Biofuel Basics: What You Need To Know

The term 'biofuel' is a type of fuel that is derived immediately from living matter (like corn ethanol). Biofuels are useful, sustainable resources that make a good alternative to fossil fuels (like petroleum). Historically, they have been manufactured from food crops, e.g., corn, sugarcane, palm oil, cottonseed, sunflowers, wheat and soybeans. Biofuels are carbon neutral and do not release greenhouse gas. However, new technologies are enabling biofuel production from non-edible gases, wood, and other plant waste material. So what are the biofuel basics?

The beauty of biofuels is that they suck carbon dioxide out of the air as they grow. When we burn them in our automobiles, we release carbon dioxide, but it is the same carbon that the plants absorbed while growing. Just on that basis, biofuels appear to be zero net emitters.

What are the Biofuel basics?

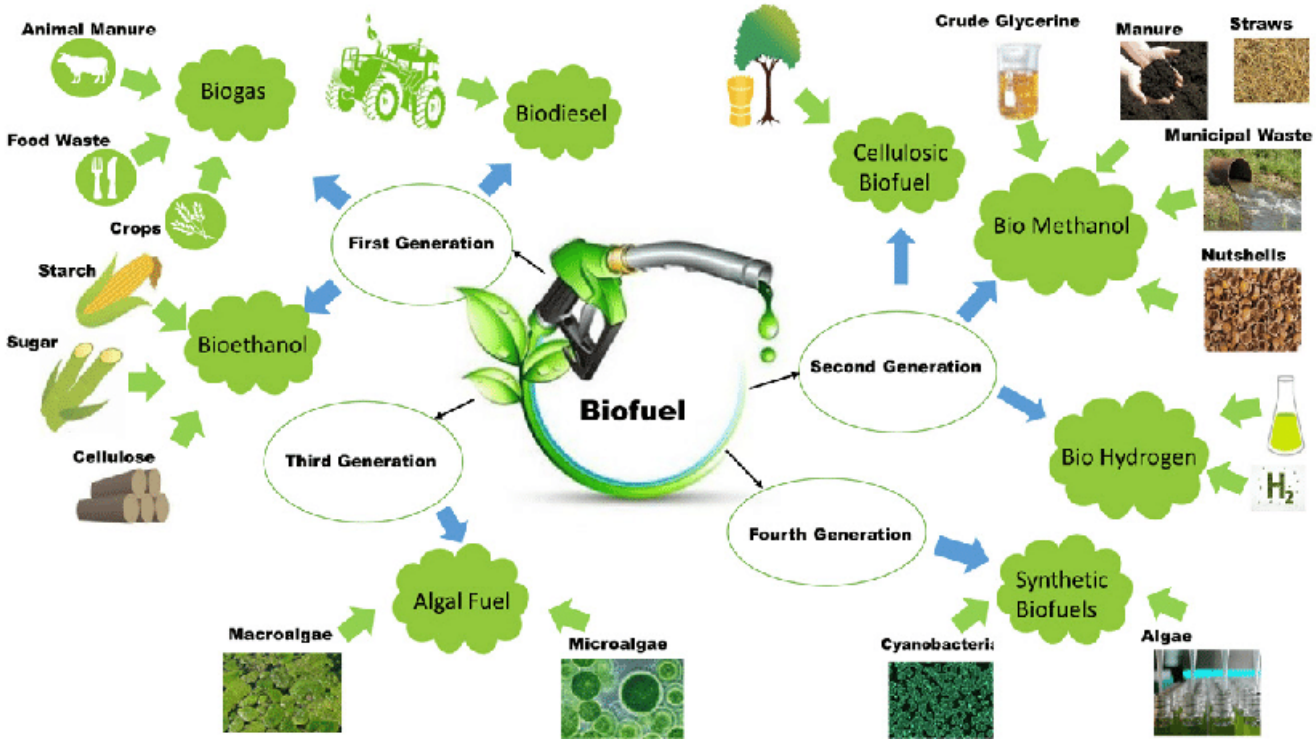
The problem with biofuels is in the processing of the raw materials to make fuel. At present, it is still relatively expensive to produce. However, there are a number of developments in biofuel technologies that look set to realise the enormous potential they offer as an alternative energy source. There is an exciting production process behind biofuels and the modifications that are driving new efficiencies in the industry.

Replacing fossil fuels with biofuels is useful to work toward capturing renewable organic material. They have the potential to reduce some undesirable aspects of fossil fuel production and use, including conventional and greenhouse gas (GHG) pollutant emissions, exhaustible resource depletion, and dependence on unstable foreign suppliers. Demand for biofuels could also increase farm income. Additionally, many biofuel feedstocks require land, water, and other resources. Research suggests that biofuel production may give rise to several undesirable effects. (Dahman,et al.,2019)

It takes energy to grow biofuels; fertiliser, tractors, transportation, and energy to

convert plants into liquid fuels. Planting and growing these crops also changes how much carbon is stored in the soil. Using existing food crops or arable land for biofuel production could lead to the deforestation of farms. This is expanded elsewhere, making up for lost food production.

We must accurately assess the impact of biofuels and look at what's called a 'life cycle analysis,'. This is simply explained as the effort it takes to grow the crops, harvest them, convert them to fuel, transport them to distribution sites, and combust them.



Biofuel basics: a schematic representation of the types and generation of biofuels. Source: Microalgae as a Feedstock for Biofuel Production: Current Status and Future Prospects

Biofuel Basics: Generations of Biofuels

First-Generation

First-generation biofuels are made from sugar crops (sugarcane, sugarbeet), starch crops (corn, sorghum), oilseed crops (soybean, canola), and animal fats. Bioalcohols such as ethanol, butanol, and propanol are produced through the fermentation of sugar and starch crops. Biodiesel can be produced by processing oils and animal fats. The most popular bioalcohol fuel is ethanol. The majority of

automobiles can run on gasoline-ethanol mixtures with up to 10% ethanol (by volume). E85 is a gasoline-ethanol mixture that contains up to 85% ethanol and is suitable for use in flexible fuel cars. According to the U.S. Department of Energy, there were more than 2300 E85 fueling stations spread around the U.S. in 2013.

Second-Generation

Producers and scientists make these from non-food crops such as wood, organic waste, food crop waste, and certain biomass crops, eliminating a major problem with first-generation biofuels. Second-generation biofuels also aim to be more cost-competitive with existing fossil fuels. Life cycle evaluations of second-generation biofuels also show increased net positive energy gains to overcome another important limitation of first-generation biofuels. (Kowalski, et al., 2022)

Third-Generation:

Third-generation biofuels use specially modified energy crops such as algae. We grow algae to serve as a low-cost, high-energy, fully renewable resource. This resource is also predicted to have the potential to produce more energy per hectare than conventional plants. Algae can also grow on land and water bodies unsuitable for food production. Another advantage of algae-based biofuels is that they can be processed into other different fuels such as diesel, gasoline, and jet fuel. It is potentially carbon neutral (absorbs and emits the same amount of carbon). (Moreira Neto, et al.,2019)

Fourth-Generation:

Fourth-generation biofuels aim not only to generate sustainable energy but also to provide a way to capture and store CO_2. Biomass raw materials that absorb CO_2 during the growth process are turned into fuel through the same process as second-generation biofuels. This process differs from 2nd and 3rd generation production because we capture carbon dioxide during all stages of production, using processes such as oxy-combustion.

Scientists sequester carbon dioxide by storing it in old oil and gas fields or saline aquifers. This CO_2 capture makes 4th generation biofuel production carbon-negative rather than just carbon-neutral, as it captures more CO_2 than it

produces. The system not only captures and stores carbon dioxide from the atmosphere but also reduces CO_2 emissions by replacing fossil fuels (Abdullah, et al., 2019).

Types of Biofuels

Renewable energy sources, biomass can be converted directly into liquid fuels, called 'biofuels' to help meet transportation fuel needs. The two most common types of biofuels in use today are ethanol and biodiesel, both of which represent the first generation of biofuel technology.

The Bioenergy Technologies Office of Energy Efficiency and Renewable Energy collaborated to develop next-generation biofuels made from waste, cellulosic biomass, and algae-based resources, mainly focused on the production of hydrocarbon biofuels—also known as 'drop-in' fuel. This serves as a petroleum substitute in existing refineries, tanks, pipelines, pumps, vehicles, and smaller engines.

Biofuel Basics: Bioethanol

Ethanol (CH3CH2OH), which is renewable, is produced from a variety of plant components commonly referred to as "biomass". Alcohol known as ethanol is added to gasoline to boost octane and reduce pollutants that contribute to pollution, such as carbon monoxide. Most conventional gasoline-powered vehicles can run on ethanol blends up to E15 (15% ethanol, 85% gasoline). The most popular form is E10 (10% ethanol, 90% gasoline). Some automobiles, known as flexible fuel vehicles, are made to run on E85. This alternative fuel has a substantially greater ethanol percentage than ordinary gasoline (51%-83% ethanol, depending on area and season). In the US, ethanol is present in about 97% of gasoline.(AFDC, 2023).

Conversely, scientists are still working on technology that would enable the utilisation of cellulose and hemicellulose. The non-edible fibre material makes up the majority of plant matter. Currently, we produce the majority of ethanol using plant starches and sugars, primarily corn starch, in the United States. We use fermentation to describe the common process of turning biomass into ethanol. Plant sugars metabolise and create microorganisms (such as bacteria and yeast)

during fermentation. This produces ethanol.

Biofuel Basics: Biodiesel

It is pretty simple- we can replace diesel fuel (made from petroleum) with biodiesel. This is liquid fuel scientists create from renewable resources like fresh and used vegetable oils and animal fats, produced by mixing alcohol with vegetable oil, animal fat, or used cooking grease. Biodiesel is harmless and biodegradable. We use biodiesel to power compression-ignition (diesel) engines, just like petroleum-derived diesel. Biofuel basics include pure biodiesel (B100) and the most popular blend, B20 (which contains 20% biodiesel and 80% petroleum diesel). Both can be blended with petroleum fuel in any ratio.

Biofuel Basics: Biobutanol

Biobutanol is 4-carbon alcohol produced by the fermentation of biomass. Scientists can produce this in ethanol production plants. Biobutanol is mainly used as a fuel for internal combustion engines. Its properties are similar to gasoline. Some gasoline vehicles can even use biobutanol without modification and it can be added to gasoline at concentrations of up to 11.5% by volume. Conversely, the main drawback of biobutanol is its lower energy content (lower than gasoline), averaging 10-20%. Biobutanol has the potential to reduce CO_2 emissions by 85% compared to gasoline. (Rathour, 2018)

Biofuel Basics: Biogas

Biogas is an environmentally-friendly, renewable energy source produced by the breakdown of organic matter such as food scraps and animal waste. As a renewable fuel, we produce biogas when we break down organic matter, such as food or animal waste, creating a scientific process between microorganisms in the absence of oxygen. This process is called anaerobic digestion. For this to take place, we need to enclose the waste material in an environment where there is no oxygen.

Biogas can occur naturally or as part of an industrial process to intentionally create it as a fuel. Biogas consists mainly of methane and carbon dioxide. It can also include small amounts of hydrogen sulphide, siloxanes and some moisture. The relative quantities of these vary depending on the type of waste involved in

the production of the resulting biogas. If we clean biogas enough, we can upgrade it to natural gas standards, replacing natural gas. The matter then transforms into biomethane, used in a similar way to methane, as a cooking and heating resource.

Renewable Hydrocarbon 'Drop-In' Fuels

Petroleum fuels, such as gasoline, diesel, and jet fuel, contain a complex mixture of hydrocarbons (molecules of hydrogen and carbon). When we burn them, they produce energy. We also produce Hydrocarbons from biomass sources through a variety of biological and thermochemical processes. Biomass-based renewable hydrocarbon fuels are nearly identical to the petroleum-based fuels they are designed to replace. They're compatible with today's engines, pumps, and other infrastructure.

Biofuel Plant Crops

Sugarcane

Brazil has been growing energy crops since the 1970s. This was a response to the Middle East Oil Crisis from that decade, as producing ethanol from sugarcane is six times cheaper than using corn. Scientists turn sugarcane into bioethanol, like corn. Brazil invested billions of dollars into this industry, and it is now cheaper to purchase than gasoline. In the 1980s, most cars in Brazil were ethanol-powered. Today, we power most cars with either fossil fuels or biofuel (Nogueira, 2013).

Palm Oil

Palm oil is one of the most energy-efficient examples of biofuel available. Diesel engines are also compatible with biofuels made from palm oil. Palm oil has been especially popular in Malaysia and Indonesia. Unfortunately, the growing of palm trees presents its own problems. Competition with other plant-based crops has caused the burning of thousands of acres of rainforest each day. This damages the ecosystem and threatens biodiversity.

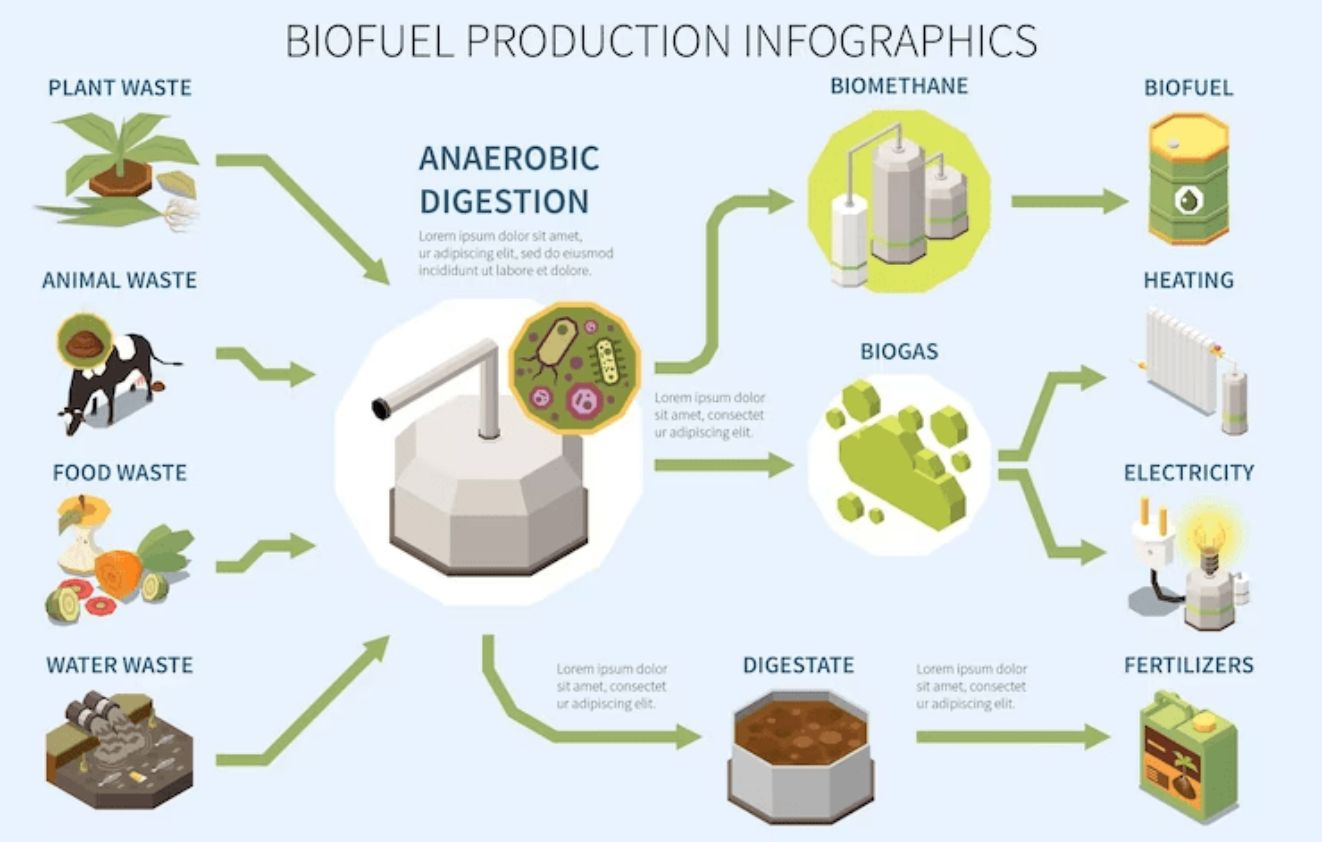
Soybeans

Emphatically, humans can use soybeans as an alternative fuel source, dominating

the biofuel industry in the U.S. Motor vehicles, heavy equipment, and even buses can run on pure soybean biodiesel or by blending soy biodiesel with more traditional diesel fuels.

Jatropha

India is currently the world's largest Jatropha producer, and their biodiesel industry is centred around this crop. It is of particular benefit to rural farmers who can grow this crop on agricultural land that is unsuitable for many other crops. Also, Jatropha plants can live for 50 years and cope well with drought and pests. We can crush the seeds of the plantd to release the oil for biodiesel production. Even the seed cases and vegetable matter can be processed using scientific methods of biomass conversion. Hemp, Switchgrass, and Algae show enormous potential.



Biofuel basics: production infographics like this with types of organic waste create anaerobic digestion biogas usage with 3D isometric vector.
Source: Freepik

Biofuel Basics: How Sustainable Are Biofuels?

Biofuel shows a lot of promise for our energy-dependent future because it is both renewable and environmentally friendly. In other words, biofuel is sustainable. However, there aren't many systems in place that are yet economically viable for industrial-scale production. Corn and, to a lesser extent, soybeans and milo are the only crops to date that are used for biofuel production in the U.S.

There are drawbacks too, including the amount of land and resources (such as water and fertiliser) required to grow the crops- and the use of food crops as fuel. This, in particular, creates problems with higher food prices and deforestation.

The best examples of Biofuels are those produced from plant materials that are not consumed by humans, such as corn stalks, grasses, and wood chips. When we harvest and process 'biomass', scientists can convert the plant cells into a state that is suitable for biofuel production. Unfortunately, the processes that scientists use to turn biomass into biofuel can be very expensive. In addition, some biofuel reactions require harsh chemicals that can create their own environmental problems.

Recent Developments in Biofuel Technology

Gamma-Valerolactone (GVL)

Humans produce a chemical called Gamma Valerolactone (or GVL), from plants. Dumesic can deconstruct biomass to produce sugars that can be chemically or biologically upgraded into biofuels or chemicals. Since GVL creation is derived from plant material, it's both renewable and more affordable than most enzyme-based deconstruction methods.

Recently, the application of GVL makes biofuel much cheaper and more efficient. We generate GVL from biomass. Originally used in the perfume industry because of its sweet herbal odour, it's a useful resource. Many pharmaceutical products contain it. GVL can extract over 70% of the original sugars trapped in the dense

structure of biomass, to produce simple sugars that are much easier to transform into fuel.

GVL has the potential to create cost-disruptive bio-renewable fuels and chemicals for a wide range of industries. This one-step process is much cleaner and more affordable than current deconstruction methods and could help a number of industries become 'green'. This includes biofuels and the paper and pulp industries.

Genetically Modified

Genetically Modified (GM) crops and biofuels are made for each other. The enhanced yields available from the current generation of GM crops (such as corn and soybeans) can help farmers meet the growing feedstock demand for biofuels, producing sufficient quantities of food and animal feed. In the future, GM crops with even higher yields and entirely novel GM varieties of grasses and trees should make biofuel production even more efficient and inexpensive (Brookes, 2022).

Domestic biofuels are an attractive alternative to petroleum-based transportation fuels. We produce biofuels from plant matter, such as sugars, oils, and biomass. Scientists create this plant matter by using photosynthesis, a process that converts solar energy into stored chemical energy in plants. However, photosynthesis is an inefficient way to transfer energy from the sun to a plant and then to biofuel. Electrofuels bypass photosynthesis by using self-reliant microorganisms. They use direct energy from electrical and chemical compounds to produce liquid fuels and are an innovative step forward.

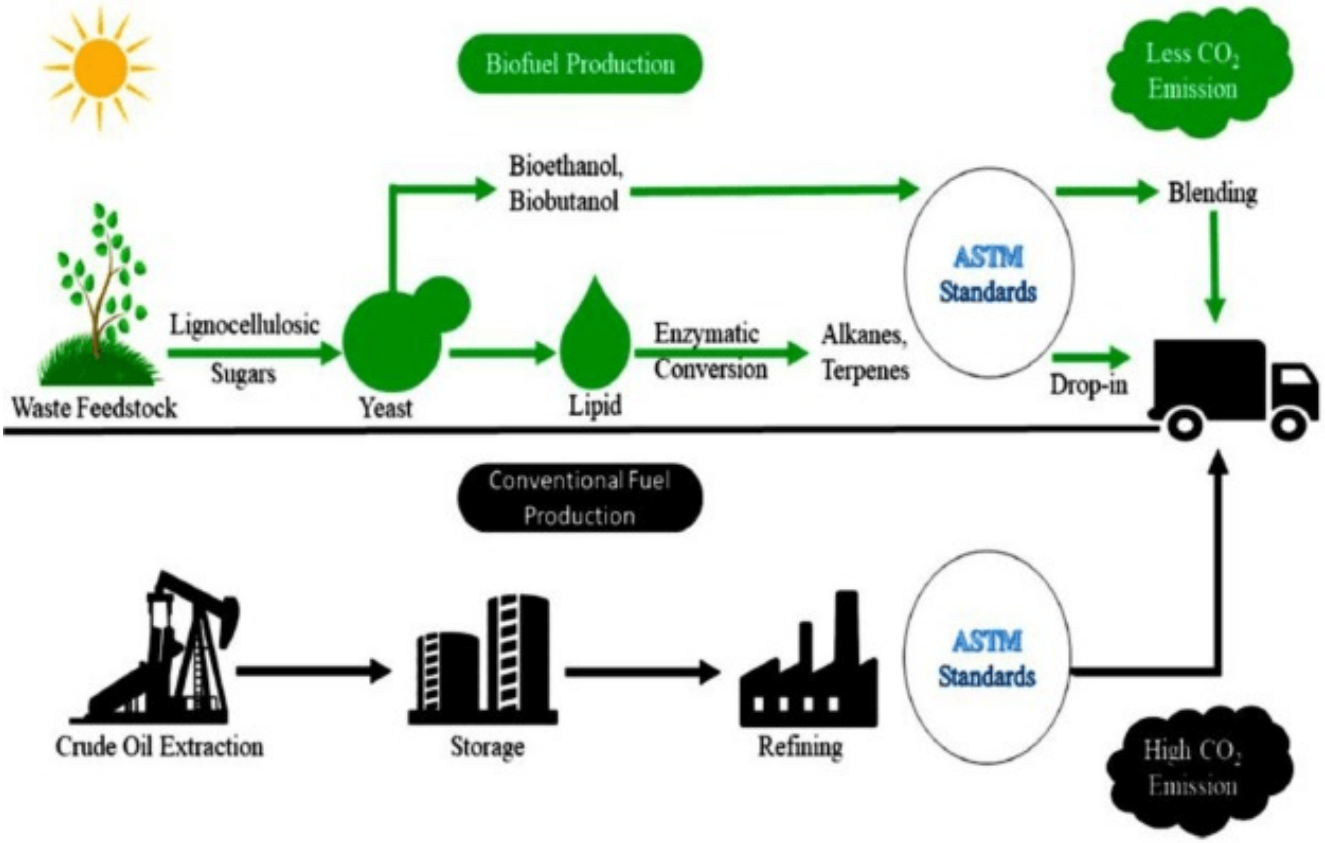
aren't Electric Cars part of a sustainable Future?

The demand for biofuels is expected to double in the next few years, and could potentially allow us to decrease our dependence on fossil fuels considerably. The next wave of electric cars is in commercial and passenger vehicles. We have fierce competitors for renewable energy-powered vehicles. Furthermore, biomass may be particularly useful in industry and raw power generation.

Modern society has touted electric cars as a sustainable innovation and the future of transportation. However, this is too good to be true, as the push for electric cars only prolongs the issue of car dependency, and does not move the needle in terms of mitigating climate change (Davis, 2023).

It's easy to get the sense that electric vehicles are clearly the way of the future. As a result of Tesla's rapid share price rise, Elon Musk momentarily became the richest man on Earth, and the firm declared its first profitable year since its inception in 2003. Charging stations and solar farms are also being installed by municipalities, which are also expanding their fleets of electric vehicles. Ford and GM, as well as direct competitors to Tesla, like Lucid, are committing to phase out gasoline-powered vehicles and solely create electric vehicles from as early as 2035.

Additionally, there are alternative methods to achieve these objectives, and electric cars aren't as environmentally friendly as they appear at first glance. Let's find out why EVs might not be the future of transportation.



Recent advances and viability in biofuel production have been promising.
Source: Energy Conversion and Management

Why should we focus on Biofuel Basics?

Fighting Global Warming

The global community must look for new, low-carbon fuel and energy sources to combat climate change. Since one of the main contributors to greenhouse gas emissions is transportation, replacing fossil fuels with renewable alternatives like biofuels is an effective strategy to lower these emissions. When other options, such as switching to electric vehicles, are not viable (due to high vehicle costs or a lack of a vehicle charging network), biofuels provide a way to reduce the carbon emissions of transportation. (Khanna, 2011)

A Reaction to Increased Energy Use

We project that, by 2050, the world population will reach 10.5 billion people. Significant economic growth in emerging economies would lead to a significant rise in energy consumption. We must boost the use of renewable energy sources, such as biofuels, and use natural resources more effectively if we are to meet this expanding demand.

Energy Supply Security

Due to the dispersed nature of resources, the security of supply will face issues as energy demand rises. By lowering the world's reliance on fossil fuels, biofuels contribute to improving and securing energy security. The global distribution of biomass is more realistic than the use of other resources.

Maximising Limited Resources

A good example of how to respond to the demands of a circular economy is by using garbage and residue as raw materials for biofuels. Our continued survival depends on reducing waste and maximising the use of our precious natural resources. (Jeswani, 2020)

achieving the United Nations Sustainable Development Goals (SDGs): how Do they link to Biofuel Basics?

The United Nations General Assembly established 17 Sustainable Development Goals (SDGs) in 2015. We must accomplish this by 2030 for humanity to thrive.

We must thoroughly analyse their key concerns to mitigate climate change and develop sustainable and environmentally friendly industries, jobs, and communities. The SDGs are inclusive of social, political, and economic issues.

Despite the promise of biofuels, just 1% of the world's energy consumption currently comes from them. 3% of our gasoline (for road transportation) is made from biofuels (Sharma et al., 2020). There are many chances to improve the use of renewable fuels. By 2050, some international organisations and governments hope to utilise biofuels to provide 25% of their energy needs for transportation. Recent trends toward using hydrogen to power vehicles may affect this estimate.

Scientists have liberated lignin monomers as a raw material and altered lignin multimeric rings to develop novel products. Every day, human research investigates a number of enzymes, including laccases and ligninases (Mate & Alcalde, 2017). The next 10 years should expose the lignin's potential. If this occurs, the 2G bioethanol industry's value will come from using the residues to create more value. 2G technology will then contribute SGD 3 to product recycling at that point.

Microalgae are important because they have a propensity to consume CO^2, the main greenhouse gas and the primary cause of climate change. SDG-6, "Clean water and sanitation," SDG-7, "Affordable and clean energy," and SDG-13, "Climate action," all clearly reflect the significant contribution of microalgae. Microalgae were also discovered to significantly contribute to the circular economy (Olabi, 2023).

Moving Forward

Using land for bioenergy instead of food production for energy production is a contentious issue. Bioenergy crops are problematic from many different angles. There is strong criticism that it may result in loss of food production, higher food prices, deforestation, and other changes in land use, having a detrimental impact on greenhouse gas emissions, biofuels produced from using edible biomass stocks have been at the centre of the food versus fuel controversy.

We can avoid the battle for food by boosting the production of third-generation biofuels and second-generation (non-edible) biofuel feedstocks, together with cutting-edge technologies like genetically modified algae biomass. In preventing

conflict with food production, humans can utilise second-generation biomass feedstocks, and plant on marginal land.

Humans can integrate biofuel crops into existing agricultural and landscape lands in a multifunctional strategy to provide many benefits, including use as fuel, so that food and bioenergy don't have to compete for space.

A Thrivable Framework

Sustainable transportation is an incredibly nuanced concept and there are multiple ways to approach it. In some cases, choosing an electric car over a gasoline-powered one might actually be the right choice. Electric cars aren't an umbrella solution for the pollution caused by gasoline cars.

Sustainable development is necessary if we want to thrive. We must meet the fuel needs of the present without compromising the ability of future generations to do the same. To do so, farms need to transition to efficient irrigation systems and the energy sector must invest in **renewable sources**. Individuals need to do more to decrease their personal usage and governments need to take responsibility for managing the needs of a growing population.

To learn more about biofuels and the development of sustainable resources visit the **THRIVE blog**. We invite you to **join THRIVE** and be part of the change. Let's build a 'thrivable' world where human societies and the environment not only survive, but thrive, well into the future.