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Bioenergy: Socio-Economic and Environmental Implications and Future of Biofuels

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Abstract:
Bioenergy is a promising energy source, by 2040, the estimated increase in global energy demand over present levels is about 28%. In terms of generating fuels, either solid or liquid. To mitigate human climate change, biofuels can replace fossil fuels. Emissions of greenhouse gases. Yet, evidence that biofuels are generated in a sustainable manner should be the foundation for any policy decisions about them. To this goal, life cycle assessment (LCA) offers details on the environmental effects linked to the manufacturing of biofuels. Here, we examine developments in biomass conversion to biofuels and their effects on the environment. through life cycle analysis. Gasification, combustion, pyrolysis, enzymatic hydrolysis pathways, and fermentation are examples of processes. Gasification, combustion, and pyrolysis are examples of low temperature thermochemical processes, which occur below 300 °C, and high temperature processes, which occur above 300 °C. In contrast to gasification, which operates at temperatures between 800 and 1300 °C, pyrolysis operates at a relatively lower temperature of up to 500 °C. We concentrate on the following topics: 1) the benefits and drawbacks of the thermochemical and biochemical conversion routes of biomass into various fuels, as well as the possibility of integrating these routes for better process efficiency; 2) methodological approaches and key findings from studies on biomass to biofuel conversion pathways published from ; and 3) social, economic, and environmental trends and knowledge gaps in biomass conversion into biofuels using thermochemical and biochemical methods. The circular economy is hopeful about the convergence of hydrothermal and biochemical routes of bioenergy.

Keywords: Bioenergy, Biomass, Biofuel, Thermochemical, Biochemical, climate change.

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1. INTRODUCTION

Bioenergy More than a third of the world's population [1] uses it as their primary source of energy, burning dung, agricultural waste, and wood fuel in typically ineffective and polluted cookstoves. It is also the modern renewable energy source with the fastest rate of growth, producing power and transportation fuels on an industrial scale to provide modern energy services. These two facets of bioenergy—traditional and modern—present formidable obstacles to sustainable growth.

According to Chakradhari and Singh Patel [2], biomass is a sustainable energy source since solar energy is stored in it and it grows back relatively quickly compared to fossil fuels. It will be necessary to evolve technologies, fuel supply infrastructure, energy and social regulations, even cultural practices, in order to move away from traditional biomass. Contrarily, modern bioenergy poses a difficulty because it is expected to become a significant source of the world's energy supply, humans have relied almost exclusively on bioenergy for their energy needs for hundreds of thousands of years. Very little water, wind, sun, and geothermal energy have also been utilised over the past two millennia [3]. Fossil fuels (FFs) were also burned in small amounts prior to the explosive expansion of coal after 1800, followed by oil and gas in the 20th century, which caused FFs to overtake bioenergy as the main source of energy. Present-day bioenergy production is likely at its highest level ever [4]. Moreover, it is still by far the biggest source of renewable energy (RE) in the world. The global average for the proportion of bioenergy in total primary energy is 10%. From 80% or more in some African nations to almost nothing in others like Kuwait, Singapore, or the United Arab Emirates, its proportion varies greatly from one nation to the next [5]. Bioenergy is used as fuelwood or animal dung in tropical Africa, as well as in a few Asian and South American nations, and is burned at relatively low energy efficiency. This traditional bioenergy use still seems to represent a sizable portion of current bioenergy consumption (Table 1). Additional uses for bioenergy include converting it into liquid fuels for transportation, namely bioethanol and biodiesel, using it to generate electricity and fuel contemporary boilers, and using it as a component in the creation ofAdditional uses for bioenergy include converting it into liquid fuels for transportation (mostly bioethanol and biodiesel), using it as a fuel source for modern boilers and electric power plants, and adding it to the process of making biogas. According to the International Energy Agency (IEA) [6], Table 1 shows the split of bioenergy in 2020.

Table 1. IEA estimates of present (2020) global bioenergy (EJ), by type.

Bioenergy Type	2020 EJ
Modern solids	31.8
Modern liquids	3.8
Modern biogas	2.2
Traditional fuelwood	24.1
All biomass	**61.9**

Source (IEA) [6].

Compared to solar and wind energy, which can only be produced for as long as the climate permits it, bioenergy represents a dependable, predictable, and independent sustainable alternative to limited fossil-based resources [7,8]. Similar to how it becomes difficult to balance supply and demand due to their unpredictable natural energy flow changes, negative economic externalities result [7,8]. Yet, the growth of bioenergy crops promotes biodiversity and carbon sequestration [9]. The world's population will expand by 33% (6–8 billion people) by 2030, creating a demand for food, water, and energy that will increase by 50%, 30%, and 50%, respectively [10]. The situation will become much more problematic by 2050 as feed production is anticipated to rise by 100% globally and by 70% locally.

Overall, the environmental sustainability of biomass production determines the scope of the possible advantages of bioenergy and bioproducts. In order to determine the overall sustainability of these systems and provide solutions to reduce the environmental hot spots and energy sinks, it is crucial to use advanced sustainability assessment tools, such as exergy analysis and the combination of these techniques known as exergoenvironmental and exergoeconomic analyses. In light of this, the current study's objectives were to: (i) identify trends the main socioeconomic and environmental posed by BCSs, (ii) discuss the novel biological approaches in bioenergy (iii) describe the challenges in the sustainable production of biofuels and, (iv) Key considerations for evaluating bioenergy's future potential as an energy source are its global technical potential and capacity to mitigate climate change. The outlook for bioenergy as perceived by several worldwide energy organizations and businesses is then discussed. Finally, recommendations are made, emphasizing the unpredictability of all future projections as well as the need for bioenergy to compete with other non-carbon sources, energy savings, and carbon dioxide removal (CDR).

Energy is the foundation of modern society. In classical physics, energy is defined as the ability to do work [11, 12]. Energy usage is directly or secondarily affiliated to the development of humanity [13]. In the past, fossil fuels had been consumed rapidly forenergy, and their negative impacts on the environment had been ignored [14]. Although conventional energy resources based on oil, coal, and natural gas are significant contributors to economic development, they are growing concerns regarding their environment and human health impacts [15].

Bioenergy refers to renewable power from organic sources that can be used for heat, electricity and fuel, and their co-products. There has been a resurgence of interest in bioenergy recently, and several articles have already addressed the potential impact of biotechnology on renewable energy [16]. The definition of a term defined by different organizations and experts "bioenergy is the renewable energy derived from recently living biological material called biomass." [17]. The U.S. Department of Energy's Oak Ridge National Laboratory's (ORNL)

Bioenergy Feedstock grid describe bioenergy as, “profitable, renewable energy produced from biological matterd the conversion of the complex carbohydrates in organic compound to fuel.” Food and Agriculture Organization of the United Nations [18]. Bioenergy refers to energy derived from biomass or its metabolic by-products. Bioenergy accounts for about 10% of world total primary energy supply, including traditional use for heating and cooking (‘traditional biomass’ [19]. The contribution of modern bioenergy (i.e., excluding traditional bioenergy) to total energy use is about four times that from wind and solar PV combined [20].
This biological source includes crops grown specifically for this purpose, such as sugar cane, corn and palm oil, but also natural waste products, animal products and manure. In recent years, interest in bio-energy as a sustainable alternative has increased due to the 17-fold growth in global energy use in the last century [21]. It is estimated that known petroleum reserves will be depleted within the next 50 years. Consequently, alternative energy sources will become more valuable. The mention of biofuels in the State of the Union speech by US president Bush in 2005 is just one example of the increased awareness of the importance and potential of bio-energy for the world’s energy consumption. Other examples include the EU incentives for its use in order to achieve the Kyoto protocol goals and success of ethanol in Brazil [21] . The biomass and biomass deduced energies can be the perfect result to the two grueling problems brought to humanity by fossil energies. Biomass of plants on Earth uses photosynthesis to transform solar energy into chemical energy stored in biomass or carbohydrates, while consuming atmospheric carbon dioxide and water on the planet. Biofuels demand solar energy, carbon dioxide and water on the earth, thus still lifelong with the Sun and the Earth. Unlike fossil energies, they aren't subject to geographical position, and factors (similar as war). Their directors are the green plant that cover the land face of the Earth. The green plant plays a direct part in mitigation of the two largest global greenhouse effect gases i.e., water vapor and carbondioxide. [22] When biofuels are consumed, they release carbon dioxide and water. This is a perfect balance for the terrain on the entire earth.[23] Use of plant to produce bioenergy and biofuels is nearly perfect for the Earth. still, utmost of the concerns is whether the biomass and biofuels can produce enough energy to replace fossil energies now, that is, to top up the gap

The introduction should be typed in Times New Roman with font size 10. Author can select Normal style setting from Styles of this template. The simplest way is to replace (copy-paste) the content with your own material. In this section, highlight the importance of topic, making general statements about the topic and presenting an overview on current research on the subject. Your introduction should clearly identify the subject area of interest.

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2.DEVELOPMENT OF BIOENERGY

The use of biofuels is no novel invention. Fueling up with plant oils or ethanol was common long before the evolution of the combustion engine [24]. Vegetable and animal oil lamps have been used since the beginning of civilization. then in 1834, the first US patent for alcohol as a lamp fuel was awarded to S. Casey [25]. Around 1850, thousands of distilleries produced an estimated 24 million liters (90 million gallons) of “Camphene” (a camphor oil scented blend of turpentine and ethanol) per year [25].

Biofuels have been utilized BEFORE the time of the automotive industry [26]. For instance, Rudolph Diesel tested his first engine on peanut oil [27] after pulverised coal was found to be unsuccessful. Until the 1940s, biofuels were seen as viable transport fuels and bioethanol blends such as ‘Agrol’, ‘Discol’ and ‘Monopolin’ were commonly used in the US, Europe and other regions [27]. moreover, evolution of bioethanol ceased after the Second World War as petroleum-derived fuel became inexpensive. During the oil crisis in 1970s, many countries showed renewed interest in production of commercial biofuels; however, only Brazil started to produce ethanol at a large scale.In Brazil, mixing ethanol from sugar cane into the fuel has been mandatory ever after 1977 and the government incentivised the development of 100% ethanol fuel vehicles and the associated distribution infrastructure. During the late 1990s, with the rise in crude oil prices and concerns over energy security, the US and many nations in Europe developed policies in support of domestic biofuel industries [28]. The development of policies for mitigating climate change has further increased interest in biofuels. This involves strategies to reduce GHG emissions from the transport sector. Since then, over sixty countries have launched biofuel programs [29]. As a consequence, the biofuel sector has grown considerably in recent years and currently it contributes around 4% to transportation fuels globally [30]. However, this has also led to various controversies over the sustainability of biofuels production and use [31], which has affected the growth of the sector [32]. In the remainder of this report, the sustainability issues associated with liquid biofuels are discussed, with an emphasis on their use in transportation Prior to that, the next section provides an overview of the biofuels policy landscape in the EU and the UK, followed by their current and projected future production worldwide and in the UK [33] .

The first oil machine was invented in Vienna by Julius Hock in 1870, and the first petroleum-based car was built by Etienne Lenoirand and Alphonse Bear de Rochas in 1890 [35], the human needs of all modes of transport gradually increased, resulting in a large number of productions of the modern transportation such as automobiles, ships, trains and aircrafts. These modern means of transport led to the human increased demand for oil, in consequence exacerbating the exploitation of oil. There is no doubt that the worldwide surge in oil extraction will deplete the Earth's oil supplies sooner or later, as the Earth has a limited amount of oil reserves.

Nearly all of the request was dominated by gasoline due to cheap Middle Eastern oil painting. During oil painting heads similar as 1973- 74 and 1979- 1980, numerous countries showed renewed interest in biofuels. The only nation that revived the bioethanol assiduity permanently was Brazil. During the 1970s, growers, alcohol directors, and machine manufacturers cooperated. Brazil began to produce ethanol by turmoil of sugar club. originally, gasoline was blended with 20("E20") or 25("E25") ethanol, and after the alternate oil painting extremity pure ethanol, was also available as energy, causing the auto assiduity to apply the necessary machine variations. The Brazilian bioethanol product increased from 600 million liters (160 million gallons) in 1975 to13.7 billion liters (3.6 billion gallons) in 1997, by far the loftiest in the world (International Energy Agency (IEA), 2004). Not until 2006, the United States surpassed the Brazilian bioethanol product with a periodic capacity of18.4 billion liters (4.9 billion gallons) compared to 17 billion liters (4.5 billion gallons). This was a dramatic rise holding into account that the US had produced [36].

The major comeback of biofuels in the United States and utmost other nations was driven by the enormous rise in crude oil painting prices since the late 1990s. Meanwhile, oil painting prices have reached sustained highs of over US$ 80 per barrel and might well continue to increase due to political insecurity in the Middle East and enterprises over the implicit oil painting peak (loftiest product rate), demonstrated in July 2008 when the oil painting price surpassed US$ 145 per barrel for a short time. Other important motorists include the hunt to gain energy independence [37]and growing enterprises on the effect of hothouse gas emigrations on the world's climate, which could be canceled by using renewable biomass for biofuel product. Also, MTBE (Methyl tert- butyl ether), an oxygenatedanti-knocking cumulative for machines, was confined in numerous countries and banned in some US countries similar as California and New York (which regard for app. 45 of the United States MTBE consumption) in response to environmental and health enterprises (EIA, 2003; IEA, 2004). As a suspected carcinogenic agent, MTBE began turning up in significant quantities in ground water, since it's largely answerable in water, binds weakly to soil, and isn't readily biodegradable in the terrain [38]; EIA, 2003; IEA, 2004). Of World War I led to a sudden and large demand for acetone as a solvent for the production of cordite. The dominant source for acetone up to this time was calcium acetate imported from Austria, Germany, and the United States. As acetate imports from Austria and Germany were not available during that time and the production capacity in the US was almost negligible compared to the required quantities, Strange and Graham, Ltd. were contracted by the British War Office to supply acetone. The average amount of acetone they could produce each week was 440 kg (970 pounds), which was a fairly inefficient amount. Therefore, a switch to the Weizmann process was requested. Thus, production could be increased to 900 kg (2,000 pounds) acetone per week. Hence, the disregarded by-product acetone helped the ABE fermentation process, becoming eventually the second largest biotechnological process ever performed [39,40]. Grain and corn could no longer be brought into the United Kingdom in the necessary quantities due to the threat posed by German submarines. Therefore, the Weizmann process wastransferred to Canada and the United States. Plants were built in Toronto in 1916 and TerreHaute, Indiana in 1917 [39,40,41].

Acetone's consistent availability undoubtedly contributed significantly to the victory in World War I, many new strains were isolated [42]) and patented and new fermentation plants were built in the United States, Puerto Rico, South Africa, Egypt, the former Soviet Union, India, China, Japan, and Australia. Two-thirds of the butanol produced in the United States up to 1945 came from fermentation. During World War II, the focus shifted to acetone production again [39,40] However, a few years after the end of the war, most of the plants in Western countries were closed because of rising substrate prices and competition by the growing petrochemical industry. The ABE fermentation was only continued in countries that were cut off from international supplies for political or monetary reasons. For instance, the South African apartheid regime ran a plant in Germiston with acapacity of 1,080 m³ (11,625 cubic foot) until 1982 [40,43]

3.BIOFUEL GENERATIONS

According to the way of biomass usage, biofuels can be divided to the primary and the secondary ones [44] .

The primary biofuel is the biomass without any additional treatment: wood, wood chips, animal fats, residues of forest and agricultural crops. The fuel of that kind is usually used for heating, cooking and agricultural needs and is widespread in Third World countries. Traditional biomass is another name for primary biofuels [45]. On the one hand, this fuel does not require resource expenses for its processing; on the other hand, the field of its application is rather small. For the year 2013, energy obtained from the traditional biomass has reached about 9% of all energy consumed in the world. The secondary biofuel is produced from biomass (the primary biofuel) by extraction of the most energy-intensive substances (biohydrogen, biomethanol, biodiesel), which can be used to substitute ubiquitous fossil fuel.

In its turn, the secondary biofuel can be divided into three generations: the first, the second and the third [46,47,48]. This division is based on the general feedstock for fuel production, the processing methods, and historical sequence of the fuel's appearance on the world energy market.[49].

3.1.The first generation:

A feedstock for the manufacturing of bioalcohols and biodiesel is the biomass of food crops that has been enhanced with sugars, starches (stems of sugar cane and sugar beet), and oils (soybeans, sunflower seeds, and rapeseeds). of the first generation, corn crops for ethanol and soybeans for biodiesel. Currently in use, these feedstocks have been producing higher yields. The simple and comparatively cheap method of treatment e microbial fermentation is the advantage of the production of this fuel. But there are several problems concerning this biofuel [47]: Low productivity of cultivated lands: only insignificant part of grown biomass is used for biofuel production. Competition with food processing industry for the usage of lands.

3.2. The Second generation:

feedstocks consist of the residues or “left overs” from crop and forest harvests. Lignocellulose is highly presented in plant biomass in comparison with oils and starch; it is the main component of cell walls. Lignocellulose consists of three components: cellulose (40e50%), lignin (15e20%), and hemicellulose (25e35%) [47]. All of these components are of certain value for people, but the process of extraction of particular component, especially of cellulose, is rather difficult. Lignin is an amorphous polymer, which consists of phenylpropane structures. It provides cellulose stiffness and stability against many hydrolytic enzymes. Lignin can be removed by dissolution in alkaline-alcohol solutions. Lignin per se can be burned to obtain heat or electricity; also, Hemicellulose can be hydrolyzed to produce monomeric sugars that can then be fermented to produce alcohols. A straight glucose polymer called cellulose has a particular stiffness that prevents it from being hydrolyzed [47]. With the advancement of cellulosic conversion technologies, they exhibit great potential for implementation in the near future.

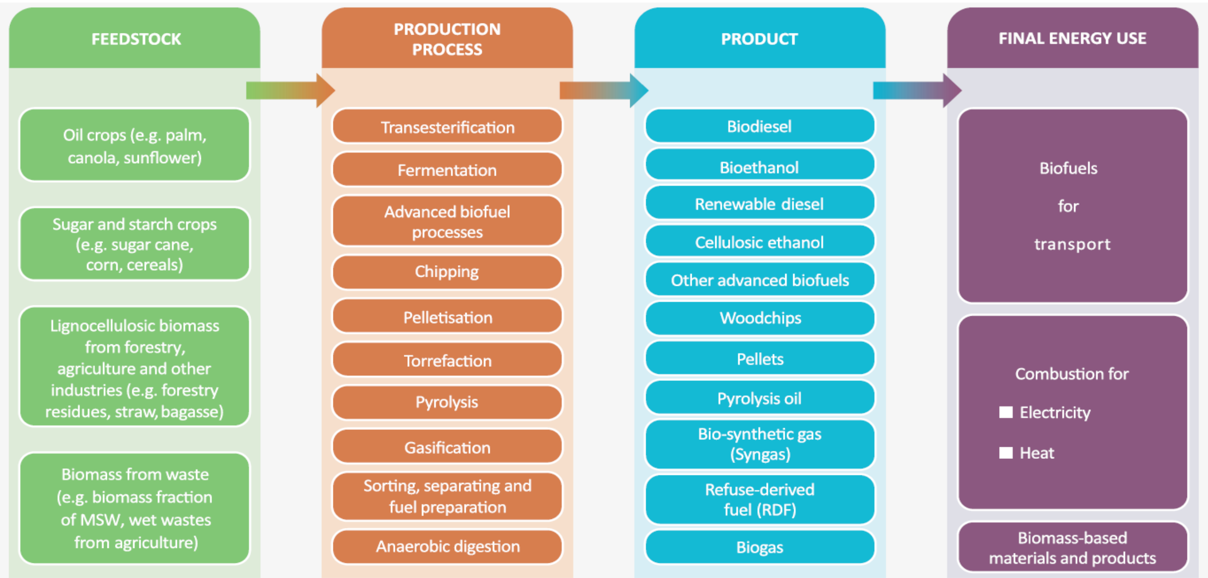
3.3. The Third generation:

feedstocks are crops, such as perennial grasses, and are commonly referred to as “energy crops”. fast growing trees, and algae .and use of algal biomass for fuel synthesis is relatively new direction of bioenergetics . They are designed exclusively for fuels production They represent a key long-term component to a sustainable biofuels industry. The biomass from algae is related to the third generation of biofuel. Data from many studies show that compared to biomass from oil plants, algal biomass can collect a disproportionately large amount of lipids. This fact makes algae a viable feedstock for the creation of biodiesel [50,51]. Algal bioenergetics and plant bioenergetics primarily differ in how they produce their biomass. Plants only demand the special effort to create specific conditions and the growth strategies already known from agriculture. On the other side, plant bioenergetics uses expensive resources (arable lands) and yields relatively little biofuel as compared to the bulk of the organic feedstock. Microalgae can grow in conditions, which are unsuitable for plant growth: saline soils, waste water. So, the usage of microalgae is being considered as an interesting potential feedstock for biofuels production [52,53]. Nevertheless, algae require special systems of growth e bioreactors, their construction depends on the species of alga grown.

production techniques or pathways are still in the research and development (R&D), pilot or demonstration phase. While these distinctions are in common usage, they present some difficulties and need to be used with caution. Firstly, the same well-understood technologies and processes used to convert food or feed crops into 'conventional' or 'first generation' biofuels, can be used to convert many non-food or non-feed feedstocks into biofuels. As such, a fuel that some may refer to as 'advanced' may be advanced in so much as the feedstock is different (and potentially more challenging to convert into a fuel) while the technological process may in fact be the same. The second main issue is related to defining wastes. Whether something is defined as a waste depends upon whether it has apre-existing use or value, which is a contextual question. This is an issue if consistency is to be maintained, the EU has introduced policy mechanisms whereby, to incentivise their production, biofuels derived from wastes, residues or other non-food biomass are 'double counted' towards obligations to blend low-carbon fuels into the fuel pool. Until a recent amendment to the EU Renewable Energy Directive (RED), in September 2015[54], the same substance could be considered as having a use and therefore not being waste in one member state but considered as waste in another. For example, tall oil (from wood processing industries) is double counted in Sweden, but used as a chemical precursor in the UK and therefore not considered eligible [55]. Since the amendment in September 2015, the RED has a list of feedstocks for double-counted biofuels but still allows for the production of advanced biofuels in the installations existing prior to September 2015, the use of feedstocks not included in the list but determined to be waste by the competent national authorities.The definition of what constitutes waste may also evolve over time as businesses and policymakers focus more on creating "circular" economies.[57] As a result, the value of materials that are currently seen as wastes may alter. While these nuances and challenges with defining biofuels are significant and require a careful use of language, we have found it useful to differentiate between biofuels derived from different food and non-food feedstocks. Within the latter category, we distinguish between biofuels derived from dedicated energy crops, residues, wastes and algae. As such, for the purposes of this study, we have adopted the terminology of first, second and third generation biofuels and distinguish between them only by feedstocks

4. BIOMASS FUEL SOURCES:

A renewable energy source, biomass and its byproducts can be used to produce power. Biomass is frequently used in place of or in addition to coal for this purpose [58]. There are at least five different kinds of feedstock that can be used to produce electricity. Resources for Biomass "Feedstocks" are generally used to refer to renewable biomass resources that are either used directly as fuel or transformed into another sort of energy product [59] .



Source: IEA Bioenergy Roadmap, 2017

Dedicated energy crops, agricultural crop residues, forestry crop residues, algae, wood processing residues, municipal garbage, and wet waste are all examples of biomass feedstocks (crop wastes, forest residues, purpose-grown grasses, woody energy crops, algae, industrial wastes, sorted municipal solid waste [MSW], urban wood waste, and food waste) [60].

4.1. SPECIFIC ENERGY CROPS

Non-food crops known as "dedicated energy crops" can be grown on marginal land (area unsuitable for growing conventional crops like corn and soybeans) particularly to produce biomass. Herbaceous and woody are the two broad categories into which these falls. Herbaceous energy crops are grasses that are harvested annually after 2 to 3 years of development and are perennial (plants that live for more than 2 years). They include wheatgrass, bamboo, sweet sorghum, tall fescue, kochia, switchgrass, miscanthus, and other plants.rapid-growing hardwood trees that are harvested five to eight years after implantation are known as shortened-rotation woody crops.. They include hybrid willow and poplar, as well as sycamore, silver maple, eastern cottonwood, green ash, black walnut, and sweetgum. Several of these plants have the potential to enhance soil and water quality, increase animal habitat in relation to annual crops, diversify revenue sources, and increase agricultural production [61].

4.2. CORN RESIDUE FROM AGRICULTURE

Existing lands offer numerous chances to maximize agricultural resources without obstructing the production of food, feed, fiber, or forest products. Around the United States, agricultural crop residues, which comprise the stalks and leaves, are numerous, diverse, and widely dispersed.Rice straw, wheat straw, oat straw, barley straw, sorghum stubble, and maize stover are a few examples (stalks, leaves, husks, and cobs).. Farmers have the chance to make additional money by selling these wastes to a nearby biorefinery [62].

4.3. WOODLAND RESIDUES

As trees are cut down or cared for, low-value tree components are obtained from the surrounding woodlands. Forest biomass feedstocks fall into one of two categories: whole-tree biomass harvested specifically for biomass or forest leftovers left over after logging wood (including limbs, tops, and culled trees and other tree components that would otherwise be unmarketable).[63] After logging, dead, sick, malformed, and other unsaleable trees are frequently left in the forest. This woody waste can be gathered for bioenergy usage while yet leaving behind enough to support habitat and preserve essential hydrologic and nutrient aspects. On millions of acres of forestland, there are also possibilities for the use of surplus biomass [64]. In addition to helping with forest restoration, productivity, vitality, and resilience, overharvesting of woody biomass can also lower the danger of fire and pest infestation. Without having a negative effect on the health and stability of the forest's biological structure and function, this biomass might be collected for use in bioenergy [65].

4.4. ALGAE

A vast range of extremely productive organisms, including microalgae, macroalgae (seaweed), and cyanobacteria (formerly known as "blue-green algae"), are referred to as algae as feedstocks for bioenergy. Many people use sunlight and nutrition to produce biomass, which has essential elements like lipids, proteins, and carbohydrates that can be improved and turned into a range of biofuels and goods. Algae can grow in fresh, salty, or brackish water from surface water sources, groundwater, or ocean depending on the strain. They can also flourish in water from second-use sources, including produced water from oil and gas drilling operations, treated industrial wastewater, municipal, agricultural, or aquaculture wastewater [66].

4.5. RESIDUES FROM PROCESSING WOOD

Byproducts and waste streams from the processing of wood are referred to as wood processing residues, and they offer a substantial energy potential. For instance, the production of sawdust, bark, branches, and leaves or needles during the processing of wood for goods or pulp. The leftovers can then be used to create biofuels or other bioproducts. These leftovers can be practical and reasonably priced sources of biomass for energy because they are already collected at the point of processing [67].

4.6. SORTED COMMUNITY WASTE

Yard trimmings, paper and paperboard, plastics, rubber, leather, textiles, and food wastes are examples of mixed commercial and household waste (MSW). By redirecting substantial amounts of MSW from landfills to the refinery, MSW for bioenergy also presents a chance to lower household and commercial waste [68].

4.7. DAMP WASTE

Wet waste feedstocks include manure slurries from concentrated livestock operations, organic wastes from industrial operations, commercial, institutional, and residential food wastes (especially those currently disposed of in landfills), organic-rich biosolids (i.e., treated sewage sludge from municipal wastewater), organic wastes from industrial operations, and biogas (the gaseous product of the decomposition of organic matter in the absence of oxygen) derived from any of the above feedstock streams. Rural economies can generate more income and trash-disposal issues can be resolved by turning these "waste streams" into electricity [69]. Note that all of the abovementioned feedstock would be considered second generation types of bioenergy. At the moment, first generation crops, such as soy and palm oil are still widely used. In Holland, incentives were given by the government to electricity companies that would provide green electricity, such as from biomass. When a number of electric companies decided to import palm oil to use as the feedstock for its green electricity, they received criticism from various environmental groups. The process of turning biomass into electricity can be done in various ways. The most common practice seems to be through so-called 'anaerobic digestion' in a biogas power plant [70]. This entails the transformation of the biomass, including wood products and animal waste, into methane gas. Gas turbines may then convert this gas into electricity, which can then be utilized in homes [71]. Both business and residential establishments utilize the same gas for heating [72]. Burning wood biomass is another option for generating steam for the standard steam-driven generators that also use fossil fuels [73].

4.8.BIO – BASED PRODUCTS:

Many chemical products and materials that are currently made from petroleum can also be made from biomass. Building blocks for a variety of consumer items, including plastics, solvents, paints, adhesives, and drugs[74], can be made from biomass. Currently, such plant resources are utilized to make paper and as chemical feedstock, but the US Department of Energy claims that there is enormous development potential for additional uses. Products made from bio-based chemicals include paint, ink, and lubricants. The potential products that can be generated from biomass [74].

5.BIOMASS CONVERSION TECHNOLOGIES:

There are numerous bioenergy pathways that can be employed to transform unprocessed biomass fuel into an end product. Many conversion technologies have been created and are adjusted to the various physical characteristics and chemical make-up of the feedstock as well as the necessary energy service (heat, power, transport fuel) [76]. It is being developed to upgrade biomass feedstock technologies, including as palletization, torrefaction, and pyrolysis, to transform bulky raw biomass into denser and more useful energy carriers for more effective transport, storage, and practical application [77]. The primary use of bioenergy in the globe is for the direct combustion of biomass to produce heat, which is frequently more affordable than using fossil fuels[78]. Technology range from simple modern gadgets to crude burners. Modern, large-scale heat applications are frequently integrated with electricity generation in combined heat and power (CHP) systems for a more energy-efficient use of the biomass resource [79].

The actual process of turning biomass into biofuels follows the stages of biomass cultivation and preparation. Many methods for turning biomass into biofuel can be described, regardless of the type of biomass. Generally speaking, they can be divided into four types according to cost, end-product purity, and environmental friendliness [81, 52].

5.1. BIOMASS PYROLYSIS:

Pyrolysis is a thermal conversion process that takes place at high temperatures without the use of any oxidants or oxygen. demonstrates pyrolysis products and applications. Solid biochar, liquid, and gaseous synthesis gas are the main byproducts. Temperature, retention duration, and the type of biomass being used all affect how much of these co-products are produced. The reactor being used affects both product quality and quantity. The following guidelines govern biomass pyrolysis procedures:

1. The lowest pyrolysis temperature and the longest residence time result in the highest production of solid bio-char (or charcoal).

2. Between 400°C and 600°C, liquid yield is often at its highest.

3. Syngas performance is greatest when operating at the highest temperature. Syngas mostly consists of hydrogen and carbon monoxide (CO) (H). Lower molecular weight hydrocarbons like CH, ethylene (C H), and ethane are among the other component gases (C H)[82].

When applied to agricultural land, bio-char can be utilized as a soil amendment to deliver carbon and nutrients. Activated carbon, a particularly valuable adsorbent material for water and wastewater treatment procedures, can also be made from high-carbon biochar. The purification of all inorganics from the carbon to produce graphene, one of the toughest compounds generated from carbon, yields the bio-maximum char's value.

With short residence times, such as those in fluidized bed pyrolysis systems, the quality of the liquid product (bio-oil) is improved or enhanced, but not with auger pyrolyzers. Typically, auger pyrolyzers have lengthy residence times. Less viscous bio-oil is produced by short residence durations, and it is simple to use catalysts to transform it into biofuel (gasoline or diesel). Bio-oil produced by the pyrolysis process has many uses. It is possible to extract valuable compounds, upgrade the bio-oil through catalytic processes to produce transport fuels, and co-fire it in an engine to produce power or in a boiler to provide heat [83].

In order to produce heat, yngas can simply be burned as it is produced. Before using syngas in an internal combustion engine, tar may need to be removed. This internal combustion engine is connected to a generator to produce electricity.

5.2. BIOMASS GASIFICATION:

Syngas is created through gasification, which is a partial thermal conversion of biomass. Earlier textbooks used the term "producer gas" to refer to this gas. Syngas can be used in internal combustion engines to produce electricity or it can be cleansed of tar and burned to provide heat. The synthesis gas can also be utilized as a feedstock for bacteria that also create coproducts from the biofuel industry to make bio-butanol.

There are many different types and designs of gasifiers, such as moving bed systems and fixed bed systems (updraft, downdraft, or cross-draft gasifiers) (fluidized bed gasification systems).

This depicts a fluidized bed gasification device. Biomass is regularly supplied to a big biomass bin. A bed material, typically refractory sand, is present in a fluidized bed reactor to transport the reaction's necessary heat. To ensure the creation of synthesis gas rather than heat and water vapor, the air-to-fuel ratio is adjusted so that the amount of air is below the stoichiometric need for combustion (i.e., combustion is incomplete). After partial thermal conversion, high carbon bio-char is the only solid that is left, and it is removed using a succession of cyclones. The synthesis gas is burned to produce heat, which is the system's most basic use [84].

If electricity is required, tar must be removed from the synthesis gas before it can be used to power an internal combustion engine. Gasification systems typically have conversion efficiency of less than 20%. An average conversion efficiency of roughly 15% can be used to quickly estimate output [85].

5.3. BIOMASS COMBUSTION:

For example, burning wood to provide heat for cooking is a traditional method of direct combustion of biomass. The most effective thermal conversion method for producing heat and electricity is combustion [86]. Unfortunately, due to the high ash and water content of the majority of agricultural biomass products, not many biomass products can be burned [87]. At greater combustion temperatures, the ash component may melt, causing slagging and fouling problems. As melted ash cools, it solidifies into slag, which collects on conveying surfaces (fouls) [88].

5.4. BIOCHEMICAL PROCESSES:

The four main biochemical processes involved in anaerobic digestion are hydrolysis, acidogenesis, acetogenesis, and methanogenesis. utilizing these procedures, organic materials (such proteins, carbohydrates, and lipids) are transformed into Using external and internal enzymes from the microorganisms, hydrolysis transforms complex organic matter into monomer or amino acids, simple carbohydrates, and long-chain fatty acids are examples of dimeric substances (LCFA).Acidogenic bacteria transform the hydrolysis products into smaller molecules such as volatile fatty acids (VFA), alcohols, hydrogen, and NH during acidogenesis. Alcohols and VFA (other than acetate) are transformed into acetic acid or hydrogen and CO during acetogenesis. The extensive group of facultative and obligate anaerobic germs known as acidogenic and acetogenic bacteria includes Escherichia coli, Clostridium, Peptococcus, Bifidobacterium, Corynebacterium, Lactobacillus, Actinomyces, Staphylococcus, Streptococcus, Desulfomonas, Pseudomonas, and Streptococcus [89].

Acetic acid and methanol, an alcohol, are transformed into CH and CO during methanogenesis. Furthermore, CH is created by converting CO with hydrogen. A variety of obligate anaerobes known as methanogenic archaea, including Methanobacterium formicicum, Methanobrevibacter ruminantium, Methanococcus vannielli, Methanomicrobium mobile, Methanogenium cariaci, Methanospirilum hungatei, and Methanosarcina barkei, are among them [89].

Heat, electricity, fuel, and raw materials are the four main outputs of a biomass energy conversion system. Any conversion process' objective is to minimize losses in order to achieve the best level of conversion efficiency. Each type of product's energy conversion efficiency can be calculated as follows:

$$\text{Energy Conversion Efficiency (\%)} = \frac{\text{Energy Output (MJ)}}{\text{Energy Input (MJ)}} \times 100\%$$

There are three main methods for converting biomass (Figure The employment of chemicals or catalysts for conversion at room temperature or a little higher is known as physicochemical conversion. Using particular microorganisms or enzymes to produce useful goods is known as biological. For conversion, thermo-chemical reactions take place at high temperatures (and occasionally pressures). The end products of biomass conversions can take the place of typical chemicals (like lactic acid), fuels (like diesel), and materials produced from fossil resources (e.g., gypsum).

5.4.1. BIODIESEL PRODUCTION:

By physiochemically converting refined vegetable oils and fats using a straightforward catalytic process utilizing methanol (CH OH) and sodium hydroxide (NaOH) at a slightly increased temperature, biodiesel—which is compatible with diesel fuel—is produced. Transesterification is the term for the procedure. Because of the ester connections that hold a glycerol molecule to three fatty acid molecules, vegetable oils are also known as triglycerides. A catalyst that breaks the ester bonds results in the production of glycerin and the conversion of the fatty acid component into its methyl ester form, which is the technical name for biodiesel. The most prevalent commercial catalyst for the manufacture of biodiesel is sodium methoxide (CH ONa), which is produced when methanol and sodium hydroxide are combined. The process's basic mass balance is 100 kg of vegetable oil plus 10 kg of catalysts. 10 kg of glycerin and 100 kg of biodiesel the specific facility design affects the energy balance. The energy in the biodiesel must be greater than the energy required to create the vegetable oil utilized in the process for it to be regarded a viable product. The transesterification procedure is broken down into numerous phases in a commercial system. To reduce catalyst use, methanol and catalysts are recycled after each stage. At each stage, crude glycerin is also recovered to reduce the amount of extra methanol used [90]. The leftover catalyst is then added at the very end of the operation; the quantity must be precisely measured. This final stage reaction reduces the number of unreacted mono-glycerides (or remaining glycerol that still has a fatty acid chained to it via an ester bond). The most popular biodiesel product in the United States is soybean methyl ester, which is produced when soybean oil is used. The most popular feedstock in Europe for the production of rapeseed methyl ester is canola (rapeseed) oil. To raise the coproduct's economic worth, glycerin is further refined.

The employment of chemicals or catalysts for conversion at room temperature or a little higher is known as physicochemical conversion. Using particular microorganisms or enzymes to produce useful goods is known as biological. For conversion, thermo-chemical reactions take place at high temperatures (and occasionally pressures). The end products of biomass conversions can take the place of commonly produced materials, fuels, and chemicals from fossil resources, including lactic acid (e.g., gypsum). The topic of this chapter is energy produced through bioconversion [91].

5.4.2. BIOETHANOL PRODUCTION:

Bioethanol is created from sugar, starchy, or lignocellulosic crops using microorganisms or enzymes and is compatible with gasoline or diesel. Yeast, such as Saccharomyces cerevisiae, or other similar bacteria can easily convert plant-based sugars into ethanol, but starchy crops require enzymes, such as amylases, to convert starch to sugar, which the yeasts then use to generate bioethanol. Similar enzymes are required by lignocellulosic crops, such as those generated by Trichoderma reesei, to convert cellulose into simple sugars. Heat is also produced by the fundamental mass balance for converting plant sugars from biomass into ethanol (C H O): $C_6H_{12}O_6$ + yeast + $2C_2H_6O + 2CO_2$ (with heat) [92].

Dry milled corn is the most typical feedstock used to produce bioethanol in the United States (maize; Zea mays). Dry corn kernels are ground into a powder, then water is added while the mixture is heated (or gelatinized) to cook the starch and activate the amylase enzyme to break it down (saccharification). Starch is changed into sugars by this process[93]. The end product, which is primarily glucose, is then fermented by yeast for three to five days with the following mass balance to produce bioethanol:

$$\mathbf{2C_6H_{10}O_5 + H_2O + amylase \rightarrow C_{12}H_{22}O_{11}}$$

The repeating units of polymers of glucose [(C H O)] with an n-th power of n depict complicated starch molecules. This polymer is broken down by the enzyme amylase into simple compounds like sucrose (C H O), a disaccharide with only two molecules of glucose [94]. Alternately, the invertase enzyme is utilized to convert sucrose into glucose sugar.A yeast acts on the sugar product to transform the sugar into bioethanol, such as the commercial yeast Ethanol Red (supplied by Fermentis of Lesaffre, France and sold internationally)[95]. Because the final product (a broth) has an alcohol concentration that is extremely close to 10%, it is referred to as beer. Distillers grain, the solid component, is typically dried and fed to animals. The beer is distilled to produce bottoms, also called still bottoms, and to collect 90–95% of the bioethanol (often 180–190 proof), which is subsequently refined using molecular sieves. (A molecular sieve is a crystalline material having pores of carefully chosen molecular diameters that, in this case, only allow the passage of molecules of ethanol.) The finished product after separation and purification can then be combined with gasoline or utilized on its own [96].

5.4.3. BIOGAS PRODUCTION:

Methane (CH; also known as natural gas) and carbon dioxide (CO) are the two main components of biogas, which is created by microbes from lignocellulosic biomass in anaerobic conditions [97]. Ruminant animals' intestines frequently contain suitable bacteria (e.g., cows). These microorganisms hydrolyze or ferment complex cellulose materials to produce big organic acids, which are then further broken down into smaller organic acids (such as acetic acids) and hydrogen gas [98,99]. As the breathing gases for these bacteria, hydrogen gas and certain organic acids, including CO, are further transformed into CH and CO [94]. If the CO component is eliminated, biogas (CO + CH) is identical to natural gas (CH). A typical fuel produced by refining crude oil is natural gas.

Worldwide, wastewater treatment facilities frequently use high-rate anaerobic digesters for the production of biogas (Figure). Simpler digesters make use of basic fluidized beds, enlarged beds, up flow and down flow anaerobic filters, and anaerobic contact processes. The up flow anaerobic sludge blanket, or UASB, is a well-liked Dutch design [92]. The anaerobic fluidized bed and enlarged bed granular sludge blanket reactor designs are two enhancements to the UASB. In contrast to the US, where there are few high-rate systems, they are widely used in Europe. In the US, the majority of biogas plants are merely covered lagoons [100].

6.ENVIRONMENTAL AND SOCIOECONOMIC ASPECTS

The production and use of bioenergy can have additional (positive and negative) environmental, health, and social implications. This is in addition to offering a potential solution for solving the dual concerns of energy security and climate change. The majority of environmental consequences are related to the manufacturing of feedstock. Processing fuel typically has less of an impact on the environment [101].

Processing fuel typically has less of an impact on the environment [101]. Although there are ways to lessen the environmental effects of biofuel plants, they might not be put in places with loose environmental laws or insufficient law enforcement [102]. Almost 20% of new car sales in the first half of 2008 were E85 vehicles. From July 5, rules have also made it possible to convert gasoline or diesel vehicles to run on ethanol or gas. The risk of further expansion of agricultural land into forests and other areas with high biodiversity values is amplified by bioenergy strategies that primarily focus on biofuels for transportation and encourage increased cultivation of conventional agricultural crops for the production of first-generation biofuels. This could result in continued ecosystem conversion and biodiversity loss [103,104]. Due to the well-documented degradation of soils and water bodies that frequently goes hand in hand with intensive agricultural methods, they may further exacerbate worries about the ability of the agricultural resource base (soils, freshwater) to sustainably support a growing agricultural output, Increasing competition for crops used as food and feed is not a direct result of greater bioenergy use.

There are a wide range of conversion alternatives that use feedstocks other than food/feed crops to produce energy from biomass. Bioenergy expansion could use other sources, such as agricultural and forestry residues, that do not require additional land or water as part of strategies that shift demand to alternative feedstocks, primarily lignocellulosic ones. However, these sources may have adverse effects if extraction rates are too high. Moreover, a larger variety of terrain types could be used to cultivate lignocellulosic crops. Sustainable management approaches could make marginal lands, pastures, and grasslands—which are unsuitable for first-generation biofuels due to environmental and greenhouse gas implications—into a new resource for the production of feedstock. By reducing the percentage of rainfall lost to wasteful evaporation, the cultivation of perennial energy crops also offers a chance to boost water production. Degraded or marginal land could be used to produce lignocellulosic feedstock. Marginal lands may, however, also be put to other purposes, suggesting that current land users must be included if beneficial local socioeconomic development is to be ensured. In many instances, this can necessitate alternatives to monoculture plants, such agroforestry systems that combine the production of bioenergy with that of food crops and livestock. Moreover, the inevitable result of rising biomass demand may not be biomass production on marginal or degraded land. Farmers will take food crops into account when bioenergy use rises and they adopt bioenergy crops, as healthy soils also lead to higher yields for the bioenergy crops. environmental consequences (such as sloping soils susceptible to erosion on the Loess Plateau in China). Restrictions may also forbid farmers from cultivating energy crops on more of their land than a specific percentage of their land (6). There are numerous examples of how integrating technical, ecological, and social knowledge at the local level makes it possible to produce biomass for energy while minimizing risks and producing extra benefits, like improved productivity in agriculture and forestry and the provision of environmental services. One of the most important advantages of greater usage of bioenergy is often mentioned as rural development. Both industrialized and developing nations have differing perspectives on this. Rural development is viewed as a means of differentiating and sustaining the agricultural sector and rural areas in general in industrialized countries. In developing nations, rural development is viewed as part of a larger picture of livelihoods that includes employment, much-needed revenue, and the advancement of the agricultural system. The relationship between bioenergy and food security is primarily of concern for developing nations, because increased susceptibility to rising food costs may have impacts on populations outside of those who could directly benefit from bioenergy. Indirect and direct socio-economic issues, such as land disputes and human rights abuses, are also sustainability concerns. Comprehensive reporting on mitigation strategies in agriculture and land use in general is outside the purview of this paper. To address the challenges of reducing hunger and poverty, enhancing rural livelihoods, and facilitating equitable and environmentally, socially, and economically sustainable development, it is now widely acknowledged that the model that fueled agricultural development in industrialized countries and the spread of the green revolution must be revised (IAASTD 2008). In this context, rising bioenergy demand creates difficulties but also opportunities to encourage more environmentally friendly land and water use worldwide. Many biofuel crops can improve agricultural output by offering crucial environmental services in agricultural settings, such as reducing erosion and regulating the microclimate. Positive rural development may be realized if domestic and foreign investors in developing nations can successfully involve local communities and make them partners in the development of a biofuels industry that integrates with food production, reaping the benefits of the inflow of technology, infrastructure, and capital for the benefit of both food and bioenergy production. In conclusion, bioenergy can support environmental and energy policy goals but it may also have very undesirable side consequences. In order to support consistent energy and environmental policy goals, bioenergy policy must be developed. Moreover, regulation of bioenergy is necessary to ensure that larger environmental and social issues are taken into account and that the environmental benefits offered by bioenergy systems are acknowledged and rewarded.

FUTURE PERSPECTIVES OF BIOENERGY

The need to stop relying on fossil fuels will inevitably necessitate a reconstruction of the current industry in order to use renewable resources and manufacture chemicals, fuels, and materials sustainably. Since that industrial waste streams and by-products are produced in large numbers and are currently underutilized, incorporating biorefinery concepts into existing industrial facilities offers an alternate processing option [105].

As a result, sustainability will be improved and market opportunities will be more diverse through the creation of value-added products from waste and by-product streams. In order to increase the sustainability of biofuels, chemical and biodegradable polymer manufacturing should take place concurrently [106]. This study identified possible businesses where the production of PHA and biofuels may coexist. The technologies that will be used on an industrial scale are still being developed in this research area, which is still in its early stages. Furthermore, land-intensive bioenergy scales only through the use of enormous amounts of land, a resource whose availability is essentially constrained. Land-intensive bioenergy makes the most sense as a transitional element of the global energy mix, playing an important role over the next few decades before fading, most likely after mid-century, due to the land constraint, the intrinsically low yields of energy per unit of land area, and rapid technological progress in competing technologies. It will need a unique combination of policies and incentives to manage an efficient trajectory for land-intensive bioenergy that promotes acceptable use in the short term but reduces lock-in in the long term [107].

7.CONCLUSIONS

Microbial production of biofuels has regained importance due to the scarcity of fossil fuels and the large increase in greenhouse gas CO2 that results from burning them. Yet, first-generation biofuels have significant disadvantages since they either compete with the food business or have undesirable characteristics. Many second-generation biofuels have been created in recent years and are close to commercialization, but they still need to be scaled up for validation. One of the most promising second-generation biofuels is biobutanol, which has been utilized effectively on a wide scale for decades and has many advantages over bioethanol. An industrial application of the acetone-butanol-ethanol fermentation dates back to the early 19th century and has a history of almost 100 years. While many fermentation facilities were shut down following World War II, research into the physiology, biochemistry, and genetics of C. acetobutylicum was kept going. Based on these discoveries, metabolic engineering, downstream processing, and substitute substrates for sugar all work to continuously increase the biological efficiency of solvent generation. Many factories in China and Brazil are already back in operation, and major companies like BP and DuPont have committed to producing biobutanol. Recent metabolic engineering experiments showed butanol generation using E. coli in high yields as well as from different carbon sources like syngas with C. ljungdahlii. Also, we face complicated, multifaceted problems that require a variety of integrated policies geared toward a bioeconomy. by supplying a renewable and sustainable energy source, reducing soil deterioration, and enhancing rural development, could contribute to the socioeconomic prosperity. Nevertheless, rather than taking a business-as-usual strategy, the development and application of bioenergy must be based on a bottom-up approach. The latter, as shown in this review, has added potential harm to the already precarious situation. This literature review offers policymakers and institutions a general overview of the topic's complexity, the key factors to take into consideration, as well as the initial key principles for the introduction of sustainable bioenergy on the system of rural communities. It also includes comprehensive and interdisciplinary recommendations. In the end, the sustainable development of Bioenergy may help a developing bioeconomy accomplish the Sustainable Development more quickly.

References

1. Int. Energy Agency (IEA). 2006. *World Energy Outlook 2006*. Paris: OECD/IEA.
2. Suryakant Chakradhari, Khageshwar Singh Patel. (2016) Combustion Characteristics of Tree Woods. Journal of Sustainable Bioenergy Systems, Vol.6 No.2.
3. Moriarty, P.; Honnery, D. Switching off: Meeting Our Energy Needs in a Constrained Future; Springer: Singapore, 2022; 90p, ISSN 2191-5520.
4. Smil, V. Energy Transitions: History, Requirements, Prospects; Praeger: Santa Barbara, CA, USA, 2010.
5. International Renewable Energy Agency (IRENA). International Renewable Energy Statistics 2021. 2021. Available online: https://irena.org/publications/2021/Aug/Renewable-energy-statistics-2021 (accessed on 23 June 2022).

6. International Energy Agency IEA. World Energy Outlook 2021; IEA/OECD: Paris, France, 2021. Available online: https://www.iea. org/topics/world-energy-outlook (accessed on 24 June 2022).
7. Theuerl, S.; Herrmann, C.; Heiermann, M.; Grundmann, P.; Landwehr, N.; Kreidenweis, U.; Prochnow, A. The Future Agricultural Biogas Plant in Germany: A Vision. Energies 2019, 12, 396. [CrossRef].
8. Szarka, N.; Scholwin, F.; Trommler, M.; Jacobi, H.F.; Eichhorn, M.; Ortwein, A.; Thrän, D. A novel role for bioenergy: A flexible, demand-oriented power supply. Energy 2013, 61, 18–26. [CrossRef].
9. Yadav, P.; Priyanka, P.; Kumar, D.; Yadav, A.; Yadav, K. Bioenergy Crops: Recent Advances and Future Outlook. Prospect. Renew. Bioprocess. Syst. 2019, 315–335. [CrossRef].
10. May, M.; Levine, I.;Woods, J.; Flagella, Z.; Lee, K.T.; Sharma, S.; Gresshoff, P.; Hanley, S.; Ceulemans, R.; Vogel, K. Energy Crops; Royal Society of Chemistry: Cambridge, UK, 2010; ISBN 978-1-84973-204-8.
11. S. G. Tzafestas, Energy, Information, Feedback, Adaptation, and Selforganization: The Fundamental Elements of Life and Society, Springer, 2018.
12. Y. Demirel, Energy: production, conversion, storage, conservation, and coupling, Springer Science & Business Media, 2016.
13. R. A. Dias, C. R. Mattos and J. A. Balestieri, Energy policy, 2004, 32, 1339-1347.
14. T. Kandpal and H. Garg, Applied energy, 1999, 64, 71-78. 1.Stewart, C.N. (2007) Biofuels and 283–284. biocontainment. Nat. Biotechnol. 25.
15. A. Herzog, T. Lipman and D. Kammen, University of California, Berkeley, 2001.
16. Sims, R.E.H. et al. (2006) Energy crops: current status and future prospects. Glob. Change Biol12, 2054–2076.
17. A.https://www.ieabioenergy.com/bioenergy-a-sustainable-solution.
18. Anju Dahiya (FAO)2,3Bioenergy Biomass to Biofuels2014: Paperback ISBN: 9780124079090.
19. IEA. (2020a). World energy balances 2020. https://www.iea.org/reports/world -energy-balances-overview.
20. IEA. (2018). Renewables 2018. https://www.iea.org/repor ts/renewables -2018.
21. Tim Steinweg Sanne van der Wal Amsterdam Bio-energy 2007, March Sector Overview SOMO.
22. Katherine Calvin ,et al, 2021 Bioenergy for climate change mitigation: Scale and sustainability https://doi.org/10.1111/gcbb.12863.
23. Chunlin Liu and Chuanxin Sun (2011). The Future Crops for Biofuels, Economic Effects of Biofuel Production, Dr. Marco Aurelio Dos Santos Bernardes (Ed.), ISBN: 978-953-307-178-7, InTech, Available from: http://www.intechopen.com/books/economic-effects-of-biofuel-production/the-future-crops-for-biofuels.
24. Köpke Michael, Noack Steffi and Dürre Peter 2011 The Past, Present, and Future of Biofuels – Biobutanol as Promising Alternative Institute of Microbiology and Biotechnology, University of Ulm Germany.
25. Kovarik, B. (1998). Henry Ford, Charles F. Kettering and the fuel of the future. Automot Hist Rev, Vol.32, pp. 7-27 LanzaTech (2010) LanzaTech..
26. A.Biofuels: From Hopes to Reality Carioca J. Friedrich, H.3 and Ehrenberger, S.31Universidade Campus do Pici, Fortaleza.
27. Amyris Company Overview. Seminário InformEx 2010 Latin America. realizado nos dia23 e 24/08/10 no Centro de Conveners Amcham. Paulo/SP.
28. “Shell and Cosan announce merger and creation of Radzen”. Available at:http://www.ruralcentro.com.br/notdcias/34825.
28. International Energy Agency. World Energy Outlook 2006, OECD/IEA, 2006, Paris.
29. Harada, J., Amorim, C.A., Braga, P.L., Machado, L.D.B., Oliveira, R.R., Cabral, N., Abner, M., Jose, R.N., Silva, L.G.A. and Rosa, D.S. (2017) Characterization of Biodegradable Mulch Black Films Incorporated with Organics Fertilizers and Rice Husk Ash. Proceedings of the 146th TMS Annual Meeting and Exhibition, San Diego, 26 February-2 March 2017.
30. Pereira, BR. “Cane Polyethylene”. DOW, 12th Congress of Responsible Care, ABIQUIM, São Paulo, 2008.
31. “People and Sustainability at the Center of the Strategy”. BRASKEM Petrochemical Company, 12th Congress on Responsible Care, ABIQUIM, São Paulo, 2008.
32. Leite, A.L.S. and Leal, M.R.L.V. Biomass Future Based Supply. Brazilian Network onGreen Chemistry: Awareness, Responsibility and Action. Ediçóes UFC, Fortaleza, 2008, pp. 217-234.
33. Bryan, B., Hellemans, A. (1993). The timetables of technology: A Chronology of the Most Important People and Events in the History of Technology. New York: Touchstone.
34. International Energy Agency (2004). Biofuels for transport: An international perspective, OECDPublishing, ISBN 92-64-01-51-24, Paris, France.
35. Noack Steffi and Dürre Peter 2011 The Past, Present, and Future of Biofuels –Biobutanol as Promising Alternative Köpke Michael, Institute of Microbiology and Biotechnology, University of Ulm.

36. Schubert, C. (2006). Can biofuels finally take center stage? Nature Biotechnol, Vol.24, pp. 777-784.
37. Shen, C. R.; Lan, Squillance, P. J.; Pankow, F. J.; Korte, N. E. & Zogorski, J. S. (1997). Review of the environmental behavior and fate of methyl tert-butyl ether. Environ Toxicol Chem, Vol.16, pp. 1836-1844.
38. Dürre, P. & Bahl, H. (1996). Microbial production of acetone/butanol/isopropanol. In: Biotechnology, M. Roehr, (Ed.), VCH Verlagsgesellschaft: Weinheim, Vol.6, 2nd Ed., pp. 229-268.
39. Jones, D. T. & Woods, D. R. (1986). Acetone-butanol fermentation revisited. Microbiol Rev Vol.50, pp. 484-524.
40. Gabriel, C. L. (1928). Butanol fermentation process. Ind Eng Chem, Vol.20, pp. 1063-1067.
41. McCutchan, W. N. & Hickey, R. J. (1954) The butanol-acetone fermentations. Ind Ferment, Vol.1, pp. 347-388.
42. Ross, D. (1961). The acetone-butanol fermentation. Prog Ind Microbiol, Vol.3, pp. 73-85.
43. Demirbas A. Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. Energy Convers Manag 2008;49:2106e16.
44. Renewables 2015 global status report. REN21. Paris: REN21 Secretariat; 2015. ISBN 978-3-9815934-6-4.
45. Surriya O, Syeda SS, Waqar K, Gul Kazi A, Ozturk M. Bio-fuels:a blessing in disguise. In: Ozturk M, Ashraf M, Aksoy A,Ahmad MSA, editors. Phytoremediation for green energy.Springer; 2015. p. 11e30. http://dx.doi.org/10.1007/978-94-007-7887-0_2.
46. McKendry P. Energy production from biomass (Part 1): overview of biomass. Bioresour Technol 2002;83(1):37e46.
47. Demirbas A. Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. Energy ConversManag 2008;49:2106e16.
48. A Roman Voloshin 2016 Review: Biofuel production from plant and algal biomass Article in International Journal of Hydrogen Energy · DOI: 10.1016/j.ijhydene.2016.07.084.
49. Allakhverdiev SI, Kreslavski VD, Thavasi V, Zharmukhamedov SK, Klimov VV, Ramakrishna S, et al.Photosynthetic energy conversion: hydrogen photoproduction by natural and biomimetic systems. In: Mukherjee A, editor. Biomimetics, learning from nature. Rijeka, Croatia: InTech d.o.o; 2010. p. 49e76.
50. Abdelaziz AEM, Leite GB, Hallenbeck PC. Addressing the challenges for sustainable production of algal biofuels: II. Harvesting and conversion to biofuels. Environ Technol2013;34:1807e36.
51. Chisti Y. Biodiesel from microalgae. Biotechnol Adv2007;25:249e306.
52. Wang B, Li Y, Wu N, Lan CQ. CO2 2008 bio-mitigation using microalgae. Appl Microbiol Biotechnol;79:707e18.
53. Sustainability of liquid biofuels 2017,Royal report Academy of Engineering293074 ,www.raeng.org.
54. DEFRA, Crops Grown for Bioenergy in England and the UK: 2016. www.gov.uk/government/uploads/system/uploads/attachment_data/file/578845/nonfood-statsnotice2015i-19dec16.pdf.uk.
55. NNFCC, Domestic Energy Crops; Potential and Constraints Review. 2012.www.gov.uk/government/uploads/system/uploads/attachment_data/file/48342/5138-domestic-energy-cropspotential- and-constraints-r.PDF.
56. Robert D. Perlack2005 BIOMASS AS FEEDSTOCK FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY: THE TECHNICAL FEASIBILITY OF A BILLION-TON ANNUAL SUPPLY 37831-6285.
57. Sanchez ST, Woods J, Akhurst M, Brander M, O'Hare M, Dawson TP, Edwards R, Liska AJ, Malpas R. 2012 Accounting for indirect land-use change in the life cycle assessment of biofuel supply chains. J. R. Soc. Interface. 9, 1105–1119. (doi:10.1098/rsif.2011.0769).
58. Hu, Q., Sommerfeld, M., Jarvis, E., Ghirardi, M., Posewitz, M., Seibert, M., Darzins, A., 2008. Microalgal triacylglycerols as feedstocks for biofuel production: perspectives and advances. Plant J. 54, 621e639.
59. https://www.energy.gov/eere/bioenergy/biomass-resources.
60. VIJAI K. GUPTA, MARIA G. TUOHY, CHRISTIAN P. KUBICEK, 2014 BIOENERGY RESEARCH: ADVANCES AND ISBN: 978-0-444-59561-4 .
61. APPLICATIONS McHenry, M.P., 2010. Carbon-based stock feed additives: a research methodology that explores ecologically delivered.
62. C biosequestration, alongside live-weights, feed-use efficiency, soil nutrient retention, and perennial fodder plantations. J. Sci. Food. Agr. 90, 183e187.
63. Antle, J.M., Stoorvogel, J.J., Valdivia, R.O., 2007. Assessing the economic impacts of agricultural carbon sequestration: terraces and agroforestry inthe PeruvianAndes.Agric.Ecosyst.Environ. 122 (4), 435e445.
64. Camsund, D., Devine, E., Holmqvist, M., Yohanoun, P., Lindblad, P., Stensjo¨ , K., 2011. A HupS-GFP fusion protein demonstrates a heterocyst-specific localization of the uptake hydrogenase in Nostoc punctiforme. FEMS Microbiol. Lett. 316, 152e159.

65. Seabra, R., Santos, A., Pereira, S., Moradas-Ferreira, P., Tamagnini, P., 2009. Immunolocalization of the uptake hydrogenase in the marine cyanobacterium Lyngbya majuscula CCAP 1446/4 and two Nostoc strains. FEMS Microbiol. Lett. 292, 57e62.
66. Anonymous, 2012b. Renewable Resources for the Production of Bioplastics: Impact on Agriculture - Status and Outlook. Fact sheet. European Bioplastics http://en.european-bioplastics.org/wpcontent/uploads/2011/04/fs/Renewable_resources_eng.pdf.
67. Biofuels and Bioproducts from Wet and Gaseous Waste Streams: Challenges and Opportunities 2017 Bioenergy Technologies Office ,U.S. Department of Energy.
68. Wikipedia website, "Anaerobic Digester," no datehttp://en.wikipedia.org/wiki/Anaerobic_digester (07-02-07).
69. Wikipedia website, "Biogas," no date, http://en.wikipedia.org/wiki/Biogas (07-02-07).
70. Haq, Z., "Biomass for electricity generation," no date http://www.eia.doe.gov/oiaf/analysispaper/biomass/index.html> (07-02-07).
71. Powers corecard website, "Electricity from: Biomass," no date http://www.powerscorecard.org/tech_detail.cfm?resource_id=1 (07-02-07).
72. U.S. Department of Energy website, Energy Efficiency and Renewable Energy, Biomass Program, "Products," no date, http://www1.eere.energy.gov/biomass/products.html (07-02-07).
73. Energetics Incorporated, for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Biomass Program, "Industrial Bioproducts: Today and Tomorrow," July 2003, http://www.brdisolutions.com/pdfs/BioProductsOpportunitiesReportFinal.pdf (07-02-07).
74. Alakangas, E. Towards international standards – industrial wood pellet standards under development, 21st Euro- pean Biomass Conference and Exhibition 2013, Copenhagen, 3 – 6 June 2013, paper, 3 p.
75. CARB (2009) Proposed Regulation to Implement the Low Carbon Fuel Standard. California Environmental Protection Agency, Air Resources Board, Stationary Source Division, Sacramento, California, 374 pp.
76. Cherubini F, Peters GP, Berntsen T, Stromman AH, Hertwich E (2011) CO(2) emissions from biomass combustion for bioenergy: atmospheric decay and contribution to global warming. Global Change Biology Bioenergy, 3, 413- 426.
77. EC (2012) Proposal for a directive of the European parliament and of the council amending directive 98/70/EC relat- ing to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Brussels, 17.10.2012. COM(2012) 595 final. 2012/0288 (COD). Available: http://ec.europa.eu/energy/renewables/biofuels/doc/biofuels/com_2012_0595_en.pdf.
78. Ikram, Mehrez & Shobana, Sutha & Semaan, Georgeio & Kim, Sang-Hyoun & Kumar, Gopalakrishnan. (2022). Biomass Based Bioenergy: Technologies and Impact on Environmental Sustainability. Journal of Korean Society of Environmental Engineers. 44. 10.4491/KSEE.2022.44.1.1.
79. Nigam PS, Singh A. Production of liquid biofuels from renewable resources. Prog Energy Combust Sci2011;37:52e68.
80. McKendry P. Energy production from biomass (Part 1): overview of biomass. Bioresour Technol 2002;83(1):37e46.
81. Ozturk M, Ashraf M, Aksoy A, Ahmad MSA, editors. Phytoremediation for green energy. Springer; 2015. p. 11e30. http://dx.doi.org/10.1007/978-94-007-7887-0_2.
82. McKendry P. Energy production from biomass (Part 1): overview of biomass. Bioresour Technol 2002;83(1):37e46.
83. [32] Chini Zittelli G, Rodolfi L, Biondi N, Tredici MR. Productivity and photosynthetic efficiency of outdoor cultures of Tetraselmis suecica in annular columns. Aquaculture2006;261:932e43.
84. Taftan Data. 1998. Combustion of fossil fuel, using thermo utilities, MS Excel add-ins. On line: http://www.taftan.com/xl/fossil.html
85. Variny, M., et al. 2021. Advances in Biomass Co-Combu.stion with Fossil Fuels in the European Context: A Review. Processes. 9, 100 https:// www. mdpi. com/ 2227- 9717/9/ 1/ 100.
86. Vassilev SV et al (2013) An overview of the composition and application of biomass ash. Part 1. phase-mineral and chemical composition and classification.
87. Kosaric, N., & Blaszczyk, R. (1992). Industrial effluent processing. In: J. Lederberg (Ed.), Encyclopedia of microbiology (Vol. 2, pp. 473–491). New York, NY: Academic Press. https://eng.libretexts.org/Bookshelves/Biological_Engineering/Introduction_to_Biosystems_Engineering_(Holden_et_al.)/01%3A_Energy_Systems/1.02%3A_Biogas_Energy_from_Organic_Wastes.
88. Capareda, S. (2014). Introduction to biomass energy conversions. Boca Raton, FL: CRC Press. https://doi.org/10.1201/b15089.
89. Hamilton, D. W. (2012). Organic matter content of wastewater and manure, BAE 1760. Stillwater: Oklahoma Cooperative Extension Service.

90. Lettinga, G., van Velsen, A. F., Hobma, S. W., de Zeeuw, W., & Klapwijk, A. (1980). Use of the upflow sludge blanket (USB).
91. reactor concept for biological wastewater treatment, especially for anaerobic treatment. Biotech. Bioeng., 22(4), 699-734. doi.org/10.1002/bit.260220402.
92. Lilienthal, P., & Lambert, T. W. (2011). HOMER. The micropower optimization model. Getting started guide for HOMER legacy.
93. Ver. 2.68. Boulder, CO and Golden, CO: Homer Energy and NREL USDOE.
94. Maglinao, R. L., Resurreccion, E. P., Kumar, S., Maglinao, A. L., Capareda, S., & Moser, B. R. (2019). Hydrodeoxygenationalkylation
95. pathway for the synthesis of a sustainable lubricant improver from plant oils and lignin-derived phenols. Ind. Eng. Chem. Res., 1-50. https://doi.org/10.1021/acs.iecr.8b05188.
96. Pimentel, D. (2003). Ethanol fuels: Energy balance, economics, and environmental impacts are negative. Natural Resour. Res., 12(2), 127-134. https://doi.org/10.1023/A:1024214812527.
97. Stout, B. A. 1984. Energy use and management in agriculture. Belmont, CA: Breton Publ.
98. Watts, S., & Hertvik, J. (2018). CapEx vs OpEx for IT & Cloud: What's the difference? The Business of IT Blog, January 2 issue. Retrieved from https://www.bmc.com/blogs/capex-vs-opex/.
99. Zah, R, Boeni, H, Gauch, M, Hischier, R, Lehmann, M, and Waeger, P. Life cycle assessment of energy products: environmental impact assessment of biofuels. Switzerland: N. p., 2007. Web.
100. Balachandra, P. & Ravindranath, N.H. & Lakshmi, C Sita & Manuvie, Ritumbra. (2011). Biofuel production and implications for land use, food production and environment in India. Energy Policy. 39. 5737-5745. 10.1016/j.enpol.2010.07.044.
101. Lugo, E. (2007). Ecosystem services, the millennium ecosystem assessment, and the conceptual difference between benefits provided by ecosystems and benefits provided by people. *J. Land Use & Envtl. L.*, *23*, 243.
102. Rivera-Ferre, M. G. (2008). The future of agriculture: Agricultural knowledge for economically, socially and environmentally sustainable development. EMBO reports, 9(11), 1061-1066.
103. Mekala, N. K., Potumarthi, R., Baadhe, R. R., & Gupta, V. K. (2014). Current bioenergy researches: Strengths and future challenges. In Bioenergy research: advances and applications (pp. 1-21). Elsevier.
104. Cherubini, F., & Strømman, A. H. (2011). Life cycle assessment of bioenergy systems: state of the art and future challenges. Bioresource technology, 102(2), 437-451.
105. Walter V. Reid, Mariam K. Ali, Christopher B2019. Field The future of bioenergy https://doi.org/10.1111/gcb.14883.

Nicolae Scarlat, Jean-Francois Dallemand 2019, Future Role of Bioenergy https://doi.org/10.1016/B978-0-12-813056-8.00010.

107. Matthias Jordan, Volker Lenz, Markus Millinger, Katja Oehmichen 2019 , Daniela Thrän Future competitive bioenergy technologies in the German heat sector: Findings from an economic optimization approach https://doi.org/10.1016/j.energy.2019.116194