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Review

Second-Generation Bio-Fuels: Strategies for Employing Degraded Land for Climate Change Mitigation Meeting United Nation-Sustainable Development Goals

Atreyi Pramanik [1], Aashna Sinha [1], Kundan Kumar Chaubey [1,*], Sujata Hariharan [1], Deen Dayal [2], Rakesh Kumar Bachheti [3], Archana Bachheti [4] and Anuj K. Chandel [5,*]

1 Division of Research and Innovation, School of Applied and Life Sciences, Uttaranchal University, Arcadia Grant, P.O. Chandanwari, Premnagar, Dehradun 248007, Uttarakhand, India
2 Department of Biotechnology, GLA University, Mathura 281406, Uttar Pradesh, India
3 Centre of Excellence in Nanotechnology, Department of Industrial Chemistry, Addis Ababa Sciences and Technology University, Addis Ababa P.O. Box 16417, Ethiopia
4 Department of Environment Science, Graphic Era University, Dehradun 248002, Uttarakhand, India
5 Department of Biotechnology, Engineering School of Lorena (EEL), University of São Paulo (USP), Estrada Municipal do Campinho, N°. 100, Lorena, São Paulo 12602-810, Brazil
* Correspondence: kundan2006chaubey@gmail.com (K.K.C.); anuj10@usp.br (A.K.C.)

Abstract: Increased Greenhouse Gas (GHG) emissions from both natural and man-made systems contribute to climate change. In addition to reducing the use of crude petroleum's derived fuels, and increasing tree-planting efforts and sustainable practices, air pollution can be minimized through phytoremediation. Bio-fuel from crops grown on marginal land can sustainably address climate change, global warming, and geopolitical issues. There are numerous methods for producing renewable energy from both organic and inorganic environmental resources (sunlight, air, water, tides, waves, and convective energy), and numerous technologies for doing the same with biomass with different properties and derived from different sources (food industry, agriculture, forestry). However, the production of bio-fuels is challenging and contentious in many parts of the world since it competes for soil with the growth of crops and may be harmful to the environment. Therefore, it is necessary to use wildlife management techniques to provide sustainable bio-energy while maintaining or even improving essential ecosystem processes. The second generation of bio-fuels is viewed as a solution to the serious issue. Agricultural lignocellulosic waste is the primary source of second-generation bio-fuel, possibly the bio-fuel of the future. Sustainable practices to grow biomass, followed by their holistic conversion into ethanol with desired yield and productivity, are the key concerns for employing renewable energy mix successfully. In this paper, we analyze the various types of bio-fuels, their sources, and their production and impact on sustainability.

Keywords: greenhouse gas; biomass production; second-generation bio-fuels; sustainability; environment; climate change

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1. Introduction

Natural resource depletion and finite fossil fuel supplies have put tremendous strain on the world's expanding human population. Global concerns about declining ecosystem services and rising greenhouse gas emissions demand immediate attention. This decade (2021–2030) has been dubbed the "Century on Natural Regeneration" by a number of international organizations, including the United Nations (UN), to quicken the achievement of the UN Sustainable Development Goals (SDG) [1]. Based on the most recent statistics and projections, the SDGs Report 2022 offers a thorough analysis of how the 2030 agenda for Sustainable Development has progressed. It maintains record of regional and global achievement towards the 17 Goals through in-depth analyses of particular indicators for each Goal. According to the report, cascading and related problems are seriously endangering both the 2030 plan for sustainable development and human life. The importance and magnitude of the issues we confront are emphasized throughout the report.

All of the SDGs are impacted by the convergence of crises, which are primarily caused by COVID-19, climate change, and wars as well as issues with food and nutrition, health, learning, the ecosystem, and peace and security SDGs. The study explains how years of gains in eradicating hunger and poverty, enhancing health and education, supplying necessities, and a lot more have been reversed. It also highlights areas that must get critical intervention if the SDGs are to be preserved and significant advancements for people and the environment accomplished by 2030 [2].

For the purpose of addressing climate change challenges at a regional, national, and international level, numerous research efforts are being made to address the present concern of recovering natural resources, such as the degraded land resources and second-generation biomass or bio-energy crop production. Complete investigation and optimization, though, continue to be a major ground obstacle for sustainability. It is necessary to thoroughly investigate the many options and technological aspects for second-generation biomass crop plantation from the degraded areas in order to address these difficulties in bio-energy production [3].

Further, the achievement of the UN-SDGs for global targets (Figure 1) would be research and development of various optimization methodologies for sustainable bio-energy production in industrial systems.

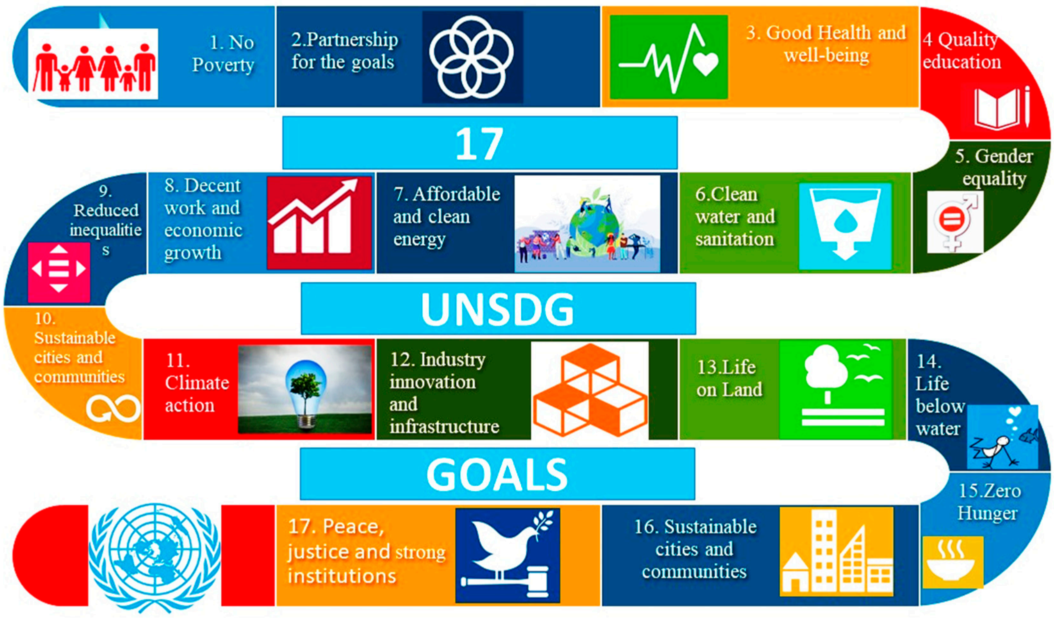


Figure 1. 17 UN-SDG goals.

The scope of important studies focused on forestry techniques, phytoremediation technologies, biomass, and bio-energy crop production for restoring degraded lands and reducing the effects of climate change would be expanded by this holistic approach from the ground to industrial systems [4]. As they are an alternative energy source that is in danger of going extinct, we will analyze the various types of bio-fuels, their sources, and their manufacturing processes in this review study. The circular economy strategy puts forward the idea of trash as a benefit, opening up fresh viewpoints and proving its environmental sustainability [5]. System analysis in conjunction with bio-processing and biomass conversion processes could provide additional opportunities for optimization research. Utilizing various accounting techniques could assist in evaluating the viability of manufacturing systems from the ground, and utilizing various accounting techniques could aid in evaluating both the industrial systems' conversion processes as well as the long-term viability of production methods [6]. However, many pilot and demo facilities have lately been planned, with research accomplishments predominantly happening in North America, Europe, and a few developing countries. International Energy Agency (IEA) forecasts indicate that demand for bio-fuels, particularly second-generation bio-fuels, will increase quickly in an energy industry that aims to stabilize atmospheric CO_2 at 450 parts per million (ppm).

Recently, both the United States (US) and the European Union (EU) passed comprehensive bio-fuel support policies. Due to the size of the two markets and their significant bio-fuel imports, the US and EU mandates could be a major driving force behind the development of second-generation bio-fuels globally. Additionally, current IEA analysis predicts a loss in national production in both the US and EU that would need to be filled by imports [7]. Brazil and China, whose infrastructure permits the export of bio-fuels and whose prototype facilities are already operational, may benefit most from this gap in second-generation bio-fuels. Due to a lack of R&D activity, inadequate infrastructure, and a shortage of skilled personnel, other countries, such as Cameroon and Tanzania, may face considerable difficulties in meeting the demand for second-generation bio-fuels in the EU and US in the imminent future [1]. In this review paper, we discuss the different types of bio-fuels, their sources, and their method of production as an alternative source of energy that is on the verge of extinction.

2. Methodology

This article presents a comprehensive literature review with the aim to critically analyze the methods of bio-fuel and bioenergy production, and sustainable development goals, within the scope of renewable fuel production.

For data collection, first, a search was conducted through database search engines like PubMed, Scopus, Google Scholar, and Directory of Open Access Journal (DOAJ) using keywords such as (a) "Biomass" AND "Pretreatment", (b) "Saccharification" AND "Ethanol fermentation", (c) "Second generation bio-fuel production", (d) "Forestry practices for biomass production" (e) "SDGs", (f) "Food and fuel debate" AND "Climate change mitigation", among others. This yielded 150 studies, and this number was reduced to 100 studies after removing duplicates. Following this, 61 articles were selected depending on the criteria and scope (Figure 2).

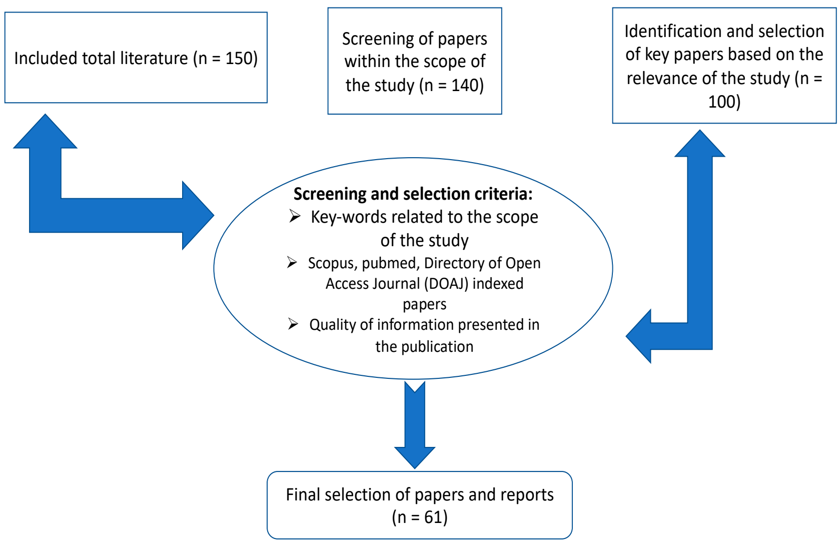


Figure 2. Flow diagram showing the selection criteria and procedure of second-generation bio-fuels production.

3. Bioenergy from Feedstocks

Utilization of marginal land for bio-fuel production has drawn a lot of interest due to its potential to produce bioenergy feedstock while reducing the use of fertile agricultural land for food/feed crop production. According to Gopalakrishnan et al. (2011), at least two criteria allow for the classification of 1.6 million ha, or 4 million acres, of land (or around 8% of the total land area) as marginal. On this land, second-generation lignocellulosic bioenergy crops like switch-grass (*Panicum virgatum* L.), miscanthus (*Miscanthus giganteus*), natural prairie grasses, and short-rotation woody crops might be cultivated without substantially affecting the production of food or feed [8].

Forest weed *Lantana camara* (*L. camara*) is poisonous. In many nations throughout the world, it is known as an invasive weed. The plant *L. camara* is extremely competitive. It swiftly covers an open area. It seriously harms the local biodiversity and environment. Although it is an ecologically resilient species, the infestation density rather than the species' vast distribution is a potential future threat to ecosystems. Due to its invasiveness, capacity for spread, and negative effects on the economy and ecology, it is considered one of the worst weeds in approximately 50 countries. The weed engulfs native vegetation in dense, impenetrable thickets. A dominant weed species has been implicated with threats to ecology and biodiversity. However, *Lantana* generates a significant amount of woody biomass used for energy purposes [9]. The invasive species *Prosopis juliflora* (*P. juliflora*) is another one. Millions of hectares of farmland and forest have been blanketed nationwide. The ecological effects of *P. juliflora* expansion are numerous. The loss of local flora and animals as well as diminishing water bodies are associated with its existence. The weed has been used for a variety of purposes. Its wood is used to make activated carbon and charcoal. Its wood is highly calorific, extensively dispersed throughout India's many agro-climatic zones, and anticipated to play a significant part in upcoming bioenergy programs. The habitat for wildlife is negatively impacted by these two invasive species. *L. camara* has less ash than other plants. *P. juliflora* biomass (2.3%) and *L. camara* biomass (3.8%) provide the additional benefit of these species' briquettes. Another crucial factor for contrasting the fuel characteristics of various feedstock is the fixed carbon concentration. A fuel's high energy value is correlated with its high fixed carbon content [9,10].

4. Eucalyptus as a Source of Paper and Pulp Production

One of the necessities for daily life is paper, and the paper industry is the foundation of the economy in many Eucalyptus-growing countries. Other industries, including education, communication, and product packaging, benefit from the use of paper and paper-based products. It was assumed that India's consumption of paper and paperboard is projected to double from 10 Mt yr^{-1} (WWF, 2010) [11]. Pulp and paper mills will need to decrease their consumption of forest products, and counties need to increase their forest plantations, because of the execution of national and state government policies toward forest protection and afforestation. Additionally, the government is promoting the establishment of plantations on unused and degraded land. The paper industry will have to rely more and more on imports of pulp or finished paper goods due to the generally limited availability of raw resources. In India, eucalyptus has been cultivated in about 170 different species, varieties, and provenances; the most notable and popular of them is the eucalyptus hybrid, also known as Mysore gum, which is a variety of *Eucalyptus tereticornis*. Eucalyptus hybrids play a major role in providing wood, and house-hold applications in Indian environments, due to its: (a) fast growth, (b) the ability to overtake weeds, (c) a fire-resistant character, and (d) the capacity to adapt to a wide range of edaphoclimatic conditions [11].

5. Bio-Fuels

Green Fuel refers to clean fuels, which are also known as bio-fuels. Substrates that produce heat when combined with oxygen, i.e., during the combustion reaction, form fuel. Green fuels originated from green or biological sources; therefore, they add less load on the environment; i.e., they are eco-friendly and also bio-renewable [12]. Bio-fuels are the kind of energy materials which are obtained from the renewable resource materials (biomass) produced in agricultural land and natural aquatic systems as the primary products of photosynthesis (Tables 1 and 2) [13]. Interest in producing bio-fuels is enormously increasing for the following reasons:

- Cutting down the dependence on petroleum (crude and products)
- Growing environmental concerns
- Economic concerns.

Table 1. Different feedstocks contributing to production of bio-fuel.

Feedstock	Condition	Bio-Fuel Production (L/ha)	Reference
Corn	Hydrolysis/fermentation	3800	[14–16]
Sugarcane	Fermentation	7200	[14,17–19]
Sugar beet	Hydrolysis/fermentation	7900	[14,20–22]
Wheat	Hydrolysis/fermentation	1700	[14,23,24]
Cassava	Hydrolysis/fermentation	137	[14,25,26]

Table 2. Raw materials used for second-generation bio-fuel production.

Second Generation Fuel (Raw Material)	Strategy	Reference
Soybean oil	Dominant biomass for the manufacturing of biodiesel	[27]
Palm oil	Dominant biomass for the manufacturing of biodiesel	[27]
Rapeseed	Dominant biomass for the manufacturing of biodiesel	[27]
Crude glycerol	Electrochemically converted (uses in the pharmaceutical, cosmetics, food, etc.), thermochemical conversion (Biomass gasification, Biomass pyrolysis, Biomass combustion)	[28,29]
Sunflower stalk (saccharification)	Residue is liquefied to produce bio polyol. Sunflower stalk waste products (strongly condemn) and biodiesel (crude glycerol) are combined to create biopolyol, which can result in the manufacture of polyurethane.	[30]

There are two types of bio-fuels:

- Gaseous fuels like biomethane and biohydrogen
- Liquid fuels like bio-ethanol, biobutanol, bio-gasoline, biokerosene, and biodiesel.

An overview of bio-fuel production is given below. Tables 2 and 3 gives an overview of different types of bio-fuels and method of production.

5.1. Municipal Solid Waste (MSW) as a Source of Biomass

In addition to certain commercial and industrial compost that is comparable in type to home waste and has been dumped in municipal landfill sites, municipal solid waste (MSW) is predominantly waste produced by households. In addition to being a potential liability if it needs to be disposed of, MSW is a sizable resource that can be profitably recovered: for example, through the recycling of commodities like aluminum cans, metals, glass, fibers, etc., or by recovery processes like energy conversion and composting. Countries should follow the waste hierarchy as depicted in Figure 3.

Table 3. Method of production of different bio-fuels.

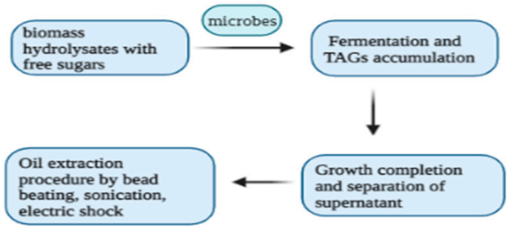
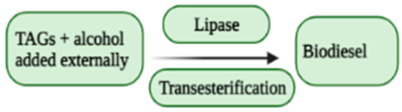
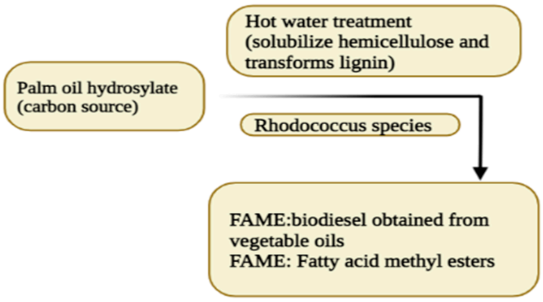
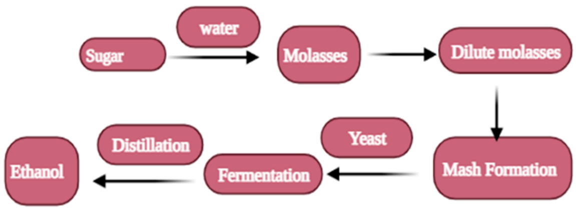
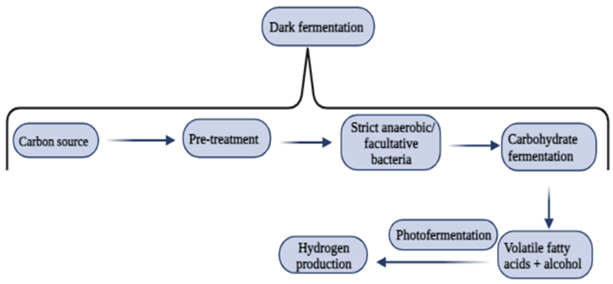
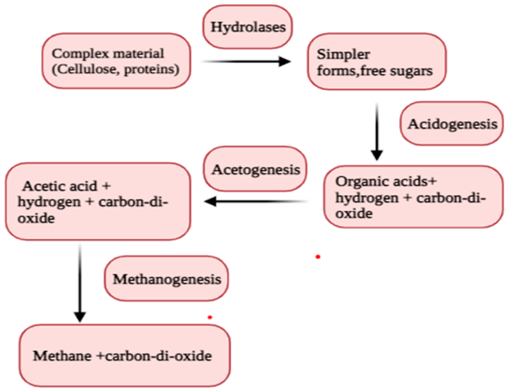
Types of Bio-Fuels	Method of Production	Reference
Biodiesel In-vivo In-vitro Semi In-vitro/In-vivo		[31]
In-vivo biodiesel production		[31]
In-vitro biodiesel production		[31]
Semi In-vitro/In-vivo (Biodiesel production by hot water treatment)		[31]
Bio-alcohol production (Ethanol, propanol, butanol, isobutanol)		[31]
Biogas production		[31]

Table 3. *Cont.*

Types of Bio-Fuels	Method of Production	Reference
Biomethane production		[31]

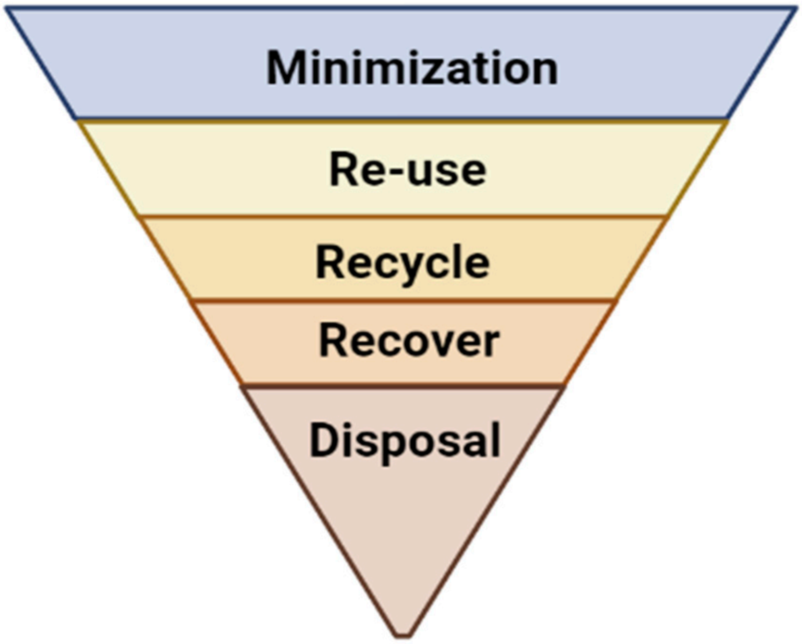


Figure 3. Waste energy inverse pyramid.

The various methods for turning MSW into energy include those shown in Figure 4. These mostly consist of thermo-chemical processes (such combustion, gasification, and pyrolysis) and biological processes (such as anaerobic digestion). All other process paths make use of an improved fuel, with the exception of mass burning or incineration systems. Either separation at the source followed by a straightforward mechanical treatment, like size reduction, or intensive mechanical treatment of MSW to generate Solid Recovered Fuel, can be used to achieve this. Major environmental consequences (or sustainability indicators) of MSW have been subject to life-cycle-based evaluations, which have demonstrated the advantages of MSW energy recovery. These benefits come in the form of decreased leaching into waterways, decreased acid gas emissions, decreased depletion of natural resources (fossil fuels and materials), and decreased soil contamination [32].

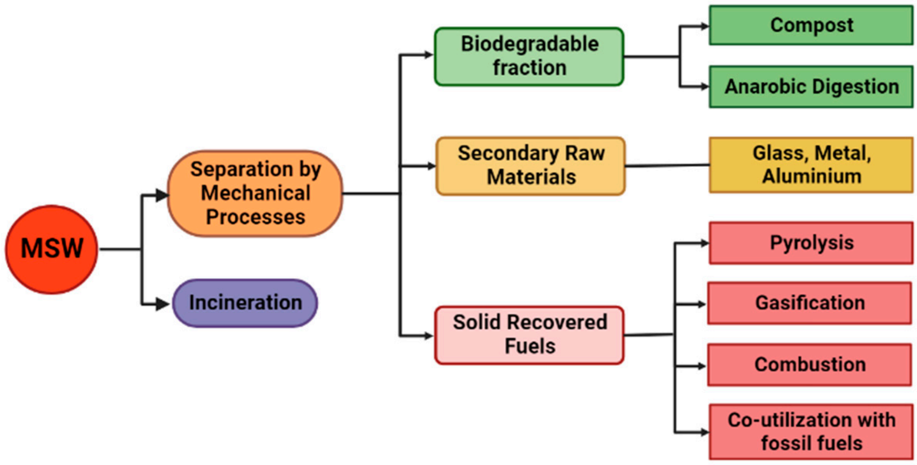


Figure 4. Methods and turning MSW into energy.

5.2. Biomethane Production Technology

Anaerobic processes involve different anaerobic bacteria, utilizing hydrolytic bacteria, acetogenic bacteria, and methanogenic bacteria. Hydrolytic bacteria break down biopolymers like cellulose and proteins to form H_2, CO_2, and low molecular organic acids. Acetogenic bacteria convert the above products into acetate while methanogenic bacteria use acetate and H_2/CO_2 etc. to produce methane.

5.3. Biohydrogen Production Technology

Bio-photolysis refers to the production of hydrogen from water with the help of sunlight by photosynthetic microbes.

$$\text{Water} + \text{Sunlight} \rightarrow \text{Hydrogen}$$

5.4. Biodiesel

The term "biodiesel" refers to a non-petroleum-based diesel fuel created by trans-esterifying vegetable oil or animal fat (tallow) and having long-chain alkyl (methyl, propyl, or ethyl) esters (Figure 5). In automobiles with stock diesel engines, biodiesel may be utilized either by itself or in combination with regular petro-diesel. Biodiesel is distinct from straight vegetable oil (SVO), which is utilized as fuel in certain converted diesel cars (either alone or in a mix). It can be made from vegetable oil or from microbial oil by trans-esterification process. The trans-esterification process could be chemical catalyzed or lipase catalyzed. The current concept of biodiesel is created by converting oils and fats to alkyl esters of monohydric alcohols to solve problems with high viscosity, high boiling point, and reactivity.

Biodiesel is now only defined as the "Monoalkyl" esters of long-chain fatty acids produced from the oils/fats of vegetable and animal sources that meet nearly all the standards of diesels generated from petroleum. Non-edible oils, like Jatropha, Karanja, and minor oils like mowrah, neem, undinahor, waste cooking oils, microbial oil and fatty acid distillates, are potential raw materials for biodiesel. Algal biomass could serve as an ideal feedstock for a spectrum of bio-fuels (biodiesel, bioethanol, biohydrogen), food (single cell protein or food ingredients), and nutraceuticals (vitamins, amino acids, biopigments, and others) [33].

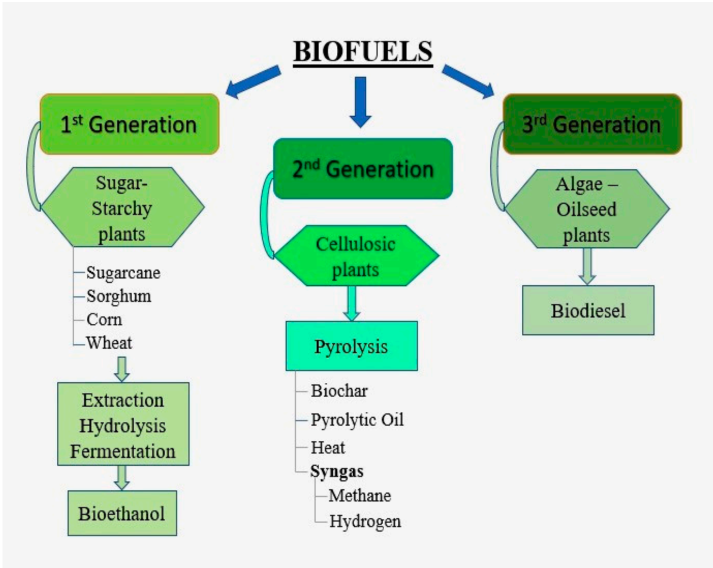


Figure 5. Bio-fuel products from lignocellulosic biomass.

6. Second Generation Bio-Fuels

Using inedible raw materials for the production of 2G bio-fuels, often referred to as "advanced bio-fuels", solves the issue of the "food versus fuels" competition. Furthermore, burning 2G bio-fuels results in balance or even lower correlation carbon emissions (Table 3).

Among the non-food feed stocks employed in novel processes that produced 2G bio-fuels were food waste, manure, spent cooking oil, wood, sawdust, garbage, leftovers from agriculture and food processing techniques (abandoned fuelwood), and energy crops (Figures 5 and 6) [34]. The lignocellulosic remains of crops would be the most plausible options among these sources due to their quantity, widespread availability around the world and throughout the year, and low cost. 2G bio-fuels are not industrially viable due to heterogeneity in structure in their leftovers' composition, which necessitates additional complicated production procedures. Currently, it is projected that 0.4 billion liters of 2G bio-fuels are produced annually: that is, 0.4% of all ethanol produced. Cellulosic ethanol production is predicted to increase to 0.8 billion liters in 2023 by the IEA for advanced bio-fuels [35].

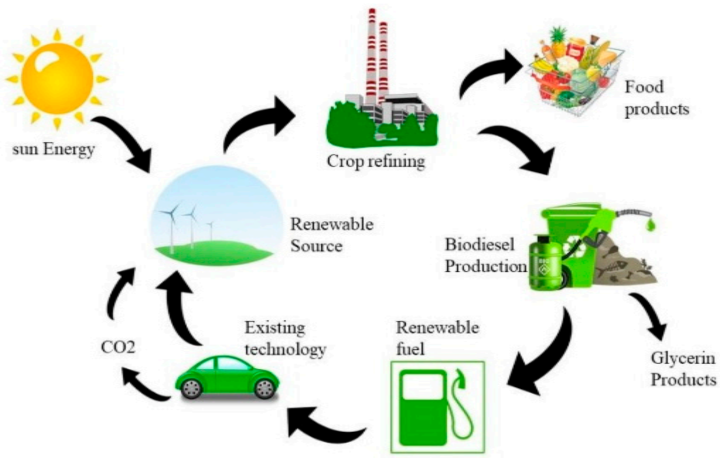


Figure 6. An overview of biodiesel production from algal feedstock.

7. Food vs. Fuel Debate

The dispute around the trade-offs involved in using grains and oilseeds for the production of bio-fuels vs. animal feed and human nourishment is a part of this problem. The relevance of evaluating the sustainability of bio-fuel production and use has increased recently, particularly in light of the need to reduce GHG emissions, the argument over whether to use fuel or food, and the growing need to uphold environmental and social norms [36]. The second generation switched to the development of specialized energy crops like Jatropha in response to the dispute over whether food or fuel should come first. *Jatropha curcas* is a low-cost biodiesel feedstock that has more oil than other species and strong fuel characteristics. It is a feedstock made from inedible oilseeds. Thus, it will not have an effect on food costs or the argument between food and fuel. Jatropha can be used in diesel engines to get a similar level of performance while emitting fewer pollutants than diesel. The crop has a significant positive impact on rural living as well. Additionally, the plant can produce up to 40% more oil per seed depending on weight [37].

Jatropha seed is a crop that is gaining popularity due to a number of factors, including the manufacturing of biodiesel. This is due to its seeds' high oil levels, which can range from 25% to 35%. Jatropha is appealing for more reasons than only its high oil content, however. It is a highly adaptable crop that thrives in dry or semiarid climates and is perennial, drought-resistant, and nutrient-restricted tolerant. The fact that this extremely adaptable crop is not seen as a food crop and does not have to compete for agricultural land offers a potential resolution to the ongoing food vs. fuel conflict. This makes Jatropha an appealing choice for bio-fuel conversion; however, there are still many questions regarding this plant [35]. Figure 7 shows a transition to green fuels from conventional fossil fuels, which will result in the development of clean energy and a carbon-neutral economy empowering employment creation at various levels.

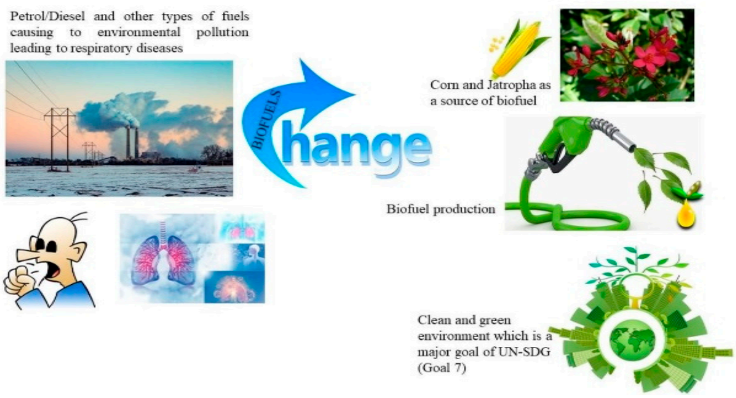


Figure 7. Figure shows that a transition to green fuels will result in a green environment resulting in clean energy.

Sugarcane's strong biomass output is an important biological component that helps the plant create bioethanol with a high positive LCEB (life cycle energy balance) and a positive GHGE (greenhouse gas emission) balance [38]. Low net greenhouse gas (GHG) emissions from sugarcane bio-fuel result in a diminished negative environmental impact as measured by pollution indices. In 2007, it was estimated that Brazil's net emissions of greenhouse gases decreased by 25.8 million tons CO_2 equivalent. With 9.8% fermentable sugars in its juice, sugarcane is the most cost-effective source of bioethanol, whereas sweet sorghum has 11.8%. While sweet sorghum has 21% lignin, 27% hemicellulose, and 45% cellulose with potential ethanol output of 12,938 and 5804 kg per ha, respectively, sugarcane bagasse has 22% lignin, 24% hemicellulose, and 43% cellulose. Although sugarcane is more productive than its rivals (sweet sorghum, sugar beet), more fiber and sugar must still be added to the plant for it to become energy cane. About 50% of the dry mass of sugarcane is made up of sucrose, whereas 14% is made up of fiber. Additionally, the following characteristics make sugarcane a superior option as an energy crop: less flower output, erect growth habit, ratooning ability, drought tolerance, cold tolerance, pest and disease resistance, and rapid early growth. Changing plant cellulose content and total biomass through the control of growth hormones and biomass synthesis pathways may be essential for the development of energy cane [14].

8. Forestry Practices for Biomass Production and Tackling Climate Change Issues

Bio-fuels of the second generation are created from lignocellulosic crops. The technology of this generation makes it possible to separate the plant's cellulose and lignin so that the former may be fermented into alcohol. Many types of biomass can be utilized to create these bio-fuels because biomass is defined as any source of organic carbon. Algae or multiple other products are other possibilities. Biomass energy is produced using a variety of feedstocks, including landfill gases, garbage, and plants like perennial grasses and trees. Wood pellets from forests can be used to produce electricity, heat, and possibly even liquid fuels. The key benefit of biomass is that it cannot be drained like fossil fuels. The fundamental benefit of biomass is that, unlike fossil fuels, it is not exhaustible. Due to the abundance of plants on Earth, biomass has the potential to be a significant way for renewable energy that must be utilized as a long-term replacement for fossil fuels. While burning fossil fuels creates emissions into the environment that leads to climate change, sustainably managed biomass is regarded as being carbon-neutral. This fuel source has had fewer harmful effects on the environment, such as global warming and water and air pollution [39].

It is clear that the loss of fertile land and the requirement to secure the food security of a growing global population are mutually exclusive. It is necessary to continue plants' net carbon uptake in order to lessen climate change. As a result, creating resilient ecosystems depends on both preventing additional land degradation as well as facilitating land rehabilitation. Training, research, dissemination, and slightly higher compared advanced technologies are necessary to enable efficient biomass and bio-energy manufacturing. Recent studies give the following examples of technologies for producing bio-energy from various types of biomass:

- Although old-fashioned biomass practices like firewood and charcoal are highly prevalent in many areas, their effectiveness might be significantly increased by using controlled charcoal manufacture units and capturing solid, liquid, and gaseous fuel portions. Although these bio-energy methods need significant capital to create and maintain, it is challenging to go from traditional to scientifically higher specialized biomass power technologies (combined heat and power schemes, bio-fuels, etc.). This demonstrates the urgent need for eco-friendly, easy integration of low-cost bio-energy technologies with present biomass supplies and technology (i.e., wood chips or pellets from wastes, to replace coal).
- To determine (i) the level and nature of energy demand (such as electricity, liquid fuel, etc.), as well as (ii) the available renewable production to fuel bio-energy units, it is also necessary to examine more complicated systems designed to replace fossil fuels. Although several biological and/or chemical processes can convert biomass into energy, the economic sustainability of these methods in underdeveloped nations is still unknown.
- To enable the development of better energy systems, new bio-energy technologies should be carefully evaluated for their socioeconomic benefits and drawbacks. The merging of biomass resources with low-impact forestry to support the creation of green technologies was a significant result. Boosting energy output while keeping the environment green is difficult, and there are several different approaches to this problem (Figure 7).
- Using methods to cultivate deciduous biomass plants on barren or damaged terrain. Although the technique relies on cautious variety identification across all domains, it

may lead to initially poor yields due to the creation of varied stands, cautious usage, and long-term yield studies.

- Bio-energy leftovers (slurries, burn, and smoke) should be used to stop the degradation of soil nutrients; these can be recycled into soils directly for soil improvement. However, during the generation of ethanol and bioenergy, nitrogen and other important macronutrients for plants are typically lost through chemical activation or exhaust fumes. To maximize regulated absorption and long-term ammonium nutrition while minimizing environmental impact, slow-release fertilizers made from bio-energy wastes (or modified biochar) are a potential option.
- However, the impact of the biomass energy part of the economy on different societies has received little attention. The deployment of bio-energy technology is intended to increase socioeconomic wellbeing in countries where forests are maintained by people (such as in Indonesia and Nepal) [40].

A plan to counteract the damaging effects of tropical habitat destruction is land rehabilitation. Lands are deemed to be degraded when they have poor biotic diversity and edaphic conditions are decreased to such an extent that the land is unable to serve any particular use. In other words, degradation is destruction of ecosystem reserves such biomass, seed banks, soil minerals, and organic matter to a point from where returning to original land quality is not possible. On the other hand, reclamation is the process by which degraded lands are returned to productivity with biotic functions. However, this is a difficult stage as there are limitations of biota. On the contrary, rehabilitation is a process where a degraded land is returned to a fully functional state [41]. Land rehabilitation systems involves reversal effects and a couple of actions:

- Removal of the stress source such as high frequency forest fire, over-grazing, or removal of biomass.
- Addition of species (plants and/or animals) or materials (fertilizers, organic residues or water).
- Managing the soil quality to control the synchronization of release of nutrients and plant uptake.

One of the most important components of land rehabilitation is planting trees. Forests can be brought back to their old form only by tree planting, which henceforth increases biomass production. By planting trees, soil nutrition, soil fertility and soil organic matters are re-established [41].

Borchard et al. (2016) introduced advanced technology and bio-energy techniques to incorporate solid, liquid, and gaseous bio-fuels into current methods for producing green and clean energy (Figure 6) [40]. Two different kinds of bio-fuels were covered. (a) Usually, species with rapid growth rates are chosen for biomass production. Although commonly utilized in the tropics, *Calliandracalothyrsus* and *Gliricidiasepium* do not do well in conditions of water-logged soil. Large tracts of peat land exist in Southeast Asia, and during the rainy season, high water tables are necessary to protect them. Therefore, it is imperative to find woody crops that can produce valuable biomass outputs and are compatible with semi-terrestrial soils. (b) *Calophylluminophyllum, Pongamiapinnata*, and *Reutealistrisperma* are a few of the species that have been discovered and assessed for their capacity to generate oil and convert it into usable liquid fuels.

9. Phytoremediation Technologies for Effective Land Restoration and Biomass Production

A striking method for purifying soils contaminated with a variety of hazardous organic and inorganic substances is phytoremediation. Typically, phytoremediation entails restoring the soil's microbiota, physicochemical qualities, and fertility in order to promote the growth of the suitable climax cover plant. In order to accomplish these goals for land damaged by coal mining, South Africa created a myco-phytoremediation method known as Fungcoal. In the late 1990s, the practice of using eco-friendly plants to remove or make harmless ecological contaminants was known as phytoremediation. Both organic and inorganic pollutants, present in either solid or liquid substrates, or air, were addressed utilizing one or a mixture of phytoextraction, phytodegradation, phyto-stabilization, rhizo-filtration, and phyto-volatilization.

In 2005, phytoremediation was expanded to encompass both plants and the utilization of microorganisms associated with plants for restoring the environment. It was viewed as a practical and non-intrusive bioprocess remediation approach at the time. The development of modelling frameworks, according to its proponents, offers a possibility to capitalize commercially on a phytoremediation strategy by producing value-added goods from biomass. Nevertheless, the cycling of soil organic carbon (SOC) for plant growth is mostly dependent on soil microbes [42]. Recent years have seen growing evaluation of biomass integration in energy production processes to boost the positive effects on the economy and environment. This combination can lessen metal remobilization and assist in removing the financial barriers to phytoremediation. In addition to assisting in meeting the world's energy needs, the commercialization of residual biomass from phytoremediation that can be converted into bioethanol, biodiesel, biogas, and heat, and thus, would also offer a way to promote a bio-based economy for long-term growth.

A process called phyto-mining aims to extract valuable metals from plant biomass. Because these metals are used as raw materials in contemporary industries like batteries and electrochemistry, metals are released into the environment. Therefore, it is paradoxical that they end up as soil contaminants at the conclusion of their life cycle. By retrieving the metals, a process called phyto-mining seeks to break this cycle. The crucial step is leaching the polluted plant biomass with acids in order to recover the adsorbed metal and produce biomass with metal concentrations within the limits of environmental guidelines [43]. The buildup of heavy metals in soil has increased dramatically because of several human (industrial) actions in addition to natural processes.

Due to their non-biodegradability, heavy metals linger in the environment, pose a risk of contaminating crop plants, and may eventually build up in people's bodies due to bio-magnification. Since heavy metals are harmful, they provide a serious risk to both public health and the biosphere. The importance of cleaning up land pollution is therefore crucial. Phytoremediation makes it feasible to ecologically friendly replant soil that has been contaminated by heavy metals. Phytoremediation is the use of plants to remove hazardous substances from the environment or to lessen their bioavailability in soil [39]. Plants can take up ionic compounds from the soil through their root systems. Plants extend their root systems into the underlying ground to form rhizosphere ecosystems that absorb heavy metals and manage their bioavailability, clean up contaminated soil, and preserve soil fertility.

10. Optimization Strategies in Bioprocessing Industries for Efficient Second-Generation Bio-Fuel Production

Given the effects of global warming as well as the depletion of non-renewable resources, there is an urgent need for alternative forms of transportation fuel. The cellulose, hemicellulose, and lignin structural elements of lignocellulosic biomass are presented, together with the technological unit stages of pre-treatment, enzymatic hydrolysis, fermentation, distillation, and dehydration. The goal of the pre-treatment step is to reduce the amount of inhibitors present and increase the amount of carbohydrate surface area available for enzymatic saccharification. Enzymatic hydrolysis yields fermentable sugars, which are then transformed into ethanol by microbial catalysts. Lignocellulose-derived carbohydrates (hemicellulose and cellulose) pave a sustainable platform for the production of not only bio-fuel but also bulk and specialty chemicals in addition to functional oligosaccharides, eventually benefitting lignocellulose bio-refineries [44,45]. Energy demand rises because of population increase and expanding industrialization, yet conventional fossil fuels, especially petroleum, are limited resources that release GHG when burned. Future global energy demands must be met using environmentally responsible and sustainable energy sources.

Researchers, business partners, and governments are consequently very interested in bio-fuels, specifically cellulosic bioethanol, butanol, and biodiesel. Particularly, bioethanol is seen as a possible drop-in fuel that could serve as a substitute for gasoline in the transportation industry [46]. Many people have characterized the growth of bio-fuels as essential for addressing two sides of such an "energy trilemma"—by lowering greenhouse gases through the development of diesel substitutes, and also (especially in the USA) by permitting countries to break their improved energy security by reducing reliance on the global trade of fossil fuels. Only the first generation of bio-fuels has so far seen broad acceptance. Bio-fuels are typically divided into each of two (or rarely up to four) decades or phases of development. The majority of first-generation bio-fuels come from plants that are converted into ethanol, such as sugar cane, corn, or soybeans. Second-generation bio-fuels, which have not yet been extensively accepted commercially, convert lignocellulosic biomass—typically, "deciduous tree" agricultural waste, but sometimes specifically grown plants like switch grass or *Miscanthus*—into fuels via a range of physical, biological, or chemical methods (and other useful chemicals) [47].

11. Highlights from COP26 Agenda towards Net Zero Emissions through Bio-Fuels Implementation

The Conference of the Parties (COP) to the UN Framework Convention of climate change, alternatively known as the climate summit event, brings together governments to unanimously discuss and review how climate change and global warming can be managed. The 26th meeting called COP26 was held at Glasgow, Scotland. The following are the four goals of COP26 that need to be achieved [48]:

Goal 1: "Secure global net zero by mid-century and keep 1.5 degrees within reach". Carbon neutrality or zero carbon emission is to be reached by 2050 and the global warming temperature should be below +1.5 degree centigrade. To achieve this deliverable, countries are required to fast-track the phase-out of coal and encourage investments in renewable energy. This can be done by restricting deforestation and gearing up to electric vehicles.

Goal 2: "Adapt to protect communities and natural habitats". The climate is changing due to human behavior and deforestation. It will continue to change even if there is carbon emission reduction. COP26 aimsto encourage countries affected by climate change to protect and restore the ecosystem. It encourages building defenses and installing warning systems in areas, helping infrastructure and agriculture to be more resilient to avoid loss of homes, lives, and livelihood.

Goal 3: "Mobilize finance". To achieve the first two agendas, approximately $100 billion is required per year. As a helping hand, international financial institutions must play their role and work towards the releasing of funds in private and public sector finance. This step is essential to secure global net zero.

Goal 4: "Working together to deliver". COP26 looks forward to achieving the challenges discussed only when countries work together. It urges to turn ambitions into action by speeding up collaboration between governments, businesses, and civil society to deliver goals faster than stipulated time.

Concisely, COP26 urges every country to come forward and help hand-in-hand with the vision of net zero carbon emission, low deforestation, and renewable economy.

12. Sustainability Assessment of Bio-Fuels

Sustainability is showing a growing trend in terms of paper publications, which reflects the fact that people are interested in improving the environment. Nevertheless, COP26 also demonstrates that not all nations are eager to assist this transformation, and that it will ultimately be difficult to do so given the stark inequalities in growth, emission levels, economic production factors, efficiency, and social repercussions [49].

- Bio economy: A bio economy is defined by the European Commision as an economy which uses renewable biological resources [50]. A bio-economy involves several sectors like agriculture, forestry, fishing and aquaculture, and the manufacture of food, beverages, and tobacco, etc. It is categorized under three main standpoints: (i) the bioecology vision; (ii) the biotechnology vision, and (iii) the bioresource vision [51].

Bioeconomy sectors and sub-sectors investigated in some countries showed vast variations in their objectives and strategies. Table 4 summarizes the objectives and priorities of different countries.

Table 4. Objectives and priorities of some countries for their bioeconomic growth.

Name of Country	Priorities/Objectives	Reference
Argentina	Bio economy is seen as tool for sustainable development Recognized as a positive substitute for new behavior generation Source of employment to face the stern challenge of climate change	[52] [53]
Germany	Country has primacy for progressing towards a knowledge-based bio economy The priorities include: the creation of a reliable supply of high-quality food; the conversion of an economy based on fossil fuels to one that is more resource- and raw-material-efficient while preserving biodiversity and soil fertility	[52] [54]
Malaysia	Significant donor to economic growth, that provide benefit to society via innovations in agricultural productivity, inventions in healthcare and implementation of sustainable industrial processes.	[52]
Netherlands	The utilization of renewable natural resources and wastes offers Dutch enterprises economic opportunity, as do CO_2 emissions, the circular economy, and knowledge of the limited nature of fossil fuels.	[52,55]
South Africa	Objective is to make the country economically sound using renewable feedstock, particularly in industrial and agriculture sectors The goal is to have a low-carbon economy	[56] [52]

- Environment: The pollution caused by petroleum hydrocarbons, oil, and heavy metals is becoming an increasingly significant problem because of the increased demand for crude oil and products related to crude oil in many fields of application. Due to the ecological harm it causes to terrestrial, aquatic, and marine ecosystems, this pollution has attracted a great deal of attention. Recently, biosurfactant compounds have drawn a lot of attention since they are seen as a viable solution and environmentally friendly material for remediation technology. The unique trait of biosurfactants is that they minimize and lower the interfacial tension of liquids. These qualities make it possible for biosurfactants to be used in a range of industrial situations, including emulsification, de-emulsification, biodegradability, foam generation, cleaning efficiency, surface activity, and detergent composition [57].
- Surfactants' primary job is to reduce interfacial tension; emulsifiers, on the other hand, progressively bind to the surface of the droplet and provide longer-term stability. Many synthetic surfactants and emulsifiers have significant levels of toxicity and ecological effect, which has sparked interest in more natural compounds like biosurfactants and bio-emulsifiers. The primary sectors connected to human health, including pharmaceuticals, food, and cosmetics, are interested in these bio-based surface-active compounds, many of which have previously been discovered and used extensively [58].
- Bio-fuel productions offer several employment opportunities at various levels. Beside job creation, this sector offers unique economic support to farmers, in turn strengthening the rural economy [59]. A bio-fuel driven economy will give a big impetus to the circular economy, eventually developing a renewable economy. Microalgae have the potential to deliver a value-based product using waste from dairy industries. Microalgae cultivation using dairy waste can provide biolipids, carotenoids, aminoacids, enzymes, and other high value products. Recently, Gramegna et al. [60] obtained lipids (12% to 21% (*w*/*w*)) from *Auxenochlorella protothecoides* cultivated on dairy-wastes, showing a high lipid productivity of ~0.16 g/L/d.

- The governmental sector along with the private sector should make concerted efforts to develop the circular economy globally, offering large-scale employment for the development of a better society and finally addressing the UN-SDG goals of poverty alleviation, employment, and climate change.

13. Limitations

The production of bio-fuel is a complex process involving many process configurations. First-generation (1G) ethanol production is a well-established process. It is produced directly from sugars from sugarcane molasses, corn grains, and other starchy and sugar feedstock. Brazil and USA are global leaders in production of 1G ethanol from sugarcane molasses and corn grains, respectively. Blending of 1G ethanol in petroleum is being employed in many countries. However, 2G ethanol production needs diversified process configurations involving pretreatment, enzymatic hydrolysis, and fermentation, making the process costly and time consuming. Agricultural residues such as sugarcane biomass (bagasse and straw), rice straw, and corn stover, among others are principal feedstock for 2G ethanol production. However, technical maturity and economic viability of the 2G ethanol process are two major hindrances for the successful deployment of lignocellulosic bio refineries [61,62].

Another promising bio-fuel is biodiesel, which also has significant momentum in world. Vegetable oil, oil from seed yielding crops, and microalgae are principal feedstock explored for biodiesel production. However, the cost of production and regular availability of feedstock with affordable price, and food preference over to bio-fuel production, are the major limitations to making biodiesel a successful renewable fuel alternative. Beside the technical maturity and cost of the production process, the use of sugars and oil as raw material for bioethanol and biodiesel has an important role in the success of bio-fuel production. More research towards the development of a robust and simplified process employing low-cost feedstock, preferably grown on marginal land proven at an industrial scale, is required for bio-fuel production at commercial scale.

14. Future Prospects

To assure the creation of effective forest-based bio-energy systems, a variety of groups of research and development for the bio-energy area are needed:

(a) Creating strategies for forest-based bio-energy that are tailored to: (a) regional energy needs; (b) socioeconomic and environmental factors to support successful implementation; and (c) delivering advantageous groupings of renewable energy kinds (e.g., bioenergy, water energy, etc.).
(b) Creating straightforward evaluation tools to facilitate the creation of strategies for the production of sustainable and financially viable forest-based bio-energy (covering biomass manufacture, bio-energy technologies, efficient recycle of deposits and effective policies).
(c) Evaluating forest community-based bio-energy methods for their socioeconomic and environmental effects as solutions to advance energy security and alleviate poverty in emerging nations.
(d) Inspiring administrations to create laws and guidelines that encourage the growth of forestry-based bio-energy in training, economic incentives, and the advancement of bio-energy activities.

With increasing pollution and global warming, icebergs are melting at an alarming rate. Scientists fear that if the current condition persists, the water body of the globe, which covers 70% of the planet, will increase to a far greater extent, which will be a matter of concern for the human race. Therefore, it is high time that people should be aware and take care of the environment. Deforestation is another concern for increasing global warming. With phytoremediation being a solution, people should plant more trees and decrease the use of fossil fuels to reduce air pollution.

15. Conclusions

Bio-fuels area promising renewable and sustainable energy alternatives that can help in addressing the issues of environmental pollution. There are different types of bio-fuels that are used, the production of first-generation bio-fuels has significant constraints, and second-generation bio-fuel methods have been developed. These issues can be resolved, and second-generation bio-fuels can produce a higher percentage of ethanol sustainably and inexpensively with greater environmental advantages. In order to increase the quantity of bio-fuel that can be produced sustainably utilizing biomass, second-generation bio-fuel methods are used. Numerous techniques exist to generate renewable energy from organic and inorganic environmental assets (such as sunlight, air, water, tides, waves, and convective energy), as well as a number of technologies that do the same with biomass with various characteristics and derived from various sources (e.g., food industry, agriculture, forestry). However, the manufacture of bio-fuels is difficult and controversial in many regions of the world since it competes for soil with the availability of crops, and could harm the ecosystem. As a result, wildlife management practices are required to generate sustainable bio-energy while preserving or even enhancing crucial ecosystem processes.

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