Advances in Bioenergy

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The Sustainability Challenge

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Contents

About the Editors

Peter D. Lund is Professor in Advanced Energy Systems at Aalto University (Helsinki) where he chairs the multidisciplinary Energy Science Initiative. He is also a Visiting Professor in Wuhan, China. His primary interest is in sustainable energy systems, innovations, and policies. Dr. Lund is active in senior roles with EU initiatives in energy: he chaired the Advisory Group Energy of E.C. 2002-06, he chairs the Energy Steering Panel of European Academies Science Advisory Council (EASAC) and is a steering committee member of Euro-CASE energy platform. He has served in advisory role in many energy programmes world wide, including IEA, EIT, Baltic and Russia cooperation. Dr. Lund is Editor-in-Chief for *Interdisciplinary Reviews: Energy and Environment* and European Editor for *International Journal of Energy Research* (Wiley). Peter Lund has given numerous invited talks and written over 500 research papers on energy.

John Byrne is Director of the Center for Energy and Environmental Policy (CEEP) and Distinguished Professor of Energy and Climate Policy at the University of Delaware. He has contributed to Working Group III of the United Nations-sponsored Intergovernmental Panel on Climate Change (IPCC) since 1992 and shares the 2007 Nobel Peace Prize with the Panel's authors and review editors. He holds several senior academic, advisory and policy advisor positions, among others in South Korea, China, India and the USA. His work in the US includes service as an advisor to the National Council for Science and the Environment (US) and the Interagency Working Group on Environmental Justice, coordinated by the US EPA. Dr Byrne created the first undergraduate and graduate degrees in the United States in the combined area of energy and environmental policy and a recent external review conducted by a committee of internationally respected scholars rated the CEEP graduate program among the three best in the field. He has published 17 books and over 150 research articles.

Göran Berndes is Associate Professor in Energy and Environment at Chalmers University of Technology in Sweden. Göran Berndes' research integrates land use and energy systems at scales ranging from local case studies to the global context. The research is in particular directed towards the production and use of biomass for food, energy and materials purposes. Important aspects include: (i) the effectiveness of different ways to produce and use biomass for energy, using long-term energy system modeling and Life Cycle/Well-to-Wheel analyses linked with land use change modeling and assessment of the associated flows of C; and (ii) the resource (e.g., land and water), environmental and socioeconomic implications of bioenergy strategies and also of the alternative strategy to use land for enhancement of biospheric carbon sequestration.

Iacovos A. Vasalos was a Professor at Aristotle University of Thessaloniki, Department of Chemical Engineering from 1979 to 2005. He is currently Emeritus Researcher at the Chemical Process and Energy Resources Institute (CPERI), Centre for Research and Technology Hellas (CERTH). He started his career in the Amoco Research Center in Naperville, Illinois, where he worked for 10 years from 1969 to 1979, as a research engineer, project manager, process specialist in catalytic cracking, research supervisor, and as a consultant until 1999. He is the author or coauthor of 132 scientific publications and 43 international patents many of which have been successfully applied in refineries. He was instrumental in founding and organizing CPERI and CERTH. He was also actively involved in a series of EU-funded projects in areas such as clean fossil fuels, syngas production, biofuels, environmental catalysis with emphasis on catalytic reaction engineering and modelling coupled with overall process simulation.

Preface

Bioenergy is one of mankind's most important natural energy sources. It dominated energy supply until the industrial revolution and still plays an important role in many countries. Today around 10 percent of the world's primary energy is derived from the use of biological materials. Its potential is far beyond the present use even when we restrict development to observe a "food first" principle and nature conservation objectives.

From a technology point of view, bioenergy is a versatile fuel as it can be converted to all final energy forms such as electricity, thermal energy or fuel. Contrary to many other renewable energy sources it can be stored for a long time. It is a local energy source which is available practically everywhere in different forms except for very harsh climatic conditions. In addition, when properly utilized, bioenergy is a highly sustainable energy source.

By nature biomass and bioenergy are strongly coupled to ecosystems and both are closely linked to biodiversity and development issues as well. Because of these linkages, bioenergy cannot be evaluated only from a technology or energy supply point-of-view, but requires a multidisciplinary approach to estimating its utilization. This book seeks to provide a multidisciplinary, "whole-picture" view while at the same time identifying advances in the different fields of bioenergy research and technology development.

Measures to reduce energy demand growth and the promotion of bioenergy and other renewable energy sources are nowadays cornerstones in climate and energy security agendas around the world. Support for bioenergy is also in many countries part of policy packages for promotion of rural development with intentions to improve energy access, increase employment, and stimulate positive development in agriculture and forestry. In this respect, bioenergy must be a part of any serious green energy economy agenda.

The use of biomass for cooking, space heating, and lighting in developing countries presently accounts for roughly 80 percent of global bioenergy use. However, recently a rapid increase in interest in other biomass uses for energy has emerged as countries contemplate steps to address concerns about energy insecurity and climate change. These so-called "modern" biomass uses for energy are so far mainly restricted to the burning of municipal organic waste, straw, wood and forest industry by-flows to provide heat and electricity, anaerobic digestion of organic waste to produce biogas, and the use of conventional agriculture crops such as cereals, oil seeds, and sugar crops to produce biofuels.

However, the technologies used for converting biomass to fuels, heat and electricity continue to develop and can be expected to change the way we produce and use bioenergy products. Especially, emerging options for converting lignocellulosic biomass into refined solid, liquid and gaseous fuels gives access to new feedstock resources. New production systems for lignocellulosic biomass offer a broadened resource base. Perennial grasses and trees grown in short rotations (both coppice and single-stem plantations) represent new feedstock supply options in agriculture. Similarly, technology development in planting, silvicultural treatments and biomass extraction support an increasing biomass harvest from forests. This development will not the least be important in the case of biofuels for transport, which hitherto have been produced based on either easily degradable organic waste or food/feed crops. While different types of organic waste can be relatively cheap feedstock sources, cultivated feedstocks cost more and the ones used today make up a substantial part of the total production cost of such biofuels.

In addition to technological development and new types of feedstock for biomass, there are several other factors that contribute to the utilization of biofuels such as renewable energy related standards mandating the use of certain types of biofuels as well as tax incentives and other measures

associated with low carbon fuels policies, which also limit the carbon intensity of biofuels.

The society's "footprint" on Earth will inescapably expand in order to provide food, energy and materials for an increasing human population. Yet, society expects that emerging bioenergy systems should reduce impacts caused by the existing - primarily fossil - energy systems, and that policies are developed to address risks associated with bioenergy implementation. Much attention is being directed to the possible consequences of land-use change (LUC), referring to well-documented effects of forest conversion and cropland expansion into previously uncultivated areas, possibly resulting in biodiversity loss, increased greenhouse gas emissions and degradation of soils and water bodies. There are also concerns about risks for negative social and economic impacts, including land-use conflicts, human rights violations and food-security impacts.

The management of natural resources to provide needs for human society while recognizing environmental balance is the challenge facing society. As for other human activities, governance of bioenergy development is much about balancing trade-offs between partly incompatible environmental and socioeconomic objectives. There are currently several initiatives to develop sustainability certification systems. These may hedge against some of the undesired consequences of expanding bioenergy systems and promote a positive development where implemented effectively. Complementary to sustainability certification, there is a need to develop competitive business cases that are efficient along the entire bioenergy supply chain, from feedstock production to energy markets.

The policy challenge for those wishing to utilize the planet's bioenergy potential is complex. One clear principle is balance striking the proper balance between specific energy and food needs, and more broadly between socioeconomic development and environmental sustainability goals. This challenge is fraught with uncertainties: we cannot readily know if and to what extent the delicate web of biodiverse life would be disturbed under different utilization scenarios; and we do not know if social changes in diet and family formation or international efforts to significantly alleviate poverty and hunger will succeed in enabling greater use of bioenergy of certain kinds and on certain scales. Risks embedded in these uncertainties are large, leaving many researchers unsatisfied with our statistical ability to estimate them. When policy confronts "wicked problems" like these, it is common to counsel that we observe a precautionary principle in our actions and aspirations. This second principle also has a large role in shaping policy options. For example, "food first" and other scenario evaluation approaches exemplify this thinking. Several chapters in this book contribute to this understanding, indicating that research has come a long way recently in helping us to understand the bioenergy opportunity in a precautionary manner.

It is also important that policymakers consider the bioenergy opportunity in an integrated manner as part of a multiprong strategy. There have never been "perfect" or "silver bullet" solutions in the energy field and we must be careful not to examine bioenergy in a rarefied light which would undermine its consideration altogether simply because we want an outcome free of any risk. Precaution should lead us to minimize the magnitude of adverse impacts while also balancing the need for social change sufficient to meet our pressing challenges of energy security and climate change. Precaution, balance and integrated thinking are cross themes of this book and serve as guideposts for its contribution to discussions of policy design and implementation.

This book offers an authoritative overview of opportunities and challenges associated with bioenergy utilization. In addition to up-to-date and detailed information on key issues for biomass supply and conversion to energy, the book discusses conditions for the mobilization of sustainable bioenergy supply chains and outlines governance systems to support this mobilization.

The idea for this book came from the Publisher when John Wiley & Sons established a new journal, the *Wiley Interdisciplinary Reviews: Energy and Environment*, which publishes review-type articles by authoritative authors. This book is based on selected articles from this journal. The initial vision and effort of Tony Carwardine from Wiley was decisive for starting this book project. He is now retired, but he provided helpful inputs into the shaping of the book.

The Editors would also like to thank Peter Creaton, Dan Finch, Ella Mitchell, Peter Mitchell, Faith Pidduck, Kerry Powell, and Prachi Sinha Sahay from Wiley for their valuable help during the different phases of the book process.

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