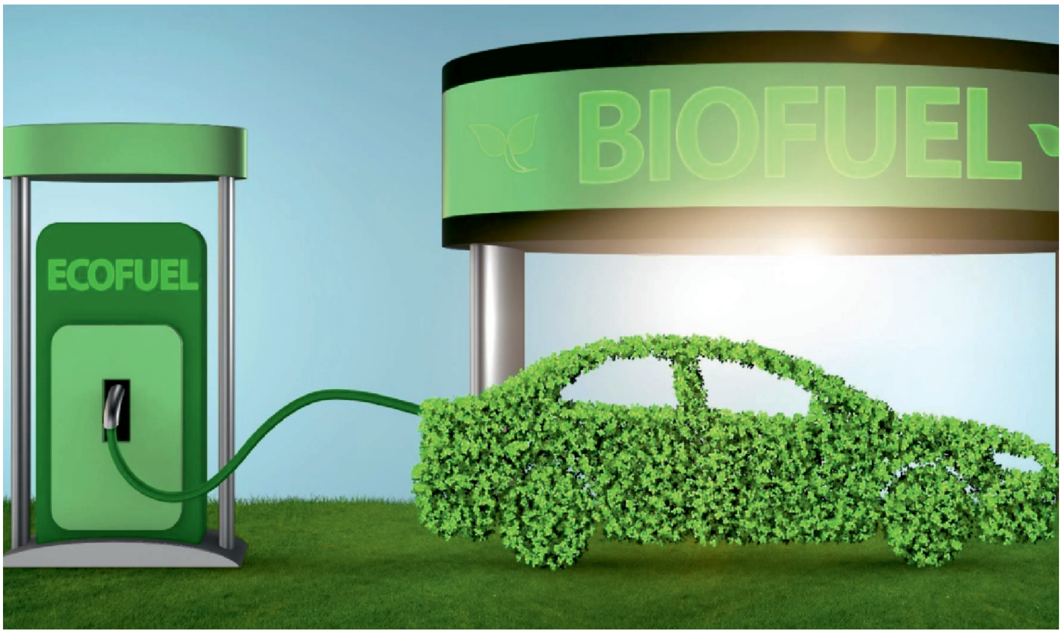
BIOFUEL AS AN ALTERNATIVE SOURCE OF ENERGY



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CHAPTER 1

BIOFUEL AS RENEWABLE ENERGY SOURCE

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Biofuel is a kind of renewable energy that is made from microbial, plant, or animal sources. Biofuels include things like ethanol, biogas, green diesel made from plants like algae, and biogas. In Brazil and the United States, ethanol is usually made from sugarcane and maize, respectively methane derived from animal manure and other digested organic material. Biofuels may be solid, liquid, or gaseous. The latter two varieties are the most useful since they are easier to supply, distribute, and safely burn[1].

Our impression of impact and change with respect to viability, in particular, determines whether biofuels are a useful development, an original alternative, or a race for unheard-of money. This drives us to put these understandings into conceptual practice. They compiled a variety of force viewpoints for the biofuel research. To begin a more thorough and extensive exploration of the distinctions between ontological and epistemological points of view in this field of study I begin by outlining the key features by listing the many viewpoints on force that are often examined in reference to biofuels along with three ideal type origins[2], [3].

A. The idea of "power with" refers to total reinforcement achieved via mutual acquisition and persuasion. It suggests ways to establish shared ideals, choose a course of action that would be good to do, and display all of the attributes. With this knowledge of power, the use of biofuels may be a natural progression for everyone (climate protection, energy security, regional development, etc.).
B. The ability to communicate with the most subject-matter experts possible in order to "complete things." Pitkin portrays performance as being non-social, but Barnett and Duvall view it as being influenced by the social connections of constitution that shape the performers' identities along with their skills and practises. Footnote Professionals with a capacity-based perspective may emphasise the association of spreading biofuels as a cutting-edge alternative in social regimes that are now reliant on oil.
C. Power over demonstrates how powerful performers, designs, and debates may unexpectedly and rapidly impact other people's behaviours and concerns. Many people, including Dahl, Bachrach and Baratz, and Lukes, have presented compelling cases for this. Although being aware that these notions partly fall under the capacity to category, research is also being done in many other areas by looking at the concepts of rambling power within this classification. According to a control viewpoint, biofuels should be seen as a competition for previously unimaginable wealth: There are few winners and many losers in this new field, despite everyone's hopes for surprise riches[4], [5].

Thanks to its customarily extensive character, the power discourse around biofuels may be enlarged. Control is simultaneously categorised under the spectacular amalgamation of the four "essences of power" in the method. I'll argue that when force isn't explicitly stated in talks of biofuels, concepts of capability and power often take primacy. This demonstrates that experts have overstated the potential of biofuels as a cutting-edge substitute for petroleum goods and a positive development for advancing humankind. The idea of having control over something has been increasingly popular recently, especially as research has started to define power more clearly. This has been used expressly to show why, rather than how any method of managing biofuels (biofuel administration), the biofuel boom should be understood as a race for historically unheard-of wealth. Studies show that the development of the biofuels sector benefited large corporations. We may better understand this progression by examining patterns and dialogues that support fundamentalist and post-structuralist viewpoints[6]. Using the concepts of Foucault, researchers have defined the real essence of the objections (and agreements) made over the biofuel proposal. It is absurd to arbitrarily divide power with, ability to, and control over in a proper analysis, similar to scientific heuristics. These distinctions provide different light on different aspects of comparable visible defects. Actually, most of these behaviours have a connection to force[7]. The biofuels life cycle is shown in Figure 1.

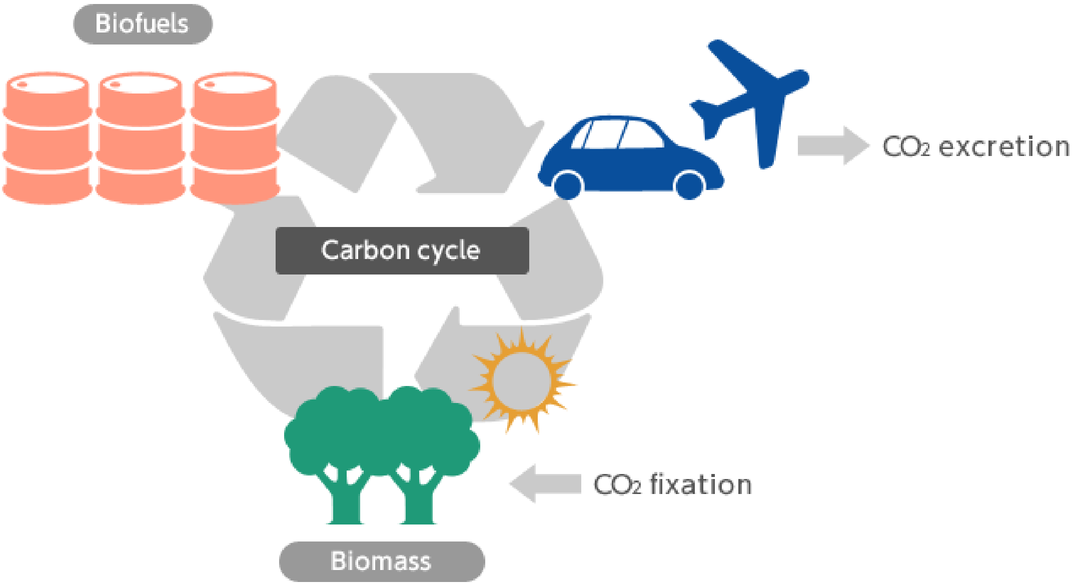

Figure 1: Illustrate the process of the Biofuels cycle.

Understanding the interactions between different points of view may help us better understand how change happens at all of its phases other than covers and inconsistencies. I'll start by outlining each viewpoint independently to do this. In the framework of a review of biofuel research, I shall provide sources in support of each position. These are only sample instances. The linkages between each of these perspectives on biofuel research will next be shown. Aware of the negative effects that cycles of force paired with the ability to exert them may have.

Researchers have once again shown how powerful organisations have impacted biofuel administration to their own benefit. So, the biofuels boom should be seen as a competition for hitherto unheard-of riches. Yet, argue that exchanges might potentially be reciprocal. This is particularly relevant to the main argument of the essay. As a creative alternative, biofuels may encourage changes in the existing power structures, lessen injustices and disparities in the agro-food and transportation sectors, and foster economic development. In order to control and study these interactions, we need a sophisticated power methodology.

A biofuel is any fuel that is produced from plant, animal, or algal waste, as well as biomass. Due to the ease with which such feedstock material may be produced, biofuel is considered as a source of sustainable energy as opposed to fossil fuels like petroleum, coal, and natural gas. In view of rising petroleum prices and growing concern about the contribution of fossil fuels to global warming, biofuel is often marketed as a practical and environmentally responsible alternative to petroleum and other fossil fuels. Several opponents express concerns about the scope of the development of specific biofuels due to the possible large-scale transfer of arable land from food production and the corresponding economic and environmental effects of the refining process.

Types of biofuels

Wood, for example, may be used directly as the starting material for a fire to produce heat. A power plant may use the heat to drive generators, which produce electricity. Many power plants now in operation burn wood, grass, or other biomass. Liquid biofuels are especially important because of the large infrastructure that is already in place to use them, notably for transportation. Ethanol is the most often manufactured liquid biofuel and is created by fermenting starch or sugar. Brazil and the US are two of the biggest ethanol producers. The majority of the world's corn (maize) grain is converted into the biofuel ethanol in the United States. It is often blended with kerosene to make "gasohol," a 10% ethanol fuel. To manufacture ethanol biofuel, which is often used as a fuel with a concentration of 100% ethanol or as part of gasoline mixtures with 85% ethanol, sugarcane is mostly utilised in Brazil. In contrast to "first-generation" ethanol biofuel created from food crops, "second-generation" cellulosic ethanol is produced from low-value biomass with a high cellulose content, such as wood chips, agricultural waste, and municipal waste. Cellulosic ethanol is often produced using a variety of grasses that may be cultivated on subpar soil or sugarcane bagasse, a leftover from the sugar-processing industry. Cellulosic ethanol is largely used as an addition in gasoline since it transforms less quickly than first-generation biofuels[8], [9].

The second-most common liquid biofuel is biodiesel, which is mostly made from oily plants (like soybean or oil palm) and to a lesser extent from other oily sources (such as waste cooking fat from restaurant deep-frying). Diesel engines utilise biodiesel, which is often blended with petroleum diesel fuel in various ratios. Europe has seen the biggest increase in popularity. The use of algae and cyanobacteria as a source of "third-generation" biodiesel shows promise, notwithstanding the difficulties in commercial development. Certain algae species contain up to 40% lipids by weight, which may be converted into biodiesel or synthetic petroleum. Algae and cyanobacteria may generate 10 to 100 times more fuel per unit area than second-generation biofuels, according to some estimates. The development of methanol, butanol, and dimethyl ether as well as methane gas and biogas, which might be created when biomass decomposes without oxygen, are examples of further biofuels.

Economic and environmental considerations

When evaluating the economic benefits of biofuels, one must take into account the energy required to produce them. For instance, using fossil fuels for the manufacturing of fertiliser, the transportation of grain, and the distillation of ethanol are necessary for the production of ethanol from maize. In contrast to sugarcane, cellulosic ethanol, or algal biodiesel, which may have an even larger energy gain, maize ethanol has a comparatively moderate energy increase. Depending on how they are generated, biofuels may possibly have serious environmental problems in addition to benefits. As growing plants extract carbon dioxide, a substantial greenhouse gas, from the atmosphere via photosynthesis before burning, plant-based biofuels should theoretically have no impact on climate change and global warming. The substance is referred to as "carbon neutral." But, in practise, using a renewable fuel would not always be favourable since industrial production of agricultural biofuels produces more greenhouse gas emissions. These emissions include carbon dioxide from the use of fossil fuels during the manufacturing process and nitrous oxide from soil treated with nitrogen fertiliser. In this regard, cellulosic biomass is regarded to be more favourable.

Land use is a crucial factor to take into account when evaluating the benefits of biofuels. The debate over "food versus fuel" was sparked by the first-generation biofuels' predominate use of widely available feed stocks like maize and soybeans. Due to the removal of arable land and feedstock from the human food chain, the economics of food supply and cost may be affected. Worldwide competition for natural ecosystems may result from the production of energy crops for ethanol. When corn-based ethanol is the emphasis, for example, grasslands and shrublands are transformed into monocultures of the crop, and when biodiesel is the focus, ancient tropical forests are cleared to make way for oil palm plantations. The loss of natural habitat may have an impact on the hydrology, pace of erosion, and general biodiversity of wildlife regions. The clearing of land may also result in the sudden release of a significant amount of carbon dioxide once the plant matter it contains is burned or allowed to decompose.

Most of the negative aspects of biofuels are linked to their poor variety, which includes common agricultural items like maize, soybeans, sugarcane, and oil palm. A wide diverse array of plants may be employed as an alternative, as shown in the North American tallgrass prairie. Such high-diversity biofuel sources could take the place of degraded agricultural land that is no longer productive and instead improve wildlife habitat, reduce erosion, remove pollutants from water, store carbon dioxide from the atmosphere as carbon compounds in the soil, and ultimately restore fertility to degraded lands. Such biofuels may either be converted into liquid fuels as technology develops or they can be burned right away to provide energy.

The production of biofuels is anticipated to increase quickly even though there will likely be a lot of research and debate about the best way to create them in order to meet all needs simultaneously. The Energy Independence and Security Act of 2007 mandated, the United States must use 136 billion litres (36 billion gallons) of biofuel annually, a rise of more than six times above output levels in 2006. The legislation demands, subject to certain conditions, that 79 billion litres (21 billion gallons) of the total amount be biofuels other than ethanol produced from maize. It also extends various government subsidies and tax incentives for the development of biofuels.

When combined with the cutting-edge technology known as carbon capture and storage, biofuels have the potential to permanently remove carbon dioxide from the atmosphere. Under this scenario, carbon dioxide would be absorbed as it is emitted during the burning of biofuels to create power and would be removed from the atmosphere as biofuel crops developed. Collected carbon dioxide might potentially be kept as solids like carbonates, in deep ocean sediments, or in geological formations beneath the planet.

Methane

A colourless, odourless gas known as methane is created both naturally and as a consequence of certain human activities. One of the strongest greenhouse gases and the most fundamental hydrocarbon in the paraffin family is methane. Its chemical name is CH_4.

Methane's chemical characteristics

Methane is lighter than air due to its specific gravity of 0.554. In water, it hardly dissolves at all. In the presence of air, it burns fast, emitting carbon dioxide and water vapour; the flame is ferocious, drab, and hardly visible. The melting point of methane is 182.5 °C (296.5 °F), while its boiling point is 162 °C (259.6 °F). While methane is often rather stable, if there is between 5 and 14 percent by volume of methane in the air, it might be explosive. Such combination explosions are prevalent in coal mines and collieries and have played a role in a number of mining disasters.

Sources of methane

In the natural world, anaerobic bacteria devour plant materials immersed in water to produce methane where it is sometimes called marsh gas or swamp gas. Wetlands are the main natural source of methane produced in this way. Other important natural sources of methane include termites from their digestive processes, volcanoes, vents on the ocean floor, and deposits of methane hydrates that are found along continental boundaries and under Antarctic ice and Arctic permafrost. Methane is the primary component of natural gas, which contains between 50 and 90 percent of it, and also occurs as a component of firedamp (flammable gas) in coal seams depending on the source.

Methane is mostly produced when coal and natural gas are extracted and burned in human-related processes. As a result of operations like the extraction and processing of natural gas and the destructive distillation of bituminous coal to produce coal gas and coke-oven gas, significant amounts of methane are emitted into the environment. Waste management, animal husbandry, and biomass burning are other human activities connected to methane production where bacteria produce methane as they decompose sludge in waste-treatment facilities and decaying matter in landfills.

Uses of methane

Methane may include considerable amounts of hydrogen and other chemical molecules. Methane reacts with steam at very high temperatures to generate carbon monoxide and hydrogen, the latter of which is used to create ammonia, which is used in fertilisers and explosives. Other beneficial molecules that may be produced [10]from methane include methanol, chloroform, carbon tetrachloride, and nitromethane. Incomplete combustion of methane results in carbon black, which is often used as a reinforcing component in tyre rubber.

Contribution as a greenhouse gas

Methane that is produced and released into the atmosphere is absorbed by methane sinks, which include soil and the troposphere's methane oxidation process (the lowest atmospheric region). The bulk of the methane produced naturally is absorbed by natural sinks, countering it. Yet, human methane production may increase methane concentrations more quickly than sinks may decrease them. Since 2007, there has been an increase in methane in the atmosphere of 6.8 to 10 parts per billion (ppb). atmospheric methane concentrations had risen to 1908.61 ppb, or almost three times the 600–700 ppb preindustrial range.

The atmosphere's methane concentrations are increasing, which supports the greenhouse effect. When greenhouse gases, particularly carbon dioxide, methane, and water vapour, absorb infrared radiation net heat energy and reradiate it to the Earth's surface, heat may be trapped and considerable climatic change may result. The greenhouse effect is indirectly impacted by rising atmospheric methane. For example, during the oxidation of methane, hydroxyl radicals (OH) remove methane from the atmosphere by reacting with it to produce carbon dioxide and water vapour. As atmospheric methane concentrations rise, hydroxyl radical concentrations decrease, thereby prolonging the lifetime of methane in the atmosphere.

GASOLINE FUEL

Internal combustion engine fuel, sometimes known as gasoline or gasolene, is a mixture of flammable, volatile liquid hydrocarbons derived from petroleum. Furthermore, it functions as a solvent for fat and oil. Gasoline, which was initially a byproduct of the petroleum industry with kerosene as the principal product, became the preferred fuel for cars due to its high energy of combustion and simplicity in combining with air in a carburetor[11].

Originally, crude oil was merely divided into its more valuable and volatile components before being processed to make gasoline. Later processes, known as cracking, attempted to boost the production of gasoline from crude oil by shattering large molecules into smaller ones. The 1913 innovation of thermal cracking, which employed heat and high pressure, was supplanted by 1937's creation of catalytic cracking, which uses catalysts to speed up chemical reactions and generate more gasoline. Alkylation, which combines an olefin and a paraffin like isobutane, isomerization, which changes straight-chain hydrocarbons into branched-chain hydrocarbons, reforming, which rearranges the molecular structure using heat or a catalyst, are additional methods for improving the quality and supply of gasoline.

Gasoline, a complex mixture made up of hundreds of distinct hydrocarbons. Most are saturated and contain 4 to 12 carbon atoms per molecule. Depending on the season and altitude, the boiling point of gasoline used in automobiles is normally between 30° and 200° C (85° and 390° F). Aviation fuel contains lower ratios of the less and more volatile components than gasoline for vehicles.

A fuel's ability to resist knocking, a warning that the combustion of fuel vapours in the cylinder is happening too rapidly for efficiency, is measured by a fuel's octane number, which is a unit of measure for antiknock qualities. The practise of tetraethyllead addition to combustion retardants was first discontinued in the 1980s owing to the toxicity of the lead compounds generated during combustion. Other additives that are often added to gasoline include detergents to reduce the buildup of engine deposits, anti-icing agents to prevent stalling caused by carburetor ice, and antioxidants oxidation inhibitors to reduce the creation of "gum."

Due to the rising cost of petroleum and hence gasoline in many countries in the late 20th century, gasohol, a mixture of 90% unleaded gasoline and 10% ethanol, was utilised increasingly often (ethyl alcohol). Gasoline burns well in gasoline engines and is a potential substitute fuel for various uses due to the renewability of ethanol, which can be produced from grains, potatoes, and certain other plant materials.

Patricia A. Woertz

From 2006 until 2014, American businesswoman Patricia A. Woertz served as president and CEO of agricultural processor Archer Daniels Midland Co. (ADM). She was born in Pittsburgh, Pennsylvania, on March 17, 1953. After completing his accounting education at Pennsylvania State University, Woertz became a certified public accountant and joined the accounting firm Ernst & Young in Pittsburgh (B.S., 1974). When she moved to the Gulf Oil Company's Pittsburgh office in 1977, her duties grew to encompass strategic planning, marketing, and the refinery sector. After being charged with overseeing asset sales as part of Gulf's 1984 merger with Chevron Corporation, she went on to supervise Chevron's upstream audit team in Houston. Woertz oversaw Chevron's strategic planning through 1991. She advanced swiftly to more significant positions, finally becoming to the presidency of both Chevron International Oil Co. (1996–98) and Chevron Products Co. (1998–2001). While Woertz was ChevronTexaco's executive vice president of downstream operations, he was responsible for 30,000 employees worldwide (the two petroleum companies merged in 2001). He was in charge of all downstream oil production-related operations, such as refineries and service stations.

ADM showed its dedication to the biofuels sector, which is not in the food industry, by appointing Woertz to run the company. ADM was anticipated to maintain its position as the world's leading producer of crop-based fuels despite the company's dominance of the soy, wheat, corn, and other food product sectors because to Woertz's vast expertise in the oil business. ADM already controlled over 30% of the US market for ethanol made from maize by 2006. (a market that was projected to double by 2012). Despite making substantial ethanol investments, ADM expanded its portfolio under Woertz. Notably, it spent $3 billion to purchase Wild Flavors, a company that sells natural ingredients, in 2014. In that year, she resigned from her post as president and CEO. Nonetheless, she remained in her post as board chairman, which she had assumed in 2007, until she retired in late 2015.

Ethanol chemical compound

Ethanol, sometimes referred to as ethyl alcohol, grain alcohol, or alcohol, is a chemical with the molecular formula $C2H5OH$ that is a member of the family of organic compounds called alcohols. Ethanol is a crucial industrial chemical that is used to produce other organic chemicals, as a solvent, and as an additive to car gasoline a combination known as gasohol. Beer, wine, and distilled spirits are just a few alcoholic beverages that include ethanol as an intoxicating ingredient.

The two main processes for making ethanol are the hydration of ethylene and the fermentation of carbohydrates, which is the process utilised to generate alcoholic beverages. During fermentation, carbohydrates are transformed to ethanol by enlarging yeast cells. The primary fermented raw materials used in the production of industrial alcohol maize include grain crops like corn, sugar crops like beets and sugarcane, and sugar crops like sugarcane and beets. Ethylene is hydrated by passing a mixture of ethylene and a substantial quantity of additional steam through an acidic catalyst at high temperatures and pressures.

Fractional distillation is required to concentrate the ethanol produced by fermentation or synthetic synthesis that has been diluted into an aqueous solution. Only straight distillation can provide the mixture with a constant boiling point and 95.6% by weight ethanol. Absolute, or anhydrous, alcohol may be created by dehydrating the mixture with a constant boiling point. Typically, ethanol used for industrial purposes is denatured with methanol, benzene, or kerosene to make it unfit for ingestion.

A nice ethereal perfume and burning flavour may be detected in pure ethanol. It is a colourless, flammable liquid with a 78.5 °C [173.3 °F] boiling point. Alcohol is toxic and damages the central nervous system. Although higher dosages impair coordination and judgement, eventually resulting in coma and death, intermediate amounts relax the muscles and seem to invigorate the body by blocking the brain's inhibitory processes. It may lead to alcoholism for certain individuals who find it to be an addictive chemical. Ethanol is converted in the body to acetaldehyde, carbon dioxide, and water in around half an ounce, or 15 ml, per hour, or approximately 100 calories per day. As alternatives to petroleum-based transportation fuels, biofuels are garnering more and more attention on a worldwide scale in an effort to help solve issues with energy pricing, energy security, and global warming associated to liquid fossil fuels. In this usage, the term "biofuel" refers to any liquid fuel produced from plants.

Plant-based materials that might replace gasoline made from petroleum. Biofuels may vary in familiarity from fairly well-known fuels like ethanol created from sugar cane or diesel-like fuel produced from soybean oil to less recognisable fuels like dimethyl ether (DME) or Fischer-Tropsch liquids (FTL) manufactured from lignocellulosic biomass. This classification of liquid biofuels into "first-generation" and "second-generation" fuels has only recently grown in favour. These terms don't have clear technical definitions. The main difference between them is the feedstock they use. A first-generation fuel is often produced from sugars, grains, or seeds, i.e., one that uses just a specific typically edible portion of a plant's above-ground biomass production and one that needs minimum processing to produce a finished fuel.

First-generation fuels are already produced in large commercial volumes in a number of countries. Non-edible lignocellulosic biomass, such as non-edible wholeplant biomass or non-edible agricultural waste such as rice husks or maize stalks, is often used to produce second-generation fuels e.g. grasses or trees grown specifically for energy. Second-generation fuels are not yet being produced commercially by any country. The capacity of various biofuels to replace conventional fuels made from petroleum. Alcohol fuels may substitute gasoline in spark-ignition engines, whereas compression-ignition engines can run on biodiesel, green diesel, and DME. A diesel-like fuel for compression ignition engines is one of the hydrocarbon fuels made by the Fischer-Tropsch process that is most often used. Notwithstanding the emphasis on biofuels for the transportation sector, the use of biofuels for cooking offers a potentially significant use on a global scale, especially in rural areas of developing countries. In any case, burning biofuels will yield less pollution emissions than burning solid fuels, sometimes by a significant margin.

Almost 3 billion people in developing countries suffer severe health consequences from the indoor air pollution that comes from cooking with solid fuels. Hence, biofuels may play a significant role in improving the health of billions of people. It's noteworthy that producing biofuel is required far less for cooking energy needs than for transportation. According to one estimate, 4 to 5 exajoules of clean cooking fuel might be used yearly to satisfy the basic cooking needs of 3 billion people. This is about equal to 1% of the total energy used by businesses today.

Although many poor nations are increasingly interested in "modernising" their use of biomass and increasing access to clean liquid fuels, some industrialised countries are trying to grow or build new biofuels sectors for the transportation sector. For a number of reasons, certain developing countries may be especially interested in biofuels. Several of the countries have climates that are excellent for growing biomass. As biomass production is by its very nature a labor-intensive, rural industry, it may open up new job prospects in locations where the majority of people typically reside. In certain locations, biomass energy production for the rehabilitation of degraded lands may be of interest. The possibility for revenue generation in remote areas usually, cellulose accounts for around 50% of the dry mass of any given plant, with hemicellulose coming in at 25% and lignin coming in at 25%. Different components may be present in various ratios depending on the kind of biomass.

Technologies for producing biofuels

Making valuable products like liquid fuels is intriguing. Opportunities for fuel export to clients in richer countries might be intriguing. Moreover, there could be a means to make up for avoided carbon emissions of greenhouse gas emissions can be decreased, such as via Clean Development Mechanism credits. The removal of land from use for agriculture, production of fibre, conservation of biodiversity, or other vital purposes may be the most important of them. Increasing biofuel production and usage also brings with it certain issues. Concern is also expressed about the world's rising reliance on water resources for the production of feed-stocks for biofuels.

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CHAPTER 2

HISTORICAL BACKGROUND OF BIOFUEL

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Solid biofuels have been utilized since humans first discovered fire. Wood is the oldest biofuel since humans have used it for cooking and heating since ancient times. With the development of electricity, mankind discovered a new use for biofuel. Biofuel has been used for the production of electricity for a very long time. While this sort of fuel was known long before fossil fuels like gas, coal, and oil were discovered, the finding of fossil fuels significantly restricted its production and usage. The benefits that fossil fuels provided helped them become quite popular, particularly in wealthy countries[1], [2]. Liquid biofuel has been used since before the automobile was invented.

During World War II, there was a huge demand for biofuels due to their expanding usage as an alternative to imported gasoline. Germany was one of the countries that had a severe gasoline shortage at the time. Around this period, additional inventions were also achieved, like the use of gasoline and alcohol manufactured from potatoes. The concept of combining grain alcohol with gasoline was initially conceived in Britain. Although there were several notable scientific developments throughout the conflicts, the low cost of oil from the Middle East and the Gulf States during the peacetime once again eased the burden[3].

As the supply increased, the geopolitical and economic interest in biofuel decreased. From 1973 and 1979, a severe gasoline scarcity affected the different countries as a result of geopolitical conflict. As a consequence, the Organization of Petroleum Exporting Countries substantially decreased exports, especially to nations outside of OPEC (OPEC). Because of the persistent gasoline shortage, several academics and governments have expressed worry about the energy crisis and the usage of biofuels. Once the 20th century got under way, people started to concentrate on utilising biofuels. People's interest in biofuels was primarily inspired by the increase in oil costs, the emission of greenhouse gases, and a desire for rural development [4]–[6].

In this country, ethanol has been dubbed the "fuel of the future" for at least a century. Its promise as a cheap, clean fuel with domestic availability has long been recognised. According to Alexander Graham Bell, who published this in 1917's National Geographic, alcohol creates a beautiful, clean, and powerful fuel. Alcohol can be produced using corn stalks and, in fact, pretty much any other vegetative material that can support fermentation. We won't ever have to be concerned about running out of gasoline as long as we can produce an annual crop of booze to any desired level. Using alcohol as fuel hasn't always been simple, despite its promise. Throughout its history, manufacturers of biofuels have battled with petroleum-based fossil fuels for tax exemptions and subsidies, usually to little avail. Due to its larger political and economic clout, the fossil fuel sector has usually had the upper hand, but things may be starting to shift.

Things weren't always like that. Since the 1820s, whale oil, which is more costly, has been replaced as the main fuel for lamps by a combination of camphene and alcohol, with sales of this fuel reaching 100 million gallons yearly, or almost ten times as much. Farmers who had their own stills were used to producing lamp oil from agricultural wastes, among other things. Everything abruptly came to a stop in 1862 when a $2 per gallon levy on alcohol was enacted to help pay for the Civil War. Kerosene, or coal oil as it was referred as in those days, was only taxed at a rate of ten cents per gallon. By 1870, kerosene sales had reached 200 million gallons per year.

This back and forth cycle would continue over the next century. The development of the vehicle marks the beginning of the history of biofuel. In order to move a little boat up the Connecticut River in 1826, Samuel Morey built the country's first internal combustion engine. He fueled himself on a combination of turpentine and whisky. Several sources credit German inventor Nicolaus August Otto with creating the first automobile engine. In 1876, he developed a four-stroke internal combustion engine that operated on alcohol, a substance that was readily accessible and untaxed in Europe at the time. Rudolph Diesel displayed his first engine, which used peanut oil, in 1900. The Ford Model T was originally made available in 1908 and was designed to run on ethanol as well.

Gasoline blends with biofuels were an attempt at a comeback in the 1930s. Ford opposed the oil tycoons and backed Agrol of Atchison, Kansas now Midwest Grain Products. The firm had 2,000 stations in the Midwest until it filed for bankruptcy in 1939. During the war, there was a strong need for synthetic rubber, which was created in large part using ethanol in 75% of all cases. Ethanol was also included in aviation fuel. After the war, gasoline was so cheap that ethanol virtually disappeared from the market until the oil crisis of the 1970s. Interest in alternative fuels increased due to the scarcity of gas and long lines at the pumps. Exxon, a big supporter to the institution, put pressure on the university to terminate Professor Thomas B. Reed's research despite his outspoken support for the development of innovative fuels. Yet, during that decade "gasohol," a blend of alcohol and gasoline, became readily accessible thanks to a 58 cent per gallon tax credit. Ethanol's attraction once again decreased when petrol prices fell, and in 2005, the tax credit was decreased to 47 cents per gallon. More recently, concerns about climate change and reliance on foreign oil have entered the public and political discourse, which has resulted in a number of choices that have enabled the use of biofuels to once again acquire popularity.

The 1992 Energy Policy Act required manufacturers to create models that can run on alternate fuels. The Renewable Fuels Standards (RFS) Program pushed the use of ethanol and biodiesel in 2006 with the goal of increasing their use by twofold by 2012. The Energy Independence and Security Act (EISA) of 2007 required the usage of 15 billion gallons and 36 billion gallons of ethanol in the gasoline supply by 2015, respectively. The EISA also establishes a restriction on the amount of grain that may be allocated for fuel of 15 billion gallons in order to prevent excessive disruption of the food supply. The remaining fuel will likely come from cellulosic ethanol, which has been slow to become available, as well as biodiesel and other unnamed advanced biofuels, some of which may include algae or other organisms[7].

From the invention of fire by humans, biofuels in the solid state have been used. Even in the distant past, humans utilised wood as their primary source of energy for heating and cooking. Mankind found a new method to use the biofuel with the invention of electricity. From a very long time ago, biofuel has been utilised to create power. This kind of fuel was found even before the discovery of fossil fuels, however production and usage of biofuel were severely impacted by the finding of fossil fuels including gas, coal, and oil. Fossil fuels acquired a lot of popularity because to the benefits they offered, particularly in industrialised nations. From the beginning of the car industry, liquid biofuel has been employed.

German Nikolaus August Otto was one of the first innovators to persuade the public to utilise ethanol. The diesel engine was created by a German named Rudolf Diesel. He created a diesel engine that ran on peanut oil, and Henry Ford subsequently created the Model T automobile, which was built from 1903 until 1926. This automobile was made specifically to run on biofuel made from hemp. Nevertheless, certain areas of Texas and Pennsylvania saw exceptionally low petroleum prices as a result of the discovery of vast reserves of crude oil, which reduced the usage of biofuels. The majority of trucks and automobiles started utilising this kind of gasoline since it was so much more affordable and effective.

Due to growing usage as a substitute for imported gasoline during World War II, there was a significant demand for biofuels. Germany was among the nations that had a severe gasoline scarcity at this time. Further innovations like the utilisation of gasoline and potato-derived alcohol were made during this time, among other things. Grain alcohol combined with gasoline was an idea that was first developed in Britain. The numerous significant technical advancements occurred throughout the conflicts, but during the peacetime, the Middle East's and the gulf nations' cheap oil once again reduced the strain.

The geopolitical and commercial interest in biofuel diminished as the supply rose. Due to the geopolitical strife, a significant fuel shortage struck the different nations between 1973 and 1979. As a result, exports, particularly to countries outside of OPEC, were drastically reduced by the Organization of Petroleum Exporting Countries (OPEC). The problem of the energy crisis and the usage of biofuels caught the attention of numerous scholars and governments due to the ongoing gasoline scarcity. People started paying more attention to the usage of biofuels in the 20th century. People's interest in biofuels changed mostly due to factors such as increasing oil costs, greenhouse gas emissions, and rural development concerns.

History of Biodiesel Fuel

The diesel engine, created in the 1890s by inventor Rudolph Diesel, is now the go-to engine for power, dependability, and excellent fuel efficiency all across the globe. The French government and Dr. Diesel himself were among the first to experiment with vegetable oil fuels. Dr. Diesel believed that early diesel engines might be powered by pure vegetable oils for agriculture in distant places of the globe where petroleum was not yet readily accessible. Research undertaken in Belgium in the 1930s laid the foundation for modern biodiesel fuel, which is produced by turning vegetable oils into substances known as fatty acid methyl esters. But, the biodiesel business as we know it today did not become established in Europe until the late 1980s.

In order to outperform the late 1800s' inefficient, heavy, and sometimes deadly steam engines, the diesel engine was created. According to the compression ignition theory, which governs diesel engines, fuel is delivered into an engine's cylinder after air has been compressed to a high pressure and temperature. Fuel enters the cylinder, self-ignites, burns quickly, forces the piston back down, and transforms chemical energy into mechanical energy as it does so. The first compression ignition engine patent, granted in 1893 to Dr. Rudolph Diesel, bears his name. Diesel rose to fame because to his inventive engine, which could run on a variety of fuels.

Early Work

Early diesel engines ran on a variety of fuels, from kerosene to coal dust, and had intricate injection systems. It was just a matter of time until someone realised that vegetable oils would make good fuel due to their high energy content. The French government hired the Otto firm to create a diesel engine that could operate on peanut oil for the 1900 World's Fair, which served as the first public display of vegetable oil-based diesel fuel. Vegetable oils attracted the attention of the French authorities as a potential home fuel for its colonies in Africa. Later, after doing in-depth research on vegetable oil fuels, Rudolph Diesel rose to prominence as a key proponent of the idea, claiming that farmers would gain from producing their own fuel. Yet it would be over a century before such a notion was widely accepted. Petroleum became readily accessible in a number of forms shortly after Dr. Diesel's passing in 1913, including the kind of fuel we now refer to as "diesel fuel." Petroleum is readily accessible and inexpensive, thus the diesel engine design was modified to account for its unique characteristics. The end product was a very effective and fuel-efficient engine. Wherever power, economy, and dependability are needed, diesel engines will eventually become the industry norm during the next 80 years.

Modern Engine, Modern Fuel

Even in times of high oil prices and shortages, vegetable oil-based fuels received little attention due to the ubiquitous availability and inexpensive cost of petroleum diesel fuel. Short-lived interest in utilising vegetable oils to power diesel engines was shown during World War II and the 1970s oil crisis. Sadly, owing to traditional vegetable oils' significantly greater viscosity compared to petroleum diesel fuel, modern diesel engine designs could not operate on them. Vegetable oils required to have their viscosity reduced in order for the diesel engine to adequately burn them. Pyrolysis, mixing with solvents, and even emulsifying the fuel with water or alcohols have all been suggested as ways to accomplish this job, but none of these have yielded a successful result. The idea to transform vegetable oils into fatty acid alkyl esters and utilise them as a substitute for diesel fuel was initially put out by a Belgian inventor in 1937. Vegetable oil undergoes transesterification, which breaks it down into three molecules that are considerably less viscous and easier to burn in a diesel engine. Modern biodiesel, also known as fatty acid methyl esters, is produced as a result of the transesterification process. Early in the 1980s, environmental, energy, and agricultural overproduction issues pushed the usage of vegetable oils back into the spotlight; this time, transesterification was the chosen process for making such fuel substitutes.

Biodiesel Goes Worldwide

Early in the 1990s, pioneering work by scientists like Martin Mittelbach in Europe and South Africa advanced the development of the biodiesel fuel business, whereas the U.S. sector developed more slowly owing to cheaper pricing for petroleum diesel. In order to convert wasted cooking oil into biodiesel, Pacific Biodiesel established one of the first biodiesel manufacturing facilities in the United States in 1996 on the Hawaiian island of Maui. When the terrorist events of 9/11/2001 led to historically high oil prices and a rise in concern about energy security, the biodiesel business in the U.S. became well-known. The majority of fuel was produced in the European Union as of 2005, when global biodiesel output reached 1.1 billion gallons, although biodiesel projects across the globe have been expanding as a result of increased crude oil costs and worries about global warming.

The Future of Biodiesel Fuel

Biodiesel is swiftly rising to become one of the alternative fuels with the highest growth rates in the world due to its low emissions profile, simplicity of use, and several other advantages. Biodiesel is cost-competitive with petroleum diesel with just a little amount of subsidies, and millions of consumers have discovered and benefited from the fuel's advantages. The capacity to create renewable feedstocks, such as vegetable oils and fats, will determine whether biodiesel can remain economically competitive with petroleum in the future without displacing agricultural land or damaging natural ecosystems. Sustainable biodiesel production will assist the world cope with the growing petroleum shortages while bringing about positive effects on the economy and environment long into the twenty-first century.

A biofuel is a kind of fuel made from plant biomass, comprising components from recently deceased creatures and from the metabolic waste products of live species. This biomass may be turned into biofuels through thermal, chemical, and biological conversion. Biomass fuels have been used for a very long time throughout human history. As opposed to advanced or "second-generation biofuels," which are created from lignocellulosic biomass, or woody crops and agricultural waste, conventional biofuels, also known as "first-generation biofuels," are derived from starch, sugar, or vegetable oil. Because of this, it is more difficult to extract the necessary advanced biofuel, which necessitates multiple physical and chemical processes in order to convert it to liquid fuels for transportation. In order to reduce dependency on foreign oil and address the unpredictability of oil prices, the U.S. government has prioritised the development of renewable energy sources. President Barack Obama's remark that "Renewable energy is a crucial part of strategy for the USA" is notable and conveys the relative significance of biofuels. The United States has mandated increased biofuel production, spending hundreds of millions of dollars in this nascent sector.

The biofuel business serves the economy in two ways by providing both energy and essential chemicals. Only biodiesel and bioethanol, including ethyl tertiary butyl ether (ETBE), account for more than 90% of the market for biofuels on an industrial scale. Lignocellulosics have not yet been fully used as alternative substrates. Yet, research is ongoing, and several businesses and institutes receiving public funding are working to create workable procedures. The use of biobased alcohols as fundamental chemicals or solvents is once again being discussed amid rising crude oil costs and escalating political unrest in oil-producing nations. Improvements in biomass conversion to biofuels, improving biomass resource production, and biofuel testing for engine compatibility and emissions modelling are some of the main fields of biofuel research. Understanding how the public assesses risks and advantages for new breakthroughs like biofuels is vital for policymakers and business leaders alike in order to forecast the future of scientific energy innovation. On the basis of greater comprehension, further communication tactics between the general public and the scientific community may be developed. The present chapter focuses on the history of biofuels to date and goes on to provide information on public perceptions of biofuels, including their many benefits and drawbacks in the political, ethical, economic, and environmental spheres.

Several developing nations are becoming more interested in biofuels as a way to "modernise" the use of biomass and to provide access to clean liquid fuels while addressing issues with energy prices, energy security, and global warming related to petroleum fuels. This article includes information about biofuels to aid in the comprehension of the technological implications of the development of biofuels. It aims to set the stage for: (a) comprehending the constraints of "first-generation" biofuels (made today from grains, seeds, and sugar crops); (b) providing meaningful descriptions of "second-generation" biofuels (made from "lignocellulosic" biomass, such as crop residues or purpose-grown grasses or woody crops) that are accessible to non-experts; (c) presenting key energy, carbon, and economic comparisons among biofuels; and (A commercial production of second-generation biofuels is not currently taking place anywhere.

They are produced from non-edible raw materials, which reduces the direct rivalry between food and fuel that most first-generation biofuels experience. In comparison to first-generation biofuels, such feed stocks may be developed expressly for energy reasons, allowing greater output per unit land area. Moreover, more of the above-ground plant material can be turned to biofuel. As compared to most first-generation biofuels, most second-generation biofuels are expected to have reduced feedstock prices and significant energy and environmental advantages. Nevertheless, compared to first-generation biofuels, second-generation biofuel systems need more advanced processing machinery, more investment per unit of output, and bigger facilities (to exploit capital-cost scale economies). Moreover, more research, development, and demonstration work is required on feedstock production and conversion in order to realise the commercial energy and (unsubsidized) economic potential of second-generation biofuels. Depending on whether biochemical or thermochemical methods were employed to turn the biomass into fuel, second-generation biofuels may be categorised. By biochemical processing, second-generation ethanol or butanol might be produced. Readers may be less acquainted with second-generation thermochemical biofuels, yet many of these fuels are being produced commercially from fossil fuels using methods that, in some instances, are similar to those that would be used for biofuel synthesis. These fuels include methanol, dimethyl ether, and Fischer-Tropsch liquids (FTL) (DME). Throughout, there are several initiatives aimed at commercialising second-generation biofuels. In the case of biochemical fuels, innovations in the study and engineering of microbes created to process certain feed stocks are required. These innovations must be followed by large-scale demonstrations to demonstrate commercial feasibility. Before considerable commercial manufacturing could start, 10 to 20 years would probably be needed.

Less research and development is required for thermochemical fuels because many of the equipment components required for biofuel production are already commercially available for use in the conversion of fossil fuels, and because processing is not particularly sensitive to the type of input feedstock. Thermochemical biofuels might be produced commercially in five to ten years. Land use effectiveness, net lifetime energy balance, net lifecycle greenhouse gas balance, and economics are among the metrics for comprehending and assessing biofuel systems. The least efficient use of land among all biofuels is shown by starch-based first-generation fuels (measured in km/year of vehicle travel possible with the biofuel generated from one hectare). The land-use efficiency of first-generation fuels based on sugar is nearly twice as high, while second-generation fuels provide an additional boost of 50% or more. According to net energy balances, the production of one unit of biofuel from corn in the United States today requires roughly 0.7 units of fossil energy, one unit of biodiesel from soy in the United States needs roughly 0.3 units, and one unit of ethanol from sugar cane in Brazil only needs about 0.1 units. Energy balances for the majority of second-generation biofuels will be as favourable as for Brazilian ethanol.

The amount of greenhouse gas (GHG) emissions that are reduced during the course of using a biofuel instead of a petroleum fuel depends on the specific biofuel and the manufacturing process, which usually produces some GHG emissions. In general, larger GHG reductions from biofuels are more probable when sustainable biomass yields are high and fossil fuel inputs to accomplish them are low, when biomass is effectively converted to fuel, and when the resultant biofuel is utilised efficiently in replacing fossil fuel. Very little advantages for GHG reduction are offered by first-generation biofuels made from grains and seeds. More GHG emissions are reduced by sugar cane ethanol, and further reductions are possible with second-generation biofuels. The usage of biofuels is mostly motivated by economics. With the exception of sugar cane-based ethanol produced in Brazil, the production costs of all first-generation biofuels are fundamentally high owing to the usage of expensive feedstocks. Without subsidies, even the most productive ethanol producers (outside of Brazil) cannot compete till oil prices are above the $50 to $70 per barrel level. Since its start in the 1970s, the Brazilian ethanol sector has developed to the point that it can now generate competitive ethanol at oil costs of around $30 per barrel. Second-generation biofuels might potentially have better economics than the majority of first-generation fuels since they would be produced from less expensive feedstocks.

A number of problems are implied by the technology discussed in this study for the growth of the biofuels businesses in underdeveloped nations. The main drawbacks of first-generation biofuels, such as the direct conflict between food and fuel, cost competitiveness, and greenhouse gas emission reductions, are not projected to vary much between developing and industrialised nations. Nonetheless, because to superior growing conditions and lower labour costs, many developing nations have the ability to generate biomass at cheaper prices than in developed nations, giving them a potential competitive advantage. The topic of whether second-generation biofuel technologies are applicable to underdeveloped nations is brought up by the fact that they are predominantly being developed in industrialised nations. In order to attain the optimum economics, technologies created for industrialised nation applications would often be labor-intensive, capital-intensive, and geared for large-scale installations. Moreover, biomass feed stocks may vary significantly from feed stocks suitable for uses in underdeveloped nations. Technology transfer concerns arise because developing nations will need to be able to modify such technologies for their unique circumstances. It will be crucial for a nation to have a technological innovation infrastructure in place for effective technology adoption and adaption.

This encompasses the entire group of individuals and organisations capable of producing fundamental knowledge, assimilating knowledge from the global community, establishing successful joint ventures with foreign businesses, developing government policies that support necessary research and technological adaptation, putting into practise technology-informed public policies, etc. One of the main factors influencing Brazil's ethanol program's success is its innovation system. Governments may play significant roles in promoting the growth of the biofuels sector in underdeveloped nations. The enactment of regulatory requirements for the use of biofuels will aid in the establishment of competitive second-generation enterprises. Direct financial incentives may also be taken into consideration, with specific "sunset" clauses and/or subsidy limitations included from the beginning. Policies that encourage international collaboration would aid in giving local businesses access to intellectual property held by foreign corporations. Developing nation partners in such joint ventures may supply host locations for demonstrations and initial commercial plants, as well as pathways into local biofuels markets, given their natural endowment of favourable environment for biomass production. Lastly, a robust international biofuel and/or biofuel feedstock trade system is required for there to be viable domestic biofuels businesses, since nations that only depend on domestic production would be susceptible to the whims of the market and the effects of the weather on agriculture. To ensure that broad biofuel production and usage will be helpful in achieving social and environmental objectives while avoiding needless trade obstacles, sustainability certification may be important in the context of global commerce.

First-Generation Biofuels

The most well-known first-generation biofuel is ethanol, which is produced by fermenting either sugar from sugar beets or cane, or sugar from maize kernels or other starch-containing crops. Butanol may be produced by similar procedures but using different fermentation microbes. Butanol is now undergoing commercialization efforts, while the ethanol market is already well-established. Brazil (from sugar cane) and the United States (from maize) each contributed around 18 billion litres, or 35% of the total, to the world's output of first-generation bio-ethanol in 2006. In 2006, ethanol production in China and India accounted for 11% of the world total, but it was substantially lower in other nations. The feed stocks used in production include cane, maize, and a number of other sugar or starch crops (sugar beets, wheat, potatoes). With Brazil and the United States having by far the highest development ambitions, several nations are increasing or considering increasing their production of first-generation ethanol. Brazil's ethanol output is anticipated to more than quadruple between now and 2013, while the United States' production capacity will double from its level in 2006 once new facilities that are now under construction are finished. The majority of first-generation biofuels have little promise in terms of replacing petroleum or reducing carbon emissions efficiently. On an energy level, this ethanol will still make up less than 4% of total gasoline plus ethanol use in the United States in 2007. However, the enormous quantity of fossil fuel necessary to make this ethanol considerably cancels out the decreases in carbon emissions brought on by the maize plants' photosynthetic absorption of carbon.

In comparison, the potential for sugar cane-based ethanol is far greater in terms of replacing petroleum or lowering carbon emissions. In Brazil, ethanol consumption in 2006 was about 50% that of gasoline, and this country's use of ethanol resulted in significant reductions in carbon emissions, partly as a result of using the sugar cane's fibre as the energy source for ethanol production. Brazil's capacity to manufacture sugar cane ethanol is not exceptional, despite having the biggest sugar cane-ethanol sector in the world. Sugar cane is grown in more than 80 nations, and some of them already make some fuel ethanol.

The other well-known first-generation biofuel is biodiesel produced from oil-seed crops. With around 2.3 billion litres produced as of 2005, Germany was the global leader in production (mainly from rapeseed and sunflower). Since 2005, production has been expanding quickly on a global scale. Production of biodiesel mainly made from soybeans increased in the United States from an estimated 284 million litres in 2005 to 950 million litres in 2006. Beginning in 2008, the Brazilian government required the addition of 2% biodiesel to conventional fuel, with the obligation growing to 5% in 2013. It will take around 800 million litres of biodiesel to reach the 2008 target. Brazil had an established biodiesel production capacity of roughly 590 million litres per year at the end of 2006, and this capacity is anticipated to more than quadruple this year. Particularly in SouthEast Asia (Malaysia, Indonesia, and Thailand), where the bulk of the world's palm oil for food consumption is produced, interest in palm biodiesel is rising. The non-edible oil tree Jatropha is gaining popularity because of its capacity to produce oil seeds on a variety of different types of terrain. Jatropha biodiesel is being explored in India as a part of a plan to reclaim wastelands. The potential for biodiesel made from oil-bearing seeds to replace petroleum or reduce carbon emissions is limited, much as the potential for alcohol fuels made from starch, as will be explored later.

Supplementary biofuels the production of second-generation biofuels from lignocellulosic biomass allows for the use of less expensive, non-edible feedstocks, hence minimising direct conflict between food and fuel. In terms of the method utilised to transform the biomass into fuel, second-generation biofuels may be further divided into biochemical and thermochemical types. All additional second-generation fuels listed here would be produced by thermochemical processing, with the exception of second-generation ethanol or butanol, which would be produced through biochemical processing. Due to the lack of first-generation analogues, second-generation thermochemical biofuels may be less well-known to readers than second-generation ethanol. Yet, a lot of second-generation thermochemical fuels are now produced commercially from fossil fuels utilising methods that, in some instances, are the same as those that would be used in the creation of biofuels. Methanol, refined Fischer-Tropsch liquids (FTL), and dimethyl ether are some of these fuels (DME). Fossil fuels may also be used to produce mixed alcohols, but since some of the methods for doing so are still in their infancy, there is currently no commercial production of them. Green diesel, another thermochemical biofuel, lacks a clear fossil fuel equivalent. Thermochemical processes are also used to make unrefined fuels, such as pyrolysis oils, although these must undergo extensive refinement before being utilised in engines.

Second-generation biochemical biofuels:

Second-generation ethanol or butanol has the same fuel characteristics as their first-generation counterparts, but the production method is fundamentally different since lignocellulosic feedstock is used. The terms "cellulosic ethanol" and "cellulosic biobutanol" are often used to describe second-generation biochemically generated alcohol fuels. The pre-treatment, saccharification, fermentation, and distillation processes are the fundamental phases in the production of these. In order for the complex carbohydrate molecules that make up cellulose and hemicellulose to be broken down by enzyme-catalyzed hydrolysis water addition into their component simple sugars, pretreatment is intended to help separate cellulose, hemicellulose, and lignin. 3 A crystalline lattice of lengthy glucose (6-carbon) sugar molecule chains makes up cellulose. It is difficult to unbundle into simple sugars due to its crystallinity, but once unbundled, the sugar molecules may be readily fermented to ethanol using known microorganisms. Certain microorganisms for butanol fermentation are also known. Hemicellulose may be readily broken down into its component sugars, including xylose and pentose, which are composed of polymers of 5-carbon sugars. While it is more difficult to ferment 5-carbon sugars than 6-carbon sugars. 5-carbon carbohydrates may be fermented into ethanol by several microorganisms that have relatively recent development. Phenols, which make up lignin, are almost incapable of being fermented. Yet, lignin may be salvaged and used as a fuel to generate power and process heat in an alcohol manufacturing plant.

The manufacturing of second-generation ethanol has been suggested using a range of different process concepts. Using separate hydrolysis or saccharification and fermentation stages is one very well-defined method for producing ethanol. Additional ideas include condensing the hydrolysis and fermentation processes into a single reactor simultaneous saccharification and fermentation and including enzyme synthesis from biomass into the condensed bioprocessing along with the saccharification and fermentation processes. Whilst there hasn't been as much research done on butanol, it can be processed in a manner similar to that of ethanol. Iogen has the only operational commercial demonstration facility for the manufacture of cellulosic ethanol in the world, which is located in Canada. It began operating in 2004 and now generates 3 million litres of ethanol from wheat straw annually. A 5 million litres per year manufacturing facility, which will be run by Abengoa in Spain beginning later this year, is among the newly announced commercial units.

According to the National Renewable Energy Laboratory (NREL) of the US Department of Energy, technological advancements will enable ethanol yields to approach 400 litres per dry metric tonne of converted biomass, up from about 270 litres per tonne that can currently be achieved at least on paper with available technology. In order to achieve these objectives, the Department of Energy has announced cash grants to assist the creation of three significant bioenergy research centres and a number of significant commercial-scale initiatives designed to show the feasibility of cellulosic ethanol. Despite the fact that cellulosic ethanol can now be generated, it still needs extensive effective research, development, and demonstration activities to make it competitively (without subsidies) from lignocellulosic biomass. Important objectives for research and development include:

A. Developing biomass feed stocks with physical and chemical structures that facilitate processing to ethanol, e.g. lower lignin content, higher cellulose content, etc;
B. Improving enzymes (also called cellulase) to achieve higher activities, higher substrate specificities, reduced inhibitor production and other features to facilitate hydrolysis;
C. Developing new micro-organisms that are high-temperature tolerant, ethanol-tolerant, and able to ferment multiple types of sugars (6-carbon and 5-carbon).

The use of genetic engineering may considerably assist in achieving these aims. For applications involving microorganisms present in industrial processes, such as cellulose hydrolysis or 5-carbon sugar fermentation, genetic alteration of organisms seems to be largely accepted. The use of genetic engineering to enhance biomass feedstocks, however, is causing more worry since there is a chance that genetically modified species may interbreed with wild species or expand and outcompete them, endangering biodiversity in both scenarios. Application of genetic feedstock alterations must be done with caution to ensure that these issues are taken into account.

Thermochemical biofuels of the second generation the mechanisms used in thermochemical biomass conversion occur at substantially greater temperatures and pressures than those used in biochemical conversion systems. The versatility of feed stocks that may be accommodated with thermochemical processing and the variety of final fuels that can be generated are key fundamental qualities separating thermochemical from biological biofuels. Gasification or pyrolysis are the first steps in the thermochemical generation of biofuels. The former produces a clean finished fuel that can be put straight into engines, but it often takes more money and bigger scale for better economics. The subject of this topic is gasification-based processing, which may be used to create a range of different biofuels, including Fisher-Tropsch liquids (FTL), dimethyl ether (DME), and other alcohols.

In the process of gasification, biomass that contains between 10 and 20 percent moisture is heated (usually by burning some of the biomass in oxygen) and transformed into a combination of combustible and non-combustible gases. The removal of contaminants from the gas is followed, in certain situations, by compositional changes using the "water-gas shift" reaction to make the gas, also known as synthesis gas or syngas, ready for further downstream processing. As carbon dioxide ($CO2$) dilutes the syngas, it is then taken out to speed up processes further down the line. Carbon monoxide (CO) and hydrogen ($H2$) are the two main substances in the now-clean and concentrated syngas, often with a negligible quantity of methane ($CH4$). Liquid fuel is created when CO and $H2$ are passed through a catalyst ($CH4$ is inert). The kind of biofuel that is created depends on the catalyst's design. Not all of the syngas that passes over the catalyst will be converted to liquid fuel in the majority of plant configurations. The unconverted syngas would normally be burnt to generate energy, which would then be used to power the plant entirely or in certain circumstances export electricity to the grid. The dashed lines reflect a second method for converting syngas to liquid fuel that is less economically developed than the catalytic process previously discussed. In this method, ethanol or butanol is produced from the syngas by specially developed microorganisms.

Perspectives on First- And Second-Generation Biofuels

Land use effectiveness, net life cycle energy balance, net life cycle greenhouse gas balance, and economics are metrics that may be helpful for understanding and assessing first- and second-generation biofuel systems.

Land-Use Efficiency for Providing Transportation Services

The limiting resource for the development of biofuels is eventually land. The total quantity of biomass that may be generated on a given plot of land varies greatly depending on the species that are used, the soil and climate, and agronomic practises. Sugar cane, a first-generation biofuel feedstock, has a high productivity per hectare that is comparable to the best productivities that have been attained with eucalyptus plantations, which may be a second-generation biofuel feedstock. However, a first-generation biofuel factory only uses a small portion of the biomass from sugar cane to produce liquid fuel, but a second-generation biofuel facility would employ almost the whole above-ground eucalyptus plant. The lignocellulosic fractions of sugar cane, such as bagasse and other fibrous waste, might be converted into a second-generation ethanol fuel, making sugar cane ethanol one of the most land-efficient biofuels.

The amount of transportation service that can be delivered from a hectare of land is a useful indicator of land-use efficiency. One may calculate the number of vehicle-kilometers that a hectare of land can support by taking into account the rate of biomass feedstock production per hectare, the efficiency of turning the feedstock into a biofuel, and the efficiency of utilizing the biofuel in a vehicle. As only a portion of the above-ground biomass is utilized as an input to a biofuel production plant, starch-based first-generation fuels have the lowest output of vehicle-kilometers/hectare/year of all biofuels. According to this indicator of land-use efficiency, first-generation fuels based on sugar perform nearly twice as well as those based on starch. Due to its greater utilization of the available above-ground biomass than first-generation fuels, second-generation fuels may increase land-use efficiency by 50% or more when compared to fuels based on sugar.

Greenhouse Gas Emissions

The volume and carbon intensity of the fossil fuel inputs required to make the biofuel, as well as the kind of fossil fuel that the biofuel replaces, affect how effectively greenhouse gas emissions (GHGs, including CO_2, CH_4, and others) may be avoided using biofuels. A thorough GHG accounting takes into consideration the whole biofuel life cycle, from biomass planting and growth through biomass conversion to biofuel combustion at the point of consumption. (This whole life cycle study is frequently referred to as a "well-to-wheels" analysis in the context of automotive applications.) Carbon dioxide is removed from the atmosphere by photosynthesis at the same rate at which the already-harvested biomass is releasing it into the atmosphere, resulting in a carbon-neutral situation, if the harvested biomass is replaced by new biomass growing year after year at the same average rate at which it is harvested. Nevertheless, often some fossil fuel is used to produce, transform, or transport the biofuels to the point of consumption, resulting in net positive GHG emissions throughout the duration of the fuel's life cycle. The emissions that are saved while using biofuel in lieu of fossil fuel will be partially compensated by these emissions. The conversion of land from its present use to the production of biomass energy feedstock may potentially result in net GHG emissions. In the event that existing forests are cut down to make way for energy crops, the net emissions may even be positive. If perennial energy crops (which may increase soil carbon) are developed in place of annual row crops that were being produced on carbon-depleted soil, the net emissions may even decrease. Land use change emissions may be substantial, although they are heavily influenced by regional circumstances. As a result, to make the discussion in this publication more straightforward, no GHG emissions linked to such land use changes are taken into account. An extensive body of research has been done on GHG life cycle assessments (LCAs) of biofuels. The majority of published LCAs were conducted in North or Europe, with the good research of Brazilian sugar cane ethanol being an exception. It is possible that the disparate findings from various research for the same biofuel and biomass source might be explained by the significant context-specific variability and ambiguity around input parameter values in LCA analysis. Rape methyl ester (RME), which may replace traditional diesel fuel, is expected to reduce greenhouse gas emissions per vehicle kilometre (v-km) by anywhere between 16 and 63%, or by a factor of four. The range of decrease for SME (soy methyl ester) is between 45% and 75%. The range for sugar beet ethanol is considerably smaller but complicated by three alternative sets of assumptions about how GHG emission credits are assigned to the residual pulp co-product of ethanol production. As compared to gasoline, ethanol from wheat exhibits effects ranging from a 38% reduction in greenhouse gas emissions to a 10% penalty.

Examining the specifics of each study, such as analytical bounds, numerical input assumptions, and calculation procedures, is necessary to comprehend such variance in LCA outcomes. Nonetheless, it is feasible to make a few definite inferences without going into that much depth. When sustainable biomass yields are high and fossil fuel inputs to obtain them are low, when biomass is converted to fuel effectively, and when the resultant biofuel is utilised efficiently, higher GHG reductions with biofuels are more possible. Conventional grain- and seed-based biofuels can only offer modest benefits for reducing greenhouse gas emissions (GHG) per megajoule of fossil fuel displaced, per vehicle mile travelled, or per hectare of land used. In any case, these fuels will only be able to offer modest levels of fuel displacement over the long term due to the relatively inefficient land use they require. The primary factor for grains and seeds to perform poorly is because they often make up less than 50% of the dry mass of the above-ground biomass, which puts them at a yield disadvantage.

Increased fuel conversion rates somewhat offset reduced biomass yields from seeds and grains. For instance, modern technology allows for the production of around 380 litres of ethanol from a dry tonne of maize grain. This contrasts with currently available technology for the conversion of cellulosic biomass to ethanol, which can only produce around 255 litres/dry tonne at least on paper; no plant of this size has been constructed. Further advancements in the manufacture of cellulosic ethanol are anticipated to erase the conversion efficiency advantage now held by maize ethanol: yields from lignocellulose are anticipated to be 340 liters/ton in 2010 and 437 liters/ton. Fischer-Tropsch fuels made from lignocellulose can produce around 280 litres of diesel equivalent, which is equal to 471 litres of ethanol, and might be commercially available in the 2010–2015 period. Long-term, high-yielding lignocellulosic energy crops may be used to increase the efficiency of land use in minimising GHG emissions. A coordinated development effort should likely result in significant yield improvements with reduced inputs per tonne of biomass generated, according to decades of experience with growing food crop yields and recent experience with producing lignocellulosic energy crops[8].

Although research and development assistance for energy crop development has traditionally been rather modest, recent significant private sector expenditures in research and development are projected to quicken the pace of progress towards improved yields. Land needs to accomplish GHG emission reductions with biofuels will be decreased if high yields are sustainable and acceptable from a biodiversity and other viewpoints. In the process of creating biofuels, particularly through thermochemical conversion, it is also possible to collect some by-product CO_2 for long-term subterranean storage, which might result in negative GHG emissions for a biofuel system. Thermochemical co-processing of coal and biomass has also been proposed to generate carbon-neutral liquid fuels by collecting and storing part of the CO_2 produced during the conversion process. Lastly, it is important to remember that biomass may be used to create liquid fuel as well as heat or power. This may result in lower GHG emissions per unit of land area than producing liquid petroleum. Biomass is the sole renewable source of carbon, making it the only renewable resource for manufacturing carbon-bearing liquid fuels. Nevertheless, a number of renewable resources are available for producing power or heat (hydro, solar, geothermal, wind, etc.).

Economics

Almost all first-generation biofuels are subsidised in production costs, with the exception of sugar cane ethanol in Brazil. Regulations in the majority of nations, including Brazil, generate demand. Since its start in the 1970s, the Brazilian ethanol sector has developed to the point where it can now generate ethanol that is competitive with gasoline at oil prices that are far lower than those of today. Contrarily, until oil prices rise beyond the $50 to $70 per barrel price range, even the most effective ethanol producers (outside of Brazil) are unable to compete on their own without subsidies. The high production costs outside of Brazil may be attributed to the comparatively high cost of the palatable crops used as feedstock for first-generation biofuels. Due to the rapidly expanding demand for feed-stocks for the manufacture of biofuels, prices for the feed-stocks have in certain instances lately climbed considerably, such as with maize in the United States. The United States Department of Agriculture anticipates that corn planting acreage will reach record highs and that maize prices will continue to rise until the end of this decade. Such market effects bring the conflict between food and fuel posed by first-generation biofuels to the fore.

The higher capital cost per unit of output sets second-generation biofuels production apart from first-generation technologies in general. This higher capital intensity will be countered by cheaper feedstocks, resulting in reduced overall production costs. High capital intensities will, however, force implementation to take place at bigger sizes in order to benefit from scale economies. Up to relatively high plant sizes, this cost reduction will often more than cover the increased biomass costs caused by longer average transportation distances associated with the bigger scale of production. Capital costs per unit of production capacity decrease as plant size increases. Building second-generation systems that are bigger than most first-generation systems will thus be strongly encouraged economically. Economies of scale will probably be more important for thermochemical conversion than for biochemical conversion due to the inherent nature of the technologies involved. But, the degree to which cost learning occurs after commercial introduction, similar to what is observed in the Brazilian sugar cane ethanol business, will be a more crucial aspect in obtaining low cost for either method.

The National Renewable Energy Laboratory (NREL) in the United States predicts that improvements in the engineering of biological organisms and processes and in the less expensive production of lignocellulosic feed stocks like switchgrass will lead to commercial competitiveness of biological fuel ethanol at crude oil prices below mid-2006 levels sometime in the next 10 to 20 years. A short-term objective of NREL is for commercial ethanol production prices to be comparable with ethanol made from maize by the year 2012, providing technical knowledge is available. If a plant were to be constructed utilising currently available technology, cellulosic ethanol costs would be well over this goal. In order to achieve costs below those of maize ethanol over the long run, it is anticipated that both low feedstock prices and high production scales would be necessary. With the temperate temperature conditions present in much of the continental United States, it will be difficult to deliver substantial quantities of biomass at an average cost of $30/tonne or less. Due to their unique climatic characteristics, many poor nations, however, may have a comparative advantage, and there is a higher likelihood that sustained low-cost biomass production may be accomplished in such locations.

Since many of the equipment components required for second-generation thermochemical systems are already commercially established from applications in the conversion of fossil fuels as previously described, thermochemical biofuels could enter commercial production in a few years with relatively modest further development and demonstration efforts. According to current technological understanding, a large-scale biomass-FTL production facility in the United States would need an oil price in the neighbourhood of $70/barrel to be competitive without subsidy processing, say, 5,000 dry tonnes of biomass per day at a cost of $50 to $60 per dry tonne delivered. Thermochemical biofuel production may be competitive at considerably lower oil costs ($50/barrel of oil) and/or at smaller scales where it can be combined with a facility generating biomass by-products useful for energy, such as the pulp and paper sector. Long-term production costs for standalone thermochemical fuel production systems (not integrated with any other industrial processes) are aimed to be competitive with $50/barrel of oil. Thermochemical biofuels will compete at oil prices lower than those mentioned above in nations where biomass production costs are lower than in the United States due to superior growing conditions and where building and labour costs are also cheaper.

Implications for Trade and Development

There is now a sizable market for biofuels in developed nations, partly due to governmental requirements for their blending with petroleum-based fuels. This demand is expected to increase significantly in the coming years as a result of more onerous regulatory requirements, persistently high oil costs, and worries about energy security. Similar causes will increase demand for biofuels in many emerging nations. Trade opportunities for biofuels or their feedstocks will grow. The technologies discussed in this article suggest a number of problems with the growth of local and/or international markets for biofuels in poor nations. In terms of direct food vs. fuel conflict, cost competitiveness, and greenhouse gas emission reductions, the constraints of first-generation biofuels are not anticipated to vary much between poor and industrialised nations. While the environment in many developing nations is more conducive to the growth of first-generation biofuel feedstocks than in many developed nations, agricultural productivities are often lower.

So, increasing agricultural productivity would aid in reducing conflicts between food and fuel to some degree. It would also be beneficial to focus biofuel feedstock production on areas more suited for producing food crops. In any event, since first-generation biofuel feedstock pricing may be determined by global commodities markets, the economics of these fuels may not be all that superior to those that may be attained in developed nations. Moreover, lower production scales that may be preferred in underdeveloped nations to decrease the requirement for investment capital would often result in higher production unit costs for biofuels. However, credits for first-generation biofuels aside from sugar cane ethanol based on the Brazilian model will be modest without innovation in production techniques that reduce fossil fuel use compared to current industrialized-country norms. Clean Development Mechanism credits may help to improve economics. Since that second-generation biofuel technologies are mostly being researched in affluent nations, concerns about its applicability to poorer nations should be taken into consideration. In order to attain the optimum economics, technologies created for industrialised nation applications would often be capital-intensive, labour-minimizing, and built for large-scale installations. Moreover, feed stocks that are suited for production in poor nations may be quite different from the biomass feed stocks for which technologies are built. Developing nations will need to be able to adopt such technology in order to take use of their comparative advantages of better growing conditions and reduced labour costs. It will be crucial to adjust feed stocks to the specific biogeophysical characteristics of the area to maximise biomass production per hectare while lowering costs. Also, it will be crucial to adapt conversion technologies to lower capital intensities and raise labour intensities in order to create more jobs and lessen the sensitivity of product cost to scale. Second-generation biofuel businesses in developing nations should be competitive with those that will be formed in wealthier nations if such adjustments can be achieved effectively.

Technology transfer is complicated by the sustainable implementation of developed-country technologies in developing nations. A nation must have a mechanism in place for technological innovation in order for technology adoption and adaption to be effective. Regional innovation frameworks may do this for smaller nations. An innovation system refers to individuals engaged in a wide range of activities and institutions, such as (a) research universities/institutes producing fundamental knowledge and assimilating knowledge from the global community; (b) industries capable of forming joint ventures with foreign companies and incorporating innovation and learning into shared technologies; and (c) governmental organisations capable of recognising and supporting the necessary research and technological adaptation Participation in the early (pre-commercial) phases of technology development is the optimum starting point for technological innovation. One of the main factors in the Brazilian ethanol program's success is the innovation system, which is also in existence in a few other sizableemerging nations, such as China and India[9], [10]. Governments may play significant roles in promoting the growth of the biofuels sector in underdeveloped nations.

The focus of government efforts on second-generation biofuels may be reasonable given that first-generation biofuel technologies are currently quite well established but still have limits due to economic and other factors. By implementing legislative requirements for the use of biofuels, competitive second-generation businesses will be enabled (particularly in bigger nations or regional clusters of smaller countries). Direct financial incentives, such as price subsidies for biofuels or grants for R&D&D, might also be taken into consideration, although they should be established with explicit "sunset" clauses and/or subsidy ceilings (e.g., linked to oil prices and with limited durations). Policies that encourage international collaboration would also aid in giving indigenous businesses in underdeveloped countries access to intellectual property held by multinational corporations. In such collaborative ventures, developing nation partners may supply host locations for demonstrations and initial commercial plants, as well as access points to regional markets for biofuels, due to their natural environment favourable for biomass production. Second-generation biofuels won't have much of an influence in any developing nation for some time, even with strong government backing and a strong structure for technological innovation.

Consider Macedo's predictions for how long it will take for Brazil to develop a commercial second-generation biofuel business utilising the lignocellulosic part of sugar cane (defined by Macedo as having 5 to 15 commercial production facilities functioning). He predicts that a competitive thermochemical biofuel industry (producing FTL or DME) could be established by 2020, and a competitive biochemical biofuel industry (producing ethanol by consolidated bioprocessing) might be established between 2020, taking into account all of the steps necessary to get there (including research, development, pilot-scale demonstration, and commercial-scale demonstration). Given the Brazilian context for these estimates, which includes one of the lowest-cost lignocellulose production systems in the world, a well-established and competitive first-generation biofuels industry, significant sugar cane production expansion plans that offer opportunity for rapid introduction of innovations, an established technology innovation system in the nation, and supportive government policies, the time to establish second-generation biofuels industries in a "average" decadal time frame has come.

On the other hand, research and development surprises could reduce these projections given the enormous degree of worldwide effort now focused on the commercial development of biofuel technology. Lastly, robust international biofuel and/or biofuel feedstock trade networks are required for the domestic biofuels businesses to be viable, since nations that only depend on domestic production would be exposed to the whims of the market and the effects of the weather on agriculture. To ensure that broad biofuel production and usage will be helpful in achieving social and environmental objectives while avoiding needless trade obstacles, sustainability certification may be important in the context of global commerce. It is difficult to predict the long-term contribution that emerging nations will make to a global biofuel economy given the still-early stage of commercial development of second-generation biofuel technology. They may simply start exporting second-generation feedstocks, capitalising on their favourable geographic conditions and cheap labour for biomass production. A more desirable progression would be for them to turn into producers, consumers, and exporters of finished biofuels, preserving more of the significant added value involved in converting the feed stocks to finished fuels locally.

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CHAPTER 3

TYPES OF BIO-FUEL

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A biofuel is any fuel that produces bioenergy and is made entirely from plant or animal components. Biomass is another name for this substance. The name "bio" is used to denote this fuel source's organic nature since, unlike fossil fuels, it is not derived from a geological process (petroleum and coal). It is a preferred renewable energy source because of how simple it is to extract and how easily it can replenish. The process of photosynthesis results in the production of biofuels, which plants utilise to make their own sustenance. Some of the best plants for producing biofuels are wheat, soy, sunflower, maize, and sunflower seeds. Herbivores like domesticated cattle are major consumers, and as a consequence, biofuel is made mostly from the plant materials found in their faeces. Commercial, agricultural, industrial, and home waste may be used in an indirect manner to produce biofuels, which offer a number of advantages. As the fuel may exist in three states solid, liquid, and gas it has some parallels to fossil fuels.

VARIOUS TYPES OF BIOFUEL

1. Wood

This kind of organic material-based fuel is the most basic. Biomass, a fuel that includes firewood, sawdust, chips, charcoal, and pellets, is produced by both plants and trees. As a result, wood is one of the fuel kinds that is most often used worldwide. They commonly gather these various kinds of wood to heat their houses, cook their meals, and power small appliances in their dwellings.

2. Biogas

The gaseous state of biofuels looks like this. It is progressively but gradually replacing natural gas since it burns similarly to it. Biogas is mostly methane gas despite being produced by the anaerobic breakdown of biomass. Biogas is used by the majority of agricultural industries and is increasingly packaged in gas cylinders for household usage. Since each one contributes a unique element, plants and animals are mixed to create the fuel. For example, although humans contain nitrogen, plants have significant quantities of carbon and hydrogen. These elements are required for the production of biogas[1], [2].

3. Biodiesel

This biofuel is liquid in texture. It generally focusses on plants with high energy content in order to create pure biodiesel. It is produced by mixing oils and fats from plants and animals, respectively. Alcohol is a further ingredient used in the production of biodiesel. Furthermore, grease from plants and animals is used as a supplement[3], [4].

In his experiments, Rudolf Diesel, the man who created the diesel engine in 1897, used vegetable oil as a fuel. Since it is mostly utilised in diesel engines, the fuel generated from vegetable oils and animal fats that we now refer to as biodiesel bears his name (as is petroleum diesel fuel).

Biodiesel is permitted for blending with petroleum diesel/distillate since it complies with American Society for Testing and Materials (ASTM) standard D6751.

Vegetable and animal lipids are transesterified to create biodiesel. The primary feed stocks used to produce biodiesel in the United States are vegetable oils, mostly soybean oil. Animal fats from meat processing facilities, used/recycled cooking oil, and yellow grease from restaurants are other significant U.S. biodiesel feedstocks. In other nations, palm oil, sunflower oil, and rapeseed oil are the main feed stocks used to produce biodiesel. Algae have the potential to be used as biofuels. Algae have pockets of fat that keep them buoyant; these fat pockets may be harvested and converted into biofuels. The physical characteristics and applications of biodiesel may be impacted by the feed stocks used in its manufacture[5], [6].

4. Ethanol

This biofuel, which is likewise liquid in form, is made from the biomass of both plants and animals, but mostly plants. As the name suggests, it is an alcoholic beverage. It is made by fermenting materials with a high carbon content, primarily sugars and cellulose. Another one of the suggested plants is sugarcane. Because of its purity, it is used with other fuels to reduce carbon emissions. In its pure form, it may also be used as fuel for cars. Brazil, a nation with a large sugarcane production, has had success using 100% ethanol in cars[7].

5. Methanol

Methanol is an alcohol that, like ethanol, is used as a clean fuel in some parts of the globe, notably in racing cars. The fundamental chemical difference between methanol and methane is that the latter is a liquid and the former is a gas. Biomass is converted into methanol by the process of gasification, which is carried out at very high temperatures and in the presence of a catalyst.

6. Butanol

Moreover, this alcohol serves as a biofuel. As comparison to ethanol and methanol, butanol is a liquid produced during the fermentation process that contains more energy per unit. Its chemical makeup and efficiency are also equivalent to those of gasoline, however manufacture is quite difficult. It is produced by plants, especially those that provide grains with a lot of energy, like sorghum and wheat. Because to its high energy content and longer hydrogen chain, it may be fed directly and without modification into gasoline engines.

In order to create next-generation biofuels using waste, cellulosic biomass, and algae-based resources, the Bioenergy Technologies Office (BETO) is working with business. Hydrocarbon biofuels, commonly referred to as "drop-in" fuels, are BETO's primary emphasis and may replace petroleum in existing refineries, tanks, pipelines, pumps, cars, and smaller engines.

ETHANOL

A renewable fuel known as ethanol (CH_3CH_2OH) may be produced from diverse plant resources generally 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 cars can run on ethanol blends up to E15 (15% ethanol, 85% gasoline), the most popular of which being E10 (10% ethanol, 90% gasoline). Certain automobiles, known as flexible fuel cars, are designed to operate on E85, an alternative fuel with a substantially greater ethanol percentage than ordinary gasoline (51%-83% ethanol, depending on area and season). In the US, ethanol is included in around 97% of gasoline. In the United States, maize starch is used to produce the majority of ethanol, but scientists are working to create methods that would make use of cellulose and hemicellulose, the fibrous, non-edible fibre that makes up the majority of plant matter. Fermentation is the term used to describe the usual process for turning biomass into ethanol. During fermentation, bacteria, yeast, and other microbes break down plant carbohydrates to create ethanol[8].

BIODIESEL

Diesel fuel made from petroleum may be replaced with biodiesel, a liquid fuel made from renewable resources including 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. Biodiesel is used to power compression-ignition (diesel) engines, much as petroleum-derived diesel. Pure biodiesel (B100) and the most popular mix, B20 (which contains 20% biodiesel and 80% petroleum diesel), may both be blended with petroleum fuel at any ratio.

RENEWABLE HYDROCARBON "DROP-IN" FUELS

The complex combination of hydrocarbons (molecules of hydrogen and carbon) found in petroleum fuels like gasoline, diesel, and jet fuel is burnt to create energy. Several biological and thermochemical processes may create hydrocarbons from biomass sources. Renewable hydrocarbon fuels derived from biomass are substantially comparable to the petroleum-based fuels they are intended to replace, making them compatible with the infrastructure, engines, and other devices in use today.

BIOFUEL CONVERSION PROCESSES

DECONSTRUCTION

Advanced biofuels are often produced via a multi-step process, such as cellulose ethanol and renewable hydrocarbon fuels. The biological components cellulose, hemicellulose, and lignin, which are securely bonded together in the plant cell wall's strong, stiff structure, must first be broken down. One of two methods, high temperature deconstruction or low temperature deconstruction, may be used to achieve this.

High-Temperature Deconstruction

Extreme heat and pressure are used in high-temperature deconstruction to transform solid biomass into liquid or gaseous intermediates. On this walkway, there are three main paths that are followed:

A. Pyrolysis
B. Gasification
C. Hydrothermal liquefaction.

Biomass is heated quickly at high temperatures (500°C–700°C) without any oxygen during pyrolysis. Biomass is pyrolyzed into vapour, gas, and char by heat. The vapours are cooled and condensed into a liquid "bio-crude" oil once the char has been removed. Similar steps are taken in the gasification process, but biomass is exposed to a greater temperature range (>700°C) and some oxygen to create synthesis gas also known as syngas, a combination mostly made up of carbon monoxide and hydrogen.

The ideal thermal technique for dealing with wet feed stocks like algae is hydrothermal liquefaction. In this method, water is used at high pressures and temperatures to transform biomass into liquid bio-crude oil.

Low-Temperature Deconstruction

Chemicals or biological catalysts called enzymes are often used in low-temperature deconstruction to break down feed stocks into intermediates. The physical structure of plant and algal cell walls are first opened up during a pretreatment process on biomass, which increases accessibility to sugar polymers like cellulose and hemicellulose. The hydrolysis process converts these polymers into the building components of simple sugar, either chemically or enzymatically.

UPGRADING

To create a completed product after deconstruction, raw intermediates like syngas, sugars, and other chemical building blocks must be improved. Processing on either a biological or chemical level might be used in this stage[9].

Microorganisms may ferment sugar or gaseous intermediates into fuel blendstocks and chemicals, including bacteria, yeast, and cyanobacteria. As an alternative, sugars and other intermediary streams, such bio-oil and syngas, may be treated using a catalyst to get rid of any unwelcome or reactive substances and enhance storage and handling qualities.

A petroleum refinery or chemical production facility may use stable intermediates appropriate for finishing as fuels or bioproducts that are ready for commercial sale. Any kind of fuel that directly derives its energy from plant or animal materials, commonly referred to as biomass, is referred to as biofuel. As this fuel source is created by an organic process rather than a geological one like fossil fuels, the term "bio" is used to describe its organic origin (petroleum and coal).

Due to its ease of extraction and renewability, it is a popular renewable source of energy. Since plants produce their own sustenance via the process of photosynthesis, plants are the source of biofuels. Corn, soy, sunflower, sorghum, and wheat are some of the finest plants for extracting biofuel. As domesticated cattle and other herbivorous animals are the main users, biofuel is produced from their waste, which is mostly composed of plant material. Commercial, agricultural, industrial, and home waste may be used in an indirect manner to produce biofuels, which offer a number of advantages. As the fuel may exist in three states solid, liquid, and gas it has some parallels to fossil fuels.

Various Benefits of Biofuels

1. They are renewable sources of energy

Energy is in great demand all across the world. Yet, the majority of energy sources are non-renewable, contribute to the greenhouse effect, or have the potential to cause major environmental catastrophes, as is the case with nuclear power. On the other hand, biofuels, which are clean fuel sources and ecologically sustainable, are produced from plant and animal waste.

2. Sovereignty

In contrast to fossil fuels, whose resources are not present in every country, any nation may start the production of biofuels without affecting the energy sources of other nations. Fossil fuel-rich nations have long benefited from their abundance of natural resources by setting or dictating global fuel prices and the cost of petroleum-based goods. A nation may easily establish its own product prices without having to adhere to as many international or regional restrictions if it can produce its own biofuel.

3. Ensure sustainable economy

States all around the world are embracing biofuels and advocating a decrease in the use of fossil fuels as a result of their renewable nature. Governments may lessen this dependence and encourage biofuel plants instead of expensively importing fossil fuels from Middle Eastern nations. Biofuel plants wind up being less expensive in the long term. Locally produced biofuels would lessen reliance, enhancing both economic stability and energy security. Less imports lead to greater exports, which improves independence.

4. Low costs

The majority of biofuels are simple to make and less expensive than fossil fuels. Because of this, their usage may ease everyday life for the general public and contribute to raising people's living standards by bringing [10]down the escalating living expenses that result from our reliance on fossil fuels.

5. Cleanest fuel

Carbon emissions from fossil fuels contribute significantly to air pollution. Moreover, this carbon reacts with other greenhouse gases, such methane, to produce unfavourable climatic conditions. Contrarily, since they are clean fuels, biofuels do not discharge this much carbon into the environment.

6. Production of less smoke

Fossil fuel-powered cars and other machinery emit a lot of smoke into the atmosphere on a regular basis. Biodiesel burns more efficiently and leaves behind fewer carbon deposits because it contains an oxygen atom in its chemical makeup. Biodiesels are thus more environmentally friendly and produce less smoke.

7. They help to reduce monopoly

Due to their ubiquitous usage, fossil fuels are still favoured over biofuels. This has developed into a monopoly over time, which raises living expenses and causes price inflation. Biofuels may be utilised to lessen the monopoly that fossil fuels impose since they are equivalent replacements to fossil fuels. For instance, biogas may be used similarly to natural gas. As a result, when natural gas prices rise, customers have the choice to convert to biogas. Also, motorists have the superior options of ethanol or butanol as substitutes when the price of fossil fuel increases.

8. Lower toxicity in the atmosphere

As a byproduct of combustion, carbon is produced by both fossil fuels and biofuels. The carbon, however, does not have the same impact. Fossil fuels release harmful carbon dioxide into the atmosphere, especially when methane and water vapour are present. On the other hand, the carbon produced by biofuels is naturally occurring and is used by plants for photosynthesis, which serves as a source of energy for plants.

9. They are a source of employment for locals

The majority of bio plants are constructed locally, which requires human resources including construction engineers, farmers, project managers, fuel distributors, and logisticians. This helps the local community by generating new work possibilities[11].

10. They do not produce sulfur

When burned, certain fossil fuels, such as coal, emit sulphur and aid in the development of acid rain with a high sulphur content. In contrast, biofuels don't contain sulphur.

11. Promotion of agriculture

More cultivation of the appropriate crops would result from a rise in the demand for the production of biofuels. High-carbon and high-cellulose crops may be grown on a big scale, and once the edible portions are harvested, the remaining plant materials, such fodder, can be utilised to make biofuels.

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CHAPTER 4

MERITS AND DEMERITS OF BIOFUEL PRODUCTION

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The term "biofuel" is popular right now in the transportation sector, and for good reason. Plant-based fuel generation is almost ubiquitous, it uses renewable resources, and it often produces lower emissions than gasoline made from petroleum. With the movement in global trends towards sustainable transportation, fuels like ethanol generated from maize and biodiesel made from soy, switchgrass, and palm oil seem like a good place to start when it comes to cleaner, greener roads. The cost of biofuels is not totally free, either. Cost of any fuel varies depending on a number of economic and environmental factors, and biofuel isn't always the most eco-friendly option. While a fuel made from plants may be replenished, a fuel made from fossil fuels will eventually run out. However when additional complication factors are included, biofuel often has a high price[1], [2].

A number of common crops might be economically utilised to produce biofuel in certain parts of the world. Therefore, it would either be impossible or very costly to cultivate the same plants elsewhere. The fertiliser, water, and land required to produce enough biofuel to significantly reduce the use of fossil fuels may also result in other problems, such as increased pollution or a decrease in the availability of food. Adding biofuels to our routines for consuming gasoline might be expensive. To get a new perspective on the fuels that could be more common in the future, let's look at some of the limits of biofuels[3], [4].

Potential economic gains from the development of biofuel

Using biofuels instead of fossil fuels may provide a variety of advantages. Biofuels are created from renewable feed stocks as opposed to fossil fuels, which are created from finite resources. They might thus continue to be produced and used indefinitely. Although GHG emissions are produced throughout various phases of the manufacturing of biofuels, the EPA's (2010) analysis of the Renewable Fuel Standard (RFS) found that over a 30-year period, certain types of biofuels will produce less lifetime GHG emissions than gasoline. Several economic models that have been used in academic research suggest that biofuels may decrease lifecycle GHG emissions when compared to traditional fuels. As feed stocks for second and third generation biofuels may be cultivated on marginal land, they have a greater potential to cut GHG emissions than conventional fuels. Moreover, if there are no practical alternative applications for the wastes, there is no need for increased agricultural output in the case of waste biomass, and indirect market-mediated GHG emissions may be kept to a minimum[5], [6].

The potential for indigenous biofuel generation may result in a reduction in the importation of fossil fuels. We may be less prone to the negative effects of supply interruptions if the production and use of biofuels lessens our reliance on imported fossil fuels. Petroleum consumption overseas may rise while domestic demand declines, which would be profitable for US consumers. Using biofuels might assist in reducing certain pollution emissions. When completely burned, ethanol may lower carbon monoxide emissions. It is crucial to stress that making and utilising biofuels by themselves won't lower petroleum imports, greenhouse gas emissions, or the strain imposed on finite resources. For these advantages to materialise, there must be a parallel decrease in the production and use of fossil fuels and biofuels. These advantages would be lessened if resource needs and emissions from fossil fuels rose instead of doing so with biofuels[7].

Potential Economic Costs and Effects of the Production of Biofuel

Whether they are utilised directly for human consumption or indirectly as animal feed, many plants are employed as biofuel feedstocks. The conversion of these crops to biofuels may increase the cost of food, the amount of land required for agriculture, and the use of inputs that are harmful to the environment. Moreover, cellulosic feed stocks may compete with food production for resources like fertiliser, water, and land. Because of this, several studies contend that producing biofuels may have a number of unfavourable repercussions[8].

By discharging terrestrial carbon stores into the atmosphere, changes in land use practises may result in an increase in GHG emissions. High amounts of greenhouse gas emissions are produced by biofuel feed stocks cultivated in tropical forest-free territory, such as soybeans in the Amazon and oil palm in Southeast Asia. Even using cellulosic feed stocks has the potential to raise agricultural prices, which promotes the expansion of agriculture into undeveloped regions, increases greenhouse gas emissions, and wipes out biodiversity.

During the creation and processing of biofuels, GHGs may be emitted. When fertiliser is applied, nitrous oxide is created, a strong greenhouse gas. The majority of biorefineries run on fossil fuels. Depending on the time horizon of the analysis, some research indicates that GHG emissions from the production and use of biofuels, including those from indirect land use change, may be higher than those produced by fossil fuels. According to studies on non-GHG environmental consequences, the growth of biofuel feedstocks, particularly agricultural crops like maize and soy, may lead to a rise in water pollution from fertilisers, pesticides, and silt. If ethanol production and irrigation expand, aquifers risk drying out. Air quality may deteriorate in certain locations if the impact of biofuels on tailpipe emissions and the additional emissions produced at biorefineries raise conventional air pollution overall. Notwithstanding the broad variety of estimates in the literature, economic models demonstrate that the usage of biofuels may lead to increased agricultural prices. A 2013 research found that estimates for the impact of biofuels on maize prices in 2015 ranged from a 5 to a 53% rise.

According to the National Research Council's RFS study, the price of maize rose by 20–40% because of biofuels between 2007 and 2009. According to a working paper from the National Center for Environmental Economics (NCEE), 19 studies on average found a 2 to 3 percent rise in long-term maize prices for every additional billion gallons of corn ethanol produced. Food costs grow as a result of rising agricultural prices, although American retail food prices aren't expected to be significantly affected. Malnutrition may become more prevalent in emerging nations as food costs increase.

Biofuels are fuels that have been derived from plants and crops. Bioethanol, also known as ethanol or biodiesel, is the one that is most often extracted and utilised among these. It may be used as an alternate fuel for your automobile and is combined with gasoline. In comparison to fossil fuels, plant-based fuels have fewer carbon emissions, are renewable, and can be cultivated everywhere. In addition to bolstering a faltering economy by creating employment, biofuels also significantly reduce greenhouse gas emissions by generating less pollutants. Most people are moving to biofuels to save money and lessen their dependency on oil as crude oil prices rise daily. Wheat, maize, soybeans, and sugarcane are used to make biofuels, which are sustainable since they can be produced again as needed. Despite the fact that biofuels have several benefits over their competitors, there are some additional challenging factors that we need to consider.

Various Advantages of Biofuels

1. Efficient Fuel

In comparison to fossil diesel, biofuel is derived from renewable resources and is substantially less combustible. Its lubricating qualities are noticeably improved. Compared to regular diesel, it emits less damaging carbon. Many materials may be used in the production of biofuels. Using them has a much greater total cost-benefit ratio.

2. Cost-Benefit

Nowadays, the market price of biofuels is equal to the price of gasoline. Yet, employing them has a substantially greater cost-benefit ratio overall. They emit less emissions when burned since they are cleaner fuels. Further price reductions of biofuels are conceivable given the rising demand for them. In the RFA (Renewable Fuels Association) February 2019 Ethanol Market Forecast study, it is stated that "Ethanol continues to be the world's highest-octane, least expensive motor fuel." In addition, the U.S. Department of Energy (DOE) provided $73 million for 35 programmes involving bioenergy research and development in 2019. It attempts to "allow high-value products from biomass or waste resources" and reduce the cost of creating biopower with objectives including lowering drop-in biofuel prices. Hence, using biofuels won't put as much of a strain on your pocketbook.

3. Durability of Vehicles' Engine

Modern engine designs may be adapted to use biofuels, and they work well under most circumstances. It has greater lubricating qualities and a higher cetane rating. The engine is more durable when biodiesel is utilised as a combustible fuel. Moreover, no engine modification is required. As a result, the engine runs for longer periods of time, needs less maintenance, and reduces the total cost of a pollution test. Biofuel-compatible engines emit less pollutants than conventional diesel engines.

4. Easy to Source

Crude oil, which is a finite resource, is used to refine gasoline. While the present gas reserves will last for many years, they will eventually run out. Biofuels are produced from a variety of materials, including manure, agricultural waste, other wastes, algae, and plants raised particularly for the purpose.

5. Renewable

The majority of fossil fuels will eventually run out and burn up. The usage of biofuels is efficient in nature since the majority of the sources, such as manure, maize, switchgrass, soybeans, and waste from plants and crops, are renewable and unlikely to run out very soon. Moreover, these crops may be repeatedly planted[9].

6. Reduce Greenhouse Gases

According to studies, biofuels may cut greenhouse gas emissions by up to 65%. When fossil fuels are burned, they release a lot of carbon dioxide into the atmosphere, which is a greenhouse gas. The globe warms as a result of these greenhouse gases' ability to capture sunlight. In addition, burning coal and oil raises temperatures and contributes to global warming. People utilise biofuels all throughout the globe to lessen the effect of greenhouse emissions.

7. Economic Security

Not every nation has large crude oil reserves. The fact that they must import the oil severely hurts their economy. A nation may lessen its reliance on fossil fuels if more individuals start switching to biofuels. The demand for appropriate biofuel crops rises as a result of biofuel production, stimulating the agricultural sector. Biofuels are less costly to use as fuel for buildings, companies, and automobiles. A developing biofuel business will lead to the creation of more employment, which will safeguard our economy.

8. Reduce Dependence on Foreign Oil

Although the country's reliance on fossil fuels has decreased thanks to locally produced crops, many experts think it will take a while to find a sustainable solution to our energy problems. More alternative energy options are required as crude oil prices reach all-time highs in order to lessen our reliance on fossil fuels.

9. Lower Levels of Pollution

Biofuels are less harmful to the environment since they may be produced from renewable resources. Nonetheless, there are other factors that support the usage of biofuels. When burned, they produce less carbon dioxide and other pollutants than regular diesel. Moreover, it significantly reduces PM emissions when used. While carbon dioxide is produced as a byproduct of the manufacture of biofuels, it is usually utilised to grow the plants that will be used as fuel. As a result, it might start to resemble a self-sustaining system. Also, because biofuels degrade naturally, there is less chance that they will contaminate the land or groundwater while being transported, stored, or used.

Disadvantages of Biofuels

1. High Cost of Production

Despite all the advantages connected with them, biofuels are still relatively costly to manufacture. While there is now a relatively low level of interest and financial investment in biofuel production, it can nonetheless meet demand. If the demand rises, raising the supply will be a lengthy and costly procedure. Such a drawback continues to limit the growth of the usage of biofuels.

2. Monoculture

Monoculture is the practise of growing just one kind of crop over an extended period of time rather than a variety of crops in a farmer's fields. Growing the same crop every year may be economically advantageous for farmers, but doing so may deplete the earth of nutrients that crop rotation adds back to the soil. There are several issues in cultivating a single crop across a large area of land. Secondly, producing a single crop alters the environment in a way that gives bugs more food to choose from, and this gives them free reign to kill a whole crop.

Secondly, we could employ pesticides to address the aforementioned pests, but some of them will unavoidably develop resistance to the poisons we use to eradicate them, and some of them can live in a single field of crops. When we decide to adapt a crop so that it is resistant to the pest without the need for pesticides, the next issue with genetic engineering arises. The issue still exists since it's still possible that at least some pests aren't impacted by the update. So, biodiversity, or just having a lot of various kinds of plants and animals nearby, is the key to good agriculture everywhere.

3. Use of Fertilizers

Crops are used to make biofuels, and for better growth, these crops need fertilisers. The drawback of utilising fertilisers is that they may lead to water contamination and have negative impacts on the ecosystem. Fertilizers include phosphate and nitrogen. They might be transported from the ground to ponds, rivers, or lakes nearby.

4. Shortage of Food

Plants and crops with high sugar content are used to produce biofuels. Yet, the majority of these plants are also grown for food. Even if plant waste may be utilised as a raw material, there will still be a need for such food crops. It would occupy farmland that would otherwise be used by other crops, which might lead to a variety of issues.

Although there may not be a severe food crisis, using existing land for biofuels would undoubtedly hinder agricultural growth at the moment. They are quite concerned that the rising usage of biofuels may simply lead to an increase in food costs. Algae is often preferred since it can thrive in harsh environments and has less of an influence on how much land is used. Yet, the utilisation of water is the issue with algae.

5. Industrial Pollution

When burned, biofuels have a lower carbon impact than conventional fuels. Yet, the method by which they are made compensated for that. A lot of water and oil are required for production. It is commonly recognised that big-scale biofuel production facilities produce enormous volumes of emissions and small-scale water contamination. Until more effective manufacturing methods are used, the total amount of carbon emissions does not significantly decrease. Moreover, it results in a rise in NOx.

The use of biofuels in place of fossil fuels has the potential to mitigate some of the negative effects of fossil fuel extraction and usage, including exhaustible resource depletion, conventional and greenhouse gas (GHG) pollution emissions, and dependency on unreliable foreign sources. Moreover, the need for biofuels may boost agricultural revenue. On the other side, research indicates that the production of biofuels may have a number of negative repercussions since many of the feed stocks for biofuels need land, water, and other resources. Changes in land use patterns that might lead to an increase in greenhouse gas emissions, stress on water supplies, pollution of the air and water, and higher food prices are some potential negative effects. On an energy-equivalent basis, biofuels may produce even more greenhouse gases (GHGs) than certain fossil fuels, depending on the feedstock, the production method, and the time horizon of the study. However, in order for biofuels to be competitive economically with fossil fuels, they often need subsidies and other market interventions, which causes economic deadweight losses.

Sugar crops (sugarcane, sugarbeet), starch crops (corn, sorghum), oilseed crops (soybean, canola), and animal fats are used to make first generation biofuels. Bioalcohols such as ethanol, butanol, and propanol are produced by the fermentation of sugar and starch crops. Biodiesel may 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. In 2013, there were more than 2300 E85 fueling locations throughout the Country (US Department of Energy).

Cellulose, which may be found in non-food crops and waste biomass including maize stover, corncobs, straw, wood, and wood byproducts, is the primary component of second generation biofuels, also known as cellulosic biofuels. Algae is used as a feedstock for third generation biofuels. Although commercial production of algal biofuels has not yet started, commercial production of cellulosic biofuel started in the US in 2013.

Potential economic benefits of biofuel production

The use of biofuels instead of fossil fuels might provide a variety of advantages. Biofuels are created from renewable feedstocks, unlike fossil fuels, which are finite resources. As a result, their manufacturing and usage might theoretically continue forever. EPA's (2010) study of the Renewable Fuel Standard (RFS) predicted that some kinds of biofuels might produce fewer lifetime GHG emissions than gasoline over a 30-year time horizon, despite the fact that the manufacture of biofuels produces GHG emissions at various phases of the process. Several economic models used in academic research have also shown that biofuels may reduce lifecycle GHG emissions when compared to traditional fuels. Since feed stocks may be produced on marginal land, second and third generation biofuels offer a large potential to cut GHG emissions in comparison to conventional fuels. Moreover, if there are no alternative profitable applications for the wastes, there is no need for extra agricultural output in the case of waste biomass, and indirect market-mediated GHG emissions may be kept to a minimum.

Since biofuels may be generated locally, the importation of fossil fuels may decline. We may be less sensitive to the negative effects of supply interruptions if biofuel production and usage decreases our reliance of imported fossil fuels (US EPA 2010). Increasing petroleum consumption overseas might result from decreasing domestic demand for petroleum, which would benefit American consumers economically. Certain pollution emissions might be reduced by biofuels. Particularly when burned completely, ethanol may lower carbon monoxide emissions (US EPA 2010). It is important to stress that the production and use of biofuels alone will neither lower petroleum imports, cut GHG emissions, or relieve the strain on finite resources. For these advantages to materialise, there must be a simultaneous decrease in the production and use of fossil fuels as well as biofuels. If biofuel emissions and resource demands increase rather than replace those of fossil fuels, these advantages would be lessened[10].

Potential economic dis-benefits and impacts of biofuel production

Several crops that would typically be utilised directly for human consumption or indirectly as animal feed are included as biofuel feedstocks. The conversion of these crops to biofuels may increase the amount of land used for agriculture, the amount of polluting inputs used, and the cost of food. Moreover, cellulosic feed stocks may compete with food production for resources like land, water, and fertiliser. Because of this, some study contends that the production of biofuels may result in a number of unfavourable changes.

By releasing terrestrial carbon reserves into the atmosphere, changes in land use practises might boost GHG emissions. Particularly large GHG emissions are produced by biofuel feed stocks cultivated on land cleared of tropical forests, such as soybeans in the Amazon and oil palm in Southeast Asia. Even using cellulosic feed stocks may raise crop prices, which encourages agriculture to spread out into undeveloped territory and results in GHG emissions and biodiversity losses.

Practices used in the manufacture and processing of biofuels may potentially emit GHGs. When fertiliser is applied, nitrous oxide is released, a strong greenhouse gas. The majority of biorefineries run on fossil fuels. Depending on the time horizon of the study, some research indicates that GHG emissions from biofuel production and usage, including those from indirect land use change, may be greater than those produced by fossil fuels. The development of biofuel feedstocks, especially agricultural crops like maize and soy, may result in increased water pollution from fertilisers, pesticides, and silt, according to studies on non-GHG environmental effects (NRC 2011). Aquifers may get depleted as irrigation and ethanol production increase (NRC 2011). If the effect of biofuels on tailpipe emissions and the extra emissions produced at biorefineries raise net conventional air pollution, air quality may also deteriorate in certain areas (NRC 2011).

While there is a broad variety of estimates in the literature, economic models demonstrate that the usage of biofuels may lead to increased agricultural prices. For instance, estimates for the impact of biofuels on maize prices in 2015 ranged from a 5 to a 53 percent rise, according to a 2013 research. Many analyses found a 20–40% rise in maize prices from biofuels between 2007 and 2009, according to the National Research Council's (2011) study on the RFS. According to a working paper from the National Center for Environmental Economics (NCEE), 19 studies on average showed a 2 to 3 percent rise in long-term maize prices for every billion more gallons of corn ethanol production. Increased agricultural prices result in higher food costs, however the effects on American retail food are predicted to be minimal (NRC 2011). In poor nations, rising agricultural prices can result in greater rates of malnutrition.

U.S. policy approaches to support biofuel production

The Energy Policy Act of 2005 uses a range of financial incentives to support the development of biofuels, including grants, income tax credits, subsidies, and loans. By 2012, 7.5 billion gallons of renewable fuels must be blended with gasoline yearly, according to the Renewable Fuel Standard that was created. Similar financial incentives were included in the Energy Independence and Security Act of 2007 (EISA). In order to enhance biofuel output to 36 billion gallons, EISA increased the Renewable Fuel Standard. For the latter objective, cellulosic biofuel or advanced biofuels made from feed stocks other than cornflour must account for 21 billion gallons. In order to reduce GHG emissions, the Act mandates that cellulosic biofuels must reduce emissions by 60%, biodiesel must reduce emissions by 50%, and conventional renewable fuels such as corn starch ethanol must reduce emissions by at least 20% when compared to lifecycle emissions from fossil fuels. For research and development, biorefineries that utilise less than 80% of fossil fuels to run, and commercial uses of cellulosic ethanol, EISA also offers monetary prizes, grants, subsidies, and loans. EISA is only one of several laws and regulations that have promoted the development and use of biofuels in the US in recent years. Nowadays, advanced biofuels like cellulosic and biodiesel are supported by tax incentives.

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CHAPTER 5

DIFFERENT TYPES OF SECOND GENERATION BIOFUELS

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Advanced biofuels, also known as second-generation biofuels, are currently fuels that can be made from a range of non-food biomasses. The word "biomass" in this sense refers to plant and animal waste that is used primarily as a fuel source. First-generation biofuels are primarily converted into bioethanol and biodiesel from edible oil feed stocks like rapeseed and soybean oil, as well as sugar-starch feed stocks like sugarcane and maize. When different feed stocks are used to make second-generation biofuels, more advanced technologies could be required to turn them into useable energy. Examples of second generation feed stocks include agricultural waste or leftovers, lignocellulosic biomass, woody crops, and specialised non-food energy crops grown on marginal land unsuitable for food production. The controversy over whether or not to use farms or crops for the production of biofuels at the cost of the food supply has fueled the development of second-generation biofuels[1].

1. **Waste vegetable oil:** Although having little nutritional value, vegetable oil waste might help reduce pollution. The biofuels generated from this biomass may be used in certain diesel engines without blending or refining. One advantage of such a substance is that it doesn't pollute the environment with sulphur, doesn't disrupt arable crops, and doesn't cost anything to utilise the land. Nevertheless, there are certain limitations, such as the difficulty in gathering this biomass due to its dispersion over many areas and the possibility that it might damage diesel engines if it is not well cleaned before use[2], [3].
2. **Grasses:** While they are easy to sow, their seedlings need to be carefully guarded against the much tougher weed species that are naturally present nearby. They also have some disadvantages, such as: (a) using direct biomass occasionally works well, but then using grasses to make biodiesel is unfavourable; (b) the process to turn grasses into alcohol is also more difficult than others; (c) substantial humidity levels largely suit in their growing and they can't grow on arid soils; and (d) none can grow in arid soils[4], [5].
3. **Seed crops:** Even though a large amount of it may be grown on marginal land, the energy value of this biomass is much lower than that of biofuels made from biomass from soybeans. Further challenges have been found while cultivating these crops in fields, considerably diminishing their appeal. Municipal waste is the kind of biomass that is used to create biofuels. All forms of solid waste are included, including garbage, grass and leaf clippings, and landfill gas. The second generation of biofuels provides the following fuels.
4. **Cellulosic ethanol:** To create it, cellulose and hemicellulose from lignocellulosic feedstock were separated into their individual sugars, and then those sugars were fermented.

5. **Biobutanol:** Similar to how ethanol is made, it is also manufactured using various microorganisms. While it generates less fuel than ethanol at the moment, biobutanol may be used to substitute gasoline without mixing[6], [7].
6. **Biomass to liquids (BTL) technology**: Gaseous cations are used to create syngas, and the Fischer-Tropsch process is then used to create gasoline, diesel, and jet fuel. Alcohol: Syngas may be catalytically synthesised into methanol, dimethyl ether (DME), and mixed alcohols. Alcohol may also be produced by certain specialised bacteria that digest syngas.
7. **Biosynthetic natural gas (Bio-SNG):** In any event, gasification may be used to produce clean, renewable natural gas that can be used to catalyse methanation. Microorganisms may be used in an anaerobic digestion process to produce biogas. Methane and carbon dioxide make up the majority of this gas' chemical constituents. By pumping the gas into an already-existing natural gas cylinder, the gas may then be utilised in automobiles as compressed natural gas (CNG) or liquefied natural gas (LNG).
8. **Hydrotreated vegetable oil:** It is utilised as a diesel alternative because of the highly sought-after fuel's characteristics, such as its high cetane, lack of odour, and lack of sulphur. Pyrolysis, also known as biocrude, is the process of quickly heating ash to a temperature of around 1,000 oF and then instantly cooling it. Crude oil is refined and upgraded to provide liquid fuels for fixed or mobile applications (boilers, turbines).
9. **Advantages:** Since they outperform first-generation biofuels in a variety of ways, second-generation biofuels are more intelligent. In they use a non-food feedstock (like lignocellulosic biomass materiel, for example, earth crops deposits, backwoods items buildups, or quickly developing gave energy crops). As they are not directly generated from food crops like maize and soybean, second-generation biofuels differ from first-generation biofuels. The fuel is a direct replacement for conventional oil-based fuels; there are no restrictions on blending; second-generation biofuels are more environmentally friendly and produce fewer ozone-harming substances; they don't produce co-products like animal feed; and there are fewer land requirements for this situation, reducing competition for space with other forms of energy.
10. **Disadvantages:**Second-generation fuels are not yet being produced on a significant commercial scale. Due to high production costs and technical uncertainty, current systems for harvesting, storing, and distributing biomass are inadequate for processing and distributing biomass on a large scale; a clear and long-term policy framework is required to ensure that business and financiers can invest with confidence; and agricultural/forestry sector changes are necessary to supply biomass feed stock from residues and crops, which implies a significant change in the current business environment.
11. **Water Use:** Irrigating the biofuel crops requires a lot of water, which, if not used carefully, might put a burden on local and regional water supplies. Massive amounts of water are utilised in the production of corn-based ethanol to satisfy local demand for biofuels, which may impose an unsustainable strain on the area's water resources.
12. **Future Rise in Price:** The technology used to produce biofuels today is not as effective as it might be. Researchers are working to create more efficient ways to extract this fuel. The expense of research and upcoming installation, however, will cause a huge increase in the price of biofuels. Nowadays, the costs are affordable and on level with those of fuel. The usage of biofuels can have the same negative economic effects as the current rise in petrol costs if prices continue to rise.

13. **Changes in Land Use:** When natural flora is removed from land in order to develop a biofuel feedstock, three types of ecological harm result.

    i. In the first place, the destruction of local habitat, animal habitations, and micro-ecosystems results in harm and lowers the general health of the area's natural resources. Since CO2 is retained and never released during combustion as it is with fuel stock, the natural forest nearly always performs better at removing CO2 from the environment than a biofuel feedstock.
    ii. The harm is also done in the form of the accumulated carbon debt. Before any biofuel is created, the region already has a net positive GHG output since it produces greenhouse gases in order to clear the land, prepare it for farming, and plant the crop. According to estimates, clearing native forests might result in a carbon debt that will take 500 years to pay off.
    iii. Lastly, converting land to an agricultural use nearly typically entails the application of fertilisers to maximise yields per square foot. Runoff and other agricultural contamination are the issue. Hence, expanding agriculture is likely to harm rivers and energy needed in treatment facilities, and other mitigating measures result in an even greater carbon debt.

14. **Global Warming:** Burning biofuels, which are mostly made of carbon and hydrogen, results in the production of carbon dioxide, which accelerates global warming. Although it is true that biofuels emit less greenhouse gases (GHG) than fossil fuels, this can only help to reduce global warming rather than halt or reverse it. Hence, although biofuels may be able to reduce our energy consumption, they won't be able to resolve all of our issues. It can only act as a temporary stand-in while we invest in other technologies.
15. **Weather Problem:** In colder climates, biofuel is less effective. Compared to fossil fuel, it is more prone to draw moisture, which is problematic in cold weather. Moreover, it causes the engine filters to clog by promoting microbial development in the engine.

Advanced biofuels are another name for second generation biofuels. The fact that the feedstock utilised to produce second generation biofuels is often not food crops sets them apart from first generation biofuels. Food crops can only function as second generation biofuels if they have previously served their intended purpose as food. As waste vegetable oil has been utilised and is no longer suitable for human consumption, it is an example of a second generation biofuel. On the other hand, virgin vegetable oil would be a first generation biofuel.

Second generation biofuels are produced using various feedstocks, hence various technologies are often employed to extract energy from them. This does not exclude the direct combustion of second generation biofuels as biomass. Moreover, a number of second-generation biofuels, such as switchgrass, are grown expressly for direct biomass use.

Second Generation Extraction Technology

Second generation feedstock are often handled in a different way than first generation biofuels. This is especially true for the feedstock lignocellulose, which often has to go through a number of processing stages before being fermented a first generation technique into ethanol. The following is a summary of second-generation processing technology.

Thermochemical Conversion

Gasification is the name for the first thermochemical pathway. The technique of gasification is not new and has been widely used to traditional fossil fuels for a number of years. Technologies from the second generation of gasification have been somewhat modified to account for the variations in biomass supply. Carbon-based materials are transformed into carbon dioxide, hydrogen, and carbon monoxide by gasification. In contrast to combustion, this method uses less oxygen. Synthesis gas, often known as syngas, is the gas that results. Then, energy or heat are produced using syngas. This technique makes use of wood, black liquor, brown liquor, and other feedstock.

Pyrolysis is a second thermochemical pathway. Moreover, the use of pyrolysis with fossil fuels has a lengthy history. Pyrolysis takes place without oxygen and often with the help of an inert gas like halogen. Typically, the fuel is transformed into two products: tars and char. Wood and many other energy crops may be used as the feedstock for pyrolysis to create bio-oil. Torrefaction is a third thermochemical process that, while it occurs at lower temperatures, is extremely similar to pyrolysis. Better fuels are often produced as a result of the process for use in gasification or combustion. Biomass feedstock is often transformed by torrefaction into a form that is simpler to transport and store.

Biochemical Conversion

For the purpose of producing biofuel from second generation feedstock, a variety of biological and chemical processes are being modified. For second generation feedstock like landfill gas and municipal garbage, fermentation using distinct or genetically modified bacteria is very common.

Common Second Generation Feedstock

A source must not be fit for human consumption in order to be considered a second generation feedstock. While it is not required, it usually goes without saying that second generation feedstock should be cultivated on what is referred to as marginal land. Land that cannot be efficiently exploited to raise "arable" crops, or food, is referred to as marginal land. Unmentioned here is the fact that second-generation feedstock shouldn't need a lot of water or fertiliser to flourish, which has led to disappointment in a number of second-generation crops.

Grasses

In contrast, a variety of grasses, including Switchgrass, Myscanthus, Indiangrass, and others, have received attention. As various grasses are better suited to different climates, the choice of specific grass often relies on the region. The plant Switchgrass is preferred in the US. The preferred plant in Southeast Asia is myscanthus.

The advantages of grasses are:

- They are perennial and so energy for planting need only be invested once
- They are fast growing and can usually be harvested a few times per year
- They have relatively low fertilizer needs
- They grow on marginal land

- They work well as direct biomass
- They have a high net energy yield of about 540%

The disadvantages of grasses are:

- They are not suitable for producing biodiesel
- They require extensive processing to made into ethanol
- It may take several years for switch grass to reach harvest density
- The seeds are weak competitors with weeds. So, even though they grow on marginal land, the early investment in culture is substantial
- They require moist soil and do not do well in arid climates.

The major disadvantage of grasses and the reason they are not more widely used as second generation biofuels is the need for water. Despite this drawback, grasses are useful in a variety of contexts, especially in the United States.

Jatropha and other seed crops

The manufacturing of biodiesel benefits from the utilisation of seed crops. Early in the twenty-first century, proponents of biodiesel grew very enamoured with a plant known as jatropha. The plant was acclaimed for its per-seed yield, which could provide returns of up to 40%. Jatropha seems to be a miracle crop in comparison to the 15 percent oil present in soybeans. The idea that I might be cultivated on marginal soil added to its attraction. It turns out that growing Jatropha on poor soil significantly reduces oil output. Recently, there has been a sharp decline in interest in jatropha. The destiny of Jatropha has been shared by other, comparable seed crops. Rapeseed, Cammelina, and Oil Palm are a few examples. In each instance, it was rapidly understood that the early advantages of the crops would be outweighed by the have to utilise agricultural land in order to produce adequate yields[8].

Waste Vegetable Oil (WVO)

About a century has passed since WVO were first utilised as fuel. In actuality, vegetable oil was the only fuel used by some of the first diesel engines. Since waste vegetable oil has reached the end of its useful life as a food source, it is regarded as a second generation biofuel. In fact, recycling it for fuel may lessen its total effect on the environment.

The advantages of WVO are:

- It does not threaten the food chain
- It is readily available
- It is easy to convert to biodiesel
- It can be burned directly in some diesel engines
- It is low in sulphur
- There are no associated land use changes

The disadvantages of WVO are:

- It can decrease engine life if not properly refined

WVO is arguably one of the finest sources of biodiesel and can satisfy a large portion of the demand for it if just blending is necessary. Because it is dispersed globally in eateries and homes, collecting it might be challenging.

Municipal Solid Waste

Grass and yard clippings, landfill gas, and human waste are examples of what is meant by this. In many instances, these energy sources are just being wasted outright. The carbon footprint of these fuels is far lower than that of conventionally obtained fossil fuels, even if they are not as pure as solar and wind energy. Municipal solid waste is often burnt to provide both heat and power in cogeneration units.

The usage of biofuels is expanding globally since there is a rising need for a cleaner, greener alternative to burning conventional fossil fuels. While the production of second generation biofuels from microorganisms and algae is still in the early stages of research, the production of biofuels from solid biomass crops is well established. Since it has long been known that biofuels can lessen the dangerous greenhouse gas emissions released into the atmosphere as a result of burning fossil fuels, it is anticipated that bioenergy products will play a significant role in the world's energy supply and significantly contribute to meeting the planet's constantly rising energy demand.

For a very long time, scientists have understood how to transform different forms of organic material into a liquid fuel termed "biofuel." Various types of grasses, shrubs, trees, or other herbaceous biomass, as well as some types of seaweed and algae, have all been grown and harvested specifically for conversion into various types of biofuel to power cars, boats, planes, and the internal combustion engine to generate electricity. These crops have all been tested over the years. Yet, producing biofuel in sufficient numbers has always been more difficult and costly than burning coal or oil. By adopting more efficient farming practises or a variety of biomass feedstocks, the cost of producing biofuels may be reduced.

By boosting output without the negative economic and environmental effects of earlier fuels, new technology and procedures are the key to improving both food and liquid biofuel production, leading to what is now referred to as "second generation biofuels." Despite the fact that the production of bioenergy on a global scale has been ongoing and evolving for the past few decades or so, the growing biofuel industry has recently brought to light some significant concerns regarding the viability of many "first-generation biofuels" that compete for available agricultural land as well as their effects on the prices of cereals and other starch-rich crops, sugars, and oil crops on a global scale.

Biofuels Land Use

The key challenge for many scientists and individuals has always been how to create a biofuel source that does not interfere with the global food chain and is also affordable, sustainable, and effective in terms of energy output, carbon footprint, and minimum environmental impact. With the development of so-called Second Generation Biofuels, sustainable, low-carbon fuels that do not clash with food supplies or need more land are being pursued. These second generation biofuels are designed to circumvent all the drawbacks of so-called first-generation energy crops' "food versus fuel" conundrum.

The term "second generation biofuels" refers to bioenergy crops produced from biomass feedstock that has little to no nutritional value, such as residue materials, agricultural wastes, and slurry wastes, or simply by planting quickly growing trees, shrubs, and various types of grass on otherwise unproductive waste land. Nevertheless, as oil prices declined, automobile fuel economy increased, and consumer interest in alternative fuels decreased, the expected expansion in global biofuel production primarily biodiesel and bioethanol seems to have come to a halt. Also, since consumer demand for less expensive home heating fuel has been a significant driver of the renewable fuels business, the conversion of the diverse wood biomass feedstock for sale into the more profitable biomass and peat pellet market has skyrocketed.

Government regulations and tax breaks, which have been employed in a number of nations to encourage the growth of second generation biofuels production in an effort to lower biofuel costs at the pump, are now driving the potential market for bioliquid products. In a number of nations, the large buying power of governments has also been effectively exploited to increase the market share for different bioenergy products. The desire for bioenergy might, however, grow increasingly price-driven as energy costs rise. Fracking's widespread and contentious usage has also enabled several nations to access hitherto untapped oil and gas reserves, offering another route away from coal-burning and towards energy independence. The future of second generation biofuels will ultimately be influenced by the continuous development of bioenergy and bioliquid products, which requires overcoming some of these obstacles and a number of other considerations. Use of the available arable area for their cultivation, improved agricultural production techniques, and the creation of more sophisticated biofuels technology, in particular.

Types of Biofuels

Two major categories of biofuel feedstock, referred to below as "first" and "second" generation feedstock, make up the numerous forms of biofuels now under development.

- **First Generation Biofuels:** These are the original biofuels, manufactured using traditional bioenergy methods from agriculturally produced maize, soya, rapeseed, vegetable oils, or animal and mineral fats. They may be split into two main groups: Bioethanol and biodiesel.
- **Second Generation Biofuels:** They are created using a range of non-food crop types through procedures. Waste biomass, waste from the production of wheat and maize, woody cellulose, and lignin polymers, as well as other animal slurries and liquid wastes, are all examples of second generation fuels that are more effective and ecologically beneficial.
- **Third Generation Biofuels:** This is the most recent innovation in biochemical biomass technology, manufactured from crops grown in laboratories such as perennial grasses, synthetic bacteria, enzymes, and live microalgae, all of which need additional financing, development, and processing to be economically viable on a much larger scale. These microalgae crops are environmentally friendly since they decompose.

There is starting to be a differentiation between first and second generation biofuels since not all biofuels are created equally. Today, second generation biofuel production processes based on the conversion of cellulosic resources, such as quick-growing trees and grasses from non-food renewable sources, are beginning to have a positive impact. These processes can help limit the direct competition that currently exists for the use of land between food and fuel.

The main focus is still on increasing their energy efficiency during combustion, even though "second generation biofuels" are still being developed and there is a better understanding of the overall feedstock supply chain, whether it comes from crop and forest residues or from microalgae that have been grown biochemically[9].

Second generation biofuels may not be widely accessible for some time due to the long and expensive process of bringing these bioenergy fuels to market. Yet, they are nevertheless seen as significant potential future contributions to fossil fuel alternatives. However, even if second generation biofuels production processes could be economically scaled up to increase yields and significantly reduce the millions of litres of conventional oil burned daily, the biofuel factories would still need to be able to access the staggering amounts of energy crops and feedstock they need. Although it is true that billions of tonnes of agricultural waste are generated annually around the globe, this dry stuff is dispersed widely, making it difficult to collect and transport. The planting of huge rural areas with quickly growing trees, shrubs, and enormous reed-like grasses in order to produce biofuel has drawn criticism from several environmental organisations[10], [11].

They worry that these plants' seeds may contaminate the neighbourhood and convert them into invasive weeds. Then there is a brand-new biofuel debate that pits "flora against fuel." There has only ever been one fuel that powers the whole global transportation system, and there doesn't appear to be a practical substitute for our addiction to oil today. Together with the total need for energy, the demand for oil is anticipated to increase for many decades to come. Whether used to replace gasoline (bioethanol) or diesel (biodiesel), biofuels may and should be seen as a crucial component of the global energy mix even if they do not totally replace oil.

While the ability of biofuels and bio-based products to decrease greenhouse gas emissions when compared to fossil fuels is widely acknowledged, their production and usage are not without environmental drawbacks. Carbon emissions are not necessarily lower than for conventional fuels, depending on the crop variety and other variables. Moreover, biofuels derived from agricultural sources raise food costs and make them more volatile, which has a negative effect on food security. Second-generation biofuels, however, are paving the way to solving these problems.

Order your copy of the book about the production of various biofuels from unconventional bio-feed stocks like algae and vegetable oils from Amazon right away to learn more about Second Generation Biofuels and how you can use them to power your car and home, or to examine the benefits and drawbacks of using biodiesel and bioethanol as an alternative to conventional fossil fuel oils. In Figure shown the structure of the biofuels.

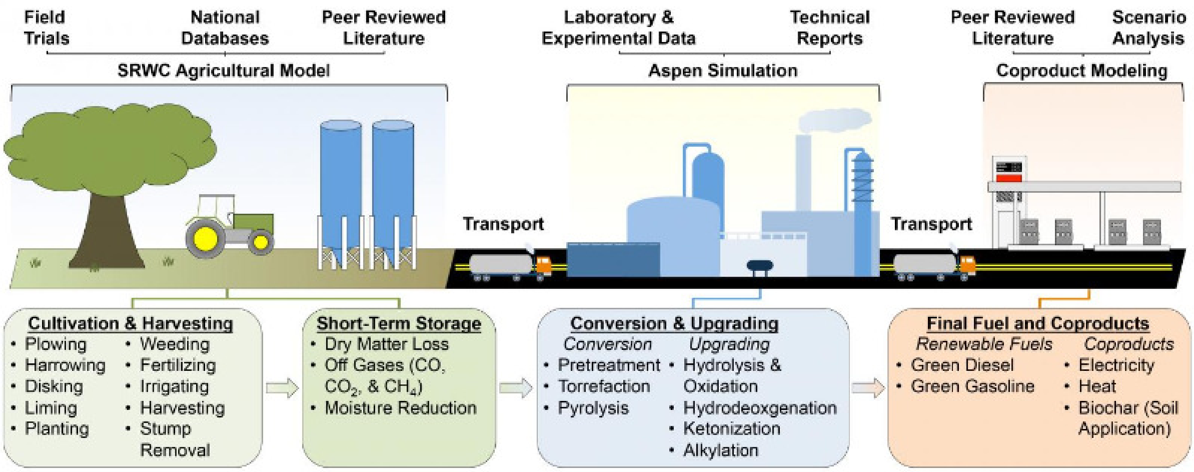

Figure 1: Illustrate the structure of the biofuels.

Many studies have raised serious questions about the potential of maize ethanol to slow global warming and lessen reliance on fossil fuels. According to some research, biofuels like maize ethanol would not reduce greenhouse gas emissions when compared to petroleum fuels following a complete life cycle evaluation, which examines the environmental effect across all phases of a product's existence. An investigation of the whole life cycle effects of a possible "second-generation biofuel" made from short-rotation oak by a team from the Universities of Pittsburgh and Oklahoma was just published in the Royal Society of Chemistry journal Energy & Environmental Science. A sustainable fuel supply may be offered by second-generation biofuels produced from managed trees and perennial grasses, according to the research.

The study "Multistage torrefaction and in situ catalytic upgrading to hydrocarbon biofuels: analysis of life cycle energy use and greenhouse gas emissions" adopted a novel strategy for the production of second-generation biofuel while also thoroughly accounting for all the steps involved in the entire supply chain. According to research co-author and associate professor of civil and environmental engineering at the University of Pittsburgh, Vikas Khanna, "Corn ethanol environmental implications weren't extensively examined until after its commercialization." The amazing thing about this initiative is that it tackles problems regarding the sustainability of new fuel sources across their whole life cycle before they arise in the future.

First-generation (or food-based) biofuels were subject to a five-year ban by the United Nations in 2007 due to worries that they would deplete farmland and produce a global food scarcity. The research by Dr. Khanna and his colleagues selected oak tree wood since it can be gathered all year long and there is no need for extensive storage facilities. Since they don't originate from food crops like maize and soy, second-generation biofuels are different from first-generation biofuels, according to Dr. Khanna. They consist of perennial grasses, woody crops, agricultural and forestry wastes, and industrial wastes. The Energy Return on Investment (EROI) ratio is a crucial indicator for assessing the usefulness of fuel.

Petroleum crude production continues to have a high energy return on investment (EROI), which stands at approximately, or 11 units of energy for every unit invested. The EROI, however, has been declining since 1986 and will only become worse as access to and scarcity of fossil fuels increase. While examining potentially useful energy sources, experts aim for a higher ratio. For instance, the EROI of ethanol produced from corn is. According to the research, multistage second-generation biofuel systems have an average EROI that varies from 1.32:1 to 3.76:1.

According to the Energy Independence and Security Act of 2007, in order to qualify for financial incentives from the government, cellulosic biofuels, like the ones employed in the research, must outperform the greenhouse gas emissions of fossil fuels by decreasing relative emissions by 60 percent. The research went above and above the required standards, demonstrating an 80% decrease in greenhouse gas emissions when compared to the benchmark petroleum diesel. Also, compared to a single-stage pyrolysis system, there was a 40% decrease in hydrogen use.

Pyrolysis, according to Dr. Khanna, is the process of heating biomass to high temperatures without oxygen in order to produce ethanol. "A significant amount of carbon will be lost if it's done rapidly and in one step. Our studies shown that a multistage, lower temperature method of pyrolysis may lengthen the carbon chain, produce more liquid fuel, and enhance the overall process' energy production.”

- Advanced biofuels, commonly referred to as second-generation biofuels, are fuels that may be produced from a variety of non-food biomasses. In this context, the term "biomass" refers to plant matter and animal waste that is specifically utilised as a fuel source.
- Sugar-starch feed stocks (such as sugarcane and maize) and edible oil feed stocks (such as rapeseed and soybean oil) are used to make first-generation biofuels, which are typically turned into bioethanol and biodiesel, respectively.
- Since second-generation biofuels are produced using various feedstocks, additional technologies may be needed to convert them into usable energy. Agricultural waste, lignocellulosic biomass, woody crops, and specialised non-food energy crops cultivated on marginal land unsuitable for food production are examples of second generation feedstocks.

Second-generation biofuels is a catch-all phrase that refers to both the 'advanced' technology used to convert feed stocks into biofuel and, if appropriate, the use of non-food crops, biomass, and wastes as feed stocks in'standard' biofuels processing processes. There is a lot of misunderstanding as a result. The difference between second-generation feed stocks and second-generation biofuel processing systems must be made for this reason. Since the food vs. fuel debate over the possibility of using farms or crops for the production of biofuels at the expense of the food supply, there has been increased interest in the development of second-generation biofuels. Wide-ranging opinions are expressed in the lengthy, contentious biofuel and food price argument that has been going on in the literature. Since the use of food crops for the production of first-generation biofuels raised worries about food security, second-generation biofuel technologies were created to permit the use of non-food biofuel feedstocks. The utilisation of land for food crops might become competitive if biomass from edible food sources is diverted to the production of biofuels.

Similar to how beer and wine are made, first-generation bioethanol is created by fermenting plant-derived carbohydrates into ethanol (see Ethanol fermentation). Food and fodder crops including sugar cane, maize, wheat, and sugar beet must be used for this. The worry is that if these food crops are utilised to produce biofuel, food prices may increase and there may be shortages in certain nations. Fertilizer requirements for corn, wheat, and sugar beet may also be considerable, limiting the amount of greenhouse gas emissions that can be reduced. A first-generation biofuel is sometimes regarded as biodiesel created by transesterification of rapeseed oil, palm oil, or other plant oils.

The objective of second-generation biofuel processes is to increase the amount of biofuel that can be produced sustainably by using biomass made of switchgrass, grass, jatropha, whole-crop maize, miscanthus, and cereals that bear little grain, as well as other non-food crops like switchgrass, grass, stems, leaves, and husks that are left over after the food crop has been extracted.The challenge in extracting useable feed stocks from this woody or fibrous biomass, which is mostly made up of plant cell walls, is one that second-generation biofuel methods are tackling. All vascular plants' usable sugars are contained inside the complex carbohydrates (polymers of sugar molecules) hemicellulose and cellulose, but the phenolic polymer lignin renders them unavailable for immediate use. By utilising enzymes, steam heating, or other pre-treatments to separate the sugar molecules from the carbohydrates, lignocellulosic ethanol is produced. Similar to first-generation bioethanol production, these sugars may subsequently be fermented to make ethanol. Lignin is a by-product of this procedure. Lignin may be used as a carbon-neutral fuel to provide heat and electricity for the processing facility as well as perhaps for nearby residences and commercial establishments. Using a variety of feedstocks, thermochemical reactions (liquefaction) in hydrothermal media may yield liquid oily products that have the potential to replace or supplement fuels. These liquid goods, however, fall short of biodiesel or diesel criteria. Products of liquefaction may have their qualities for use as fuel improved by one or more physical or chemical treatments. The primary second-generation pathways that are presently being developed are described in the next subsections.

1. Thermochemical routes

Carbon-based materials may be heated to high temperatures either with or without oxygen, air, or steam (pyrolysis) (gasification). A combination of gases, including hydrogen, carbon monoxide, carbon dioxide, methane, and other hydrocarbons, as well as water, are produced by these thermochemical reactions. A solid char is also created during pyrolysis. A variety of fuels, including ethanol, synthetic diesel, synthetic gasoline, and jet fuel, may be made from the gas by fermentation or chemical synthesis. There are other lower temperature methods, between 150 to 374 °C, that break down biomass in water with or without additions to create sugars.

2. Gasification

Technologies for gasification of common feed stocks like coal and crude oil are well known. The gasification of waste wood, agricultural and forestry wastes, energy crops, and alcoholic beverages are all examples of second-generation gasification technology. Output is often syngas for further synthesis to, for example, Fischer-Tropsch products like gasoline through catalytic conversion of dimethyl ether, diesel fuel, biomethanol, BioDME (dimethyl ether), or biomethane (synthetic natural gas). Syngas may also be utilised to produce heat and to create mechanical and electrical energy using gas turbines or gas motors.

3. Pyrolysis

A well-known method for the degradation of organic material at high temperatures without oxygen is pyrolysis. Forest and agricultural waste, wood scraps, and energy crops may be utilised as feedstock in second-generation biofuel applications to create things like bio-oil for fuel oil uses. For bio-oil to be appropriate as a feedstock in a refinery to replace crude oil, it often needs extensive extra processing.

4. Torrefaction

Torrefaction is a kind of pyrolysis that normally occurs at temperatures between 200 and 320 °C. The output and feed stocks are identical to those for pyrolysis.

5. Hydrothermal liquefaction

Similar to pyrolysis, hydrothermal liquefaction may also treat wet materials. The process normally takes place at atmospheric pressures and at moderate temperatures of up to 400 °C. Hydrothermal liquefaction is a promising method for creating fuel and chemical production feedstock due to its versatility in handling a variety of materials.

6. Biochemical routes

Second-generation biofuels are being created by the adaptation of chemical and biological procedures that are already in use in other fields. Pre-treatment is often used in biochemical processes to quicken the hydrolysis step that separates lignin, hemicellulose, and cellulose. The cellulose fractions may be fermented into alcohols once these constituents have been separated. Energy crops, agricultural and forestry waste, food industry and municipal biowaste, as well as other sugar-containing biomass, are examples of feedstocks. Products for use in transportation include alcohols (such as ethanol and butanol) and other hydrocarbons.

Types of Biofuel

The following second-generation biofuels are currently being developed, despite the fact that most or all of them are made from intermediate products like syngas utilising procedures that are the same for first-generation, second-generation, and traditional feedstock technologies. Instead of the final off-take, the distinctive element is the technology used to produce the intermediate product. A gas-to-liquid (GtL) process is one that converts gas, often syngas, into liquid fuels. The process is also known as "biomass-to-liquids" when biomass serves as the fuel source for the generation of gas (BTL).

From syngas using catalysis

- Biomethanol can be used in methanol motors or blended with petrol up to 10–20% without any infrastructure changes.[10]
- BioDME can be produced from Biomethanol using catalytic dehydration or it can be produced directly from syngas using direct DME synthesis. DME can be used in the compression ignition engine.
- Bio-derived gasoline can be produced from DME via high-pressure catalytic condensation reaction. Bio-derived gasoline is chemically indistinguishable from petroleum-derived gasoline and thus can be blended into the gasoline pool.[11]

- Biohydrogen can be used in fuel cells to produce electricity.
- Several Alcohols (i.e., mixture of mostly ethanol, propanol, and butanol, with some pentanol, hexanol, heptanol, and octanol). Syngas is converted into mixed alcohols using a variety of catalyst classes. Several people have utilised methanol-compatible catalysts. Dow Chemical made the discovery of molybdenum sulphide catalysts, which has garnered a lot of interest. Performance improvement was seen when cobalt sulphide was added to the catalyst mixture. While molybdenum sulphide catalysts have undergone extensive research, they are not yet in common usage. The Biomass Program of the Thermochemical Platform of the US Department of Energy has concentrated its efforts on these catalysts. It has also been shown that noble metal catalysts may create mixed alcohols. The majority of R&D in this field is focused on ethanol production. Certain fuels, however, are advertised as blended alcohols (see Ecalene and E4 Envirolene) the higher alcohols in mixed alcohols provide more energy than pure methanol or ethanol, making them preferable. Also, when mixing, the higher alcohols make gasoline and ethanol more compatible, which improves water tolerance and reduces evaporative emissions. Higher alcohols also have lower vaporisation temperatures than ethanol, which is crucial for cold starts. See bioconversion of biomass to mixed alcohol fuels for another way of creating mixed alcohols from biomass.
- Biomethane (or Bio-SNG) via the Sabatier reaction

Second Generation Feedstocks

A source must not be fit for human consumption in order to be considered a second generation feedstock. Agricultural and municipal garbage, waste oils, algae, and specially bred inedible energy crops are examples of second-generation biofuel feedstocks. Yet, second-generation processing systems also utilise grain and sugar crops as feedstocks. While assessing the viability of utilising biomass as a feedstock for energy, one must take into account land usage, current biomass businesses, and pertinent conversion technologies.

Energy crops

Lignin, hemicellulose, and cellulose are the building blocks of plants; second-generation technology employs one, two, or all of these substances. Wheat straw, Arundo donax, Miscanthus spp., short rotation coppice poplar, and willow are examples of common lignocellulosic energy crops. Each has unique prospects, therefore no one crop can be deemed the greatest or "worst.

A very wide variety of items make up municipal solid garbage, and overall waste generation is growing. Recycling programmes reduce the amount of garbage that is sent to the landfill in the UK, and the amount recycled rises yearly. Nonetheless, there are still plenty of options to use gasification or pyrolysis to turn this waste into fuel.

Green waste

A variety of methods may be utilised to manufacture ethanol from green waste, such as forest leftovers, garden or park garbage, or park waste. Examples of this Biogas is produced by gasifying or hydrolyzing biodegradable green waste to create syngas, which is then processed via catalytic processes into biofuels.

Black liquor

Black liquor, the used cooking liquid from the kraft process that contains concentrated lignin and hemicellulose, can be gasified with a very high conversion efficiency and potential to reduce greenhouse gas emissions to create syngas for further synthesis to produce biomethanol or BioDME, for example. The technique yields between 30 and 50 kg of crude tall oil every tonne of pulp.

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CHAPTER 6

POWER TO CHANGE: INTERRELATIONS BETWEEN POWER WITH, POWER TO, AND POWER OVER

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While the perspectives of *power with* and *power to* (over-) emphasize the potential for change with regard to biofuels, scholars with understandings of *power over* often exaggerate their negative impacts. The tripartite framework allows for the combining of different analytical perspectives and to examine their interrelations. While the three categories are first of all analytical heuristics, they also stand for different mechanisms of the exercise of power. What is deemed a "sustainable innovation" and "creative alternative" is influenced by those in positions of power. This has been shown through research. I contend that it is also feasible to resolve power imbalances the other way around, and that power with and power to may avert a situation in which there are many losers and few winners as a result of biofuel governance[1], [2].

Biofuels in and of themselves are neither a green invention, a novel replacement, nor a gold rush. The three metaphors represent three distinct outcomes of power: the use of power over results in a gold rush. Therefore, if academics just want power, they will inevitably discover winners and losers. On the other hand, if we call for the exercise of power, we could discover that biofuels are an innovative substitute. The scenario of reaching an agreement on sustainability standards for biofuel production might serve as an example of the exercise of power[3], [4]. However, the lack of structural change and the fact that biofuels have hurt rather than helped small farmers in the Global South does not preclude a shift in this regard. In this essay, I want to make the case that using consensual forms of power (power with), as well as resistance and self-empowerment (power to), may also eliminate and vanquish power imbalances (power over). According to empirical studies on deliberative processes, there is no such thing as joint action or communication amongst equals, and they are always subject to some type of power imbalance. Therefore, we must comprehend power as a means of wielding it that is both strategic (bargaining) and communicative (arguing). The direction of agents participating in processes of biofuel governance is a vital component of this process. Transitions to sustainability may result through conversations if participants are receptive to altering their opinions and constructing understandings that are common to everyone[5], [6].

According to this viewpoint, even if multinational corporations from the EU and the US have more resources than small farmers in the Global South do not necessarily rule out the prospect of them acting independently from them. For instance, sugar is economically most effective at large plantation scales since it is expensive to build. Jatropha, however, may be grown more easily through grower programmes since it requires less money. Although practically all bio-ethanol is now made from grain or sugarcane, which puts it in direct competition with food, there are other effective and financially feasible technologies for ethanol production. Perennial energy crops, such grasses and trees, as well as crop leftovers, like straw, are thought to require less inputs and less prime land than annual energy crops[7], [8].

Empowerment is feasible in some circumstances, and processes of power with and power to can have an effect on unfavourable relations of power over. Processes like stakeholder certification and conversation, for instance, show that it is feasible to reach an agreement beyond the level of the lowest common denominator. Additionally, they may reduce the perceived legitimacy of influential parties engaged in the unsustainable production of biofuels. The debate over biomass certification has emphasised the responsibility of consumers for negative social and environmental repercussions in the nations of production. Transnational corporations lost the conceptual and material resources on which their dominance over others was founded when the validity of unconditional import as well as of private certification systems was questioned. It's obvious that certification has evolved into a new normative need in the agri-food industry.

We could see a variety of kinds of support for and resistance to biofuels. While Nygren argues that certification programmes reproduce (inferior) attitudes held by southern producers as authentic and exotic outsiders, she does not totally ignore the positive impact that certification played in altering inequalities in the global networks of production and consumption. Castaneda's Silva-analysis claims that local communities now have more choices for proving their ownership of property in court, including employing video evidence to substitute missing documents or demolished landmarks.

Scholars have described movements like Via Campesina as aiming to control and oppose multinational agriculture corporations. The most striking aspect of this movement, however, is how small farmers use their authority to conduct wholesome and sustainable agriculture without the interference of huge agribusinesses, to which they would only be subjected from a power-over perspective. But, when small farmers grow organically, they do not mimic the industrial agricultural production system and their inferior positions within that system. As a result, their farming technique may be seen as both a unique option and a kind of resistance. Farmers in this Via Campesina movement also exercise power by (re-)creating a new, common peasant identity, while having profoundly different internal cultures.

In 1991, when I first began working with kids, I was managing a short-term housing facility for young people who were homeless. After receiving a welfare degree that placed a strong focus on "client self-determination," I truly battled with holding a position of control. Being in a kind of parental position where I had to decide what the children could and could not do, regulate their behaviour, and be ready to establish boundaries made me feel quite uncomfortable. I was in a true position of authority, but I was extremely nervous about it since I had seen many instances of people abusing their positions of power in pretty forceful ways. I had to develop leadership skills that were in line with my ideology and strategy. I had authority over the inhabitants, but I needed to understand that this did not sum up our relationship; there were other forms of power that were as significant and that I could cultivate.

A number of authors differentiate between four types of power.

1. Power over
2. Power with
3. Power to
4. Power within

Power over

The most frequent definition of power is having control over. This kind of power is based on compulsion, intimidation, dominance, and control and is mostly driven by fear. This kind of power is based on the idea that it can only be possessed by a select few people, that it is a limited resource, and that certain people have power while others do not.

According to Starhawk, authority eventually favours force, which allows one person or group to decide for others and seize control. It may govern by physical force, by controlling the things we need to survive, such as money, food, and healthcare, or by controlling more elusive resources, such as knowledge, acceptance, and love. We are so used to having power over us, so entrenched in its rhetoric and implied threats, that we often don't even notice how it works until we see its extreme forms.

The other types of power acknowledge that power is a dynamic that exists in every interaction and is not something that people own. Power is never static since it cannot be held or stored; rather, it is a movement, a connection, a balance, and it is always changing, as suggested by Starhawk (1990). One person's ability to control another is based on a variety of outside influences and subtle agreements.

Power with

Power with is a collective kind of power that results through connections and cooperation. It is based on mutual respect, assistance, shared authority, solidarity, sway, empowerment, and cooperative decision-making. "Social power, the influence we wield among equals," is related to "power with." Power with may assist in bridging gaps across groups such as families, organisations, and social change movements or inside groups (e.g., gender, culture, class). Power with promotes cooperation and the capacity for group action as opposed to dominance and control.

Power to

Power to refers to "the new possibilities or acts that may be developed without employing relationships of dominance" and the "creative or generative potential of power." The "unique capability of every individual to influence his or her life and surroundings" is the foundation of it. It is the ability to change things, invent something new, or accomplish objectives.

Power within

A person's "feeling of self-worth and self-knowledge; it involves an ability to understand unique distinctions while appreciating others" is tied to their "power within." Those who have a feeling of their own potential and value have power inside. Those who have power inside might recognise their "power to" and "power with" and feel like they can change the world.

Instead of acting from a position of power-over when working with families and communities, we aim to foster power with, power to, and power within. Our goal should not be to increase our influence over others, but rather to:

So let's begin with an age-old truism: that there is a finite quantity of power that is always there in some kind of mystical reservoir or pool that exists "out there" (though we never exactly know where). We don't fully understand what power is, but we do know that we want a piece of the action and, if necessary, are willing to engage in conflict to get it. Or, if we can, more of a share. The statement that "It is in the nature of power that it is impossible for one to have more without others having less" is possibly the clearest example of this "pie-slice" view of power." In Figure 1 shown the competition for external power.

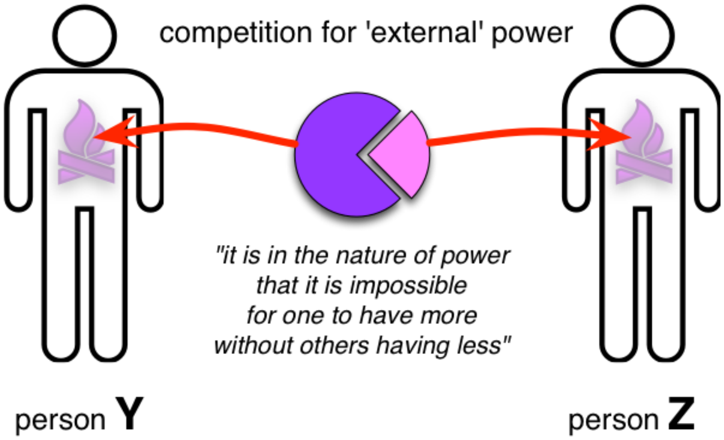

Figure 1: Illustrate the competition for external power.

One common presumption in many "activist" domains was that if one group felt they didn't have much power in their lives, it was because some arbitrary "the other" had taken it all - had stolen their rightful slice of the pie. This kind of "zero-sum" or "transactional" thinking gave rise to this assumption. So, all that 'powerless' group needed to do to become powerful was to put in place mechanisms to weaken 'the other' as much as possible to, in the words of one such activist-group, "compel him to give up his position of power." The idea was that when "the other" had less power, that first group must automatically have greater power as the "taken" piece of the pie will somehow magically transfer itself back to that first group without their having to do anything to make it happen. The assumption was that empowering someone undermines their ability to empower others.

That was, as I said, a very popular view - and regrettably often still is - among the activist circles I was directly involved in in the late 1970s and early 1980s. Many of us at the time put a lot of painful effort into putting ourselves down and holding ourselves responsible for everyone else's problems because we were battling with politicised guilt and being "shamed" for being who we were, as the many activist theories of the time demanded. The problem was that it just didn't work: although we felt much worse, others around us didn't feel any better; in fact, they often became angrier and more demanding as a result of it failing. Everyone suffered a loss, and things only got worse and worse.

With the benefit of hindsight and even a passing thought, it should be clear what went wrong: the power-model was founded on a fiction, an arbitrary, unproven premise, with no connection to anything real. We had no concept what power was or where it was located; all we knew was that we all believed we were lacking it and so believed that it had been stolen by someone else (who was not identified). When we consider things that way, we weren't that brilliant. Finally, some viable alternatives to the useless "pie-slice" concept of power started to emerge. One of these, from feminist thinker Starhawk (Miriam Simos), emerged in the 1980s. She created a power-model based on the idea of power-from-within. Starhawk claims that "the only genuine source of strength comes from inside the self."

With this model, even though we still do not fully understand what power is, we do at least understand its location and source, which gives us some concept of how to generate it. It much outperforms the "pie-slice" power-model. She then introduces a crucial surprise about the social elements of power. She states, "We can help each other uncover the strength from within"; she refers to this as a power-with interaction:

With this "power-with," which seems to come from nowhere but ultimately comes from inside each person, more and more [9]power may be generated in a positive feedback loop. The problem, of course, is that the outdated "pie-slice" power structure still exists; far too many individuals still adhere to the adage from The Godfather that "real authority cannot be given, it must be seized." Starhawk refers to this encounter as one of power-over:

Sadly, beyond those early definitions, Starhawk's power-model quickly unravels. (The details of why it fails are detailed in the preceding piece; but, they are not very pertinent at this time.) The ideas of power-from-within, power-with, and power-over all make good foundational ideas, albeit as we'll see, they require some modifications and additions. In reality, however, the most important factor is the overarching goal of any power encounter, whether it is to exert power "with" the Other in one of many distinct meanings or "against" the Other in one of many other senses. There are more classes of the later, and we'll need them to make the model comprehensive enough to make sense in the actual world. Starhawk's "power-over" is simply one class of the latter.

In order to bridge that gap, it's important to remember that in physics, the word "power" really refers to "the capacity to accomplish work," whereas the official definition of the term "work" is "the rate at which energy is consumed." Power is the capacity to do tasks, if we translate it into human words. The problem with such notion is that it might very well refer to slavery "work produces freedom" and all that. Hence, we need immediately add at least one qualifier to that definition: Power is the capacity to carry out tasks as an expression of individual purpose, responsibility, and choice.

So what exactly is "labour" if power is the capacity to act? The quick response is that work is everything humans do, or, to use that physics definition of "labour," it is any method people choose to use energy. So digging a hole is effort, as is figuring out a technical issue, but so is connecting with someone, settling a fussy kid, or regaining optimism in the midst of sorrow. Work is anything individuals choose to do, and power is the capacity to accomplish it. We may also find it interesting to do a cross-map here to the asset-dimensions in Enterprise Canvas in order to clarify what work truly is and connect it to our other enterprise-architecture domains:

- *physical* – working on ‘things’, anything tangible or physical
- *mental* [‘virtual’] – working on ideas, concepts, problems

- *emotional* [‘relational’] – working on relationships with others
- *spiritual* [‘aspirational’] – working on personal meaning and purpose, sense of self, or relationships with ‘that which is greater than self’

Keep in mind that the majority of actual scenarios entail working on many dimensions at once, much as with the asset-dimensions in Enterprise Canvas. When power-with actually occurs, it is a process in which both relational work and spiritual work take place at the same time, but in different ways for each of the parties in the interaction. This is because Starhawk's power-with almost by definition involves relational work, the creation and maintenance of connections between two or more people, and her power-from-within is, in essence, spiritual work, working on one's sense of self, meaning, and purpose. All of the power dynamics that occur during teamwork occur concurrently with the collective team's mental and/or physical labour. In other words, those many types of functional power constantly interact with one another. Whilst it's important to keep in mind that in the actual world they only function when cooperating, it's often helpful to gently tear apart - at least conceptually all of those distinct strands of labour and power in order to understand a setting[10].

To reframe all of the above in Starhawk’s terminology: Power-from-inside is the capacity to generate and access human power from within oneself, to carry out one's own tasks as an expression of one's own free will, accountability, and purpose. And power-with is the capacity to support one another in creating and accessing power inside oneself and sharing that power with others as an expression of shared responsibility, purpose, and choice**.**

We may potentially utilise the categories in a framework like the Duluth Model, which, in essence, gives us a record of what goes wrong in interpersonal and larger relationships, to make proposals regarding the nature of power-against:

- Coercion and threats
- Intimidation
- Economic abuse
- Emotional abuse
- Using privilege
- Using isolation
- Using children
- Minimising, denying and blaming

There are also two other common categories of power-against that, for some unknown reason, are absent from the original Duluth model:

- Sexual abuse
- Third-party abuse

When someone sets up "authority people" and other third parties to commit acts of abuse or violence against someone else on their behalf, this is known as third-party abuse. Since the initial abuser hides or poses as a "victim," and because the true victim is sometimes wrongly identified as the "perpetrator" of some other wrongdoing or abuse, it is a particularly difficult and complicated kind of abuse to identify and resolve. The one sort of abuse that school children report being most fearful of is rumor-mongering, for instance. When we examine that laundry list of problems, there may be one thing that unites them all: in far too many situations, societal "power" is assumed to be the capacity to put off doing something rather than the capacity to accomplish it. The first problem with the adage "power is the capacity to avoid labour" is that it is demonstrably false. The more "successful" it is, the less real work is done since its definition of success is that labour is avoided. What's more concerning is how addicting it is as a fantasy. It is consequently employed more often as less and less effective results are obtained due to the ingrained notion that it "should" work. This is especially true when the relevant work can only be completed by the self, as in all sorts of spiritual labour 'feeling of meaning and purpose', etc..

Moreover, it fosters the more worrisome societal illusion that power and position should be distributed proportionately to those who put in the least effort or who most successfully manipulate others to carry out their tasks for them. As a result, hierarchies of all kinds or dysfunctional corporate hierarchies are all too common. As a result, it is also a social reality that people are paid less the closer they are to performing laborious physical labour. At the extreme of this are stay-at-home parents and other carers, who perform some of the hardest work of all but are still valued at almost nothing in our insane money-based economy. As we look more closely at those Duluth Model categories, it becomes evident that there are two very different themes that run across all of those abuse manifestations, but they interact with one another in various ways. We may refer to these two types of power-against as power-over and power-under in order to be true to Starhawk's concept.

Naturally, this "power-over" is deliberately dysfunctional, which is similar to the implications of the traditional "pie-slice" power mode. For the sake of this definition, I'd say: Any effort to elevate Oneself by demeaning another is referred to as power-over. There is also a "lose/win" form, when one puts oneself down to support others; although this is often seen as socially admirable, it is ultimately just as problematic. Violence is the slang word for gaining control. The important thing to note about "from anybody, to anyone" is that "the Other" might very well be the writer's own self, such as when I beat myself up for not finishing this precisely on time.

Since it tends to be passively dysfunctional and focuses more on what isn't done than what is, "power-under" is a little more subtle. For the sake of this definition, I'd say: Any effort to shift responsibility onto the other without their involvement or agreement is known as power-under. (Like with power-over, there is also a "lose/win" variant that assumes responsibility from the other without their participation and agreement; as with power-over, this form is sometimes perceived as admirable but in reality is just as dysfunctional as the "win/lose" version.) Abuse is the slang word for misuse of authority. Keep in mind the crucial phrase "from anybody, to anyone" since, once again, "the other" might truly be the Self, as in my attempt to delay writing this till tomorrow.

Together, power-over and power-under are components of what I referred to as "power-against" in that overview up above. All of this may be helpfully cross-mapped onto the SEMPER model of power and effectiveness at work:

- ‘**++**‘: *‘individual as wholeness-responsibility’* – outcome of full *power-from-within*, usually grounded in support of collective *power-with*
- ‘**+**‘: *‘organisation supports individual’* – collective *power-with*
- ‘**=**‘: *‘command and control’* – reins-in the dysfunctions sufficient to leave some space for self-generated *power-from-within*, without *power-with*
- ‘**–**‘: *‘passive-dysfunction’* – individual and/or collective *power-under*
- ‘**—**‘: *‘active-dysfunction’* – individual and/or collective *power-over*

While theoretically a type of helpful anarchy since it is always, in the end, an expression of the individual as individual, constructive power-from-within, when completely supported by mutual power-with, drives an upward-spiral towards ever-greater success. In contrast, the major risk of power-against is that it may, in any form, become intensely addictive, leading to a full-blown state of "kiddies' anarchy’ shown in Figure 2.

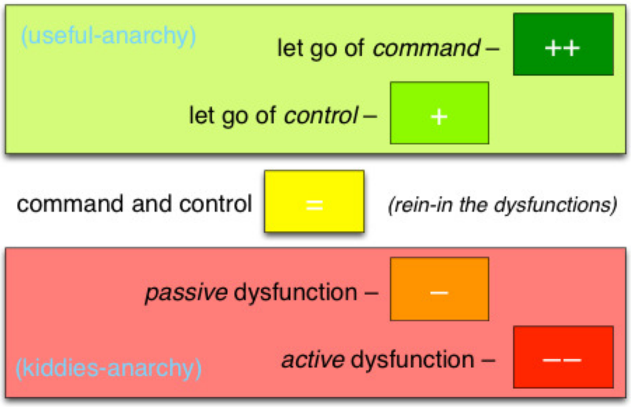

Figure 2: Illustrate the connection between the useful anarchy and kiddies anarchy.

Power-against may also take the weirdly symmetrical, balanced, and mutually interacting shapes, even if they are sometimes merely a balance of horror or mutual dysfunction. For instance, a classic codependent pairing is what we see all too frequently in dysfunctional relationships, where each party alternates between the relative roles of "perpetrator" and "victim," constantly switching from one power-against tactic to another, in a wildly unstable tug of war. Despite this, the relationship as a whole remains relatively stable, so much so that if either party attempts to escape the mess and end the mutual dysfunction, the other will resist. In that regard, the "power-over" portion of Starhawk's power-model would need to be changed to something more like to this.

Though the parties in a dysfunctional "power-against" relationship may be, as shown in the graphic above, respectively male and female, it is important to note that they may also be both male and female, the same age or different from one another, from the same or different cultures, or even human and non-human once we begin to examine relationships with animals and the like in greater detail. Everything revolves around power, whether it is power inside and outside, or the illusion of power as "the capacity to escape labour," or power against, power over, or power beneath. Power-with or power-against are the only options, and power-against is ineffective for everyone. At the end, we have a power-model that is useful, sensible, and whose symmetry makes it much more tenable from a systems-thinking viewpoint as well as in terms of empirical data. The following would be a graphic summary using a kind of "traffic-light" colour coding:

But before we continue, there's one more thing we need talk about: the connection between power and responsibility. Simply said, there is no power if there is no accountability. In actuality, here is where the idea of "rights" as a whole disintegrates. According to the power-model described above, individuals may only be legitimately given the same social and legal authority as others if they also share the same legal obligations. Anything less would indicate a structurally imposed power-under on the part of the person, which would ultimately lead to a perceived "need" for some kind of power-under or power-over to protect and balance against that power-under, and farther down into a codependent downward cycle. Simply put, Not A Good Idea...

Hence, even while the idea of "rights" would appear to make sense as a remedy to many social evils, the truth is that they simply don't work, as I've discussed in a number of postings on this site. They combine a claim of a desired end with a statement of lack of responsibility: it's my right, and others alone are responsible for bringing it to me. But, they make no mention of how the hell it may be done. This is true of all ostensibly granted rights, but it becomes particularly problematic when such rights are intrinsically asymmetric, meaning they only apply to one group. In that case, the excluded group is arbitrarily given all of the obligations but none of the 'rights'. Once again, because of the systemically created power imbalance, this is not a good idea.

In reality, "rights" are essentially a tame-problem "solution" to a wild-problem situation, which invariably makes the issue at hand far more difficult to solve and more "wicked." We must use a reframe and reorganise the separate "rights" as mutually intertwining obligations in order to achieve the desired results. A working example relating to "rights of possession" may be found in the post An architecture of responsibility. A typical reframing for this would start something like this:

- Identify the *desired outcome* for each of the respective 'rights' (for example, apply a Five Whys or suchlike to identify the real deeper needs behind the respective 'right')
- Identify the *mutual responsibilities and interlocks* of actions, decisions and behaviours that would enable the respective outcome in real-world practice
- Identify *checks and balances* that would ensure that the responsibilities are perceived as 'fair' to all respective parties

The main issue and risk with a lot of the "rights" language is that it is almost totally centred on the person rather than the interaction between Self and Other. Instead, what we too frequently get is a one-sided assumption of individual "entitlement" and damn everyone else - "I have rights, you have responsibilities" - all powered by significant amounts of self-dishonesty and Otherblame. It frequently lacks any real notion of mutuality or fairness across the board. This is the reason why the "rights" conversation is stagnating right now and is unlikely to go forward unless those problems are openly discussed. That type of mess damages everyone, which is kind of sad, but with just a little bit of true systems-level thinking, at least some of the problem's fundamental issues might be remedied with no work at all. We must go above and beyond what has been done so far if we are to tackle the all-too-real power-related difficulties for everyone. Nonetheless, I do hope that the power-model mentioned above may really provide some assistance in that regard. I'll get back to you on that.

Practical applications for enterprise-architecture

Probably the most useful point from this session is to take those definitions around power, and apply them to everyday contexts. A refresher on those definitions again:

- **power** is **the ability to do work** (or, in a human context, extended as '*the ability to do work, as an expression of choice, responsibility and purpose*')
- ***delusory*-'power'** is **'the ability to *avoid* work'**
- **power-from-within** is **the ability to source and access power from within the self** (in general, applicable only to humans or other animals)
- **power-with** is **the ability to assist each other to generate and access power-from-within** (alternatively, *the ability to do work, as an expression of shared choice, shared responsibility and shared purpose*) (mostly human and other animals, but the assisting party may be IT and/or machine in some contexts)
- **power-over** is **any attempt, by anyone, toward anyone, to prop Self up by putting any Other down**
- **power-under** is **any attempt, by anyone, toward anyone, to offload responsibility onto the Other without their engagement and consent**

And a perhaps-useful reminder:

- **'rights'** will need to be restructured as **interlocking mutual responsibilities**

At the first level, apply these solely to technical concerns, such as interfaces between systems:

- What is the work to be done?
- What energies, assets and resources will be needed for that work to be enabled and enacted?
- Who or what has the power – the responsibility or 'response-ability' – to do that work?
- Where do any structures risk creating a context where one or more systems prop themselves up by putting others down – such as by demanding arbitrary priority, or creating a deadlock?
- Where do any structures risk creating a context where one or more systems attempt to offload responsibility onto others without their engagement or consent – such as in a mission-critical control-system left to run inappropriately 'open-loop'?

- What mutualities and interlocks are required to ensure that the system *overall* runs in a balanced way that is 'fair' to all parties in the interaction?
- Who or what decides what constitutes 'fair' within the design and operation of the system?

Extend these inquiries to broader-context issues as well. What happens, for instance, if security and access are no longer seen as 'rights' but rather as interdependent responsibilities? What do their obligations entail? What are the interconnections and mutualities that enable it to benefit all parties? What is required to keep the distribution of duties evenly throughout the whole domain? For this, Enterprise Canvas' "Validation" paradigm could be useful. Evidently, power-related concerns of various types are also fundamentally crucial to the majority of enterprise design work, particularly once it extends beyond a strictly IT-centric sector. The preceding checklist is equally applicable, but please, please, take caution while using it. In particular, avoid using technology in complicated human circumstances till you've got a lot of expertise using relatively simple technological systems at progressively more sophisticated degrees of complexity, from Simple to Difficult to Ambiguous to Not-Known.

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CHAPTER 7

ECONOMIC AND ENVIRONMENTAL CONSIDERATIONS

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It is important to consider the energy needed to generate biofuels when assessing their economic advantages. For instance, the production of ethanol from maize necessitates the use of fossil fuels for farming machinery, fertiliser production, crop transportation, and ethanol distillation. In this regard, ethanol produced from corn offers only a modest energy boost; sugarcane offers a larger one, and cellulosic ethanol or algal biodiesel may even offer a higher boost.

Although there are some environmental advantages to using biofuels, there may be significant environmental disadvantages as well, depending on how they are produced. The carbon dioxide (a significant greenhouse gas) that is released into the air during combustion will have already been removed from the atmosphere earlier as growing plants engage in photosynthesis, so in theory plant-based biofuels as a renewable energy source make little net contribution to global warming and climate change. It is referred to as "carbon neutral" material. In reality, however, using a renewable fuel may not always be advantageous due to increased greenhouse gas emissions from the industrial manufacturing of agricultural biofuels. These emissions include nitrous oxide from nitrogen fertilizer-treated soil and carbon dioxide from the use of fossil fuels throughout the production process. Cellulosic biomass is thought to be more advantageous in this aspect[1], [2].

An important consideration when assessing the advantages of biofuels is land utilisation. The "food versus fuel" controversy was brought on by the first-generation biofuels' primary usage of common feed stocks like corn and soybeans. The economics of food availability and price may be impacted by biofuel production because it removes arable land and feedstock from the human food chain. Energy crops raised for ethanol can also compete for natural habitats around the world. For instance, a focus on corn-based ethanol is converting grasslands and shrublands into monocultures of the crop, and a focus on biodiesel is clearing old tropical forests to make room for oil palm plantations. The hydrology, the rate of erosion, and the overall biodiversity of wildlife areas can all be affected by the loss of natural habitat. As the plant matter that it contains is burned or allowed to decay, the clearing of land can also cause the abrupt release of a significant amount of carbon dioxide[3], [4].

The traditional agricultural crops maize, soybeans, sugarcane, and oil palms, which are low-diversity biofuel sources, are most affected by some of the drawbacks of biofuels. The North American tallgrass prairie is one example of a highly diversified collection of species used as an alternative. Such high-diversity biofuel sources could replace degraded agricultural land that is no longer productive and instead increase wildlife habitat, lessen erosion, clean up waterborne pollutants, store carbon dioxide from the atmosphere as carbon compounds in the soil, and ultimately restore fertility to degraded lands. Such biofuels might be directly burned to produce energy or, as technology advances, transformed into liquid fuels[5], [6].

While there will likely be much research and discussion regarding the best technique to grow biofuels to meet all needs at once, the production of biofuels is expected to continue expanding quicklythe Energy Independence and Security Act of 2007 in the United States required the usage of 136 billion litres (36 billion gallons) of biofuels annually, an increase of more than six times over production levels in 2006. The law extended some government subsidies and tax breaks for the development of biofuels and mandates, subject to certain restrictions, that 79 billion litres (21 billion gallons) of the total amount be biofuels other than ethanol derived from corn.

One unique promise of biofuels is that they may be able to permanently remove carbon dioxide from the environment when used in conjunction with a cutting-edge technology known as carbon capture and storage. According to this scenario, carbon dioxide would be removed from the atmosphere as biofuel crops grew and captured as carbon dioxide is released during the burning of biofuels to produce electricity. Captured carbon dioxide may be sequestered (stored) in geological formations beneath the earth, in deep ocean sediments, or theoretically as solids like carbonates[7].

There has been a lot of discussion about the quick changes that have influenced biofuel policy and sectors, and there are still a number of unresolved problems. This essay aims to give a concise overview of economic assessments of biofuels. It goes without saying that a thorough evaluation of models and findings in this context is outside the purview of this work, is probably premature given the state of the art, and will thus not be attempted. We begin by quickly going through the key characteristics of the development of the biofuel business, with a focus on the factors that influence policy. Our presentation prioritises US issues and regulations due to the prominence of ethanol in the modern biofuel business and the United States' predominate role in ethanol production, while some context is provided for the other main actors (Brazil and the EU). Following that, there is a review of the key economic issues related to biofuels. Particular focus is placed on the fundamental analyses of biofuel mandates, the evaluation of numerous prior studies that have estimated the market impacts of biofuels, the insights from a particular model, and an assessment of biofuel laws and regulations as well as the environmental effects of biofuels.

Environment - Economy Linkages:

Natural and environmental resources are impacted by all economic activity in one way or another. The stock of natural resources is altered by operations including extraction, processing, production, transport, consumption, and disposal. These operations also put additional strain on the ecosystem's systems and introduce wastes into the environment. Economic actions now also have intertemporal welfare effects and have an impact on the stock of natural resources that will be accessible in the future. According to this viewpoint, the availability and quality of natural and environmental resources have an impact on how productive an economic system is.

The three economic functions of natural and environmental resources are: waste disposal services, which are connected to the ability of the environment to absorb waste; natural resource inputs into production; and directly consumed life support services and aesthetic amenities. Understanding the link between economic development and the environment depends on the input function of natural and environmental resources. A productive asset is one whose quality influences how productive an economy is. Examples include water, soil, air, biological, forest, and fishery resources. The direct link between environmental issues and economic development is brought out by concentrating on the environment as a producer of goods. Economic management thus has an influence on the environment, and environmental quality has an impact on how well the economy operates. Economic expenses associated with environmental deterioration lead to losses in productivity and human capital. Some expressions of such decreased output include lost labour productivity brought on by illness, foregone agricultural production owing to soil degradation and erosion, lost fisheries output and tourist revenue due to coastal erosion, or lost soil productivity brought on by deforestation. In addition, a growing corpus of epidemiological data indicates that air and water pollution is having a negative impact on people's health and mortality, especially in the developing countries. The young, the very old, and the underprivileged are most impacted negatively by water and air pollution. As a result, pollution management is a component of sustainable development rather than a "luxury product" to be purchased after the development process has begun. Sustaining Development is Required

Environmental deterioration brought on by economic growth without regard for the environment may lower the standard of living for both current and future generations. The goal of sustainable development is to find a balance between the requirements of economic growth and the need for environmental conservation. It aims to bring together aspects of social concerns, environmental conservation, intergenerational justice, and economic efficiency. While the phrase "sustainable development" has many different meanings, it often refers to a long-term trend of non-declining human welfare. The Brundtland Commission of 1987 described sustainable development as "filling the demands of the present without sacrificing the capacity of future generations to satisfy their own needs."

In order to preserve the stock of productive assets (physical, human, and environmental) through time and provide a social safety net to fulfil the fundamental needs of the poor, the idea of sustainable development attempts to maximise the net benefits of economic activity. While some analysts have argued in favour of a "weak sustainability" rule that seeks to maintain the total monetary value of the stock of assets while assuming a high degree of substitutability among the various asset types, others have supported a "strong sustainability" rule that demands a separate preservation of each category of critical assets while assuming that these are complements rather than substitutes. Hence, sustainable development aims to quicken progress while also taking into account the criteria of intergenerational justice.

As the economy begins to recover from the crisis, focus has switched to restoring steady and long-lasting economic growth in the UK. Attention has been drawn to the environment in this context due to difficulties like preventing hazardous climate change and signs that we may be nearing or surpassing other environmental limits:

- Ensuring environmental assets are available to improve wellbeing and to facilitate future economic growth; and
- Managing the risks to growth from adverse environmental events.

With the various services it offers and as a direct input into industry, the natural environment is crucial to our economy. Minerals and fossil fuels are examples of environmental resources that directly assist in the creation of products and services. Other services provided by the environment, including as carbon sequestration, air and water pollution filtering, flood risk reduction, and soil formation, support economic activity. Also essential to our well-being, it gives us possibilities for amusement, enhances our health, and does much more. The prosperity and well-being of the economy and its population, in both developed and emerging nations, depend on economic growth. It encourages technological advancements, such as those that will be required to keep consumption and production independent of their environmental effects. Technology also plays a critical role in allowing other wellbeing-enhancing factors, such as advancements in health, education, and general quality of life. growth in the economy and well-being Usually, when we talk about economic growth, we mean a rise in the quantity of goods and services that an economy produces, as measured by metrics like the Gross Domestic Product (GDP). Although the value of products and services offered via the market is reflected in the GDP and other comparable metrics, many additional commodities and services that are not offered through the market but nonetheless contribute to societal wellbeing are not included. For instance, labour done in the house or other volunteer or unpaid activities, as well as the many benefits the natural environment offers to support commercial activity Because of this, the GDP does not accurately represent many of the elements that influence society's well-being. 6. Human wellbeing is a complicated and multifaceted notion that is influenced by a variety of variables, such as income levels (both absolute and relative), health status, level of education, living arrangements, and environmental quality. It has been been described in terms of subjective or self-reported happiness. Several studies have shown that rising GDP in high-income nations does not correspond to rising levels of happiness.

Others, however, have seen the opposite. For instance, Stevenson and Wolfers (2008) discover a strong correlation between rising GDP and rising levels of perceived wellbeing for both established and developing nations. As there is no direct correlation between GDP and self-reported happiness, it is important to concentrate on the variety of variables impacting wellbeing. A number of factors are identified as contributing to wellbeing in a recent report by the Commission on the Measurement of Economic Performance and Social Progress, including material living standards, health, education, personal activities like work, political voice and governance, social connections and relationships, environment (present and future condition), and insecurity (of an economic as well as a physical nature). Despite the fact that wellbeing is a multifaceted notion, economic development continues to play a significant role in allowing or driving gains along many of these aspects. It is necessary to promote ongoing advancements in the quality of living, health, life expectancy, education, and economic opportunity, as well as to assist the government in achieving a number of economic, social, and environmental goals.

The rest of this essay concentrates on the connection between environmental sustainability and economic development, as measured by growth in gross domestic product. The discussion between environmental protection and economic development While if economic expansion has raised living standards and improved quality of life for many people throughout the globe, it has also led to the depletion of natural resources and the destruction of ecosystems. There has been significant discussion over whether or not economic development can be achieved without unsustainable environmental damage, and there is a growing understanding that economic growth at the present pace of depletion and degradation of natural assets cannot continue forever. For instance, the rise in CO2 levels in the atmosphere brought on by human activity implies that the globe is already undergoing some degree of climate change and that it will be very difficult to maintain temperature increases to below two degrees. The Millennium Ecosystem Assessment of 2003 showed that 15 out of the 24 ecosystem services it assessed were being degraded or utilised in an unsustainable manner, and that the usage and consumption of natural resources like minerals and metals were continuing to rise.

Others believe that the Earth's limited resources have a limit on how far economies may continue to grow through time10. Others contend that sustainable resource use and ongoing economic development are mutually reinforcing, with the consequences of inactivity likely to be far higher than the price of taking action today. The purpose of this essay is to examine how the natural environment supports and contributes to economic development as well as how environmental policy may enhance environmental outcomes while preserving the long-term health and stability of the economy. Instead of attempting to provide a solution to the issue of what degree of economic development is sustainable, it examines the available data and proposes a strategy for ensuring ecologically sustainable economic growth for both the present and the future.

Both the economy and the environment Natural assets that serve as inputs for natural resource extraction and environmental services are referred to as natural capital by the OECD. The soils we utilise to produce crops, the clean air and water we breathe, and the minerals and ores we mine from the ground are all included in this. According to the Millennium Ecosystem Assessment's (2005) ecosystems services framework, the benefits and services offered by the natural environment may be categorised into four main groups:

- Provisioning services – products obtained from ecosystems, including fresh water, food, fibre13, genetic resources, biochemicals, natural medicines and pharmaceuticals.
- Regulating services – benefits obtained from the regulation of natural processes, including air quality, climate, water/flood, erosion, water purification, disease and pest control, pollination, buffering pollution.
- Cultural services – non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic enjoyment.
- Supporting services – services that are necessary for the production of all other ecosystem services, including soil formation, photosynthesis, primary production, nutrient cycling and water cycling.
- Only provisioning services – the products obtained from ecosystems – typically have market prices; for example, ores and minerals. Many other ecosystems services provide benefits outside of markets, such as the ocean’s role in supporting a range of marine life, or the carbon sequestration of peat soils. Therefore, measures of economic activity, such as GDP, do not capture the full benefits provided to us by the natural environment, nor do they reflect the extent to which environmental resources have been depleted or degraded.

Natural capital contributes to economic output through two main channels:

- Directly as an input to the process of economic activity; and
- Indirectly through its effect on the productivity of the other factors of production. Growth is also generated by industries where the output is a clean and healthy natural environment; for example, natural asset management and services that mitigate the environmental impacts of economic activity. Natural capital as a direct input to wealth creation The natural environment provides the raw materials for economic production of goods and services (provisioning services):
- Non-renewable resources are those with a finite endowment, which can be depleted over time. Non-renewable resources like fossil fuels, minerals, metals, and basic aggregates are extracted from the natural environment to produce energy, machinery, consumer products, the built environment, and much else; in 2007, UK economic activity resulted in the extraction of over 450 million tonnes of fossil fuels and minerals within the UK14;

- Renewable resources are those which are capable of being replenished through natural processes or their own reproduction. However, these resources can be exhausted if they are consumed at a rate faster than the rate of replenishment. Renewable resource, such as forests and fisheries, contribute directly to economic activity; for example, in 2007, the UK fishing sector was worth nearly an annual £400 million16. Overall, the sectors of the economy directly dependent on these provisioning services were worth over £41 billion in 2007, and contributed a little under 3.5% of total gross value added17. Natural capital as an indirect input to wealth creation arguably more important than these direct effects are the indirect inputs from the natural environment into economic processes. The indirect inputs provided by ecosystems facilitate the processes of production and act as a sink for the adverse environmental effects of economic activity. They include:
- **Global life support functions**: Natural areas provide global life support functions, including climate regulation and regulation of the chemical composition of the atmosphere and oceans. While natural areas play a role in the maintenance of life-essential services, it is difficult to evaluate and demonstrate the contribution that particular habitat types or areas make. However, one area where the contribution of particular habitats is being recognised and evaluated more explicitly is with regard to the ability of forests to act as a store for carbon.
- **Water regulation**: Natural areas can buffer hydrological flows and dampen environmental fluctuations, provide flood and storm protection, and prevent run-off damage. Natural processes can also provide water quality benefits; for example, by preventing sediment run-off into rivers.
- **Pollution filtering**: Natural resources play an important role in pollution control and detoxification, including the removal of nutrients and pollutants from water, filtering of dust from the air, and providing noise attenuation.
- **Waste sink**: The natural environment provides a repository for all non-recycled waste produced by economic activity. In the absorptive capacity of the atmosphere, the oceans, and the soil, the natural environment is able to assimilate some of that waste without diminishing the provision of its other services.
- **Soil retention and provision**: The natural environment, such as many wetland habitats, provide benefits by preventing soil loss and by storing silt.
- **Nutrient cycling**: Ecological processes provide benefits through the storage, processing, and acquisition of nutrients essential for plant growth.
- **Waste decomposition**: Naturally occurring micro-organisms provide benefits through their ability to break down organic matter and speed up the process of waste decomposition. Ecosystems also have a wide range of impacts on both the quantity and quality of labour. The World Health Organisation estimates that the apportioned burden of disease from water and air pollution accounts for the loss of over 100 million disability-adjusted life years globally each year.

Although if less developed nations experience the bulk of global repercussions, the UK economy also bears a considerable financial burden as a result. Between 12,000 and 24,000 premature fatalities are thought to occur annually as a result of the impact of outdoor air pollution on our cardiovascular and respiratory systems. According to estimates, it would shorten life expectancy by up to 7-8 months on average for each individual and cost the Kingdom £20.5 billion annually. There are more ways in which the natural environment enhances human capital. For instance, there is data that suggests the presence of green areas increases people's propensity to engage in and maintain physical exercise, a crucial component of both good physical and psychological wellness. According to a recent estimate, obesity-related expenses in England total around £2.5 billion, while the lack of physical exercise costs the country more than £8 billion annually. The accessibility of green spaces and wildlife-rich places may also have broader advantages, such as decreasing stress, enhancing mental health, lowering crime rates, and increasing worker productivity. Last but not least, maintaining a clean and healthy atmosphere may help to draw in and keep investment[8].

For instance, UK Trade and Investment emphasises the importance of the environment to firms and entrepreneurs thinking about investing in the UK23. Economic activity that produces environmental goods and services Opportunities for employment and income development are made possible by the need for a clean, healthy environment; examples include organic agriculture and the sectors in charge of maintaining and conserving natural resources. Some sectors work to lessen the effects of economic activity on the environment, for instance by producing renewable energy, using waste management strategies, and developing goods and technology that lessen production-related noise and air pollution. Others, including water treatment services and land remediation, work to lessen negative environmental effects and return natural resources to their prior state. The UK economy greatly benefits from these sectors. According to a recent analysis, the UK market for low-carbon and environmentally friendly goods and services, including their supply chains, was worth over £100 billion in 2007/08. They supported 880,000 employment, with predictions that number would increase to almost 1.3 million by 2015.

Environmental and economic growth interactions this part examines the link between economic growth and environmental quality and explores its primary causes. Whereas the previous section focused on the value of natural capital to economic growth25, this section examined that relationship. Kuznets curve for the environment the link between economic development and environmental quality is often described using the Environmental Kuznets Curve (EKC). It alludes to the idea that certain indicators of environmental quality and economic production per person have an inverted U-shaped connection. The following may be used to describe how the curve is shaped: Environmental deterioration increases together with GDP per capita. Yet after a certain threshold is reached, rising GDP per person results in less environmental harm.

Specifically:

- At low incomes, pollution abatement is undesirable as individuals are better off using their limited income to meet their basic consumption needs;
- Once a certain level of income is achieved, individuals begin considering the trade-off between environmental quality and consumption, and environmental damage increases at a lower rate; and
- After a certain point, spending on abatement dominates as individuals prefer improvements in environmental quality over further consumption, and environmental quality begins to improve alongside economic growth shown in Figure 1.

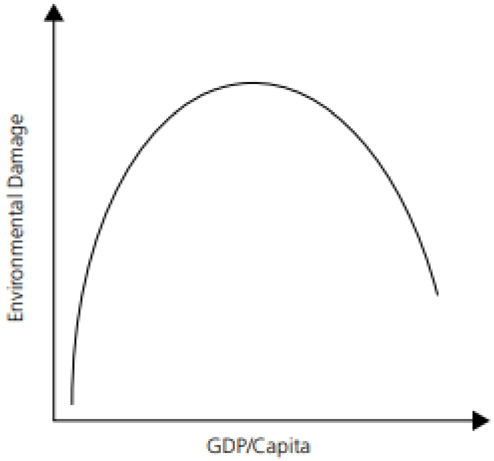

Figure 1: Illustrate the rising GDP per person results in less environmental harm.

Other possible explanations for the shape of the EKC include:

- **Technological progress:** firms initially concentrate on expanding production as quickly as possible, but as technology evolves production processes become cleaner and more resource efficient;
- **Behaviour Change:** society is at first interested in higher levels of consumption, regardless of the means by which it is achieved, but after a certain point greater consideration is given to other factors affecting quality of life, including the environment;
- **Lewis growth model:** the development pattern of any economy is characterised by the changing patterns of economic activity.

1. **Stage 1:** society concentrates resources in the primary sector (i.e. extraction, agriculture) to satisfy necessary consumption;
2. **Stage 2:** resources are switched to the secondary sector (i.e. manufacturing) as basic needs are satisfied and further consumption is concentrated on consumption goods; and
3. **Stage 3:** society moves from the secondary to the tertiary sector (i.e. services) characterised by much lower levels of pollution.

In an increasingly globalised society, when the transition from stage 1 to stage 3 may occur as the consequence of a shift rather than a decline in pollution levels, this model is less useful. When the Environmental Kuznets Curve connection was first noticed for certain types of air pollution (suspended particles and NOX), it was projected that $5,000 would mark the tipping point, or the amount beyond which rises in GDP per capita would result in decreases in emissions. The turning point has often been estimated to be higher in later studies31, however there is evidence that the EKC holds true for a wider range of environmental variables32. The tipping point, according to more recent assessments, is $34,000. These studies predict that the majority of moderately developed countries will reach their pollution peaks by the middle of this century, although only 10% of them are currently close to doing so33. The emissions of moderately developed countries will not return to their current levels until the end of the twenty-first century. Especially in wealthy nations that have passed their turning point, one extreme policy interpretation of the EKC would be to promote economic development and avoid expensive environmental regulations34. Others contend that enforcing strict environmental restrictions too soon might hinder economic development and, in the long term, worsen environmental damage.

However, there are several reasons to question the relevance of the EKC hypothesis to policy-making.

- To start, just a small number of contaminants are employed to define environmental quality in EKC assessments. The results drawn from these investigations may not, however, apply to all forms of environmental harm. For instance, until energy usage was taken out of the Ecological Footprint, a total assessment of the burden humans impose on the ecosystem, there was no indication of an EKC link. For contaminants with considerable local effects, the Environmental Kuznets connection seems to be the greatest. On the other hand, emissions of carbon and other greenhouse gases have risen along with increases in GDP per capita, even in the richest nations, where the repercussions are global and dispersed.
- Second, it has been discovered that the econometric data used to support the EKC is less trustworthy and robust than previously believed35. For instance, the analysis's findings are significantly influenced by the model used to explain the connection between wealth and pollution36.
- Finally, hysteresis may limit the applicability of EKC to environmental policy. For example, cleaning up a polluted waterway, where the cost of avoiding the pollution in the first place is lower than the subsequent cost of the cleanup, the costs of repairing damage and improving environmental quality once the economy is past its turning point may be significantly higher than the cost of preventing the damage or undertaking mitigation earlier.
- Fourth, research has revealed that nations with comparable income levels behave differently, with no obvious or consistent signals of convergence. However, it has been said that the EKC's diminishing portion only occurs in societies with relatively uniform income distribution and low levels of inequality.

The EKC link cannot, however, be generalised to all forms of environmental harm, across all nations, and across all economic levels, even if there is some evidence that it exists for particular countries and for certain local pollutants. However, its use as a predictor of environmental performance as nations evolve is limited. Several perspectives on how the economy and the environment interact other explanations for the connection between environmental quality and economic development exist. According to the limitations theory, environmental thresholds could be crossed before the economy reaches the EKC turning point. For instance, more expenditure on sustaining species variety in the context of biodiversity won't be able to bring back extinct species.

Drivers of the economy-environment relationship

These diverse ideas show that there are many different dimensions and a complicated interaction between economic development and the environment. While there may not be any concrete proof on the nature of the link between the economy and the environment, these ideas provide a helpful framework for considering the elements that influence this relationship. Generally speaking, there are three impacts:

- **The scale effect**: economic growth has a negative effect on the environment, where increased production and consumption causes increased environmental damage;
- **The composition effect:** the composition of production changes along the growth path: initially economic growth leads to industrialisation and as the goods balance shifts from agriculture to manufactured products, environmental damage increases but the balance then shifts from producing manufactured goods to producing services, due to both demand- and supply-side changes, reducing the level of domestic environmental damage;
- **The technical effect:** technological developments lead to a change in the environmental impacts of production. Whilst this often means reductions in environmental intensity, for example improvements in energy efficiency, it could also represent technological advances that lead to greater environmental damage such as through increased energy use.

Changes in societal preferences may also affect environmental harm, for instance by supporting changes in how strictly industries are required to comply with environmental regulations. The link between economic growth and the environment is determined by the proportional magnitude of these influences. Achieving global decoupling for global pollutants like CO2 requires coordinated worldwide effort to limit emissions. Environmental best practises, technological transfers, and spillovers are crucial for attaining global decoupling for more regional pollutants. The transfer of technology and knowledge from developed economies, for instance, in the form of more environmentally friendly agricultural practises, or through technology spillovers that happen as a result of international investment and globalised supply chains, can improve the environmental efficiency of production at the global level. These transfers and spillovers have two advantages since they both assist emerging countries transition to a more resource-efficient development path and reduce the amount of environmental harm exported from advanced economies, which is increasingly being driven from outside the advanced nations. The UK's environmental and low carbon businesses have an opportunity because to the growing attention being paid to environmental sustainability worldwide. For instance, a recent study by the Department of Business, Innovation, and Skills found that the UK had a high comparative advantage, which is a gauge of the country's relative strength in the production of that good or service, in sectors like environmental consulting, wind power, building technologies, and recovery and recycling, among others.

By increasing the use of low-carbon and renewable energy, increasing resource efficiency, and reducing the environmental effects of manufacturing, the products and services these businesses generate allow reductions in the environmental impact of production such as air or water pollution. Even accounting for the impacts of the current recession, a recent research predicted this industry will increase by between 4.7% and 7.7% between 2009 and 2020, estimating an environmental products and services market of between \$1.2 and \$1.9 trillion52. With this global demand, UK enterprises have the chance to dominate their respective markets and for this industry to perhaps be a future engine of UK productivity and growth.

Natural resources and long-term economic expansion In order to manufacture commodities and services, production variables are combined, which is how wealth creation is often explained. Although some of these products and services are utilised for personal consumption, others are used to increase capital stock. Yet, this definition of output gives an imperfect picture of the contribution of natural capital to economic development and wealth creation and does not completely account for the function of natural capital in the production process.

The key factors of production to be considered in the context of economic growth are:

- **Produced capital** – usually man-made capital such as machinery and infrastructure;
- **Human capital** – such as labour effort, skills, education, experience;
- **Natural capital** – the raw materials and services provided by the natural environment, such as wood, minerals, water, nutrient recycling; and
- **Social capital** – whilst definitions of social capital differ, it generally includes institutions and ties within communities.

Economic output rises when these components of production are present in greater quantities, for instance when the labour force grows or when tools and infrastructure are developed. Additionally, technological advancements and improvements to these production-related factors increase output and productivity. For instance, technological advancements, knowledge accumulation, and knowledge application enable new and improved ways to combine the various production-related factors to produce output. qualities of natural capital in particular There is a compelling case for recognising natural capital, together with produced capital, human capital, and social capital, as a substantial element of production in and of itself and for properly accounting for it in choices about production and consumption. The goal of economic development is consistent and in line with the efficient use of resources, and there are no long-term restrictions on the availability of capital, which may be replaced or refilled by created commodities and services, according to classic wealth creation theories. However there are a few characteristics that set natural capital apart from other forms of wealth.

Environmental assets may have critical thresholds

Certain renewable environmental assets may undergo non-linear and irreversible alterations if adjustments are made over unidentified thresholds. The separation between different stable states is marked by these thresholds. The asset may eventually run out of resources if certain key thresholds are crossed because it may no longer be able to function as intended or can no longer be appropriately refilled. Ecosystems are frequently subject to these thresholds, which include "source limits" like fish stocks and top soil where breaching this threshold will result in an ecosystem change or collapse and "sink" limits like the maximum amount of chemical outputs from production that water and soil can absorb, where breaching this limit can result in a temporary or permanent disruption to ecological functioning. Scientifically speaking, it is unclear if and where crucial thresholds could exist. The precautionary principle would advise stopping deterioration or depletion far before these thresholds are achieved in the absence of strong proof.

Environmental assets may have finite limits:

As is commonly assumed for capital assets, the stocks of non-renewable environmental assets are restricted throughout the long term in addition to the short term. For instance, non-renewable resources like metals and minerals are finite in the long term, and further depletion would ultimately result in the disappearance of all virgin reserves. It remains difficult to pinpoint where and when these constraints are present, for instance, to determine which assets are non-renewable and subject to limits and for how long.

Changes to environmental assets are potentially irreversible:

Natural resource depletion and deterioration are often irreversible, at least during the timeframes relevant to human civilisation. For instance, whereas a worn-out piece of equipment may be replaced or a deteriorated road can be restored, it is more difficult to restore an extinct species or an old forest environment. These natural resources are often less interchangeable than generated or human capital.

Changes to environmental assets have impacts that extend over many generations:

The welfare and resources of future generations will be impacted by the activities of the current generation. Damage to environmental capital, for instance, has an effect on people now as well as future generations. Environmental asset usage decisions also need to be assessed over a comparable time frame. The appraisal and pricing of environmental assets into economic choices are complicated by intergenerational effects. Individuals' discount rates may vary over time and be greater than those demonstrated by society as a whole, making it possible for short-term decisions to be made that are at odds with long-term desires.

The selection of the discount rate is especially challenging due to uncertainty about the societal rate of time preference over the very long run. Use and provision of natural capital efficiently economic expansion requires capital production, whether it be generated, human, social, or natural. Only if sufficient investments are made in other forms of capital64 can declining levels of certain natural assets be compatible with sustained growth. It is possible to achieve sustainable long-term growth by investing the proceeds from the depletion of environmental assets in physical capital (such as infrastructure), human capital (such as skill levels), or even other types of natural capital (by, for instance, compensating biodiversity losses in one location by creating new habitats elsewhere). Maintaining a minimal stock of these assets must be taken into consideration, nevertheless, to the degree that the services supplied by natural assets have important thresholds or cannot be replaced by other commodities and services. The ecological services that the ozone layer provides, for instance, cannot be replaced by technology or created capital. This method is used to measure the "true" level of savings in an economy by indicators like Adjusted Net Saving (or Genuine Saving), which take into account not only standard "gross" savings but also the depreciation of physical capital, investment in human capital, and the depletion and degradation of natural capital.

These indicators provide a useful technique to capture changes in the overall capital stock, including changes in natural capital66, despite the major measurement and computation challenges. Production inputs must be utilised to the point where the cost of utilising an extra unit equals its contribution to economic output in order to be used economically. When it comes to environmental inputs, the value of every extra unit used is calculated in terms of the societal advantages that are lost when the resource is used. So, valuing natural resources appropriately and taking them into account when making choices about production and consumption is necessary for sustainable economic development. Overusing these advantages is caused by undervaluing or improperly appreciating them.

There is often a price reaction when resources become scarcer, such as when mineral deposits are exhausted; prices rise as resources become scarcer. This encourages the development of replacements for it in the manufacturing process as well as the more effective use of the resource during production. This not only prevents the abuse of natural resources but also boosts economic growth via increased efficiency. Nevertheless, since many natural capital components lack markets, this price response and the associated incentives for efficiency will not take place. In situations when natural capital exhibits unidentified critical thresholds, other types of intervention may be explored. It may frequently be preferable to take a more cautious approach and set environmental targets instead, typically a little below where the true critical threshold is thought to exist, given the many scientific and economic challenges associated with valuing natural assets and identifying critical thresholds.

Rationale for environmental policy:

Environmental policy has the responsibility of overseeing the supply and use of natural resources in a manner that promotes ongoing gains in prosperity and welfare for both the present and the future generations. To do this, government action is required for a variety of reasons. Natural resources would specifically be overused in the absence of government intervention due to market failures69 in their supply and usage. The public good characteristics of the natural environment, "external" costs and benefits, where one party's use of a resource has an impact on others, challenges in capturing the full rewards of private investment in environmental R&D, and information failures are the causes of these market failures. Here, each of these market failures is covered in more depth.

Public good characteristics of the natural environment:

A significant factor in the under-provision of environmental goods and services is the fact that many of them are either fully or partially public commodities. Markets alone will not be able to offer the socially optimal level since consumers may free-ride and providers are unable to collect or price for all the advantages the item provides due to its non-rivalry70 and non-excludable71 qualities. For instance, using farmland as a natural flood barrier may protect a whole area from flooding. A person who benefits from these defences does not diminish their availability to others (nonrival), and people cannot be barred from using their advantages (non-excludable). People may not want to pay for the benefit as a consequence, and service providers might not want to keep providing it[9].

Existence of externalities:

Externalities arise when one party's usage of a resource results in costs or advantages for another party, yet these effects are not taken into account when making economic choices. Economic agents individuals, businesses, or governments thus fail to fully bear the costs and benefits of their activities on society. Positive externalities tend to lead to under-provision of the item or service, while negative externalities tend to lead to over-provision. Externalities may be either positive or negative depending on whether activities have unpriced beneficial or destructive impacts. As an illustration, in the absence of regulation, sewage companies that discharge effluent into waterways will not be held accountable for the full social cost of their activities, including the loss of recreational and other benefits and/or the cost to society to repair the harm, which will cause environmental degradation above the point at which it is economically feasible. On the other hand, beekeepers may not always be able to profit from the positive externality of bees pollinating plants for their honey, which results in a lower degree of service than would be economically feasible.

Private under-investment in environmental R&D:

The amount of R&D investment that is optimum for society as a whole is not provided by the market alone. Private R&D investment falls short of what is ideal since the private rate of return on investments does not fully account for the societal advantages of this investment. Since many environmental advantages are non-market and are not represented in market pricing, the market will also underfund environmental R&D because investors won't be able to profit from their investment. For instance, Stern (2006) identified a significant impediment to combating climate change as the underinvestment in R&D into renewable and other low carbon technology. Efforts to account for the externality and pricing in the cost of environmental pollution boost the private return on environmental investments and partially make up for underinvestment in R&D. Therefore, to solve this market failing and stimulate investment to the socially optimal level, more government assistance is needed.

Information failures:

Information failures happen when the information required for individuals or businesses to make the best choices is insufficient, expensive to get, inaccessible, or difficult to understand. This is particularly true for environmental systems, which are by their very nature complex, non-linear, and indicative of a broad variety of interdependencies. Considering these difficulties, decision-makers may not always possess the knowledge required to produce an effective result. As a consequence, there may be missed chances to improve the state of the economy and the environment. For example, information failures are a common reason why firms and people do not adopt resource efficiency techniques that not only enhance environmental results but also save them money.

Range of available policy instruments:

In order to solve these market failings, the government has a variety of policy alternatives. The many policy tools that governments may use to enhance the distribution of environmental assets and encourage long-term sustainable economic development are summarised in this section. Market-based (economic) tools, such as fiscal and other measures that directly or indirectly price in externalities in order to more accurately represent the whole societal cost of an activity. For instance, these instruments may be created to tax activities that have societal costs and to subsidise those that provide broader benefits by lowering the cost of doing the activity (by raising the cost of undertaking it). Market-based instruments have the benefit that, although they establish the price or quantity criteria, the market will then look for the most efficient and economical manner to function within the established boundaries.

Climate change:

The EU Emissions Trading System (EU ETS) is a crucial instrument for combating climate change on a global scale. It restricts the amount of carbon that specific sectors of the economy may emit, so indirectly pricing such emissions. Companies participating in the programme are permitted to exchange emissions permits, allowing abatement to take place where it is most affordable.

Waste policy:

The Landfill Tax, which tries to internalise the external costs of transporting garbage to landfills and encourage the use of alternative waste treatments, is a crucial instrument in reducing waste. By directly raising the cost of land-filling garbage, the landfill tax directly incentivizes the efficient level of waste flowing to landfills, in contrast to quantity-based instruments like the EU ETS. Yet, quantity- and price-based instruments are both effective and economical means of achieving the desired results.

Delivering wider environmental goals:

The Common Agricultural Policy (CAP) Single Payment System requires farmers to comply with some environmental land management requirements, but the Environmental Stewardship Programme incentivizes farmers to go above and above these requirements. The programme supports environmental land management practises that preserve biodiversity and preserve and improve the natural landscape.

Direct Regulation, such as performance- and technology-based criteria that increase the cost of engaging in ecologically harmful activities while implicitly pricing in the externality. While direct rules are often less effective and efficient than market-based tools, there are times when they are suitable, such as when the dangers of non-compliance are assessed to be too great or when agents' alternatives and costs for complying are comparable.

Vehicle standards:

Environmental rules that establish strict and mandatory criteria for vehicle emissions define the automotive market. Since 1993, the EU has imposed progressively stricter requirements on automakers with regard to the amount of emissions from their cars. Manufacturers are encouraged to continue investing in innovation to decrease emissions below the existing threshold by the ever stricter regulations, which are set at levels that are challenging but technologically feasible.

Reducing water pollution from agriculture:

Since nitrate pollution must be eliminated before water can be delivered to customers and because it has the potential to damage the natural water ecosystem, it is a problem. On agricultural land, nitrates infiltrate water in excess of 60%. Farmers must take special actions to decrease the quantity of nitrates that run off into water courses in areas designated as nitrate vulnerable zones, which, as of 2009, have covered around 70% of England75. Public expenditure programmes that make up for the under-provision of environmental assets and services by the private sector include providing minimum levels of such assets and services as well as funding environmental R&D. They also guarantee that everyone has access to environmental services at a sufficient level and quality.

Spending on flood defences:

Flood defences are a local public benefit that, if left to the market, would not be adequately delivered. Thus, government spending on flood defence system construction and modernization aims to manage flood risk efficiently while preventing or reducing needless damage to private and public property. The estimated national flood defence spending in 2010–11 is £780 million, up from £310 million in 1997–1998.

Support for electric vehicles:

The Government has committed to spending £400 million to support the creation, production, and usage of next-generation ultra-low carbon vehicles, including the installation of charging stations in three to six major UK cities and a significant financial incentive for the purchase of new electric cars. Although the former helps build the necessary infrastructure to get beyond other obstacles to their uptake, the latter directly influences the demand for automobiles. In turn, market growth encourages manufacturers to spend money on better models. When implemented in concert with other measures, information supply, including actions to remove information gaps and incomplete information78, may have a major positive impact on the economy and the environment. Without trustworthy information, many activities or behaviours that may improve the environment and the larger economy can go unnoticed.

Energy using Products labelling:

Due to inconsistent and inaccurate information on product energy efficiency, customers often make poor choices, missing out on chances to save money and lessen environmental effects. In order to solve this information gap and provide customers access to information on energy efficiency at the time of sale, the EU introduced a labelling policy for energy-consuming items in the late 1990s[10].

Encouraging business resource efficiency

Businesses may take a variety of actions that not only lower their expenses but also assist the environment, such as using less water and creating less garbage for landfills. Businesses may not always use these solutions, however, due to market failures such as a lack of knowledge and other obstacles to altering behaviour such as divided incentives and organisational inertia. The efforts of government-funded organisations like the Waste and Resources Action Plan81 and information programmes like "Saving Money - It's Your Business" and "The Top Ten Recommendations for Resource Efficiency" assist in removing these obstacles. Combining several instruments the prevalence of many market failures and regional and global environmental problems need the deployment of a variety of tools. The many market imperfections and other efficiency hurdles exist at the global, national, and sectoral levels, and no one tool can effectively address them. Technology/spending programmes push new technologies into the market, while market-based instruments, direct regulation, and information campaigns draw them in. This push-pull complementarity between instruments may be more successful and cost-effective in achieving the intended result. The EU ETS is supplemented, for instance, by laws pertaining to energy-consuming items like TVs, lightbulbs, and white goods (such as refrigerators, freezers, and washing machines). While the EU ETS sets a general cap on CO2 emissions from the use of electricity, product policies such as minimum standards, labelling, and promotional campaigns address information gaps and other downstream barriers to behaviour change so that emissions reductions are realised in the most efficient way possible. Therefore, environmental policy that targets the various market failures and takes a multi-dimensional approach is likely to be more cost effective and better able to deliver the desired outcome given the numerous and sometimes mutually reinforcing market failures in the provision and use of environmental resources. By using environmental resources sustainably, strong and credible environmental policy would not only improve environmental results but also support the economy as a whole and ensure long-term economic development.

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CHAPTER 8

ENVIRONMENTAL IMPACTS OF BIOFUELS

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Biofuels Help Mitigate Climate Change

We must examine emissions throughout the entire process of producing, transporting, and utilising the fuel in order to determine the overall impact of replacing fossil fuels with biofuels on greenhouse gas emissions. The primary instrument for doing this is life-cycle analysis. It contrasts a particular biofuel system with a benchmark system, typically gasoline. The type of crop, the location, and the manner in which feedstock production and fuel processing are carried out all have a significant impact on greenhouse gas balances. Some types of biofuels have the potential to produce higher greenhouse gas emissions than fossil fuels[1], [2].

The amount of fossil energy used for feedstock production and transportation, including for the production of fertiliser and pesticides, for crop cultivation and harvesting, is a significant factor contributing to greenhouse gas emissions. Nitrous oxide emissions are still another crucial element. It is released when nitrogen fertilisers are utilised, and it has a 300-fold greater greenhouse gas effect than carbon dioxide[3], [4].

Because they reduce the energy and greenhouse gas emissions that would otherwise be required to manufacture the feed, byproducts from the biofuel industry, such the proteins used in animal feed, help to mitigate climate change. When replacing fossil fuels with first generation biofuels, most studies have concluded that using the most effective systems and excluding carbon dioxide emissions from changes in land use results in reductions in greenhouse gas emissions of 20 to 60%.

In Brazil, sugar cane is used to create ethanol, and second-generation biofuels often lower emissions by 70 to 90%, again excluding carbon releases attributable to land-use change. Since land-use changes have a significant impact on greenhouse gas emissions, it is important to know whether increased biofuels production will be met through improved land productivity or through expansion of cultivated area[5].

Expansion of cultivated land

Approximately 8.3 billion hectares of the 13.5 billion hectares of land surface area on earth are either grassland or forest, while 1.6 billion hectares are used for agriculture. Between 250 and 800 million hectares might be made accessible for the increase of biofuel crop production after removing forest land, protected areas, and agricultural land required for food production.

About 1% of cropland worldwide was used for biofuels in 2004, and the IEA predicts that this percentage would rise to 3–4 times that amount. Some land that was once unprofitable could be put back into use, as in the case of the former Soviet Union. In reality, more land is anticipated to come from non-cereal croplands, set-aside land, and new, currently uncultivated land, particularly in Latin America and Africa, as well as Australia, Canada, the United States, and the European Union. Intensive research has significantly increased crop yields, although it has mostly concentrated on a few crops and places. Actual yields are still below their potential in many parts of the world. In comparison to other places, Africa has not benefited as much from current high-yield crop varieties and farming techniques[6]–[8].

How will biofuel production affect water resources?

Water is utilised extensively during the manufacture of biofuels to wash plants and seeds as well as for evaporative cooling. However, irrigation has a major influence on the local water supply. Unless they can be irrigated, crops like sugar cane, oil palm, and maize have relatively high water requirements and are best suited to high-rainfall areas. Rainfed agriculture accounts for three-quarters of Brazil's sugarcane production and a smaller portion of the USA's maize production.

The availability of water resources may constrain the production of biofuel crops in countries that would otherwise have a comparative advantage. The amount of irrigation water needed in lower rainfall areas can be significant. Many irrigated sugar-producing regions in southern and eastern Africa and north-eastern Brazil are already operating close to the limits of the available water. Even plants like jatropha that can be grown in semi-arid areas may require some irrigation during hot and dry summers.

Water quality will be impacted by increased biofuel crop production. For instance, turning pastures or forests into maize fields could exacerbate issues with soil erosion and runoff of excess nitrogen and phosphorus into surface and groundwaters. Chemicals and pesticides can also wash into bodies of water.

How will biofuel production affect soils?

Both changes in land use and increased agricultural production have the potential to degrade soil quality, although the effects vary according to how the area is farmed. Different agricultural methods can increase the output of biofuel crops while minimising negative effects or even improving environmental quality. These include suitable agricultural rotations and conservation tillage. It is possible to lower soil quality by removing plant remains that would otherwise nourish the soil and permanent soil cover that prevents erosion. It is only possible to extract 25 to 33% of the available crop leftovers from grasses or maize without damaging soil quality, notably soil organic content. When opposed to annual crops like rapeseed, maize, or other cereals, perennial plants that can be harvested over a number of years, like palm, short-rotation coppice, sugar cane, or switchgrass, have higher levels of soil cover and organic carbon. In the case of sugar cane, nutrients from sugar-mill and distillery wastes can be applied to maintain soil quality.

How could an environmentally sustainable biofuel production be ensured?

Making bioenergy sustainable can be greatly aided by the adoption of "good practices" in the areas of harvesting, processing, and distribution as well as soil, water, and crop protection, energy and water management, nutrient and agrochemical management, biodiversity and landscape conservation, and crop and nutrient management. For instance, good forestry and agricultural practices, like conservation agriculture, can lessen the harmful effects of biofuel production on the environment. It is important to establish sustainability criteria or standards with the active collaboration of developing country partners and go hand in hand with training and support for implementation. These efforts are already underway in a number of fora, such as the Global Bioenergy Partnership and the Roundtable on Sustainable Biofuels. Payments for environmental services may also serve as a means of promoting adherence to sustainable production standards and practices.

In the near future, there will need to be a significant supply of low carbon renewable transportation fuels in order to fulfil the aim of lowering greenhouse gas (GHG) emissions, dependence on fossil fuels, and dependence on imported fuels. Globally, biofuels are anticipated to play a significant part in accomplishing these objectives. For instance, the National Renewable Action Plans of the European Union (EU) call for a 33% increase in biomass-based energy by 2020 from 2013. (NREAPs). According to requirements under the increased Renewable Fuel Standard in the United States, 36 billion gallons of renewable fuel will be incorporated into transportation fuels. (RFS2). RFS2 divides biofuels into four categories: conventional biofuel, cellulosic biofuel, biomass-based diesel, and advanced biofuels. The latter two must have life cycle GHG emissions, or carbon intensity (CI), that are at least 50% lower than those of ordinary petroleum diesel. The Low Carbon Fuel Standard (LCFS), which aspires to lower the CI of transportation fuels by 10% in 2020 based on a sales-weighted average, promotes renewable fuels in California, including biofuels. A known CI of each fuel included in the programme is required by several regulations, notably RFS2 and LCFS, to ensure the reduction of carbon emissions using a life cycle assessment (LCA) methodology. LCA makes an effort to quantify all environmental effects of systems and goods. The growing use of LCA-based analysis in the U.S. and EU to assess the effectiveness of biofuels and mitigate climate change in policy has shown the value of LCA as a tool for decision-making and shown the difficulties in creating ecologically desirable and sustainable biofuel pathways. The majority of biofuel manufacturing procedures involve intricate, multifaceted systems. Together with producing biofuel, they also create co-products that are commercially beneficial, such fertiliser and animal feed. Such byproducts are often crucial for figuring out how economically viable and environmentally responsible biofuels are. Researchers have extensively examined the difficulty and implications of addressing co-products in LCAs for biofuel production systems. This dissertation looks more closely at co-product use, modelling it, and discussing how to handle it in LCA.

Since they may avoid some of the negative consequences of terrestrial oil crops, microalgae-derived biofuels are becoming a more popular alternative to conventional energy crops. In addition to their great production and oil content, microalgae need a lot less space and don't need fertile crops. Yet, to produce a high volume of oil during growing, microalgae need a lot of fertiliser. Moreover, gathering and dewatering the biomass need a significant amount of energy. The results of numerous life cycle assessment (LCA) studies of algal oil production show greenhouse gas (GHG) emissions from algae biodiesel varied from 20 to 500 g CO2e /MJ while the energy return on energy investment (EROI) of algae biodiesel ranged from 0.2 to 6. These studies were conducted to evaluate environmental impacts and identify energy-intensive processes of the system with various assumptions on growth parameters and oil extraction or conversion technologies. These results fall within this range as a consequence of technique and model-induced variability as well as genuine variation in system performance, both in real-world and simulated scenarios. The approaches used to address co-products stand out as needing further research and direction among the various causes of method and model-induced heterogeneity.

The majority of biofuel production methods are multi-functional systems that generate both commercially important co-products like algal cake, which can be used as fertiliser and animal feed, and biofuel products. Because there are typically multiple methods for handling co-products and because there is no consensus on when each of the 12 different methods should be used, practitioners of life cycle assessments (LCAs) of biofuel production systems frequently struggle with the problem of co-product allocation [4]. Certain methodologies are needed to either reflect consequences due only to the biofuel or spread the environmental impacts across the biofuel and co-products in order to avoid primarily attributing environmental burdens to the biofuel. The methodologies used to divide environmental loads across core goods like biofuels and co-products, as well as the assumption made about how co-products are used, may have a substantial impact on the outcomes of an LCA. Moreover, various co-product use assumptions may favour certain allocation techniques, which means that the choice of allocation method may be influenced by utilisation decisions. Although standardising allocation techniques across research might alleviate this, this is often not practicable owing to variations in system boundaries, route designs, and the amounts and quality of the goods. A hybrid allocation strategy is sometimes used to depict a realistic use of the energy products and co-products. Many research have examined the shortcomings and benefits of each allocation method. There is disagreement over the ideal allocation technique for biofuel LCA, hence it is advised for case studies to compare a number of different allocation strategies. This study compares two algal fuel pathways renewable diesel from hydrothermal liquefaction (HTL) and biodiesel from a solvent-based lipid extraction (LE) process to examine the actual, method-induced, and model-induced variability of algal biofuels. Each of these channels produces unique coproducts that may be used in unique ways and that can be allocated using unique approaches.

In the U.S., ethanol is mostly made from corn starch; in 2015, 34% of maize (5175 out of 15414 million bushels) was used to make ethanol for gasoline. The negative consequences of corn ethanol production on the environment have been extensively studied in the literature; these discussions often stress the rivalry with resources for food and feed, as well as the effects of changing land use. Fuel policies like California's Low Carbon Fuel Standard (LCFS) and the federal Renewable Fuel Standard (RFS2) look to second generation (2G) ethanol produced from cellulosic feedstock like corn stover to avoid the drawbacks of first generation (1G) fuel like corn grain-derived ethanol in their efforts to promote fuels with lower greenhouse gas (GHG) emissions. There are still obstacles to expanding the production of cellulosic ethanol after years of research. There were only four commercial cellulosic ethanol production plants operating in the United States as of 2015: DuPont, POET, Abengoa, and Quad County Corn Processors. The inefficient conversion of cellulose to fermentable sugars, high capital costs, and the need for a significant quantity of often low-density feedstock must all be addressed in order to produce cellulosic ethanol on a commercial scale.

A new trend in technology is to retrofit existing corn starch ethanol production facilities with a cellulosic ethanol process train. This so-called "bolt-on" technology creates sugar from corn stover to mix with sugar from corn grain in order to overcome these issues. The plant produces a mixture of cellulosic and maize ethanol as a result of the bolt-on technology's partial displacement of the requirement for sugars from corn starch. The bolt-on equipment may only be able to produce a limited quantity of cellulosic ethanol, but it nevertheless allows facilities to experiment with cellulosic materials without having to make the costly capital expenditure of standalone plants [4]. In addition, since lignin is produced as a residual product of corn ethanol production and may be burned to provide power and heat, lowering the need for process fuels, corn ethanol plants can gain more generally from retrofits that include cellulose feed stocks [9].

The economic viability of combining 1G and 2G ethanol producing plants was investigated as early as 2005. Co-located 1G and 2G ethanol producing facilities from sugarcane and bagasse have been the subject of several techno-economic assessment (TEA) and life cycle assessment (LCA) studies. Co-located 1G and 2G ethanol exhibits lower production costs and environmental benefits, such as decreased GHG emissions, when compared to a stand-alone 2G ethanol factory. A Study of co-located 1G and 2G ethanol facilities utilising maize grain and stover as feedstock came to similar findings. A small number of co-located 1G and 2G ethanol products have undergone life cycle GHG intensity calculations and LCAs. The Project LIBERTY plant, which employs maize and stover feedstocks, was modelled in a 2015 LCA assessment. Using land use change (LUC) GHG emissions for corn grain ethanol and stover ethanol of 7.6 and -0.6 g CO2e/MJ, respectively, the carbon intensity (CI) for corn and stover ethanol was calculated at 57 and 25 g carbon dioxide equivalent (CO2e) per MJ. The distribution of lignin-derived energy between the corn ethanol plant and the stover ethanol plant in a combined heat and power (CHP) unit was the main topic of the research. The displacement allocation approach was used to manage distiller's grains and solubles (DGS), which resulted in a credit of 15 g CO2e/MJ maize ethanol. Previous studies have carefully considered the energy produced by the burning of stover or bagasse, but it seems that the co-product DGS in either wet or dry form was not given the same rigorous consideration. This study adds to the sparse LCA literature on co-located 1G and 2G production facilities and advances methods and knowledge related to allocation of livestock feed co-products by taking into account the influence of dairy ration science, regional feedstuff availability, and real-world market conditions on co-product displacement calculations. These two contributions specifically address gaps in the existing literature.

Demand for food has increased due to global population expansion and changing dietary patterns, notably for nutrient- and protein-rich animal items like fish and shellfish. As a consequence, ocean resources have being used at previously unheard-of rates, resulting in a decline in marine biodiversity, modifications to the food chain, and other changes to the ocean's structure. According to a survey of global fish populations by the FAO (Food and Agricultural Organization), 17% of them are overexploited, and more than 52% are at danger of population reduction. Since wild fish are caught for both direct human consumption and as a source of food for cultured fish, fishing and aquaculture operations are the main causes of the depletion of ocean resources. Fishmeal from low-value pelagic fish has historically been a cheap major source of protein for farmed fish. Yet, the aquaculture industry's quick expansion has led to a rise in both the price and demand for these fish as well as a decline in the supply of fishmeal. More stringent regulations implemented in many nations to prevent fishery depletion and collapse are expected to slow down the total fish supply from ocean catch fisheries. This will result in lower catches of high-value fish intended for human consumption as well as lower catches of low-value fish that would be used to produce fish for human consumption in an aquaculture system. A search for alternatives to low-value fish as a protein source has been prompted by the rising demand for fish and worries about the sustainability of marine species that are heavily harvested. Researchers have been looking for cheaper plant-based meals to replace fishmeal, but sadly, they often have negative effects on fish development performance or need high doses of additional dietary supplements to attain high growth rates. Many aquatic creatures eat algae naturally, and it may be a better option than feeds derived from terrestrial sources such soy meal since it better satisfies the needs of aquatic organisms. Algae-based fishmeal may replace products from wild capture fisheries in proportion to their nutritional content or market value, thus reducing withdrawals and the associated effects on ocean ecosystems. This is if critical nutrients can be given by algae-based fish feed.

As a byproduct of algal oil, which has long been researched as a possible source of biofuel, defatted algae2 meal is created. Microalgae may sometimes be produced on low-quality water sources that are unsuitable for terrestrial crops, which helps them avoid some of the most difficult issues that terrestrial bioenergy crops face, such direct and indirect land use change. Defatted microalgae meal has been researched as a possible substitute for fishmeal for farmed fish species utilising a variety of fish species and microalgae strains, and many of these studies indicate a great deal of promise for successfully supplying protein, lipids, vitamins, and energy to cultured fish. When utilised as livestock feed, microalgae-based diets have sometimes shown to increase the weight, growth, health, and immune system of both fish and animals. The fact that microalgae may be a source of fatty acids necessary for fish development may be a contributing factor in this. The possible environmental impact on ocean fisheries when microalgae-based meals are used as fish feed to prevent fishing for replacement species is thus outlined. It also covers the potential impact on terrestrial resources if microalgae-based meals replace crop-based feeds either for aquaculture or livestock.

The world is now dealing with two crises: the depletion of fossil fuels and the destruction of the environment. The current situation has intensified the hunt for alternative fuels that offer a harmonious relationship with sustainable development, energy saving, efficiency, and environmental protection. The global petroleum dilemma may have a workable answer in the form of biofuels. Automobiles powered by gasoline and diesel are the main emitters of greenhouse gases (GHG). Several alternative energy sources, including biomass, biogas, primary alcohols, vegetable oils, and biodiesel, have been investigated by scientists worldwide. While these alternative energy sources are very eco-friendly, their benefits, drawbacks, and particular uses must be considered on a case-by-case basis. Some of these fuels may be utilised right away, while others need to be modified to give them qualities that are more similar to those of conventional fuels. The last ten years have seen a considerable rise in environmental concerns, especially after the Earth Summit in 1992. Global environmental deterioration caused by excessive use of fossil fuels includes the greenhouse effect, acid rain, ozone depletion, and climate change. As a result, new technologies or alternate sources of energy for the world's motor vehicles are required. Two worldwide bio renewable liquid transportation fuels have the potential to take the place of gasoline and diesel. These are biodiesel and bioethanol. Good alternative fuel bioethanol is made mostly from food crops. Because of its advantages for the environment, biodiesel has lately become increasingly appealing. One of the major energy-consuming industries is transportation. It is presumable that biodiesel is utilised to replace fossil fuel-based diesel.

Bioenergy, which may be defined as energy generated from any source of biomass, including plants, animals, and organic waste, makes up around 10% of the world's total energy output. Bioenergy is used in a variety of ways, from conventional energy in rural areas to liquid biofuels in the transportation industry. This essay especially focuses on the development of "biofuels," which are here defined as liquid biofuels for transportation. While any organic material (often referred to as "feedstock") might theoretically be used to make biofuels, the majority of the existing or "first generation" biofuels are based on food crops. Nowadays, ethanol from sugars and biodiesel from oil seeds account for 98% of biofuel production. Sugar cane and maize are the primary crops used to make ethanol, while rapeseed and oil palm are the most popular sources of oil used to make biodiesel. According to different feed stocks are more or less effective at producing bioenergy, and certain feed stocks also provide valuable byproducts like oilcake for animal feed. Due to the large diversity of feed stocks employed, the type is crucial when discussing first generation biofuels. Both "third generation" biofuels made from algae and "second generation" biofuels that employ cutting-edge technology to break down lignin and cellulose to turn biomass and waste products into fuel are presently being developed. There is no clear definition of the precise standards that lead to the labelling of "first-generation," "second-generation," and "third-generation" biofuels. The term "first generation" biofuels will be used in this study to refer to any biofuel that is presently being produced on a substantial scale.

The manufacturing of liquid biofuels is rising quickly. To combat climate change, provide energy security, and promote rural development, governments are establishing goals to increase the percentage of biofuels in their energy mix. The majority of studies to far has been on how well biofuels work in lowering carbon emissions, with concerns voiced about their potential in this regard. The possible effects of biofuels on biodiversity have received far less consideration. The biofuel crop and historical land usage will determine how biofuels affect biodiversity. When appropriate crops are cultivated in appropriate regions, biofuels may benefit biodiversity. Also, if they aid in reducing climate change, biodiversity as a whole may reap the benefits inadvertently. Yet, it has already been shown that biofuels have a detrimental effect on biodiversity when they directly alter natural ecosystems or indirectly alter undisturbed land. In the tropics, the increase of biofuel production has led to the destruction of wetlands and tropical forests, while in temperate zones, biofuel production has invaded designated lands[10].

It has been shown that biofuel feedstock plantations, especially oil palm and maize plantations, sustain far lower levels of biodiversity than natural ecosystems and may lead to soil erosion and watercourse contamination. The degree of biodiversity effects is influenced by the management of a feedstock crop. In certain cases, well managed plantations may be advantageous for biodiversity, particularly if they are located on marginal or degraded soils. Future land needs will rise along with the demand for biofuels. Biodiversity is expected to suffer from conversion of natural terrain. Moreover, post-conversion management may harm biodiversity, for instance, by contaminating soil with fertilisers. While there is a great deal of ambiguity around this, some claim that the "next generation" of biofuels will need less space or be more productive and so lessen adverse consequences on biodiversity. One method to lessen the effects of biofuel production on biodiversity is the implementation of sustainability guidelines. Nevertheless, the creation and application of these criteria is proving challenging, in large part because there are no widely recognised definitions for important phrases like "high biodiversity" and "degraded" areas. In any case, it is probable that better land use planning will need to be integrated with sustainability criteria as part of the answer.

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CHAPTER 9

USES FOR BIOFUEL

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Biofuel has further uses besides being used as a diesel fuel alternative. It's a common misconception that this chemical is exclusively used for transportation. However, biofuel may also be used as cooking oil and cleaning oil in addition to creating hydrogen. From home heating to car gasoline, biofuels may be utilized as an alternative to satisfy energy needs. A biofuel is any fuel produced from biomass, sometimes known as organic matter. In addition to animal waste, this also comprises any form of plant or microbial debris, including wood. These fuels are considered as renewable energy sources since the natural cycle of life continuously refills them[1], [2].

As a result, they provide a good alternative to fossil fuels like coal, oil, and natural gas. These substances need to be produced over many centuries, and then they need to be removed from the soil using expensive and hazardous techniques. The world's fossil fuel supplies will ultimately run out, particularly if we continue to use them at the rate at which they are being used. Additionally, they are being used more quickly than they are being produced.

The top 10 applications for biofuel are shown below.

Transport

More than 30% of the energy used in the US is used for transportation-related activities. Transport uses up more than 60% of absorbed oil and 24% of global energy. This suggests that more than a third of all oil is used in the functioning of automobiles.

The major downside of alternative energy is that, unlike solar, wind, and other kinds of alternative energy, it cannot be utilised for transportation. According to experts, effective technical advancements are still decades away.

Biofuel may essentially be transformed into hydrogen steam that can be used in a fuel cell adjacent to it. Significant manufacturers have already invested in biofuel car charging infrastructure[3]–[5].

Energy Production

In addition to providing fuel for automobiles, fuel cell technology may also be utilised to produce electricity. Biofuel may be used to generate energy in backup systems in areas where emissions are most relevant. This is true for structures like schools, hospitals, and other institutions housed in residential neighbourhoods.

Actually, the largest market for biofuel in the UK comes from the utilisation of waste gas to power more than 350,000 homes.

Supply Heat

Bioheat has risen during the previous several years. The primary use of natural gas obtained from fossil fuels is hydraulic fracturing, which generates heat that will result in the production of natural gas. Natural gas does not always have to originate from fossil fuels; it may also come from recently grown material[6].

Significant amounts of biofuel are used for heating. The most cost-effective way to heat a home is with a wood-burning stove rather than with electricity or gas. A biodiesel mix will reduce emissions of sulphur dioxide and nitrogen oxide.

Electronics Recharging

Cooking oil and sugar, according to Saint Luis University researchers, were utilised to build a fuel cell that generates electricity. Users will be able to make use of this technology rather than generate energy. Instead of utilising batteries, customers would be able to charge everything from computers to mobile phones. Even though they are still in the research stage, cells have the potential to grow into a ready source of power.

Eliminate grease and oil spills

Biofuel is widely known for being environmentally friendly and might help clean up spills of oil and grease. It has been investigated as a potential cleaning solution in areas where crude oil fouled the streams.

Furthermore, it has been shown that the results have expanded the recovery zones and made it possible to remove it from the water. Biofuel has the added benefit of being a safe industrial solvent for cleaning metal since it has no negative side effects.

Cooking

The performance of biodiesel is on par with that of kerosene, which is the most widely used fuel for stoves and non-wick lights.

Use lubricant

Diesel fuel is required because sulphur provides gasoline the highest lubricity and has to be reduced. This is necessary to keep the engine functioning properly and avoid an early infection failure.

Take away paint and glue

Biofuel may be used to remove adhesive and paint instead of risky chemicals. Additionally, biofuel is seen to be the best approach to phase out non-critical usage.

Produce energy once fossil fuels are exhausted

When the amount of oil on hand starts to run out. We have thus begun to consider how fuel may be extracted without endangering the ecosystem. The development of biofuel will assist in the creation of an efficient, cost-effective energy generation technology.

Reduce the price and reliance on imported oil

More than 84% of the world's petroleum production is used in the United States. Despite an increase in gasoline usage, the U.S. has recently begun to cut the need since 2006. Due to this, biofuels are the most efficient component of energy conservation. Analysts claim that in the case of an oil interruption, employing biofuel in lieu of imported oil will help to stabilise the economy. More significant than how much money the US spends on oil imports is the stabilisation of the whole economy.

In addition to being used as alternative fuel sources, many of the by-products of biofuel production are also proving to be beneficial. As a result, these by-products may help the biodiesel business resemble the petroleum sector, where fuel is only one of many lucrative products. After that, these products may be utilised as feedstock for other businesses in a process known as "biorefining." One of them is glycerol, a syrupy liquid that is also sometimes called glycerine and is a byproduct of the manufacturing of biodiesel. Nowadays, glycerol may be found in everything from food to soap to explosives. Unfortunately, the market for glycerol has oversaturated due to an increase in worldwide biodiesel output. If biodiesel production rises, the price of glycerol, which is now between 20 and 50 cents per pound, might go as low as 5 cents. Thus, it would be beneficial to increase the number of beneficial applications for the syrupy liquid so that producers of biodiesel could sell their glycerol at a higher profit rather than paying someone to cart it away5. Making propylene glycol from glycerol is one such attempt. This substance is extensively utilised in the scientific and medicinal communities. Scientists are also considering how to make money from the distiller's dry grain and lignin leftovers from cellulosic ethanol, which uses feedstock including switchgrass, maize husks, and prairie grass. Lignin has so far shown some promise. Lignin, a naturally occurring polymer that contributes to the strength and stiffness of plants, makes up 15% to 25% of the majority of plants. The majority of designs for manufacturing cellulosic ethanol include burning the lignin to provide steam and heat for the operation. Lignin is valued around $40 per tonne as a fuel. At Iowa State, hydrogen and a biopolymer known as PHA are being produced from distiller's dry grain, a major byproduct of maize ethanol that is now mostly marketed as animal feed. It is anticipated that this biodegradable substance might be utilised in place of surgical gowns and gloves, which are now disposed of as medical waste. Moreover, sorbitol for use in industrial goods, high-fructose corn syrup made from maize, amino acids, and other items are manufactured[7].

IMPLICATIONS FOR USE OF BIOFUELS

Notwithstanding the beneficial applications of biofuels and their help to mitigating the effects of climate change, several business concerns have surfaced.

A. Climate change? According to research by Nobel Laureate Paul Crutzen7, the production of nitrous oxide (N 2O) from frequently used biofuels like rapeseed biodiesel and corn (maize) bioethanol may have an equal or greater impact on global warming than the cost savings from using fossil fuels due to global cooling. Crops that need less nitrogen (N), including grasses and woody coppice species, have a more favourable influence on the climate.

B. Supplying transportation with fuel? If one examined biofuels more extensively, they would not be found to be a long-term, viable alternative to the requirement for transportation fuels. Even if all of the 300 million acres (500,000 square miles) of crops presently being harvested in the United States generated ethanol, it would only meet roughly half of the country's demands and not all of the gasoline and diesel fuel currently used for transportation. 8. According to research conducted by the Agriculture Department on the current American method for producing ethanol fuel from maize, one acre of corn would produce around 350 gallons of ethanol. Yet ethanol only has around a two-thirds the fuel value of gasoline; in terms of energy production, 1.5 gallons of ethanol in the tank is equivalent to 1 gallon of gasoline.

C. How efficient is biofuel? Fertilizer, harvesting, transportation, and corn processing all need significant energy input in order to generate ethanol. According to some studies, when all inputs are taken into account, the net energy of ethanol is actually negative, meaning that it requires more energy to produce ethanol than is produced. Even with a net positive energy production of 30,000 British thermal units (Btu) per gallon, one gallon of gasoline would still need four gallons of ethanol made from maize. Corn farming covers 73 million acres in the United States. The whole maize harvest in the United States would produce 25.5 billion gallons, or around 6.3 billion gallons of gasoline, at 350 gallons per acre. The yearly use of gasoline and diesel in the United States is 170 billion gallons. Consequently, just 3.7% of the demand for vehicle and truck transportation would be met by the whole US grain output. Around 15% of the demand might be satisfied by using the whole 300 million acres of farmland in the United States for ethanol production made from maize. This might pose an even bigger problem in the Caribbean where land is scarce.

D. How well may agricultural waste be used? It is suggested that agricultural wastes from maize (corn stover) and sugar cane (bagasse) may be utilised to manufacture ethanol instead of corn. The sums are still a drop in the ocean, however. According to a recent research by the United States Energy Information Administration, using the crop wastes from maize production may produce nearly 10 billion gallons of ethanol annually. A half-gallon of gasoline's worth of net energy, or around 60,000 Btu per gallon, would be more readily accessible than with ethanol made from maize. Yet, the total amount of maize waste produced in the US would only be enough to make 5 billion gallons of gasoline. Moreover, soil fertility is harmed by not re-plowing wastes into the ground9. Growing any crop for biofuels has similar restrictions and issues, whether it be switchgrass, hybrid willow, or hybrid poplar. Even if switchgrass or another crop could produce 1,000 gallons of ethanol per acre, more than twice as much as it could from corn plus stover, and if its net energy was 60,000 Btu per gallon, ethanol from 300 million acres of switchgrass would still not be able to meet our current needs for gasoline and diesel, which are expected to double. At that time, less than half of our demands would be covered by the ethanol. The same can apply to bagasse and sugar cane.

E. Fuel vs food: The struggle between food and fuel highlights the destructive implications large-scale biofuel programmes would have on agriculture. Humanitarian policy would be to retain farmland for producing food, not fuel, given the global population increase projections. One kid dies from hunger-related causes every five seconds, or more than 16,000 children every day, and the problem is only going to grow worse. It would be unethical to use farmland that is required for human food production as an automotive fuel source. Moreover, it would reduce soil fertility and long-term capacity to sustain food production. We would eliminate the agriculture that would be necessary for our grandkids and their descendants to live10. Although this is going on, it should be noted that the[8] worldwide trade in biofuels is already having a severe influence on food sovereignty, rural livelihoods, forests, and other ecosystems. Large-scale monocultures of trees, sugarcane, maize, oil palm, soy, and other crops are necessary for the large-scale, export-focused production of biofuel. These monocultures are already the primary driver of deforestation and rural population loss globally. As a result of the fast rising demand for these crops as a source of biofuel:

- Tighter competition for land, which results in increased land concentration, the exclusion of small-scale agriculture, and the extensive conversion of forests and other ecosystems. In cases where fertile lands are used for housing settlements, the effects on land use should also be taken into consideration. Examples include: arable land that is currently used to grow food being used to grow fuel, which causes food prices to soar and causes hunger, malnutrition, and poverty among the most vulnerable groups in society; rural unemployment and depopulation;
- Indigenous Peoples' and rural communities' loss of traditions, cultures, languages, and spiritual values; the widespread use of agrochemicals that harm ecosystems and human health; the devastation of watersheds and pollution of rivers, lakes, and streams; the competition for water; droughts and other local and regional climatic extremes; and the widespread use of genetically modified organisms that pose unprecedented risks.

Women and indigenous peoples, who are economically oppressed and more reliant on natural resources like water and forests, will be most negatively impacted by these consequences. The impact on inflation may be more significant for the Caribbean. When food is redirected to the manufacture of biofuels, supplies would decline with corresponding price rises, which would drive inflation[9].

F. Price competitiveness

The primary factors of biofuel competitiveness are market prices, which include both those for fossil fuels and agricultural feedstocks. Considering the extreme volatility of both of these commodities, the competitiveness of the biofuel industry is inherently hazardous and requires long-term thinking on the part of investors. Any biofuel development effort in the Caribbean must successfully use economies of scale in production. It is crucial in this respect to have the knowledge and capability to choose the best technology and feed stocks in order to generate biofuels that are competitive with fossil fuel. For instance, insights may be drawn from economic analyses carried out for certain feed stocks in different nations. On the other hand, biofuels made from woody biomass and bagasse are increasingly used in the co-generation of steam and electricity since they are extremely competitive with the present price of fossil fuels.

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It is obvious that biofuels are not a complete answer to the world's energy issues, but they do have the potential to provide a more environmentally friendly type of energy that may likely help slow down climate change. Hence, tight management is needed to ensure high productivity and optimal yields of biofuels. The following would be required as a result:

- Control of fertilizer prices because rapidly increasing fertiliser prices could lead to under-usage;
- Efficient water collection and management are important;
- Development of strategies for managing crop residues as removal of crop residues can harm soil structure, promote erosion and damage the ecosystem;
- The challenge for developing countries is to find resources for large-scale biofuel production by buying into the best technology and processes available;
- Development of partnerships in biofuel production between developed and developing countries to alleviate poverty, speed rural progress and reduce greenhouse gases;
- Bioethanol is made from starch and sugar and biodiesel is made from different kinds of vegetable oils, so it is important that standards are developed for certification even as the world awaits the mass production of ethanol from cellulose material[10].
- The World Trade Organization (WTO) needs to set rules and standards for biofuel trading, whether as agricultural, industrial or even environmental goods. Scientists in developing countries must be prepared to advise governments and participate in this process;
- Biofuel development will require careful management and support from the public sector;
- The necessary legislation for use of domestically produced biofuel needs to be put in place. This will also give investors the stamp of approval;
- Promotion of integrated agro-energy farming policies in consultation with scientists, engineers and the general public to take into account the interconnectedness of the biofuel industries with livestock, farming, fisheries, and the conservation of forests and watershed areas to ensure maximising national benefits and sustainable development. This integrated approach is also important for coherent and sustainable water and land management;
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CHAPTER 10

NATIONAL POLICY ON BIOFUELS

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A National Policy on Biofuels was created by the Ministry of New and Renewable Energy in 2009 to encourage the use of biofuels throughout the nation. In the past 10 years, biofuels have attracted attention on a global scale, and it is critical to stay up with the rate of advancements in the industry. The government's ongoing efforts, such as Make in India, Swachh Bharat Abhiyan, and skill development, as well as the lofty goals of doubling farmer income, reducing imports, creating jobs, and turning waste into wealth, make biofuels strategically important in India. Due to the persistent and significant lack of domestic feedstock for biofuel production, India's biofuels programme has been significantly impacted, which needs to be addressed[1], [2].

Salient Features

1. To allow for the extension of appropriate financial and fiscal incentives under each category, the Policy divides biofuels into "Basic Biofuels" such as First Generation (1G) bioethanol and biodiesel and "Advanced Biofuels" such as Second Generation (2G) ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third Generation (3G) biofuels, bio-CNG, etc.
2. The policy broadens the range of raw materials that can be used to make ethanol by allowing the use of sugarcane juice, sugar-containing materials like sugar beet, sweet sorghum, starch-containing materials like corn, cassava, damaged food grains like wheat, broken rice, and rotten potatoes, as well as materials that are unfit for human consumption[3], [4].
3. During the period of surplus production, farmers run the danger of not receiving a fair price for their crop. Because of this, the Policy permits, with the National Biofuel Coordination Committee's permission, the use of excess food grains for ethanol production for blending with gasoline.
4. With a focus on Advanced Biofuels, the Policy suggests a viability gap finance plan for 2G ethanol Bio refineries of Rs. 5000 crore in 6 years, in addition to enhanced tax advantages, higher purchase price as compared to 1G biofuels[5], [6].
5. The Policy supports the establishment of supply chain mechanisms for the manufacture of biodiesel from short-gestation crops, used cooking oil, and non-edible oilseeds.
6. In order to coordinate efforts, the Policy paper has outlined the roles and duties of all relevant Ministries and Departments with regard to biofuels.

Expected Benefits

- **Reduce Import Dependency**: At the present exchange rate, one billion E10 lights save Rs. 28 billion. Around 150 billion litres of ethanol are anticipated to be supplied during the 2017–18 ethanol supply year, saving around Rs. 4000 billion in foreign exchange.

- **Cleaner Environment**: E-10 can reduce CO2 emissions by around 20,000 tonnes per crore of lights. There would be a reduction in CO2 emissions of 30 lakh tonnes for the ethanol supply year 2017–18. Greenhouse gas emissions will be further reduced by cutting back on crop burning and turning agricultural trash and leftovers into biofuels.
- **Health benefits**: Reusing cooking oil for food preparation for an extended period of time, especially when deep-frying, poses a health risk and increases the risk of numerous illnesses. It is possible to use wasted cooking oil as a feedstock for biodiesel, which will stop it from being diverted to the food business.
- **MSW Management**: In India, 62 MMT of municipal solid waste are produced each year, according to estimates. Technologies are available that can turn garbage (including plastic) and MSW into drop-in fuels. Such garbage has the potential to reduce fuel use by 20% or more per tonne[7].
- **Infrastructural Investment in Rural Areas**: One 100klpd bio refinery is expected to need a capital investment of about Rs. 800 crore. Twelve 2G bio refineries are now being built by Oil Marketing Companies with an estimated cost of Rs. 10,000 crore. The expansion of 2G bio refineries around the nation will encourage infrastructure spending in rural regions.
- **Employment Generation**: 1200 employment in plant operations, village level entrepreneurs, and supply chain management may be generated by a 100klpd 2G bio refinery.
- **Additional Income to Farmers**: Using 2G technology, farmers may transform agricultural waste and residues that would otherwise be burned into ethanol and sell it for a profit if a market is created for it. Additionally, during the era of surplus production, farmers run the danger of not receiving a fair price for their crop. Therefore, converting excess grains and agricultural biomass can assist in stabilising prices.

The Union Cabinet approves the Amendments to the National Policy on Biofuels -2018.

The "National Policy on Biofuels – 2018" was made public by the Ministry of Petroleum and Natural Gas on June 4, 2018, and it replaces the National Policy on Biofuels that was released by the Ministry of New & Renewable Energy in 2009.

The National Policy on Biofuels has been amended in response to developments in the field of biofuels, decisions made at National Biofuel Coordination Committee (NBCC) meetings to increase biofuel production, recommendations from the Standing Committee, and the decision to advance the introduction of ethanol-blend gasoline with up to 20% ethanol nationwide.

The National Policy on Biofuels has been modified in the primary ways listed below:

- To boost the production of biofuels in the nation under the Make in India initiative by units based in Special Economic Zones (SEZ)/ Export Oriented Units (EoUs);
- to push the ethanol blending objective of 20% blending of ethanol in petrol to ESY.
- to add additional members to the NBCC.
- to remove or change particular clauses in the Policy in accordance with decisions made at National Biofuel Coordination Committee meetings;
- to authorise the export of biofuels in certain circumstances;

One of the economies in the world with the quickest growth rates is India. Economic development, equality, and human welfare are the main goals of the development objectives. An essential component of socioeconomic progress is energy. A nation's energy strategy strives to attain an ideal balance of primary resources for energy production, efficiency, security, and access that is environmentally beneficial. In the next decades, fossil fuels will continue to dominate the energy landscape of our nation. Yet, conventional or fossil fuel resources must be exploited carefully since they are scarce, non-renewable, and harmful. In contrast, renewable energy sources are locally available, non-polluting, and almost endless. India has a wealth of renewable energy resources at its disposal. Thus, it is important to promote their usage in every manner.

The price of crude oil has been oscillating on the global market and has recently grown dramatically, rising to a level of over $ 140 per barrel. Global economies, especially those of emerging nations, are being severely strained by this unanticipated rise in crude oil costs. Around 95% of the demand for transportation fuels is met by petroleum-based oil, and that need is continually growing. About 156 million tonnes of crude oil were used in 2007–2008, according to preliminary estimates. Just around 23% of the demand can be satisfied by indigenous crude oil; the remainder is satisfied by imported petroleum.

Unless alternative fuels to replace or augment petro-based fuels are created based on domestically generated renewable feedstocks, India's energy security would remain at risk. The nation has a glimmer of hope for energy security in biofuels. Biofuels are environmentally benign fuels, and using them would allay worries about keeping carbon emissions in check. One of the main polluting industries has been noted to be transportation. Hence, the use of biofuels has grown more important given the tightening of automobile vehicle emission rules to reduce air pollution. Since biofuels are made from renewable biomass resources, they have a strategic advantage over conventional energy sources in promoting sustainable development and supplementing them to meet the country's enormous rural population's energy needs as well as the rapidly rising demand for transportation fuels brought on by high economic growth. Biofuels are increasingly able to provide these energy demands in a way that is economical, ecologically friendly, and less reliant on the importation of fossil fuels, boosting national energy security.

Energy security and environmental concerns are two major factors driving the global expansion of biofuels, and a variety of market mechanisms, incentives, and subsidies have been implemented to support this growth. In addition to these factors, developing nations see biofuels as a viable tool for promoting rural development and opening up job possibilities. In particular, the Indian approach to biofuels differs substantially from the present international techniques, which may put food security at risk. It is purely dependent on non-food feed stocks to be grown on deteriorated or wastelands that are unsuitable for agriculture, eliminating a potential conflict between the security of fuel and food. The goal of this policy is to encourage and promote the best growth and usage of domestic biomass feed stocks for the production of biofuels in the context of global views and national imperatives. In accordance with the Policy, new feed stocks will be used to build the next generation of more effective biofuel conversion technology. The policy outlines the vision, medium-term goals, strategy, and method for the development of biofuels and suggests a framework of enabling mechanisms and technical, financial, and institutional initiatives.

The Policy seeks to mainstream biofuels and, as a result, sees them playing a crucial role in the nation's energy and transportation sectors in the next decades. The Policy will result in an acceleration of the development and promotion of the cultivation, production, and use of biofuels, which will gradually replace gasoline and diesel in stationary and other applications, contribute to energy security, and help to mitigate climate change, in addition to generating new employment opportunities and fostering environmentally sustainable development. The policy's objective is to guarantee that there is always a sufficient supply of biofuels on the market to fulfil demand. By 2017, it is suggested to combine 20% of biofuels, including biodiesel and bioethanol. The biodiesel blend values that are specified are meant to be recommended in the near future. From October 2008, the blending amount of bioethanol has been required, and it will remain required until the indicated goal is reached.

For purposes of this Policy, the following definitions of biofuels shall apply: "Biomass" resources are the biodegradable portion of products, wastes, and residues from agriculture, forestry, and related industries as well as the biodegradable portion of industrial and municipal wastes. "Biofuels" are liquid or gaseous fuels produced from biomass resources and used in place of, or in addition to, diesel, petrol, or other fossil fuels for transport, stationary, portable, and other applications.

The following list of biofuels is included in the Policy's coverage on bioethanol, biodiesel, and other biofuels:

- "bio-ethanol" is ethanol made from biomass, which includes sugar- and starch-containing plants like corn, cassava, and algae, as well as cellulosic materials like bagasse, wood waste, and agricultural and forestry residues; "biodiesel" is a methyl or ethyl ester of fatty acids made from vegetable oils, both edible and non-edible, or animal fat of diesel quality; and "other biofuels" includes bio methane [8]. In order to produce bio-diesel, waste and degraded forest and non-forest areas in India will be used exclusively for the growing of shrubs and trees containing non-edible oil seeds. Molasses, a byproduct of the sugar industry, is the primary ingredient used to generate bio-ethanol in India. It would be made sure that in the future, the newest technologies would be built using non-food raw materials. As a result, the debate over whether to prioritise food or fuel security in India is irrelevant. Landless labourers, farmers, and other cultivators will be urged to start plantations that will serve as the raw material for biodiesel and bioethanol. Corporates would also be allowed to engage in contract farming for plantations with the help of farmers, cooperatives, Self Help Organizations, etc. in cooperation with Panchayats as needed. A minimum support price for the non-edible oil seeds used to make bio-diesel will be utilised to sustain such cultivation or planting. A fair playing field is required for increased development and deployment of biofuels to support the Policy goals in light of the present direct and indirect subsidies to fossil fuels and price distortions. From time to time, appropriate financial and fiscal measures will be taken to assist the creation and promotion of biofuels as well as their use in various industries. All areas of research, development, and demonstration, including the production of feed stocks and the processing of biofuels for a range of end uses, will be supported. The development of second-generation biofuels as well as the creation of novel feed stocks for the manufacture of bio-ethanol and bio-diesel will also get attention.

On abandoned, degraded, or fallow land owned by the government or a community, both in forests and nonforest regions, tree plantations containing non-edible oilseeds will be established. The Minimum Support Price method outlined in the Policy might potentially be used to implement contract farming on private wasteland. Agriculture-related plantations will be discouraged. Throughout the nation, there are more than 400 types of trees that produce non-edible oilseeds. Depending on each species' techno-economic feasibility for the generation of biofuels, its potential will be fully realised. To be distributed to growers and cultivators, high-quality seedlings would be cultivated in nurseries of approved institutions / organisations specified by the States. If plantations of non-edible oil seed producing trees and shrubs are dispersed across more than one village or more than one block/taluk, discussions with the local community will be conducted via Gram Panchayats/ Gram Sabhas, Intermediate Panchayats, and District Panchayat. Moreover, the Fifth Schedule Areas would adhere to PESA's regulations. A key component of this policy is the announcement and implementation of a Minimum Support Price (MSP) for oilseeds with a provision for periodic modification in order to guarantee fair prices for the farmers. The MSP mechanism's implementation specifics will be carefully crafted after appropriate discussions with the relevant Government agencies, States, and other stakeholders. The National Biofuels Coordination Committee, which is planned to be established under this Policy, will then decide once the Biofuel Steering Committee has given it some thought. It will be looked at if the Statutory Minimum Price (SMP) system, which is used for sugarcane procurement, may be expanded to include oilseeds used by processing plants to make biodiesel. The biodiesel processors would be in charge of paying SMP. Several States have previously established various amounts of the minimum support price for oilseeds.

Financial and Fiscal Incentives

For new and second generation feedstocks, sophisticated technologies and conversion processes, as well as production units based on new and second generation feedstocks, financial incentives, including subsidies and grants, may be taken into consideration based on merit. A National Biofuel Fund may be taken into consideration to provide such financial incentives if it becomes required.

Biofuels qualify for the different tax breaks and incentives that the federal government and state governments provide to the new and renewable energy industry since they are made from renewable biomass resources. Biodiesel is free from excise tax, but bioethanol already has a concessionary 16% excise charge. There are no additional planned central taxes or tariffs to be applied on bioethanol and biodiesel. If the equipment and machinery needed to produce biodiesel or bioethanol, as well as the engines used in stationary and other applications that operate on biofuels, are not made locally, custom and excise tax reductions will be made available. Demonstration and research and development.

This policy would place a strong emphasis on innovation, R&D, and demonstration in the area of biofuels. Plantations, biofuel processing and production technologies, as well as improving the efficacy of various end-use applications and using byproducts, will be the main areas of research and development. Local R&D and technological development based on local feed stocks and demands will be given high priority. Whenever feasible, patents will be filed and these efforts will be compared to international efforts. The development and support of multi-institutional, time-bound research programmes with distinct objectives and benchmarks. The following areas would see intense R&D work: (a) Production of biofuel feedstock based on sustainable biomass with active participation of local communities through non-edible oilseed bearing plantations on wastelands, including production and development of high sugar content varieties of sugarcane, sweet sorghum, sugar beet, cassava, etc. (b): Advanced conversion technologies for first-generation biofuels and developing technologies for second-generation biofuels, such as biomass-to-liquid (BTL) fuels, bio-refineries, and the ethanolization of ligno-cellulosic materials such agricultural leftovers, forest wastes, and algae. (c) Technology for stationary applications for motive power and energy generation using a decentralised approach, as well as technologies for end-use applications, such as the modification and development of engines for the transportation sector. Using waste materials from the manufacturing of biodiesel and bioethanol, such as oil cake, glycerin, bagasse, etc[9], [10].

Via public-private partnerships, demonstration projects for biofuels, including those for the production, conversion, and use of bio-ethanol and bio-diesel, will be established (PPP). Grants would be given to academic institutions, research organisations, specialised institutes, and industry for R&D and demonstration projects. It will also be explored to strengthen current R&D facilities and establish specialised centres in high-tech fields. Links would be made between the organisations or agencies developing technology and the organisations that employ it. The transfer of knowledge to industry would be made easier. In order to become more competitive on the global stage, industry will be encouraged to participate in R&D and technological development via greater investment. A subcommittee of the biofuel steering committee, comprised of the departments of biotechnology, agriculture, new and renewable energy, and rural development, would be established to oversee research and development in the field of biofuels. The subcommittee would be headed by the department of biotechnology and coordinated by the ministry of new and renewable energy.

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CHAPTER 11

RENEWABLE HYDROCARBON BIOFUELS

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Renewable hydrocarbon biofuels (also called green or drop-in biofuels) are fuels produced from biomass sources through a variety of biological, thermal, and chemical processes. These products are chemically identical to petroleum gasoline, diesel, or jet fuel. Since they meet the same ASTM fuel quality standards as the petroleum fuels they replace, these biofuels can be used in existing engines and infrastructure.

Types of renewable hydrocarbon biofuels include:

Biodiesel and renewable diesel are two different types of fuel. Previously referred to as "green diesel," renewable diesel is a hydrocarbon that is typically created by hydrotreating as well as through gasification, pyrolysis, and other biochemical and thermochemical processes. It complies with the petroleum diesel ASTM D975 criteria[1], [2]. Transesterification is used to create the mono-alkyl ester that is biodiesel. It is permitted to combine biodiesel with conventional diesel since it complies with ASTM D6751.

- **Renewable diesel**: Renewable diesel is a biomass-derived transportation fuel suitable for use in diesel engines. It meets the ASTM D975 specification for petroleum in the United States and EN 590 in Europe. It is a commercial fuel produced in the United States and imported from Asia. Five plants produce renewable diesel in the United States, with a combined capacity of over 590 million gallons per year. Production is expected to grow in the near-term with 2 billion gallons of capacity at six plants currently under construction and expansion at three existing plants[3], [4]. The U.S. Environmental Protection Agency (EPA) releases RFS RIN statistics, which shows that the country used over 960 million gallons in 2020. The U.S. Energy Information Administration (EIA) does not track renewable diesel output. Due to the financial advantages provided by the Low Carbon Fuel Standard, California uses almost all domestically generated and imported renewable fuel.
- **Sustainable aviation fuel (SAF):**SAF is a fuel made from renewable resources that, when compared to conventional fuels, allows for a reduction in net life cycle carbon dioxide emissions. SAF is the recommended and now widely accepted word for non-petroleum synthesised jet fuel components made in accordance with ASTM D7566's standards. Because SAF complies with ASTM D1655, when combined with normal jet fuel, it may be utilised in current aircraft and infrastructure. SAF has been in use at Los Angeles International Airport since 2016 and at San Francisco International Airport starting in late 2020. It is commercially accessible in limited numbers. In Los Angeles, there is one domestic SAF production plant in operation. Several more are being built or planned, and imports from a foreign producer started in late 2020. While EPA discloses RFS RIN data, which shows that the United States used 4.6 million gallons in 2020, EIA does not record SAF output[5], [6].

Seven SAF "pathways" or fuel classifications have currently been authorised under ASTM D7566. Before they may be recognised as ASTM D1655 comparable and subsequently utilised in an aeroplane, all of the neat SAF quantities must be mixed with regular aviation turbine fuel. The seven authorised routes are listed in the D7566 Annexes:

- Fischer-Tropsch (FT) hydroprocessed synthetic paraffinic kerosene (FT-SPK) fuel utilising solid biomass sources (for example, wood waste); maximum blend level 50%
- Synthesized paraffinic kerosene (HEFA-SPK), with a maximum blend level of 50%, made from animal fats, discarded cooking oil, algae, and vegetable oils (such as camelina).
- Direct-sugar-to-hydrocarbon fuel (HFS-SIP), a synthetic isoparaffin fuel made from hydroprocessed fermented sugars (SIP), with a maximum blend content of 10%
- FT-SPK with aromatic fuel utilising solid biomass resources (for example, wood waste); maximum blend level 50%
- ATJ-SPK, an alcohol-to-jet fuel with a maximum blend level of 50%, is made from isobutanol or ethanol.
- Jet fuel produced by catalytic hydrothermolysis (also known as hydrothermal liquefaction; CHJ); maximum mix level 50%.
- 10% maximum blend concentration of HEFA with hydrocarbons (HC-HEFA) made from esters and fatty acids.

- **Renewable gasoline:** Also known as biogasoline or "green" gasoline, renewable gasoline is a biomass-derived transportation fuel suitable for use in spark-ignition engines.

Production

Diverse biomass sources can be used to create renewable hydrocarbon biofuels. Lipids (such as vegetable oils, animal fats, greases, and algae), as well as cellulose material, are among them (such as crop residues, woody biomass, and dedicated energy crops). Where production is taking place, the commercial facilities mostly concentrate on producing renewable diesel, while more SAF production is anticipated given the number of plants now under development. It is typical for one facility to produce both SAF and renewable diesel[7], [8]. Five commercial renewable diesel plants with a combined capacity of 550 million gallons existed as of 2020, and one facility that produced both renewable diesel and SAF had a capacity of 42 million gallons. Eight new facilities are being built, and three existing ones are being expanded, adding an additional 2 billion gallons of capacity. At least three of the facilities will also manufacture SAF. The majority of the new plants and expansions of existing plants are for the production of renewable diesel. The majority of the renewable diesel that the United States imports comes from factories in Singapore. Due to California's Low Carbon Fuel Standard, SAF and almost all renewable diesel are used there.

Numerous techniques are being investigated by researchers to manufacture sustainable hydrocarbon biofuels. Production facilities can be standalone or integrated with oil refineries.

The following technological avenues are being investigated for the generation of renewable hydrocarbon biofuels:

- **Traditional hydrotreating:**when used in petroleum refineries, hydrotreating entails reacting the feedstock (lipids) with hydrogen at high pressures and temperatures while a catalyst is present. This technique is currently utilised in commercial plants.
- **Biological sugar upgrading:**This technique employs organisms that convert carbohydrates to hydrocarbons together with a biochemical deconstruction procedure similar to that utilised with cellulosic ethanol.
- **Catalytic conversion of sugars:**This pathway transforms a stream of carbohydrates into hydrocarbon fuels through a series of catalytic reactions.
- **Gasification:**During this procedure, biomass is transformed thermally into syngas and catalytically into hydrocarbon fuels.
- **Pyrolysis:** This method entails the chemical breakdown of organic compounds at high temperatures without oxygen. The procedure yields a liquid pyrolysis oil that may be converted into hydrocarbon fuels either alone or in combination with crude oil in a conventional petroleum refinery.
- **Hydrothermal processing:**By initiating chemical breakdown of biomass or wet waste materials under high pressure and moderate heat, this method creates an oil that may be catalytically converted into hydrocarbon fuels.

Biofuels that have physical properties similar to and can be used for the same purposes as petroleum distillate fuels include biodiesel, renewable diesel, renewable jet/aviation fuel, and renewable heating oil. Along with fuel ethanol, they qualify for use under the U.S. Renewable Fuel Standard (RFS) Program and may also qualify for use under state government fuel standards and programs.

Biodiesel is one of the first biofuels

In his experiments, Rudolf Diesel, the man who created the diesel engine in 1897, used vegetable oil as a fuel. Since it is mostly utilised in diesel engines, the fuel generated from vegetable oils and animal fats that we now refer to as biodiesel bears his name (as is petroleum diesel fuel). Biodiesel is permitted for blending with petroleum diesel/distillate since it complies with American Society for Testing and Materials (ASTM) standard D6751.

Vegetable and animal lipids are trans esterified to create biodiesel. The primary feed stocks used to produce biodiesel in the United States are vegetable oils, mostly soybean oil. Animal fats from meat processing facilities, used/recycled cooking oil, and yellow grease from restaurants are other significant U.S. biodiesel feedstocks. In other nations, palm oil, sunflower oil, and rapeseed oil are the main feed stocks used to produce biodiesel. Algae have the potential to be used as biofuels. Algae have pockets of fat that keep them buoyant; these fat pockets may be harvested and converted into biofuels. The physical characteristics and applications of biodiesel may be impacted by the feed stocks used in its manufacture.

Fuels made from biomass sources, such as vegetable oils, animal fats, or specialty crops, are known as renewable hydrocarbon biofuels. These compounds may be utilised in current infrastructure and engines since they share a chemical composition with typical petroleum-based goods. As a result, these biofuels must undergo rigorous testing, much like petroleum-based goods.

Diesel made from petroleum has a far higher carbon footprint than renewable fuels. By balancing the carbon dioxide emitted while burning renewable hydrocarbon biofuels with conventional fuels, carbon dioxide absorbed by growing feed stocks lowers greenhouse gas emissions. These fuels' production helps businesses achieve their goals of cutting down on water consumption, other air pollutants, and greenhouse gas emissions.

These advantages have led to the conversion of many gasoline production facilities' conventional refining operations to biodiesel or biofuel production processes, or they intend to do so. There are several obstacles associated with this conversion, including making sure that correct sampling procedures are employed to sample these fuels.

FACING INCREASED LEGISLATION AND REGULATION

The Renewable Fuel Standard (RFS) programme is a federal law that mandates the replacement or reduction of a certain amount of petroleum-based jet fuel, heating oil, and transportation fuel with renewable fuel. The Energy Independence and Security Act of 2007 (EISA), which raised long-term output targets to 36 billion gallons of renewable fuel annually, considerably expanded the scope of the RFS programme.

The RFS program includes four categories of renewable fuel:

1. **Advanced biofuels** - produced from types of renewable biomass, such as sugarcane, biobutanol, and bionaphtha
2. **Biomass-based diesel** - produced from biomass such as soybean oil, canola oil, waste oil, or animal fats
3. **Cellulosic biofuel** - produced from cellulose or hemicellulose of corn stover, wood chips, Miscanthus ornamental grasses, or biogas
4. **Conventional renewable biofuel** - including ethanol from corn starch or other renewable fuels

MAXIMIZE SAFETY WITH REPRESENTATIVE SAMPLING

In order to test renewable fuels for quality, safety, and integrity, much as you would in a regular refinery, they must go through many of the same manufacturing processes as conventional fuels.

Sampling can help production plants:

- Meet stringent environmental standards

- Maximize product quality
- Ensure product integrity
- Maintain safety of personnel and equipment

The first step in ensuring proper sampling is to sample at suitable locations within the biofuel production process. These can include:

- **Renewable feedstock sources**: Sample raw materials before production to ensure appropriate ingredients enter the process
- **Intermediate hydrodeoxygenation (HDO) products**: Sample products to ensure sufficient removal of oxygen
- **Hydrogen sulfide**: Sample for hydrogen sulfide (H2S) to ensure elimination of corrosive contaminants
- **Sour water**: Sample to ensure sufficient removal of H2S and ammonia to condition the water for discharge or to be reused in the plant

Due to accelerated population expansion and rising industrialisation, petroleum fuel use has grown in recent decades. Regrettably, increased reliance on these energy sources has led to significant issues with environmental degradation, national energy security, and the depletion of fossil fuel reserves. Alternative sources of energy based on petroleum are thus highly desired. Renewable energy sources are anticipated to become even more prominent in the future. The development of geothermal, wind, and biomass energy sources is advancing quickly, and they are now economically competitive. Yet, barely 3% of the energy used in developed nations now comes from biomass. The most popular biomass-based liquid fuels to replace petroleum-based fuels are biofuels, which mostly consist of fatty acid methyl esters and include bioethanol and biodiesel (FAME).

Several benefits of using biofuels include a decrease in greenhouse gas emissions, sustainability, and supply security4. The major difference between biofuels and petroleum-based fuels is their oxidant contents, which ranges from 10 to 45 percent in biofuels as opposed to nearly nil in petroleum-based fuels. As a result, many attributes are drastically different. Biofuels have a poor energy density due to their high oxygen concentration, which also tends to corrode common metals6. As a result, interest in renewable energy sources other than bioethanol and biodiesel has increased due to the demand for renewable hydrocarbon fuels. Triglycerides, which have the same carbon chain as fuels derived from petroleum, make up the majority of plant oils. In order to create sustainable hydrocarbon fuels, the triglycerides in plant oils may be transformed into hydrocarbons by removing oxygen.

The selection of the feedstock, which relies on the oil content and fatty acid composition of the plant oils, is the first step in the production of renewable hydrocarbon fuels. Various renewable hydrocarbon fuels may be made using diverse plant oils with varied fatty acid contents. Nowadays, edible plant oils, such as those from soybean, sunflower, rapeseed, and oil palm, are the primary sources for research on renewable hydrocarbon fuels. However given the possible conflict between crop production for energy against food, expanding the supply of renewable fuels from industrialised agriculture as it is now done might be challenging in the future. As a result, non-edible resources should become the focus of study. There are a number of ways to transform plant oils into sustainable hydrocarbon fuels, including catalytic cracking and deoxygenation, yet each has unique benefits and drawbacks. Using catalytic cracking, renewable hydrocarbon fuels may be produced in large quantities at a relatively low reaction temperature. Plant oils are often upgraded by deoxygenation, which involves eliminating oxygen with or without the addition of hydrogen. In order to highlight the significance of the feedstock on the properties of renewable hydrocarbon fuels, this review provides an overview of the production of renewable hydrocarbon fuel by taking into account the use of various edible and non-edible plant oils in different treatment methods and production processes. Renewable hydrocarbon biofuels are fuels made from biomass sources using a range of biological, thermal, and chemical methods. They are also known as green or drop-in biofuels. Chemically, these goods are equivalent to petroleum-based jet fuel, diesel, and gasoline. These biofuels may be utilised in existing engines and infrastructure since they fulfil the same ASTM fuel quality requirements as the petroleum fuels they replace[9].

Types of renewable hydrocarbon biofuels include:

- **Renewable diesel**: Renewable diesel is a diesel-compatible transportation fuel made from biomass. It complies with European Standard EN 590 and American Standard ASTM D975 for petroleum. It is a commercial gasoline that is made in America and brought in from Asia. In the US, five facilities with a total annual capacity of more than 590 million gallons manufacture renewable diesel. With six facilities now under construction and three existing plants expanding, a 2 billion gallon capacity is planned to be added in the near future, increasing production. The U.S. Environmental Protection Agency (EPA) releases RFS RIN statistics, which shows that the country used over 960 million gallons in 2020. The U.S. Energy Information Administration (EIA) does not track renewable diesel output. Due to the financial advantages provided by the Low Carbon Fuel Standard, California uses almost all domestically generated and imported renewable fuel.

- **Sustainable aviation fuel (SAF)**: SAF is a fuel made from renewable resources that, when compared to conventional fuels, allows for a decrease in net life cycle carbon dioxide emissions. SAF is the recommended and now widely accepted word for non-petroleum synthesised jet fuel components made in accordance with ASTM D7566's standards. Since SAF complies with ASTM D1655, when combined with normal jet fuel, it may be utilised in current aircraft and infrastructure. SAF has been in use at Los Angeles International Airport since 2016 and at San Francisco International Airport starting in late 2020. It is commercially accessible in limited numbers. In Los Angeles, there is one domestic SAF manufacturing plant in operation. Many more are being built or planned, and imports from a foreign manufacturer started in late 2020. Although EPA discloses RFS RIN data, which shows that the United States used 4.6 million gallons in 2020, EIA does not record SAF output.

Seven SAF "pathways" or fuel classifications have now been authorised under ASTM D7566. Before they may be recognised as ASTM D1655 comparable and subsequently utilised in an aeroplane, all of the neat SAF quantities must be mixed with regular aviation turbine fuel. The seven authorised routes are listed in the D7566 Annexes:

  - Fischer-Tropsch (FT) hydroprocessed synthesized paraffinic kerosene (SPK) fuel using solid biomass resources (e.g., wood residues) (FT-SPK); maximum blend level 50%
  - Synthesized paraffinic kerosene from hydroprocessed esters and fatty acids (HEFA) fuel derived from used cooking oil, animal fats, algae, and vegetable oils (e.g., camelina) (HEFA-SPK); maximum blend level 50%
  - Synthesized isoparaffin fuel from hydroprocessed fermented sugars (SIP), formerly known as direct-sugar-to-hydrocarbon fuel (HFS-SIP); maximum blend level 10%
  - FT-SPK with aromatics fuel using solid biomass resources (e.g., wood residues) (FT-SPK/A); maximum blend level 50%
  - Alcohol-to-jet SPK fuel produced from isobutanol or ethanol (ATJ-SPK); maximum blend level 50%
  - Catalytic hydrothermolysis (or hydrothermal liquefaction) jet fuel derived from fats, oils, and greases (CHJ); maximum blend level 50%.
  - HEFA with hydrocarbons (HC-HEFA) produced from esters and fatty acids at 10% maximum blend concentration.
- **Renewable gasoline**: Renewable gasoline, sometimes referred to as biogasoline or "green" gasoline, is a transportation fuel made from biomass that may be used in spark-ignition engines. It complies with the requirements of EN 228 in Europe and ASTM D4814 in the United States.

Production

Many biomass sources may be used to create renewable hydrocarbon biofuels. Lipids (such as vegetable oils, animal fats, greases, and algae), as well as cellulose material, are among them (such as crop residues, woody biomass, and dedicated energy crops). When production is taking place, the commercial facilities mostly concentrate on producing renewable diesel, while more SAF production is anticipated given the number of plants now under development. It is typical for one plant to generate both SAF and renewable diesel. Five commercial renewable diesel facilities with a total capacity of 550 million gallons existed as of 2020, while one facility that produced both renewable diesel and SAF had a capacity of 42 million gallons. Eight new facilities are being built, and three existing ones are being expanded, adding an additional 2 billion gallons of capacity. At least three of the facilities will also manufacture SAF. The bulk of the new plants and expansions of existing plants are for the production of renewable diesel. The majority of the renewable diesel that the United States imports comes from factories in Singapore. According to California's Low Carbon Fuel Standard, SAF and almost all renewable diesel are utilised there. Several techniques are being investigated by researchers to manufacture sustainable hydrocarbon biofuels. Producing facilities may be standalone or integrated with oil refineries. The following technological avenues are being investigated for the generation of renewable hydrocarbon biofuels:

- **Traditional hydrotreating**: When used in petroleum refineries, hydrotreating entails reacting the feedstock (lipids) with hydrogen at high pressures and temperatures while a catalyst is present. This technique is presently used in commercial plants.
- **Biological sugar upgrading**: With the inclusion of organisms that convert carbohydrates to hydrocarbons, this method employs a biochemical deconstruction procedure similar to that utilised with cellulosic ethanol.

- **Catalytic conversion of sugars:** In this route, a stream of carbohydrates is transformed into hydrocarbon fuels via a sequence of catalytic events.
- **Gasification**: This procedure involves the thermal conversion of biomass to syngas and the catalytic conversion of syngas to hydrocarbon fuels.
- **Pyrolysis**: This method involves the chemical breakdown of organic compounds at high temperatures without oxygen. The procedure yields a liquid pyrolysis oil that may be converted into hydrocarbon fuels either alone or in combination with crude oil in a conventional petroleum refinery.
- **Hydrothermal processing**: In this method, moist waste materials or biomass are chemically broken down at high pressure and moderate temperature to create an oil that can be catalytically converted into hydrocarbon fuels[10].

Benefits

Renewable hydrocarbon biofuels offer many benefits, including:

- **Engine and infrastructure compatibility**: Since they are chemically similar to their petroleum equivalents, renewable hydrocarbon biofuels have less compatibility problems with current infrastructure and engines.

- **Increased energy security**: Domestic production of renewable hydrocarbon biofuels from a range of feed stocks may help create jobs in the United States.

- **Fewer emissions**: By balancing the carbon dioxide emitted while burning renewable hydrocarbon biofuels in comparison to conventional fuels, carbon dioxide absorbed by growing feed stocks lowers total greenhouse gas emissions.

- **More flexibility**: In lieu of traditional diesel, jet fuel, and gasoline, renewable hydrocarbon biofuels enable the creation of different products from a variety of feed stocks and manufacturing processes.

Alternatives to petroleum-derived fuels that are completely compatible with the current petroleum infrastructure are intriguing solutions for gasoline and diesel. A completely compatible drop-in fuel would need only minor adjustments to the current infrastructure for the distribution and supply of petroleum fuels and would be totally compatible with current cars and engines. Drop-in substitutes would be made of hydrocarbons and be chemically identical to the hydrocarbons present in petroleum fuels. A range of feedstocks, both renewable and non-renewable, may be converted into hydrocarbons utilising a number of different techniques. Synthesis from coal and natural gas are two non-renewable manufacturing methods that are included under synthetic diesel fuel. Many procedures may be used as the foundation for renewable diesel fuel manufacturing methods:

- *Oleochemical processes* convert lipid feed stocks such as oil from oilseed crops or animal by-products into hydrocarbon fuels. Hydroprocessing is the most important example of a commercially applied oleochemical process. Diesel produced via this route is often referred to as *hydrogenated vegetable oils* (HVO) or *hydrogenated esters and fatty acids* (HEFA).
- *Thermochemical processes* use heat in the absence of oxygen to produce an intermediate that is further processed into a hydrocarbon fuels. Two routes to thermochemical processing are

pyrolysis and gasification. Additional processing such as hydroprocessing, decarboxylation/decarbonylation or synthesis would be required to yield hydrocarbon fuels.

- *Biochemical processes* use microorganisms to produce longer chain alcohols and hydrocarbons that may require further processing to produce a hydrocarbon fuel. “Hybrid” thermochemical/biochemical technologies such as fermentation of synthesis gas and catalytic reforming of sugars/carbohydrates are also possible.

It should be emphasised that although these fuels include hydrocarbons, paraffins make up the majority of those hydrocarbons. Paraffins and aromatic hydrocarbons are only two of the several kinds of hydrocarbons included in petroleum fuels. It may be difficult to seal against leaks and deal with the solubility of fuel breakdown products if a fuel made nearly exclusively of paraffins substitutes one that contains considerable aromatics. When aromatics are present, gasoline distribution infrastructure and car fuel systems with nitrile rubber seals in contact with fuel swell. The nitrile rubber seals shrink when the gasoline's aromatic concentration falls to low enough levels, which may lead to fuel leaks. Nitrile rubber seals are no longer commonly used in current automobiles, although they are still present in certain older machinery and in the gasoline distribution system. Moreover, aromatics have the ability to maintain a certain amount of fuel breakdown products in suspension. If the fuel's aromatic concentration is too low, any degradation products that may be present might become insoluble, causing deposit buildup and filter clogging. Because of this, even though these paraffinic fuels are thought of as "drop-in" substitutes, vigilance is still needed to reduce the possibility of certain operating issues.

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CHAPTER 12

IMPORTANCE OF BIOFUELS

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In recent years, much emphasis has been focused on the challenge of manufacturing ethanol from cellulosic and lignocellulosic material since there is not yet enough technology to allow efficient and economically viable means of breaking down the multipolymeric raw material. Cellulases and other cellulose-degrading enzymes must thus be produced using efficient ways. Lignocellulosic biofuels are thus anticipated to be among the choices provided to reduce high energy costs, along with more efficient energy use and the use of other alternative fuels.

Due to considerations like the depletion of petroleum supplies and the expanding need for energy from both industrialised and rapidly industrialising nations like India and China, it is essential to seek into alternate and efficient techniques to replace these fuels in the future. Concerns like the sharp rise in fossil fuel prices in recent years, escalating worries about climate change like global warming, insecurity, and unrest among governments as a result of their depleting natural resources define an urgent need for a sustainable path towards the development of renewable fuel technologies. Among the various types of alternative fuels taken into consideration (liquid fuels from coal and/or biomass with and without carbon capture and storage (CCS)), biofuels derived from lignocellulosic biomass offer the most clean and sustainable alternative to fossil fuels due to their cost-competitiveness compared to the current expensive methods of producing ethanol from sugarcane and corn[1], [2].

The production and use of biofuels have increased significantly on a global scale, from 18.2 billion litres in 2000 to around 60.6 billion litres in 2007. This amount is estimated to contain bioethanol to a degree of 85%. Its rise is mostly a consequence of the causes mentioned above as well as rising concerns about global warming and greenhouse gas emissions as a result of excessive fossil fuel usage since biofuels are carbon-neutral and reduce greenhouse gas emissions. Another argument in favour of the viability of biofuels as an alternative fuel for transportation is how easily they can be integrated into our present liquid fuel system[3], [4].

An essential step in the production of biofuels is the breakdown of the cellulose fibres by enzymes. Yet, making these enzymes is still an expensive process since they are made in massive microbial bioreactors. The manufacturing of these enzymes may be done at a reasonable cost by using transgenic plants as heterologous protein production systems. Plant-based enzyme production offers advantages over conventional bacterial and fungal cultures and is especially intriguing since the required protein can be synthesised to accumulate at enormous quantities in plants, even levels larger than 10% of total soluble protein[5], [6].

Ethanol, an alcohol fuel, is created from the sugars found in cereals like maize, sorghum, and wheat as well as in potato skins, rice, sugar cane, sugar beets, molasses, and grass clippings. Nowadays, bioethanol is produced using two different methods. Growing and fermenting starch or sugar crops to create ethanol is the first way. The second approach uses naturally oil-producing plants like Jatropha and algae to produce oils that may be used directly as diesel engine fuel after being heated to decrease viscosity [7], [8].

Nevertheless, at the present, the majority of it is produced utilising sugar and sources of starch (corn in the US) (sugarcane in Brazil). The two countries that generate the most fuel ethanol are Brazil and the United States, which produced 51.9% and 37.3% of the world's bioethanol, respectively, according to the most current data from 2008. In order to provide one-fourth of its needs for ground transportation, Brazil specially produces a significant volume of ethanol from the fermentation of sugarcane sugar. Similar to this, to meet part of its own needs, the United States produces ethanol from maize. Sadly, while being revolutionary inventions, this method of generating ethanol is not cost-effective and can only meet around 15% of the country's demands. Their use as energy crops therefore seems to be problematic given that they are essential food sources that are unstable in terms of long-term availability and cost.

Due to land availability issues and increasing price pressures, production of grain- and corn-based ethanol would soon be limited to fewer than 8% of the US transport fuel mix. Despite projections to the contrary, sugarcane-based ethanol production in Brazil is anticipated to reach 79.5 billion litres, much like how maize and grain-based ethanol production is restrained by the same agro-economic restrictions. As maize is the main source of starch in animal feed, making ethanol from it has raised the price of cattle and poultry, for example. Innovative, sustainable technology is critical for biofuels to considerably progress the creation of renewable energy sources and the lowering of greenhouse gas emissions. The second generation or lignocellulosic sources are therefore the most desirable option for the large-scale production of biofuels due to the advantages of high carbohydrate recovery efficiency in comparison to other technologies and the potential for technology improvement due to breakthrough biotechnology processes.

It is imperative to look into alternative and effective methods to replace these fuels in the future due to factors like the limited petroleum reserves and the continuously rising energy demands by both industrialised and highly populous countries on the path to industrialization, such as India and China. An urgent need for a sustainable path towards the development of renewable fuel technologies is also defined by concerns like the sharp increase in fossil fuel prices in recent years, growing concerns about climate change like global warming, insecurity, and unrest among governments due to their depleting natural resources. These are just a few examples. Due to their cost-competitiveness compared to the current expensive methods of ethanol production from sugarcane and corn, biofuels derived from lignocellulosic biomass offer the most clean and sustainable alternative to fossil fuels among the various types of alternative fuels considered (liquid fuels from coal and/or biomass with and without carbon capture and storage (CCS)).

From 18.2 billion litres in 2000 to about 60.6 billion litres in 2007, the production and usage of biofuels have grown dramatically on a worldwide scale. Around 85% of this quantity is thought to be bioethanol. As biofuels are carbon-neutral and lower greenhouse gas emissions, this growth is mostly due to the causes mentioned above as well as growing worries about global warming and greenhouse gas emissions brought on by the excessive use of fossil fuels. The simplicity with which biofuels may be integrated into our current liquid fuel infrastructure is another aspect supporting their feasibility as an alternative fuel for transportation.

The cellulose fibres are broken down by enzymes that may break them down as a crucial stage in the creation of biofuels. Yet, since these enzymes are produced in enormous microbe bioreactors, producing them is still a costly operation. The use of transgenic plants as heterologous protein production systems is one strategy for the low-cost manufacture of these enzymes. As the necessary protein can be produced to accumulate at large levels in plants, even levels higher than 10% of total soluble protein, plant-based enzyme synthesis has benefits over conventional bacterial and fungal cultures. It is also economically viable.

Scaling up protein expression is another significant economic benefit of plant-based protein synthesis over microorganism-based protein production. Scaling up microbial systems would need expensive massive fermentors and accompanying equipment, but scaling up plant-based protein products would merely need to grow more seeds and harvest a greater area. So, compared to more conventional methods of cellulase production by cellulolytic fungi or bacteria, transgenic plants that produce cellulase may result in considerable capital cost reductions.

The sugars present in cereals like maize, sorghum, and wheat, as well as in potato skins, rice, sugar cane, sugar beets, molasses, and grass clippings, are used to make ethanol, an alcohol fuel. There are currently two processes used to produce bioethanol. The first method involves growing and fermenting starch or sugar crops to make ethanol. In the second method, naturally oil-producing plants like Jatropha and algae are used to create oils that, after being heated to decrease viscosity, may be used directly as fuel for diesel engines.

Nevertheless, at the moment, it is mostly made using sources of starch (corn in the US) and sugar (sugarcane in Brazil). According to the most recent numbers (from 2008), Brazil and the United States produced 51.9% and 37.3% of the world's bioethanol, respectively. Brazil specifically generates a significant amount of ethanol from the fermentation of sugarcane sugar to meet one-fourth of its demand for ground transportation. Similar to this, the United States makes ethanol from maize to fulfil some of its own requirements. Sadly, while being ground-breaking innovations, the production of ethanol via this approach is not profitable and can barely satisfy less than 15% of the nation's needs. Being key food supplies that are uncertain in terms of long-term availability and price, their usage as energy crops consequently seems to be undesirable[9].

The manufacture of grain and corn-based ethanol would soon be restricted to fewer than 8% of the US transport fuel mix due to land availability constraints and mounting pricing pressures. Similar to corn- and grain-based ethanol production, sugarcane-based ethanol production in Brazil is expected to expand to 79.5 billion litres, although this technology will ultimately be constrained by the same agro-economic considerations. As maize is the primary source of starch in animal feed, using it to make ethanol has, for instance, increased the cost of cattle and poultry.

In order for biofuels to significantly advance the development of renewable energy sources and the reduction of greenhouse emissions, there is an urgent need for innovative and sustainable technology. This makes the second generation or lignocellulosic sources the most alluring choice for the large-scale production of biofuels due to the advantages of a high efficiency of carbohydrate recovery compared to other technologies and the possibilities of technology improvement due to breakthrough processes in biotechnology.

One of the aspects that strongly favour the generation of ethanol from cellulosic biomass is the fact that maize ethanol emits more greenhouse gas emissions than gasoline whereas cellulosic ethanol from non-food crops emits less than electricity or hydrogen. Due to the complicated structure of the raw materials and the absence of technology to effectively and cheaply extract fermentable sugars from the intricate multi-polymeric raw materials, the generation of biofuel from lignocellulosic materials is a difficult task.

Microbial cellulases are still expensive to produce despite decades of study targeted at lowering the cost of their manufacture. Producing these enzymes inside agricultural biomass is one method of reducing such expenses. The science of plant genetic engineering for the generation of biofuels has made some significant breakthroughs, although it is still in its early stages. Creating effective methods for genetically modifying plant systems to produce cellulose-degrading enzymes is an universal difficulty. In order to boost enzyme synthesis and create enzymes with greater biological activity, research is especially essential to concentrate on the targeting of these enzymes to numerous subcellular sites. Chloroplasts have the ability to create far more of these enzymes, and significant developments have been made in the types of crops that can now have their chloroplasts genetically modified. Nevertheless, further work is required to create systems that genetically engineer the chloroplasts of biomass crops like cereals and perennial grasses.

Asia's demand for oil is anticipated to rise quickly due to the region's burgeoning urbanisation, rising economic levels, and expanding population. Nonetheless, the majority of the nations in the area significantly rely on imports for their oil supply owing to the region's low resource reserves, which is a key, if not the most crucial, worry in their energy strategies. As increasing the use of biofuels would not only reduce oil demand but also help to diversify the sources of importation for liquid fuels, they are seen as one of the potential solutions to the problem of oil security. Also, producing biofuels offers a further way to boost farmers' revenue. In the latter half of the 19th century, biofuels were first used. Up until the 1940s, this use persisted, but the declining cost of fossil fuels prevented further advancement. 1 Midway through the 1970s, when ethanol production from sugarcane in Brazil and subsequently maize in the United States started, interest in the commercial manufacture of biofuels for transportation once again increased. From 8,082 thousand tonnes of oil equivalent (ktoe) in 2001 to 52,219 ktoe in 2011, the global usage of biofuels has grown. 2.1 percent of the world's total demand for transportation fuel was met by biofuels.

In 2011, use of biogasoline in the world's two largest markets the United States and Brazil accounted for 81 percent of total consumption. The Organization for Economic Co-operation and Development (OECD) member nations, which make up the majority of Europe, use the most biodiesel, using 58.9% of the global total in 2011. Just 5.6 percent of the world's total biofuel output and 5.1 percent of biofuel consumption in 2011 were attributed to the Asia and Pacific area. 2 Yet, Asia is anticipated to increase. This research focused on the possibilities of the Asian biofuels industry due to the region's rising interest in biofuels. Finding the potential for biofuels, such as bioethanol and biodiesel, across Asia as well as policy measures to encourage their sustainable usage are the goals.

The quantitative results in both supply and demand outlooks, the use of integrated energy-agriculture models with surveys of the most recent biofuel policies, and the analyses of regional prospects, including those of supply-demand gaps within the region which consists of 16 Asian countries, including the ASEAN 10 countries, Australia, China, India, Japan, New Zealand, and South Korea are the study's distinguishing characteristics. The Economic Research Institute for ASEAN and East Asia supported and approved the conduct of this research (ERIA). In 2011, biofuel policymakers from Indonesia, Malaysia, the Philippines, and Thailand formed a working group (WG), with the Institute of Energy Economics, Japan (IEEJ) serving as the group's organiser[10].

Growing importance of biofuels in Asia

One of the key conclusions of the Internal Energy Agency (IEA) is that emerging Asia, which accounts for about two-thirds of the total rise in demand throughout the projected period, is becoming the centre of oil demand growth. The IEA estimates that under its present policy scenario, the percentage of biofuels would rise from 1.5 percent in 2012 to 2.9 percent by 2035, but under its CO2 emission stabilisation scenario, it must reach 8.9 percent by 2035. For Asia to lessen its reliance on fossil fuels, the use of biofuels will become essential. If the possibility of the rising percentage of oil consumption in Asia is to be addressed, it is possible to emphasise the significance of biofuels as alternatives to oil products even more. The Asian Development Bank (ADB) predicts that oil consumption will increase going forward. The dependency on conventional biomass, such firewood and charcoal, in the residential sector is another crucial reality. With the advancement of electrification, this percentage is anticipated to decline in the future. The most cost-effective strategy is to switch to biofuels instead of oil since they are more competitive and will become more so as long-term oil prices rise.

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CHAPTER 13

RENEWABLE ENERGY AND FUTURE OF BIOFUEL

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The use of waste materials as a source of energy might be crucial in the fight against climate change. Reddie & Grose's Andrew Carridge investigates the potential of biofuels. One of the main topics dominating COP26 is the world's addiction to fossil fuels in transportation and what countries might and should do to convert to greener alternatives. On May 18, the first long-distance aeroplane fueled by biofuels took off. A sustainable aviation fuel (SAF) derived from leftover cooking oils was utilised on an Air France-KLM trip from Paris to Montreal. Additionally, the UK government said this year that starting in September, it will require the use of E10 gasoline petrol containing up to 10% sustainable bioethanol [1], [2].

Even while this is a positive move, there is still room for improvement. The International Energy Agency (IEA) reports that the production of transport biofuels increased by 6% on an annual basis in 2019 and that yearly output increases of 3% is anticipated through. To comply with the IEA's Sustainable Development Scenario, continuous production growth of 10% annually is required until, however this falls short of that goal (SDS).

In order to provide universal access to energy, lessen the harmful effects of air pollution on human health, and combat climate change, the SDS proposes a significant reform of the world's energy system[3], [4]. The IEA emphasises the necessity of innovation to lower prices in order to scale up both advanced biofuel usage and the acceptance of biofuels, in addition to governmental assistance[5].

Second generation biofuels

Food crops are used to produce the first generation of biofuels. Using yeast fermentation, sugar or starch from feed stocks including maize, sugar cane, and soybeans can be transformed to bioethanol. Biodiesel may be created by trans esterification of oils, such as virgin vegetable oils.

Although the bulk of the biofuels now on the market are first generation biofuels, their usage has the potential to endanger food supply and biodiversity. On the other hand, second generation biofuels use feed stocks that are often not food crops or are unfit for human consumption. This can include things like:

- Straw,
- Bagasse,
- Perennial grasses.
- Vegetable oil
- Leftovers

Common second generation feed stocks may provide more biomass per unit area and may be able to grow on land that is not suitable for food crops since the full crop is available as feedstock for conversion to fuel.

The process of making bioethanol from second generation feed stocks requires two steps: first, the biomass's cellulose and hemicellulose components are converted to sugars, and then the sugars are fermented to make ethanol. The first phase is technically difficult, and research is focused on finding quick and inexpensive solutions to complete the process. Second generation biofuels based on cellulose have had a limited market penetration thus far due to a lack of commercial viability[6], [7].

Third generation biofuels

Algal-based biofuels are referred to as third generation biofuels. Microalgal biomass is adaptable and may be utilised to make biodiesel by transesterification as well as bioethanol through fermentation.

Algal fuels can be cultivated practically everywhere that is warm enough and have extremely high yields. Algae may also be cultivated in waste water, which gives them the added benefit of assisting in the waste processing process without requiring any extra land. Algae could also be able to grow by using discarded carbon dioxide[8]–[10].

Although algae can be produced in open water, research into third generation biofuels has at least in part focused on closed systems like photobioreactors in order to maximise productivity and control. To make photobioreactors more affordable and scalable, research on the technology is still ongoing.

The future for biofuels in transport

The UK government declared in 2020 that it will stop selling new gasoline and diesel vehicles in the country. So, will biofuels be used in transportation in the future? It might seem that way. In industries like long-distance trucking, shipping, and aircraft where electrification is not currently a viable alternative, biofuels may be especially well-suited.

Additionally, the function that biofuels sometimes known as "bioelectricity" can play in the generation of electricity cannot be overlooked. Therefore, biofuels can complement electric transportation by lowering upstream emissions during the generation of energy.

Bioenergy for electricity and heat

Approximately 10% of the primary energy supply in the world today, according to the IEA, comes from bioenergy. It contributes five times more to the overall ultimate energy demand than wind and solar put together. Although the production of electricity from bioenergy climbed by almost 5% in 2019, the heating industry continued to be the dominant source.

The station also employs BECCS technology ("Bioenergy with carbon capture and storage") to guarantee that none of the carbon produced by its biomass boilers is discharged into the atmosphere. It is clear that biofuels are crucial to both the sustainability of our energy supply and the lowering of greenhouse gas emissions. For biofuels to scale up and become more cost-effective, especially for use in transportation, more innovation is necessary. The potential for using waste materials as raw materials and the reliance on biomass resources, which are more widely distributed globally, make biofuels very promising.

Under the base-case prediction, the total worldwide demand for biofuel increases by 20%. About all of the growth in the usage of renewable diesel and biojet fuel occurs in developed economies.

Since these fuels may be generated with minimal GHG emissions, mixed at high levels, and created from wastes and residues, regulations intended to decrease GHG emissions are boosting demand in this situation.

Eighty percent of the world's increase in the use of biofuels comes from the United States, Canada, Brazil, Indonesia, and India, all of which have extensive growth-supporting legislative frameworks. In Europe, even though state-level regulations are becoming stricter, declining transportation fuel consumption almost completely halts volume increase.

The future of biofuel generated from plant material is attracting intense attention globally as oil prices are approaching record highs. Despite a tripling in volume from 4.8 billion gallons in 2000 to around 16.0 billion in 2007, less than 3% of the world's transportation fuel supply is still made up of biofuels. Concentrated in the United States, Brazil, and the European Union, production accounts for around 90% of global output (EU). If development efforts in other nations, like Malaysia and China, are successful, production may become more distributed. Corn, sugar, and vegetable oils are the main feedstocks, also known as raw materials, used in the production of biofuels.

As the production of biofuels has expanded quickly, hopes about viable alternatives to oil-based energies have grown. Yet, there are growing worries about how rising commodity prices may affect the world's food system. The International Monetary Fund claims that rises in the cost of maize, wheat, and soybeans, mostly due to demand-side factors such increased biofuel demand, caused a 10% increase in global food prices in 2006. Due to growing feed costs, the Chinese government placed a halt on the use of maize for ethanol production and is instead encouraging alternate feed stocks including cassava, sweet sorghum, and jatropha that do not directly compete with food crops an oil-bearing plant originally from South America.

Early in 2007, Mexico set a price ceiling on tortillas to rein in food inflation brought on by more expensive maize imports. The 10-year high real sugar price in 2006 put a strain on low-income people's budgets in Brazil and abroad. Since then, prices have dropped. In order to reduce the growth in the price of local cooking oil, the Indonesian government raised the export tax on crude palm oil in the middle of 2007. The cost of maize and other feed is rising for US cattle farmers, which might result in higher retail meat prices. And in Japan, old worries about the nation's near total reliance on imports of feed grain and oilseeds to maintain its substantial livestock industry have been resurrected. The future price of oil, the availability of inexpensive feedstocks, governments' continued commitment to supportive policies, technological advancements that could lower the cost of second-generation biofuels, and competition from unconventional fossil fuel alternatives are just a few of the interrelated factors that will affect the outlook for the world's biofuels[11].

A New Era of High Oil Prices Attracts Investment in Biofuels

The most significant element enhancing the competitiveness of alternative fuels, including biofuels, is the increase in oil prices. The unusual six-year surge in oil prices has expanded the availability of conventional and alternative energy sources while also extending the window for efficiency improvements and encouraging energy conservation. While these changes may ultimately result in reduced oil prices, most projections do not indicate that actual prices will go below $50 per barrel.

High oil prices have previously only lasted a little time. Prices tended to increase quickly, often as a result of armed conflict, peak in a matter of weeks or months, and then drop quickly. After these price surges, the quick drop in oil prices made it harder to maintain alternative fuel initiatives and lessened customer incentives to limit their use of petroleum-based goods. In contrast to earlier times of high oil prices, the present oil market is strongly influenced by demand-side forces. These variables include strong economic development and increased oil consumption from middle-income nations that are expanding quickly and have customers who are wanting a better quality of living and who have large energy demands. China and other middle-income nations have accounted for about two-thirds of the recent increase in global oil consumption.

Profitability of Biofuels Depends on the Availability of Low-Cost Feedstocks

The biggest expense in producing biofuels is the cost of the feedstock, which in 2003–04 ranged from 37% for sugarcane-based ethanol in Brazil to 40%–50% for corn-based ethanol in the United States. 34 percent of the cost of producing sugar-based ethanol in the EU was borne by sugar beets. These cost shares are now significantly greater due to increased commodity costs. Energy is another significant cost factor that, in certain nations, may make up as much as 20% of running expenses for biofuels.

A straightforward metric of how competitive biofuel produced from different feed stocks is the ratio of crude oil prices to feedstock prices. For instance, after 2004, when oil and ethanol costs surged but corn prices remained steady, the ratio of crude oil to corn prices grew dramatically. However from September 2006, the ratio dramatically decreased, making biofuels less cost-competitive. When soy and palm oil prices increased in 2006–2007, biodiesel producers in Europe and Southeast Asia also saw a decline in competitiveness. Contrarily, from 10-year highs in 2006, global sugar prices fell by 50%, improving the relative prospects for Brazil's ethanol industry.

The profitability of a biofuel plant is also influenced by the sale or useful use of byproducts. As a byproduct of the ethanol manufacturing from maize, dried distillers' grain (DDG) may be used as a protein-rich ingredient to animal feed. DDG sales have the potential to increase ethanol producers' earnings by up to 10% to 15%. Some ethanol facilities absorb carbon dioxide, which is often discharged into the environment, and sell it for use in the food and beverage industry. The fibrous residue left behind after crushing sugarcane, known as bagasse, may be burnt to provide heat for distillation and energy to operate equipment, or it can be sold to nearby utilities. Pharmaceutical, food manufacturing, and feed industries all use glycerin, a byproduct of biodiesel synthesis.

Government Support Is Used To Reduce Volatility

The EU, China, the top two producers of biofuels, the United States and Brazil, as well as other nations, all have robust long-term government participation. Governments cite the need to diversify energy sources, increase energy security, and achieve environmental and rural development goals as justification for their support. Governments often create assistance programmes to aid new biofuel businesses in overcoming scale and cost constraints as well as profit unpredictability.

In response to investor and producer worries about the double-edged uncertainty of unpredictable feedstock and energy input costs and biofuel output prices, governments have implemented a number of legislative mechanisms that mitigate risk and uncertainty. To assure a market for biofuels, the most popular technique is a mandate to mix biofuel with its fossil fuel equivalent. The degree to which this requirement is obligatory, the phase-in duration, the required volume or mix percentage, and whether a countrywide or regional approach is used vary from country to country.

In order to offset the increased cost of producing biofuels compared to the production of gasoline and diesel and to entice people to purchase gasoline or diesel containing biofuel, countries also depend on subsidies, tax credits, and favourable taxation. For the cultivation of feed stocks for biofuels, Europe gives an energy premium of 18.7 euros per acre. India's government provides sugar mills with discounted loans for 40% of project expenses if they want to build up ethanol manufacturing plants. Brazil promotes usage by charging hydrous ethanol ethanol that contains water and E25 25 percent ethanol a lower sales tax than gasoline.

The United States offers a tax credit of $0.51 per gallon for ethanol blenders and $1.00 per gallon for biodiesel made from animal and vegetable fats or $0.50 for used cooking oil or animal fat. For smaller biofuel facilities, several States and additional Federal incentives are available. Import limitations are further employed to support the developing biofuel sector. Effective tariffs in the EU vary from roughly 45 percent for undenatured and 24 percent for denatured ethanol to 9 percent in Canada (for ethanol imports from Brazil, with no duty for renewable fuels from the United States). The EU waives import taxes and charges for several developing nations (not including Brazil). When the 2.5% tax and the $.54 per gallon levy are added together, the U.S. tariff on ethanol is now over 25%.

Brazil is the only nation that encourages the use of biofuels above the necessary levels of blending by enabling customers to choose it as a gasoline replacement. The production of flexible fuel vehicles and the availability of ethanol at practically all petrol stations have been supported by the Brazilian government capable of using pure gasoline, E25, or pure hydrous alcohol. Moreover, incentives would be offered by the proposed U.S. law to increase E85 distribution and the production of additional E85-capable automobiles.

Biofuels are not a perfect alternative for oil-based fuel, despite having certain similarities. With little to no engine modification, biofuels may be utilised in current gasoline and diesel engines in mixes of up to 10% for ethanol and 20% for biodiesel. In contrast to hydrogen fuel cell technology, which would need a vastly different distribution infrastructure, this compatibility.

However ethanol only provides two-thirds the energy of gasoline, whereas biodiesel has 90% the energy of diesel. As a result, a vehicle will receive less mileage as the biofuel mix increases. Because of its propensity to absorb water and dissolve contaminants on the inner surfaces of multiproduct pipelines, ethanol is more costly to ship and cannot be moved via low-cost pipes due to the risk of contamination. Brazil and the US are both considering building ethanol-specific pipelines, which would be cost-effective with increased output.

Looking to the Future: The Potential of Second-Generation Biofuels

The future of biofuels is still fraught with many unknowns, including competition from unconventional fossil fuel substitutes and worries about environmental trade-offs. The degree to which the land intensity of the existing biofuel production can be lowered is perhaps the largest area of uncertainty. From 100 gallons per acre for EU rapeseed to 400 gallons per acre for U.S. maize to 660 gallons per acre for Brazilian sugarcane, the quantity of biofuel that may be generated from a single acre of land varies.

Cellulosic ethanol has the potential to increase per-acre ethanol output to over 1,000 gallons, thus lowering the need for land. The strong cellular substance that gives plants their stiffness and structure is broken down to create cellulosic ethanol, which is then produced by fermenting the sugar that results. The most accessible biological substance in the world is cellulose, which is found in low-value materials including wood chips and wood trash, quickly growing grasses, agricultural leftovers like maize stover, and municipal garbage.

The cost of producing one gallon of cellulosic fuel in the United States is now expected to be more than $2.50, as opposed to $1.65 for maize ethanol. Companies looking to make cellulosic ethanol economically viable are being supported by venture capital and government subsidies, particularly in the United States but also in a number of other nations including Canada, Brazil, China, Japan, and Spain.

Other costs of cellulosic ethanol production, such as the effects of harvesting grasses, trees, and agricultural residues on the erodibility and fertility of land resources, need to be adequately studied in the interim. There are also concerns about the upstream logistical and environmental costs of gathering, moving, and storing massive quantities of big-volume raw materials for processing.

Competitive Fossil Fuel Alternatives

High oil prices have made a variety of liquid fuel alternatives, including biofuels, more popular. Substantial investments are being made in the development of unconventional sources, such as oil sands and heavy crude oil, as well as the conversion of coal to oil, which are harder to reach conventional oil resources that are found in distant locations or deeper oceans. The U.S. Department of Energy predicts that even while global oil output will rise by 30%, unconventional fossil fuel production will rise much more quickly. It is anticipated that global biofuel output would more than treble. The production costs of many fossil fuel substitutes are lower than those of biofuels. For instance, oil from Canada's oil sands can be produced for $30 per barrel. Some predict that output would increase to more over 3.5 million barrels per day from the current level of over one million barrels per day. Another option is to turn coal into oil, which is particularly appealing to nations with large coal reserves, like China and the United States.

Despite significant initial investment expenditures, oil prices of $40 per barrel could be sufficient to make this technique economical.

What Are the Environmental Tradeoffs?

The environmental advantages of biofuel development and usage, particularly the ability to decrease emissions such as greenhouse gases, are a major factor (GHG). Road transportation is thought to be responsible for 25% of man-made carbon dioxide (CO2) emissions, a major GHG. During the last 40 years, the world's use of roads has increased significantly, and this trend is expected to continue, particularly in middle-income nations that are now experiencing fast urbanisation, middle-class rise, and economic growth.

When burnt, gasoline and biofuels both release carbon dioxide. Theoretically, biofuels are carbon neutral since the crops that generate them recently absorbed CO2 from the atmosphere. By releasing CO2 that was formerly absorbed and held in plant matter over millions of years, gasoline and other fossil fuels contribute to the atmospheric CO2 supply. In a "life-cycle" study, which considers not only burning but also the production and processing of the feedstock into fuel, the benefit of biofuels is less obvious. While estimates vary greatly, the majority of research show that biofuels have a positive net energy balance energy production exceeds energy intake. Net balances are minimal for corn-based ethanol and larger for biodiesel made from soybeans, sugarcane, and cellulose. As compared to gasoline, the biofuel with the greatest net energy balance cuts GHG the most.

The potential land needs if biofuels become a more widely used fuel are an additional crucial environmental factor. The University of Minnesota estimates that all U.S. corn and soybean acreage dedicated to ethanol and biodiesel production would only offset 12 percent and 6 percent, respectively, of the consumption of gasoline and diesel for transportation fuel. This amount would drop even further if adjustments were made for the amount of fossil fuel needed to produce the biofuel. It is unlikely to use this much land to satisfy a relatively tiny portion of the demand for transportation fuel. A lower income economy would need less resources to fulfil domestic fuel consumption. However in nations like Indonesia, Malaysia, and Brazil, increasing feedstock production that encroaches on sensitive rainforest regions and animal habitats is still a worry.

Future Role of Biofuels Depends on Profitability and New Technologies

Efficiency improvements and technological progress the cost of producing biofuels and its effects on the environment might be continuously decreased with better biomass yields per acre and more ethanol produced per tonne of biomass. In tropical regions, where growing seasons are longer, per-acre biofuel yields are greater, and fuel and other input costs are lower, biofuel production is expected to be both economically successful and ecologically friendly. For instance, Brazil powers its ethanol distilleries with bagasse, a byproduct of sugar production, whereas the United States relies on natural gas or coal.

The viability of biofuels on a worldwide scale will be determined by a variety of interconnected variables. High oil prices will be crucial in this: Unlike to earlier eras when oil prices soared and then plummeted quickly, undermining the viability of emerging alternative fuel programmes, the last six years of persistently increasing oil prices have given economic support for alternative fuels. On the other hand, growing feedstock costs (corn and vegetable oil, not sugar), which make up a significant portion of the cost of producing biofuels, have had a detrimental impact on the sector's profitability. In the U.S., Brazil, and the EU, where biofuel production has been most prominent, government assistance to lessen profit uncertainty has been a recurrent theme for this commodity-dependent business.

In addition to conservation and the use of other alternative fuels, biofuels will probably be included in a portfolio of remedies to the high cost of oil. Due to its land intensity, biofuels are expected to continue playing a minor part in the world's fuel supply. More land would be needed to grow maize in the US than is now used for all agricultural output if ethanol were to completely replace all current gasoline usage. Technology will play a key role in expanding the use of biofuels. Biofuel yields per acre might more than quadruple and land needs could be drastically reduced if the energy of cheap, readily accessible cellulose materials could be affordably utilised worldwide.

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CHAPTER 14

ROLE OF BIOFUELS

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If the rapid development of biofuels during the last 10 years is to continue, a number of challenges must be overcome. The dynamics of expanding ethanol plant capacity support this conclusion. It is unlikely that corn-based ethanol output in the United States would rise over the cap established under the RFS mandate (15 billion gallons by 2015). A similar but distinct issue is the so-called "blend wall," where the present infrastructure may make it difficult to raise the volumetric fraction of ethanol in transportation gasoline over 10%. Since this blending ratio is effectively already attained by present production levels, this blend wall is a challenge that must be overcome if the contributions of advanced biofuels including cellulosic ethanol are to meet the high targets set out by the RFS rules. Nevertheless, it seems that this is not the biggest issue facing "second-generation" biofuels[1], [2].

Commercial production of second-generation biofuels is not keeping up with the RFS criteria, which may be too optimistic. The logistical issues of feedstock supply and the conversion of pilot plants into commercially viable entities remain difficult to solve effectively. Nowadays, significant technical feasibility issues are being tackled. The development of biofuels continues to face a variety of challenges, which encourage continued interest in the next generation of biofuels. The two most prominent ones are:

(i) The actual, practical impact that biofuels can have on reducing GHG emissions in relation to climate change issues; and,

(ii) The "food vs. fuel" argument and how large-scale biofuel production affects food costs. As was previously said, while biofuels do help to reduce carbon emissions, their capacity to considerably reduce the consumption of fossil fuels is also restricted. Particularly, some contend that the use of biofuels for that purpose is intrinsically inappropriate[3], [4].

The surge in commodity prices that led to the food crisis of 2008 raised concerns about the consequences of biofuel growth on food prices. Even though there doesn't seem to be a single or straightforward explanation for this phenomenon (or other price booms in the past), it is obvious that a significant increase in the diverting of basic staple commodities to biofuel production, which materialised over a short period of time, had the potential to have a very significant impact on commodity prices, especially at a time when the stocks (relative to production and demand) had been running at historically low levels. There is a tonne of evidence that the production of biofuel has a significant impact on commodity and food prices, even though the size of estimated price effects appears to fall within a fairly wide range and, unsurprisingly, also depends on assumptions and modelling framework (e.g., partial equilibrium models appear to suggest larger price effects than CGE models). Earlier worries about the effects of biofuel on food prices and their implications for food security may resurface in a more heightened manner as the full extent of biofuel mandates in the United States, EU, and elsewhere is realised over the course of the next few years and global demand recovers from the great recession[5].

A significant element in such circumstance is the impact of sustainability rules. For instance, Brazil's sugarcane ethanol could be required to meet the RFS regulations of the United States, which mandate the production of 4 billion gallons of advanced biofuels(in addition to cellulosic biofuels and biodiesel). To achieve low-carbon regulations, the United States may need to buy sugarcane ethanol from Brazil, while at the same time, the United States may be exporting corn-based ethanol to Brazil. Lack of international harmonisation of sustainability standards and the absence of defined rules and institutions for certification and enforcement of these criteria create the prospect that these standards may substantially hamper trade. The proliferation of biofuel programmes and subsidies may fast create conditions that are favourable to trade conflicts. The contribution of biofuels would be maximised, nevertheless, by effective production and full use of competitive advantages given that reducing carbon emissions is a global concern[6], [7].

Nowadays, scientists agree that emissions of carbon dioxide (CO_2) and other greenhouse gases harm the ecosystem (GHGs). Fossil fuels, which are now both our primary source of energy and CO_2 emissions, are under growing pressure to be reduced and ultimately phased out as a consequence of this. For instance, in 2009, fossil fuels accounted for 80% of the global energy consumption of 16 TeraWatts (TW), and their burning resulted in the emission of 7.8 billion metric tonnes of carbon (GtC), or 28.6 Gt of CO_2. Despite the development of technology for more energy-efficient consumption, these figures will rise due to population expansion and rising average income, and the predicted energy demand by 2050 is at least 27.0 TW. The current atmospheric CO_2 concentration is 394.5 parts per million by volume (ppmv), and during the last 40 years, the net accumulation has grown steadily at a pace of 1.03–2.13 ppmv each year (The Maua Loa Observatory). Consequently, if emissions are not reduced, it will be anticipated to reach roughly 500 ppmv in 2050.

The melting of the West Antarctic and Greenland ice sheets, which will cause a sharp increase in sea level, and alterations in the thermohaline circulation (THC), which will cause sharp climatic shifts, are the two most concerning effects of global warming. It has been hypothesised that maintaining CO_2 levels below 450 ppmv may stop the West Antarctic Ice Sheet from collapsing and the THC from shutting down. Hoffert and Covey (1992) hypothesised that concentrations of 550 ppmv, if maintained, may result in global warming that was opposite in sign from the cooling of the planet during the previous Ice Age but similar in scale[8], [9]. These calculations show that total annual CO_2 emissions from 2050 and onwards should not exceed 6.0 GtC in order to stabilise the atmospheric CO_2 concentration at 450 ppmv by 2100, according to various scenarios to stabilise atmospheric CO_2 concentrations at 450-650 ppmv over the next few hundred years. Assuming that the current proportions of oil, gas, and coal will be maintained, this would require yearly replacement of approximately 8.0, 5.5, and 7.3 Gigawatts (GW) of these fossil fuels, respectively. In order to reach this level, it will be necessary to reduce actual emissions at a rate of 44.2 million metric tonnes of carbon (MtC) per year. To sustain the increase in energy demand, it will also be required to create 0.29 TW of carbon emission-free energy. Overall, we determined that in order to meet the CO_2 emission goal of 44.2 MtC in 2050, about 12 TW of carbon-neutral fuel must be generated. Working Group III of the Intergovernmental Panel on Climate Change (IPCC) reported comparable figures[10].

It will be required to apply a variety of innovative CO_2-constrained energy supply systems in order to address this enormous issue. Recently, the IPCC Working Group III proposed using all technologies to better achieve environmental objectives at reduced prices. There are a limited number of alternative fuels for transportation, despite the fact that there are several alternatives for producing energy and heat, including nuclear, hydro, wind, and solar. The usage of electric vehicles is becoming more popular due to their energy efficiency, which is roughly 80% compared to about 20% for vehicles with internal combustion engines. The energy density of batteries, however, is substantially lower than that of liquid fuels, and battery panels weighing 272-408 kg must be used to go 145–400 km. This should be compared to the weight of a conventional gasoline tank, which holds 45 gallons and weighs 50 kg. Hence, for electric cars to significantly replace vehicles with internal combustion engines, cost reduction and, in particular, increase in energy density are essential needs. Further problems with the usage of electric vehicles include their incompatibility with the present infrastructure and their need for a steady supply of the rare materials utilised in their batteries. For these reasons, the International Energy Agency (IEA) and the National Petroleum Council (NPC) in the United States of America (USA) predicted that in 2050, electricity would make up a modest portion of the energy used for transportation. The use of internal combustion engines using diesel and jet fuels with an energy density of 12–13 kW h kg1 is most likely to be used for ships, aircrafts, and trucks, with electricity most likely only being used for short distance transportation using personal cars (city driving), as well as for locomotives, trains, trams, and buses, where electricity can be provided through existing overhead power lines or an electrified third rail (power lines required high investment).About 2.9 TW of liquid transportation fuels are used globally today, and the majority of these fuels are made from oil.

Oil consumption climbed by 31% between 1980 and 2008, but intriguingly, recognised reserves also grew at a comparable rate because to better exploration and extraction methods. While oil reserves are growing, access to affordable oil is claimed to be restricted at a supply of around 75 million barrels per day, which leads to huge rises in oil price as demand approaches this upper bound. Despite this, oil prices have climbed dramatically in this time. This has to be understood in light of the 110 million barrels per day supply need for transportation gasoline that is predicted for 2020. The Fischer-Tropsch method may be used to convert coal into liquid transportation fuels, but it is highly energy- and CO2-intensive. While carbon capture and storage (CCS) may be utilised to reduce CO2 emissions, these technologies are still in their infancy and do not yet provide a competitive advantage. Liquefied natural gas (LNG) is expected to be used more frequently as a transportation fuel as a result of the discovery of significant natural gas resources in the United States that can be economically extracted. Although the initial investment is higher than for standard trucks, the payback period is only 3–4 years given the current price differential between diesel and LNG. Busses have already benefited from the technology for using LNG in internal combustion engines, but broader use will need spending money on the required infrastructure. Natural gas burning will also produce net CO2 emissions of roughly 443 g CO2 per kW h. Together with CCS, natural gas can be utilised to create energy that is CO2 neutral, but as was already said, the cost of this technology is still too high.

Nowadays, biofuels account for around 2.7% of the world's transportation energy (or 0.12 TW8), with ethanol (84.6 billion gallons in 2011) and biodiesel made from rapeseed or soybean oils dominating the market (19.0 billion litres in 2011). Brazil produces 21.1 billion litres of ethanol from sugar cane, while the United States produces 52.7 billion litres of ethanol mostly from maize. These two production methods are sometimes referred to as first generation bioethanol. The National Petroleum Council (NPC) in the USA expects that oil, natural gas, and biofuels would predominate in transportation fuel consumption in the USA by 2050, however maize ethanol won't be present and will be replaced by lignocellulosic ethanol, also known as second generation bioethanol.

The development and use of biofuels are often criticised, despite the fact that they are now widely used and will likely be used much more in the future. This was especially evident in Dr. Hartmut Michel's recent editorial, "The Absurd of Biofuels," which was published in Angew. Chem., Int. Ed. 25 In the editorial, Dr. Michel makes the case that growing plants to produce energy is a bad use of the land since photosynthesis has a maximum efficiency of 4.5% and a probable efficiency of about 1%. He contrasts this to the 15% of solar panels that are now in use and makes the case for solar photovoltaic (PV) systems together with the usage of electric vehicles because they will utilise the land around 600 times more effectively than a biomass-biofuels-combustion engine combo. The case of ethanol from sugar cane or lignocellulose obtained from low-input high-diversity grass is less dramatic, i.e. 120 times less efficient with net energy gains of 26.0 and 28.0 mW h ha1, even though these arguments are not in dispute for ethanol and biodiesel produced from corn and soybean oil respectively, which have a net energy gain of 5.2 mW h ha1 and 4.0 mW h ha1. Also, since bagasse and other solid agro-industry wastes are created concurrently with the processing of crops and thus serve as a possible solution to disposal issues, biofuels made from biomass waste, such as this, do not have a land-use problem. As with others, Dr. Michel contends that bioethanol is not a CO2 neutral fuel. In addition to the objections highlighted by Dr. Michel, concerns about prices and the use of agricultural land for the production of fuels rather than food are often voiced (food versus fuel issue). In the sections that follow, we'll address each of these concerns in an effort to show that a large portion of the criticism is actually related to current technologies, whereas emerging technologies will address all of these concerns and thereby represent alluring potential solutions to our future problems by ensuring a sustainable supply of liquid transportation fuels.

The high cost of biofuels and the consequent need for government subsidies to ensure cost-competitive production of biofuels are often used as arguments against them. It is obvious that biofuels cannot be competitive with fuels made from conventional oil, such as oil supplied by the Organization of Petroleum Exporting Countries (OPEC), but depending on the feedstock, they may be able to compete with non-conventional oil derived from deep waters or the Arctic as well as oil extracted using enhanced oil recovery techniques (EOR oil). So, sugar cane ethanol will be included in the transportation fuel supply curve for 2020 as a biofuel that won't need subsidies, making it more affordable or in the same price range as fuels generated from non-conventional sources of oil. The only way corn-based ethanol, which is produced in a less effective manner than sugar cane ethanol, will be able to compete with oil on the market is via government mandates and subsidies. So, it is anticipated that corn-ethanol won't be produced in large quantities after 2050, when cellulosic ethanol and advanced biodiesel will play a significant role in the supply curve. In the next 10 to 15 years, lignocellulosic ethanol, also known as second generation bioethanol, will likely replace current corn-based ethanol production due to cost competitiveness. Due to the poor energy yield per hectare (mW h ha1) of rapeseed and soybean cultivations (5.7 and 9.1 mW h ha1, respectively, compared with 18.8 mW h ha1 for maize and 36.12 mW h ha1 for sugar cane), traditional biodiesel production is likewise not cost-competitive. With existing technology, it is relatively costly to produce advanced biodiesel by microbial fermentation; however, the cost of production will drop significantly if lignocellulosic feed stocks (or biomass feedstocks) are used instead. As a result, the claim that biofuels are expensive is a problem for two of the three technologies now in use, namely the production of bioethanol from maize and biodiesel from rapeseed oil, whereas bioethanol from sugar cane is competitive in terms of production costs. Nevertheless, with new technologies like ethanol generation from biomass and the creation of advanced biofuels, the cost of producing biofuels is anticipated to be competitive[11].

Another common complaint is that biofuels do not reduce CO_2 emissions when compared to fuels derived from oil, meaning that they are not now CO_2 neutral. This is only partially true for ethanol made from maize, since it only has an average carbon intensity that is 12% lower than that of gasoline. This is mostly caused by the significant energy expenditure required for cultivation and ethanol distillation. Yet, compared to gasoline or diesel, the two major forms of biofuels now in production significantly reduce CO_2 emissions. While its usage is not CO_2 neutral, biodiesel made from soybeans has a carbon intensity that is on average 41% lower than diesel made from oil, and ethanol made from sugar cane has a carbon intensity that is 60% lower than that of gasoline. It is anticipated that the carbon intensity of the second generation of biofuels utilising biomass as a feedstock would be reduced by a comparable 60%. However, if lignocellulosic residues are utilised, such as through the use of forest, agricultural, and livestock residues, short-rotation forest plantations, energy crops, the organic portion of municipal solid waste, and other organic waste streams, this can significantly increase and turn CO_2 negative.

According to some estimations, biomass from low-input, high-diversity grasslands may reduce greenhouse gas emissions more significantly or even result in carbon-negative emissions due to net carbon dioxide absorption. However, it is crucial to conduct accurate assessments of land-use change as the conversion of grassland and forests into new cropland, such as switchgrass or corn, can result in an increase in emissions, underscoring the significance of recycling waste or reorganising current farming, such as switching from tobacco to energy crops. The residues from the most significant crops now grown aggregate to around 2 TW, while biomass from low-input, high-diversity grasslands may easily contribute another 2 TW. This amount of energy may be converted into advanced biofuels or ethanol to produce between 0.7 and 1.6 TW, or around 25 to 55 percent of the present energy used for transportation. Moreover, the lignin in this biomass may be burned to produce 0.8–1.8 kW h L1 of biofuel, which is electricity. By taking into account the carbon sequestration associated with the use of abandoned and degraded land, the use of 1 TW of biofuels generated from these resources may cut CO_2 emissions by roughly 1.45 GtC or even more, which will nearly entirely assure the necessary reduction of CO_2 emissions.

There is a rise in the need for land for food production due to population growth and dietary changes (more people are consuming meat). So, it has been claimed that we shouldn't use land for the development of biofuels, i.e., a food vs fuel dilemma. We assessed the global biomass output in order to solve this problem. Global photosynthesis employs a portion of the 120 000 TW that the sun gives the planet each year, coupled with water and CO_2, to create around 100 billion tonnes of dry biomass per year. About 6.5% of this biomass is diverted for human consumption, but a third of it is lost or wasted every year, primarily in industrialised nations, where this loss amounts to 95–115 kg per person annually due to mechanical damage, harvesting spills, degradation, the loss of edible parts, and wastes from household consumption and supermarket handling. The loss, which in low-income nations ranges from 6 to 11 kg annually per person, is mostly attributed to technical, storage, packaging, and marketing constraints. 34 The potential use of land for food production is further constrained in low-income nations due to a lack of agronomic resources such as technical aid, low income per unit of land, labour migration, and soil erosion. Nowadays, 35 nations need food aid from outside, with the majority of them being in Sub-Saharan Africa and regions of Asia that are experiencing violent civil wars.

With the aim of reducing hunger and poverty as well as enhancing livelihoods, social equity, and sustainable development using Africa's own renewable resources, numerous commitments and programmes have been addressing agricultural, food supply, and rapid population growth problems in sub-Saharan Africa in recent years. If commercial, agricultural, and political impediments are removed, this continent may become a potential exporter of grains. Moreover, South America has the ability to increase both food and lignocellulosic biomass production. In order to better use the potential of this area, there is a stronger infrastructure here, but it is still inadequate for funding and enhancing agriculture. The earlier factors only pertain to the effective use of arable land in low-income nations, but there is a large area of depleted and poor quality land that extends throughout the globe and is between 385 and 472 million hectares that may be utilised for the cultivation of low-input, perennial grasses. One key possibility for supplying food has been the cultivation of plants from the Agavaceae family, which can thrive in dry and damaged environments. Agave bagasse may also be used to make biofuels. To secure the availability of food in the future, issues with food waste, losses, production, and distribution may just need to be solved. Remainings from linked agro-industrial operations may also be utilised to make biofuel. Hence, if the appropriate infrastructure is put in place for managing agricultural goods, the question of food vs fuel is almost nonexistent.

Our justifications above make it very evident that most of the criticism levelled against biofuels has to do with how they are currently produced, particularly maize ethanol and vegetable biodiesel. Nevertheless, it is unlikely that these procedures will be used in the future biofuel sector, which is shifting towards the development of advanced biofuels and second generation bioethanol. The cost of producing biomass-based second generation bioethanol is a major driving factor, and the timelines for reaching technological advancements and feedstock sustainability milestones are 5 and 25–35 years, respectively. Yet, the generation of advanced biofuels is required if the usage of biofuels is to be increased. Due to its low energy density (8.0 kW h kg1) and high hygroscopicity, ethanol is not a suitable fuel and is only created via yeast fermentation, which has a very high efficiency in converting carbohydrates to ethanol. Advanced biofuels, on the other hand, are of great interest since they can integrate even more seamlessly into the existing infrastructure, guarantee high levels of blending, or even entirely replace transportation fuels made from fossil sources.

One example of an advanced biofuel with increased properties is butanol (10 kW h kg1), and at the moment, Butamax (a Dupont-BP joint venture) and Gevo are working to create commercial butanol production. Farnesane (12.8 kW h kg1), fatty-acyl ethyl esters (11.25 kW h kg1), and olefins (13.08 kW h kg1) are other high density biofuels, or advanced biodiesels. Companies like Amyris, LS9, and Solazyme are developing, testing, and producing these biodiesels at the pilot scale, respectively. Up to 15-20% is often advised for traditional biodiesel, while farnesane satisfies the ASTM D975 diesel standard and has earned EPA approval to be mixed at up to 35% with petroleum diesel. Also, it is said that the other sophisticated biodiesels may be utilised in current engines without modification, since they have been tested, for instance, in military ships. As a result, at the pace at which technologies for producing advanced biofuels are developing, it will take between 8 and 20 years to demonstrate their economic viability, and it's probable that implementation won't begin. Many research unequivocally confirm these shifts away from ethanol made from maize and vegetable biodiesel and towards advanced biofuels made from biomass.

By removing obstacles to their complete integration with the existing end-used technology, internal combustion engines, advanced biofuels made from lignocellulose may have a favourable influence on current concerns about the usage of biofuels. Because it requires the development of numerous sectors, such as the production of advanced transportation engines and related industries of materials, components, control systems, installers, and business services, these technologies, known as conventional transportation, will not be abruptly changed to other technologies based on electricity or hydrogen. Instead, they will be gradually introduced. It takes a long time for technology to develop and spread in this way (between 2 and 7 decades). So, based on historical development, it has been anticipated that solar PV technologies, which now account for roughly 0.04 TW (Renewables 2011), would reach between 0.2 and 6.9 TW by 2050. Compare this to the expected rise in biofuel use from 0.12 TW in 2011 to between 1.2 and 7.4 TW by 2050.

Some research groups are currently working on the development of less-recalcitrant lignocellulosic materials to decrease pretreatment efforts and costs for the conversion of biomass into fermentable sugars by hydrolysis. Biofuel development and production advances go beyond the development and optimization of technologies for the conversion of lignocellulose to the desired fuel. The duration of wave absorption may be doubled by replacing photosystem I with a new reaction centre that uses farther-red-absorbing pigments, and the assimilation of CO_2 can be increased by engineering the ribulose-1,5-bisphosphate (RuBP) carboxylase/oxygenase. Also, the development of an integrated process that can transform lignocellulose into biofuels in a single step might result from cells exhibiting hydrolytic activities, which would also result in a reduction in production costs. Alcohols may be produced via an electro-microbial method that converts CO_2 and sunlight. The previous ten years have seen a lot of developments towards shifting the economy to a bio-based economy. Ignoring the creation of biofuels would mean foregoing the chance to use the full spectrum of biotechnological applications (such as synthetic biology, systems biology, and metabolic engineering) to address the major issue of ensuring a reliable supply of transportation fuels for the future while also reducing CO_2 emissions at reasonable costs and thereby helping to combat global warming.

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CHAPTER 15

BIOMASS POTENTIAL

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On our world, plants are constantly growing, far outpacing the fundamental energy needs of humans. Naturally, only a portion of the expanding biomass as a whole can be converted into energy[1], [2]. There is still a sizable quantity of biomass that is well suited for exploitation, nevertheless. Biomass resources include waste products from other companies and homes as well as feedstock from agriculture, forestry, and their connected sectors. The European Environment Agency (EEA) claims that without affecting biodiversity, soil, or water resources, the use of biomass for the creation of clean energy in the European Union may rise dramatically in the next decades. The potential biomass that exists in Europe seems to be enough to help achieve the challenging goals for renewable energy while also protecting the environment[3], [4]. Biomass is an ecologically benign source of heat, electricity, and transportation fuels that may be obtained from forests, agriculture, and organic waste. So, using it may aid in lowering greenhouse gas emissions and achieving the European Union's renewable energy objectives (EC DG ENV 2006). It goes without saying that the production of biofuels from biomass competes with various uses and applications beyond the energy industry[5], [6]. There are now worries that the manufacturing of biofuels will affect food production. Nonetheless, many agricultural goods are already overproduced in Europe. Production limitations and hefty premiums are paid for agricultural goods and set-aside land in order to ensure lucrative market pricing. As a result, there is now no competition between the production of food and biofuels. Yet, as the need for biomass rises, the production of biofuels will face competition from the chemical and regenerated raw materials sectors as well as from the food industry. However economic synergies between the use of various intermediate products and co-products have been found, and the first instances of so-called integrated refining ideas have already been put into practise[7], [8]. In its Vision Report, the European Commission identifies three key issues that need to be resolved in order to boost the supply of biomass:

- Supply the industry with secure raw material: Efficient land use by the use of whole-crop solutions and by exploiting both fertile and marginal land. Ensure that both primary production and residues are evaluated for their energy potential. Sustainability in biomass production- handling techniques.
- Improve the acceptability of the biomass sector by strengthening the communication channels among the relevant stakeholders, especially the farming and forestry sectors with the respective fuel and energy sectors.
- Balance domestic biomass production against international biomass trade.

Agriculture productivity in Europe has been steadily increasing for decades, and this trend will continue in the future. Yet in the future, far bigger areas will need to be planted with energy crops in order to increase the production of biofuels. On the other hand, improved agricultural production and advancements in plant breeding will result in a greater availability of biomass.

Increased productivity is promised by new agricultural cultivation and harvesting techniques including mixed crop farming and double crops. Also, these techniques help with environmental and natural resource preservation. New energy crops that have not previously been grown will also be created. On pasture land and waste land, which together make up around one-fourth of the earth's land area, different species of trees and plants that have been suited to the local environment may be planted. Plant residues are also predicted to have a significant potential. This comprises biological wastes, straw, and leftover wood from forestry and landscape preservation. Extended biomass production, however, may have a negative impact on biodiversity, soil, and water resources. Hence, ensuring sustainable biomass production is quite important. Carefully evaluating the amount of biomass that can be utilised without adding such extra pressures (EC DG ENV 2006). According to a recent assessment by the European Environment Agency, the potential for generating electricity from "environmentally compatible biomass" in Europe might rise from the anticipated 190 Mtoe in 2010 to around 295. Thus, the EU has enough biomass to achieve its 2010 renewable energy objective without endangering the environment. The EC's Biomass Action Plan (EC 2005) estimates that 150 Mtoe of biomass usage is necessary to save 210 Mt of CO2eq. After 2010, the potential also permits high renewable energy goals that might call for between 230 and 250 Mtoe of primary biomass [9]. The EEA analysis considers a variety of environmental restrictions in addition to the main drivers of bioenergy production (agricultural, forestry, trash, and greenhouse gas emission reductions). The latter comprise:

- Maintenance of extensively cultivated agricultural areas
- Dedication of at least 30% of the agricultural land to environmentally-oriented farming
- Establishment of ecological areas in intensively cultivated agricultural lands
- Use of bioenergy crops that reduce soil erosion, nutrients input, pesticide pollution and water abstraction
- Maintenance of current protected forest areas
- Adaptation of the forest residue removal rate to local site
- Increased share of protected forest areas
- Waste minimization strategies

The EEA estimated that approximately 47 Mtoe of bioenergy can be produced from the released agricultural land area in 2010 without putting additional environmental pressures on the environment by only taking into account the potential of environmentally friendly agricultural bioenergy and excluding the bioenergy potential from forestry and from wastes. The Vision Report (EC 2006a) simply depicts the biomass required for fuel generation, in contrast to the EEA research, which also takes into account the biomass potential for solid, gaseous, and liquid biofuels. Consequently, 18 Mtoe of biomass will be required in 2010 for the production of biofuel in order to meet the RES 12% objective. Several more studies on the potential of biofuel production in various European nations and areas exist in addition to the EEA research and the Vision Report. For instance, KAVALOV used several scenarios to evaluate the "Biofuels Potentials in the EU." He came to the conclusion that considerable changes in the agricultural production patterns in the EU would be necessary to fulfil the 5.75% transport biofuel goal in 2010. He said that taking into account techno-economic issues and farm policy goals might make it difficult to put such changes into effect. It is difficult to forecast the actual biofuel potential for the future since the European biofuel potential is dependent on a wide range of variables, including biofuel legislation, crude oil prices, food supplies, technological advancements, democracy, consumer behaviour, and trade concerns.

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CHAPTER 16

BIOFUEL POLICIES

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Many goals have been established in the European Union (EU) to promote biofuels. These policies are described in detail in official documents of the European Commission, and a succinct summary will follow. Several activities that will promote the use of biomass for the generation of renewable energy are detailed in the "Biomass Action Plan" (EC 2005) of the European Commission[1], [2]. In the report "An EU Strategy for Biofuels," the EC has identified three objectives for biofuels":

- To further promote biofuels in the EU and emerging nations, to guarantee that their production and use are environmentally friendly on a worldwide scale, and to ensure that they contribute to the Lisbon Strategy's goals while taking competitiveness into account,
- To improve the cost-competitiveness of "second generation" biofuels, research into "third generation" biofuels, and assist market penetration by expanding demonstration projects and addressing non-technical obstacles in order to be ready for the large-scale usage of biofuels. and
- To examine the possibilities for developing nations, especially those impacted by the EU's reform of the sugar regime, to produce biofuel feed stocks and biofuels, and to outline the potential contribution of the EU to the growth of environmentally friendly biofuel production. These include actions the Commission will take to encourage the development and use of biofuels[3], [4].

These policy axes are:

- Stimulating demand for biofuels
- Capturing environmental benefits
- Developing the production and distribution of biofuels
- Expanding feedstock supplies
- Enhancing trade opportunities
- Supporting developing countries
- Supporting research and development

The Biofuels Research Advisory Council (BIOFRAC), a high-level expert panel assembled by the EC DG Research, wrote the Vision Report. The report "is based on the members' prior experience, present behaviour, and anticipated future outcomes." This vision statement was not intended to serve as a road map or to prompt the development of goals. Instead, it outlines the difficulties that lie ahead and makes suggestions as to how to overcome them[5], [6]. The vision paper establishes the groundwork for a Strategic Research Agenda within this context. Moreover, it suggests setting up a European Technology Platform for Biofuels to develop and carry out this research agenda. " By 2010, the EU wants to boost the market share of biofuels to 5.75% by energy content and the proportion of renewable energy sources (RES) in gross inland consumption to 12%. The EU is encouraging the development of biofuels, particularly for the transportation sector, in order to lower greenhouse gas emissions, maintain European competitiveness, and diversify fuel supply sources. Subsequent analyses have shown that further efforts are required in order to reach the 2010 objectives. The total amount of biomass used for energy in 2003 was 69 Mtoe. It will need an additional 74 Mtoe by 2010, divided as follows: electricity 32 Mtoe, heat 24 Mtoe, and biofuels 18 Mtoe, to meet the 2010 RES 12% goal for the biomass sector. Hence, the total amount of biomass used for energy in 2010 would be 130 Mtoe. Only focused activities, improved coordination of EU policies, and targeted measures will be able to increase biomass output in the near term. Hence, in order to encourage the use of biomass and biofuels, the Commission has adopted an ambitious and well-coordinated strategy. The strategy contains the aforementioned Biomass Action Plan as well as an EU Biofuels Strategy. According to the Commission, the actions included in the action plan may expand biomass consumption to roughly 150 Mtoe by 2010 or shortly afterwards. The EC has approved a number of legislative measures to help accomplishing these goals. 2003 saw the agreement and adoption of the EU's Biofuel Directive 2003/30/EC, which promotes the use of biofuels or other renewable fuels for transportation. The Directive (1) established a voluntary biofuel objective of 2% by 2005 and 5.75% in order to stimulate the use of biofuels[7], [8].

By 2010, (2) mandated that member states provide yearly reports, and (3) requested that the Commission perform an evaluation in 2006 that incorporated public input. The European Commission issued suggestions for a new energy policy for Europe on January 10, 2007. They included a roadmap for renewable energy that proposed a legally enforceable 10% objective for each Member State's proportion of biofuels in gasoline and diesel by 2020, along with the implementation of a sustainability programme for biofuels. The whole energy package is now being examined by the European Parliament, which will soon vote on revisions. The revised Biofuels Directive will be issued in January 2008 after being finalised by the European Commission. [1]The Parliament, national Ministries, and the Commission will then need to agree on this. Also, the taxation of biofuels is closely related to the marketing of biofuels. Directive 2003/96/EC, titled "Restructuring the Framework for the Taxation of Energy Products and Electricity," addresses issues related to the taxation of biofuels. The EU member states are allowed to exclude all biofuels from mineral oil taxes under this rule. This decision is applicable to both pure fuels as well as the proportionate blending of biogenic components with fossil fuels. Biofuels are inextricably tied to Directive 98/70/EC, which was revised by Directive 2003/17/EC "Quality of petrol and diesel fuels," since only high-grade biofuels are preferred. Today, this order permits fuel distributors to mix 5% bioethanol and biodiesel into the gasoline and diesel they distribute[9].

Market Barriers of Biofuels

The market presents a number of obstacles for the development of renewable energy sources. These obstacles prevent the growth of renewables unless specific legislative measures are put in place, until there are no alternative fossil resources, or unless the cost advantage of renewables is much greater than that of fossil fuels. It is necessary to identify obstacles and find solutions in order to encourage the rapid adoption of biofuels. The Union of Concerned Scientists has identified four major kinds of obstacles to the widespread adoption of renewable energy technology (RET) (UCS 1999):

- Commercialization barriers faced by new technologies competing with mature technologies
- Price distortions from existing subsidies and unequal tax burdens between renewables and other energy sources
- Failure of the market to value the public benefits of renewables
- Other market barriers such as inadequate information, lack of access to capital, high transaction costs

Biofuels are subject to the same restrictions as RETs. It is necessary to discuss these obstacles in more depth in order to identify strategies for getting over them. Nine major market barriers may be used to describe the primary market restraints related to biofuels:

1. **Economical barriers:** The production of biofuels is still expensive, markets are immature and beneficial externalities are not accounted.
2. **Technical barriers:** The fuel quality is not yet constant and conversion technologies for certain biofuels are still immature (e.g. for synthetic biofuels).
3. **Trade barriers:** Certain biofuels still don't have any quality standards in place. Therefore, there is no uniform sustainability guideline for Europe. Due to denaturation requirements, there are obstacles to the international trading of bioethanol.
4. **Infrastructural barriers:** Infrastructures need to be either new or changed depending on the kind of biofuel. The utilisation of biohydrogen and biomethane, in particular, requires significant adjustments to the infrastructure.
5. **Causality dilemma:** Owners of gas stations contend that automakers must first sell modified vehicles before selling biofuels. According to the automobile sector, infrastructural development must come first. The chicken-and-egg conundrum—which came first, the chicken or the egg?—is a real obstacle to the implementation of FFV and the marketing of E85 in various European nations.
6. **Ethical barriers:** Biomass feedstock sources may compete with food supply.
7. **Knowledge barriers:** The general public, but also decision makers and politicians are lacking knowledge on biofuels.
8. **Political barriers:** Lobbying groups influence politicians to create or conserve an unfavorable political framework for biofuels.

9. **Conflict of interest:** Competition between the "promoters" of first- and second-generation biofuels might hinder the growth of these fuels as a whole. The kind of biofuel and the particular framework requirements will also have a significant impact on the hurdles outlined above. Hence, major scientific, commercial, and political obstacles must be overcome in the next years in order to make biofuel a key component of a sustainable global transportation system.

Biofuel Standardization

International standards, particularly European standards, have progressively replaced national standards as the European Union has developed and expanded. The European Committee for Standardization is responsible for creating these European standards (CEN). Stakeholders and authorities have called attention to the need for biofuel requirements and standards since the market share of these fuels has grown significantly in recent years. As a result, the European Union has made significant efforts to standardise biofuels; since 2003, there has been an uniform European standard for biodiesel. The standards for bioethanol also moved forward. The CEN's Technical Committee No. 19 is working very hard to publish the unified European bioethanol standard. An early draught is already accessible to the general public. The creation and use of standards reduces trade barriers, enhances safety, boosts product, system, and service compatibility, and fosters a shared technical knowledge. All standards contribute to creating the "soft infrastructure" of contemporary, creative economies. They provide designers, engineers, and service providers assurance, references, and benchmarks. They provide "an ideal degree of organisation" (CEN 2006). Standards are thus crucial for biofuel producers, suppliers, and consumers. The market launch and commercialization of new fuels need a standard. A fuel quality monitoring system and Regulation 98/70/EC, which was modified by Directive 2003/17/EC, "Quality of petrol and diesel fuels," are related to European standards for automobile fuels. The encouragement of the use of biofuels or other renewable fuels for transportation is mostly related with the taxation of biofuels, and is governed by European Directive 2003/30/EC. Directive "Biofuel Taxation Problems" addresses this topic. reorganising the system for taxing electricity and energy items".

International Trade of Biofuels

Compared to the international trade in fossil fuels, the trade in biofuels is very tiny. The majority of commerce in biofuels occurs between nearby nations and regions. Yet if biofuel output rises steadily, new commercial partnerships will be formed in the future. As a result, commerce will also grow across large distances. Many national, EU-wide, and worldwide policies have an impact on the trading of any product across international borders. Also, there are rules and laws specific to the international trade in biofuels. Some clarifications and definitions are provided so that you may better comprehend our rules. In international commerce, a good's "economic" nationality is determined by its origin. Non-preferred and preferential origins are the two types. Non-preference origin gives things a "economic" nationality. It is used to identify the country of origin of goods that are subject to various commercial policy measures, such as quantitative limits, anti-dumping measures, or tariff quotas. Also, it has statistical uses. The non-preferential origin of the items is also connected to other regulations, such as those concerning public bids or origin labelling. Also, the Common Agricultural Policy (CAP(EU))'s export reimbursements are often based on non-preferential origin.

Traded commodities between certain nations benefit from preferential origin, such as duty-free or significantly reduced entrance. In either scenario, the tariff categorization of the items is crucial in identifying their origin. When attempting to discover a good's origin, it is crucial to know its Combined Nomenclature (CN) code. In the Community, goods in commerce are designated by this code number. The rate of customs tax that will be charged and how the products will be handled for statistical reasons are both decided by the CN. The Common Nomenclature (CN) is a system for identifying commodities and merchandise that was developed to simultaneously satisfy the needs of the European Customs Tariff and the Community's external trade statistics. Moreover, data on intra-community commerce utilise the CN[10]. There is currently no formal customs categorization for biofuels. So, it is impossible to determine with precision how much imported ethanol, oilseeds, and vegetable oil are eventually utilised in the transportation industry. The European Commission will weigh the benefits and drawbacks of recommending distinct nomenclature codes for biofuels, as well as any potential legal repercussions. In order to increase the economic viability of biofuels and their feed stocks and meet the growing demand for them, the Commission is working to promote both EU domestic production and improved import prospects. Task 40, a task under the IEA Bio-energy Agreement7, is one of the key international organisations active in policy on trade of biofuels. Its goal is to support the growth of sustainable biomass markets over the short, medium, and long terms, at various scale levels (from regional to global). Future goals for this job on international biomass commerce include its growth into a true "commodity market" that will sustainably balance supply and demand. Long-term security is mostly dependent on sustainability. The World Trade Organization (WTO), which deals with worldwide or almost international trade regulations, is another significant party in the global trade of biofuels. The WTO is a global organisation whose goal is to advance free trade by encouraging nations to do away with import tariffs and other trade restrictions. It is the sole international organisation in charge of policing trade regulations. It manages trade talks, adjudicates trade disputes between nations, and enforces free trade agreements. All members of the WTO are required to comply by its judgements, which are final. The WTO serves as both judge and jury in disputes between the US and the EU over trade in biofuels. Members of the WTO have the authority to enforce its rulings by enacting trade penalties on nations that have broken the rules.

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CHAPTER 17

LIPID DERIVED BIOFUELS

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Lipid sources are a significant source of biofuels. Pure plant oil17 (PPO) and biodiesel are the two primary categories of lipid-based fuels. PPO and biodiesel are covered under the heading "lipid derived fuels" in chapter 6 since their fundamental manufacturing processes are comparable. For instance, the processes in the process for producing feedstock and extracting oil are the same for both fuels. Nevertheless, further purification stages are required for the ultimate synthesis of PPO, while the trans esterification step is required for the creation of biodiesel. Yet, the final products (PPO and biodiesel) have entirely distinct characteristics. Thus, PPO and biodiesel qualities, technological applications, and standards challenges will be covered in separate chapters. Again, common chapters will cover horizontal issues like energy balance emissions, environmental effects, and economics[1], [2].

Feedstock Production

Using various feedstock materials for PPO and biodiesel synthesis has a wide range of opportunities. In addition to specifically grown oilseeds like rapeseed and soybean, other potential feed stocks for the manufacture of fuel include microalgae, animal fats, and waste oil. These final two forms of feedstock are currently not widely used, however[3], [4]. These may be further classified into waste oil, seeds, algae, and palm fruits. While palm fruit output is among the greatest, seeds from diverse plants are the most prevalent feedstock sources for PPO and biodiesel synthesis. They include ricinus, sunflower, rapeseed, peanut, sorghum, and jatropha seeds. In the next chapters, specific details about these feedstock factories will be discussed. Agricultural, topographical, and climatic factors predetermine the choice of a devoted feedstock. Yet it must also be remembered that various feedstock types have distinctive characteristics. For instance, there are significant differences between various oilseed species in terms of oil saturation and fatty acid content. High cetane number and greater oxidative stability are the hallmarks of biodiesel made from highly saturated oils, although it performs poorly at low temperatures. As a result, in warmer areas, pure plant oil (PPO) with a high degree of saturation is more appropriate as feedstock[5].

Oilseed Crops

Oilseed crops are the main source of feedstock for the manufacturing of PPO and biodiesel. The cultivation of soybeans, rapeseed, and cottonseed are the three most important oilseeds now grown. Rapeseed, which is mostly grown in Europe, is the predominant feedstock used in PPO and biodiesel. Rapeseed oil accounts for about 85% of biodiesel production, followed by sunflower seed oil, soybean oil, and palm oil. Oilseed crops usually provide lower yields per hectare in temperate climates than starchy cereal feedstock like maize and wheat. Nevertheless, oil seeds often have more favourable overall energy balances since they need less processing. Hence, tropical oilseed crops in particular may be quite prolific[6], [7].

Rapeseed Rape, also known as canola or colza, is a member of the Brassicacea plant family and is related to other oil seed crops including mustard species (*Brassica nigra, Sinapis alba*), and Gold-of-pleasure (*Camelia sativa*). Rape is grown and seeded either in the spring (annual) or the fall (biennial) (annual). The plant may develop a 1.5 m stem and has a lengthy taproot. Pointed pots are used to contain the seeds. With yields of 3 t/ha, winter rape is harvested throughout Europe around the end of July. Summer rape produces 2.1 t/ha and ripens in September. Rapeseed should be grown at least two years apart from other cruciferous plants, such as broccoli, cauliflower, cabbage, and Brussels sprouts, to prevent the spread of plant disease. The growth potential for rapeseed farming are often constrained by this constraint in addition to issues with soil quality[8]–[10].

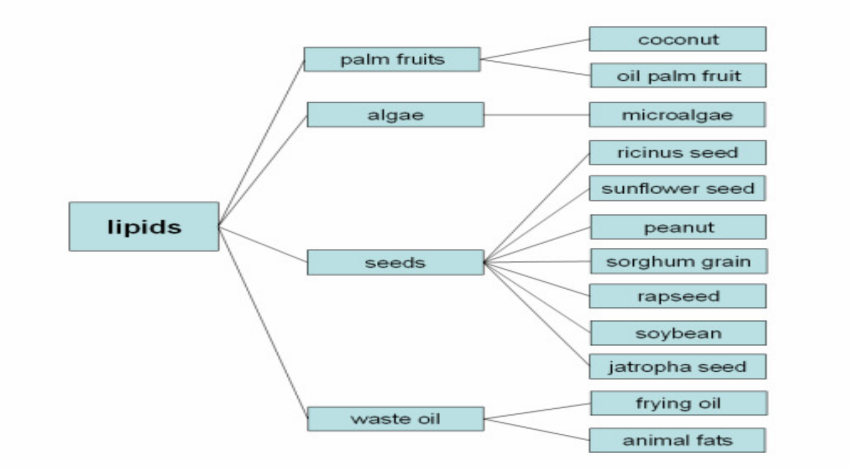

Figure 1: Types and classification of lipid feedstock sources (examples).

Erucic acid, which makes about 50% of rapeseed oil, is quite abundant and may seriously harm the heart and liver. With the help of successful breeding, rape plants with lower concentrations of these chemicals were produced. Currently, the majority of plants are "double zero" (00) cultivars, which only contain trace amounts of erucic acid. Rapeseeds have high monounsaturated oleic acid concentrations and low concentrations of saturated and polyunsaturated acids. Rapeseed oil is a perfect raw material because of its qualities for combustion, oxidative stability, and low temperature behaviour. Rape is being grown more and more each year, with a 2% yearly increase. The area planted for rapeseed in China, the greatest producer in the world, is growing quickly. India, the third-largest producer, has little increase. In 2005, 1.4 million hectares of rapeseed were planted in Europe with the intention of producing biodiesel. Germany produced around half of the biodiesel used in Europe, while France, the Czech Republic, and Poland all contributed significantly.

Soybeans Soy

The most widely grown oilseed crop globally is (Glycine max). In the USA, soybean oil is the most widely used biodiesel feedstock. It is also the vegetable oil that is produced the most commonly globally. Soybean oil is mostly produced in the United States, Brazil, and Argentina, where it is increasingly utilised to make biodiesel. This is mostly because it is common, not because it is particularly desirable as a feedstock for biofuels. Iodine levels in soybean oil range from 121 to 143 gI2/100g, which is comparable to sunflower oil. Experts debate whether soybean oil can fulfil biodiesel criteria as a result. Soy produces very little biodiesel per hectare when compared to other oilseed crops. Nevertheless, soy may thrive in both tropical and temperate environments. It also replenishes soil nitrogen because of its capacity to fix nitrogen. A favourable fossil energy balance is more likely since relatively less fertiliser input is required. In Brazil and the United States, soybeans are farmed alternately with maize and sugar cane. Nowadays, just a tiny portion of the soybean supply is converted into fuels.

Palm oil

One of the two palm trees, along with the coconut palm, that are used to produce oil is the oil palm (*Elaeis guineensis*), which is mostly grown in South Asian nations. The two biggest producers are Malaysia and Indonesia, where the output of palm oil has increased significantly during the last ten years. The second-largest planted area is in Nigeria, while Brazil is predicted to have great potential. While most palm oil is used for food, demand for palm biodiesel is anticipated to grow quickly, especially in Europe.

The Netherlands and the United Kingdom are the two biggest importers of palm oil into the EU. Between 1995 and 2004, UK imports alone more than quadrupled to 914,000 tonnes, accounting for 23% of all EU imports (WWI 2006). As palm oil imports into the EU rise, sustainability guidelines for its production are required in order to prevent negative effects on the producing nations. Yet, compared to other edible vegetable oils, the key benefits of palm oil are its very high hectare yields and current reasonable international market pricing. High levels of medium-chain saturated and monounsaturated fatty acids define palm oil. Excessive levels of saturated fatty acids provide unacceptably high values for the cloud point (+13°C) and cold filter clogging point (+11°C), which restrict temperate areas from using plain palm oil methyl esters throughout the winter. High fatty acid concentration in the feedstock further complicates the manufacture of typical alkali-catalyzed biodiesel, necessitating deacidification or acid-catalyzed pre-esterification procedures[11].

Coconut

The coconut palm, or Cocos nucifera, is another source of feedstock used in the manufacture of oil. As a result, so-called copra is used. The dried flesh, or kernel, of the coconut is known as copra. Coconut oil is a triglyceride that mostly consists of saturated fatty acids (86%), with just trace levels of monounsaturated and polyunsaturated fatty acids (6% and 2%, respectively). While coconut oil includes seven distinct saturated fatty acids in total, its main saturated fatty acids are lauric acid (45%), myristic acid (17%), and palmitic acid (8%). Oleic acid is the sole monounsaturated fatty acid in it, whereas linoleic acid is the only polyunsaturated fatty acid. Coconut oil is one of the most stable vegetable oils since it doesn't oxidise quickly and doesn't become rancid easily. Although refined coconut oil has a higher smoke point of 232°C (450°F), unrefined coconut oil melts at 20–25°C and smokes at 170°C (350°F). In the Philippines, the biodiesel sector prefers this feedstock. It is another feedstock with a high yield that yields highly saturated oil. Even with a 1% minimum mix, vehicles using coco-biodiesel may cut emissions by as much as 60% and boost mileage by one to two kilometres owing to increased oxygenation.

Sunflower

The fifth biggest oilseed crop in the world is the oil from sunflower seeds (Helianthus annuus). It makes up the majority of the remaining biodiesel feedstock in Europe after rapeseed. As compared to soybeans and rapeseed, sunflower seed yields per hectare are greater and comparable, respectively. While being somewhat less fruitful than rapeseed, it is more widely used because of its custom and uses less water and fertiliser. The use of sunflower seed oil for the generation of fuel is limited by its high linoleic acid concentration. Pure sunflower oil methyl esters also contain large levels of iodine, making them unsuitable for use as fuel. Fuels made entirely of sunflower oil will similarly perform poorly in terms of oxidative stability. Breeders have created cultivars that are higher in oleic acid to address the issues.

Jatropha

One of the 150 Jatropha species found in the Euphorbiaceae family is physic nut, or jatropha (Jatropha curcas). This oilseed crop thrives in marginal and semi-arid environments. The bushes are fruitful for decades, may be picked twice a year, and are seldom grazed by cattle. One of the most potential sources of feedstock for industrial biodiesel production in India, where almost 64 million hectares of land are designated as wasteland or uncultivated land, is jatropha. Also, it is especially well suited for fuel consumption in small-scale or village settings. The seed yields have a significant role in the economic feasibility of jatropha-based biodiesel. Yield statistics for the plant have shown significant fluctuation up to this point, which may be ascribed to variations in germplasm quality, planting procedures, and environmental conditions

Moreover, a number of production estimations are based on extrapolating yields from individual plants or tiny demonstration plots owing to the lack of data from block plantations. (WWI 2006) As the crop matures, some organisations that support jatropha anticipate much higher yields. Researchers predict that growing the crop on 11 million hectares of wastelands in India might result in the production of up to 15 billion litres of biodiesel by 2012. To ascertain if these levels of productivity are attainable, further research and demonstration efforts are required.

Many plants in India have a significant potential for producing oil. More than 300 distinct tree species that yield oil-bearing seeds may be found in India. There, it is believed that there are roughly one million tonnes of non-edible oils that may be made available annually, the most plentiful of which are sal oil (180 000 t), mahua oil (180 000 t), neem oil (100 000 t), and karanja oil (55 000 t). These non-edible plant oil sources are particularly interesting since they do not directly compete with vegetable oil for use in human food and because many plants may be produced in arid to semi-arid environments that are not ideal for growing food crops. While non-edible oilseeds are not now used extensively, they may be a significant part of local economy.

Microalgae

In so-called algaecultures, microalgae are grown. They are a kind of aquaculture that involves raising different types of algae for food or other items that may be made from algae. Microalgae are tiny, single-celled aquatic plants that have the capacity to generate significant amounts of lipids (plant oils) that are ideal for use in the manufacturing of biodiesel. There are two primary methods for growing algae: Both "open-pond" systems and closed systems may be used to cultivate algae. Algae in open-pond settings are susceptible to bacterial and other microbial invasions. There have only been a few of species successfully farmed for oil extraction in an outdoor setting. There is no control over the lighting or water temperature in open systems. The growth season is only permitted during the warmer months and is highly dependant on the local climate. These systems' cheap costs and large manufacturing capacity are benefits. Algae may also be grown in a closed system, such as a pond system that is covered by a greenhouse. These systems are often smaller systems for primarily economic reasons, although they offer many of benefits. More species that are shielded from outside species may be cultivated thanks to these methods. The growing season is also prolonged by it. A photobioreactor that has a light source built in may also be used to produce algae. Everything the algae need to thrive (CO2, nutrients, water, and light) must be added to the closed system since it is a closed system. A covered pond may also be regarded as a photobioreactor.

Different types of photobioreactors include:

- Tanks provided with a light source
- Polyethylene sleeves or bags
- Glass or plastic tubes

Light only penetrates the top 7 to 11 cm of most cultures of algae due to the thick growth, hence it is necessary to agitate the water and algae mixture in order for light to reach all of the algae. Furthermore, glow plates are put into the pond in certain applications. These are sheets of glass or plastic that may be dipped into a tank's water to directly illuminate the algae at the proper concentration. Algae may be collected via microscreens, centrifugation, or flocculation after being grown. These technologies allow for the growing of microalgae in dry and semi-arid areas that are unsuitable for the growth of common plants. With no need for acreage or fresh water, this approach does not compete with agriculture for food. Moreover, it is predicted that the per-hectare production would be several times higher than that of even tropical oil plants. Saline water, which has few competing applications in agriculture, forestry, industry, or communities, may also support the growth of algae. Examples of salty water include water from damaged aquifers or the ocean.

Algae may be fed by CO_2 emissions, therefore growing algae beside power stations has recently gained attention. This is conceivable since the main nutrients for the development of microalgae are carbon dioxide and nitrogen oxides. Consequently, integrated systems might create oil-rich microalgae that consume pollutants from coal, petroleum, and natural gas power plants. Now, GreenFuel, a private startup, is striving to commercialise this technology.

Animal Fats

Co-products of the meat and fishing sectors include animal fats. Fish, fowl, hogs, and cattle may all provide it. These co-products may become a more important source of biodiesel production in the future due to their low retail pricing, particularly if they are used to power the vehicle fleets of businesses that produce these raw materials. Also mention the potential of using two additional sources of animal fats due to several animal diseases and scandals ("Creutzfeldt-Jakob Disease - CJD," "Bovine Spongiform Encephalopathy - BSE," etc.). On the one hand, animal meat and bone meal, which is no longer permitted to be used as fodder, is tested for its applicability to biofuel production, making use of the 10-15% of fat contained. On the other hand, diseased cattle's tallow is seen as an intriguing feedstock. The supply is inconsistent across all of these sources, which is an issue. It is conceivable for there to be a rapid surge in the amount of material available, followed by a time when there is no supply. Consequently, because it has not been generated especially for a biodiesel programme, all animal fat is just a byproduct and is often prohibited. All of these animal fats, however, have large levels of saturated fatty acids, which produce methyl esters with subpar low temperature capabilities. Wintertime complications result from this. Animal fat methyl esters, however, are good fuels in terms of heating value and cetane number due to the high degree of saturation. The morality of utilising animal parts as fuel for transportation should not be disregarded. Public outrage might develop when animal-based biofuels are sold. Due of these issues, it is anticipated that animal fats will not produce a significant amount of oil or biodiesel in the future. It will only be used in a certain niche.

Waste Oils

There is a large variety of waste oils available for biofuel production. In general these waste oils are inexpensive and offer an additional environmental impact by using substances which would otherwise have to be disposed. The origin of the oil can be characterized by three types:

- Waste oil from households and restaurants
- Waste oil from food industry
- Waste oil from non-food industry

The waste oils that are most often used in the manufacturing of biodiesel include rapeseed, soybean, palm, and coconut oils. These waste vegetable oils (WVO) must undergo extra processing in order to remove impurities and deal with the acids that high temperatures release. The usage of used cooking oil from homes and restaurants is briefly described. They discuss the use of recycled frying oil in Austrian bus fleets and its effectiveness. Since 1992, recycled-frying-oil methyl esters (RFO-ME) have been synthesised there for commercial use. Around fifty buses are using RFO-ME in the City of Graz without any issues, since this fuel only slightly varies from that of RME. In comparison to RME, RFO-ME exhibits significantly worse low temperature characteristics and slightly greater viscosity and carbon residue values. There are other co-products in the food business that may also be utilised to make biodiesel. A very acidic oil called rice-bran oil is recovered from the waste rice dehulling produces. The pulp of the palm fruit oil is also discussed. The waste product left behind after removing the palm seeds—which are often thrown in the trash without further processing is known as palm fruit pulp. Soybean soapstock is created during the refining stages of the manufacturing of edible soybean oil. It's possible to make biodiesel using this byproduct as well.

Moreover, whey, a waste product of the dairy industry, and extremely acidic sulphur olive oil, a co-product of the refining of olive oil, may be used for the generation of biodiesel. In addition to the sources of waste oil listed above, industrial waste oils are sometimes utilised in the manufacturing of biofuels. Hence, tall oil, a byproduct of producing sulphate pulp from resinous forests like pine and spruce, serves as an example.

Fuel production

Currently, PPO and biodiesel processing mostly uses oil from plant sources (oil crops) that are only extracted for the manufacture of biofuels. As a result, the generation of gasoline from certain oil crops is the main topic of discussion in this chapter. While the potential for the manufacture of fuel from microalgae, animal fats, and waste oils is quite great, the quantity of fuel produced to far is very modest. Oil crops are harvested based on the plant type and available technology. Using rape as an example, a combine harvester is used to complete the harvest. The seeds are either kept beforehand or sent immediately to the oil mill. Oil extraction, which may be done in a number of ways, is the initial stage in the creation of biofuels.

Oil Extraction

The initial stage in the production of PPO and biodiesel is the oil extraction from the feedstock. There are two primary kinds of vegetable oil production processes in terms of size and infrastructure:

- Industrial: centralized production by refining in large industrial plants
- Small scale pressing: decentralized cold pressing directly on farms or in cooperatives

The cleansed oil seeds are only manually pressed in small-scale cold pressing facilities at temperatures no higher than 40 oC. Filtration or sedimentation are used to get rid of suspended particles. Press cake with a residual oil level of typically above 10% is a byproduct that is utilised as a protein-rich fodder. Despite the possibility of providing farmers with extra revenue, decentralised oil production by farmers is not being used frequently due to increased production costs. Also, the co-product might be utilised right away to feed the animals.

Treatment of feedstock in centralised industrial large-scale operations is a popular method of oil extraction. The feedstock must first undergo pre-treatment. Rape oil processing is given here as an example of oil extraction to make the point more clearly. In Figure 30, the process-chart is shown. Rape seeds must first be dried as part of the pre-treatment, but only if they will be kept for more than ten days. In this situation, the rape seeds' regular 15% water content must be decreased to 9%. The rape seeds are afterwards cleaned. There are also bigger seeds that need to be peeled, such sunflower seeds. The seeds are then crushed, and the temperature and moisture content are adjusted. A certain moisture level must be adjusted since too much moisture hinders solvent penetration while too little moisture increases compactness and, in turn, hinders solvent penetration. For the purpose of inactivating germs and preventing smearing of the press due to coagulated proteins, conditioning at a temperature over 80 °C is required. Also, since the oil is more liquid, it can fly better and the solvent can permeate the crushed seeds more effectively. As opposed to small-scale cold pressing, after conditioning, the oil seeds are pressed at these higher temperatures (80 °C). Hence, around 75% of the entire amount of rapeseed oil may be extracted. This pressed raw oil is then filtered and dried, and the resulting pure oil may be utilised for biodiesel manufacturing or for further refinement into PPO. The press cake is a byproduct of pressing rapeseeds. It is further processed since it still has 25% of the original amount of rapeseed oil. The press cake must first be crushed in order for the additional solvent typically hexane to extract the oil at temperatures as high as 80 oC. A combination of oil and hexane, often known as miscella, and the so-called extraction grist are the end products of this manufacturing phase. Both chemicals are separated from the solvent, which is then added back into the process. As in cold pressing, the oil contains more undesirable components after these treatment stages. By refining, they are eliminated. An oil that has been thoroughly refined and is of edible oil grade is the final product. The method used to extract oil from other oilseed crops is similar to that used with rapeseed. Several phases in the procedure might be changed or added. For instance, some seeds don't need to be peeled. Unrefined oil is always the ultimate result, however. The plant oil may be used directly as PPO after refinement, which is covered in more detail below. It must be transesterified in order to be used as biodiesel.

Oil Refining

Refining is a crucial step in the production of PPO and in the preparation of vegetable oil for the biodiesel transesterification process. In order to get rid of unwanted components such phosphatides, free fatty acids, waxes, tocopherols, and colourants, it is crucial. These contaminants may shorten the time that oil can be stored and impede further processing. The oil mass (4 to 8%) and solvent levels are lowered during this initial refining stage. The procedures involved in refining are dependent on the source of feedstock since the quality of the vegetable oil affects the process. Also, there are refining options, and some of the procedures are being combined. But, a streamlined procedure. Degumming, or the elimination of phosphatides, is the first purification process in oil refining. This is important because phosphatides cause the oil to get murky while being stored and because they encourage the buildup of water. There are two methods for removing phosphatides: acid degumming and water degumming. By degumming the water, soluble phosphatides may be eliminated. In this way, water is added to the oil at a temperature between 60 and 90 degrees, and the water and oil phases of the combination are separated centrifugally. If phosphatides cannot be hydrated, acid degumming is used. There are acidic compounds added, such as citric or phosphoric acid. Include advantages of using enzymatic hydrolysis or utilising modest quantities of methanol in this process step to efficiently remove both soluble and insoluble phosphatides. The deacidification process is the second refinement stage. It is a crucial process for edible oils because it prevents free fatty acids (FFA) from developing rancid tastes. These FFAs are present in pure unrefined oil in amounts ranging from 0.3 to 6%. Also eliminated in this stage are phenol, oxidised fatty acids, heavy metals, and phosphatides. The removal of all these impurities is crucial for the manufacture of fuel as well as edible oils since they affect storage life and transesterification in the biodiesel process.

Several methods of deacidification are in operation:

- Neutralization with alkali: This is the most applied method. FFA's are saponified with alkaline solutions and the resulting soap is separated.
- Distillation: For this alternative more energy is needed.
- Deacidification by esterification: This is done by esterification of FFA's with glycerin
- Deacidification and extraction of colorants and odors with various solvents: (z. B. ethanol, furfural, propane)

Transesterification

The synthesis of biodiesel involves a chemical transesterification process that modifies the molecular structure of lipid molecules. The physical characteristics alter as a result. Although while pure plant oil (PPO) that has been refined may be used in rebuilt diesel engines, biodiesel, which is produced via a transesterification phase, offers a number of benefits. One benefit is that biodiesel has a lower viscosity than PPO. Diesel engines' fuel injection time, pressure, and atomization are negatively impacted by increased viscosity. Since biodiesel and fossil diesel are so similar, they may be used in conventional diesel engines that only need minor modifications. Glycerin soap and methyl or ethyl esters are produced as a consequence of the transesterification process, also known as alcoholysis, which involves "cracking" the refined oil molecule and removing the glycerin (biodiesel). Triglycerides, which are three hydrocarbon chains linked by glycerol, are what make up organic fats and oils. By hydrolyzing the bonds, free fatty acids are created. The resulting methyl or ethyl fatty acid esters are created by mixing or reacting these fatty acids with methanol or ethanol (monocarbon acid esters). The glycerin descends to the bottom and the biodiesel (methyl-, ethyl ester) rises to the top when the mixture separates and settles out. Now, in order to prevent a reversed reaction, the separation of these two chemicals must be carried out thoroughly and swiftly. The addition of an acid or base often catalyses these transesterification processes. Figure 32 depicts the chemical transesterification process. Methanol and ethanol are the two major alcohols utilised in the transesterification process. Potentially, higher or secondary alcohols might likewise be used to perform transesterification. The most popular process for producing biodiesel is termed methanolysis, which also goes by the name of transesterification with methanol. Compared to other alcohols, methanol is distinguished by its cheaper cost and stronger reactivity. Heating a combination of 80–90% oil, 10–20% methanol, and trace quantities of a catalyst may cause this reaction. Due to the poor solubility of methanol in vegetable oil, thorough mixing of all components is required for the reaction. Fatty acid methyl ester is the biodiesel that is produced during methanolysis (FAME). As methanol is often a fossil fuel, using bioethanol in an ethanolysis process to produce a totally renewable fuel is sometimes cited as the more ecologically beneficial option. Ethanol is also much less harmful and modestly raises the fuel's heat content and cetane number. Nevertheless, substantially more energy is required for ethanolysis, and issues with the separation of the ester and glycerin phases are recorded more often. The price of process energy also seems to be greater. The ethanolysis product known as biodiesel is also known as fatty acid ethyl ester (FAEE).

Properties and Use of Lipid Biofuels

Due to the differing conversion method and the vast array of feedstock sources of oils and fats, the properties of lipid-derived fuels are often far more varied than those of bioethanol. In reality, ethanol is one extremely particular molecule. In contrast, depending on the source of the feedstock type, the molecules of pure plant oil, animal fat, and biodiesel differ. Nonetheless, following refinement and transesterification, PPO and biodiesel, respectively, must match certain qualities and criteria. A basic comparison of rapeseed oil, biodiesel, and BtL fuels is provided before specific qualities of biodiesel and PPO are presented in the next chapters. Moreover, fossil diesel is contrasted with these biofuels. The high viscosity and flashpoint of rapeseed oil are shown in the table. It also demonstrates how closely fossil diesel and BtL fuels' characteristics resemble one other.

Properties of Pure Plant Oil (PPO)

As compared to the qualities of fossil diesel, the attributes of pure plant oil (PPO) are significantly different. PPO, for instance, has a much greater viscosity, particularly at lower temperatures. It has a viscosity that is up to 10 times greater than that of fossil diesel. This characteristic creates technical difficulties for conventional engines while cold starting and operating in the winter. It has been challenging to combine PPO with regular diesel fuel since it tends to gum up at lower temperatures. The performance of engines is affected by the various qualities of plant oils, however. It is possible to employ PPO-diesel blends in unmodified engines in tropical regions by blending some tropical oils with more saturated, shorter-chain fatty acids, such coconut oil, directly with diesel fuel. Moreover, pure plant oil has a flashpoint that is substantially greater than regular diesel. It is located at 240 oC, one of the often mentioned flashpoints exceeding 300 oC, and is consequently extremely safe in storage, transit, and handling. As a result, according to the "Ordinance for Flammable Liquids," pure plant oil, for instance, is not included in any danger classifications in Germany. Moreover, PPO degrades quickly in soil and water, and it is not categorised as a water hazard, for example, in Germany. PPO characteristics are described in-depth by REMMELE (2000). The refined PPO normally cannot be utilised in standard diesel engines because to its unique features. Diesel engines need to be modified to operate on pure plant oil, which often entails adding a system for preheating the oil, or a special engine like the Elsbett engine has to be utilised. Conclusion: PPO usage in temperate countries is often limited to niche markets by technological hurdles. Nevertheless, pure rapeseed oil has had its fuel quality requirements established in Europe, and PPO has had some experience being used and handled in day-to-day operations.

Properties of Biodiesel

The general characteristics of biodiesel, particularly its viscosity and ignition characteristics, are comparable to those of fossil diesel. While biodiesel has a 5–12% lower energy content per litre than diesel fuel, it nevertheless provides a number of benefits. For instance, biodiesel has a much greater cetane number and lubricating effect, both of which are crucial in preventing engine wear. As a result, biodiesel's fuel efficiency is comparable to that of diesel. In addition, the oxygen included in the alcohol component of biodiesel aids in the fuel's full combustion. Reduced levels of air contaminants such particles, carbon monoxide, and hydrocarbons are the results. Biodiesel may aid in lowering sulphur oxide emissions since it almost entirely lacks sulphur. Similar to how regular diesel requires extra anti-freezing procedures, biodiesel is susceptible to cold temperatures. In order to ensure winter compatibility, additives are used, enabling usage down to minus 20 °C. The quick oxidation of biodiesel is another issue. As a result, prolonged storage may be problematic, however additions may improve stability. Biodiesel has several characteristics that are comparable to those of solvents. As a result, it may damage rubber and plastic parts like gasoline lines and seals. This leads to issues in cars that haven't received approval or that are using biodiesel for the first time after extensive usage of fossil fuel. In this situation, biodiesel works like an ingredient in detergent to dissolve and loosen sediments in storage tanks. Filter blockage is brought on by the emission of fossil fuel residues. Thus, it is advised to replace the fuel filter after few biodiesel tank fills. Traditional diesel engines may run on up to 100% biodiesel fuel with no problems, but utilising blends higher than 20% may necessitate replacing certain rubber hoses since they are vulnerable to the solvent nature of biodiesel.

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CHAPTER 18

TECHNOLOGY APPLICATIONS FOR LIPID BIOFUELS

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In general, far fewer technical applications are viable for employing biodiesel and pure plant oil than are technological uses for ethanol. Yet, lipid biofuel engine technologies are already well-proven. The diesel engine, often known as a compression ignition engine, is the best technology for lipid biofuels. In contrast to spark ignition engines, which use a separate source of ignition, such as a spark plug, these engines are internal combustion engines in which the fuel is ignited by high pressure and temperature. In 1892, the German inventor Rudolf Diesel created the first engine of this kind. He also showed that peanut oil can be used to drive this engine. Engines with Compression Ignition for Biodiesel Usage There are various properties of biodiesel that may harm traditional engines[1], [2]. Since biodiesel has solvent qualities, it may dissolve deposits in the fuel delivery system and unclog fuel filters, for instance. As a result, compression ignition engines that are designed to run on fossil fuel must be retrofitted. The relevant steps depend on the biodiesel to fossil fuel mixing ratio. Compression ignition engines may utilise biodiesel either unblended or blended with fossil diesel (B100). At any proportion, biodiesel blends seamlessly with fossil diesel. The most common mixes include 5%, 20%, and 30% biodiesel, respectively, and are designated B5, B20, and B30. Nevertheless, most diesel cars, especially those produced after the mid-1990s, can operate on blends up to B20 with little to no changes. Older versions with vulnerable plastic and rubber parts must have those parts replaced with stronger materials. Several of today's models have been recognised by manufacturers to be biodiesel compatible[3], [4]. Since it improves lubricity, particularly of ultra-low-sulfur diesel, the automobile industry favours blends of up to 5 percent biodiesel content (B5) for use in current vehicle fleets. As long as the pure product complies with an accepted quality standard, the majority of original equipment manufacturers (OEM) provide a warranty of B5. Several Manufacturers worry that, among other possible issues, increased mix levels can deteriorate fuel lines, filters, o-rings, seals, and fuel injector orifices. The increasing viscosity of biodiesel, particularly at higher mixes, has drawn criticism from the car sector. In the combustion chamber, this feature may have an impact on fuel flow and spray, especially in cooler temperatures. Nonetheless, if sufficient care is used while handling and using gasoline, there should be no issues (WWI 2006). Although using low blends merely needs little or no technical adjustments, using high blends, such B100, takes more work. It can need for some fine tuning as well as modifications to the engine or fuel system components. Tank warmers and anti-gel additives must be used in colder areas due to B100's high viscosity. More recently, only in combination with unique biodiesel packages have permits for B100 been given. The new EU exhaust gas standard EURO IV is the primary cause. In 2005, this standard was put into effect. Without further safeguards, biodiesel as a pure fuel is no longer able to meet the tougher levels of this standard due to the greater nitrogen oxide emissions (NOx). The engine management system may be changed to the appropriate fuel mix ratio and combustion can be improved as a result using a sensor that recognises the various fuels or mixes. In this manner, it is simple to meet the EURO IV exhaust gas regulations. Some new Volkswagen cars now come with the biodiesel sensor as an option[5].

Compression Ignition Engines for PPO Use

Pure plant oil is compatible with diesel engines, but because of its relatively high viscosity (about 12 times that of regular diesel), engines need to be modified. Incomplete combustion, coking of the injectors, poor atomization of the fuel in the combustion chamber, and the buildup of soot deposits in the piston crown, rings, and lubricating oil may all occur when PPO is used in unmodified engines. Several refitting ideas have been developed in Germany by a number of vendors[6], [7]. They either have a so-called "2-tank system" or pre-heat the fuel and injection systems. The engine starts with diesel when employing this later technology and switches to PPO once the working temperature has been attained. Then, just before being shut off, it is converted back to diesel to make sure that when it restarts, PPO won't be present. The alternative fuel pre-heating technique calls for an electric fuel pre-heating system, enhanced injection technology, and the installation of glow plugs in the combustion chamber. Depending on the kind of engine, the different refitting techniques now in use range in price from over a thousand to over a thousand euros. A warranty is not typically provided for engine modifications. In instance, improvements to earlier precombustion chamber diesel engines have a strong track record, but newer common-rail or pump/injector systems are not thought to have entirely addressed all issues. Moreover, PPO leaking into the motor oil often need far less frequent oil changes. PPO should not be used in unadopted engines, either in pure form or when combined with diesel, since its combustion characteristics are too different from those of diesel, and this might result in damage to the injection systems and engine deposits[8], [9].

Standardization of Lipid Biofuels

Standardization of PPO

The study of pure plant oil (PPO) as a fuel is at the forefront in Germany. Since 2000, rapeseed oil has been subject to RK 5/2000, a quality standard. In Germany, rapeseed is almost the only oil plant farmed due to weather and yield factors. The standard DIN V 51605 (2006-07) "Fuels for vegetable oil compatible combustion engines - Fuel from rapeseed oil - Requirements and test procedures" will be released by the end of 2006. The RK standard is presently being developed. On the European or worldwide level, this new standard is already available for purchase from the German Institute for Standardization.

Standardization of Biodiesel European

Union the requirements for biodiesel are much more advanced than those for ethanol. There is a uniform biodiesel standard across Europe: The requirements and test procedures for EN 14214, "Automotive Fuels - Fatty Acid Methyl Esters (FAME) for Diesel Engines,".

The requirements for biodiesel properties in this standard include:

- Test methods
- Ester Content
- Density at 15 °C

- Viscosity at 40 °C
- Flash Point
- Sulfur Content
- Carbon Residue (10 % Bottoms)
- Cetane Number
- Sulfated Ash Content
- Water Content
- Total Contamination
- Copper Strip Corrosion (3hr at 50 °C)
- Thermal Stability • Oxidation Stability, 110 °C
- Acid Value
- Iodine Value
- Linolenic acid methyl ester
- Polyunsaturated (≥ 4 double bonds) methyl esters
- Methanol Content
- Monoglyceride Content
- Diglyceride Content
- Triglyceride Content
- Free Gylcerol
- Total Gylcerol
- Alkaline Metals (Na + K)
- Phosphorus Content

Several national standards from various nations were eliminated by the EN 14214 European biodiesel standard. For instance, prior national standards in Austria, the Czech Republic, France, Germany, Italy, and Sweden include NORM C1191; CSN 65 6507; standard of the Journal Officiel; and DIN E 51606; UNI 10635; and SS 155436; respectively. There may be extra national standards and quality tests in addition to the official European norm. Due to the expansion in the number of trading companies and manufacturers of biodiesel, coordinated quality protection became necessary at this time. Manufacturers, biodiesel merchants, filling stations, as well as other potential clients such additive makers, contractors, etc., are among its members[10].

The aims of AGQM are:

- Guaranteeing the minimum quality requirements according to EN 14214,
- Guaranteeing the supply of bulk consumers and filling stations with quality biodiesel and
- Presenting biodiesel as a high-quality product for establishing confidence with consumers and the automobile industry.

In general, it can be shown that the AGQM quality assurance system's biodiesel criteria are tougher than those outlined by EN 14214. (AGQM 2006). For instance, AGQM claims that certain characteristics are more specific to prevent product deterioration across the whole life cycle (HAUPT 2006). The quality of gasoline that customers obtain is always the major consideration for these characteristics. Rapeseed is the ideal feedstock to provide excellent grade gasoline. As a result, AGQM is now primarily labelling RME (Rapeseed oil methyl ester).

Up to 5% biodiesel (FAME) additives to diesel fuel are allowed without labelling, according to "Automotive Fuels, Diesel, Requirements and Test Methods". Higher mixes may be marketed, but they must be labelled as such (save for 100% biodiesel). Biodiesel must always be combined in line with EN 14214. The EN 590 standard has been in use in Germany since March 2004. PPO are not permitted as mixes in standardised fuels, unlike biodiesel. USA Standard ASTM D 6751 for pure biodiesel used in blends of up to 20% with diesel fuel is the one most often cited in the United States. Comparable to the extra quality management programme AGQM in Germany, the BQ-9000 standard by the National Biodiesel Accreditation Commission serves as the equivalent quality system in the US. The BG-9000 programme is a voluntary, cooperative scheme for accrediting biodiesel fuel producers and distributors. The programme combines the ASTM D 6751 biodiesel standard with a quality systems programme that covers fuel management, storage, sampling, testing, blending, shipping, and distribution procedures. Any biodiesel producer, marketer, or distributor of biodiesel and biodiesel blends in the United States and Canada is eligible to use BQ-9000.

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CHAPTER 19

SUSTAINABILITY OF LIPID BIOFUELS

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The use of lipid fuels, such as PPO and biodiesel, has different environmental consequences depending on the fuel itself, the technology of the vehicle, the tuning of the vehicle, and the driving style. The environmental impacts of generating feedstock and processing the fuel must be taken into account in order to provide a thorough assessment of a particular fuel.

Water Issues

As compared to fossil fuel, the use of biodiesel lowers more than just exhaust emissions. Another benefit is that biodiesel itself is far less damaging to land and water. Thus, the Federal Environment Agency (UBA) classifies biodiesel in class 1 according to the German system of water pollution classifications, while fossil diesel is categorised in class 2 "water danger." The fact that biodiesel degrades quickly and is biodegradable is the basis for this categorization. RME may biodegrade in less time than it takes for fossil diesel to do so, according to research. RME degraded to roughly 88% after 28 days, according to ZHANG et al. (1998), while fossil diesel fuel only degraded to 26% during the same time period. Moreover, biodiesel is far more water soluble than fossil diesel, allowing marine life to withstand much larger amounts of fuel in the event of spills. Further to groundwater and biodiversity, agricultural, and drinking water concerns, this is crucial for marine transportation[1], [2]. Leakage must be prevented in any case, however, since biodiesel is produced when noxious methanol combines with vegetable oil during the transesterification process. PPO is much less damaging than biodiesel since it is totally generated from plant products (it includes no methanol). PPO is fully risk-free and doesn't need any particular safety measures since it degrades quickly in soil and water. Rapeseed oil is not even included in the lowest class 0 of the German classification system for water contamination. In addition to the direct effects of biodiesel and PPO on soil and water, feedstock production and fuel processing also has an impact on water concerns. As with any agricultural crop, herbicides and fertilisers are necessary for the development of feedstock[3], [4]. Pesticide runoff has the potential to contaminate groundwater and reduce the quality of the water. Eutrophication may result from increased fertilising. Water is required for irrigation in specific areas and on certain crops. In locations with limited water supplies, this is an issue. The many agricultural techniques have an impact on all of these water challenges related to feedstock production, and each one must be assessed independently. Water may be used extensively throughout the PPO and biodiesel production processes. On a life cycle basis, B100 uses three orders of magnitude more water overall than petroleum diesel. Water is mostly used to clean plants and seeds, remove soap and catalysts from oil, and wash plants and seeds. By doing so, wastewater is created and has to be cleansed. demonstrating that wastewater discharges for biodiesel made from soybeans are about 80% lower than those for petroleum fuel over its entire life[5].

Land Use and Biodiversity

Growing the raw materials for pure plant oil and biodiesel may cause major environmental issues, making this phase of lipid biofuel manufacturing the most harmful to the environment. Hence, the habitat and biodiversity as well as the soil, water, and air quality are the key effects of the environmental impact of land usage for PPO and biodiesel production. It relies on a number of variables, including the selection of the feedstock, what it replaces, and how it is handled. The creation of feedstock necessitates the usage of a significant quantity of land. Crop yields and the subsequent biodiesel yields are the main determinants of how much land is required to manufacture biodiesel[6], [7]. Agricultural yields are often assessed in kilogrammes or tonnes per hectare, whereas biodiesel yields are calculated in litres per hectare since they are measured per tonne of crop input. According to the agricultural location, environment, weather, and growing season, average crop yields vary greatly. Yet, the majority of areas have seen a moderate but steady improvement in agricultural and conversion yields. In terms of litres of biofuels per hectare of land, it looks expected that yields will continue to increase in the majority of areas at a pace of around 1% to 2% each year. In comparison to biodiesel, bioethanol often yields higher quantities per hectare of farmland than biodiesel. For the manufacture of biodiesel, the average usual yields per hectare in the EU are 1.200 litres for rapeseed, 1.100 litres for barley, 1.000 litres for sunflower seed, and 700 litres for soybean. For contrast, sugar beets in the EU produce 5.500 litres of ethanol per hectare whereas sugar cane in Brazil can produce up to 6.500 litres. Future farmland needs might become rather considerable and place restrictions on the possibility for biodiesel production if biodiesel production is considerably increased. As a result, wastelands, set-aside sites, and degraded lands may all be utilised to produce feedstock. Greater PPO and biodiesel use would benefit the agriculture industry as well since it gives producers a another outlet for distribution. On the other hand, if all setaside land were turned into fields for the production of biofuels, such rapeseed or sunflower, biodiversity would be diminished since setaside land is a highly valuable home for many plant and animal species[8], [9].

Human Health

As it shapes public opinion, arguments on the effects on human health may be powerful political tools for either supporting or opposing biofuels. As a result, this subject has to be handled with extreme care. Nevertheless, it must be made clear that although using biodiesel and pure plant oil does present certain hazards to people, the effects of consuming fossil diesel are often considerably more severe. The unburned fuel toxicity for PPO and biodiesel is often lower than the toxicity of fossil diesel[10], [11]. A lot of vegetable oils are even edible and are used in cooking. Contrarily, hazardous exhaust fumes from both biodiesel and fossil diesel are thought to have immediate negative health impacts on people. The most noticeable effects are the creation and exacerbation of allergic reactions, as well as eye and upper respiratory tract discomfort. Nevertheless, consequences may be lessened by gas after treatments such catalytic converters, and many tailpipe emissions of biodiesel combustion are reduced when compared to the emissions of fossil fuel. In line with this, biodiesel also lowers several health hazards connected to fossil fuel. For example, the burning of biodiesel produces less polycyclic aromatic hydrocarbons (PAH) and nitrated polycyclic aromatic hydrocarbons (nPAH), both of which have been linked to cancer. There is a thorough comparison of the carcinogenic hazard of exhaust emissions from lipid biofuels and fossil fuels.

Economy of Lipid Biofuels

Since technology for PPO and biodiesel synthesis from oilseed crops are now sufficiently developed, relatively high production costs remain a significant obstacle to commercial growth despite ongoing advancements in the production of lipid biofuels. Oil crop expenses are a significant portion of total costs for lipid fuels made from first generation feedstock. The entire cost of producing lipid fuels varies since agricultural prices are quite unstable. The price of the oil and competition from high-value applications, such cooking, particularly affect the cost of manufacturing biodiesel generated from oil-seeds. Costs for biodiesel generated from these waste sources are cheaper as well since the feedstock price for used grease and oil is lower. This is particularly true when the used oil is given away for free or even at a loss. Yet, since waste oils are impure, extra processing expenditures are required to purify them. Additionally, there are only a certain amount of waste oils. It may be raised by systematic collecting methods, such as those used in Graz and other Austrian towns. The production size of biodiesel has a substantial influence on cost, much like ethanol production, although less so than for ethanol since processing accounts for a lesser portion of total cost. The cost of producing lipid biofuels is significantly influenced by the value of co-product sales. Glycerin is a byproduct of the manufacturing of biodiesel and may be sold. Nowadays, the economics of biodiesel production are greatly enhanced by the sale of glycerin. Yet, since glycerin markets are constrained, a rise in glycerine output from biodiesel might result in a drop in glycerine prices that is close to zero. The cost of biodiesel would skyrocket in the event that glycerin prices collapsed. As glycerine is merely a byproduct of the manufacture of biodiesel, this only has an impact on the production of biodiesel and not PPO. As PPO does not undergo the pricey transesterification process, net manufacturing costs are reduced.

DREIER & TZSCHEUTSCHLER (2001) provide a thorough cost calculation example for Germany's biodiesel manufacturing life cycle. The competitiveness of biodiesel in Germany is therefore greatly influenced by tax incentives and agricultural subsidies for set-aside land. The national legal frameworks and subsidies in EU member states continue to have a significant impact on how competitive PPO and biodiesel are today. Agriculture may benefit from subsidies as well as from market incentives for the biofuel itself. Tax exemptions have a significant influence on biodiesel and pure plant oil end-user prices as well. Direct cost comparisons are difficult, but generally speaking PPO and biodiesel provide significant economic benefits over fossil fuels. Fossil fuel-related negative externalities are often inadequately measured. Among other things, expenses for health and the environment as well as military spending are the most significant negative externalities. PPO and biodiesel, however, have the potential to provide a variety of positive externalities, including fewer greenhouse gas emissions, lessened air pollution, and the creation of jobs. PPO and biodiesel also reduce reliance on imported crude oil. In light of this, PPO and biodiesel are liquid fuels that are more socially and ecologically beneficial, a point that is sometimes overlooked in directcost calculations. Because of this, biofuels often seem to be uncompetitive, despite the fact that, when weighing environmental and social costs, a biofuel market may actually deliver long-term economic advantages. With generating 95% of the world's biodiesel capacity, the European Union has the largest biodiesel market in the world. Germany is a market and production leader for biodiesel in the EU. Germany produced 1 669 000 tonnes of biodiesel in 2005, an increase of 61.3% over 2004 as seen in Figure 38. In 2005, France created a market for 493 000 tonnes of biodiesel, while Italy established a market for 396 000 tonnes. In comparison to 1 933 400 tonnes in 2004, a total of 3 184 000 tonnes of biodiesel were produced in the EU in 2005. There are only two major markets outside of Europe: Indonesia and Malaysia (ARNOLD et al. 2005). Now, a viable biodiesel industry has also begun to develop in the USA. Comparatively small compared to biodiesel, the worldwide PPO market.

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CHAPTER 20

BIOMETHANE PRODUCTION

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The transition to gaseous fuels in the transportation sector is gradual and difficult for future transportation initiatives since the infrastructure for transportation today is dependent on liquid fuels. Nonetheless, there is currently a market for automobiles that run on gaseous fuels rather than liquid fuels. The majority of them now use natural gas. Pure or bivalent natural gas automobiles are already common models from several automakers. The biomethane-subsidized natural gas is one of the potential future possibilities for sustainable transportation fuels. The most effective and environmentally friendly biofuel currently in use is biomethane. Almost all forms of biomass, even wet biomass, which is unusable for the majority of other biofuels, may be used to make it. Another reason to use gaseous biofuels for transportation purposes is the chance to diversify the sources of feedstock.

Feedstock Production

Biogas is the starting point for the synthesis of biomethane and may be obtained from a variety of feedstock sources[1], [2]. Compared to traditional liquid biofuels, a far wider range of feedstock sources may be employed for biogas production. For instance, only plant resources holding a specified quantity of oil may be used to make biodiesel. In contrast, almost any organic material, including animal and vegetable feedstocks, may be used to make biogas. The feedstock may come from a variety of sources, including leftover harvests, manure, vegetable oil leftovers, and animal waste. Specialized energy crops are being used increasingly often as a source of feedstock for the generation of biogas. Lately, domestic organic wastes, municipal solid wastes, and wastewater sludge have all been used as feedstock. The gathering of biogas from landfills is another source of feedstock. In Germany, biogas is mostly created through the fermentation of manure and maize silage in agricultural facilities[3], [4]. The capacity to employ so-called "wet biomass" as a feedstock source is one of the key benefits of methane generation. Other biofuels as PPO, biodiesel, or biomethane cannot be made from wet material. Sewage sludge, pig and dairy farm manure, and leftovers from food processing are all examples of wet biomass. Moisture levels of greater than 60 to 70% define them all. Using waste materials has several extra advantages in addition to being a superb method for producing biogas. As a result, it helps to lessen animal waste and smells. Environmental risks including excess liquid manure generation are successfully eliminated by digestion[5], [6]. Hence, producing biogas is a great option for livestock producers to abide with the growing government rules around animal waste. Moreover, it eliminates disease-causing bacteria that are present in waste products. Yet, employing animal fodder may also be very important. For example, the anaerobic breakdown of chicken manure with high levels of organic nitrogen results in significant amounts of unfavourable ammonium. The BSE epidemic also calls for more economical and environmentally friendly methods of handling animal waste. Yet, farmers are often inspired to employ digester technology for waste treatment by a mix of environmental, financial, and regulatory factors. Wet biomass, in addition to waste products, also includes crops grown specifically for energy or any other vegetal materials with high moisture concentrations. The feedstock may even be grass. By advancements in the fermentation process, it was discovered that energy crops were suitable for the generation of biogas[7]–[9]. As opposed to waste materials, energy crops' biggest drawback is the requirement for extra agricultural space since this land is also required for the production of PPO, biodiesel, and bioethanol. Yet, energy crops for biogas generation offer a number of benefits that make them highly promising going forward. The ability of energy crops to provide very high yields even when they are widely farmed is one major benefit. Chemical pesticides and fertilisers are either not necessary or are used sparingly. The generation of biogas may also benefit from damaged and unusable crops brought on by bad growth and climatic circumstances, insect infestation, and both. Also, because the whole plant may be utilised to produce biogas, cultivations do not need to reach their full maturity. It's not necessary to dry harvests. The kind of feedstock has a significant impact on the quantity and quality of biogas. The average production of biogas is 4 100 litres per acre, according to (BENSMANN 2005). This is around 127 GJ/ha equivalent, which is almost three times more than RME and 1.5 times greater than ethanol. Energy crop optimization is projected to result in significantly improved yields.

Biomethane Production

There are two phases involved in producing biomethane. Initially, feedstock sources must be used to manufacture biogas. Second, further processing and cleaning must be performed on the biogas in order to produce biomethane appropriate for transportation uses.

Digestion Process

Anaerobic digestion is used to create biogas. In the lack of air, microbial activity breaks down organic stuff. In order to digest complex organic molecules, symbiotic groups of bacteria carry out various tasks at various stages of the digestive process. There are basically four different kinds of microbes at play. Complex organic wastes are broken down by hydrolytic bacteria into sugars and amino acids. These substances are subsequently transformed into organic acids by fermentation microorganisms. Acids are transformed into hydrogen, carbon dioxide, and acetate by acidogenic bacteria. Eventually, the methanogenic bacteria convert carbon dioxide, hydrogen, and acetic acid into biogas. As these bacteria are temperature-sensitive, the digestive process must take this into account. At least 20 °C must be present in order to encourage bacterial activity. Higher processing temperatures often lower the amount of time needed and the size of the digester tank by 25% to 40%. The many categorization choices for digestive routes. Anaerobic digesting bacteria may be categorised according to their sensitivity to heat as psychrophile (25 °C), mesophile (32–38 °C), and termophile (42–55 °C) bacteria. The feedstock and the kind of digester being used are taken into consideration while choosing the process temperature. In order to assist the bacteria to do their task, digesters must be heated in colder locations. Depending on the feedstock, digester type, digestion temperature, and other factors, digestion might take a few weeks to a few months.

Digester Types

The most widely used method for producing biogas is the digestion of feedstock in unique digesters. In addition to providing anaerobic conditions for the bacteria within, they need to be sturdy enough to survive the pressure rise. Moreover, anaerobic digester systems may practically eliminate a significant source of water contamination by reducing faecal coliform bacteria in manure by more than 99%. Also, the quantity of methane that would otherwise enter the atmosphere is decreased by the digester's capacity to manufacture and trap it from the manure. Global climate change is facilitated by atmospheric methane gas. Several technology and digester kinds are readily accessible nowadays. In general, biogas plants range in size from modest residential installations to huge industrial facilities with storage capacities of several thousand cubic metres. The size of the digester has an impact on logistics, and vice versa. For example, material has to be gathered from various farms and transferred to central digestion facilities for larger scale digesters. Regardless of the kind of digester, they are often constructed close to the feedstock source, and many are frequently used in combination to provide a steady flow of gas. After the process temperature, a categorization was previously discussed in the preceding chapter. In order to ensure a certain process temperature that should be constant, digesters must meet standards. Thus, particularly in colder areas, the digester has to be heated and insulated. The design and kind of the digester are also influenced by the water content of the substrate. The classification of wet digestion, which is fed with dry mass contents lower than 15%, and dry digestion, which is fed with dry mass contents between 20 and 40%, is one of the most popular classifications considering the water content of the substrate. Dry digestion is often used for the fermentation of energy crops, while wet digestion is typically used to manure and sewage sludge. The number of process stages allows for the classification of digesters. The most often used technology today are single-stage and two-stage digesters, while single-stage digesters are the topic of this article. They are distinguished by the lack of any unique process step separation (hydrolysis, acidification, methanisation). Every stage of the procedure is carried out in a single digester. The two-stage and multi-stage technologies' process stages are carried out in two or more distinct digesters. But, digesters may also be categorised based on how they are filled and how often they are filled. These technologies are included in digester types[10]:

Batch type: when the digester is first loaded with feedstock, it is then completely emptied.

- Continuously expanding type: firstly, the digester is filled up to 1/3, then it is continuously filled until it is full and finally the digester is emptied
- Continuously flow type: the digester is initially filled completely, then the feedstock is continuously added and digested material is continuously removed
- Pug flow type: the feedstock is added regularly at one end and overflows the other end
- Contact type: this is a continuous type, but a support medium is provided for the bacteria

Biogas purification

Biogas, which normally contains between 55 and 80 percent methane and 6 percent carbon dioxide, is the end result of digestion. Little amounts of hydrogen sulphide and other trace gases are also present. Methane must be separated from CO2 and the other biogas components since only methane may be used as a transportation fuel. Biomethane, the end product, has a methane percentage of 95 to 100%. It is thus highly comparable to natural gas and appropriate for all natural gas uses. The water scrubber technology and the PSA technology are the two most popular biogas upgrading methods (pressure swing adsorption). The process of removing CO2 from gas is usually done in two parts, with the first step being the essential one. Prior to the CO2 removal, minor impurities (such as sulphides) are often removed, and the water dew point may be changed either before or after the upgrade (depending on process). Membrane technology, which has the potential to be energy efficient, is another intriguing innovation. The gasification process may also yield biomethane. Yet, it must be understood that the process of producing biogas differs significantly from that of biomass gasification. The process of gasification uses heat to break down solid biomass resources to create flammable gas, often known as producer gas.

Properties and Use of Biomethane

Methane, the most basic hydrocarbon, is a gas at room temperature and pressure (STP). CH4 is its chemical formula. Methane is also an odourless, combustible gas. Moreover, it is a greenhouse gas, having a GWP of 23 in 100 years (IPCC 2001). In other words, over the course of a century, methane heats the globe 23 times more than CO2 of the same mass. Biomethane is produced after the digestion and purification of biomass. Biomethane also contains trace quantities of other substances than NH4 in contrast to pure NH4. Nonetheless, biomethane contains 95–100% methane. For fuel purposes, it may be said that the fuel quality increases with methane concentration.

Technology Applications for Biomethane

Infrastructure Requirements for Biomethane

Due to their much lower energy density, gases need more storage area and are far more difficult to transport and store than liquid fuels. Biomethane has to be kept in specially fitted pressure tanks at a pressure of 200 bars in order to be transported. Yet, the benefits of combustion qualities outweigh these inherent drawbacks. The emission of certain harmful compounds, including nitrogen oxides and reactive hydrocarbons, may be decreased by up to 80% when compared to gasoline and diesel. In general, there are two ways that biomethane may get to a customer. One method is to feed it into the current natural gas network, which is linked to the natural gas filling stations.

As treatment to achieve natural gas quality and delivery into the natural gas network still offer high criteria, the technological obstacles are what make this difficult. Moreover, a solid legal foundation must be provided for the gas infeed. Because of this, operators of biogas plants today choose a different path: building decentralised biomethane filling stations on-site at biogas facilities.

Vehicle Technologies for Biomethane

Untreated biogas often isn't appropriate for transportation purposes due to its low (60–70%) methane concentration. Moreover, untreated biogas often contains large levels of pollutants. As a consequence, biomethane is produced once the biogas has been cleaned. As biomethane is so close to natural gas, it may be utilised in engines for any kind of vehicle that can run on that fuel. Both fuels, natural gas and biomethane, have genuine methane contents that are over 95%. Also, it is believed that engine performance, driveability, emissions, and maintenance are equal. Moreover, as long as the biomethane properties meet the specifications set out by the car manufacturer, no special warranty coverage is necessary. Devoted compressed natural gas (CNG) or liquefied natural gas (LNG) automobiles, bi-fuel (gasoline/CNG) vehicles, and dual-fuel (LNG/diesel or CNG/diesel) vehicles may all be taken into account. Currently, Sweden is the country that uses the most biomethane for transportation. Its fleet of urban buses powered by CNG and biomethane numbers around 4.500 vehicles.

Standardization of Biomethane

In the European Union, there is no widespread standards for biomethane as a transportation fuel. This is explained by the fact that biomethane has fewer uses and is simpler to produce than bioethanol or biodiesel. After going through several purification processes, biomethane mostly consists of methane (> 80%Vol) and CO2. Nevertheless, in response to Sweden's increasing need for biomethane, the Swedish Standard (SS) 155438 "Motor fuels - Biogas as fuel for high-speed otto engines" was created. According to this criterion, biomethane has a methane concentration of 97% (+/- 1-2%). STG Technical Group number 85 created this Swedish standard (TK 85). It is used for otto engines, which include modified diesel engines equipped with glow plugs or spark plugs. An engine is considered high-speed if it has a maximum speed of at least 16 revolutions per minute (ATRAX ENERGI 2005). From a material-technical standpoint, this Swedish standard has been modified so that fueling and engine equipment designed for natural gas may also be utilised for biomethane. The definition of biomethane according to this standard is "gas generated through microbial fermentation of organic material in an anaerobic (oxygen-free) environment" (ATRAX ENERGI 2005).

650 natural gas filling stations have now undergone field testing in Germany. The German Technical and Scientific Association for Gas and Water (DVGW Deutsche Vereinigung des Gas- und Wasserfaches e.V.) categorises natural gas for transport into two groups: group H (high caloric gas), which contains 87 to 99.1 vol% methane, and group L (low caloric gas), which contains 79.8 to 87 vol% methane. A labelling system similar to that used for natural gas could be readily adapted for the usage of biomethane, therefore one for biogas would be helpful. As the first biomethane filling station opens in Germany in June 2006, there is currently no such standard for biomethane. Biomethane Emissions.

Greenhouse Gas Emissions

Methane and carbon dioxide are the two GHG emissions that are impacted by the production and use of biomethane. The global warming potential (GWP) of methane, a greenhouse gas, is rather high at 23 in 100 years (IPCC 2001). When averaged over a century, methane heats the globe 23 times more than the equivalent quantity of CO2. There are several natural and human-related (anthropogenic) sources of methane emissions. Production of fossil fuels, animal husbandry (manure management and enteric fermentation in cattle), rice farming, biomass burning, and waste management are all human-related activities. Significant amounts of methane are released into the atmosphere as a result of these processes. It is estimated that human-related activities account for 60% of worldwide methane emissions (IPCC 2001). Wetlands, gas hydrates, permafrost, termites, freshwater bodies of water, non-wetland soils, and other sources like wildfires are all natural producers of methane.

The regulated digestion of manure in a digester may limit these methane emissions, making the natural fermentation of animal manure of particular importance in the generation of biomethane for transportation. Methane is released when manure is applied to fields and pastures as well as when it is kept in open agricultural storage tanks. The use of a controlled digestion plant may lower these emissions. As a result, biomethane is a green energy source that also helps to lower agricultural methane emissions. Nonetheless, it must constantly be ensured that the digester does not leak. When assessing biomethane as a transportation fuel, carbon dioxide emissions must be taken into account, just as they are for all other biofuels. So, it is necessary to incorporate the emissions from every stage of the biomethane life cycle. The feedstock has a significant impact on these CO2 emissions. Emissions during the manufacture of feedstock may be reduced to a minimum if biomethane is created from waste products like manure. If specialised energy crops are employed as a feedstock source, this benefit will vanish. Yet, it can be said that when compared to fossil fuels, biomethane may reduce carbon dioxide by 65 to 85%. It heavily relies on the source of feedstock that is selected.

Toxic Exhaust Emissions

In addition to the favourable greenhouse gas balance, using biomethane results in lower harmful exhaust emissions than burning liquid fuels. Some sources25 claim that there may be seen decreases in exhaust emissions. The information may be utilised for both fuels since biomethane and natural gas have the same characteristics.

Sustainability of Biomethane

The health of humans is unaffected by biomethane. Yet, since it asphyxiates, biomethane has the potential to replace oxygen in a working environment. If the oxygen concentration is displaced below 18%, asphyxia may occur. As manure and other wastes are the primary sources of biomethane production, neither land usage nor biodiversity are negatively impacted. The effect on land usage and biodiversity of using certain energy crops for bioethanol production depends on the kind of feedstock used. Yet, because almost any feedstock may be used to produce biogas, biodiversity considerations are not difficult to make. the energy output in transport kilometres per acre of various biofuels in Germany. Biomethane has the highest outputs per hectare when compared to biodiesel, bioethanol, and BtL, making it the most cost-effective alternative to use agricultural land for energy production. The usage of biomethane also has a number of beneficial and agreeable side effects for people. First off, digesters release far less smells than open storage facilities do while collecting animal faeces because of their impermeability. Second, unlike other cars, those powered by biomethane often produce less noise. This is because biogas has strong combustion characteristics.

Economy of Biomethane

Infrastructure is the biggest obstacle to utilising biomethane for transportation. Vehicles powered by biogas cannot be used in conjunction with typical cars powered by liquid fuels. Nonetheless, numerous European nations built a fantastic infrastructure for natural gas. Both biomethane and natural gas can be produced using the current infrastructure. While the conversion of biogas into biomethane is a relatively new technology, experience from Sweden and other nations demonstrates that it is now feasible to do so with excellent dependability and at competitive prices. The Swedish experience demonstrates that biogas may be a cost-effective, environmentally friendly fuel with the potential to significantly lower emissions in urban transportation. In Sweden now, 8000 automobiles run on methane as fuel. In 2005, biogas made up 45% of the total amount of methane given to automobiles; natural gas made up the remaining 40%. In Sweden, the market for using biogas as a car fuel is expanding. This is shown by the 25% increase in 2005 over 2004 in the sale of biogas for automobiles.

Both the price and demand for crude oil have been steadily rising for a number of years. In the fall of 2007, the price of light crude oil even approached $100 USD per barrel. New oil field discoveries are dwindling quickly. In order to maintain the high level of living in Europe and throughout the globe, new solutions must be discovered. The development of new methods for processing and using biofuels is continuously advancing, as was shown in the previous chapter.

In comparison to fossil fuels, biofuels are getting more and more competitive. The usage of biofuels has a variety of benefits that may be used to advance trade, environmental, agricultural, and energy policy. As a consequence, the use of biofuels is becoming more and more popular as a means of achieving a more sustainable transportation sector, and numerous European nations have put in place cutting-edge laws to encourage their production and usage. A vision for biofuels in the European Union is presented in the Vision Report of the European Commission. The future of biofuels is dependent on both technological advancements and supporting legislation, on the one hand. Three significant topics were chosen in order to illustrate probable future technological improvements, and they are discussed in the following chapters of Part C. The first article discusses the debate that is now taking place between first and second generation biofuels, the second article provides an overview of integrated biorefinery ideas, and the third article outlines tactics for new vehicle technologies.

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CHAPTER 21

NON - ETHANOL FUELS

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Due to technical difficulties (corrosive and very hygroscopic: it prefers to spontaneously combine with 4% water), ethanol is seen by many academics and engineers as a sub-optimal biofuel. The transportation of and assimilation of ethanol into gasoline present several challenges. It is not the finest energy molecule. However, this molecule only has a minor amount of attention in Europe because of the region's heavy reliance on diesel engines for transportation. Additionally, this molecule's power energy is insufficient to provide the energy required to fly an aircraft[1], [2]. The fact that ethanol is already a partly oxidised derivative of carbon does not make it a preferred fuel in terms of energy yield. Nevertheless, there are other biofuels than ethanol that have been researched for use as liquid transportation fuels. They include fatty acids, fatty alcohols, biodiesel, biobutanol, biopropanol, acetone, and methanol. the energy densities of various substrates for fuel. Vegetable and animal oils are often transesterified to create biodiesel. It is made up of methyl and ethyl esters of fatty acids. According to lifecycle accounting and existing methods, biodiesels made from soybeans provide a greater net energy gain (93%) than ethanol made from maize grains (25%). Yet, the difficulty in finding conventional agricultural supplies and the need for diesel in Europe prompted several businesses to create other production paths[3], [4]. Businesses like Amyris and LS9 employed SB technologies to create the new sugar to diesel pathway. Based on Jay Keasling's research on the isoprenoid pathway, Amyris sought to develop so-called "No Compromise TM fuels." These renewable fuels provide a better environmental performance by decreasing lifetime (GHG) emissions of 80% or more when compared to petroleum fuels, according to Amyris. They also don't require a sacrifice in performance or a price penalty. They also function in today's engines and are distributed to customers utilising the current petroleum distribution system. Early in 2012, Amyris ceased its research and development efforts for biofuels. The primary ingredient used to make biodiesel (renewable diesel) and other products is fatty acids. Fatty acids are capable of esterification and acid-base reactions much like any other carboxylic acid[5], [6]. Fatty alcohols are produced when fatty acids are reduced and may be utilised as biofuels. Bio-ethanol might be used in the trans-esterification of biodiesel to create less viscous ethyl esters, which would result in a better fuel. The direct creation of fatty acid ethyl esters from ligno cellulose by engineered organisms like Actinomycetes as well as the generation of wax esters in plants are two potential longer-term routes to biodiesel that are now the subject of ongoing research. The cost and size of this road are two major obstacles that will affect its development. Nowadays, ethanol production is more cost-effective than this. Yet, the producers contend that commercialization will drive down costs and point out that gasoline is far more profitable than ethanol. B butanol Third-generation biofuels include alcohols like bio-propanol and bio-butanol, which are often not seen as significant as fuels on the market until 2050 owing to the existing lack of manufacturing expertise. More funding may hasten their development. It is possible to utilise the same feed stocks as for first-generation ethanol, but this needs more advanced technology. Chemical processes, such as dehydration and hydrogenation, may produce propane[7]. Butanol is a transport fuel with characteristics more similar to gasoline than bioethanol (UNEP, 2009). In general, butanol is preferred above ethanol as an alternative fuel. It is a "higher" (4-carbon) alcohol that more closely matches the hydrocarbons found in diesel and gasoline, which typically include 4–12 carbon atoms (usually 9 – 23 carbon atoms). Butanol has a greater energy density than ethanol, is transportable over the pipeline network that exists now, and can be utilised straight in traditional gasoline engines. While butanol is poisonous to the fermentative strains, it has been generated with acetone and ethanol in the Acetone butanol ethanol (ABE) fermentation by Clostridium acetobutylicum with the disadvantage of poor yields and low product concentrations. The Escherichia coli butanol manufacturing pathway has been modified to increase yield. By introducing the isobutanol route and upregulating a crucial enzyme in the photosynthetic pathway in Synechococcus elongatus, an even greater productivity was attained.

Longer carbon chained alcohols would be preferable (e.g., octanol). Alkanes, however, would always be the preferable option wherever feasible. The future of this approach is dependent on two major obstacles: I proving that a method exists for producing butanol commercially and affordably at scale; and (ii) market acceptance. An acetone. Due to its high volatility compared to other alcohols, acetone, one of the co-products from the ABE fermentation, may be recovered quickly by direct exhaust from the gas stream. It can be made using genetically altered E. coli. From strains co-expressing a secondary alcohol dehydrogenase, it may be converted to isopropanol, another potential biofuel or chemical feedstock. Similar to the Fisher-Tropsch method for BtL, which creates synthetic fuels from biomass via a thermochemical pathway, methanol may be created from a variety of biomass feed stocks by a thermochemical approach. From 10% to 20%, it may be incorporated with gasoline. Dimethylether (DME) may be produced via catalytic dehydration of methanol. DME is a gas over 25 °C or below 5 bar. As a result, its usage as a fuel for transportation is comparable to that of liquefied petroleum gas (LPG). It is incompatible with regular diesel fuels. Syngas may also be used to produce DME directly. The third BioDME project intends to show how lignocellulosic biomass may be processed at an industrial scale to produce synthetic ethanol that is ecologically friendly. The Supermethanol project converts crude glycerine to methanol for use in biodiesel plants by reforming it in supercritical water (FP7 - 212180) 4) attempts to turn crude glycerine into methanol and utilise that methanol again in the biodiesel plant. As a result, the production of biodiesel will have better energy balance, carbon performance, sustainability, and overall economics. A byproduct of the biodiesel production process is glycerine. The research builds on the consortium's knowledge of reforming glycerine in supercritical water to provide a synthesis gas suited for direct once-through methanol synthesis (glycerine to methanol; GtM). Since there is a (partial) assurance of methanol supply and because their output is utilised as a green, sustainable feedstock, producers will be less reliant on the spot price of methanol. The chemical isobutene. The gaseous (predecesor) biofuel isobutene is produced using a wholly artificial metabolic pathway created by the French firm Global Bioenergies. With the help of the metabolic pathway created by Global Bioenergies, renewable resources like sugar cane, beets, and cereals can be turned into isobutene, a synthon that is readily transformed into a variety of polymers and fuels. The large-scale development of low-cost chemical processes has made it possible to convert isobutene into a variety of fuels, including gasoline, kerosene, diesel, and ETBE. Due to their great energy density and simplicity in handling and storage, these goods have been in use for decades. These chemicals can be mixed together in the petrochemical sector of today, unlike ethanol, whose widespread usage would need a radical overhaul of the infrastructure. This manufacturing method is a biological equivalent of the Fischer- Tropsch process, however it does not call for a high-temperature stage, making it better for the environment and energy. Further biometabolites of the future. Methane is produced by archaea.

Plants and certain bacteria generate ethylene in small amounts. So, it is not more absurd to contemplate using SB to enhance the synthesis of alkanes and alkenes by living organisms than some of the ways previously suggested. In the very near future, it will be crucial to make investments in the investigation and rebuilding of metabolic pathways.

Economic Possibilities

While significant amounts of bioethanol have been generated in recent years and further growth is anticipated, its long-term viability has been called into doubt due to its low energy density, miscibility with water, corrosive characteristics, and need for engine modifications. Biodiesel and butanol, both of which may be processed in the current petrol infrastructure and transportation vehicles, may offer a prospective edge over bioethanol. As diesel is the fuel with the highest demand worldwide and a growth rate that is three times that of the gasoline market, biodiesel has been regarded as the principal renewable substitute. For research into bio-butanol manufacturing, the US Defense Advanced Research Project agency funded $ 2 million in 2009. A significant byproduct of the manufacture of biodiesel is glycerine. The quantity of (crude) glycerine has increased in lock step with the fast expansion of biodiesel manufacturing capacity in Europe. Production of glycerine has outpaced demand since 2004, and the discrepancy is becoming worse. The cost of crude glycerine fell precipitously over the course of 10 years beginning in the middle of the 1990s as a consequence of rising biodiesel output and a dearth of glycerine-specific markets. The cost was less than 100 €/t (5.8 €/GJ) in 2006, which is just somewhat more expensive than its energy cost. Small- and medium-sized biodiesel producers cannot afford to refine their own crude glycerine at this pricing point. So, these firms are in constant search of novel glycerine uses. As a result, the key players in the European biodiesel industry are scrambling to find new uses for (crude) glycerine. By examining if (crude) glycerine may be reformed in supercritical water for the manufacture of syngas and conversion into methanol, the supermethanol project, financed by the European Commission's Seventh Framework Programme, seeks to uncover a practical alternative use. Alcohols like bio-propanol and bio-butanol are examples of third-generation biofuels, which are often not seen as significant as fuels on the market until 2050 owing to the existing lack of manufacturing expertise (OECD/IEA, 2008). Yet, further investment may hasten their growth. With more advanced technology, the same feed stocks used for first-generation ethanol may be employed. Since its gasoline currently complies with EU regulations, Butamax (Dupont + BP) estimates that its first commercial facility will be operating by 2013. Chemical processes, such as dehydration and hydrogenation, may produce propane. Butanol is a transport fuel with characteristics more similar to gasoline than bioethanol.

Environmental Impact

Studies on the environmental effects of biodiesel have shown that it has significant advantages over bioethanol made from maize in terms of environmental benefits. According to one estimate, using biodiesel instead of diesel may cut GHG emissions by 41%. It also eliminates numerous main air pollutants, and the discharge of nitrogen, phosphate, and pesticides has a negligible effect on human and environmental health. It is important to note that nitrogen fertiliser was often used to increase biomass, and one GHG pollutant that results from improper nitrogen usage, nitrous oxide, has a significant and quickly expanding greenhouse impact. The same calculation notes that a 12% decrease in GHGs results in lesser benefits for bioethanol produced from maize. In several studies, the benefits of biodiesel on air pollution have also been shown.

Regarding greenhouse gas emissions, land usage, water consumption, air pollution, and biodiversity, the effects of non-ethanol biofuels made from non-food feed stocks such as lignocellulose are similar to those of bioethanol. Despite the fact that biodiesel may be utilised in standard engines without requiring any modification, its chemical makeup is quite different from that of regular diesel[8].

A combination of methyl esters, used in the current manufacture of biodiesel, are created by "transesterifying" plant oils such rapeseed, soybean, or palm oil with methanol, which is typically generated from fossil fuels. The procedure reduces the oil's viscosity, enhances its consistency and miscibility with diesel, as well as other qualities including its viscosity while cold. Since each plant species' oil has a somewhat distinct chemical make-up, the qualities of the finished product also change, and mixes of the many oils may be required to create a standard. Bioethanol might be used for the transesterification to provide a better fuel. Less viscous ethyl esters would result from this, especially when cold. There is still considerable variation in quality due to trace pollutants and the efficiency of various procedures. When employed as the raw material, this is more obvious when waste oils and fats are utilised. To guarantee a thorough reaction and a clean result, the fatty acid content has to be totally neutralised and either eliminated or transformed. As a result of worries over engine warranties, materials, cold weather performance, and compatibility, biodiesel is now only allowed to make up 5% of diesel in Europe. The method by which the original ligno-cellulosic material intended to be converted into biofuels is made available specifically, what are the methods allowing for its transit or its cracking needs to be taken into account. The scenario is similar to that of bio-ethanol as long as agriculturally generated biomass is employed.

Foreseeable Social and Ethical Aspects

Non-ethanol biofuels are a blend of diverse substances that have varying social effects. The eventual dominance of biofuel must be taken into consideration when assessing the effects of such fuels. In the absence of this information, a case-by-case assessment of the social effect may be made: the bioalcohols. Instead of using gasoline, biobutanol may be utilised directly as an automobile fuel. So, using it would result in significant shipping savings, especially for the car sector no engine modifications required. It is also not as corrosive as ethanol. If this and other non-ethanol bioalcohols were manufactured on a worldwide scale for consumption, it would result in significant cost savings and the recycling of resources and technical materials used in the production of gasoline. Biodiesel. The widespread usage of biodiesel in the past, notably in city buses and trucks, and the simplicity of use in ordinary engines as in the case of biobutanol lead to a future large-scale biofuels economy based on biodiesel having little social effect. Therefore, the projected substitutes are not gasoline for diesel and diesel for biodiesel, but rather gasoline for bioethanol. The social effect would be minimal in each scenario.

Even locally generated organic waste may be used to make gas biofuels. If a local fuel economy was implemented as opposed to a ready-to-use provided fuel economy, it would mean significant social changes. Stable biomass Similar to biogases, local production might have a significant influence on solid biomass management. Also, combining the processing of waste such as household or agricultural waste with energy generation would constitute a shift in the way that energy is now used and entail clear social changes. They include changing, designing, and trading the necessary equipment, as well as the development and destruction of employment related to waste management.

Impact on Social Interaction

If SB is successfully applied to non-ethanol production, it could encourage the development and trade of the necessary methods and tools, foster the emergence of new industries involving substrate management (organic and agricultural waste, sawdust, etc.), and foster communication between the two fields. Another problem is the conversion of infrastructure, including pipelines, whose specifications will vary depending on the kind of biofuel being delivered owing to significant variations in their corrosive qualities. There aren't any significant ethical distinctions between non-ethanol and ethanol biofuels as compared to bioethanol. In certain circumstances, the justice of distribution must be considered together with the simplicity of local production for local consumption. There are two quite distinct possibilities: one involves large-scale production of bioalcohols or biogas and subsequent transportation, and the other involves combining huge factories with local production for local consumption. This would be especially advantageous to far-off (exotic) farmers who may burn their agricultural waste as fuel, utilise their animal waste to create biogas, or create biodiesel from vegetable oil. The effectiveness of using edible oil directly in ancient diesel vehicles such as Mercedes demonstrates that using ordinary waste as biofuels does not always need complicated processes. The majority of these domestic biofuels may pose a dependence threat to gasoline. While it may be difficult for these local tactics to expand, they would undoubtedly appear in underdeveloped nations. Such techniques suggest a switch away from less sustainable feedstock and production methods in favour of biofuels based on grains such as maize[9].

ETHANOL BENEFITS AND CONSIDERATIONS

A domestically generated, renewable transportation fuel is ethanol. Ethanol reduces emissions when it is used in low-level mixes like E10 (10% ethanol, 90% gasoline), E15 (10.5% to 15% ethanol), or E85 (flex fuel), a gasoline-ethanol blend that, depending on the region and the time of year, contains 51% to 83% ethanol. The usage of ethanol requires various issues, just like any alternative fuel.

Energy Security

In 2020, the United States became a net exporter of petroleum, with exports outpacing imports, however imports of 6.11 million barrels per day continued to play a significant role in keeping domestic and global markets in balance. Around 30% of the nation's overall energy requirements and 70% of its petroleum use are met by the transportation sector. Strengthening national security and lowering transportation energy costs for companies and consumers are two benefits of using ethanol and other alternative fuels as well as cutting-edge technology to minimise fuel usage.

Fuel Economy and Performance

Depending on the energy differential in the utilised mix, several factors have an influence on fuel efficiency. For instance, E85, which has a concentration of 83% ethanol, provides about 27% less energy per gallon than gasoline (the impact to fuel economy lessens as ethanol content decreases). FFVs are designed to run on gasoline. Fuel economy would probably rise if they were tuned to operate on greater ethanol blends due to the improved engine performance.

Moreover, ethanol is more powerful and performs better than gasoline thanks to its higher octane number. For instance, due to E98's high octane, Indianapolis 500 racers often fuel their racing vehicles with it. The Co-Optimization of Fuels and Engines effort looked at how using ethanol blends and other high-octane biofuels may increase engine efficiency.

Job Impacts

In remote locations where employment options are required, ethanol production generates jobs. The Renewable Fuels Association estimates ethanol production supported more than 73,000 direct employment nationwide, $52.1 billion of the GDP, and $28.7 billion in family income.

Emissions

The carbon dioxide absorbed when the feedstock crops are cultivated to make ethanol balances the carbon dioxide generated by a vehicle when ethanol is consumed. In contrast, gasoline and diesel are refined from petroleum that has been mined from the soil. When these petroleum products are burnt, no emissions are reduced. In comparison to the production and consumption of gasoline and diesel, corn-based ethanol generated from dry mills reduces greenhouse gas (GHG) emissions by an average of 40%, and depending on the type of feedstock, by an additional 88% to 108%. Visit the website to discover more about FFV fuel efficiency, GHG ratings, and smog ratings from the US EPA[10].

Equipment and Availability

Low-level mixes of E10 or below may be utilised in any regular gasoline vehicle and don't need any additional fuelling equipment. Existing fuelling equipment can also accept mixes higher than E10, although some of it has to be modified to meet federal code requirements. For further information on suitable equipment, see the Codes, Standards, and Safety page and the Manual for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends. FFVs are a cost-effective alternative fuel vehicle choice since they come standard with no additional cost throughout the country and can run on E85, gasoline, or any mixture of the two. 44 states have fueling stations that provide E85 (flex fuel). Locate local ethanol (E85) filling stations.

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CHAPTER 22

ALGAE - BASED FUELS

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The first to suggest that microalgae be farmed as a source of lipids for food or fuel was Harder and Von Witsch in 1942. After World War II, studies on culturing methods and engineering systems for cultivating microalgae on greater sizes, notably species in the genus Chlorella, started in the US, Germany, Japan, England, and Israel. H. G. Aach demonstrated, meantime, that Chlorella pyrenoidosa may be made to amass as much as 70% of its dry weight in lipids by nitrogen deprivation. After World War II, there was less of a demand for alternate transportation fuel, therefore research at this time concentrated on cultivating algae as a food source or, in certain circumstances, as a means of wastewater treatment[1], [2].

During the oil embargo and oil price spikes of the 1970s, interest in the use of algae for biofuels was reignited, prompting the US Department of Energy to launch the Aquatic Species Program in 1978. With the aim of creating liquid transportation fuel from algae that would be cost-competitive with fuels obtained from petroleum, the Aquatic Species Program invested $25 million over 18 years[3], [4]. The research programme concentrated on growing microalgae in open, outdoor ponds since these systems are inexpensive yet prone to environmental perturbations like temperature changes and microbial invasions. The most promising algal strains were added to the SERI microalgae collection at the Solar Energy Research Institute (SERI) in Golden, Colorado and used for additional research after 3,000 algal strains from all over the country were gathered and screened for desirable qualities like high productivity, lipid content, and thermal tolerance[5], [6].

One of the program's most important conclusions was that high fat synthesis and quick development were "mutually incompatible" since the former required more nutrients and the latter needed less. The final study made the case that genetic engineering could be required to get over these and other inherent limits of algal strains, and that the best species might change depending on the location and time of year. While it was successfully shown that producing significant amounts of algae for fuel in outdoor ponds was possible, the programme was unable to do so at a price that would be competitive with petroleum, particularly when oil prices fell in the 1990s. Even under the best-case scenario, it was predicted that the price of unextracted algal oil would range from $59 to 186 a barrel, while the price of crude oil in 1995 was less than $20. As a result, in 1996, the Aquatic Species Program was discontinued due to financial constraints [7], [8].

Projects concentrating on various uses of algal cultures have indirectly made further contributions to the study of algal biofuels. For instance, the Research Institute of Innovative Technology for the Earth (RITE) in Japan launched a research programme in the 1990s with the aim of creating CO_2 fixation systems utilising microalgae. Many RITE investigations showed that algae could be cultivated utilising flue gas from power plants as a source of CO_2, a significant advance for algal biofuel research even if the studies' primary objective was not energy generation. Research on the generation of biofuels from algae has also benefited from studies concentrating on the extraction of hydrogen gas, methane, or ethanol as well as dietary supplements and medicinal chemicals from algae[9].

Algal biofuel research slowed down somewhat when the Aquatic Species Program was shut down in 1996. The Department of Energy, Department of Defense, National Science Foundation, Department of Agriculture, National Laboratories, state financing, private money, as well as funding from other nations, nonetheless, sponsored a number of initiatives in the US. [33] More recently, a resurgence in interest in algal biofuels was sparked by rising oil prices in the 2000s, and US federal funding has increased, along with funding for a large number of research projects in Australia, New Zealand, Europe, the Middle East, and other regions of the world. A wave of private companies has also entered the field. The first retail sales of gasoline generated from algae were made by Solazyme and Propel Fuels in November 2012, while Sapphire Energy started selling algal biofuel to Tesoro in March 2013.

Oilgae, another name for algal fuel, is a third-generation biofuel made from algae (UNEP, 2009). Lipids and fatty acids are found in microalgae as sources of energy, metabolites, storage products, and membrane components[10]. Algal oils may be thought of as prospective replacements for the byproducts of fossil oil since they share qualities with both animal and vegetable oils. Algae are used as feedstock in aquaculture to make triglycerides (from algal oil), which are then used to make biodiesel. Essentially the same processing method is used to produce biodiesel from second-generation feedstocks. Higher lipid concentrations may be attained in a nitrogen-limited environment, even though many microalgae species are capable of synthesising substantial quantities of lipids (lipid contents surpass those of most terrestrial plants). While the idea of utilising algae to produce gasoline was first brought up more than 50 years ago, a concerted effort only really got going during the oil crisis of the 1970s. At the National Renewable Energy Lab (NREL) in Golden, Colorado, the US Department of Energy (DOE) invested $ 25 million in algal fuels research from 1978 to 1996 as part of its aquatic species programme. Important developments from the programme laid the groundwork for current algae biofuel research. In 1994, microalgae underwent their first genetic change; a few years later, researchers were able to effectively extract and describe the first algal genes that encode enzymes anticipated to increase oil production.

Via a programme at the Research Institute of Innovative Technologies for the Planet, the Japanese government supported algal research from 1990 to 2000. The program's main goals were to reduce carbon dioxide and boost algae development using concentrating mirrors that catch light. While several of these methods had success and many are currently being studied by scientists, none had a large-scale commercial payoff. Algal systems were unable to compete with the low-cost crude oil of the late 1990s, which was a contributing factor in the DOE program's closure in 1996. But, since the middle of the 1990s, genetic engineering's methods have advanced, and researchers are now using them more often on algae with the goal of producing fuel. Finding the genes involved in lipid production and how they are controlled is a major focus of the effort. In order to mislead the organisms' metabolic pathways into creating storage lipids even when the algae are not under stressful circumstances, which is when they begin overproducing oil and lipids, it is intended to modify those genes. High oil yields from microalgae may be processed into transport fuels like jet fuel and diesel. Microalgae biofuels have many benefits over traditional agricultural biofuels, including their ability to. Increase oil production per hectare of land.

- Do not require arable land or freshwater to grow and thus do not compete with food crops;
- Produce a higher - quality fuel product;
- Can produce non - fuel high - value products (e.g., biopolymers, proteins, animal feed).

The potential benefits of these technologies for the common good, including the production of biodiesel, methane, butanol, ethanol, aviation fuel, and hydrogen using waste or saline water as well as CO_2 from industrial or atmospheric sources, appear compelling if sustainable and profitable processes can be developed. For the synthesis of a huge range of chemicals, including biofuel, several microalgae appear promising. Monocultures must be maintained to grow these algae and the products they produce, which often calls for enclosed photobioreactors. An enclosed, lit culture tank created for the regulated biomass generation of phototrophic liquid cell suspension cultures is known as a photobioreactor. Despite their higher cost, photobioreactors offer a number of significant benefits over open pond systems. In Figure 1 shown the microalgae are used to produce biomaterials, including biofuels.

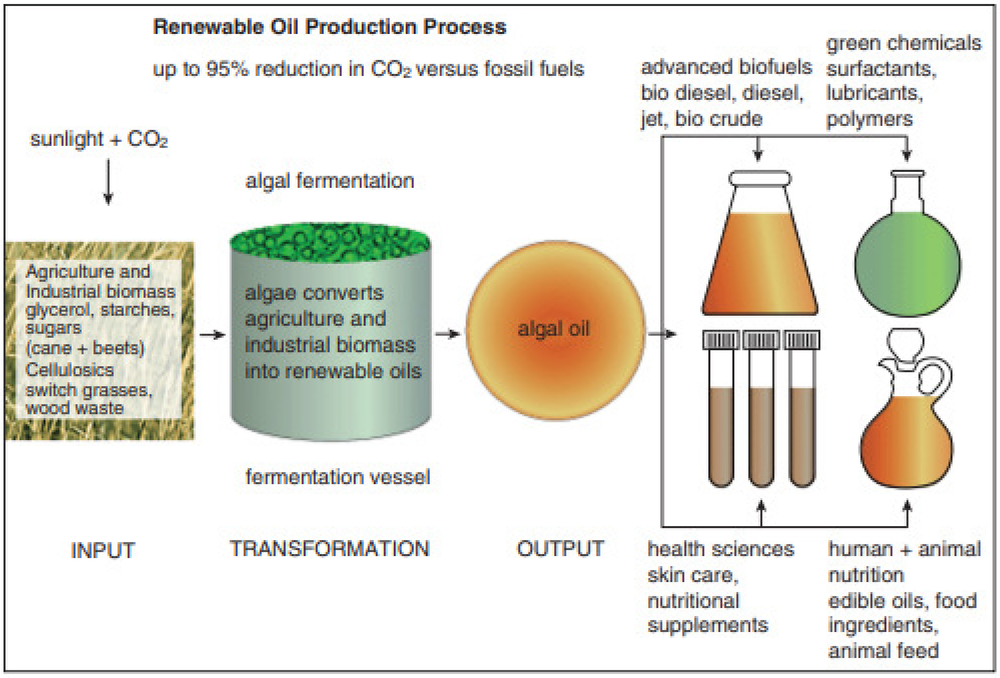

Figure 1: An illustration of how microalgae are used to produce biomaterials, including biofuels.

Prevent or minimize contamination, permitting axenic algal cultivation consisting of only one species of microalgae;

- Offer better control over biocultural conditions (pH, light, carbon dioxide, temperature);
- Prevent water evaporation;
- Lower carbon dioxide losses due to gassing;
- Permit higher cell concentrations.

Nevertheless, photobioreactors are more costly to construct and run than ponds because of specific needs such as cooling, mixing, oxygen buildup management, and biofouling. Waste streams are being used together with the development of new, more affordable, and creative techniques to make the production of microalgae financially appealing. While algae are grown economically in industrialised nations, the majority of these areas are characterised by yearly changes in solar light energy and temperature. Potential growing locations for the commercial production of algae products may be more advantageous in tropical developing nations.

Economic Potential

While long believed to be a plentiful and all-around source of renewable fuel, algae have so far been unable to competitively compete with other, more traditional sources of energy. What are the main obstacles to achieving economic competitiveness, and how may they be removed? The Algae Biofuels Challenge was introduced in the UK by the Carbon Trust (2008), with an anticipated cost of £ 20 to £ 30 million. This effort comprises two phases: I addressing basic research and development problems, and (ii) a pilot-scale algae oil production demonstration. A development and investment plan that, by 2020, might make low-cost algal biofuels commercially viable. the whole plan[11].

The base case and the projected scenario were both models that were employed. The base case makes the following assumptions: I production of microalgal biomass using 500 ha of microalgal production systems, (ii) oil extraction, (iii) co-production and extraction of a high-value product (HVP; for example, -carotene at 0.1% of biomass, $ 600/kg), and (iv) sale of the remaining biomass as feedstock (e.g., soymeal or fi shmeal substitute). In contrast, the projected instance does not include the co-production of HVPs since it is meant to reflect the microalgal biofuel sector at its mature stage. For an investment to be viable, the internal rate of return (IRR) must be more than 15%. This requirement can be fulfilled in the base case, but in the projected situation (fuel production alone), it can only be reached when the price of oil hits $100 per barrel. As 200 hectares are required for the microalgae business to be economically viable (without taking into account government tariffs and other regulatory systems that favour new and renewable energy), it seems that this sector is only viable for huge industries. Veterinary applications, agrochemicals, seed suppliers, biotech, water treatment, coal seam gas, material supplies and engineering, fuel refiners and distributors, bio-polymers, pharmaceutical and cosmetic industries, coal-fired power plants (CO 2 capture), and transportation industries like aviation are just a few of the areas where microalgae biofuel production and other sectors have significant synergies. Thus, there are good potential for the growth of a fast increasing sustainable industrial base, whose productivity is less reliant on water purity and independent of soil fertility. As a result, these technologies may be scaled up to meet a significant portion of the world's oil needs without putting further strain on water supplies and perhaps even help with food production. Within three to five years, the firms that produce algae-based fuel want to produce fuel at a cost of $ 50 to $60 per barrel.

The Defense Advanced Research Projects Agency is aiming for $1 per gallon algal oil or $1 per gallon finished cost of jet fuel with a capacity of 189 million litres per year as it develops new jet fuel technologies for the military. The price of algal technology is mostly determined by two biological variables. The first step is a rapid selection of the top strains among the 40 000 species of microalgae that are currently recognised. Engineering the metabolic pathways that regulate oil synthesis in algal species is the second. Increases in photosynthetic efficiency, growth rate, and oil content may all be achieved by genetic manipulation. These changes can also be used to pinpoint and manage the biochemical triggers that lead an organism to collect oil. Several industry professionals have come to the conclusion that genetic engineering technology is inevitable due to its potential. Numerous businesses are working on strains of genetically enhanced algae, including Kuehnle AgroSystems in Hawaii, Solazyme, Seambiotic, and Algenol.

Environmental Impact

Algae-based biofuel has a great chance of replacing a significant fraction of the petroleum used in transportation, which would decrease the amount of fossil carbon that is used annually on a worldwide scale. According to some studies, microalgae are the only sustainable biodiesel source that can provide the whole world's need for transportation fuel. Early projections indicate that, algae-based biofuels might replace some of the 70 billion litres of fossil-derived fuels now utilised in transportation globally. This would result in an annual carbon reduction of more than 160 million tonnes of CO_2 worldwide, saving an estimated € 17 (£ 15) billion in market value. As comparison to traditional agricultural biofuels, algae might provide six to ten times more energy per hectare while cutting carbon emissions by up to 80%. Algae may also be cultivated on non-arable soil utilising saltwater or wastewater, unlike typical biofuels. Many types of algae may be found thriving in saltwater, salty aquifer water, or even treated wastewater. It is anticipated that the manufacturing of algae-based biofuel won't compete for the limited amount of arable land and may clean up rivers of pollutants and nutrients. As a result, many of the harmful environmental and ecological effects connected with first-generation biofuels are avoided when employing algae as a biofuel feedstock. Algal biofuels benefit the environment by lowering the amount of pollution released by humans and by needing less water subsidies. Also, it is possible for the algae producing unit to be connected to a CO_2 emitting company, which would also help to reduce CO_2 emissions. Algae ponds are thought to be capable of absorbing around 80 tonnes of CO_2 per acre per year when operating at full capacity. PetroAlgae provides a practical method to help large carbon emitters, such as steel mills, coal-fired power plants, cement plants, and industrial facilities, satisfy the increasingly strict worldwide carbon regulations. Also, PetroAlgae views carbon management as another potentially lucrative business for the future since micro-crops can absorb almost twice as much CO_2 as their weight.

Foreseeable Social and Ethical Aspects

Aquatic biofuel cultures shouldn't compete with crops, despite the misconception that all "land-grown" biofuels negatively influence the availability of food and other agricultural products (especially in the case of lignocellulosic bioethanol). Nevertheless, it should be noted that sizable artificial or semi-artificial aquatic extensions used for growing algae may in fact compete with fish and seafood produced by aquaculture, another sort of human food. The interaction of the business with aquaculture and agriculture (see following topic) as well as its ecological implications, such as turning wetlands into biofuel factories, will determine the social impact of a potentially big algae-based biofuel economy.

Could the Application Change Social Interactions?

Agriculture and the cultivation of algae are extremely different. A number of changes in social interaction may take place if SB methods increase the green algae's already high rates of lipid synthesis in order to encourage their usage as biofuel producers. One possibility is that farmers on appropriate grounds (mostly those located near wetlands and lakes, but also those who live along the shore) would switch to growing green algae. In terms of the industrial structures of the various civilizations, this would have significant societal repercussions. Also, much as with other biofuels, the local vs monopoly-based economy provides two non-exclusive future alternatives. However in the case of green algae, local production would be simpler than local biodiesel production. Ethical concerns. It may be necessary to use large surfaces to grow the algae in order to optimise the surface to volume ratio and allow for appropriate lighting of algal cultures. A competent legislative framework should be used to control the conflict between algae cultivation, agriculture, and aquaculture since it is more than just a technical problem. Fairness in distribution Local manufacturing is feasible, but in underdeveloped nations, local transformation may not be good. Another prediction is that underdeveloped nations won't be able to meet the technological standards needed to light algal cultures effectively, which would result in lesser production even in tropical conditions. A plausible scenario, while difficult to predict, is that local and specialised production coexist, with the latter playing a predominate role in terms of production and, notably, processing.

Algae is the source of the energy-dense oils used in algae fuel, also known as algae biofuel or algae oil, which is a substitute for liquid fossil fuels. Algal fuels are a substitute for well-known biofuel sources like maize and sugarcane as well. It may be referred to as seaweed oil or fuel when manufactured from seaweed (macroalgae). Although the energy (stored as hydrogen gas) is created by solar photosynthesis and originates from the sun, it is likewise carbon negative until the dead plant matter is burnt. Water and air are the sole byproducts of the hydrogen's combustion into emissions.

Numerous businesses and governmental organisations are sponsoring initiatives to lower startup and running costs and make the sale of algal fuel feasible. Algae fuel and other biofuels only emit CO_2 that has recently been extracted from the atmosphere via photosynthesis while the algae or plant developed, in contrast to fossil fuels, which release all CO_2 when burned. Interest in algaculture (growing algae) for producing biodiesel and other biofuels utilising land unsuitable for agriculture has increased as a result of the energy crisis and the global food crisis. Algal fuels are appealing due to their high flash point, ability to be created utilising salty and wastewater, ability to be cultivated with little disruption to freshwater resources, biodegradability, and relative environmental safety. Because to their high initial and running expenses, algae are more expensive per unit mass than other second-generation biofuel crops, but they are also said to produce 10 to 100 times more gasoline per unit area. According to the US Department of Energy, 15,000 square miles (39,000 km2) or almost half of Maine's geographical size would be needed to replace all of the country's petroleum-based fuel in the US. This region represents just 0.42% of the US map. The maize harvested in the United States in 2000 covered less than 17 of this area. [13]

If given production tax incentives, the chairman of the Algal Biomass Organization predicted that the price of algae fuel will match that of oil by 2018. Rex Tillerson, the chairman and CEO of Exxon Mobil, claimed in 2013 that after agreeing to invest up to $600 million over ten years in development in a joint venture with J. Craig Venter's Synthetic Genomics in 2009, Exxon withdrew after four years (and $100 million) because it realised that algae fuel is "probably further" than 25 years away from being commercially viable. 2017 saw the publication of a breakthrough in the advanced biofuels research being conducted jointly by Synthetic Genomics and ExxonMobil. The innovation was the ability to genetically modify Nannochloropsis gaditana to have a lipid content that was doubled (from 20% in its normal form to 40%–55%). But, in 2012, 2013, and 2015, respectively, Solazyme, Sapphire Energy, and Algenol, among others, started selling algal biofuel commercially. Just a few initiatives remained in 2017 after the most had been discontinued or switched to other uses[12].

Fossil hydrocarbons are essential to the functioning of the world economy since they are used to make everything from plastics and fertilisers to the energy needed for lighting, heating, and transportation. Fossil fuel demand will rise as a result of our developing economy and population. Data indicate that as nations' gross domestic products per capita rise, so will their usage of fossil fuels, and so will competition for these scarce resources. Other factors include rising atmospheric CO_2 levels and the possibility of a large greenhouse gas-mediated climate change, which currently seems likely to have an impact everywhere in the globe. Lastly, petroleum is a finite resource that will someday run out or become too costly to retrieve, even if it is partly generated from ancient algal reserves. Due to these causes, renewable energy alternatives are being developed that can replace fossil fuels, provide all countries better access to fuel resources, and significantly reduce carbon emissions into the atmosphere. While no one method is likely to provide a complete answer, a mix of tactics may be used to significantly reduce our reliance on fossil fuels. Many technologies have been investigated as renewable energy sources. The remaining difficulty is creating sustainable renewable energy sectors that can compete on price with current energy sources.

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CHAPTER 23

MICROBIAL FUEL CELLS AND BIO-PHOTOVOLTAICS

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A microbial fuel cell (MFC) is a machine that taps into microorganisms' capacity to generate electricity by transforming chemical energy into electrical energy. The true difficulty is in transferring these laboratory-developed technologies into industrial settings in order to design systems for larger-scale bioenergy production. The identification of novel electrode types and a deeper understanding of the functions of membranes, separators, and nanowires have recently improved the overall performance of MFCs. Within a few years, MFCs might begin to be commercialised. While MFCs were initially intended to generate energy, they may also be used for other things. For instance, methane, hydrogen, and hydrogen peroxide may be produced by adding more voltage to the potential that the bacteria create. Moreover, membranes may be employed in MFCs in a manner that maintains electrical power output while desalinating water[1], [2].

Solar energy is by far the most plentiful main energy source since it falls on Earth in excess of 100 000 TW annually. According to estimates, Earth now uses 10 TW of energy annually, and by 2050, that number will have doubled to 20 TW. The current methods for directly converting solar energy to electricity, such as photovoltaic cells based on semi-conductors, are less efficient and more costly. As a result of the scarce components they contain, their producibility is likewise dependent on shaky market circumstances[3], [4]. Natural systems for capturing solar energy are quite efficient. They may serve as the cornerstone of a novel, efficient, affordable, and renewable solar system. One application uses intact photosynthetic cells to implement the evolution of oxygen and the synthesis of hydrogen in a semi-biological photovoltaic system. In this case, protein complexes contain capabilities for self-repair and are inherently more stable[5], [6].

The system will consist of two chambers, or half-cells, with hydrogen synthesis restricted to one chamber and oxygen evolution restricted to the other. Moreover, the method may be used to generate a DC electrical current, much like conventional silicon-based solar panels. Investigations are being done on another kind of bio-photovoltaic conversion device. It is based on dye-sensitized solar cells (DSSCs), which sensitise chlorine-e6 to visible light (Chl - e 6). The latter comes from Spirulina chlorophyll that has been coated on a nanocrystalline TiO_2 film. The University of Cambridge's Department of Chemical Engineering and Biotechnology is working on a bio-photovoltaic device that uses the photosynthetic system of living material such as cyanobacteria or algae as an alternative approach. The goal is to transform solar energy into electrical energy, which will subsequently be used to power a current or establish a potential difference that will ignite a chemical reaction. These few examples demonstrate the enormous study being conducted in this important field and the variety of intriguing techniques[7]–[9].

MFCs can be classified according to their electron transfer scheme and main bacterial species:

- Indirect electron transfer through the interaction of reduced metabolic products with the anode;
- Enhanced electron transfer with artificial mediators: Escherichia coli , Pseudomonas , Proteus , and Bacillus species; Microorganisms that produce their own mediators: *Shewanella oneidensis* , *Geothrix ferementans* and *Pseudomonas species (Pseudomonas aeruginosa);*
- Direct electron transfer to electrodes: *Shewanella putrefaciens* , *Aeromonas hydrophila* ;
- Oxidation of organic matter with electricigens (benthic unattended generator): *Geobacter sulfurreducens, G. metallireducens* , *G. psychrophilus* , *Desulfuromonas acetoxidans* , *Geopsychrobacter electrodiphilus* , *Rhodoferax ferrireducens* .

Economic Potential

Two industries might be thought of when analysing the financial advantages of energy produced by MFC: the automobile industry and specialised applications (fine mechanics, medical technology, telecommunications, IT, etc.). One such use is in the automobile industry. Due to the importance of this business on the worldwide scale, this would generate a huge turnover. Due to the variety of such uses, special applications in other fields also have the potential for billion-dollar scale turnovers (for example, a laptop battery functioning with alcohol that is transformed to water and discarded.

Environmental Impact

There is a need to create affordable wastewater treatment systems and sustainable renewable energy sources, particularly without the usage of fossil fuels, due to global environmental concerns and energy instability. This issue may potentially be resolved by an MFC by producing direct energy while organic matter is being oxidised. The use of MFCs to generate "green" energy from organic wastewater or artificially manufactured carbohydrate substrates has lately attracted more interest. MFCs may eventually prove to be a useful instrument for producing power from garbage. The following substrates have been used in studies so far:

- Acetate;
- Glucose;
- Lignocellulosic biomass;
- Synthetic or chemical wastewater;
- Brewery wastewater;
- Animal wastewater;
- Starch processing wastewater;
- Dye wastewater;
- Landfill leachates;
- Cellulose and chitin;
- Inorganic and other substrates.

Tested substrates' complexity and content strength have increased (higher organic loading rate). Electric current and power production from these devices are still far from being useful for large-scale applications. It is anticipated that more technical developments in terms of substrates, pricing, and materials will enable these systems to compete on the market. Yet, one encouraging feature is that the MFC setup may use a range of novel substrates. Examples include wastewater from large-scale, molasses-based distilleries with high levels of organic matter, wastewater from several biorefineries, wastewater from the pharmaceutical sector with stubborn contaminants, or waste plant biomass (agricultural residue) that is presently burnt. The most advantageous alternative, financially speaking, is probably the combination of MFCs with current separation, conversion, and treatment technologies. The fact that MFCs may be employed as electricity generating and bioremediation instruments simultaneously, acting as a direct waste to energy conversion system, is an obvious advantage of MFCs. Despite the still-relatively modest power output, the technology is developing quickly and might someday be helpful to lower the cost of small sewage and industrial wastewater treatment facilities. MFCs may be powered by waste, but the environment can also serve the same purpose. For instance, MFCs placed in natural waterways may provide enough electricity to run low-power (bio)sensors. Nevertheless, keep in mind that the maximal cell potential is produced by each of these microbial fuel cells.

About 800 mV, which restricts its application for powering electrical gadgets at the moment. The US Navy Research Laboratory's Center for Bio/Molecular Science and Engineering created the benthic unattended generator, or BUG, a meteorological buoy that functions in the Potomac River. The buoy is distinctive in that it only uses a collection of microbial fuel cells for electricity. These BUGs are made up of electrodes that are electrically coupled to electrodes in the water above and that are embedded in the silt at the river's bottom. The buoy communicates data through a radio transmitter (also powered by a BUG) to a receiver while monitoring air temperature and pressure, relative humidity, water temperature, and performance indicators of the BUGs. The organic material that has accumulated in many freshwater and saltwater ecosystems is an almost limitless source of fuel. Also, the significant oxygen that is available in the water above acts as an almost limitless oxidant. Using this fuel and oxygen, BUGs electrochemically react to produce electrical power that last forever (as long as the fuel cell lasts). For a variety of remotely deployed maritime devices, BUGs are being developed to provide continuous power. The Office of Naval Research (ONR) and the Defense Advanced Research Projects Agency jointly finance BUG research. Rice fields may also use a similar approach. A microbial fuel cell that researchers have created enables them to produce up to 330 watts of electricity per hectare of rice fields. The MFC may catch part of the energy generated in rice paddies, perhaps before it is released as methane, by taking advantage of a process called rhizodeposition. A technique that simultaneously uses rice plants to create power and decrease methane emissions would have a large beneficial environmental effect since rice fields occupy well over one million square kilometres of land and contribute between 10 and 20% of the world's methane emissions[10].

Social and ethical issues that may be foreseen the ability to combine many energy processes in one location is one of this technology's key advantages. For instance, using the same machinery, waste treatment, electric power generation, hydrogen creation, and water desalination might all be accomplished simultaneously. This characteristic distinguishes bio-photovoltaic applications, and their widespread adoption would undoubtedly have a profound social effect by combining two of the most significant barriers to human development: energy and waste treatment. New companies and employment would develop, just as with the other biofuels. The integration of the fields of treatment, biofuel, and electric power into a single technology is another factor that is anticipated to have a significant influence on social relations. Of course, this would only be the case if microbial cell fuel-based techniques made a major contribution to these processes. However because of the clustering effect, even a very narrow diffusion of the approach would have an effect. Ethical concerns. Apart for those relating to the socioeconomic impacts of combining waste treatment and energy regulations with those of distribution, MFC is not particularly ethically challenged. Another category of ethical problems could arise if higher order animals were used to produce electricity, such as a dog with MFC that uses blood sugar and oxygen to power a GPS receiver on its necklace or cetaceans (dolphins) that use a similar system to generate electricity for electronic sensors that look for enemy submarines distribution with fairness. Laboratory-scale modules are the state-of-the-art in bio-photovoltaic technology; they function, but only at modest voltages and intensities. Local manufacturing with very basic equipment might be feasible, assuming the successful development of more productive systems. These gadgets would provide electrical power that is ready for use. This makes biophotovoltaics one of the most promising technologies in terms of distributive justice, coupled with the prospect of combining MFC with water treatment and the ability to utilise cell fuel wastes as biofuels.

Recommendations for Biofuels

We are certain that synthetic biology will contribute to the development of cutting-edge and next-generation biofuels. The focus of current efforts is mostly on enhancing the production of bio-ethanol from agricultural products, however there are serious issues with this strategy since ethanol mixes poorly with water and has limited usage in current engines. Since their chemical characteristics are more closely related to those of petroleum-based gasoline, other non-ethanol biofuels like biobutanol and biodiesel are considerably better suited to replace it. Current barriers in the manufacturing of butanol and other non-ethanol fuels, such as low fermentation yield and toxicity to butanol-producing microbes, may be solved with the use of synthetic biology. Limitations on the usage of hemi- and lignocellulosic material are a concern for the majority of biofuels made from plant material. Any advancement in that area would unquestionably boost the viability of producing biofuel economically. Should synthetic biology be able to assist in resolving the aforementioned technological issues, another significant difficulty will emerge: an increasing amount of agricultural land will be set aside to cultivate energy crops rather than food crops. We advise using non-food competing biological resources as well, such as perennial plants grown on degraded land that has been abandoned for agricultural use, crop residues, sustainably harvested wood and forest residues, double crops and mixed cropping systems, as well as municipal and industrial wastes, in order to avoid this competition for food. Algal-based biofuels and biohydrogen are additional options to ethanol, biodiesel, and butanol made from agricultural products. Algae-based biofuels are predicted to have a significant advantage over agriculture-based ones due to their greater output per area and independence from clean water and arable land. Nevertheless, according to preliminary estimates, future algae production systems won't be financially viable until the price of a barrel of oil continually stays over $70 and the systems include at least 200 acres of land. Because to the high capital expenses of such massive production facilities, "big oil" would likely exclude SMBs or big energy companies[11].

Yet, once significant challenges relating to algal genetics, metabolism, and harvesting are overcome, algae production systems may represent a very promising path for the generation of fuel in the future. Several scientists have commended bio hydrogen as a very promising fuel, but our evaluation is more circumspect. Only when there are significant infrastructural modifications will hydrogen be useful as a fuel distribution and storage system, new fuel cell engines. This suggests a future that begins after 2050 and is also known as the hydrogen economy. While synthetic biology may help to increase the output of cyanobacteria that produce hydrogen, other factors, such as infrastructure, are considerably more important when it comes to the practical effects of hydrogen on society and the economy. The future of microbial fuel cells (MFCs) as energy converters was the subject of our final analysis. Despite the fact that we think synthetic biology has a significant future in the field of MFCs, given their low energy output, these fuel cells are likely to be used in certain niche industries and applications rather than on a broad scale.

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CHAPTER 24

THE ROLE OF BIOFUELS IN THE FUTURE

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The International Energy Agency (IEA) predicts that, India would surpass China to take over as the world's third-largest producer of ethanol. India was seventh in the world's leading producers of ethanol in 2016, it had passed Canada, Germany, and Thailand to take fourth place. India is anticipated to catch up to China's ethanol output and surpass it into occupy third place after the United States and Brazil. India's surge in ethanol output is largely the result of regulatory changes. The aim established report on ethanol blending by Niti Aayog and the Ministry of Petroleum & Natural Gas is the most recent policy initiative on which the IEA's upbeat predictions for ethanol output from India are based (MOPNG)[1].

1) **Combating climate change:** The global community must look for new, low-carbon fuel and energy sources to combat climate change. As one of the main contributors to greenhouse gas emissions, or carbon emissions, is transportation, replacing fossil fuels with renewable alternatives like biofuels is an effective strategy to lower these emissions. When alternative options, such as converting to electric cars, are not viable owing to high vehicle prices or a lack of a vehicle charging network, for instance, biofuels provide a way to decrease the carbon emissions of transportation[2], [3].

2) **Responding to higher energy consumption:** By 2050, the global population is projected to reach 8 or perhaps 10.5 billion people, and strong economic development in developing nations would lead to a huge rise in energy consumption. We need to manage natural resources more wisely and employ more renewable energy sources, such biofuels, to be able to meet this rising demand.

3) **Securing energy supply:** Due to the dispersed nature of resources, the security of supply will face issues as energy demand rises. By lowering the world's dependency on fossil fuels, biofuels contribute to improving and securing energy security. The worldwide distribution of biomass is more equal than other resources[4], [5].

4) **Making the most of scarce 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. Future survival depends on cutting down on waste and maximising the use of our precious natural resources.

One of the report's main suggestions is that the MOPNG require 10% ethanol blending (E10) in all gasoline gradually implement 20% ethanol blending (E20) in gasoline. This moves the national strategy on biofuels' 2018 recommendation of an indicative objective of mixing E20 in gasoline and 5 percent of biodiesel (B5) in diesel ahead. From a technological standpoint, Niti Aayog report is retrograde since it has reemphasized the importance of biofuels that depend on feed stocks derived from food, while the 2018 policy placed more emphasis on biofuels that rely on biomass derived from non-food sources. Several environmental organisations have criticised the effort to once again use food-based feedstock as the basis for biofuels, reigniting the argument over whether food or fuel is more important[6], [7].

Biofuels

The two forms of biofuel that are now produced in the greatest quantities are biodiesel and bioethanol based on vegetable oil or fatty acid methyl ester (FAME). The majority of first-generation biofuels (1GB), notably bioethanol and biodiesel, come from plants that are based on food and include molecules with energy like sugars, oils, and cellulose. Bioethanol still makes up two thirds of the overall output despite the fact that the proportion of biodiesel in total biofuel production has risen almost ten-fold since 2000, from 3.3 percent in 2000 to approximately 32 percent in 2020. The minimal biofuel generation from 1GBs has a detrimental effect on food security. Straw, bagasse, and forest leftovers (all non-food), as well as crops specifically developed for energy on marginal areas, are used as the feedstock for second generation biofuels (2GB). There are currently relatively few 2GB manufacturing facilities on a commercial scale. Algae-based third generation (3GB) biofuels have the potential to be a high-yield, non-arable land usage source of non-food products like biodiesel, bioethanol, hydrogen, etc. Research and development are underway for 3GBs. Research into photobiological solar fuels, also known as fourth generation biofuels (4GB), and electro fuels, which directly transform solar energy into fuel utilising basic ingredients that are abundant, inexpensive, and limitless, is just beginning[8].

The USA is first in the world for ethanol production, contributing 46% of total output, and second for biodiesel production, contributing 19% of total production. In the USA, maize is used to produce 87 percent of the bioethanol. Brazil is the second-largest producer of ethanol in the world, contributing 28% of the total output and 14% of the biodiesel. Sugarcane is the source of both Brazil's ethanol and biodiesel. The majority of the biodiesel produced in the European Union, which is the biggest producer in the world, is made from imported feedstock. In 2019, biofuels made up 0.7 percent of the energy used for transportation and 0.2 percent of all primary energy consumption globally. In India, biofuel usage accounted for around the same amount of primary energy consumption overall—0.2%—as well as 0.7% of transportation energy consumption.

The Rationale for Biofuel use

For the long-term sustainability of the environment, economy, and society, biofuels have both benefits and drawbacks. The most significant worldwide drivers of biofuels are rural development, decreased imports of crude oil, and greenhouse gas (GHG) emission reductions. The study by Niti Aayog also lists these advantages: Increasing energy security might possibly cut crude oil imports, promote local business engagement in the energy sector, and reduce vehicle emissions. Although the rise in demand for all agricultural products, not just biofuel crops, will help farmers, the advantage to farmers is clear, the benefits to the environment and energy are less clear and very context-specific.

Net Energy Balance

The energy given by the fuel (petroleum or biofuel) to the total energy inputs used in its production, known as the overall energy ratio (OER), is greatest for gasoline and lowest for cellulosic ethanol. The fossil energy ratio (FER), which compares the liquid energy output to the input of fossil fuels, is lower for biofuels since their energy intake is mostly renewable. The FER for gasoline is around 0.8, the same as its OER, while it is approximately 10 for ethanol made from sugar cane in Brazil. Since sugarcane fibre provides the majority of the energy needed to generate ethanol, the FER for sugar cane-based ethanol is high. As Brazilian ethanol is recognised as the most energy efficient among biofuels in many studies, estimates on the FER for Indian ethanol are not yet available, but they are expected to be lower than that of Brazilian ethanol.

Greenhouse Gas Emissions

The paper from Niti Aayog makes the argument for ethanol blending by citing possible reductions in GHG emissions at the point of use, or at the exhaust of automobiles. Nevertheless, research on life cycle assessment (LCA) have taken into account the environmental effects of biofuels across their whole lifespan, from plant to fuel, as well as the reduction of carbon emissions. The results are sometimes contradictory, and the estimations vary greatly. The difficulty in determining net carbon emissions from changing land use in the production of biofuels is one factor contributing to the huge range. As they take carbon dioxide (CO2) from the atmosphere during photosynthesis, all plants and trees serve as carbon sinks. Yet, since the development of new biofuel plants balances the output of CO2, biofuels are, in principle, carbon neutral. This is because burning biofuels in automobiles releases CO2 back into the environment. Nevertheless, if a forest had to be removed in order to plant biofuel crops, it would lose a significant carbon sink, meaning the ethanol generated would not necessarily be carbon neutral. The environmental advantages of biofuels are significantly diminished by forest destruction, or land use change (LUC), as it is known in academic literature. For instance, substantial deforestation of rainforests has resulted from Brazil's steady rise in demand for sugarcane-based ethanol, which has led to GHG emissions from Brazilian ethanol consumption that are almost 60% greater than those of gasoline.

The LCA research on corn-based ethanol generation and soy-based biodiesel production from China may be more relevant for the Indian situation. The research indicated that due to the relative greater usage of fertilisers, higher process energy consumption, and the coal-dominated energy mix, Chinese ethanol and biodiesel had GHG emissions that were 40 percent and 20 percent higher than those of gasoline and diesel, respectively. If LUC related GHG emissions are not included, then the majority of 1GBs emit between 3 and 111 grammes of CO2 equivalent per million joules (MJ), which is less than petroleum-based fuels. Yet, when LUC is taken into account, many of the biofuels used in climate-conscious nations like the EU (European Union) are discovered to have much greater emissions than those of gasoline and diesel[9].

Issues

The potential threats to food security and water security presented by the new objectives for ethanol blending have been emphasised in commentary that has followed the publication of Niti Aayog's report on biofuels. It is simple to see how conflicting demands from the fuel industry might endanger both water and food security since sugarcane is a water-intensive crop cultivated on land intended for food production. The argument that only excess rice and sugarcane are used to produce fuel may not be true in the long run. The production of excess food grains, which is supported by monsoon rains that are higher than expected, cannot support an aggressive ethanol blending programme in the long run. According to the Niti Aayog study, India is now a net importer of ethanol, meaning that it has not yet made a significant contribution to increased energy security. The only way to meet ethanol blending requirements if domestic output does not rise is to bring in more imports. As there isn't enough arable land to provide a large rise in domestic biofuel production, increasing domestic production will continue to be difficult and could only be possible at the price of food security. Given India's intention to electrify surface transportation, the reductions in tailpipe emissions brought about by ethanol blending are not only insufficient but also unnecessary. The primary political force for biofuel production worldwide is the benefit to farmers and rural economies. This may only have a small number of advantages at a high cost for India, which is resource-constrained.

Governments all over the globe have pushed for the use of biofuels because they are thought to lower greenhouse gas emissions compared to fossil fuels, increase energy independence, and encourage rural development. The degree to which current biofuel technologies accomplish other policy goals has been contested in the literature, despite the fact that they have been shown to boost farm revenue in principle and in reality by the US Department of Agriculture, Foreign Agricultural Service. Compared to fossil fuels, maize ethanol offers just a little reduction in carbon emissions (Farrell et al., 2006). If land-use changes are not effectively managed, corn ethanol and other first-generation biofuels, such as sugarcane ethanol and biodiesel made from soy, canola, and palm oil, may actually result in higher emissions over the next century. The production of biofuel has increased significantly in recent years, although it still still accounts for 3% of global oil usage. Between 30% and 70% of all farmland in the US and the EU would need to be put aside only to offset 10% of oil imports. There is growing evidence that current biofuels do not offer the substantial benefits they were initially thought to offer, in addition to mounting proof that they do not. It is also becoming increasingly clear that producing biofuels has a significant negative impact on food security and environmental protection. Governments updated their biofuel strategies in 2007 and 2008 to focus on next-generation technologies that lessen the conflict between food and fuel for staple crops and land as the globe reached its first food crisis in more than 30 years. By speeding mandatory development in the production of advanced biofuels and cellulosic ethanol, which employ specialised energy crops and agricultural leftovers to minimise land intensity and greenhouse gas emissions, the United States has curtailed mandated growth for traditional ethanol (Energy Independence and Security Act [EISA], 2007).

In addition to estimating the effects of US corn-ethanol and soy-biodiesel production on the food and oil markets, this article presents a basic overview of the economics of first-generation gasoline ethanol. We provide a fresh viewpoint on the factors contributing to the rise in food insecurity and emphasise the significance of the current slowdown in agricultural productivity development. According to our argument, the Green Revolution's potential advantages have been fully realised, conventional farm inputs are being regulated, research and development spending is dropping, and agricultural biotechnology is being overregulated and underutilised. A renewed commitment to biotechnology is required to develop larger yields and improved biofuel technologies, since the demand for food is predicted to increase by more than half and maybe double in the first half of the twenty-first century. We must embrace a gene revolution, to put it briefly. The population of India makes up 18% of the whole world's population. India is third in the world for primary energy consumption, just behind the USA and China. Our energy reserves only make up a tiny 0.6 percent of the overall reserves accessible in the planet. The only option, then, is to continuously concentrate on developing new sources of energy supply. According to the National Biofuel Policy, which the Government of India announced in 2018 and 2019, emphasis is being placed on utilising biofuels to address India's energy issue.

Biofuels are liquid fuels and blending components produced from biomass feedstocks, used primarily for transportation. Biofuels are endowed with multiple characteristics like being-

a. Eco-friendly
b. Import substitutes
c. Cost effective
d. Indigenous
e. Pollution free
f. Carbon neutral in theory

These characteristics make it a viable and sustainable alternative for present fossil fuels. The types of biofuels can be categorized as follows-

PRESENT STATUS

As a result of India's rapid development, both the demand for transportation fuels and the difficulties brought on by it’s over reliance on fossil fuels are escalating quickly. Due to the following prevailing factors, there is a rising demand for sustainable alternatives like biofuel. India used 44.55 thousand barrels of biofuels per day in 2019. India's daily use of biofuels climbed from 2.9 thousand barrels in 2000 to 44.55 thousand barrels in 2019, expanding at a rate of 24.37% on average each year. These figures show that effective technological use combined with political initiative may result in the investigation of alternative energy sources at the necessary rate. These are the sectors that are affected by the use of biofuels in India's overall socioeconomic and cultural contexts-

1. **Local habitats:** Usage of excessive water for the production of biofuel raw material is adversely affecting the local habitual situations.
2. **Ethanol pricing:** The current Indian policy of ethanol blending is dependent on ethanol import due to less production of ethanol in India. Less domestic production capacity is showing negative impact on ethanol pricing.

3. **Farmers' livelihood:** Due to more commercial gains, farmers are turning towards the cultivation of plants required for biofuel production. However, they are not incentivized and hence, they do it at the cost of food security and unsustainable land usage.

The availability of constant feedstock will be necessary for the adoption of biofuels. The Government of India has thus given priority to the development of technologies that would help in the creation of sophisticated biofuels utilising burning agricultural and other leftovers[10].

FUTURE STRATEGY

The International Energy Agency (IEA) predicts that, India would surpass China to take over as the world's third-largest producer of ethanol. India was seventh in the world's leading producers of ethanol in 2016, it had passed Canada, Germany, and Thailand to take fourth place. India is anticipated to catch up to China's ethanol output in and surpass it in to occupy third place after the United States and Brazil. India's surge in ethanol output is largely the result of regulatory changes. The aim established report on ethanol blending by NITI Aayog and the Ministry of Petroleum & Natural Gas is the most recent policy initiative on which the IEA's upbeat estimates for ethanol output from India are based (MOPNG).

Use of biofuels is associated with –

1. Food security
2. Water conservation
3. Energy security
4. Benefit to farmers and rural economies

These many societal interests will inevitably come into conflict with one another. India must develop and put into practise imaginative policies in order to find a golden middle that would balance these competing interests. For instance, India has the capacity to cultivate Pomgamia Pinnate and Jatropha, two non-edible plants that are the most advantageous for the manufacture of biofuels. The issue of energy security won't prevent the widespread production of biofuels if these potentials are realised with the aid of sustainable technologies.

Future debates will pit the use of e-mobility against the use of biofuels, which is another new topic. While the rise of e-mobility is propelling the car industry forward, a solid foundation is being laid for the use of biofuel in the main transportation sector. Technology for using the energy potential of biofuels must develop at the same rate as e-mobility. Therefore, in order to maintain both alternatives and create a vast sustainable alternative energy environment, a harmonising strategy must be used.

Reducing reliance on imports is one of the main advantages of using biofuels. For instance, 1 billion litres of ethanol may save Rs. 28 billion at the present exchange rate. Around Rs. 4000 crore in foreign currency will be saved because to the availability of ethanol throughout the year in amounts of about 150 crore litres. One crore litre of ethanol reduces CO2 emissions by around 20,000 tonnes, which has positive effects for the environment. There would be a reduction in CO2 emissions of 30 lakh tonnes for only one year of supply. Greenhouse gas emissions will be further reduced by cutting down on crop burning and turning agricultural trash and leftovers into biofuels.

In the light of this existing scenario, future Indian bio-fuel policy must envisage-

1. Expanding 1 G technology encompassing sustainable land use
2. Developing viable model for sustainable supply chains for 2G feedback
3. Financing research in the field
4. Directing funding to biofuel projects at national and international level
5. Developing innovative ways for inclusion of sustainably used feedstock
6. Providing incentive schemes to farmers to bring the crop residue to the biofuel production plant
7. Encourage private investment in building supply chains

India must develop a sensible biofuel strategy that promotes the best use of the fuel with the least damage and waste if it is to bear the burden of the fuel shortage. India needs a long-term, sustainable strategy for producing biofuels. The goal of the biofuel policy must be to provide co-benefits from biofuels via a variety of economic and environmental paths. The excessive import of crude oil and unavoidable reliance on it are severely straining India's economy. These negative effects may be seen in every aspect of human existence. India updated its Biofuel Policy in 2018 to switch to the route of sustainable energy solutions as the need for sustainable alternatives became urgent. This alternative, however, is still in its infancy, and India has to speed up research and technology adoption to explore its enormous potential, making it more practical and powerful without sacrificing other factors like human habitat and other ecosystem services.

The author of this article has examined the use and policy of biofuels in India at the current time in light of this fact. In an effort to exploit the enormous potential of biofuels in India, the author has sought to advocate adoption of more forward-thinking and modern future strategy by critically examining current projects and governmental approaches.

One of the most important renewable energy sources that may aid in lowering carbon emissions is biofuel, which is produced from organic materials or trash. The three most popular biofuels are bio-diesel, bio-ethanol, and biogas. Nowadays, biofuels account for around 3% of all global road transport fuels1. The Renewable Fuels Association estimates that since 2007, biofuels have reduced carbon emissions by more than 230 million metric tons. The use of biofuels in the aviation and marine industries has recently been the focus of the worldwide biofuel business.

The Indian Government's Biofuel Policies

The value of biofuels was recognised in India as early as the 1970s, when committees were formed to assess the potential for utilising bio-ethanol and bio-diesel as transportation fuels in the country. By 20033, 5% ethanol blends with gasoline were required in 9 major sugar-producing states and 4 union territories under the Ethanol Blended Petrol (EBP) Program. Due to a lack of supplies, this obligation was changed to voluntary in 2004. In order to supervise the gradual introduction of ethanol blending in gasoline throughout the majority of Indian states, the National Biofuel Policy was established. A further 20% ethanol blending objective was planned to be achieved (together with 5% biodiesel blending), and 5% ethanol blending in gasoline was made obligatory as of October 2008. 4. Currently, the EBP programme mandates that public sector oil marketing corporations sell ethanol-blended gasoline starting in April 2019 in all states and union territories (apart from Lakshadweep and the Andaman and Nicobar Islands), with a least 5% and a maximum 10% blending. Nonetheless, despite all of the steps and goals the Indian government established, the country's ethanol blending rate stayed at little over 4% by 2018.

Challenges and Risks

The Indian government has not been able to expand the biofuel business there despite new regulations and policies. Just 1.1 billion litres of biofuel were purchased by India's public sector oil marketing corporations in 2016, which is insufficient for a 3.5%6 blending rate. A supply shortage is the main factor causing this deficiency. The ethanol generated in India is mostly used by the chemical and alcohol industries, which together absorb more than 90% of the nation's total ethanol output. Since the sale of ethanol to producers of alcoholic beverages is a guaranteed market with set selling prices and continually rising demand, producers choose to do so. Public sector oil marketing firms' reluctance to negotiate long-term supply contracts with ethanol providers has made the problem worse[11].

Molasses, a by-product of the crushing of sugarcane, is fermented to create the majority of the ethanol in India. The supply of feedstock for ethanol production has decreased recently due to restrictions on the use of sugarcane juice and other food crops directly for ethanol production, which protect consumers from an increase in food costs. Since 2018, these rules have been loosened and it is now legal to produce ethanol straight from sugarcane juice. Nevertheless, unless the Indian government offers incentives, low-interest loans, and guarantees to build up distilleries for ethanol production from sugarcane juice and molasses, these actions are unlikely to have any significant impact on ethanol production or supply. The expansion of the Indian biofuel business has been constrained by issues with the supply chain. As ethanol is a highly flammable liquid, safety and risk management procedures must be followed while producing, transporting, and storing it. Due to the uneven distribution of raw resources in India, it also needs a specialised distribution network and interstate movement with transportation and storage facilities. These elements have had a detrimental impact on the growth of the biofuel business in India.

The Way Forward

Focusing more on second and third generation bio-ethanol is a crucial approach for increasing the nation's ethanol production. The utilization of agricultural and household trash for biofuel production will have considerable beneficial impacts on the supply situation since the use of food grains and sugarcane juice for ethanol production has long been questioned in a growing country like India. India produces very little second-generation biofuel at the moment. Nevertheless, in recent years, public sector oil marketing firms like the Indian Oil Corporation and Bharat Petroleum have been establishing production facilities and making investments in the manufacture of second-generation biofuels. Yet, the sector has yet to witness the effects of these changes. India's net agricultural residue availability for biofuel generation is predicted to reach about 166.6 million tones. By the same year, the demand for ethanol for gasoline blending would be close to 13.7 million tons8 (based on the desired blending rate of 20%). So, spending money on creating production facilities and developing technologies that can make ethanol from cellulosic and lignocellulosic biomass would help divert attention away from food-based biofuels and prevent the future shortage of ethanol feedstock.

Future government measures to encourage the manufacture of ethanol from maize will also be a crucial tactic. But compared to rice or sugarcane, both of which are now oversupplied on the Indian market, corn takes a lot less water to be grown. The United States, which is the world's biggest producer and user of ethanol, uses a lot of corn to make ethanol. The amount of ethanol produced throughout the nation will rise if farmers are encouraged to grow corn instead of paddy, cooperative distilleries and production facilities are given financial support, and there is a stable price and reliable market for ethanol. Also, this would help save a significant quantity of water that is now utilised for paddy farming, which is important since India is about to experience a serious water crisis. These actions may decrease foreign currency, which is now required to import gasoline, and will assist India in increasing ethanol output and blending rates.

The principal energy sources derived from biomass and food crops like sunflower seeds, palm fruit, Jatropha seeds, rapeseed, soybean, etc. are designated as biofuels. These energy sources have huge promise in a rising country like India. India has an annual biomass supply of around 500 million tonnes, of which 120 to 150 million tones are excess.

Moreover, biofuels alone are responsible for 12.83 percent of the world's renewable energy production. Moreover, greater conversion efficiency and cheaper prices are the main forces for the extraction of bioenergy. Energy security, less reliance on imports, a cleaner environment, better municipal solid waste (MSW) management, and improved health outcomes, infrastructure investments in rural regions, job creation, and overall increased revenue for farmers are all advantages of using biofuels. Biodiesel or bioethanol are the liquid biofuels, whereas compressed biogas (CBG) or bio-CNG are the gaseous biofuels.

According to the International Energy Agency (IEA), if supportive policies and investments are put in place, biofuels have the potential to satisfy more than a quarter of the global demand for transportation fuels by 2050. Governments currently support biofuels in a variety of ways, such as blending mandates or targets, subsidies, tax breaks (exemptions from excise and pollution taxes, corporate tax breaks for biofuel producers), reduced import duties, support for research and development (R&D), direct involvement in biofuel production, as well as other incentives to promote local biofuel production and use.

Biofuel Policy in India:

India began a tiny 5% ethanol blending trial programmer in 2001. The National Mission on Biodiesel, which aspired to achieve a 20% biodiesel blending in diesel by 2011–12, launched in

2003 and established the biofuel mission. The National Policy on Biofuel (NPB) was introduced in 2009 as a result, and the updated NPB was introduced in 2018.

By 2017, the NPB 2009 anticipated an optional 20% blending objective for both ethanol and biodiesel. Facilitating the best growth of local biomass feedstock for biofuel generation was the goal of NPB 2009. The NPB 2009 presented an enabling framework of financial, institutional, and technical interventions in addition to outlining the vision, objectives, and strategy for the development of biofuels.

The updated biofuels policy, NPB 2018, went into effect on May 16, 2018, and it suggested an indicativeblending objective of 20% ethanol in gasoline and 5% biodiesel in diesel. The goal of NPB 2018 is to decrease crude oil imports, increase farmer income, create jobs, make the best use of drylands, and promote sustainability. The goal of the strategy is to provide financial and fiscal incentives that are particular to the first generation (1G), second generation (2G), and third generation (3G) fuels of biofuels.

Traditional ethanol and biodiesel fall within the first generation of biofuels. The second generation includes drop-in fuels made from biomass, MSW, plastics, and industrial wastes as well as ethanol made from lignocellulosic biomass, non-food crops, industrial wastes, and residual streams. Compressed BioCNG made from food wastes, biomass, MSW, sewage water, etc. is part of the third generation. Plans like Sustainable Alternative towards Affordable Transportation (SATAT), which aims to set up compressed biogas production facilities and make CBG accessible for use as a green fuel on the market.

Key Challenges in Biofuel Production:

2G Bioethanol Production

The collection and delivery of biomass leftovers by farmers to a next-generation ethanol plant is not yet encouraged by any legislative mechanism. Establishing a trustworthy supply chain for biomass that includes biomass feedstock collection, transportation, and handling is crucial. If policymakers want to support an industry over the long run, they can set up a system that allows cooperatives or agricultural groups to participate in the collecting, storage, and transportation of leftovers.

A supply chain should be created and run to maximize economic potential, social benefit, and environmental effect while minimizing supply chain uncertainties and high market risk associated with the second-generation biofuel business. India may take advantage of its population edge by doing this. Any skill gaps should be filled via training and incorporated into bigger national initiatives like Skill India.

The pre-treatment of the feedstock to make the carbohydrates in the lignocellulose available for conversion is a significant obstacle in the manufacture of cellulosic-based bioethanol. In addition to costs, the most important factor in choosing a pre-treatment procedure is its effectiveness in preventing product deterioration, which might thwart future hydrolysis and fermentation. One-third of the overall cost of producing bioethanol goes towards raw material pre-treatment, which has an impact on the price of enzymatic hydrolysis and fermentation. Another significant question is how the plant will use the carbon dioxide it produces. Future production has to address the implementation of 2G ethanol facilities owing to high technical risk, production expense, and political/policy concerns with low potential returns.

Biodiesel production

Food security is hampered by the need for adequate land for the development of biodiesel made from edible oil. It is not practical to utilise edible oil since the majority of the supply in the nation is imported. Several agronomic and financial limitations on the production of feedstock, such as high cultivation costs, poor yield, inadequate seed supply, and inappropriate selling channels, cause farmers to shut down their plantations.

Nevertheless, using non-edible oil sources has drawbacks such as decreased performance in cold areas, the potential for contamination and impurities in animal fats, and the absence of a centralized system for gathering such raw materials.

Techniques for extracting oil, such as mechanical extraction, need further filtering and phospholipid removal. Moreover, mechanical oil extraction presses tend to be plant-specific and unsuccessful for a wide range of feedstocks. On the other hand, n-hexane extraction has a danger of having an adverse effect on the environment and human health due to the creation of sewage and volatile organic compound emissions.

The implementation of the biodiesel programmer is thought to be significantly hampered by the absence of government support. Incentives to promote the biodiesel programmer, required biodiesel blending, and installation of legislative measures to encourage usage are a few of the latest requirements to address the issues.

BioCNG production

Concerns about feedstock availability and quality exist due to weak supply chains and limited collection efficiency. Fluctuations in feedstock supply and quality might hinder plant productivity, which would eventually hurt plant profitability. One of the causes of the closure of biogas plants is the decline in the number of farm animals in rural regions, which prevents the delivery of the contracted amount of waste to plants.

Individual domestic biogas plants need to be financially invested in, but they only provide non-cash advantages like biogas, which is often used as fuel for cooking. Large-scale commercial biogas facilities, on the other hand, are run exclusively by the private sector or public-private partnerships with the intention of making money via the sale of by-products like heat, power, or transportation fuel. Long-distance trash treatment and transportation come at a hefty price. Another significant worry is the competition from organic fertilizer and substantially subsidized chemical fertilizers.

Inadequate supply of feedstock, competition from other fuels, lack of social acceptance of biogas from substrates like night soil, human excreta, and dead animal carcasses, lack of proper training and capacity building programmers, and lack of awareness of its environmental benefits are some challenges to biogas production in rural areas. One of the main causes of the sluggish expansion of the waste-to-energy business is the lack of proper MSW segregation, collection, and transportation technologies and tactics in cities.

Due to the large regional variations in waste characteristics, process standardization is challenging, which prevents the broad use of biogas technology. Anaerobic digestion is competed with by other waste treatment techniques including composting, vermicomposting, and waste to pellets, which may also be used to treat organic municipal and industrial waste. A further barrier to the adoption of biogas digesters for waste management in urban areas is the preference for inexpensive treatment options like composting. The cost of the procedure is increased by the extra infrastructure needed for biogas cleaning.

Challenges in third generation biofuels: Algal Biofuel

The generation of algae-based biodiesel is fraught with difficulties and uncertainties. Cost and expense are threats posed by economic research. Although they are still in competition with other biomasses, the commercial acceptance remains uncertain. The conversion of CO2 by algae to carbonic acid may cause an unregulated pH increase, which would ionize the medium in which the algae are grown. It could be challenging for sunlight to penetrate deep into a huge algal bloom. Hence, the main obstacles limiting the development of algal biofuel are:

- Information on the demand for and research into algal biofuel is currently scarce. But, additional research is required to determine how well algal biofuel works in vehicles, equipment, aircraft, and other vehicles.
- The high quantities of lipids fatty, oil-containing acid molecules that may be removed to make biofuels in the feedstock, which is algae, are largely responsible for the need of high lipid content fuel conversion from algae.

- Information on the demand for and research into algal biofuel is currently scarce. But, additional research is required to determine how well algal biofuel works in vehicles, equipment, aircraft, and other devices.
- Complex procedure Algal biofuel production involves a number of stages before it is ready to be used as fuel. This procedure is difficult and drawn out.
- Excessive Fertilizer usage only by using additional fertilizer can enormous amounts of algae be created. Moreover, the manufacture of fertilizer uses a lot of energy and emits a lot of carbon dioxide, which affects the algal biofuel's ability to be carbon dioxide neutral across the board.
- Reducing the amount of algal death caused by biotic and abiotic causes Algal monocultures have a high risk of being infested by pests and pathogens, so crop protection is a significant obstacle to the sustainability of algal production.
- Significant Water Need Algae need a lot of water to flourish, hence they need a lot of water sources. High temperatures may sometimes cause water levels to evaporate, which hinders development.
- Pricey to Produce To this day, the cost of producing algae biofuels is still much greater than that of fossil fuels.
- There are several kinds of algae in the earth's crust, but not all of them generate the same quantity of oil.

- Usage of Land Regardless of the growth model used or the effectiveness of oil extraction, a large amount of implementation is needed to replace a significant quantity of fossil fuel.
- The Nutrition Challenge For effective development, algae need light, nutrients, water, and a carbon source, most often CO2. Most algae need nitrogen, iron, phosphorus, and sulphur as their primary nutrients.

The Inference

The need of creating a strong biofuel industry in India in order to solve the concerns of energy security and fuel self-sufficiency has been widely acknowledged. Despite the fact that the conflict between food and fuel is very important on a global scale, India's programmer to produce biofuels doesn't really care about it since the nation has made the conscious decision to forgo using any edible feedstock, which also poses a limitation.

To take advantage of the myriad environmental, social, and economic benefits that would come from the nation's extensive biofuel production, the National Biofuel Policy was established. Lack of governmental support for sustainable supply chain norms and solutions, a lack of entrepreneurial assistance, and a lack of subsidies or incentives to encourage competition among bioenergy producers are all significant impediments to the production of biofuels.

Some of the above-mentioned obstacles could be removed with the aid of new policies and initiatives or adjustments to current ones. The use of blending biofuel with conventional petroleum should be made obligatory, and prices should be subsidized, in order to promote the biofuel business in India.Although the programmer may be maintained in the short term by supportive government policies and active participation from the neighborhood community and private businesses, it is crucial to have a strong long-term plan in place. The present trend is unlikely to be sufficient in the long term given the available possibilities for feedstock, the technical status, and the regulatory options. To address the nation's future bioenergy needs, a sizable research effort on the creation of second- and third-generation feedstock is necessary.

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Questions for Revision

1. What is biofuels?
2. What is the history behind the biofuels?
3. What are the different types of biofuels?
4. What are the different types of second generation biofuels?
5. What are the economic and environmental considerations for biofuels?
6. What are the environmental impact of biofuels?
7. What are the different types of uses of biofuels?
8. What are the national policy on biofuels?
9. What are the renewable hydrocarbon biofuels?
10. What are the biomass potential?
