Global biofuels at the crossroads:

An overview of technical, policy, and investment complexities

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Biofuels have been used for years to increase energy self-sufficiency, reduce import costs and strengthen agricultural development. More recently, biomass-based transport fuels have become a strategic focus for regions wanting to minimise vehicle emissions and increase sustainability.

These fuels are instrumental in a shift to low-carbon fuels, which would bring about sustainability in the transport sector. This potential is shaped by the transport sector, which accounts for a third of global energy utilisation, half of oil consumption, and nearly a quarter of CO_2 emissions from fossil fuel combustion.

Since 2000, the supply of global biofuels has increased by a factor of 8% to equal 4% of the world's transport fuels in 2015 (*Figure 1*). This significant increase is attributed to policies such as blending mandates, which foster greater utilisation and may insulate biofuels during times of oil price flux.

In aviation, marine transport and heavy freight industries, biofuels are deemed the only practical, low-carbon alternative to fossil fuel. Specific to aviation, total greenhouse gas (GHG) emissions were projected to increase by 400 to 600% between 2010 and 2050.

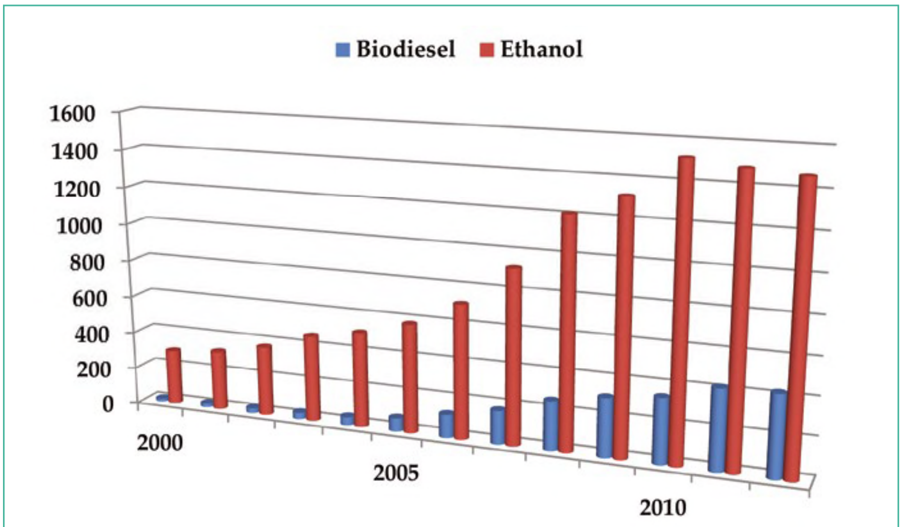
The aviation industry set targets for reducing CO_2 and flew their first commercial test flight with biofuels in 2008. As of mid-2015, approximately 22 airlines had completed more than 2 000 passenger flights with biofuel, which represented up to half the jet fuel mix. The recent signing of an agreement by 191 countries to curb aviation pollution underscores the substantial market potential for continued biofuel adoption.

Biofuel production pathways

In 2015, historical leaders Brazil and the United States (US) produced approximately 70% of global biofuel supply (mainly sugarcane-based and corn-based ethanol). Among the newer producing regions, the European Union (EU) focuses on bio-diesel from waste, soya, rapeseed and palm. This compares to production in Asia, which centres on sugarcane, corn, wheat and cassava, with investment also occurring in palm, soya bean, rapeseed and Jatropha. This regional and feedstock-based diversification may be conducive to the formation of an international biofuel commodities market.

Global biofuel supply equalled approximately 35 billion gallons (132 billion litres) in 2015, consisting roughly of a 3:1 breakdown of ethanol to biodiesel. Conventional biofuels produced from sugar, starch, vegetable oil or animal fat reflected the majority of the supply. In recent years, vegetable-based biodiesel nearly matched the ethanol supply produced from sugarcane.

Figure 1: Global biofuel production by fuel type (thousand barrels per day).

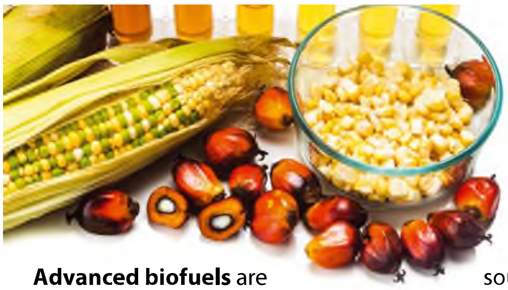


Primary fuel types

Conventional biofuels are produced from food- or feed-based crops, typically with hydrolysis and fermentation processes or esterification or trans-esterification. Ethanol and biodiesel dominate global biofuel production.

Ethanol is produced by fermentation of sugar from cane or beets, starch from corn or wheat, or root crops such as cassava. Ethanol is mostly used as a fuel additive (roughly 10%) in gasoline. Brazil is a notable exception with a fleet of flex fuel cars able to operate on any blend of gasoline and ethanol, or solely on ethanol. Vehicle design improvements could allow for mid-level blends of 20 to 40% to be used with enhanced efficiency.

Biodiesel is produced through an esterification/trans-esterification reaction of vegetable oils or animal fats with an alcohol, to generate fatty acid methyl esters (FAME) and a substitute or blend additive for diesel. Biodiesel is cleaner than fossil fuel-based diesel and attains a similar fuel economy. Biodiesel is prevalent in regions such as the EU and in Argentina and Colombia.



Advanced biofuels are typically produced from non-food crops and residues or waste materials. Key conversion processes include hydrolysis and fermentation, hydrotreating, pyrolysis and alcohol fermentation from syngas. Common forms include drop-in fuels and biobutanol.

Drop-in fuels are renewable diesel and gasoline derived from lipids (vegetable oils, animal fats and algae) or cellulosic materials (crop residues and woody biomass) similar to petroleum-based gasoline and diesel fuels. These fuels do not have compatibility issues with engines or infrastructure and are easy to adopt in the supply chain. The technical ease and lower costs of integrating these fuels into markets is an advantage, since no major investment is needed for existing petroleum-based infrastructure.

Hydrotreated biodiesel produced from vegetable oils (HVO) or animal fats does not have some of the detrimental effects of ester-type biodiesel fuels, such as issues with increased NOx emissions, deposit formation, storage stability problems, more rapid aging of the engine oil and poor cold properties. As straight-chain paraffinic hydrocarbons, HVOs do not produce sulphur and have high cetane numbers, which allows higher speed diesel engines to operate more efficiently.

Renewable gasoline can be produced from the fermentation of sugars. Drop-in fuels can also be produced with processes such as catalytic conversion of sugars.

Biobutanol is a biomass-based fuel produced by fermenting the same feedstock as ethanol but mediated by different microorganisms. Its energy density is 10 to 20% less than that of gasoline. Relative to ethanol, biobutanol has a lower vapour pressure that translates into lower volatility and fewer evaporative emissions.

Key feedstocks for production

The diversity of feedstock options for biofuels is fairly significant, with local conditions typically framing the choice.

Lignocellulose

Lignocellulosic material is derived from non-edible crops. This abundant feedstock can be obtained from many different sources, including switchgrass, trees, and agricultural crop residues such as rice straw, wheat straw, corn stover and sugarcane bagasse. Take straw as an example: 2,3 billion tons of straw were available in 2011, with the theoretical potential of making 560 million tons of ethanol.

There is an incentive to utilise this non-food crop in lieu of traditional corn. The challenge is to produce the fuel economically as the process involves breaking down fibrous plant walls into sugars, which is an expensive step. Once sugars are formed, they can be fermented to produce cellulosic ethanol.

Algae

Algae has promising potential for biofuels in terms of high oil content, limited waste streams and minimal land requirements (compared to biomass). Water is essential for algae cultivation and can include fresh water, brackish, saline and wastewater types. Methods of cultivation and recovery vary, with implications for energy and environmental effects. As of 2011, current environmental impacts were deemed negligible, as scaled production had not been demonstrated.

Corn

Corn (or maize) is a fundamental food staple that can be grown in a range of climates from tropical to temperate. Fertiliser and pesticide needs are high for this crop. For feedstock and ethanol production, water needs are relatively low on the unit basis of ethanol produced. The US is a world leader in the production of ethanol for fuel from corn.

Jatropha

Jatropha is a non-food, perennial crop that can be grown on marginal land in a range of climate, soil and water conditions. It is highly resistant to drought. The largest production is currently in Guatemala, which has designated 25 000 acres (10 117ha) of land for Jatropha cultivation. Other countries investing in this crop include Mexico, Sudan, Ethiopia and India.

Palm

Palm, a prime feedstock for biodiesel, is produced for biofuels in Indonesia, Malaysia and other countries of Southeast Asia. Its oil is a fundamental food staple and the largest source of vegetable oil consumed worldwide. Palm trees require deep soil, a relatively stable high temperature and continuous moisture throughout the year. This feedstock grows in rainy and tropical land.

Soya beans

Soya beans are a prime fuel and food crop, accounting for 25 and 65% of the global consumption of oil/fat as well as meal/cake, respectively. The largest producers are the US and Brazil. This crop can be grown in tropical, subtropical and temperate climates.

Sugarcane

Globally, sugarcane is the second largest feedstock for ethanol production, and is a basic food crop grown in tropical climates. Sugarcane is grown in deep soil using fertilisers high in nitrogen and potassium, and low in phosphorous. Sugarcane requires a constant supply of water throughout the growing season. Brazil is the most notable producer of sugarcane-derived ethanol.

Sweet sorghum

Sweet sorghum is a high sugar sorghum variety mostly produced by the US, Nigeria and India. It can grow in tropical, subtropical and temperate regions. It is more versatile than sugarcane and can grow with limited water in poor/shallow soil. Compared to sugarcane and sugar beet alternatives, sweet sorghum is drought-resistant and has a much shorter growing cycle. Given its 70% water content, sorghum must be processed quickly post-harvest.

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