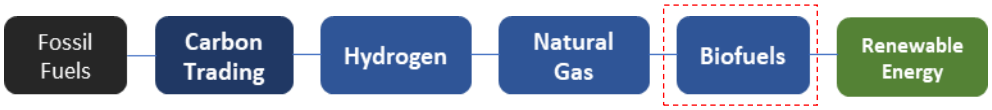
OCBC TREASURY RESEARCH

Clean Energy Series: Biofuels

10 November 2021

Biofuels Primer



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In the penultimate installation of our Clean Energy series, we look at biofuels.

This paper serves as an elementary primer for understanding the basics of the biofuels market.

This report is structured as below:

Part I: Introduction to biofuels.

This section answers the basics of the biofuels market, including what they are, the types of biodiesels and how they help in decarbonization. We also set the backdrop for first-generation vs second-generation biofuels here.

Part II: First-generation biofuels – ethanol and biodiesel.

The ethanol and biodiesel markets are explored in detail here, including their production process, feedstock, blending properties and disadvantages. We then compare the differences between the two markets and look at the current price indices for each.

Part III: Second-generation and advanced biofuels.

We list out four main second-generation and advanced biofuels to look out for – HVO (renewable diesel), UCOME, SAF and bioethanol – and why they are set to change the biofuel landscape in the long-run.

Part IV: Supply/demand dynamics and market prices.

Supply is dominated by crop availability, while demand is almost entirely dictated by government mandates. Multiple price indices exist for both ethanol and biodiesel, but in general they cost more than petroleum fuels.

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Part 1: Biofuel market basics

Answering basic questions on biofuels.

What are biofuels?

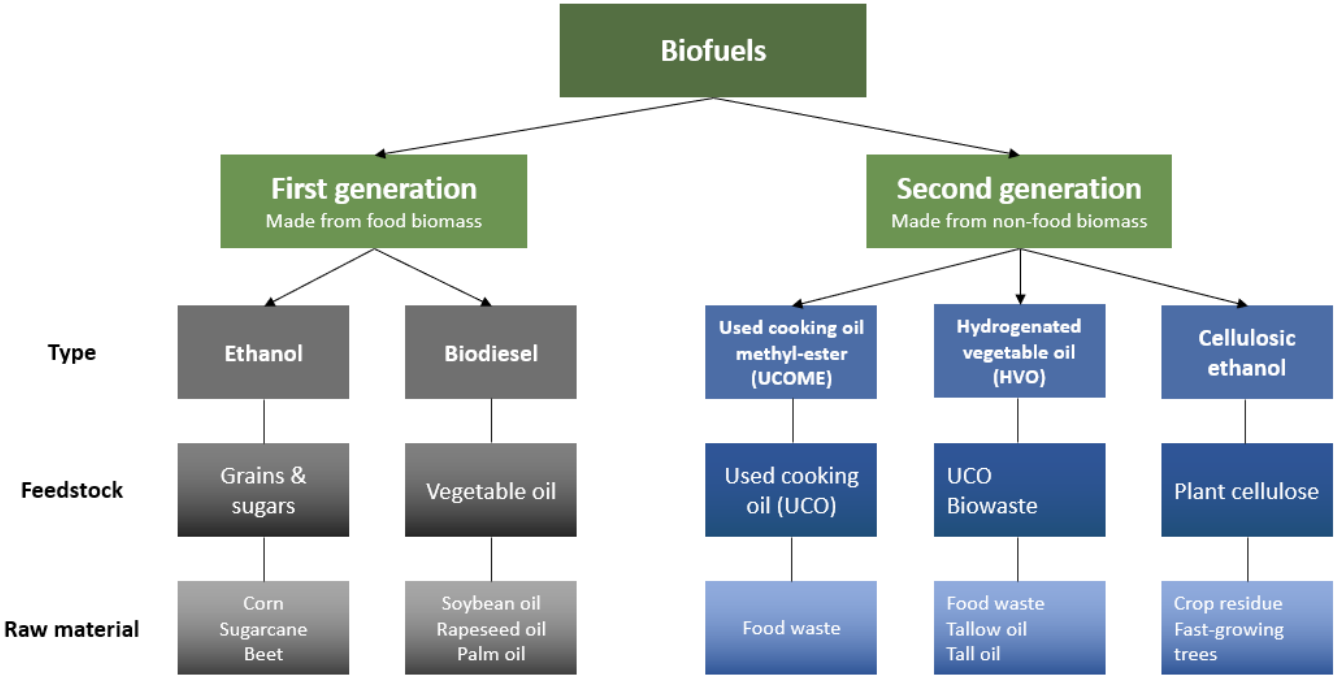
Biofuels are fuels made from organic matter, otherwise known as biomass materials. These fuels may be blended with conventional fossil fuels for transportation purposes. The term 'bio' depicts this class of fuels as having been produced by plant or animal origins, as opposed to a geological process in fossil fuels.

What are the types of biofuels?

There are multiple biofuels today that exist in the market. Of these, the ethanol and biodiesel are the most dominant biofuels in the market today. They are normally termed as **"first generation biofuels".**

There is a growing segment of biofuels that are up and coming, notably sustainable aviation fuel (SAF), hydrogenated vegetable oil (HVO, also known as renewable diesel) and cellulosic ethanol. They are termed **"second generation and advanced biofuels".** We shall refer to them as "second-generation biofuels" in the rest of the primer.

Second generation biofuels are manufactured from non-food biomass, while first generation biofuels are generally derived from food biomass.



Source: OCBC Bank

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How do biofuels help in decarbonisation?

Carbon emissions from biofuels are significantly lower than fossil fuels. Blending biofuels with conventional fuels reduce the net release of emissions into the atmosphere. In addition, since biofuels are biodegradable, accidental spillage into waters can be counteracted by normal biological degradation.

Picture source: Science Direct

Are biofuels carbon neutral?

Combustion of biofuels still produce carbon emissions on a gross basis. However, on a net basis, biofuels are considered almost carbon neutral. This is because their emissions are offset by carbon sequestration during the plant's cultivation.

In other words, the combustion of biomass releases carbon already absorbed by plants and adds no new carbon to the atmosphere.

The amount of carbon emissions from biofuels are also far lower than that of fossil fuels. Taken together, biofuels are regarded as a clean energy source.

Part II: First-generation biofuels – ethanol & biodiesel

While many types of biofuels exist today, ethanol and biodiesel currently dominate the current biofuel market.

1. Ethanol

Ethanol (CH_3CH_2OH) is a biofuel made primarily from plant starches and sugars. It is an alcohol and used as a blending agent with gasoline. Ethanol production results in a positive energy balance. In other words, the production of ethanol requires less energy than the amount of energy contained in ethanol itself.

Fermentation is the most common method in the conversion of biomass into ethanol. The process of fermentation involves microorganisms metabolizing high carbon matter – mainly sugars and cellulose – into ethanol. Corn and sugarcane are the most common feedstock for first-generation ethanol production.

Picture source: Agriculture.com

Ethanol is rarely used in its raw form as a transportation fuel. Instead, it is blended with gasoline at a fuel terminal to make E10 (10% ethanol, 90% gasoline), E15 or E85. In recent years, however, more E100 commercial vehicles have begun surfacing in the market.

Global ethanol production is dominated by two main players: the US (55%) and Brazil (29%). The US produces ethanol primarily from its corn crop, while Brazil produces ethanol from its sugarcane.

Annual world ethanol production (million gallons)							
Region	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**% of world production**
US	14,807	15,413	15,936	16,091	15,778	13,926	54.9%
Brazil	7,200	6,750	6,650	7,990	8,590	7,930	29.4%
EU	1,360	1,360	1,420	1,450	1,370	1,250	4.9%
China	770	670	800	770	1,000	880	3.2%
India	190	280	200	430	510	515	1.7%
Canada	450	460	460	460	520	428	1.7%
Thailand	310	340	390	390	430	400	1.5%
Argentina	220	240	290	290	280	230	1.0%
RoW	393	487	454	529	522	500	1.9%
Total	25,700	26,000	26,600	28,400	29,000	26,059	100.0%

Source: US IEA, OCBC

Disadvantages of ethanol

1. **Ethanol is less energy-efficient than gasoline.**
   Denatured ethanol (98% ethanol) carries about 30% less energy than gasoline per unit volume.

2. **Ethanol is a corrosive fuel.**
   Unlike conventional fuels, ethanol is hydrophilic (tends to attract water), making it difficult to transport over long distances without corroding the interior of pipelines. Water in ethanol can also damage a vehicle that is sitting too long.

3. **Ethanol demand drives up the cost of food.**
   The production of ethanol directly competes with demand for food consumption, resulting in food cost inflation. This has been the biggest source of ethical contention involving biofuels.

4. **Production is dependent on crop availability, which in turn is reliant on the weather.**
   Expectations of adverse weather drives up the price of corn and sugarcane, in turn inflating the cost of ethanol.

2. Biodiesel

First-generation biodiesel is produced from vegetable oils (vegoils), such as soybeans, rapeseed and palm. When crushed, vegoil seeds release oil. The vegoil is combined with alcohol to produce biodiesel, otherwise known as *transesterification*. Biodiesel is used as a blend with petroleum diesel to fuel compression-ignition engines (diesel engines).

Biodiesel is sold as a blend with petroleum diesel such as B10 (10% biodiesel, 90% petroleum diesel). The highest biodiesel blend at present is found in Indonesia at B30 (30% biodiesel, 70% petroleum diesel). Below is a table of the level of biodiesel blends found globally.

Country	Blend	Country	Blend
Argentina	B10	**Norway**	B5
Brazil	B10	**Ukraine**	B2.7
Canada	B4	**Australia**	B0.5
Chile	B5	**India**	B5
Ecuador	B10	**Indonesia**	B30
Peru	B2	**Malaysia**	B10
Uruguay	B6	**Philippines**	B2
USA	B5	**South Korea**	B3

Source: Biofuels Digest, OCBC

Like ethanol, biodiesel has a positive energy balance – the energy needed to produce biodiesel is less than the energy contained in the end product. Biodiesel is estimated to release 3.2 units of energy for every 1.0 unit of energy needed to produce it.

Disadvantages of biodiesel

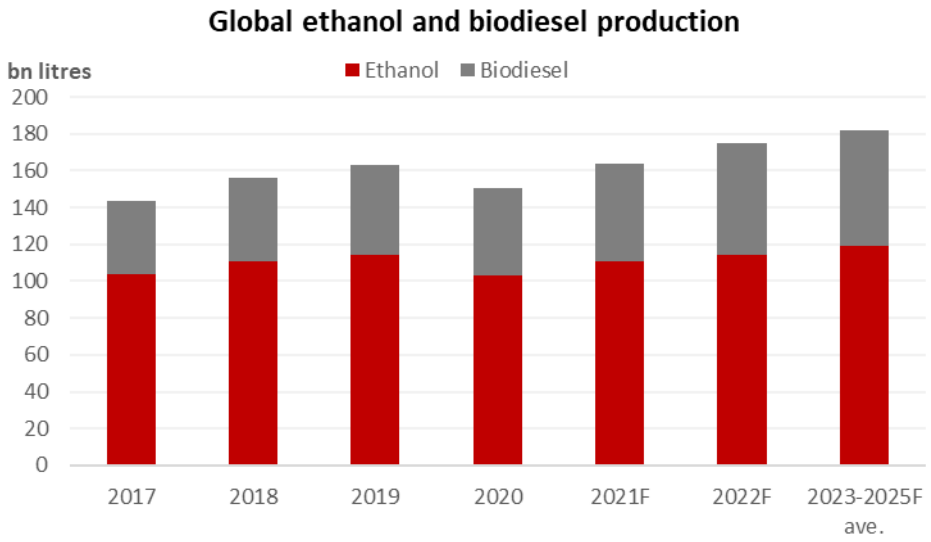
1. **Biodiesel is less energy-efficient than petroleum diesel.**

2. **Biodiesel clogs engine filters in large concentrations.**
   Biodiesel is a solvent. It releases deposits accumulated from petroleum diesel in a vehicle's fuel system, which will initially clog filters and require frequent filter replacement.

3. **Biodiesels have a high freezing temperature, meaning it starts to thicken in cold temperatures.**
   Different types of biodiesel (depending on the source of vegoil) have different crystallisation points (cold filter plugging point). Generally speaking, B50 blends and above have cold filter plugging points at around 1degC.

Ethanol vs biodiesel comparison

	Ethanol	Biodiesel
Feedstock	Sugar/starch	Vegetable oils
Input material	Corn/sugarcane/beet/wheat/barely	Soybean/rapeseed/canola/palm oil
Fossil fuel blend	Gasoline	Diesel
Vehicle suitability	Light-duty vehicles like cars, motorcycles and small trucks	Heavy-duty vehicles like delivery trucks, trains, buses and boats
Production	Fermentation	Transesterification
Blend levels	E10, E15, E85	B10. B20, B30, B40, B85, B100
Carbon intensity	55-60g CO2e/MJ	25-30g CO2e/MJ
Engine drawback	Hydrophilic corrosion	Solvent clogging of engine filter
2019 production	114.6 billion litres	48.3 billion litres
Main producers	US (55%) Brazil (29%) EU (5%)	EU (34%) US (17%) Indonesia (15%)



Source: US IEA, OCBC

Part III: Second-generation and advanced biofuels

Introduction to second-gen biofuels.

Second-generation biofuels comes from non-food biomass such as used cooking oil, food waste, wood and fast growing trees.

a) **Second generation biofuels do not compete with food crops.** While first-gen biofuels may require the direct input of food matter such as corn, second-gen biofuels almost exclusively require plant and animal waste.

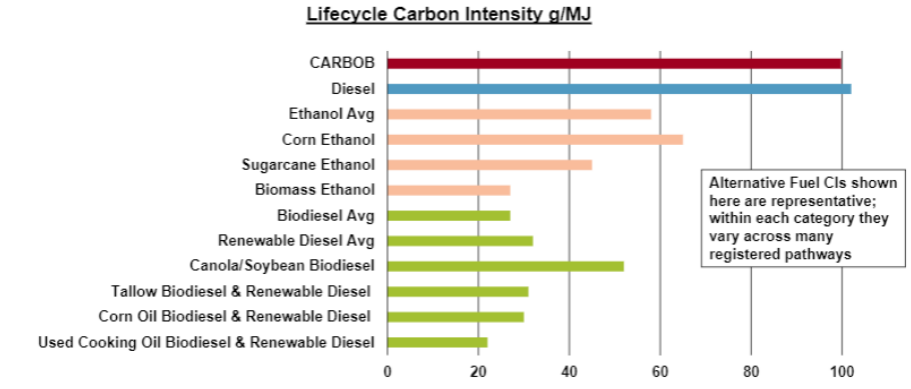
b) **Second-gen biofuels generate higher energy yield per land area,** since they allow for use of less-fertile land where food crops are unable to grow.

1. Hydrogenated vegetable oil (HVO), or renewable diesel

HVO is made from waste and residues, such as used cooking oil, tallow oil and tall oil. The result is a "Green Diesel" that has an almost identical chemical composition with petroleum diesel. Unlike traditional biodiesel, it is not an ester and hence can be used in high concentrations. It can also withstand colder temperatures than traditional biodiesels.

HVO currently represents about 10% of the entire biodiesel market. Its high CAPEX related to hydrogenation, however, has so far limited a quicker expansion. The expectations are for HVOs to eventually phase out first-gen biodiesels in the long-run, especially in the EU.

LCFS credits incentivize the production of lower carbon fuel



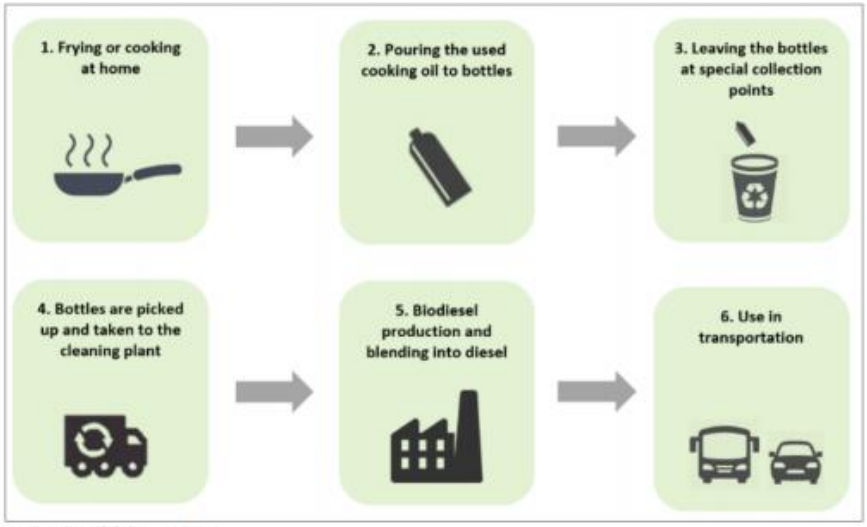
S&P Global Platts

Source: S&P Global Platts Analytics Environmental Commodities Service
SAF Average CI reflects certified tallow pathways plus temporary pathways with higher CIs

2. Used cooking oil methyl ester (UCOME)

The EU's Renewable Energy Directive II (RED II) states that increase in biofuel consumption should be produced from feedstocks such as waste oils and fats. This includes used cooking oil (UCO), which can be used to produce a type of biodiesel known as used cooking oil methyl ester (UCOME). UCOME production is relatively cheap and mature compared to HVO technology.

The biggest challenge UCOME faces is the availability of UCO from households and restaurants, for which very low recovery efficiencies and supply certainty are typical. Another challenge is the highly heterogenous nature of UCOs, where different cultures and culinary practices result in a wide range of physicochemical variability.



Source: (GREENEA, 2016).

3. Cellulosic ethanol (bioethanol)

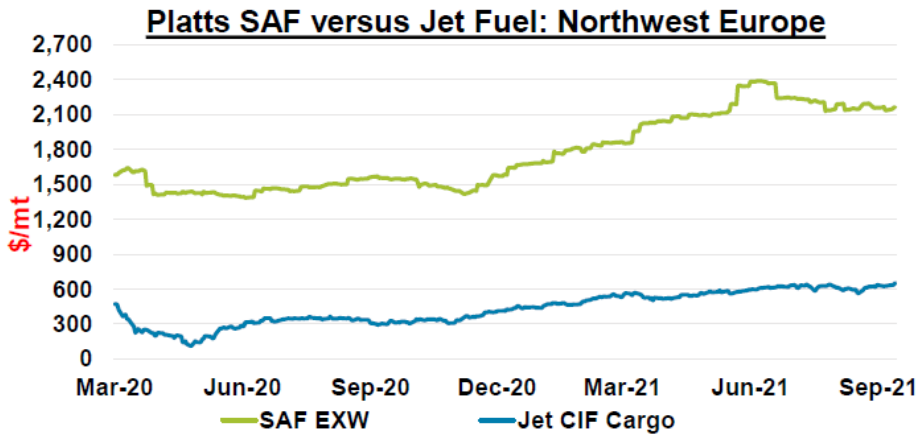
Cellulosic ethanol is made from fermentations of cellulose in plant fibres. Agriculture waste from food crops (stems, leaves and husks), dedicated fast-growing trees and grass are all potential feedstock for cellulosic ethanol production. In other words, cellulosic ethanol draws on cellulose fractions of lignocellulosic (plant dry matter) biomass for ethanol production, which is an abundantly raw material on earth.

This technology, however, remains highly expensive and requires more R&D to reduce its OPEX. Another challenge is the high quantity of impurities found in lignocellulosic biomass, which are often delivered wet and mixed with dirt, complicating processing.

4.Sustainable aviation fuel (SAF)

So far, biofuels have primarily been used as substitutes for gasoline and diesel. Sustainable aviation fuel bucks this trend as a drop-in fuel for jet fuel. Norway is the first country with a SAF mandate (0.5% blending), with an aim to peak with 30% SAF blending by 2030. The global aviation industry continues to receive heavy criticism for its soft decarbonization plans (CORSIA) – the uptake of SAF may go some way in repairing that image. SAF can be produced from agriculture resides and other food and animal waste, including UCO.

Challenges include the low energy efficiency of SAF compared to traditional jet fuel, which carry logistical concerns over long-haul flights; raising the appropriate amount of investment for production and refuelling globally; and the high price of SAF vis-à-vis jet fuel, for which airlines receive no compensation at present.



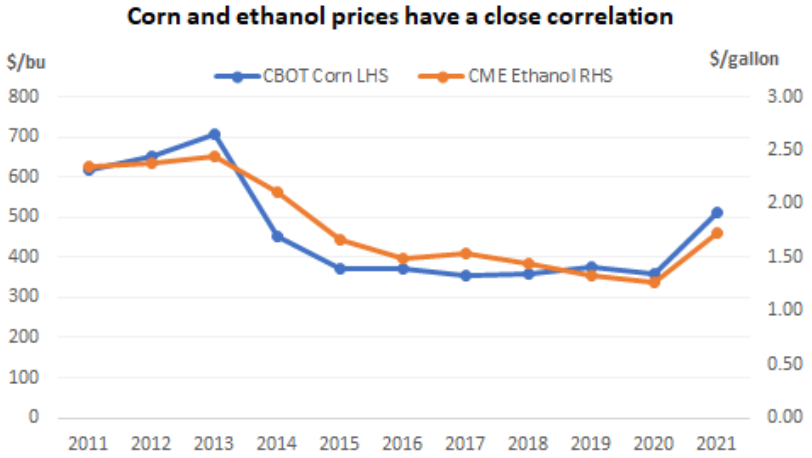
Source: S&P Global Platts Analytics

Part IV: Supply/demand of biofuels and prices

Supply/demand dynamics of biofuels

Supply

Supply is almost entirely determined by crop availability, especially for corn and sugarcane (ethanol) as well as soybeans (biodiesel).



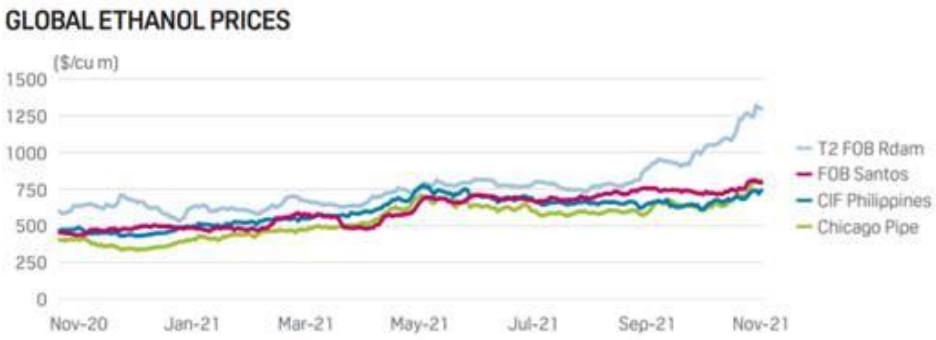
Source: USDA, Bloomberg, OCBC

Demand

Demand is almost entirely driven by government policy. In the absence of a strong government mandate, there would be almost no incentive for the continued consumption of biofuels, since they are inherently more expensive petroleum fuels.

Prices

Ethanol Spot Market		
Region	Price Index	Description
US	Chicago Pipe	Price of ethanol traded domestically in the US
S.America	FOB Santos	Price of ethanol export on loading at Santos
Europe	T2 FOB Rotterfam	Duty-paid ethanol export on loading at Rotterdam
Ethanol Futures Market		
US	CME (Platts)	Futures of Chicago Pipe
Europe	ICE ethanol T2 FOB Rotterdam Barges (Platts)	Futures of T2 FOB Rotterdam



Source: S&P Global Platts Analytics

Biodiesel Spot Market		
Region	Price Index	Description
US	B100 SME Chicago	Price of 100% biodiesel from soy methyl ester (soybeans) in the US
Europe	RME FOB ARA	Rapeseed methyl ester export price in Amsterdam-Rotterdam-Antwerp (ARA)
Europe	FAME 0 FOB ARA	Blend of fatty acid methyl esters (FAME) with a maximum cold filter plugging point of 0degC
Asia	FOB SE Asia	Palm biodiesel for export in Malaysia
Biodiesel Futures Market		
Europe	ICE Argus FAME 0 FOB Rotterdam	Futures of FAME 0 FOB ARA
Europe	ICE Argus Biodiesel RME FOB Rotterdam	Futures of RME FOB ARA

Source: S&P Global Platts Analytics

Price observations

In general, biofuels are more expensive than fossil fuels due to its lower energy density and limited supply. Gasoline in the US is trading around $2.32/gallon, while US ethanol (Chicago pipe) is trading at about $2.84/gallon at time of writing. Similarly, low-sulphur diesel is trading at $720/mt in Europe, while FAME 0 Rotterdam is trading at $1750/mt.

Concluding remarks

As the world continues on its decarbonisation path, the challenge is to find dependable and cleaner energy sources. First-generation biofuels – ethanol and biodiesel – are tabled as alternatives, but have fallen short due to their low energy density and food security concerns. These two, however, are still the biggest biofuel markets at present, with the ethanol market about thrice that of biodiesel in terms of production volume. Both have sufficiently developed capital markets.

Second-generation and advanced biofuels utilise non-food biomass as its feedstock, such as used cooking oil and lignocellulosic biomass. Some of the more promising gen-2 biofuels include hydrogenated vegetable oil (HVO), used cooking oil methyl ester (UCOME) and cellulosic ethanol (bioethanol). Sustainable aviation fuel is also seen as a promising drop-in blend for conventional jet fuel. Second-gen and advanced biofuels, however, still face multiple challenges related to pricing, industrial feasibility and supply certainty, although we believe they may eventually dominate the biofuel market in the long run.

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