Special Report

Biofuels at Inflection Point: Opportunities for Technology Developers

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Introduction (1/2)

- This report deals with the current status of biofuel production, developments in this space, and prospects. Research and development (R&D) is currently focused on the production of biofuels, such as bioethanol, biodiesel, and biogas, from waste matter. The successful application of newly developed technologies, combined with economic feasibility, can significantly increase the production of biofuels and reduce the menace caused by greenhouse gas (GHG) emissions.
- Fossil fuels supply more than 80% of the global energy required and are among the major contributors to GHG. GHG levels, responsible for global warming, are reported to be alarmingly high. The aim of the Paris Agreement is to cap the increase in temperature globally at below 2ºC; this target can be achieved by developing sustainable alternatives to fossil fuels.
- Biofuels can be an alternative to fossil fuels. The current use of renewable energy in transportation accounts for only 3% of the fuel mix. The primary energy supply from biomass accounts for 70% of the total renewable energy produced, while that from biofuels accounts for only 9%.
- Favorable government policies and the use of biomass generated from agricultural residues, municipal solid waste, and industrial waste could boost the production of biofuels. Developments in feedstock pretreatment, catalysis, product separation, and systemic feedstock collection can also contribute to the increase in production.
- Biofuel production is expected to be 968 million barrels in 2020 and could increase at a CAGR of 4.1% until 2023. By 2050, biofuels are projected to account for 22% of total fuel consumption worldwide.

Introduction (2/2)

Currently, first generation feedstocks account for the major production of biofuels.

Biofuels: These are fuels derived from biomass by biochemical or chemical methods.

Bioethanol, biodiesel, biogas, and biobutanol are the biofuels produced from different feedstocks.

Why Biofuels?

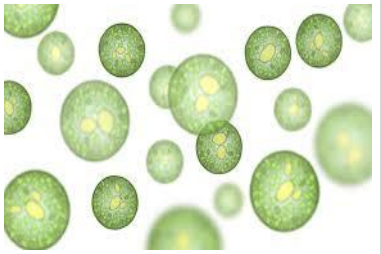
- The rise in demand for energy globally has raised the consumption of fossil fuels; consequently, emissions, which are responsible for massive environmental degradation, have increased.
- Biofuels are a potential alternative and their consumption does not emit toxic gases such as nitrogen oxide (NOx) and sulfur oxide (SOx). Blending of 10% bioethanol with gasoline can reduce GHG emissions by around 18%.
- Biofuel consumption would ideally result in zero net emittance of carbon dioxide (CO_2). The biofuels mainly produced as of now are bioethanol and biodiesel, accounting for a 73% and 27% share, respectively, in global biofuel consumption.
- Bioethanol is mainly produced in the US and Brazil, while biodiesel is produced on a large scale in the European Union (EU).

Based on the feedstock used in production, biofuels are generally classified into three generations, as mentioned here.

First generation: Food crops (corn, sugarcane, vegetable oil, etc.)

Second generation: Biomass from agricultural, municipal, or industrial waste

Third generation: Advanced biofuels such as those from microalgae



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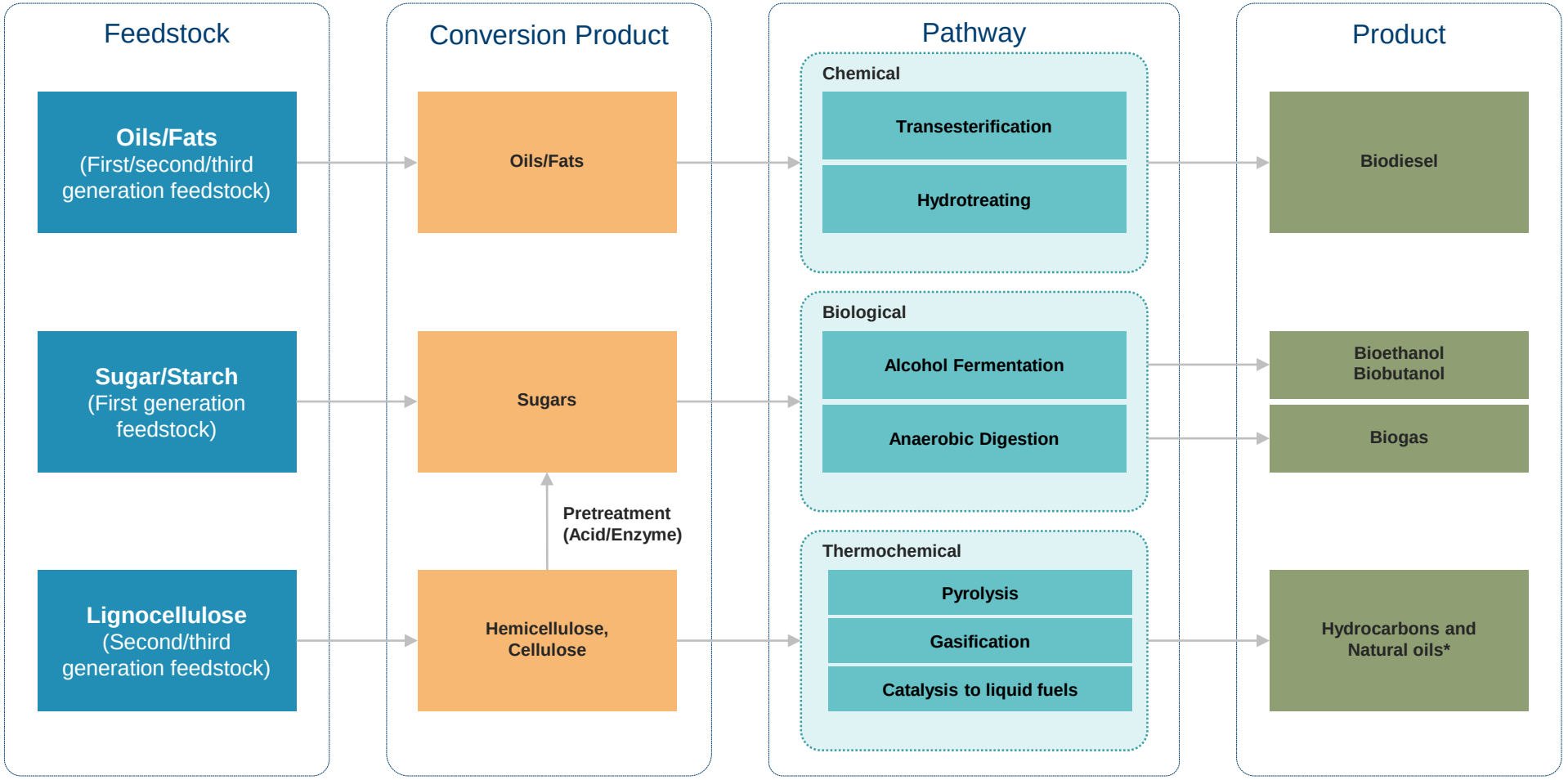
Biofuel production methods

Biomass-derived monomeric sugars and oil are utilized in the production of biofuels.



** Processed further into gasoline or diesel equivalents, syngas, and hydrogen*

Bioethanol

Bioethanol, mainly derived from corn and sugarcane, is estimated to have been a USD 58.15 billion market in 2019. Production cost of bioethanol has dropped to USD 75 per barrel of oil equivalent (boe).

Pathway	Advantages	Disadvantages	TRL (0–9)	Developments Reported	Key Players
Biological process (alcohol fermentation)	▪ Commercially developed process ▪ Different feedstocks can be treated using acid and enzymatic hydrolysis ▪ Product blended with gasoline in many regions	▪ Microbes unable to utilize pentose and hexose sugars simultaneously ▪ Processes involved not integrated, affecting the overall economics		▪ *Zymomonas mobilis* developed as an alternative to *S. cerevisiae* ▪ Other fungal strains such as *Penicillium* developed to produce cellulase enzymes ▪ Lytic polysaccharides leading to improvement in cellulose utilization ▪ Ethanol-producing strains genetically modified to utilize xylose and glucose together, obtained from lignocellulosic feedstocks ▪ Membrane processes to separate ethanol and water, with improved ethanol recovery	AEMETIS HARVESTONE GROUP GranBio

In January 2020, Tata Projects, in collaboration with Bharat Petroleum Corporation limited (BPCL), planned to set up a bioethanol plant in Odisha, India, utilizing rice straw as feedstock. The plant aims to produce 100,000 Liters (L) of bioethanol per day.

Source: *BIS Research Analysis*

Biodiesel

Biodiesel, mainly derived from palm oil and used cooking oil, is estimated to have been a USD18 billion market in 2019.

Pathway	Advantages	Disadvantages	TRL (0–9)	Developments Reported	Key Players
Catalytic transesterification	▪ Established process of production ▪ High demand for product in the market	▪ Catalysts not suitable for effective processing of second generation oils		▪ Use of genetically modified microorganisms to produce biodiesel ▪ Enzymes immobilized on flexible supports ▪ Solid catalysts, such as sodium silicate and chitosan chloride, developed along with flexible supports ▪ Solid catalysts supported on membranes to be used in catalytic membrane reactors	NESTE ADM Avril

Aementis would be supplying biodiesel worth USD 23 million to Indian oil marketing companies.

Source: *BIS Research Analysis*

Biogas

As of now, cow dung is the main feedstock for the production of biogas. The estimated global market share of biogas by volume is 37,728 million cubic meters (m^3) for 2020.

Pathway	Advantages	Disadvantages	TRL (0–9)	Developments Reported	Key Players
Biological process (anaerobic digestion)	▪ Replaces natural gas ▪ Established process of production for certain feedstocks	▪ Needs pretreatment process to utilize lignocellulosic biomass ▪ High process cost ▪ Requires further enhancements in purification to be converted into methane		▪ Bio-augmentation agents that have led to utilization of different feedstocks ▪ Co-digestion of different feedstocks, with increased biogas yield ▪ Carbon dioxide produced in the process reported to be converted into methane using bioelectrical systems (microbial electrolysis cell) and microalgae cultivation ▪ Hydrogen sulfide removed from biogas using chemical biological systems consisting of chemolithotrophic microbes	WELTEC BIOPOWER BEKON ENGIE

Gevo recently announced a contract with three dairies to produce biogas from manure; the expected production of biogas is 350,000 MMBTU per year.

Source: *BIS Research Analysis*

Biobutanol

Biobutanol is currently used as fuel in the aviation industry. Biobutanol production is expected to increase at a CAGR of 8.36% during 2019–24.

Pathway	Advantages	Disadvantages	TRL (0–9)	Developments Reported	Key Players
Biological process (fermentation process)	▪ Process can take place simultaneously with ethanol production	▪ Recovery and comparatively low product yield		▪ Genetically modified yeast to ferment corn hydrolysate and produce butanol ▪ Production of n-butanol using a modified *Clostridium* reported, with 30% increase in yield ▪ Low-energy methods for solvent recovery and purification ▪ Detailed characterization of acidogenic and solventogenic phases and metabolism using metabolic flux	gevo Butamax

Biobutanol as a sustainable air fuel has been used by Virgin Australia in commercial flights for more than 1 million kilometers.

Source: *BIS Research Analysis*

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Problems to overcome

Consumption and Regional Imbalance

- The consumption of biofuel currently is minimal compared with that of fossil fuels as the production cost for biofuels is higher than that for fossil fuels. The global consumption of biofuels should also be uniform and not focused in a particular region.

Food versus Fuel

- Cultivation of feedstocks for biofuel results in depletion of rainforests and grasslands, leading to increase in GHGs. Biofuels produced from first generation feedstocks also create food versus fuel concerns, given the utilization of food crops.

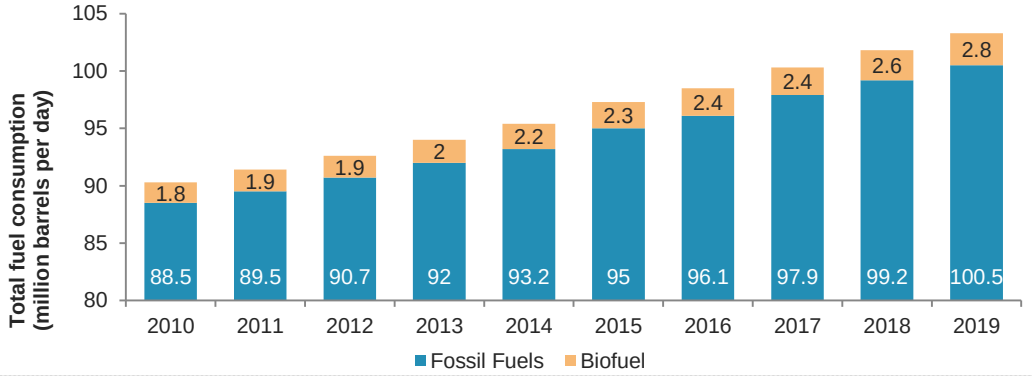
Economic Viability

- Processes for biofuel production need to be developed considering the economic viability of the end product in the market. Processes involving catalysts, microorganisms and product separation need to be developed in order to improve the current economics of biofuel production.

Carbon Neutrality

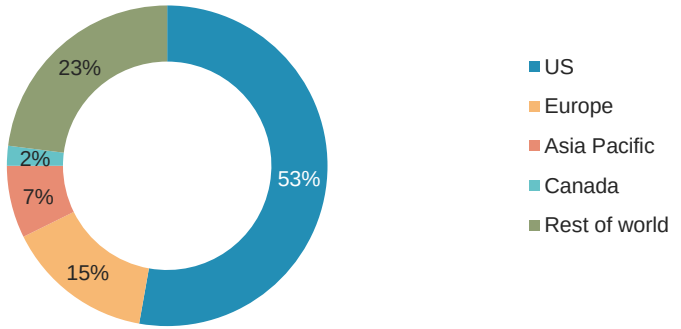
- Though biofuel consumption is considered a carbon-neutral process (CO_2 produced is re-utilized by plants), other factors, such as fuel consumed for biomass transportation, energy and water required in production process, also have to be considered.

The share of biofuels in total fuel consumption has remained restricted due to drop in the prices of crude oil; however, technological advancements in the field have helped in maintaining the share.



Biofuel production is largely concentrated in regions where feedstock is available. The US accounts for over half of the current global production due to abundant corn cultivation in the country.

Region-wise global biofuel consumption in 2017



Source: *Marketline 2018, https://www.iea.org/fuels-and-technologies/bioenergy*

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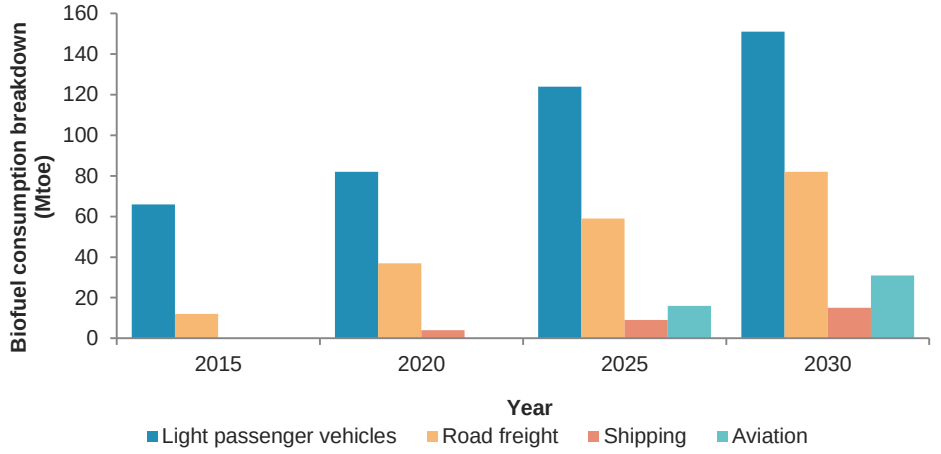
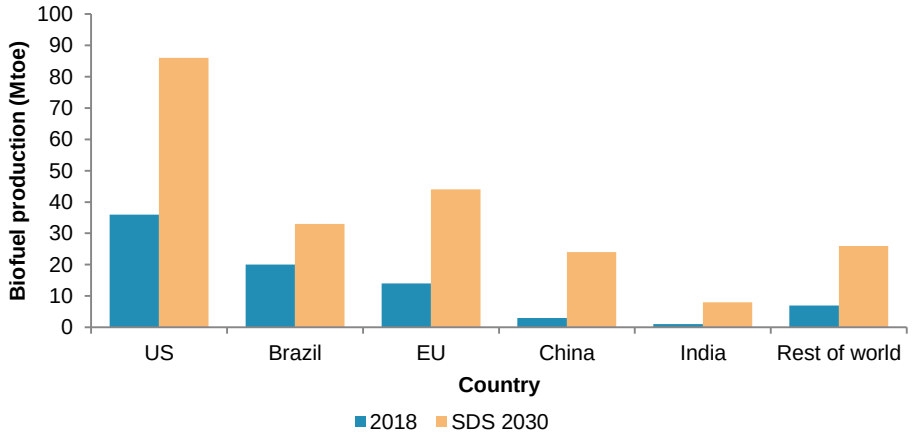
Prospects

Increase in biofuel production and consumption would be mainly influenced by government policies and investments over the next few years.

- Biofuels are set to play a significant role in reducing global warming by decreasing emissions and utilizing waste.
- During 2018, global biofuel production increased by 10 billion liters (L) to a record 154 billion L.
- The production of hydrotreated vegetable oil (HVO) is set to more than double from around 5.5 billion L in 2018 to 13 billion L in 2024.
- Biofuel output is anticipated to 25% 190 billion L over 2019–24.
- By 2050, biofuel is expected to have a 22% share in total fuel consumption.
- Further developments related to easy availability of feedstocks, feedstock processing, heterogeneous/enzymatic catalyst development, and membrane, or packed-bed-assisted product recovery can enhance the productivity of biofuels.
- Production of biofuels should be strategized based on geographic availability of abundant feedstock and production process should be standardized.
- The aviation and marine sectors would be the major consumers of biofuel in the coming years with the development of bio jet fuels.





Source: *https://www.iea.org/fuels-and-technologies/bioenergy*

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Opportunities for technology developers

- The biofuel value chain is set to evolve and transform significantly. Technologies for synthesizing downstream products would open up new opportunities. In this scenario, biofuel production from biomass could be centered on the concept of a biorefinery where other higher value products, such as bio-based chemicals and polymers, would also be produced.
- In terms of markets, along with automobile, the aviation and marine sectors would significantly contribute to the demand for biofuels in the coming years.

Production

- Yield enhancement is one of the most important factors in upscaling the biofuel market. Advanced catalysts play an instrumental role in yield enhancement.
- Enzymatic catalysts and flexible support catalysts have been found to be promising in this regard. The enzyme Eversa, developed by Novozymes, is one such product with the ability to convert different feedstocks into biodiesel. NEXBTL and Diester are other commercially available biodiesel processes developed by Neste and Avril, respectively.
- The recent technological advancements in modifying *Z.mobilis* to efficiently utilize lignocellulosic pentose and hexose sugars address the key limitations in the utilization of lignocellulosic biomass.

Recovery and Purification

- Purification of biogas via membrane processes has significantly improved the yield of methane.
- Evonik has developed the Sepuran green membrane, made of high-performance plastic (polyimide). The membrane separates methane from the other gases.
- Another product is the Prism membrane separator, developed by AirProducts. It is made of acrylonitrile butadiene styrene encased in an aluminum sleeve.

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