

# Biomass and Bioenergy Solutions for Climate Change Mitigation and Sustainability

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## **Chapter 1**

Bioenergy: Social, Economic, and Environmental Impacts..... 1

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As we know that escalating population demand and technological advancement lead us towards a new world dominion power, but with that, there is huge pressure on resources due to an increase in consumption at all levels globally. This leads to revamping environmental motifs all over the world and non-renewable sources are estimated to be not rehabilitating soon. In this case, bio-energy is energy presented as a major opportunity to address the issues of climate change by reducing carbon emissions. This chapter explore bioenergy.

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Life Cycle Assessment of Biofuels: Challenges and Opportunities ..... 22

*Majorie Moraa Nyasani, Machakos University, Kenya*

*Victor Odhiambo Shikuku, Kaimosi Friends University, Kenya*

To address energy security and climate-change concerns, substitutes are needed for petroleum-based transportation fuels. In addition to electricity and natural gas, biofuels are emerging as an important class of substitutes. The promotion of biofuels as energy is mainly driven by the perspective of oil depletion, concerns about energy security, and global warming. However, results published in the past few decades present conflicting pictures regarding the energy efficiency and sustainability of biofuels. To adequately address these real or apparent contradictions, a life cycle assessment (LCA) of biofuels is indispensable. “Life cycle” refers to all stages of a process: from the cradle, that is, raw material extraction through manufacturing, distribution, and use to ultimate disposal. This chapter discusses the benefits and limitations of biofuels from an LCA standpoint. The discrepancies and strengths in LCA of biofuels are critically analyzed and opportunities are highlighted. LCA of biofuels is shown to be critical to informing policy and for practical application.

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*Sunil Kumar Verma, B.N. College of Engineering and Technology, Lucknow, India*

Entrepreneurism is vital as entrepreneurs push technological change and innovation, consequently generating economic growth. Bio-energy entrepreneurship is the focal point of this chapter, along with entrepreneurial motivations, opportunities, and market drivers. Market drivers include government policies, trends in energy use, and progression of the energy sector into more renewables. Several factors influence entrepreneurs, which involves several factors ranging from the environment to economics, pioneering spirit, and social factors. With the help of entrepreneurial motivations and market drivers, individuals can easily visualize and plan all the bio-energy sector opportunities. Bio-energy entrepreneurs moderate the market of transformation of biomass to energy. The bio-energy field is filled with stories of failures, successes, and everything in between. There is a marginal difference between a failure story and a success story in the modern bio-energy sector, which narrow down to timing.

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*Sunil Kumar Verma, B.N. College of Engineering and Technology, Lucknow, India*

*Prashant Kumar, Department of Bioinformatics, Kalinga University, Raipur, India*

Energy is one of the most precious and demanded commodities among various industries and consumers to sustain the current lifestyle. Energy is a crucial element, which unswervingly influences the country's economic development. Numerous methods are adopted to reduce global warming, embracing clean energy from wind, solar, and biomass sources. This chapter speaks about the current situation of energy demand, the innovations in biofuel sources, and the obstacles regarding the commercialization and production of microalgal biofuel.

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*Kannadhasan S., Study World College of Engineering, India*

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Changes in weather patterns over decades or longer periods of time are referred to as climate change. Natural and human forces both contribute to climate change. Since the Industrial Revolution, humans have contributed to climate change through emitting greenhouse gases and aerosols, as well as changing land use, leading global temperatures to rise. More storms, floods, droughts, and rising sea levels may result from increasing global temperatures and the melting of ice sheets, sea ice, and glaciers. The sun's rays supply energy to the whole world. GHGs are required to trap heat and maintain a temperature that permits life to flourish on the planet. The greenhouse effect is a natural and necessary occurrence for life on Earth to survive. If the greenhouse effect did not exist, the world would be around 33°C cooler right now. Humans have contributed to the increase in atmospheric GHGs via rising fossil fuel usage and deforestation in recent decades. Increased GHG emissions have been the primary cause of global warming during the last century.

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The planet's limited natural fossil fuel reserves are anticipated to be very soon owing to massive usage. Biofuels would be a critical alternative source that may reduce global warming and CO<sub>2</sub> emissions. The food-versus-fuel dilemma is, however, one of the key drawbacks of first-generation biofuels like corn ethanol, sugarcane ethanol, etc. Cellulose and hemicellulose, the primary constituents of lignocellulosic feedstocks, could be reduced to sugars by either thermochemical/biological processes before being fermented to generate biofuels. However, owing to structural heterogeneity, more complicated operational techniques are required before the production technology can be commercialized, and several challenges must be addressed. This chapter provided an assessment of various feedstocks, availability, various processing techniques, obstacles, and current technical developments in the generation of biofuels from biomass.

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*Bela Khiratkar, Ajeenkya D.Y. Patil University, India*

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Biogas is a renewable natural gas used in production of energy which is generated by breakdown of organic matter by anaerobic digestion. It is a composition of methane, carbon dioxide, and some other gases in small quantities. The most common natural resources for production of biogas are aquatic sediments, animal waste, crop residues, wastewater sludge, and many others. Some other sources are landfills, water lagoons, etc., which are a result of human activity. There are several technologies used for biogas production, mainly biodigesters, wastewater treatment plants, and landfill gas recovery systems. Production of biogas is highly dependent on the feedstock availability and the policy support by the government.

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With the increasing population, there are problems like the shrinking of arable land, pollution, and feeding the entire growing population high-quality food and reaching consumer demand, and the list goes on. Novel superfoods are rich in nutrition and produced with the most sustainable methods, including algae, specifically microalgae. Microalgae have been studied for decades. Microalgae are one of the largest and most poorly understood organisms on planet earth, but in recent years, the research has been increased for the search of renewable and sustainable energy sources. Microalgae don't require much land for cultivation and thus do not compete with conventional agricultural land. Microalgae can double their size in 24 hours. CO<sub>2</sub>, solar rays, inorganic nutrients, and water are the basic requirements for them to

grow. There are microalgae and macroalgae (e.g., seaweed) that grow in saline and hypersaline water. This chapter presents the promising potential of algae (microalgae and macroalgae) as a superfood.

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Biofuels From Macroalgae: A Sustainable Alternative to Conventional Energy Resources..... 148

*Debraj Biswal, Government General Degree College at Mangalkote, India*

*Dipanwita Sarkar (Paria), Chandernagore College, India*

The steep rise in human population together with the simultaneous growth of urbanization and industrialization has triggered overuse of fossil fuels in the recent years. However, they are non-renewable and release carbon dioxide causing global warming. In this context, biofuels come as excellent substitutes because they are renewable and eco-friendly. They are obtained from biological products and include biodiesel, biomethane, bioethanol, and biohydrogen. They are classified into first, second, and third generation fuels depending on the biological feedstocks being used. Of these, the third-generation fuels, obtained from marine resources like algae, have attracted special research interests because they do not rival the food crop production or depend on land and freshwater for their cultivation. However, the potentialities of macroalgae as a biofuel resource have not been investigated thoroughly. The chapter tries to outline all the aspects of biofuel production from macroalgae pointing out the scopes for future research.

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A Source of Future Energy: Gas Hydrates..... 170

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Natural gas hydrate (NGH) has emerged as a future source of energy for the world that can fulfill the future energy demand. The natural gas hydrates hold twice the amount of energy than all available fossil fuels. At present, the energy demand is growing, but these are not available commercially. Various field applications on the dissociation of the natural gas hydrates have been performed till now, and the output of these field applications confirms the possibility of dissociation of the natural gas hydrates. At distinct locations in the world, the huge deposits of hydrates have been identified, but the safe and economic dissociation of gas hydrates is not known yet. Hence, the evolution of new and inexpensive, suitable methods and technologies are required for the dissociation of gas hydrates. In this chapter, the authors reviewed several articles to compare the different dissociation techniques of gas hydrates and their field applications. The advantages and disadvantages of these production methods have also been discussed.

## Chapter 11

Recent Advancements in Microalgae-Biofuel Generation Employing Nano-Additives..... 188

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Biofuels have gained significant interest as an alternative fuel in recent years owing to their environmental sustainability, cost-effectiveness, and the ability to blend with traditional fuels like gasoline without requiring engine modifications. The use of microalgae for biofuel production is universally preferred due

to its energy efficiency and environmental sustainability; current research is geared towards enhancing the production of microalgae-biofuel from the initial stages to the final product as it is a cost-effective fuel option. The use of different types of nano-additives at different stages of microalgae cultivation and incorporation into biofuel produced noteworthy improvements in the final product. This chapter focuses on the prospective uses of nano-additives in microalgae cultivation, microalgal biomass conversion to biofuels, and biofuel combustion improvement for revolutionary advancements in biofuel technology.

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The chapter discusses the methods effective for the extraction of useful energy from the macroalgae biomass including liquefaction, anaerobic digestion, fermentation to biobutanol, trans-esterification to biodiesel, pyrolysis, direct combustion, fermentation to bioethanol, and gasification. However, if the algae are suited for the production of biodiesel, they can be studied from the content of their triacylglycerols (TAGs). Due to having high fatty acid content, they have a high conversion rate to biodiesel, and the lack of sulphur, phosphorus, and nitrogen also aids in the conversion. This chapter highlights the limitations and suitability of macroalgae for the conversion process in reference to chemical composition, process optimization, and cost effectiveness. It is concluded that bio-oils and bioethanol produced from wet macroalgae are considered over biodiesel production because of high lipid content of microalgae biomass. Moreover, the chapter considers electricity production from the dry mass as it would turn profitable, and this can be achieved from fast-growing macroalgae like “Ulva.”

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Development of sustainable energy resources is a major concern in front of the scientific community and stakeholders in this field. Invariably, fossil fuels are utilized to meet the major part of energy demand all over the world, but their stocks are limited. Burning of fossil fuels also causes significant environmental pollution that results in drastic climate change. There is an emergent need of an alternative to fulfill the current energy demand in a sustainable way along with sorting out the pollution issues. Microbial biofuels could be the most appropriate choice in this regard because it bears enormous potential that needs to be exploited. But it has some challenging issues to employ it to meet out the current energy demands. This chapter illustrates the microbial biofuels, harvesting techniques, different process, and potential to utilize them as sustainable energy sources along with considerable challenges that need to be addressed

to make it an eco-friendly and economic fuel choice to pave the path of sustainable development.

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Microbial Cellulase in the Production of Second Generation Biofuels: State-of-the-Art and Beyond ..... 233

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Bioethanol from inedible cellulose-rich biomass is the most promising candidate to replace fast depleting, environmentally polluting fossil fuels. Hydrolysis of cellulose to glucose is the crucial step in its biotransformation to bioethanol. Enzymatic hydrolysis is favored over acid hydrolysis, as enzymes are eco-friendly biocatalysts with high substrate specificity and superior catalytic efficiency in mild reaction conditions. Complete hydrolysis of cellulose is achieved by cellulase. Higher cellulase production yield, stability, and catalytic efficiency are the main attentive points for the successful implementation in industrial production of bioethanol. This chapter will highlight general characteristics of microbial cellulases and their role in the bioconversion of cellulose to biofuels, economic sustainability of cellulose-based biofuels, and the latest innovations in cellulase immobilization as the most comprehensive strategy for improvement of enzyme stability, activity, and reusability for cost-effective large-scale application.

#### Chapter 15

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Sustainable development is a key aspect of modern-day development. Reducing fuel cost and emissions is considered as the most important research area in sustainable development. Biodiesel has the potential to reduce the requirement of petroleum diesel if blended in suitable proportion. Various feedstocks are being explored for biodiesel production. Oils derived from neem and jatropha can be utilized for biodiesel production. In the current investigation, optimum parameters for the production, namely catalyst proportion, temperature, and oil-to-alcohol ratio were optimized. Experiments were carried out at different blend proportions to study fuel properties, namely kinematic viscosity, aniline point, diesel index, flash and fire points, specific and API gravity, cetane number, and ASTM distillation characteristics.

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Characterization and Comparison of Various Blends of Honge Oil Methyl Ester (Biodiesel) With Diesel Fuel ..... 274

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The Honge oil, known as pongamia oil, is one of the most widely used lamp oils around the world. It is also used in leather tanning, in soap making, and as a lubricant. The Honge oil methyl ester can be used as an alternative fuel for diesel. The transesterification of methanol and Honge oil in the presence of base catalyst results in Honge oil methyl ester. In the current work, the Honge oil methyl-ester known as biodiesel was produced. It was mixed with petroleum diesel fuel in different proportions. Various physical and petroleum properties were investigated for Honge oil biofuel and also for various diesel and

ester mixtures. The optimum parameters were temperature was 65oC, catalyst quantity, 0.4 grams and oil: alcohol ratio, 1:6. The blends of 10%, 20%, and 30% compositions were most suitable as potential alternative fuel. Different proportions of biodiesel ester in diesel fuel have been also compared with petroleum diesel fuel to identify a suitable blend having good engine fuel potential.

**Chapter 17**

Explicit Conceptual Design Approach to Adapt a Biomass-Fed Anaerobic Digester and Status Indicators in Semi-Arid Areas ..... 291  
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The mitigation of adverse climate change requires holistic strategies. The strategies include the proper handling of biomass wastes such as cow dung. The handling of the wastes has to be efficient using appropriately designed anaerobic digesters. In addition, the operating status of these digesters has to be monitored for detection of any fault of the digesters. Unfortunately, existing approaches for designing and monitoring the working condition of digesters have limitations. This chapter presents the innovative and explicit conceptual design approach of adapting the biomass-fed anaerobic digester and the digester operating-status-indicators in semi-arid areas. The approach is recommended to the renewable energy system designers. Finally, the appropriate indicators are recommended to be applied by the biogas plant operators or users.

**Chapter 18**

Pretreatment of Lignocellulosic Biomass and 2G Ethanol ..... 322  
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Rapid depletion of fossil fuel-based energy sources increased the demand for alternate energy sources. Lignocellulosics-based 2G ethanol can be used as an alternative sustainable source that presents in ample amount. Sources of lignocellulose biomass are wood, food-agriculture wastes, and forest residues. Cellulose, hemicellulose, and lignin are the core components of lignocellulosic biomass. Cellulosic and hemicellulosic biomass are enzymatically hydrolyzed to produce the monomer sugar (such as glucose or xylose) which is further converted into ethanol using fermentation process. The presence of lignin provides physical barrier that limit the access of enzymes required for saccharification. Pretreatment helps in removing the lignin from biomass and reducing recalcitrance. Pretreatment can be done by conventional methods, which are chemical, physical, and biological. This study covers the different methods of pretreatment including their disadvantages and benefits along with saccharification and fermentation processes.

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## Chapter 9

# Biofuels From Macroalgae: A Sustainable Alternative to Conventional Energy Resources

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### ABSTRACT

*The steep rise in human population together with the simultaneous growth of urbanization and industrialization has triggered overuse of fossil fuels in the recent years. However, they are non-renewable and release carbon dioxide causing global warming. In this context, biofuels come as excellent substitutes because they are renewable and eco-friendly. They are obtained from biological products and include biodiesel, biomethane, bioethanol, and biohydrogen. They are classified into first, second, and third generation fuels depending on the biological feedstocks being used. Of these, the third-generation fuels, obtained from marine resources like algae, have attracted special research interests because they do not rival the food crop production or depend on land and freshwater for their cultivation. However, the potentialities of macroalgae as a biofuel resource have not been investigated thoroughly. The chapter tries to outline all the aspects of biofuel production from macroalgae pointing out the scopes for future research.*

### INTRODUCTION

Overexploitation of the fossil fuels and the non-renewable energy resources like coal, petroleum and natural gas in the last few years has not only led to the depletion of resources but has also added carbon dioxide (CO<sub>2</sub>) to the atmosphere. Needless to say, CO<sub>2</sub> is a major greenhouse gas (GHG) and causes global warming (Naik et al., 2010). The problem has been projected to rise in the years to come. This necessitates the development of alternative energy sources to meet the growing demands of the burgeoning popula-

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