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Bioenergy Systems for the Future

Prospects for Biofuels and Biohydrogen

Edited by Francesco Dalena, Angelo Basile and Claudio Rossi

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Preface

Fossil fuels are and have been the major source of energy in the last century. However, mainly in the last decade, there are developing researches to find alternative energy sources. This is mainly due to the fact that fossil fuel reserves are depleting across the world; this creates instability in the global market, which leads to a corresponding instability in fuel prices. Furthermore, fossil fuels are primarily responsible for the production of greenhouse gas (GHG) emissions (e.g., CO_2, CH_4, and N_2O), and concerning the global warming, there are other factors contributing to the transition toward bioenergy.

As documented in a 2015 report of the European Environment Agency (EEA), the recent atmospheric concentration of CO_2 indicating a 31% increase from its 1750 levels. A secure and alternative supply of energy is therefore indispensable for a sustainable future global economy.

In addition, in another report of the same year of the US Environmental Protection Agency (EPA), it was provided alarming information on the excessive amount of waste products in the world. In fact, rapid economic and tremendous population growths have caused municipal solid waste (MSW). This report informed that the world generates an estimated 1.7–1.9 billion metric tons of MSW each year. In the United States alone, about 254 million tons of MSW were generated in 2013, among which about 34% was recycled. Also nowadays, one of the methods for disposal of MSW is landfills that dispose wastes by burning. The burning of organic waste and producing a large amount of CO_2 and CO in the air enter a huge amount of methane gas produced through anaerobic decomposition of solid waste; that is a more harmful GHG than carbon dioxide.

To simultaneously solve the dilemma of energy demand, waste management, and greenhouse gas emission for communities globally, the waste-to-energy (WTE) supply chain as district energy system should be a viable method toward industrial economy. WTE technologies convert solid waste into various forms that can be used to supply energy. Energy can be derived from waste that has been treated and pressed into solid fuel and from waste that has been incinerated. In fact, WTE can be used to produce biogas (CH_4 and CO_2), syngas (H_2, CO_2, and CO), liquid biofuels (ethanol and biodiesel), or pure hydrogen.

The specialized literature documents that the WTE is able to produce 1,430 MWh/d of heat and 480 MWh/d of electricity from 1000 t/d of MSW.

In particular, in recent years, scientific industrial research has been particularly focused in the transformation of lignocellulosic feedstocks originating mainly from agricultural residues and from MSW into energy or, in other words, from biomass to bioenergy.

The transformation of these wastes to bioenergy was introduced as one of the most promising options. Examples are (a) the production of hydrogen from bioalcohols and biomethane by steam reforming reaction, (b) the last technologies such as nanocomposites for "Nano Green Energy," and (c) the application of fuel cells at low temperatures to optimize the production of bioenergy from bioalcohol.

Demonstrating the great interest of this conversion, there is a the renewable fuel standard (RFS) program in the United States, which predicts that about 44.5% of 36 billions of gallons of renewable fuel will be made with cellulosic biofuels, of which approximately 56.9% will originate from agricultural residue by 2022. The International Energy Agency (IEA), in the 2010, has also suggested that the use of bioenergy is expected to triple by 2050 to about 135 exajoules (EJ) per year; screenings of potential bioenergy range from 100 to 300 EJ by 2050.

The aim of this book is to provide, with contributions from some of the best scientists in the field, an overview on the status of the most recent research efforts. In fact, the book wants to provide a gradual knowledge starting from the characteristics of biomasses to arrive at the most innovative transformation processes in bioenergy.

In detail, the volume opens with a chapter edited by one of the editors (Rossi) and his coworkers (Bonechi, Consumi, Donati, Leone, Magnani, and Tamasi). The chapter provides a systematic overview on available biomass. Chapter 2 (Honkanen and Kataja) focuses on the technological aspects of nonfood agricultural lignocellulose transformations. It highlights the use of local biomass as energy source supports the development of the region toward self-sufficiency and helps to tackle the growth of GHG emissions at the local and regional level. Chapter 3 (Ghasemzadeh, Jalilnejad, and Basile) introduces the details of production of bioalcohol/biomethane and various feedstocks, followed by the use of membrane technologies for biofuel production. Chapter 4 (Bakhtyari, Makarem, and Rahimpour) provides an overview on the production of olefins and gasoline (aromatics) from biomass feedstocks; focusing on pyrolysis or liquefaction for the production of bio-oil followed by hydrodeoxygenation or catalytic cracking for bio-oil upgrading to olefins and gasoline type fuel. Chapter 5 (Fuess and Garcia) deals on the application of anaerobic digestion (AD) as a core treatment technology in industrial plants. This chapter concentrates on important advantages on an environmental and energetic basis, associating wastewater pollution control with bioenergy generation from biogas. Chapter 6 (Tamasi, Bonechi, Magnani, Leone, Donati, Pepi, and Rossi) reports the thermodynamic theoretical analysis of ethanol steam reforming (SR) process for hydrogen production. Chapter 7 (Palma, Ruocco, Martino, Meloni, and Ricca) focuses on catalysts for conversion of synthesis gas. This reforming process represents the most important reactant mixture for other processes devoted to the production of methanol, higher hydrocarbons (Fischer-Tropsch synthesis), and ammonia. Chapter 8 (Vita, Italiano, and Pino) analyzes the distribution of the hydrogen production from different biomass-derived fuels (bioethanol, biobutanol, glycerol, and biomethane) by conventional SR process. Chapter 9 (Iulianelli, Dalena, and Basile) considers the H_2 production from bioalcohols and biomethane in more environmentally friendly processes, based on the exploitation of bio-sources. In particular, the chapter is focused on a particular production process: SR in membrane reactors. Chapter 10 (Grams and Ruppert) is devoted to the presentation of the methods of the production of hydrogen rich gas via conversion of this renewable feedstock and its decomposition products. This chapter is divided into two parts: (a) the high-temperature processes are discussed focusing on the influence of the composition and physicochemical properties of the used catalyst on the H_2 yield and (b) the production of hydrogen by formic acid decomposition and application of the obtained H_2 for hydrogenation reactions. Chapter 11 (Nanda, Li, Abatzoglou, Dalai, and Kozinski) gives an overview of different hydrogen production technologies involving thermochemical, electrochemical, and biological routes. The primary focus of this chapter is to evaluate both advantages and limitations of several hydrogen production methods based on the available technology options, feedstock selection, end uses, and economical aspects. Chapter 12 (Fan, Afzal, He, and Zhu) summarizes the research activities in a range of nanocomposite materials in solid oxide fuel cells (SOFCs) in finding the positive roles to improve the cell components (anode, electrolyte, and cathode), electrochemical performances, and cell efficiency for green energy applications. Chapter 13 (Cassano and Conidi) deals with the most relevant applications of integrated membrane operations in specific areas of the agrofood production including fruit juice, wine, and whey processing, where the combination of different membrane technologies has been largely explored on both laboratory and industrial scales. Chapter 14 (Rahimpour, Biniaz, and Makarem) shows various stages of fuel production from microalgae. In particular, downstream procedures including microalgae cultivation, biomass harvesting, dehydration, cell disruptions, and oil extraction are discussed in details, followed by upgrading processes such as transesterification, fermentation, pyrolysis, liquefaction, and anaerobic digestion. Chapter 15 (Raza, Ullah, Afzal, Rafique, Ali, Arshad, and Zhu) is focused on the development of low-temperature solid oxide fuel cell (LT-SOFC) operated by direct bioalcohol (bioethanol and biomethanol) for sustainable developments. The content of this chapter is divided into three parts: (a) development of materials, (b) characterization and analysis, and (c) demonstration of the nanocomposite materials in a bioalcohol fuel cell (FC). Chapter 16 (Adhikari, Abdoulmoumine, Nam, and Oyedeji) discusses primary contaminants, the impact of operating conditions on them, their mitigation, and regulations governing their emissions. Additionally, best available technology (BAT) is discussed for select contaminants. The last chapter, Chapter 17 (Dalena, Senatore, Tursi, and Basile), aims to provide an update of the state of art of existing feedstocks for biofuel production from lignocellulosic biomasses. The chapter also presents a critical analysis of published data on both applications and potentiality of the bioenergy production from second- and third-generation of feedstocks.

To conclude, the editors would like to express special thanks to each one of the authors for their valuable contributions to this volume. Other very special thanks are surely addressed to all the staff of Elsevier that helped us in all the various steps for realizing this work in the best way.

Angelo Basile
Francesco Dalena
Claudio Rossi

Contents