Microbial Resources for Sustainable Energy

Basanta Kumara Behera • Ajit Varma

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Basanta Kumara Behera
Amity Institute of Microbial Technology
Amity University Uttar Pradesh
Noida, Uttar Pradesh
India

Ajit Varma
Amity Institute of Microbial Technology
Amity University Uttar Pradesh
Noida, Uttar Pradesh
India

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Foreword

"Nuclear power produces nearly 20 % of Germany's energy, but in July 2011 (only 3 months after Fukushima) the German government vowed to shut down its nuclear capability within 10 years. Not just that, but to replace it with renewable energy, cut greenhouse-gas (GHG) emissions by 40 % by 2020 and 80 % by 2050, ensure renewables contribute 80 % of Germany's energy by 2050, and ensure energy consumption drops 20 % by 2020 and 50 % by 2050." In this connection, I believe that this book would have immense contribution to bring awareness about the potential of microbes to contribute green energy in the form of biogas, algal diesel, ethanol, hydrogen, and direct electricity to overcome the present energy crisis to a certain significant magnitude. This piece of book contributes a comprehensive review on the genesis of renewable green energy and its further development for commercialization. This book will not only be helpful to technology and policy worlds but will also appeal to a broader audience. Additionally, this work would be immensely inspiring to younger researchers in finding out issues and its solution to meet local energy demands through sustainable microbial resources available in and around a specific location. It is also a must-read piece of work for all youngsters who dream to find out solution for an eco-friendly sustainable environment by introducing better option for alternative source of energy.

This book is systematized in such a way to give comprehensive and systematic knowledge on green energy to bring familiarity among readers on social acceptability of different options on biological renewable energy. The language is aimed at a *Popular Science* level of technical exposition and is relatively easy to understand although a wide spectrum of technologies are depicted. Each chapter includes an extensive list of references to assist the reader in finding sources and additional details of the referenced.

The most vital part of this book is the way of dealing a highly debatable issue on energy crisis in a most conventional manner with the illustration of impressive figures and practicable data in tabular forms. Additionally, the book carefully addresses these complexities for each energy policy topic presented. The book intentionally avoids advocacy and tries best to be an honest broker to the readers to induce the sense of their own conclusions in spite of various pros and cons of the book.

I am exceedingly proud the way the authors have worked out to draw international attention on sustainability of microbe origin green energy as an unavoidable option for alternate and clean energy to reduce the burden of greenhouse effect and also energy crisis.

Institute of Microbiology and Wine Research
Johannes Gutenberg - University
Mainz, Germany

Prof. Dr. Helmut Koenig

Preface

The security of global energy supplies is in great dilemma as oil and gas reserves are under the direct control of a small group of nations, most of which are considered politically unstable or have testy relationships with large consuming countries. About 80 % of the world's oil reserves are located in just three regions: Africa, Russia and the Caspian Basin, and the Persian Gulf. More than half of the global gas reservoirs are restricted to only three countries: Russia, Iran, and Qatar. So, any serious energy security decision should be free from foreign energy sources. Due to uncertainty of Russian policy over natural gas supply in Europe, new coal-fired power stations are back on the political agenda. In the USA, home-grown biofuels have been promoted by successive administrations as an alternative to Middle Eastern oil imports, despite being more expensive.

At present, we depend on about 80 % conventional energy for our immediate needs. However, this scenario may change a little in due course of time without drastic policy changes. On top of this, energy demand is expected to grow by almost half over the next two decades. Understandably, this is causing some fear that our energy resources are starting to run out, with devastating consequences for the global economy and global quality of life.

The present energy crisis is not due to sharp downfall of natural energy resources as a result of drastic energy demand but because we are using it in the wrong way. The increase in global temperature is mainly due to heavy accumulation of CO_2 in space as a result of burning fossil fuels for energy. The efficacy of energy industry used to be judged by two major criteria: its contribution to energy security and the cost of energy delivered to the consumer. However, now we are forced to include a third criteria related to emission of greenhouse gases, mainly CO_2 into the atmosphere. So, now we feel the urgency of finding out suitable solution to overcome the present energy crisis. At first instant, we have to reduce the use of fossil fuels in order to have control over input of greenhouse gases into atmosphere. But coal is widely used to generate electricity, in most of the countries (especially the USA, China, and India) without carbon capture and storage (CCS) technology. It is right time that all these developing countries should make a common policy for reducing discharge of greenhouse gases to a marked quantity. However, at current rates of population growth and with current technologies, this will be impossible without a global agreement to limit efflux of greenhouse gases into the atmosphere. Developed countries must shoulder the initial burden with an agreement for immediate emission cuts. In return, the largest developing countries must agree to cut their own emissions in the future, but only after having achieved some recognizable level of economic development.

The immediate solution to get partial relief from the present energy crisis is to find out effective strategies to encourage the use of alternate sources of renewable energy in order to lessen the burden of greenhouse gases. Besides various types of nonconventional energy (Solar power, Hydro-electric power (Dams in Rivers), Wind power, Tidal power, Ocean wave power, Geothermal power (heat from deep under the ground), Ocean thermal power, etc.), we have a lot of opportunities to use sustainable microbial resources for generating different energy carriers like hydrogen, ethanol, diesel directly from microalgae, macroalgae, Cyanobacteria, and fermentative bacteria. The most significant fact about microbial energy carriers is their less carbon dioxide emission property compared to conventional liquid fuels like petrol and diesel. In addition, abundant aquatic resources (both marine and freshwater) are sustainable storehouse of a variety of micro- and macroalgae which can be ultimate sources for generating green energy.

Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. It can be used in most diesel engines, especially newer ones, and emits less air pollutants and greenhouse gases other than nitrogen oxides. It's safer to handle and has virtually the same energy efficiency as petroleum diesel. In addition, it has lubricity benefits that fossil fuels do not. Biodiesel blends as low as B2 have been found to significantly reduce the amount of toxic carbon-based emissions. Microorganisms like microalgae, bacillus, fungi and yeast are all available for biodiesel production. The present research has also revealed the possibility of obtaining hydrogen and electricity directly from microalgae and formative bacteria. When hydrogen is burned, the only emission it makes is water vapor, so a key advantage of hydrogen is that when burned, carbon dioxide (CO_2) is not produced. Clearly, hydrogen is less of a pollutant in the air because it emits little tailpipe pollution. Hydrogen has the potential to run a fuel-cell engine with greater efficiency over an internal combustion engine. The same amount of hydrogen will take a fuel-cell car at least twice as far as a car running on gasoline. The concept of Microbial Fuel Cells (MFCs) has brought hope for using various types of microbes to generate electricity, directly.

This piece of work is organized to bring attention of researchers, teachers, students and policymakers for considering microbial resources as sustainable storehouse of nature and pleads for its best use as alternate form of nonconventional energy.

The first chapter narrates how green energy production begins with the photosynthetic fixation of CO_2 into biomass and subsequent conversion of biomass by using microbes as biological catalyst to produce biofuels like ethanol, methane, hydrogen, and biodiesel, relatively free from hazardous gases like any oxide of carbon, nitrogen, and sulfur. In addition, it has also been explained how the policymakers boost the nonconventional biofuels by implementing special laws to enforce them in auto industries. This has been nicely narrated with some historical facts and figures to convince readers the positive impact of biofuels in public life.

In the second chapter, the authors intend to describe updated information on biogas production by the breakdown of organic matter in the absence of oxygen. Here, special attention has been paid to highlight commercialization of biogas production technology to meet the challenge in solving rural energy crisis under effective management program. In addition, technology on generation of electricity from biogas to solve localized energy problem has also been narrated in detail.

Depletion of natural oil and diesel resources has created an enormous challenge in substituting suitable and economic fuels to meet the demand of locomotive engine and communication systems. In this regard, the authors have given special emphasis on explaining advanced process technology to obtain highly purified biogas to be used for commercial purpose and electricity generation. So, in the third chapter the authors have highlighted about the production of biodiesel from microbial biomass on commercial level to reduce the load on natural petroleum and gas resources.

The most interesting part of this chapter is about direct production of ethanol from microalgae without any biomass extraction process. This has been nicely explained with well-illustrated figures and photographs to impress readers and make them realize the effective use of microalgae with the use of new technologies being developed by researchers from the field of industrial biotechnology.

Unlike biofuels, microbial fuel cells (MFCs) are “Plug in and power” devices, which convert energy harvested from redox reactions directly into bioelectricity. MFCs can utilize low-grade organic carbons (fuels) in waste streams. The oxidation of the fuel molecules requires biofilm catalysis. In recent years, MFCs have also been used in the electrolysis mode to produce bioproducts in laboratory tests. MFC research has intensified in the past decade and the maximum MFC power density output has been increased greatly and many types of waste streams have been tested. The fourth chapter has been completely devoted to latest aspects of MFC technology and its possibility to commercialize.

The last chapter has been organized to highlight the production of hydrogen from microalgae and formative bacteria. Hydrogen (H_2) is being explored as a fuel for passenger vehicles. It can be used in fuel cell to power electric motors or burned in internal combustion engines (ICEs). It is an environment-friendly fuel that has the potential to dramatically reduce our dependence on imported oil, but several significant challenges must be overcome before it can be widely used. Hydrogen produces no air pollutants or greenhouse gases when used in fuel cells; it produces only nitrogen oxides (NOx) when burned in ICEs. The authors have taken maximum interest to draw attention of readers by illustrating impressive models on the production of hydrogen by using the vast marine ecosystem as green energy power station.

Lastly, the authors want to extend thanks and are obliged to their respective family members for showing immense passion and extending cooperation while the manuscript was under preparation stage.

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Basanta Kumara Behera
Ajit Varma

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Abbreviations

AGATE	Acid, Gas, and Ammonia Targeted Extraction
AFPRO	Action for Food Production
AMIMCI	1-Allyl-3-methylimidazolium chloride
AC	After Christ
AD	Anaerobic Digester
ATP	Adenine Triphosphate
ASP	Aquatic Species Program
BOD	Biological Oxygen Demand
BC	Before Christ
BVS	Biodegradable VS
BSA	Bovine Serum Albumin
BETO	Department's Bioenergy Technologies Office
BDTACI	1-*N*-butyl-3-methyl (tetradecyl) ammonium chloride
CO2	Carbon Dioxide
CEO	Chief Executive Officer
CNG	Compressed Natural Gas
CBM	Compressed Biomethane
CV	Calorific Value
CoTMPP	Cobalttetramethoxyphenylporphyrin
COD	Chemical Oxygen Demand
DAF	Dissolved Air Flotation
DMDO	Dimethyl Dioxirane
DOE	Department of Energy, Government of USA
DCMU	3-(3,4-Dichlorophenyl)-1,1-dimethylurea
DEA	Diethanolamine
EPA	Environmental Protection Agency
FFV	Flexible-Fuel Vehicles
EPA	Energy Policy Act
EDA	Electron Donor–electron Acceptor
EDTA	Ethylenediaminetetraacetic Acid
FAME	Fatty Acid Methyl Esters

FECVs	Fuel-Cell Electric Vehicles
GHG	Greenhouse Gas
HRT	Hydraulic Retention Time
HE	Human Excreta
HDP	High-Density Polyethylene
HNQ	2-Hydroxy-1,4-naphthoquinone
HTS	Interspecies Hydrogen Transfer
IABR	Integrated Algal BioRefinery
KVIC	Khadi and Village Industry Commission
LPG	Liquid Petroleum Gas
LDPE	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
LBM	Liquefied Biomethane
LCFA	Long Chain Fatty Acids
MDGs	Millennium Development Goals
MFC	Microbial Fuel Cell
MOW	Market Organic Wastes
MDEA	Methyldiethanolamine
MEA	Monoethanolamine
MGDG	Monogalactosyldiacylglycerol
MEC	Microbial Electrolysis Cell
NGO	Nongovernmental Organization
NMMO	*N*-methylmorpholine-N-oxide monohydrate
NAD	Nicotinamide Adenine Dinucleotide
NADP	Nicotinamide Adenine Dinucleotide Phosphate
NREL	National Renewable Energy Laboratory
NREL	National Renewable Energy Laboratory
OLR	Organic Loading Rate
PS I	Photo-System I
PS II	Photo-System II
PNAS	Proceedings of the National Academy of Sciences
PEF	Pulsed Electric Field
POMS	PeroxyMonoSulfate
PUFA	Polyunsaturated Fatty Acids
P-MFC	Plant-Microbial Fuel Cell
PMFC	Plant Microbial Fuel Cell
PBR	Photo Bio-Reactor
PAA	Peracetic Acid
PEM	Proton Exchange MembraneRED
PEC	Photo-Electrochemical
PNSB	Purple Non-Sulfur Bacterium
RED	Renewable Energy Directive
SCP	Single Cell Protein
SzIBR	Solazyme Integrated Biorefinery

SRT	Solids Retention Time
SAO	Syntrophic Acetate Oxidizers
SOD	Super Oxide Dismutase
SMFC	Sediment soil MFC
TOS	Total Organic Solid
TITE	Research Institute of Innovative Technology for the Earth
TAGs	Triacylglycerides
US	United States
USDE	United States Department of Energy
VFAs	Volatile Fatty Acids
VMOW	Vegetable Market Organic Wastes
VFA	Volatile Fatty Acids
VS	Volatile Solids
WGS	Water-Gas Shift Reaction