

Edited by Birgit Kamm,
Patrick R. Gruber, Michael Kamm

 WILEY-VCH

Biorefineries – Industrial Processes and Products

Status Quo and Future Directions
Volume 2



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**WILEY-
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E200602404

WILEY-VCH Verlag GmbH & Co. KGaA

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Library of Congress Card No.: applied for

British Library Cataloguing-in-Publication Data:

A catalogue record for this book is available from the British Library.

Bibliographic information published by Die Deutsche Bibliothek

Die Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data is available in the Internet at <<http://dnb.ddb.de>>

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Typsetting K+V Fotosatz GmbH, Beerfelden

Printing Betz-Druck GmbH, Darmstadt

Binding Litges & Dopf Buchbinderei GmbH, Heppenheim

Printed in the Federal Republic of Germany
Printed on acid-free paper

ISBN-13: 978-3-527-31027-2

ISBN-10: 3-527-31027-4

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Industrial Processes and
Products**

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Editor's Preface

In the year 2003 when the idea for this set of books “Biorefineries, Biobased Industrial Processes, and Products” arose, the topic of biorefineries as means of processing industrial material and efficient utilization of renewable products had been primarily a side issue beyond the borders of the United States of America. This situation has changed dramatically over the last two years. Today in almost every developed and emerging nation much work is being conducted on biorefinery systems, driven by the rising cost of oil and the desire of to move away from petrochemical-based systems.

In these books we do not claim to describe and discuss everything that belongs or even might belong to the topic of biorefineries – that would be impossible. There are many types of biorefinery, and the state of the technology is changing very rapidly as new and focused effort is directed toward making biorefineries a commercial reality. It is a very exciting time for those interested in biorefineries – technologies for bio-conversion have advanced to a state in which they are becoming practical on a large scale, economics are leaning more favourably to the direction of renewable feedstocks, and chemical process knowledge is being applied to biobased systems.

As the editors of the first comprehensive biorefinery book we saw it as our duty to provide, first of all, a general framework for the subject – addressing the main issues associated with biorefineries, the principles and basics of biorefinery systems, the basic technology, industrial products which fall within the scope of biorefineries, and, finally, technology and products that will fall within the scope of biorefineries in the future.

To provide a reliable description of the state of biorefinery research and development and of industrial implementations, strategies, and future developments we asked eighty-five experts from universities, research and development institutes, and industry and commerce to present their views, their results, their implementations, and their ideas on the topic. The results of their contributions are thirty-three articles organized into seven sections. Our very special thanks go to all the authors.

We are especially indebted to Dr. Hubert Pelc from Wiley-VCH publishing, who worked with us on the concept and then, later, on the development and implementation of the book. Thanks go also to Dr. Bettina Bems from Wiley-

VCH publishing, who managed with admirable professionalism and very much patience, and to the three editors and eighty-five authors from three different continents. We are also indebted to Hans-Jochen Schmitt, also of Wiley-VCH publishing, who had the not always easy task of arranging the manuscripts in a form ready for publication.

Maybe in 2030, when a biobased economy utilizing biorefinery technology has become a fundamental part of national and globally connected economies, someone will wonder what had been thought and written about the subject of biorefineries at the beginning of the 21st century. Hopefully this book will be highly representative. Until then we hope it will contribute to the promotion of international biorefinery developments.

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Birgit Kamm
Patrick R. Gruber
Michael Kamm

November 2005

Foreword

One-hundred-and-fifty years after the beginning of coal-based chemistry and 50 years after the beginning of petroleum-based chemistry industrial chemistry is now entering a new era. In the twenty-first century utilization of renewable raw materials will gain importance in the chemical conversion of substances in industry. Partial or even complete re-adjustment of whole economies to renewable raw materials will require completely new approaches in research, development, and production. Chemical and biological sciences will play a leading role in the building of future industries. New synergies between biological, physical, chemical, and technical sciences must be elaborated and established and special requirements will be placed on raw material and on product-line efficiency and sustainability. The necessary change from chemistry based on a fossil raw material to biology-based modern science and technology is an intellectual challenge for both researchers and engineers. Chemists should support this change and collaborate closely with their colleagues in adjoining disciplines, for example biotechnology, agriculture, forestry, and the material sciences.

The German Chemical Society will help direct this necessary development by supporting within its structure new kinds of organization for chemists to work on this subject in universities, research institutes, and industry.

This two-volume book is based on the approach developed by biorefinery-systems – transfer of the logic and efficiency of today's petrochemical product lines and product family trees into manipulation of biomass. Raw biomass materials are mechanically separated into substances for chemical conversion into other products by different methods, which may be biotechnological, thermochemical, and thermal. Review of biomass processes and products developed in the past but widely forgotten in the petroleum age will be as important as the presentation of new methods, processes, and products that still require an enormous amount of research and development today.

Henning Hopf
President of the German Chemical Society
Frankfurt (Germany)

November 2005

Foreword

On October 5, 2005, the Nobel Prize Committee made an interesting and important statement with regard to the prize in chemistry. It said, "This represents a great step forward for 'green chemistry', reducing potentially hazardous waste through smarter production. [This research] is an example of how important basic science has been applied for the benefit of man, society and the environment." By making this statement, the Nobel committee recognized what a new generation of scientists has known for quite some time, that by working at the most fundamental level – the molecular level – we are able to design our products, processes, and systems in ways that are sustainable.

There is general recognition that the current system by which we produce the goods and services needed by society is not sustainable. This unsustainability takes many forms. It would be legitimate to note that in our current system of production we rely largely on finite feedstocks extracted from the Earth that are being depleted at a rate that cannot be sustained indefinitely. It is equally legitimate to recognize that our current production efficiency results in more than 90% of the material used in the production process ending up as waste, i.e. less than 10% of the material ends up in the desired product. Yet another condition of unsustainability is in our current energy use; this not only relies largely on finite energy sources but also results in degradation of the environment that cannot be continued as the growing population and demands of the developing world emerge over the course of the twenty-first century. Finally, the products and processes we have designed since the industrial revolution have accomplished their goals without full consideration of their impact and consequence on humans and the biosphere, with many examples of toxic and hazardous substances being distributed throughout the globe and into our bodies.

If we are to change this unsustainable path, it will need the direct and committed engagement of our best scientists and engineers to design the future differently from the past. We will need to proceed with a broader perspective such that when we design for efficiency, effectiveness, and performance, we now must recognize that these terms include sustainability – a minimized impact on humans and the environment.

An essential part of meeting the challenge of designing for sustainability will be based on the nature of the materials we use as starting materials and feedstocks. Any sustainable future must ensure that the materials on which we base

our economic infrastructure are renewable rather than depleting. The rate of renewability is also important because certainly one could argue that petroleum is renewable if you have a few million years to wait. Serious analysis would, however, necessitate that the rate of renewability is connected to the rate of use. There are options for how to approach this technological challenge, for example using waste products from one process as a feedstock for another, that are well thought through in industrial ecology models. There is, however, recognition that an essential part of a sustainable future will be based on appropriate and innovative uses of our biologically-based feedstocks.

This book addresses the essential questions and challenges of moving toward a sustainable society in which bio-based feedstocks, processes, and products are fundamental pillars of the economy. The authors discuss not only the important scientific and technical issues surrounding this transition but also the necessary topics of economics, infrastructure, and policy. It is only by means of this type of holistic approach that movement toward genuine sustainability will be able to occur where the societal, economic, and environmental needs are met for the current generation while preserving the ability of future generations to meet their needs.

While it will be clear to the reader that the topics presented in this book are important, it is at least as important that the reader understand that these topics – and the transition to a sustainable path that they address – are urgent. At this point in history it is necessary that all who are capable of advancing the transition to a more sustainable society, engage in doing so with the level of energy, innovation, and creativity that is required to meet the challenge.

Paul T. Anastas
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November, 2005

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