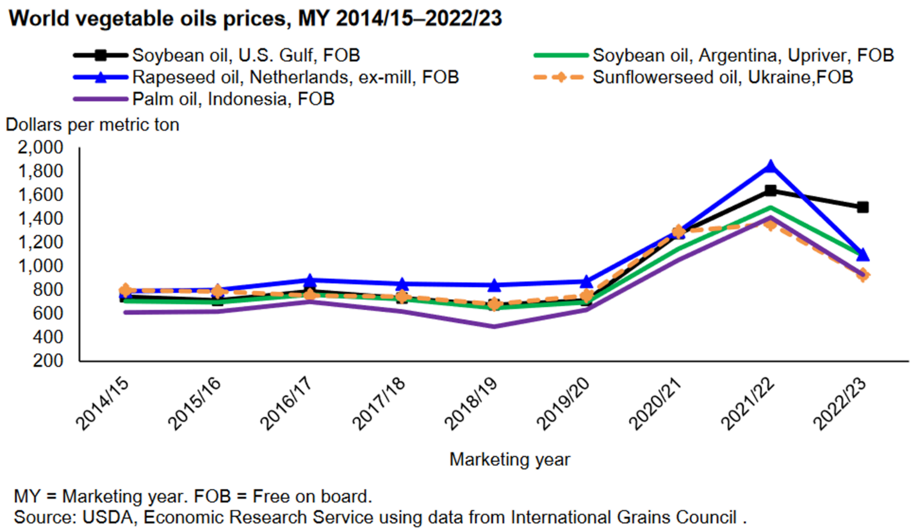


Figure 15: World vegetable oils prices [21]

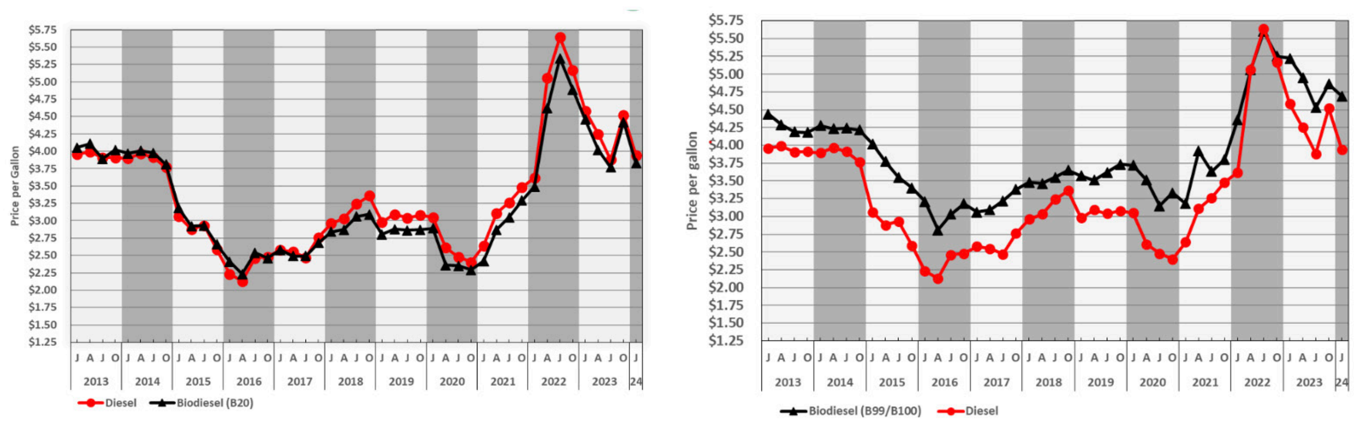


Figure 16: Historical biodiesel (B20, left) and (B99/B100, right) prices vs. fossil diesel prices. [22]

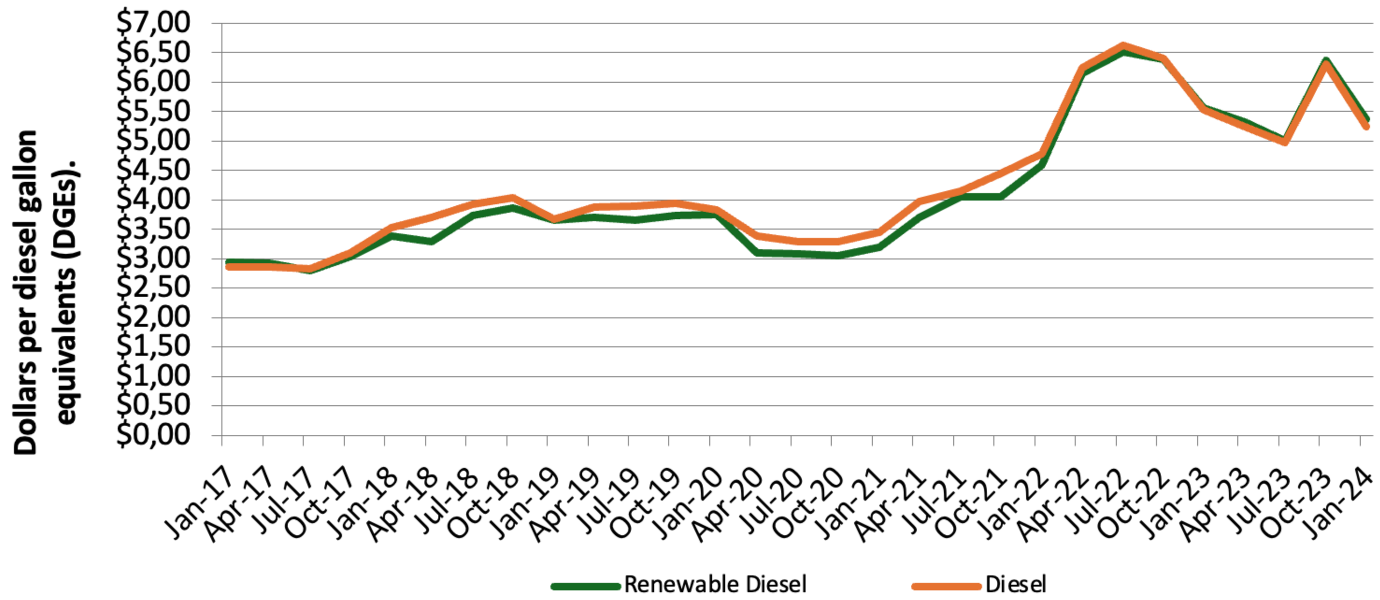


Figure 17: Historical RD vs California diesel prices. [23]

Sustainable aviation fuels (SAF)

SAF Production Capacity and consumption

Multiple pathways for producing SAF have been approved by ASTM International, a global standards organization. The hydroprocessed esters and fatty acids (HEFA) pathway is the most immediately accessible and the major commercially deployed method to produce SAF and RD.

At the end of 2023, the total operational capacity of renewable fuel facilities using the HEFA technology in the U.S. was estimated in 3.9 BGPY (Figure 11). While most of these facilities focus on the production of RD, several RD facilities in operation can potentially be upgraded to produce SAF. The support of SAF policies is driving interest in SAF production, as evidenced by 11 out of 13 planned facilities and expansions, from 2023 to 2028, will be ready for SAF and RD production. The total announced total capacity for SAF production, including announced HEFA, alcohol-to-jet, Fischer-Tropsch, and power-to-liquid facilities, is expected to reach 2.0 BGPY by 2030, with the majority announced from HEFA [24].

SAF production through non-HEFA pathways is currently minimal. The Fulcrum BioEnergy facility in Reno, Nevada, which started operation in 2022, has an 11 MGPY capacity and converts municipal solid wastes into synthetic crude oil using the Fischer-Tropsch pathway, which can be further converted into SAF. LanzaJet has recently inaugurated the world's first ethanol to jet production facility in Soperton, Georgia [25]. The Freedom Pines Fuels facility by LanzaJet will produce 10 MGPY, with 9 MGPY being SAF [26].

Consumption Patterns

As a consequence of the SAF Grand Challenge and the steadfast commitment of private industries to reduce their greenhouse gas (GHG) emissions, the utilization of SAF in the U.S. is on the rise (Figure 18). The U.S. EPA's renewable identification numbers (RIN) provide an approximated domestic consumption of SAF of around 15.7 MGPY in 2022 [27, 28]. In 2022, estimated SAF imported into the U.S. was approximately 8.0 million gallons, while around 1.0 million gallons were exported [29]. As of 2023, estimated SAF domestic consumption growth to approximately 23.3 MGPY [30].

Market Dynamics

The average RD retail prices in California in 2023 were $0.06 per gallon higher than the average fossil diesel prices in California (Figure 17). During the same period, the wholesale price premium of SAF was 2.4 times higher than that of conventional jet fuel (Figure 19) [31]. Although SAF's price premium is declining, as shown in Figure 19, it remains substantial, and its low production volume keeps it as a niche product. Although SAF domestic consumption accounted for just 1% of RD volumes in 2022 (Figure 12 and Figure 18), there is competition between SAF and RD for feedstock due to the dominance of the HEFA pathway in SAF production.

Figure 19: Price premium of SAF over conventional jet fuel [31].

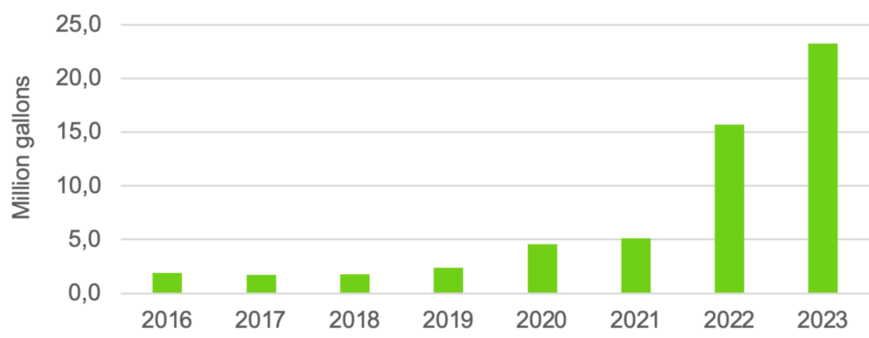


Figure 18: Estimated consumption of SAF in U.S. [30]

Federal

The U.S. EPA's RFS Program, first established in 2005, sets volumetric targets for biofuels which are regularly updated. This program supports multiple categories of biofuels, including cellulosic biofuel, biomass-based diesel, advanced biofuel, and renewable fuel, and establishes requirements for minimum lifecycle GHG emission reductions, as well as feedstocks and pathways. Renewable Identification Numbers (RINs) are generated by biofuel producers and traded in the market, tracking compliance with the program (Figure 20). These standards have contributed substantially to supporting the biofuels market in the states.

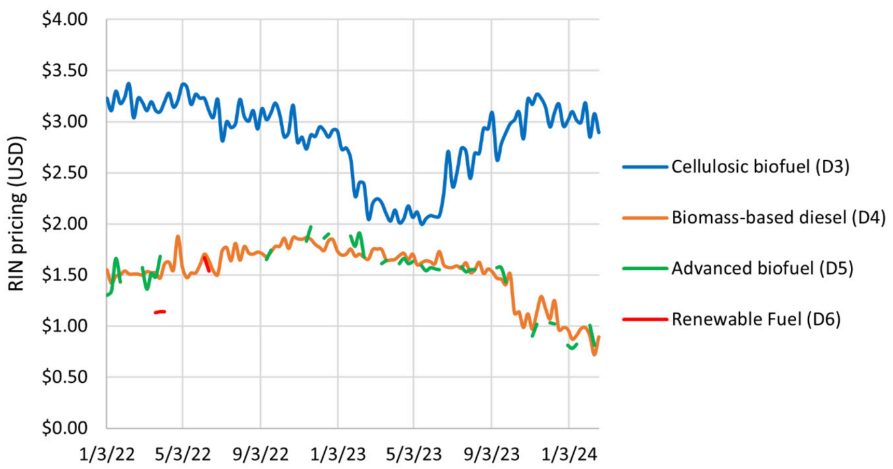


Figure 20: RFS RIN pricing for qualified RINs from January 2022 through February 2024, in USD, based on data from U.S. EPA [32].

	Cellulosic biofuel (D3)	*Biomass-based diesel (D4)*	*Advanced biofuel (D5)*	*Renewable fuel (D6)*
2023	0.84	2.82	5.94	20.94
2024	1.09	3.04	6.54	21.54
2025	1.38	3.35	7.33	22.33

Table 1: RFS requirements for biofuels for 2023, 2024, and 2025, as billion RINs, by biofuel category and D-code [33, 34].

In 2023, the target requirements were updated for the years 2023, 2024, and 2025 (Table 1). These updates include regulations for generating eRINs from biogas and from electricity to fuel electric vehicles.

The 2022 IRA provides additional support for biofuel production through multiple incentives, including the phased transition to new tax credits [35]. Existing biofuel credits, such as the Biodiesel Mixture Credit, were extended through 2024 and 2025. A new SAF Credit was introduced for 2023 through 2024 for the specific incentivization of SAF. Beginning in 2025, these credits are replaced by the Clean Fuel Production Credit, the values of which are determined by a base credit multiplied by an emissions factors based on lifecycle GHG emissions. A comparison of credit values for SAF with different CI are shown for the SAF Credit and Clean Fuel Production Credit (Figure 21).

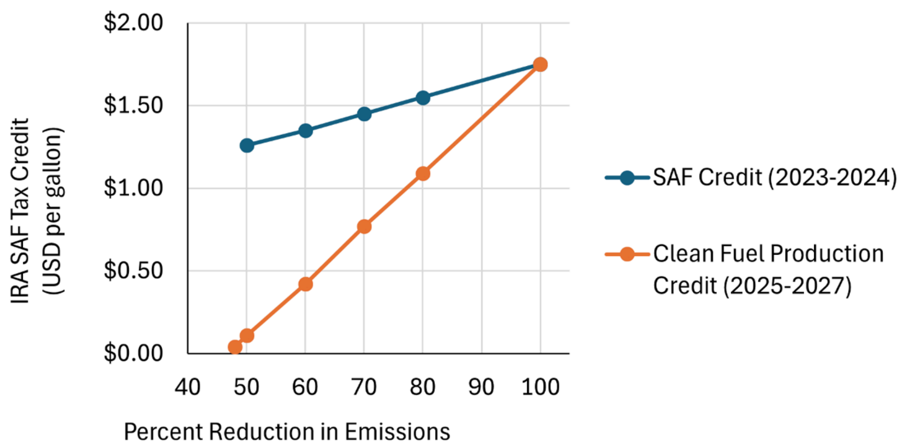
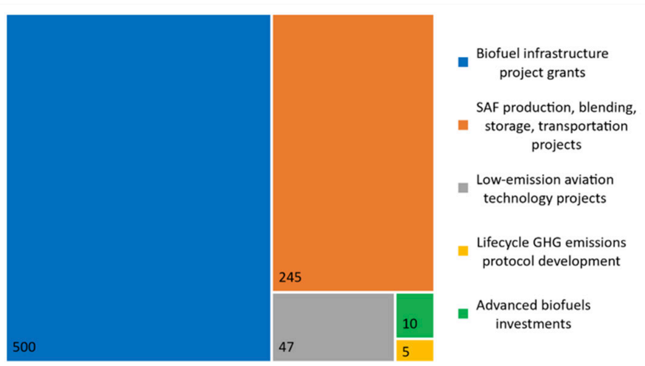


Figure 21: Credit values for SAF with different CI from the SAF Credit and Clean Fuel Production Credit established by the 2022 IRA [35] .

Figure 22: Funding supportive of biofuels and SAF in the 2022 IRA, in million USD [35].



Moreover, the 2022 IRA provides $812 million in funding for multiple grant and loan programs focused on researching innovative fuel pathways and technologies, as well as expanding infrastructure (Figure 22). A portion of the funding is allocated to SAF, including support for projects related to producing, blending, storing, or transporting SAF. Through the inclusion of tax credits, grants, and loans, the 2022 IRA supports the broader biofuels industry and specifically strengthens SAF production to meet the SAF Grand Challenge target.

State

The adoption of state-level clean fuel standards and SAF-specific tax credits remains limited but is increasing (Figure 23). California introduced the first state-level Low Carbon Fuel Standard (LCFS), which sets a threshold for transportation fuels' carbon intensity (CI) and gradually increases the required reductions. Deficits occur when fuels surpass the CI threshold, while credits are generated by fuels that meet the allowable CI limit.

Currently, aviation fuel doesn't have to meet the required CI, but SAF can generate credits voluntarily. As of March 2024 and illustrated in Figure 23, Oregon, Washington, and New Mexico have implemented clean fuel standards, and five other states have proposed similar standards. In addition, California and Washington state have cap-and-trade programs that discourage the use of petroleum-based fuels, with the exception of aviation fuel. SAF-specific credits have been adopted by Illinois, Minnesota, and Washington. The purpose of these credits is to encourage SAF production and blending within the states, SAF purchases for departing flights from those states.

An example of a state SAF-specific tax credit (Figure 25) was adopted in Washington state in 2023. To promote SAF production, facilities within the state can receive a tax credit, as well as those purchasing SAF for outbound flights. This tax credit is just one component of a broader policy aimed at fostering the growth of the SAF industry in the state, which includes several other measures, such as to incorporating low CI pathways, assessing benefits of SAF for communities in the state for facilities with a combined minimum SAF annual capacity of 20 million gallons.

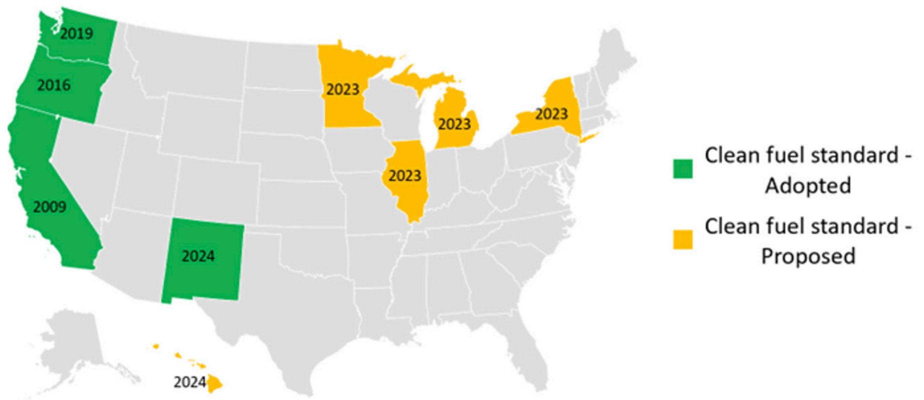


Figure 23:. States with adopted or proposed clean fuel standards, such as the LCFS in California, as of March 2024.

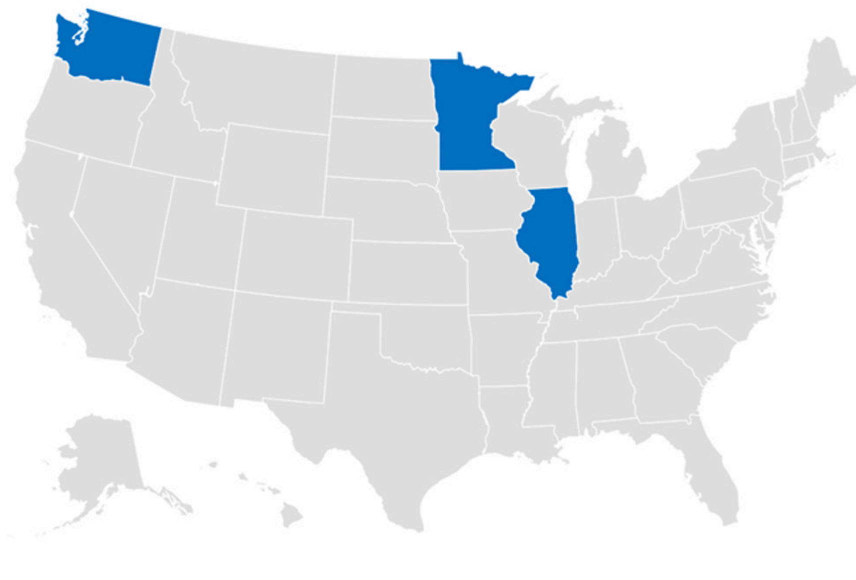


Figure 24:. States with SAF-specific tax credits, as of March 2024.

Carbon Emission Methodologies

Multiple federal and state policies supporting biofuels through tax credits have established requirements for qualifying fuels to achieve specified reductions in lifecycle GHG emissions. There is variation in the methodologies which are utilized to determine the lifecycle GHG emissions and carbon intensities of biofuels across different policies. For example, the RFS program has applied an EPA 2010 Life Cycle Analysis (LCA) Framework which draws on three different models [36]. The Clean Fuel Production Credit applies the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model (GREET) [35]. The use of different methodologies can introduce challenges, such as variation in the eligibility of fuels to qualify for incentives under different policies. To achieve greater consistency across policies, federal agencies are coordinating to align methodologies, a goal set forth by the SAF Grand Challenge and supported by funding within the 2022 IRA. In December 2023, the federal agencies in the SAFs Lifecycle Analysis Working Group (USDA, EPA, DOT, FAA) announced they are working to modify the GREET model to reflect new data, expand considerations of indirect emissions, and GHG reduction from carbon capture and storage (CCS) and other sources. The release of the modified model in 2024 will have implications for calculating lifecycle GHG emissions for SAF Credit eligibility [2].

Policy – Looking Forward

Key aspects of U.S. policies supportive of biofuels include the increased adoption of state policies, the ability to combine federal and state tax credits, and the use of performance-based incentives.

- State policies such as clean fuel standards and SAF-specific tax credits provide multiple benefits.
- Biofuel producers can take advantage of various credits, which depend on factors like biofuel types, feedstocks, and pathways. RIN credits, SAF Credit (in 2024), Clean Fuel Production Credit (in 2025), and state LCFS incentives are all used by a SAF producer under the RFS program.
- Performance-based incentives are becoming common in U.S. policies. The adoption of performance-based incentives incentivi zes the production and utilization of fuels with lower emissions, while also fostering innovation in feedstocks, pathways, and technologies to achieve even greater improvements in emissions reductions.

Technological Innovation and Research Development

Feedstock Diversification

In the U.S., biofuel production currently uses a variety of feedstocks. Corn serves as the primary feedstock for ethanol production, creating E10, E15 and E85. Soybeans play a significant role as a feedstock for biodiesel production as B20 and B100. Other vegetable oils such as canola oil, palm oil, and sunflower oil are also used in biodiesel production. Tallow and yellow grease are examples of animal fats from restaurants and food processing facilities that can be used as alternative feedstocks for biodiesel or RD production.
Research efforts are being made to expand the range of feedstocks used for biofuel production. This is important for making biofuels more sustainable and scalable. One area of exploration focuses on non-food biomass sources, like agricultural and forestry residues, dedicated energy crops, and municipal solid waste. This helps address concerns about food security and land use change in biofuel production. Shown in Figure 25, lignocellulosic biomass, encompassing agricultural residues, forestry residues, dedicated energy crops, and municipal solid waste, holds promise for advanced biofuel production. The U.S. DOE Bioenergy Technologies Office (BETO) 2023 Billion-Ton Report (BT23) is an assessment of renewable carbon resources potentially available in the U.S. [37].

This BT23 report quantifies national biomass production capacity from 60 resources, including wastes, forestry, agriculture, and algae. According to the report, the nation has the capability to achieve sustainable production of 1.1 to 1.5 billion tons per year of biomass. This would triple the current bioenergy production while simultaneously meeting the projected demand for food, feed, fiber, conventional forest products, and exports (Figure 25) (DOE 2024). About 70 billion gallons of renewable carbon liquid fuels or biofuels can be made from these biomass resources, see Figure 26.

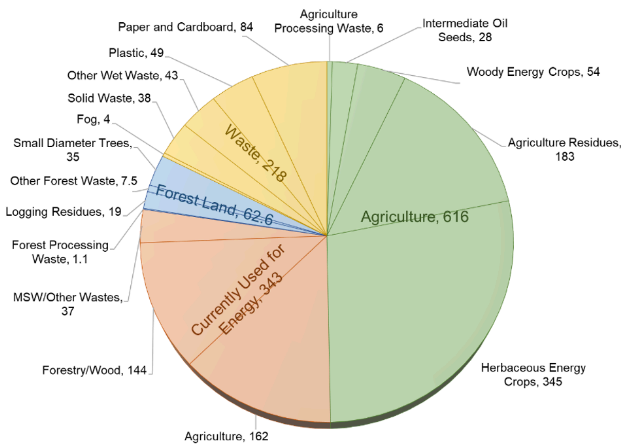


Figure 25: Biomass resources in mature-market medium scenario for a total of 1.2 billion dry short tons per year (all numbers in million tons) [37]

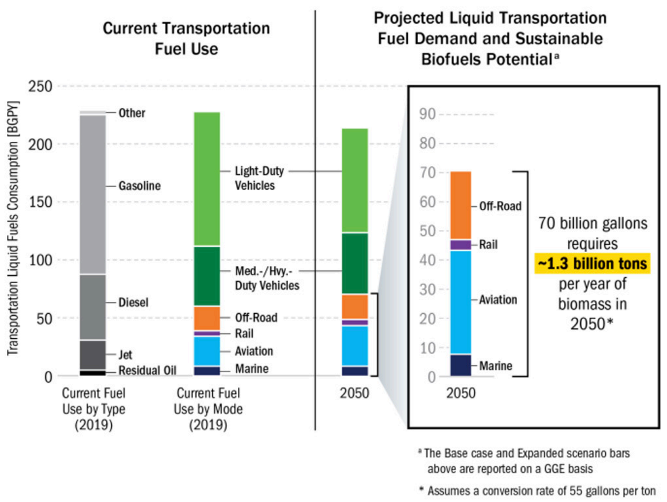


Figure 26: Evolution of liquid transportation fuel demand and sustainable biofuel supply [37, 38]w

Advanced Biofuel Technologies

Research endeavors in this realm focus on optimizing conversion processes to efficiently utilize non-food biomass for biofuel production, thereby diversifying the feedstock base and reducing dependence on traditional sources. Recent advancements in biofuel production technologies have catalyzed significant progress in the pursuit for sustainable and renewable energy sources. Shown in Figure 27, current R&D shows that 1 billion tons of biomass could produce either 60 billion gallons of renewable low-carbon fuels or 200 million metric tons of renewable chemicals and materials.

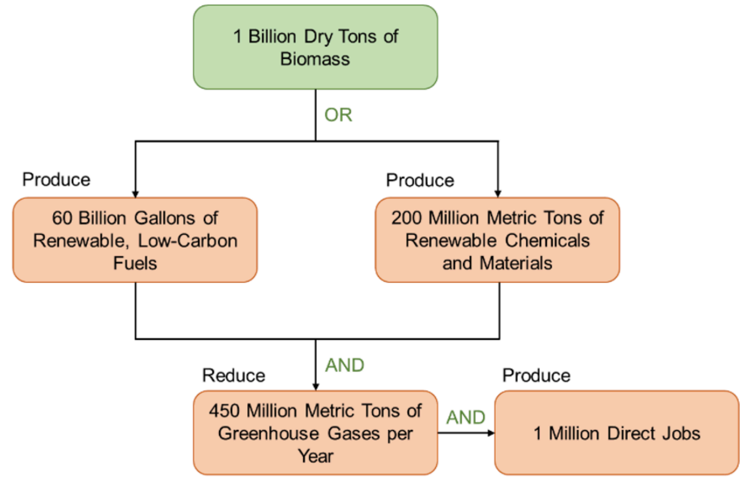


Figure 27: Outputs and benefits of biofuel production in U.S. [39]

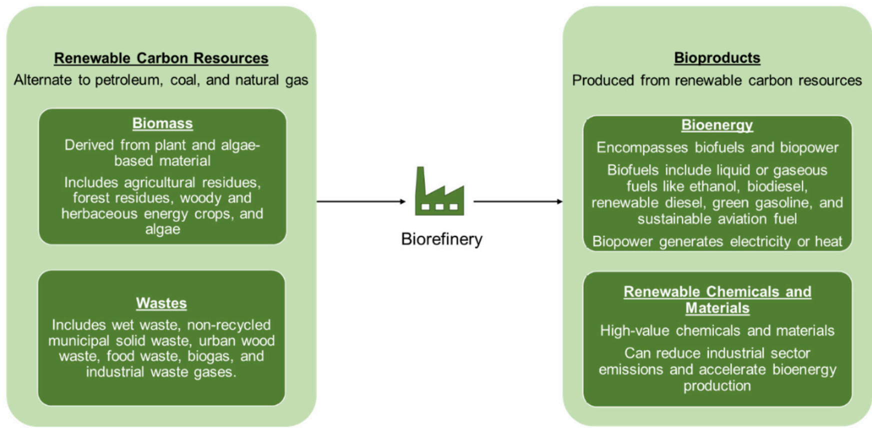


Figure 28: Transformation of renewable resources into market-ready fuels and products via biorefineries using BETO technologies. [39]

Research initiatives in this domain focus on developing advanced process technologies efficiently convert lignocellulosic biomass into useful products including both bioenergy, renewable chemicals and materials (Figure 28). These efforts aim to unlock the vast potential of biomass and waste as a renewable and abundant carbon resources as alternate to petroleum, coal and natural gas, to reduce greenhouse gas emissions for the transportation sector and industry sector[39].

Collaborative Research Initiatives

Public-private partnerships and collaborative research programs focused on biofuel innovation in the U.S. are instrumental in driving forward research, development, and commercialization efforts within the biofuel sector. A number of ongoing research initiatives and collaborative activities are summarized below and illustrated in Figure 30.

Additionally, BETO within the DOE funds consortia focused on biofuel innovation. Consortia such as the Consortium for Advanced Bioeconomy Leadership Education (CABLE), the Center for Advanced Bioenergy and Bioproducts Innovation (CABBI), and the Center for Bioenergy Innovation (CBI) promote collaboration between stakeholders to overcome technical and economic barriers to biofuel commercialization.

The National Renewable Energy Laboratory (NREL) possesses state-of-the-art biofuel pilot plant capabilities, enabling research and development in advanced biofuel production technologies. Equipped with cutting-edge equipment and expertise, NREL's pilot plant facilitates the scale-up and demonstration of novel biofuel processes, from feedstock preprocessing to fuel synthesis and refining. The facility allows researchers to test and validate new biofuel production pathways, optimize process parameters, and assess the performance and scalability of emerging technologies [40].

The Energy Earthshots Initiative is a bold and ambitious program launched by the U.S. DOE aimed at accelerating the development and deployment of breakthrough technologies to address pressing energy challenges. Modeled after President Kennedy's "Moonshot" initiative, the Energy Earthshots Initiative sets aggressive targets and mobilizes resources across government, academia, and industry to achieve transformative energy goals. By leveraging innovation, collaboration, and strategic investments, the initiative seeks to drive advancements in key areas such as renewable energy, energy storage, carbon capture, and clean transportation [41].

Aviation Sustainability Center (ASCENT) a collaborative research consortium comprising universities, industry partners, and government agencies working together to address the environmental challenges facing the aviation industry. As part of the Federal Aviation Administration's Center of Excellence for Alternative Jet Fuels and Environment (CEAJFE), ASCENT focuses on developing and advancing technologies to reduce aviation's environmental impact, including the development of SAF, noise reduction strategies, and emissions mitigation technologies [42].

[Commercial Aviation Alternative Fuels Initiative (CAAFI)] is a coalition of airlines, manufacturers, airports, government agencies, and fuel producers united to advance the development and deployment of alternative aviation fuels. By fostering collaboration and innovation, CAAFI aims to accelerate the commercialization of SAFs to reduce the aviation industry's carbon footprint and dependence on fossil fuels [43].

Furthermore, [the Advanced Research Projects Agency-Energy (ARPA-E)] plays a pivotal role in funding innovative research projects focused on biofuel and bioenergy technologies. Through programs like the [Renewable Energy to Fuels Through Utilization of Energy-Dense Liquids (REFUEL)] and [Plants Engineered to Replace Oil (PETRO)], ARPA-E supports collaborative research efforts between academic institutions, national laboratories, and private sector partners. These partnerships facilitate the translation of cutting-edge research into viable biofuel technologies, driving innovation and competitiveness in the bioenergy sector [44].

The U.S. DOE also supports Bioenergy Research Centers (BRCs), multidisciplinary research consortia dedicated to advancing fundamental research in bioenergy. Examples include the [Great Lakes Bioenergy Research Center (GLBRC)] and the [Joint BioEnergy Institute (JBEI)], which bring together researchers from academia, national laboratories, and industry to develop sustainable biofuel production technologies.

[Center of Excellence for Alternative Jet Fuels and Environment (CEAJFE)] is a research and development center focused on advancing the science and technology of alternative jet fuels and mitigating the environmental impacts of aviation. Led by a consortium of universities, research institutions, and industry partners, CEAJFE conducts cutting-edge research to develop SAF and assess their environmental performance, including emissions reductions and lifecycle analysis [42].

Moreover, [the National Alliance for Advanced Biofuels and Bioproducts (NAABB)] exemplifies a collaborative effort led by Pacific Northwest National Laboratory (PNNL) in partnership with industry, academia, and government agencies. NAABB focuses on overcoming technical and economic hurdles to the commercialization of advanced biofuels and bioproducts through collaborative research and development initiatives [45].

Finally, various state-level initiatives, such as the California Center for Algae Biotechnology (Cal-CAB) and the Texas A&M Energy Institute, support collaborative research and technology transfer activities within the biofuel sector. These biofuel innovation centers foster partnerships between academia, industry, and government to advance biofuel technologies and address regional energy challenges.

One notable initiative is the [Advanced Biofuels and Bioproducts Process Development Unit (ABPDU)], a partnership between Lawrence Berkeley National Laboratory (LBNL) and industry stakeholders. This collaborative effort provides industry partners with access to cutting-edge facilities and expertise for scaling up biofuel and bioproduct technologies from laboratory to pilot scale [46].

The U.S. DOE sponsors various [consortia] focused on collaborative research to advance bioenergy technologies and overcome key challenges in biofuel production, biomass conversion, and bioproducts development. These consortia unite researchers, industry partners, and academic institutions in multidisciplinary teams to expedite the creation and implementation of sustainable bioenergy solutions [47].

The [Agile BioFoundry] is a pioneering initiative supported by the U.S. DOE aimed at accelerating the development of bio-based products and processes. Through collaborative research efforts, the Agile BioFoundry brings together multidisciplinary teams of scientists, engineers, and industry partners to streamline the design, testing, and optimization of bioenergy technologies.

The [Algae Technology Educational Consortium (ATEC)] is dedicated to advancing algae-based biofuel production through education and training initiatives. ATEC brings together academic institutions, industry partners, and national laboratories to develop educational resources, curriculum materials, and training programs focused on algae cultivation, harvesting, and conversion technologies. By engaging students and professionals in hands-on learning experiences, ATEC aims to foster the next generation of scientists and engineers equipped with the skills and knowledge needed to drive innovation in algae-based biofuel research and development.

The [Bioprocessing Separations Consortium (BioSep)] focuses on developing advanced separation technologies to enhance the efficiency and cost-effectiveness of biofuel production processes. BioSep brings together experts from industry, academia, and government agencies to tackle key challenges in biomass pretreatment, fermentation, and product recovery. BioSep aims to optimize separation processes such as filtration, distillation, and chromatography, paving the way for increased adoption of bioenergy technologies.

[Bio-Optimized Technologies to Keep Thermoplastics Out of Landfills and the Environment (BOTTLE™)] is an innovative initiative aimed at developing bio-based alternatives to traditional plastics. By harnessing biodegradable and renewable materials, this initiative seeks to reduce plastic waste and environmental pollution associated with conventional thermoplastics. Through research and development efforts, Bio-Optimized Technologies aims to create bio-based polymers and composites that offer comparable performance and functionality to traditional plastics while minimizing their environmental impact.

The [CO2 Reduction and Upgrading for E-Fuels Consortium (CO2RUe)] is dedicated to developing technologies for capturing and utilizing carbon dioxide emissions to produce renewable fuels. By leveraging innovative processes such as electrochemical conversion and catalytic upgrading, CO2RUe aims to mitigate greenhouse gas emissions while producing valuable e-fuels that can be used as alternatives to conventional fossil fuels.

The [Chemical Catalysis for Bioenergy Consortium] focuses on advancing catalytic processes for biomass conversion into biofuels and bioproducts. By developing novel catalysts and reaction pathways, this consortium aims to enhance the efficiency and selectivity of biomass conversion, ultimately enabling the production of sustainable biofuels from renewable feedstocks.

The [Consortium for Computational Physics and Chemistry (CCPC)] utilizes advanced computational modeling and simulation techniques to accelerate the discovery and development of bioenergy technologies. By modeling complex chemical and physical processes at the molecular level, CCPC provides valuable insights into reaction mechanisms, material properties, and system behavior, facilitating the design and optimization of bioenergy systems and processes.

The [Co-Optimization of Fuels & Engines (Co-Optima)] initiative brings together experts from industry, academia, and national laboratories to optimize fuels and engines simultaneously. By considering both fuel properties and engine design in tandem, Co-Optima aims to maximize the efficiency, performance, and environmental benefits of advanced combustion engines running on biofuels, thereby accelerating the adoption of sustainable transportation technologies.

The [Development of Integrated Screening, Cultivar Optimization, and Verification Research (DISCOVR)] consortium focuses on advancing bioenergy crop development and optimization. By integrating screening, breeding, and verification efforts, DISCOVR aims to accelerate the development of high-yielding and resilient bioenergy crops suitable for sustainable biomass production.

The [Feedstock-Conversion Interface Consortium (FCIC)] addresses challenges related to biomass preprocessing and conversion. By improving the compatibility between feedstocks and conversion processes, FCIC aims to enhance the efficiency and economics of biofuel production, ultimately enabling the sustainable utilization of diverse biomass resources for energy production.

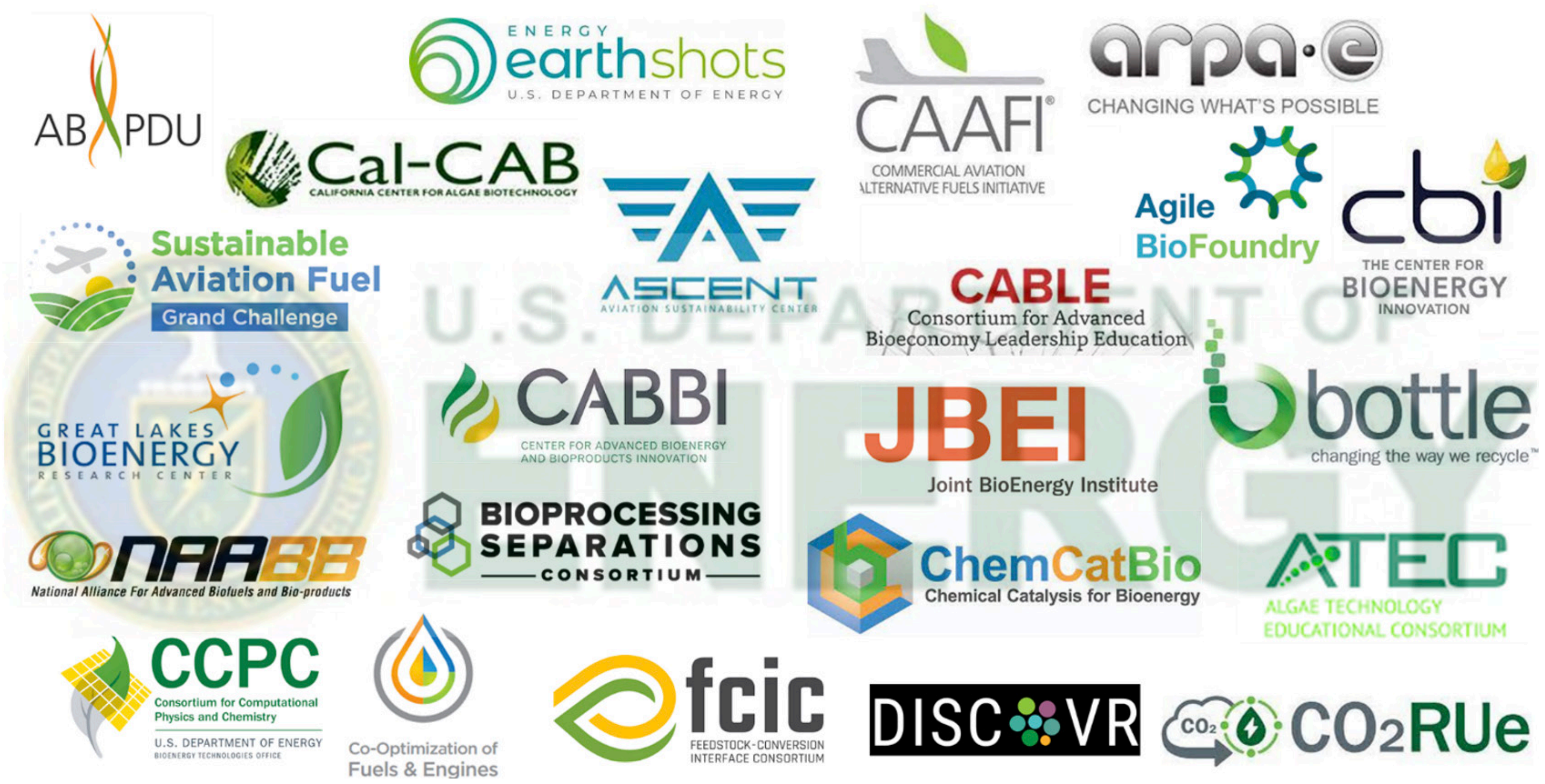


Figure 30: U.S. Bioenergy Collaborative Initiatives and Consortiums.

Environmental and Social Impacts

Environmental Sustainability

The combustion of pure biofuels has shown to result in lower emissions of particulates, sulfur dioxide, and air toxics when compared to fossil-fuel derived alternatives. Fuels that combine biofuel and petroleum usually have reduced emissions compared to those without biofuels. When compared to petroleum diesel, RD decreased emissions of both carbon dioxide and nitrogen oxide (Figure 31) [48]. California's LCFS Certified Carbon Intensities shows RD reduces carbon intensity on average by 65% when compared with petroleum diesel [49].

Biodiesel combustion may result in slightly higher amounts of nitrogen oxides relative to petroleum diesel [50]. Biodiesel (B100) decreases carbon dioxide emissions by 74% compared to petroleum diesel according to life cycle analysis. The air quality advantages of biodiesel are proportional to the quantity used in the blend [51].

Aviation-related air quality impacts have been broadly categorized into near-source and full-flight impacts. There has been evidence that pollutants emitted at cruising altitude—not just the near-airport emissions—can also have significant impacts on air quality [52-54]. While the impact of aviation emissions on air quality is widely acknowledged, the benefits of using SAF are not well understood. According to a few public studies, emissions of certain air pollutants (CO, SOx, and PM) can decrease when using a blend of conventional Jet A with SAF that is aromatic-free [52-57]. Although limited, these studies highlight knowledge gaps that must be addressed to comprehend the impact on air quality and human health when reducing or eliminating aromatics during the transition to SAF.

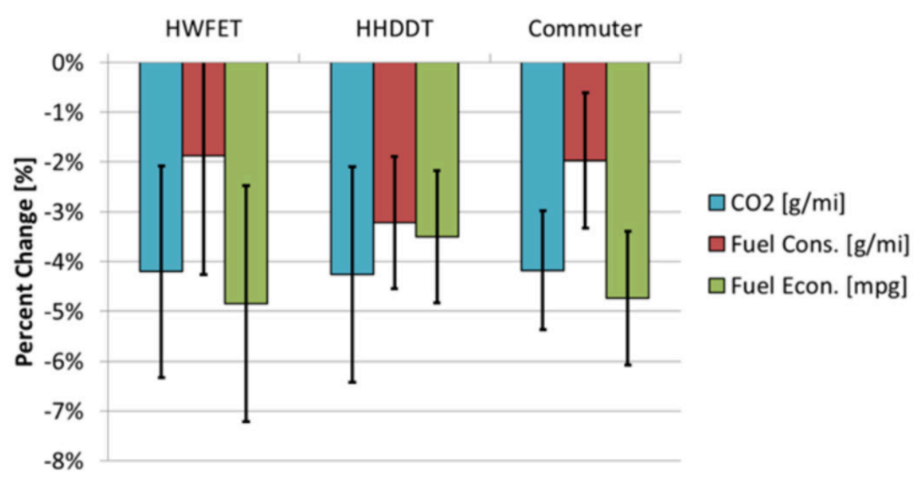


Figure 31. Percent change in CO2 emissions, fuel consumption, and fuel economy for RD compared to ultra-low sulfur diesel (ULSD). U.S. EPA Highway Fuel Economy Test (HWFET), Heavy Heavy-Duty Diesel Truck (HHDDT) [48]

Social Implications

Once SAF becomes more cost-effective, new facilities will be deployed quickly. Yet, obstacles prevent the establishment of new facilities. Getting project approvals and permits is crucial for project deployment, as it can impact timelines and even result in cancelations. Social resistance can delay the construction of new facilities. The significance of this challenge cannot be overstated for the SAF sector. The Phillips 66 and Renewable Energy Group RD project in Washington State shows how permitting delays hinders biofuel facility deployment. Recognizing and addressing community concerns is essential for a positive renewable fuel industry.

The U.S. corn ethanol industry is actively pursuing decarbonization opportunities to achieve net zero emissions by 2050, such as implementing sustainable farming practices and utilizing low-carbon renewable feedstocks and CCS technology. Several CO2 pipeline projects have been proposed in the Midwest, comprising over 4,000 miles of CO2 pipeline for the ethanol industry, illustrated in Figure 32). However, this pipeline construction proposal got cancelled or postponed to 2026 because local groups have opposed CO2 pipeline projects [58-60]. North Dakota regulators summarized several reasons for stakeholder opposition in its Summit permit denial:

"Those testifying expressed broad concerns regarding eminent domain, safety, the policy of permanent CO2 sequestration and storage, setback distances, irreparable harm to underground [drainage] systems, impacts on property values, and the ability to obtain liability insurance." CO2 pipeline safety is a particular concern [60].

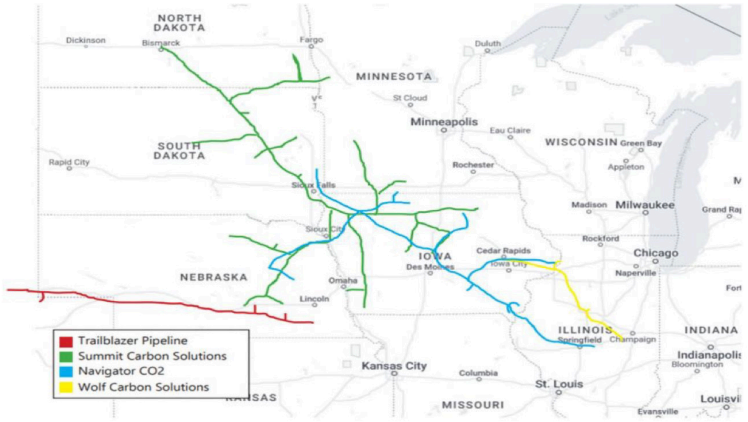


Figure 32. Proposed CO2 pipeline projects in Midwest [61].

Conclusion

The U.S. should prioritize certain areas of investment in biofuel research, development, and infrastructure to maximize the impact and sustainability of bioenergy technologies. These areas include advancements in feedstock development and utilization, focusing on high-yielding and sustainable options, as well as exploring innovative approaches for utilizing waste and non-food biomass resources. Improving conversion technologies and process efficiencies is also crucial for cost-effective and energy-efficient biofuel production. Finally, investment in infrastructure is critical to support the scaling up and commercialization of biofuel technologies, including expanding production facilities, upgrading distribution networks, and increasing the availability of biofuel refueling stations.

The future of specific biofuel pathways in the U.S. presents both opportunities and challenges. Investment in advanced ethanol production technologies, such as cellulosic ethanol and bio-based ethanol from waste feedstocks, is crucial. Exploring ethanol's potential in aviation through SAFs blended with ethanol could lead to emission reduction and fuel efficiency enhancements. RD requires national incentives and policy support to accelerate deployment and infrastructure development. Policy mechanisms like carbon pricing and mandates can incentivize investment and uptake of SAFs in the aviation sector. Electrofuels (E-fuels), produced from renewable electricity and carbon dioxide, offer a carbon-neutral alternative to fossil fuels but require investment in improving conversion efficiencies, reducing costs, and scaling up production. Supportive policies and incentives are necessary to create a market for E-fuels and stimulate investment in renewable energy and carbon capture technologies. Figure 33 shows the historic trend of investments in the biofuel sector globally.

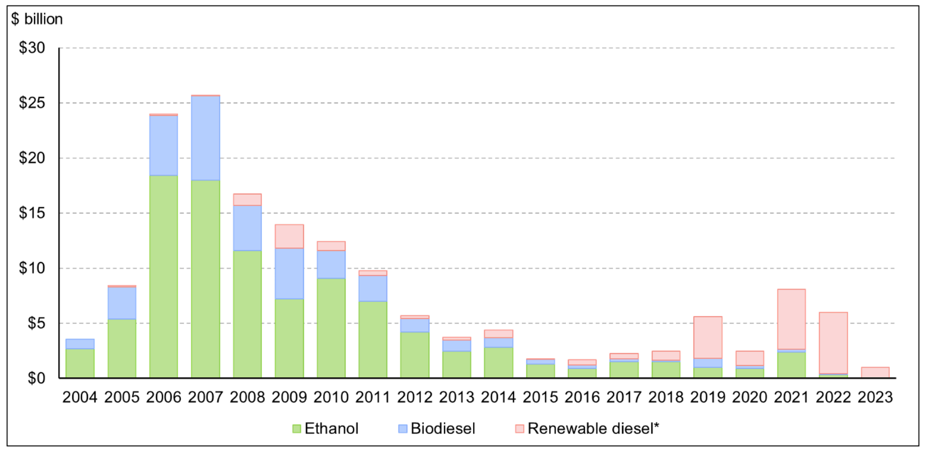


Figure 33: Global investment in biofuels sector. *Renewable diesel includes production of co-products like sustainable aviation fuels, naphtha and natural gas [62].

The pursuit of sustainable and renewable biofuels offers a pathway to a more environmentally-friendly and secure energy future for the United States. By utilizing diverse biomass feedstocks and advanced conversion technologies, the biofuels industry has the potential to reduce greenhouse gas emissions, diversify energy sources, and stimulate economic growth in rural communities. Continued investment in research and development, supportive policies, and incentives are needed to drive innovation and improve production efficiencies. Addressing infrastructure challenges, promoting consumer acceptance, and ensuring environmental sustainability through responsible land use are also important for widespread adoption. By embracing a holistic approach, the United States can create a thriving biofuels sector and contribute to a more sustainable energy landscape.

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Progress in Commercialization of Biojet/ Sustainable Aviation Fuels (SAF): Technologies and policies

Executive summary

In 2022, the aviation sector’s commitment to mitigating its climate impacts was indicated at a global level by the International Civil Aviation Organization (ICAO), setting a net zero target by 2050. ICAO’s long-term aspirational goals (LTAG) report describes the measures that will be taken to reduce the sector’s climate impact. This follows the separate target in 2021 of net zero by 2050 as agreed by the International Air Transport Association (IATA). Both documents agreed that a basket of measures would be required to meet the net zero target, including new technologies, improved operations, sustainable aviation fuels, carbon offsets, etc. However, according to IATA, 62% of emissions reductions must come from using sustainable aviation fuels.

More recently, the non-CO2 impacts of aviation have also gained attention, and it has been suggested it could account for a significant part of the sector’s total climate impact. For example, the aromatic content of jet fuel and specific types of aromatics have been identified as contributing to the non-CO2 effects. Although sustainable aviation fuels can play a role in reducing these impacts (using fuels with reduced or zero aromatics), this needs to involve modifying jet fuel standards such as ASTM D1655 and ASTM D7566.

Since the last IEA Bioenergy Task 39 biojet/SAF report in 2021, the production and use of SAF have grown substantially. In addition to the increasing availability of SAF, the number of new facilities that have been announced and are under construction should result in an exponential increase in SAF production by 2030. This has been partially driven by SAF-specific policies in jurisdictions such as the EU (the ReFuelEU Aviation mandate) and the USA (the Inflation Reduction Act (IRA) and state-specific SAF tax credits).

For example, the ReFuelEU policy has targeted aggressive blending mandates with a specific submandate for efuels. It has been suggested that the long-term certainty of mandates should reduce risk for investors while creating a level playing field for all airlines. However, the RefuelEU Aviation policy did not include incentives that would bridge the price gap between conventional jet fuel and SAF. In contrast, US policies will primarily rely on incentives to promote the commercialization of SAF. These substantial SAF blender tax credits (for two years), followed by SAF producer tax credits (for three years), should promote the consumption of available SAF based on the fully commercial HEFA process while incentivizing the development of near-commercial technologies and boosting the construction of biorefineries in the US. Hopefully, the higher incentives for SAF compared to renewable diesel will address the competition between aviation and road transportation. In parallel, the “stacking” of IRA incentives with the Renewable Fuel Standard (RFS) RIN credits, as well as state-level SAF credits introduced in Illinois, Washington, and Minnesota, should make SAF production and consumption a very-attractive financial proposition for investors and consumers.

As covered in more detail within the report, there has been significant progress in the commercialization of technologies accompanied by considerable investment in research and development. As there are specific challenges associated with various pathways, the lipid-derived HEFA-pathway will continue to supply the majority of SAF volumes up to 2030. However, alternative technologies, such as gasification with Fischer-Tropsch and alcohol-to-jet, are nearing commercial status. Although several companies are pursuing the power-to-liquids technology for efuels SAF production, this pathway is at a lower technology readiness level, with components of this technology, such as the reverse water gas shift reaction, still needing to be fully resolved.

In keeping with past reports, a dominant focus of this report is on technologies, key developments in commercialization and recent research-and-development trends. These aspects are addressed in great detail in previous reports, such as the 2014 drop-in report, the 2018 update (with a focus on coprocessing), the 2021 report (on biojet/SAF commercialization), and the 2022 report (on updates in coprocessing). This current report builds on these previous reports, which can be consulted for background.

Read the whole report here.

In the News

Policy and Regulations

Treasury issues new sustainable aviation fuel credit guidance

MAY 14, 2024

The Department of the Treasury (Treasury) and the IRS recently issued Notice 2024-37 (new notice or notice) containing additional guidance and safe harbors for the new sustainable aviation fuel (SAF) credits under sections 40B and 6426(k). The notice provides additional methods for calculating the lifecycle greenhouse gas (GHG) emissions reduction percentage under for section 40B using a modified version of Argonne National Laboratory's Greenhouse gases, Regulated Emissions and Energy use in Technologies (GREET) model. Additionally, the notice provides an additional safe harbor for an additional reduction in calculating the GHG emissions reduction percentage under GREET model using the United States Department of Agriculture (USDA) Climate Smart Agriculture Pilot Program.

Read more here.

Nova Pangaea backs UK SAF mandate plans

MAY 8, 2024

Nova Pangaea Technologies (NPT) welcomes UK Government's announcement today of its SAF mandate plans.

The mandate becoming law is key to driving investment into a domestic SAF industry placing the UK at the forefront of aviation decarbonisation with the opportunity to deliver £1.8 billion (€2.1 billion) into the UK economy and create 10,000 skilled jobs.

Cleantech companies, such as NPT, are playing a critical role in innovative approaches and delivery to meet SAF mandates and hold a common purpose interlinked with government, airlines, industry, investors, and the passenger to ensure domestic SAF success.

NPT continues to focus on its operations for commercialisation and be a key contributor, through its REFNOVA process, of 2G bioethanol enabling SAF production.

Read more here.

SABA Enters Historic Agreements for Acquisition of SAF Certificates

APRIL 24, 2024

The Sustainable Aviation Buyers Alliance (SABA) has announced the largest collection of deals to purchase high-integrity SAF certificates (SAFc).

Over five years, companies including AstraZeneca, Autodesk, Bain & Company, BCG, Deloitte, JPMorgan Chase, Live Nation, McKinsey & Company, Meta, Morgan Stanley, Netflix, Novo Nordisk, Samsung Biologics, Watershed, and Workday alongside SABA founding organisation RMI, have committed to channel close to $200 million (€187 million) into purchasing SAFc — equal to about 50 million gallons of high integrity SAF or 500,000 tons of abated CO2e.

This is roughly equivalent to the emissions of 3,000 fully loaded passenger flights from New York City to London.

Read more here.

RFA aims to intervene in legal challenge to EU Maritime Fuel Regulation

APRIL 2, 2024

The Renewable Fuels Association on Thursday filed a petition to intervene in support of a legal challenge brought by European ethanol producers against the European Union's FuelEU Maritime Regulation. By arbitrarily assuming crop-based biofuels like ethanol have the same lifecycle carbon emissions as the dirtiest fossil-based marine fuels, the EU regulation effectively bans the use of renewable, crop-based marine fuels as a tool for decarbonizing the maritime sector.

RFA's application to intervene in the proceedings supports the challenge brought by ePURE, a trade association representing European ethanol producers, and Pannonia Bio, one of Europe's largest ethanol producers. Their application seeks to annul the relevant provisions of the FuelEU Maritime Regulation, which was adopted by the EU in 2023 and is set to take effect in 2025.

Read more here.

EWABA welcomes inclusion of new feedstocks for biofuel production but rejects extra incentives for aviation

MARCH 15, 2024

The EWABA association has welcomed the long-awaited inclusion of additional feedstocks in Annex IX of the Renewable Energy Directive (RED).

This feedstock expansion will generally broaden the availability of waste-based and advanced biofuels for all transport modes and alleviate part of the pressure on some feedstocks used to produce waste-based biofuels, which have been subject to a high degree of focus.

EWABA members would like to highlight that the introduction of intermediate/cover crops for the supply of fuels exclusively for the aviation industry in part A of Annex IX will have negative consequences as it interferes with the level-playing field across sectors and challenges the principle of technology neutrality, a crucial pillar for investment certainty.

Read more here.

Neste completes its organizational change process to improve long-term competitiveness

MARCH 13, 2024

Neste has completed its organizational change process, announced on 1 November 2023. Neste informed that it will merge its three renewable business units into one Renewable Products business unit as well as restructure its functions to better support business-driven ways of working.

With the simplified organizational structure and operational model, Neste secures the execution of its growth strategy with improved cost-efficiency and strengthens its long-term competitiveness. The planned organizational changes were expected to lead to a reduction of approximately 400 job roles globally. In Finland, following thorough change consultations, the number of job roles to be reduced has been confirmed at about 320. In addition, it is estimated that 70 job roles will be reduced globally.

Read more here.

Industry developments

Exolum will invest 20 million euros in the construction of a new terminal for storage of biofuel and other bulk liquid products in the Port of Bilbao

MAY 30, 2024

Exolum will build a new terminal for the storage of biofuels and other bulk liquid products in the Port of Bilbao on a plot adjacent to its facility in Zierbena. The first phase of the project, with a planned investment of 20 million euros, will start in 2025 and is expected to be operational in 2027. It will also expand the company's service portfolio and its capacity for product storage and treatment in the area.

The construction of the new terminal will be carried out in several phases. The first phase will cover the construction of a bund with 5 tanks and a total storage capacity of 29,000 m3. This new infrastructure will be equipped with cutting-edge safety and environmental protection systems.

Read more here.

Verbio starts expansion work on second biorefinery in North America

MAY 24, 2024

Verbio has started work on converting its South Bend ethanol plant into a second integrated biorefinery in North America.

Members of Verbio management and public officials gathered to hold a groundbreaking ceremony for this next milestone.

The facility will incorporate both the production of renewable natural gas (RNG) and bioethanol using an innovative production approach.

The company, a subsidiary of Europe`s leading biofuels and bioenergy producer Verbio SE, had received approval for its expansion proposal from the City of South Bend in April. Following the application of the Verbio technology and commissioning, Verbio targets a production capacity of at least 85 million gallons of corn ethanol and 2.8 billion cubic feet (Bcf) of RNG annually.

Read more here.

Air NZ signs deal for sustainable jet fuel

APRIL 16, 2024

Air New Zealand has signed a deal to buy nine million litres of sustainable aviation fuel (SAF) - its biggest deal for the green fuel.

The agreement with Finnish company Neste was announced as part of the Prime Minister's trade trip to South East Asia, with the fuel produced at Neste's Singapore refinery.

The SAF would be blended with conventional jet fuel and supplied to Los Angeles International Airport between 1 April and 30 November, the two companies said.

They said the SAF would likely reduce carbon emissions by up to 80 percent over the life cycle of the fuel compared to using fossil jet fuel, which included its production and transport emissions.

Read more here. w

Solarig to set up SAF plant in Spain with €780m investment

APRIL 8, 2024

Solarig has reached an agreement with SOMACYL to acquire 116,000 square metres for its NUMANTIA SAF project.

The plant will be built in Parque Empresarial del Medio Ambiente (PEMA) in Soria, Spain.

Additionally, Solarig will have its new regional corporate headquarters in one of the dedicated dome buildings currently under construction.

The SAF plant will have an estimated investment of €780 million and a production capacity of 60,000 tonnes of sustainable aviation fuel (SAF) per year, avoiding the emission of 170,000 tonnes of CO2.

The innovative approach is based on the combination of two technological routes for the SAF production, by means of biomethane and renewable electricity in the same facility.

Read more here.

London Gatwick cuts its own vehicle (Scope 1) emissions by 90% after swapping diesel for Hydrotreated Vegetable Oil

MARCH 18, 2024

London Gatwick has cut carbon emissions from its diesel vehicles by 90% by swapping the fuel for Hydrotreated Vegetable Oil (HVO). The switch means London Gatwick will save more than 950 tonnes of carbon emissions per annum.

HVO is a low-carbon biofuel made from plant waste, oils and fats making it a more sustainable and lower-carbon alternative to diesel.

All 300 diesel vehicles, 85% of London Gatwick's fleet, are now powered by HVO until they are retired from use. They will then be replaced by electric vehicles as part of the airport's sustainability policy, Decade of Change.

Read more here.

Bunge Chevron JV announces construction of oilseed processing facility in Louisiana

MARCH 13, 2024

In a significant move to bolster the renewable fuels market, Bunge, a leader in oilseed processing and a key supplier of specialty plant-based oils and fats headquartered in St. Louis, Missouri, U.S.A., and global integrated energy company Chevron revealed plans for their joint venture, Bunge Chevron Ag Renewables LLC, to establish a cutting-edge oilseed processing plant in Destrehan, Louisiana, U.S.A.. This strategic development, celebrated with a groundbreaking ceremony, is located adjacent to the venture's current Gulf Coast processing operations.

Designed with versatility in mind, the new facility is set to process a variety of oilseeds, including soybeans and softseeds like winter canola and CoverCress.

Read more here.

Upcoming events

32nd European Biomass Conference & Exhibition
24 June 2024 - 27 June 2024
Marseille, France
Webpage

The series of these conferences has been organized and established by the European Commission 1980 (Brighton, UK). The conference started as a purely scientific event. Over the years as biomass use as feedstock for bioenergy and fuels increased steadily the industrial aspect was introduced to the conference.With a growing awareness of the impacts of society on the environment, one of the main themes has been government policy towards biomass as renewable resource.

Role of Bioenergy in Atmospheric CO2 Removal
25 June 2024
Online
Webpage
The World Bioenergy Association, in partnership with Bioenergy International, is pleased to invite you to the webinar ”Role of Bioenergy in Atmospheric CO2 Removal”. The session will provide valuable insights into BECCS-related projects from around the world. It will also cover the latest changes in policies, regulations, finance, and technology within the industry. The goal is to enhance our understanding of this topic through the contributions of leading industry representatives and experts. The urgency and importance of developing and deploying such technologies are increasing, making this webinar an excellent opportunity to stay up-to-date on the latest developments.

World Bio Markets 2024
26 June 2024 - 27 June 2024
The Hague, The Netherlands
Webpage

On 26-27 June in The Hague, the World Bio Markets conference will connect over 450 bioeconomy leaders with a two-day programme of pre-arranged 1-2-1 commercial meetings, knowledge exchange, and networking opportunities in order to accelerate the transition to a fossil-free economy.

Sustainable Road Transport Europe 2024
8 Sep 2024 - 29 Sep 2024
Amsterdam, The Netherlands
Webpage

The European hub for sustainable heavy-duty transport leaders – where innovation meets action Heavy-duty vehicles (HDVs) may be only 2% of the road fleet, but they pack a punch, contributing to 27% of climate emissions in European road transport. As the European Commission’s proposed revisions on CO2 emission standards set a crucial deadline of 2030 and hauliers’ customers set ever more ambitious Scope 3 targets, the road freight industry is on the cusp of paradigm shift.

Bio-energy Pavilion 2024
3 Oct 2024 - 5 Oct 2024
Greater Noida, India.
Webpage

The Bio-Energy Pavilion aims to bring together industry leaders, innovators, and enthusiasts in a space dedicated to fostering growth, collaboration, and knowledge exchange and attracting a whopping 10,000+ trade visitors.

Nordic Wood Biorefinery Conference (NWBC)
15 Oct 2024 - 17 Oct 2024
Örnsköldsvik, Sweden
Webpage

Welcome to the Nordic Wood Biorefinery Conference (NWBC), where the latest discoveries and innovations in bio-based materials, chemicals, and products from biorefineries will be presented.

BBEST & IEA Bioenergy 2024 Conference
22 Oct 2024 - 24 Oct 2024
Sao Paulo, Brazil
Webpage

Organized by the Bioenergy Research Program (BIOEN/FAPESP), the International Energy Agency Bioenergy Technology Collaboration Program, and the Bioenergy Society (SBE), the BBEST – IEA Bioenergy 2024 Conference will bring important topics such as responsible land use, agricultural productivity, resilient multifunctional landscapes, harvesting technology, logistics and scale, development of biorefineries and emerging advanced bioproducts and materials, bioelectricity, biofuels for air, sea and road transport, waste use for bioenergy production and strategies for the circular carbon economy.

World Ethanol & Biofuels
5 Nov 2024 - 17 Nov 2024
Brussels, Belgium
Webpage

Discuss the policies, commercialisation strategies, feedstock supply and technical solutions needed to bring advanced biofuels production to scale. Also hear fresh perspectives on the role of renewable diesel, alcohol-to-jet, MSW fuel and synthetic fuels for meeting decarbonisation challenges in shipping and aviation.

USIPA
3 Nov 2024 - 5 Nov 2024
Miami, USA
Webpage

Our vision at USIPA Conference is to create a platform that brings together professionals and enthusiasts from all over the world to exchange ideas, learn from each other, and create meaningful relationships.

3rd Bioenergy International Conference
6 Nov 2024 - 8 Nov 2024
Jaén, Spain
Webpage

This conference is organized by researchers of the Polytechnique Institute of Portalegre (Portalegre, Portugal), and University of Jaén (Jaén, Spain) and its goal is to to join academics, researchers and companies in an international forum to discuss matters related to bioenergy technologies, economic and policy aspects.

The European Bioenergy Future 2024
20 Nov 2024 - 21 Nov 2024
Brussels, Belgium
Webpage

This edition is particularly significant, taking place soon after the European elections and positioned at a pivotal point for the green transition. Attendees will come together to gain inspiration and exchange ideas on the industry’s future. This will be a great chance to unite the various stakeholders active in the bioenergy sector for a fruitful edition.