

YEBO LI  
SAMIR KUMAR KHANAL

# BIOENERGY: PRINCIPLES AND APPLICATIONS



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# BIOENERGY



# BIOENERGY:

Principles and Applications

Edited by

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# Preface

Our modern society depends on energy for almost everything. Energy can be considered as a basic need of today's society. We need energy for home appliances used for preparing and storing food, lighting our homes and streets, heating/cooling our homes/offices, and powering our rapidly proliferating entertainment gadgets. Our vast transportation networks (air, land, and sea) and various modes of communication essentially depend on energy, as do all industrial processes that supply commodities for our daily needs. Energy also has vast socio-economic implications in the rural areas of developing countries, where women and children often spend as much as 4–6 hours collecting firewood for cooking. Thus, energy is an inevitable part of the growth, prosperity, and well-being of our society.

Global energy consumption is expected to increase by nearly 56% by 2040, due mostly to increased demand from emerging nations such as China and India. In recent years there has been a significant shift in the dynamics of energy consumption. Non-OECD (Organization for Economic Cooperation and Development) countries, which account for 90% of global population growth and 70% of economic outputs, are expected to have over 85% growth in energy consumption from 2010 to 2040. Energy consumption in non-OECD developing Asian countries, especially China and India, will increase by 112% from 2010 to 2040. The rest of the non-OECD countries are also projected to show strong growth in energy consumption during that period: for example, by 76% in the Middle East, by 85% in Africa, and by 62% in Central and South America. It is forecast that China's energy consumption will grow by as much as twice that of the USA between 2010 and 2040.

Currently, over 85% of total energy consumption is met through the use of non-renewable sources such as petroleum, coal, natural gas, and nuclear energy. Our heavy dependence on these rapidly depleting non-renewable energy sources has several irreparable consequences such as impacts on economic development, national security, and local and global environments, especially through climate change. Thus, we must act quickly and decisively to develop sustainable, affordable, and environmentally friendly energy sources. Bioenergy derived from renewable bioresources, such as biomass (energy crops, agri- and forest residues, algae, and biowastes) is considered to be the most promising alternative.

With the growing interest in bioenergy, there is a need to prepare a new cadre of the workforce in this emerging field who could lead the research, development, and implementation efforts of bioenergy technology. There are many reference books available on this subject. However, there is no comprehensive book that could be used as a textbook at an undergraduate level. This 29-chapter textbook is one of the very first that covers comprehensively both the fundamental and application aspects of bioenergy. The chapters are organized in such a way that each preceding chapter builds up a foundation for the following one. Every effort has been taken to maintain consistency throughout the book, even though the chapters were contributed by different authors. We strove to maintain clarity in explaining the concepts, and textboxes have been provided throughout the book to further

clarify the concepts/terminology. At the end of each chapter, exercise problems have been provided, which instructors can use as an assignment for the class. A solution manual is also available.

The textbook is divided into six sections. Section I consists of seven chapters focusing mainly on the fundamental aspects of bioenergy. Section II comprises four chapters covering different bioenergy feedstocks. Section III consists of eight chapters focusing on various biological conversion technologies. Section IV has three chapters about thermochemical conversion technologies. The four chapters in Section V cover various aspects of biorefineries. Finally, Section VI comprises three chapters focusing on bioenergy system analysis. This organization will help students easily grasp the content presented in the textbook.

The editors, especially Samir Kumar Khanal (SKK), drew inspiration in preparing this textbook from King Bhumibol Adulyadej's (Thailand) self-sufficiency initiatives. SKK is also particularly thankful to Andrew G. Hashimoto (Professor Emeritus, University of Hawai'i), Ju-Chang (Howard) Huang (Chair Professor Emeritus, Hong Kong University of Science and Technology, Hong Kong), Heinz Eckhardt (RheinMain University, Wiesbaden, Germany), Akhilendra Bhusan Gupta (Malaviya National Institute of Technology, Jaipur, India), Shihwu Sung (University of Hilo, Hawaii), Chongrak Polprasert (Professor Emeritus, Asian Institute of Technology, Bangkok, Thailand), Dulal Borthakur (University of Hawaii), and Kenneth Grace (Associate Dean for Research, University of Hawaii) for their supports and encouragements. We sincerely hope that this textbook will be valuable especially to undergraduate students and instructors. The book will be equally useful to graduate students, decision makers, practicing professionals, and others interested in bioenergy.

We gratefully acknowledge the hard work and patience of all the authors who have contributed to this textbook. The views or opinions expressed in each chapter are those of the authors and should not be construed as opinions of the organizations for which they work. Special thanks go to SKK's former and current graduate students at the University of Hawai'i at Mānoa (UHM), Saoharit Nitayavardhana, Devin Takara, Pradeep Munasinghe, Surendra K.C., Sumeth Wongkiew, Duc Nguyen, Chayanon Sawatdeenarunat, and Edward Drielak, for reviewing some of the chapters and helping with solution manual. Furthermore, we are highly indebted to Justin Jeffrey, Editorial Director at Wiley, for his relentless support for our textbook project and Shummy Metilda, Production Editor at Wiley, for enforcing the publication deadline. Last but not least, we extend our sincere gratitude, love, and appreciation to our family members for their support through the years. Finally, we would like to salute the people of developing countries for their rational use of energy in their daily activities, sacrificing their comfort for the rest of the world.

– Yebo Li and Samir Kumar Khanal

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# About the Companion Website

This book is accompanied by a companion website:

**[www.wiley.com/go/Li/Bioenergy](http://www.wiley.com/go/Li/Bioenergy)**

The website includes:

- Figures
- Tables

Scan this QR code to visit the companion website



