Clean Fuels

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Trend Overview

Despite Being a Solution for Hard-to-Electrify Sectors, Practical Applications of Clean Fuels Remain Limited

As the world races towards carbon neutrality, spurred on by the 2015 Paris Agreement, changes are also taking place in the transport sector, where the electrification of transportation vehicles—in particular, electric vehicles (EVs)—is on the rise. This move is driven by the transport sector's high level of emissions, which account for over one-third of global CO2 emissions from end-use sectors, according to the International Energy Agency (IEA).

However, electrifying all transportation vehicles is not easily achievable. In emerging markets, where charging infrastructure is still underdeveloped, and in sectors such as large trucks, aircraft, and ships that demand extensive battery capacities, the transition faces delays and multiple technical hurdles. As such, there is a growing need for clean fuels—alternative fuels that can be used in existing internal combustion engine vehicles and play a pivotal role in the journey toward carbon neutrality.

Amongst the array of clean fuels, electrofuels (e-fuels) and sustainable aviation fuels (SAFs) stand out. E-fuels are synthetic fuels produced using hydrogen from renewable sources and captured CO2 from the air and emission sources such as factories. For aviation, a hard-to-electrify sector, SAFs have become the subject of growing interest as an alternative fuel. These fuels contribute to decarbonisation by using non-oil feedstocks such as CO2 itself, biomass feedstocks that incorporate CO2, and sustainable feedstocks such as waste oil during production. However, it is worth noting that the broader adoption of both these fuels is currently limited by their associated costs, with their applications mostly confined to aviation and motor racing. Specifically, the high costs of e-fuels are often linked to inefficiencies in their production. Presently, e-fuel technology is still in its infancy, and SAFs, particularly those derived from waste oil, are in the early stages of market integration.

This report delves into the specifics of e-fuels and SAFs, while also taking a look at the technical challenges, current costs, and applications of these clean fuels.

Note (*): The transportation, industrial, commercial, and residential sectors are the "end-use sectors" responsible for energy consumption.

Comparison of Internal Combustion Engines, EVs, and Major Clean Fuels

	Main Applications	Well-to-Wheel (WtW) Emissions (WtT + TwW)		
		Well-to-Tank (WtT) Fuel/Energy Production	Tank-to-Wheel (TtW) Vehicle Use	
Internal Combustion Engines + Fossil Fuels	Cars, Ships, Aircraft	Fuel Sources		- CO2 emitted by all processes
EVs	Light-Duty Vehicles	Batteries (e.g. via thermal power generation)		+ Almost zero emissions while vehicle is on the move - Vehicle weight - Time needed for transition to EVs
Internal Combustion Engines + E-Fuels	Cars, Ships, Aircraft	Hydrogen From Renewable Sources + CO2 From Emission Sources (e.g. factories)	Drop-In Fuels That Can Be Used With Existing Engines and Infrastructure (Major Adjustments Unneeded)	+ Usage of low carbon raw materials + Existing engines can be used without significant changes - Emissions while vehicle is on the move
Internal Combustion Engines + SAFs	Aircraft	Sustainable Feedstocks and Biomass (Carbon Neutral)		

Source: Compiled by Uzabase

Note: Areas in blue frames are especially crucial for carbon neutrality.

Development Phases and Applications of Clean Fuels Vary; E-Fuels Still in Infancy, SAFs Already at Early Stage of Adoption

The table below summarises the main types of clean fuels along with their respective stage of adoption in the market and primary use. Biofuels (i.e. fuels derived from biomass) started gaining attention in the latter half of the 2000s. Biomass originates largely from plants, and its growth removes CO2 from the atmosphere. However, the production of first-generation biofuels has sparked controversy as they are food-based, making them a competitor with food for land. In comparison, second-generation biofuels are obtained from non-food sources such as forest and food crop waste but also have their own limitations in that they nonetheless require large amounts of land to cultivate food crops, even though only the non-edible parts are used.

In contrast, e-fuels overcome the constraints of first-generation and second-generation biofuels, instead using CO_2 captured from emission sources and the atmosphere, as well as hydrogen from renewable energy. R&D into e-fuels has accelerated in recent years, as the production of these fuels basically consumes atmospheric CO_2 and thus slows down global warming. In particular, German companies such as Audi (DEU) have taken the lead in this area, which is being viewed globally as a means for the country—which is heavily invested in internal combustion engine-related technologies—to protect its internal combustion engine component industry amidst growing EV adoption. However, as detailed below, e-fuel remains in its infancy due to a number of challenges, including the enormous amount of energy required to produce it.

Meanwhile, in the aviation sector, biofuels have traditionally been unsuitable as a fuel source due to their inability to meet stringent quality regulations, lacking the necessary performance and safety attributes for modern jet engine use. However, the urgency of addressing climate change in recent years has spurred the development of multiple SAFs capable of meeting global regulations, helping this category of clean fuels to reach the early stages of adoption in the aviation sector. In 2021, the International Air Transport Association (IATA) set a target to reach zero greenhouse gas (GHG) emissions by 2050 through the use of SAFs, and in December of that same year, United Airlines (USA) became the first airline in aviation history to fly a commercial passenger flight using 100% SAF. The trend is gaining traction, with aviation companies increasingly entering procurement contracts and setting SAF integration goals.

Major Types of Clean Fuels

Main Category	Sub-Category	Feedstock	Phase	Main Applications	Projection of Share	Pros & Cons
Biofuels	First-Generation Biofuels	Edible biomass (e.g. sugarcane, sugar from maize, starch, vegetable oils)	Commerciali-sation	Petrol/diesel alternative	↘	**Pros:** • Overall, lower CO2 emissions than fossil fuels **Cons:** • Competition with food • Requires mixing with fossil fuels for use with existing internal combustion engines (not full replacement)
Biofuels	Second-Generation Biofuels	Non-edible biomass (e.g. corn husks and stalks, fruit peels, cellulose from wood chips)	Deployment to Early Stages of Adoption	Petrol/diesel alternative	→	**Pros:** • Does not compete with food demand (or food for land), unaffected by food prices **Cons:** • Although not in direct competition with food for land, it is not as efficient as fossil fuels and requires a lot space for the growing raw materials • Requires mixing with fossil fuels for use with existing internal combustion engines (not full replacement)
Biofuels	Next-Generation Biofuels	Algae and other micro-organisms	R&D to Research for Deployment	Petrol/diesel alternative	→	**Pros:** • Feedstock can be produced from seawater, sewage, and wastewater • Algae: high yield per unit area **Cons:** • Inefficient, with high amounts of energy needed for many processes, including for harvest and dehydration
Biofuels	SAFs	Municipal solid waste, waste oil	R&D to Research for Deployment	Petrol/diesel alternative	→	**Pros:** • No need to grow raw materials • High circularity where existing materials are recycled to be reused as long as possible **Cons:** • Inefficient, with large quantities of waste required in order to scale production • Suitable technologies required in order to remove impurities from different types of waste
E-Fuels (Electro fuels)	Power-to-Liquid (PtL)	Waste oil, algae, municipal solid waste (mostly waste oil at present)	Deployment to Early Stages of Adoption	Jet fuel alternative (global regulations established)	↗	**Pros:** • High demand; first- and second-generation biofuels do not meet standards for jet fuels • Waste oil is currently the primary feedstock; not plant based, low necessity to grow raw materials **Cons:** • Cons are similar to those of next-generation biofuels
E-Fuels (Electro fuels)	Power-to-Gas (PtG)	Atmospheric CO2/emitted CO2, hydrogen from renewables	R&D	Petrol/diesel and jet fuel alternative (SAF*)	→	**Pros:** • Not limited by availability of agricultural crops and other feedstocks • Uses CO2 as feedstock, which decarbonises to decrease global warming **Cons:** • Inefficient as high amounts of energy is required, incurring high production costs • Very low energy conversion efficiency • E-fuels for the aviation sector are still at R&D phase

Source: Compiled by Uzabase based on materials from the New Energy and Industrial Technology Development Organization(NEDO) and the German Association of the Automotive Industry (Verband der Automobilindustrie [VDA]

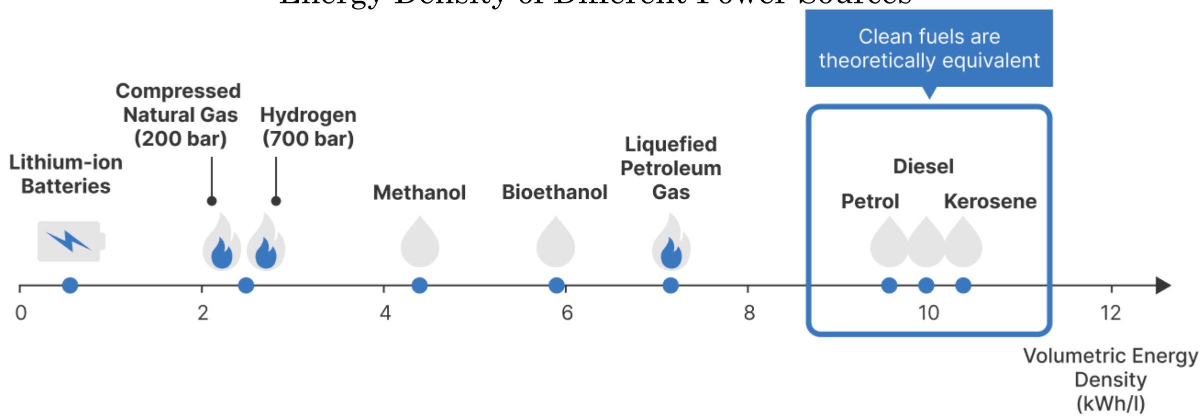
Note (*1): Some e-fuels for jets may be regarded as SAFs.

Clean Fuels Offer Superior Energy Density; Future Potential for Use in Large-Scale Transport Vehicles

Theoretically, e-fuels and SAFs have an energy density equivalent to fossil fuels such as petrol and diesel. As such, they possess higher volumetric energy density than lithium-ion batteries, which is likely to lead to potential demand for use in large-scale transport vehicles, such as those in the aviation, maritime transport, and road transport sectors, which cannot afford to rely on batteries due to weight restrictions. In addition, these fuels are compatible with internal combustion engines, and existing infrastructures can be used without major adjustments (drop-in fuels); hence, in principle, no extra costs would be incurred as the engine in a vehicle will not need to be replaced. Furthermore, such a switch has the potential to streamline the process of procurement and production of fuels, as for some countries it would remove the need for purchasing crude oil from overseas partners, for example.

It has also been suggested that clean fuels could serve as alternatives to conventional heating oil in the long term and as feedstocks for the chemical industry, replacing fossil-based ones.

Energy Density of Different Power Sources

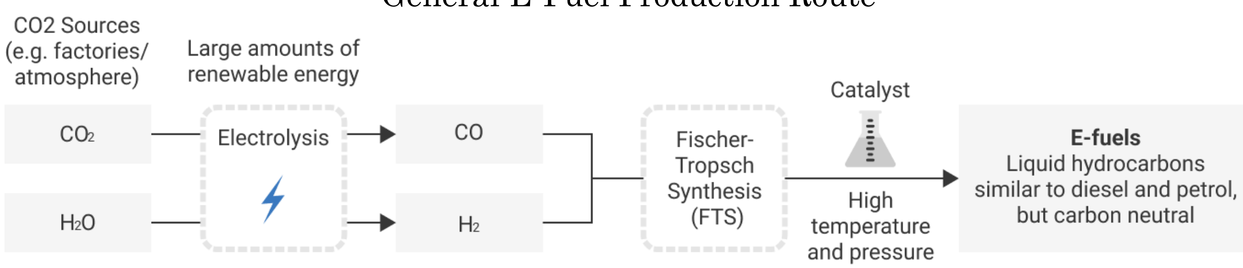


Source: Compiled by Uzabased based on "Synthetische Energieträger – Perspektiven für die deutsche Wirtschaft und den internationalen Handel" by Frontier Economics

E-Fuels: Contending with Costs and Low Energy Conversion

E-fuels consume large amounts of energy during the manufacturing process, and the consequent costs are one of the reasons why e-fuels remain in the early stages of development. Generally, e-fuels are produced via a combination of hydrogen and carbon monoxide. To produce hydrogen, energy (usually renewable) is first used for electrolysis, splitting water into oxygen and hydrogen. The latter is then combined with carbon monoxide (CO) extracted from CO2 and converted into a liquid fuel via a well-established but energy-intensive Fischer-Tropsch synthesis (FTS) process (power-to-liquid [PtL] concept)—which also consumes a lot of energy.

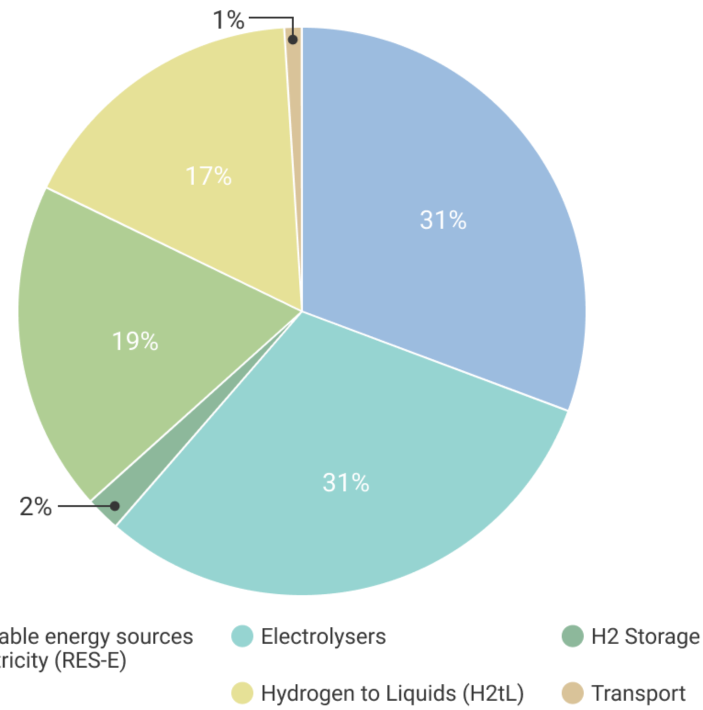
General E-Fuel Production Route



Source: Yugo, M., & Soler, A. (2019). A look into the role of e-fuels in the transport system in Europe (2030–2050) [Review of A look into the role of e-fuels in the transport system in Europe (2030–2050)]. Concawe Review, 28.

According to Concawe, an environmental research association formed by European oil companies, electrolysis-related costs (e.g. energy sources and electrolysers) account for around 60% of the total. An article by the International Council on Clean Transportation (ICCT) has also pointed out the inefficiency of the production process, in which less than 50% of the electric power used is converted into the actual fuel. Energy is also needed in the FTS process as high temperatures and pressures are needed for the chemical reactions to occur. As such, the advancement of e-fuels hinges on solutions that will help overcome the existing barriers present in energy efficiency and costs. Potential efforts under consideration include leveraging economies of scale to cut costs and the development of catalysts to improve yields.

Cost Breakdown for Production of E-Fuels (E-Liquids)



Source: Yugo, M., & Soler, A. (2019). A look into the role of e-fuels in the transport system in Europe (2030–2050) [Review of A look into the role of e-fuels in the transport system in Europe (2030–2050)]. Concawe Review, 28.
Note: Cost shares are associated with North Africa's 2030 Reference Scenario; based on PV-wind-combination and CO2 from Direct Air Capture (DAC).

SAFs at Early Stage of Adoption But Challenged by Material Procurement and Yield Limitations

The common production methods for SAFs, including for varieties of biofuels and e-fuels, are outlined in the following table. While SAFs are not usually used directly as aircraft fuel, they can be mixed with traditional jet fuels for use in existing jet engines. However, their composition is limited depending on the production method (blending limits apply: up to 50% at present). Test flights are underway towards realising flights that use 100% SAFs by around 2030.

Meanwhile, according to the World Economic Forum, most (nearly 100%) of the current SAF supply in the European market is produced via a process known as Hydroprocessed Esters and Fatty Acids (HEFA), and this is projected to continue until 2030. After which, in 2050, eSAFs (derived from PtL-like e-fuels) are expected to comprise almost half the SAF output in the market. Commonly referred to as renewable diesel or hydrotreated vegetable oils (HVO), HEFA is produced via the hydroprocessing of waste oils, vegetable oils, and fats. Limitations in these resources have encouraged the development of other technologies, which are at the preparation stages for commercialisation and production at scale. Examples include Alcohol-to-Jet (AtJ) and FTS, the latter of which uses feedstocks such as wood chips and municipal solid waste. However, both methods also face challenges in terms of resource limitations and, consequently, the yield as well. As such, methods similar to PtL are also being researched.

SAF Technological Pathways

Technological Pathway	Feedstock	Phase	Details	Feedstock Efficiency (Tonnes of SAF/Tonnes of Feedstock)
Hydroprocessed Esters and Fatty Acids (HEFA)	Waste oils, vegetable oils	Early Stages of Adoption	Hydrogenation and decarbonisation of waste oil and vegetable oil	0.51 (Feedstock: waste oil)
Alcohol-to-Jet (AtJ)	Ethanol derived from municipal solid waste and sugar from biomass	Research for Deployment, Gearing Towards Mass Production	Hydrocarbons are produced from ethanol (alcohol) via dehydration and polymerisation reactions.	0.035 (Feedstock: sugarcane)
Fischer-Tropsch Synthesis (FTS)	Wood chips, municipal solid waste, and waste materials (transformed to synthetic gas through gasification)	Research for Deployment, Gearing Towards Mass Production	A method of producing hydrocarbons from syngas, as like for e-fuels. The principle reaction is the same, but the raw materials are different (as shown on the left).	0.12 (Feedstock: municipal solid waste)
E-fuels (Power-to-Liquid [PtL])	Atmospheric CO2/emitted CO2, hydrogen from renewables	R&D to Research for Deployment	e-SAFs	N/A

Source: Compiled by Uzabase based on materials from the World Economic Forum and the Japan Transport and Tourism Research Institute (JTTRI). “Feedstock Efficiency” referenced the conversation figures from materials by the JTTRI.

EU Policy Shift and Life Cycle Assessment Driving Growth for Clean Fuels and Adoption of More Blending Mandates for SAFs

Up until around 2020, the Tank-to-Wheel approach had been applied globally to quantify the impact of vehicles on the environment in terms of tailpipe emissions when a vehicle is running, but new evaluation standards that view the entire process from a more holistic perspective have been gaining a stronger foothold, primarily in Europe, acting as growth drivers for clean fuels.

In 2019, the EU adopted a regulation that introduces a number of CO2-related targets, one of which calls for a 37.5% reduction (compared to 2021) in CO2 emissions for new cars in the region by 2030. In connection with these targets, discussions are in progress on the topic of regulating CO2 emissions via the Well-to-Wheel method (WtW; from fuel production phases—including the extraction of raw materials—to fuel use) from 2025 and the Life Cycle Assessment (LCA; from WtW to recycling phase) approach from 2030. As such, clean fuels have gained more importance in recent years.

The EU had initially planned to prohibit the sale of all new internal combustion engine vehicles, including hybrids, by 2035. However, after objections, notably from Germany, a decision was made in March 2023. The EU will now allow the sale of new ICVs post-2035 if they operate on synthetic fuels produced from hydrogen and carbon dioxide. Note that, as per this decision, biofuels are currently not considered in this category.

Compared to e-fuels, SAFs are further along in development. The below table shows the SAF blending mandated by the EU, the US, and Japan. In April 2023, an agreement was finalised regarding ReFuelEU Aviation, outlining the composition of aviation fuel at EU airports and setting forth incrementally increasing blending ratios. That same year, the US, Japan, and Singapore announced plans to cooperate on the adoption of SAFs.

SAF Blending Targets by Region

Region	Targets
EU	Operators supplying aviation fuel to airports in the EU are required to increase SAF (including e-fuel & hydrogen) in their total fuel supply to: 2% by 2025, 6% by 2030, 20% by 2035, 34% by 2040, 42% by 2045, and 70% by 2050. E-fuel targets: 1.2% of total fuel by 2030, 2% by 2032, 5% by 2035, and 35% by 2050.
USA	Aim to meet 100% of domestic aviation fuel demand with SAF by 2030, replacing approx. 3 billion gallons of SAF/year by 2030, and increasing to 35 billion gallons by 2050.
Japan	Announced a policy requiring 10% of aviation fuel provided at airports to be SAF by 2030.

Source: Compiled by Uzabase based on materials published by BAUM Consult Japan and media reports.

Monetisation

E-Fuels Consume Five Times More Energy Than EV Batteries, Will Cost Four Times More Than Petrol in 2050

As per a research paper published by Nature Climate Change(*) in 2021, the electricity-to-useful energy efficiency of e-fuels ranges from around 16–48%. This means that e-fuels would require more energy input, namely five times what is needed for direct electrification via an EV battery. Using the power supplied by renewable-energy-rich countries could provide a solution to energy conversion inefficiencies, but these are nonetheless costly and, hence, e-fuels are still regarded as inefficient.

According to projections by the German Energy Agency, even with the assumption of significant cost cuts, e-fuels will still cost 3–4 times as much as petrol in 2050 (see table below). It can thus be surmised that providing affordable e-fuels would be difficult without resolving energy conversion inefficiencies and likewise hamper adoption in the passenger car market. As such, in addition to cost-cutting measures, e-fuel manufacturers would need to anticipate and pursue demand markets where e-fuels can serve as viable alternatives, including segments of the transport market where batteries cannot be used as a method of decarbonisation and internal combustion engines will still be necessary (e.g. ships, heavy trucks).

Note (*): Ueckerdt, F, Bauer, C, Dirnaichner, Al., Everall, J., Sacchi, R., Luderer, G. (2021). Potential and risks of hydrogen-based e-fuels in climate change mitigation. Nature Climate Change. 11, 1-10.

Fuel Cost Comparison Between Conventional Petrol and E-Fuels for 1 Kilometre

	2015	2050
E-Fuels (PtL): CO2 from Air (USD)	24.7	10.9
E-Fuels (PtL): CO2 from Concentrated Source (USD)	19.7	8.2
Conventional Petrol (USD)	2.5	2.5

Source: Extracted from The Deutsche Energie-Agentur, “The potential of electricity-based fuels for low-emission transport in the EU”

Note: Figures have been converted from EUR to USD (EUR 1 = USD 1.20); calculations are based on low-temperature electrolysis in the EU.

SAFs: HEFA Leads in Efficiency but Lower Costs Anticipated for Other Methods Through Upscaling

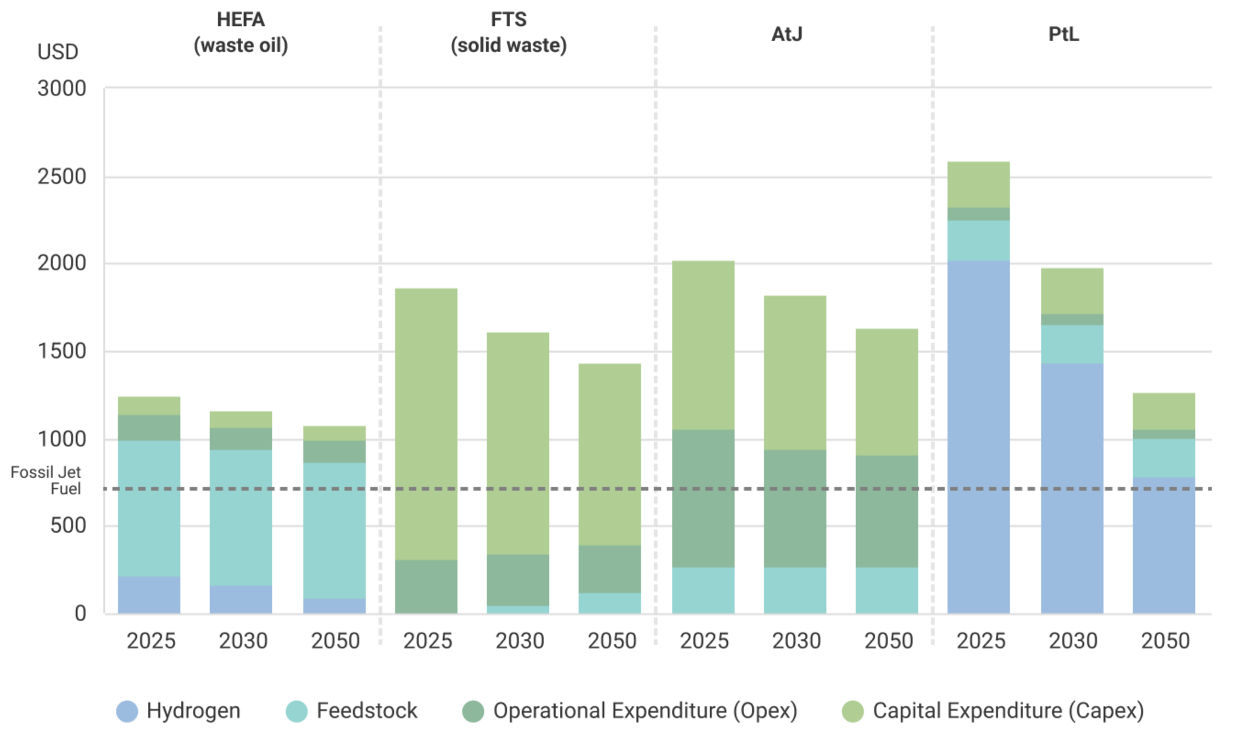
According to Markets and Markets, the global SAF market is projected to grow from around USD 1.1 billion in 2023 to roughly USD 16.8 billion by 2030. In connection with this, the World Economic Forum anticipates that SAFs will make up 10% of jet fuel consumption in the EU by 2030 (mostly 100% HEFA fuels), and this share is forecasted to increase to as much as 75% in 2050, driven by developments in AtJ, FTS, and PtL technologies.

However, producing SAFs at a cost lower than that of conventional fuels would not be easily achievable, regardless of the process used. Although HEFA fuels are the most effective pathway until 2030, fluctuations in raw material costs are likely to hinder any further trims to production costs. For FTS, which uses solid wastes as feedstock, capital expenditure already accounts for at least 80% of production costs; the potential for expansion of production scale is thus a factor for consideration for manufacturers. While the wastes for FTS may be procured at almost no cost during the initial phase (excluding transportation costs), it should be noted that any future price increments of the feedstock will impact overall costs.

As for the AtJ pathway, given that the process converts ethanol to fuels, the price of ethanol directly impacts cost structures. As previously noted for e-fuels, electricity costs form one of the barriers to the advancement of PtL technology, leading to a conclusion that cost reduction, in addition to efficiency improvements, will be key going forward.

As manufacturers expand their production scale and pursue innovation in clean fuels, government initiatives, blending mandates, and policies that generate benefits for the environment are necessary at present to propel further adoption.

SAF Production Costs (Per Ton of Jet Fuel)



Source: The World Economic Forum, "Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation November 2020"
Note: Feedstocks for HEFA priced around USD 600–950 per ton. Hydrogen comes from solar power.
AtJ feedstock costs vary in the range of USD 33–220 per ton but this is subject to change.

CO2 Reduction Possible but Emissions May Exceed Those of EVs from Viewpoint of LCA

According to eFuel Alliance, an EU-wide blending of 5% e-fuels to conventional fuels in 2030 will be equivalent to reducing 60 million tonnes of CO2. Based on the data published by the Emissions Database for Global Atmospheric Research (EDGAR), this figure accounts for around 2% of CO2 emissions by all sectors in the EU in 2020 and roughly 8% for the transportation sector.

At the same time, a vehicle running on e-fuels still emits CO2, and the longer it is used, the more emissions it will produce—and will, at a certain point, end up exceeding the LCA-based emissions of an EV. The level of emissions varies with the technologies used and some reports have highlighted that CO2 emissions from e-fuels are lower than those of conventional products due to the fact that they do not contain substances such as sulphur. However, simulations conducted by Gunnar Luderer et al. suggest that, since their production requires the consumption of electricity, e-fuels could ultimately result in the emission of up to three times as much CO2 as conventional petrol if produced from Germany's current electricity mix (as opposed to using electricity generated from renewable sources).

In the case of SAFs, while they still emit CO2, it is to a lesser degree compared to conventional fuels. Despite room for technological improvements, such as in impurity removal, SAFs continue to trail behind in areas where electrification is progressing. The following section will take a look at the limited fields in which the usage of e-fuels is currently more or less established, such as motor racing.

Future

E-Fuels: Europe at Forefront but Applications Limited to Sports Cars and Other Niche Fields

German automakers are at the forefront of e-fuel development, a position they have secured through strategic collaborations with companies specialising in renewable energy and CO2 capture technologies. However, the current industry trend leans heavily towards EVs due to constrained demand for e-fuels. Several factors contribute to this trend:

1. While Europe is inclined towards e-fuels, cost remains a significant barrier.

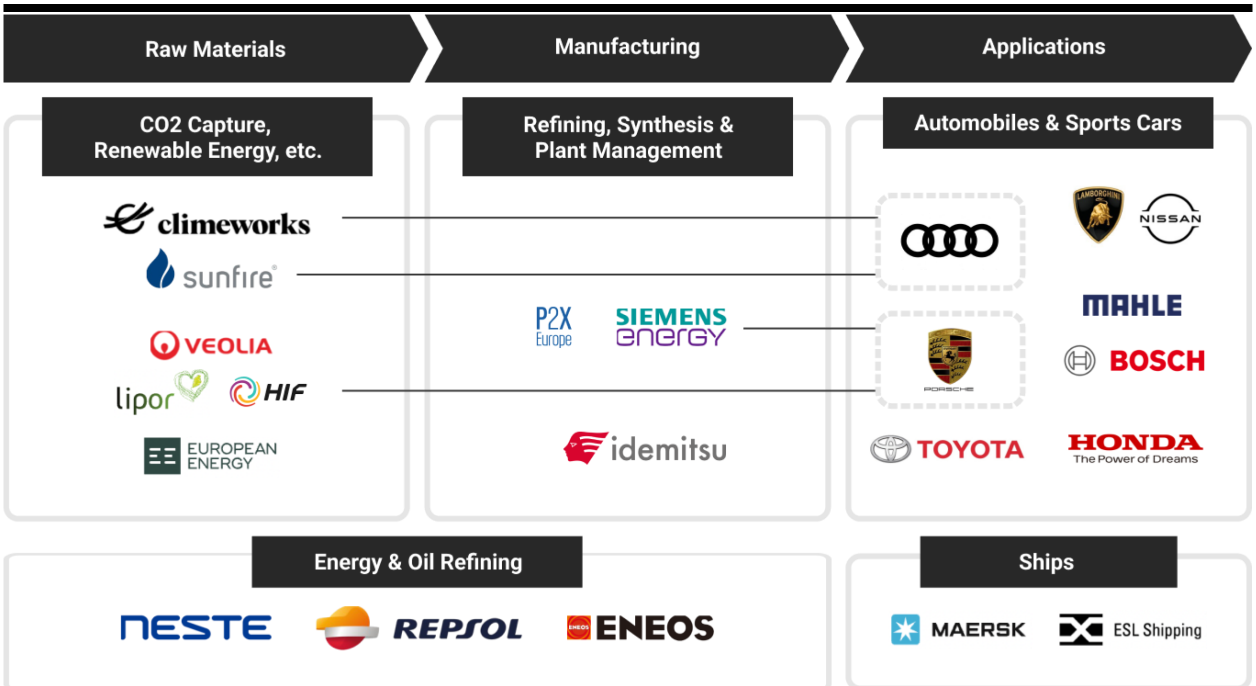
2. Many countries are emphasising the promotion and growth of hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs) instead.

For example, Audi—a pioneer in the field which succeeded in producing 60 litres of e-petrol in 2018—has partnered with Climeworks (CHE), a company renowned for its atmospheric CO2 capture technology, and Sunfire (DEU), a company specialised in CO2-based fuel refinement. Nevertheless, Audi divested its e-gas business and sold off its e-gas plant in 2021. The company has further indicated that it intends to make all new models from 2026 EVs, and it is believed that even though Audi is pioneering e-fuel, EVs might dominate their overarching strategy going forward.

Addressing e-fuel's cost challenge, Siemens Energy (DEU) spearheads a prominent large-scale demonstration project, Haru Oni. Porsche (DEU) and energy powerhouse AME (DEU) are integral contributors, aiming to achieve a production rate of approximately 550,000 kL/year by 2025. Its first product, a 2,600-litre tank of e-fuel, hit the market at the end of 2022. In the Japanese market, Idemitsu Kosan is aiming to achieve e-fuel commercialisation by 2030.

E-fuels are, as mentioned earlier, particularly expensive and hence their applications are limited to niche areas that require high power output, such as sports cars. In addition, given that the transition from passenger cars to EVs is expected to move fast in high-income countries, concentrating on markets in which fewer alternatives are available, such as those for special-purpose and heavy vehicles, should prove to be key going forward.

Leading Players in E-Fuels



Source: Compiled by Uzabase
Note: Black lines indicate partnerships.

SAFs: Industry Also Home to Companies Looking to Leverage Existing Material Supply Chains

The SAF industry is home not only to many companies from petroleum-related fields but also to startups and other entrants outside the sector, which has led to intensifying competition in the industry.

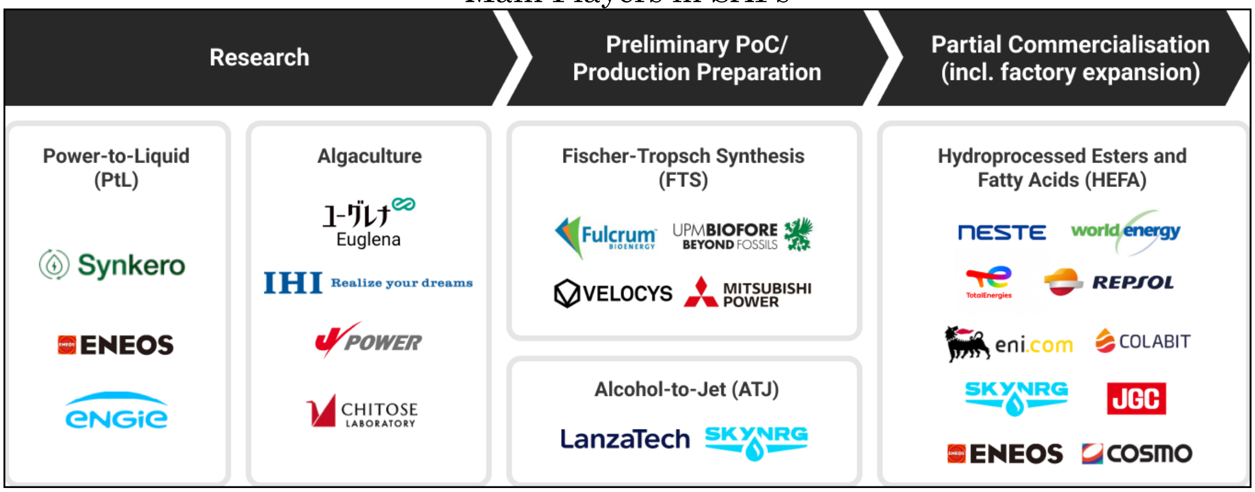
Examples of petroleum-related companies engaged in the field include global industry leader Neste (FIN), Repsol (ESP), ENEOS (JPN), and TotalEnergies (FRA). In contrast, other players enter the industry to take advantage of expertise accumulated in similar fields or save costs on raw materials, and they include Finnish forestry company UPM (FIN) and Japanese biotech startup Euglena (JPN), which leverages its expertise in microalgae products to engage in algae-based SAFs. There are also companies that explore different process methods via separate projects (e.g. PtL, HEFA) to try and break away from material limitations (e.g. ENEOS, UPM). While Japanese companies are somewhat behind in the SAF field, with European companies in the lead, players like Euglena that enter the industry through niche areas like high-yielding algae are particularly distinct from the crowd.

Meanwhile, Neste, which has honed its expertise in HEFA technology, is already producing 100,000 tonnes of SAF a year and plans to expand annual production to 1.5 million tonnes by early 2024 after acquiring the capacity to produce 1 million tonnes as of May 2023.

Other methods are also under accelerated development towards practical application. In the field of FTS, Fulcrum BioEnergy (USA) began operating the world's first plant to produce SAF from landfill waste in May 2022. In AtJ fuels, the world's first AtJ biorefinery by LanzaJet (USA), a spin-off from LanzaTech (USA), is reportedly scheduled to start operations at the end of 2023. Meanwhile, Euglena's cooking oil- and algae-based SAF has been seeing increased adoption for fuelling planes at

Narita International Airport since September 2022 and Tokyo Metropolitan Government-operated airports as of March 2023. The company has indicated that it plans to close its test plant in January 2024 and complete the construction of a commercial plant by 2025. However, it is worth noting that Euglena's SAF and biodiesel were priced between USD 2.2–2.7/litre in the last quarter of 2022. This is nearly three times the price of diesel oil, underlining the pressing need for greater cost efficiency in the sector.

Main Players in SAFs



Source: Compiled by Uzabase

Note: The phases serve as an indication of the different stages that each company is at.

Ongoing Expansion of SAF Supply Networks and Voyages for Test of Ship Biofuels

Various airline and shipping companies are moving to secure sources of clean fuel such as SAFs.

In the Japanese aviation sector, ANA is working together with JAL (JPN) and companies involved in the SAF supply chain to commercialise and promote the adoption of this clean fuel. In the US, Alaska Airlines (USA), American Airlines (USA), and JAL, along with six other Oneworld Alliance members, have also joined hands to purchase SAF from renewable fuels producer Gevo (USA). Meanwhile, starting in 2024, the Oneworld Alliance is slated to procure a total of 1.3 million kilolitres of SAF from US fuel manufacturers over a seven-year term for regular flights departing from US airports. Long-term contracts are also prominent in the air transport sector, including an agreement between DHL Express and World Energy, under which the latter will provide SAF to the former for seven years.

Some trading companies have also established their own SAF supply networks. For example, Itochu Corporation (JPN) signed a contract in February 2022 with Neste for the sole distribution of the company's SAF to the Japanese market. In January 2023, the company announced it would also receive supplies from Raven (USA), which produces SAF from municipal waste. In terms of customers, Itochu Corporation already supplies SAF to the likes of ANA and JAL. It should be noted, however, that as the SAF industry sees further development, attention should also be paid to short-haul flights as their number could potentially be reduced, replaced by electric railways and other means of transport as part of the ongoing push towards carbon neutrality.

Meanwhile, in the maritime transport sector, Mitsui O.S.K. Lines (JPN) signed a biofuel supply contract with GoodFuels (NLD) in 2021 and began trial voyages. Subsequently, in 2022, NS United Kaiun Kaisha (JPN) conducted trial voyages using biofuels in collaboration with Nippon Steel (JPN) and Toyota Tsusho Petroleum (JPN). Simultaneously, the company is exploring the use of hydrogen and ammonia as ship fuels, which are notable for emitting no carbon dioxide during combustion, as opposed to during their production.