Dale and Kim of Michigan State University began the Chapter 2 with the following statement: "We are in the early phases of a truly historic transition—from an economy largely based on petroleum to a more diversified economy in which renewable plant biomass will become a significant feedstock for both fuel and chemical production." Significant raw materials in this system will be corn, corn stover, soy beans, alfalfa and poplar.

Each contribution (as in the chapter above) is unique. The material supplied by each author deserves more space in review than I can use. Hence, I have abstracted a few items that caught my attention:

- "As a major policy goal for 2020, the Dutch government has stipulated that 10% of its energy use should be provided by renewable resources to meet the Kyoto objectives."
- "An essential component of the structural shift from petroleum to biomass as a source of carbon is a 'two-use' ethic. Everything that grows or is derived from organic sources (even plastics) should have at least two uses. MSW is collected and recycled to the biorefinery."
- "The production of fuel alcohol from cellulosic biomass is of growing interest around the world. Cellulosic biomass can be used to produced transportation fuel, with the overall process having little net production of greenhouse gases."
- "Green biorefineries are integrated technologies and technology systems for production of materials and energy processing of green plants and parts of green plants." "Green plants parts are a virtually inexhaustible raw material reservoir which is fast-growing, available world-wide, and may have ecological advantages." "In the next 10 year[s], biorefineries may be processing 100 million metric dry tonnes (dt) biomass annually for production of fuels and chemicals if a stretch goal set by the U.S. Department of Energy is met."

The chapters go well beyond a description of the raw materials, their sources, and their potential use. Many of the articles have process flow sheets, equipment schematics (including one photograph of a prototype plant), mass and energy balances, and waste treatment systems.

It is difficult to do justice in a brief review (or perhaps in this case not so brief) to a book such as this. In my opinion, the editors and contributors have done a marvelous job of reviewing the current state of biorefining. The future for this technical area is bright; indeed, it must be as renewable resources are virtually the only way of sustaining life in the future.

Gary F. Bennett *
*The University of Toledo, Department of Chemical and Environmental Engineering, Mail Stop 305, Toledo, OH 43606-3390, United States*

* Tel.: +1 419 531 1322; fax: +1 419 530 8086.
*E-mail address:* gbennett@eng.utoledo.edu

30 January 2007

Available online 17 February 2007

doi: 10.1016/j.jhazmat.2007.02.039

**B. Kamm, P.R. Gruber, M. Kamin (Eds.), Biorefineries—Industrial Processes and Products: Status Quo and Future Directions, vol. 2, Wiley–VCG Verlag GmbH & Co. KgaA, Weinheim, Germany (2006). 533 pp., US$ 375.00 (for both volumes), ISBN: 3-527-31027-4**

A recent press release I received described an innovative project to use the fermentation of grain to produce ethanol (which clearly is not new) but what is new is that this project proposes to extract biodiesel fuel from the residue that is left after removal of the alcohol. Additionally, the process will utilize cattle manure to produce methane to be burned in the production process. What is new is the system integration and energy (input) minimization.

This book is the second of two in a series that deal broadly with the "green chemistry" interest in developed countries. This volume contains 16 multi-authored chapters which are:

- *Part I*: Biobased Product Family Trees
  Carbohydrate-based Product Lines
  1. The key sugars of biomass: availability, present non-food uses and potential future development lines.
  2. Industrial starch platform—status quo of production, modification and application.
  3. Lignocellulose-based chemical products and product family trees.
  Lignin Line and Lignin-based Product Family Trees
  4. Lignin chemistry and its role in biomass conversion.
  5. Industrial lignin production and applications.
  Protein Line and Amine Acid-based Product Family Trees
  6. Towards integration of biorefinery and microbial amino acid production.
  7. Protein-based polymers: mechanistic foundations for bioproduction and engineering.
  Biobased Fats (Lipids) and Oils
  8. New syntheses with oils and fats as renewable raw materials for the chemical industry.
  9. Industrial development and application of biobased oleochemicals.
  Special Ingredients and Subsequent Products
  10. Phytochemicals, dyes, and pigments in the biorefinery context.
  11. Adding color to green chemistry? An overview of the fundamentals and potential of chlorophylls.
- *Part II*: Biobased Industrial Products, Materials and Consumer Products
  12. Industrial chemicals from biomass—industrial concepts.
  13. Succinic acid—a model building block for chemical production from renewable resources.
  14. Polylactic acid from renewable resources.
  15. Biobased consumer products for cosmetics.
- *Part III*: Biobased Industry: Economy, Commercialization and Sustainability
  16. Industrial biotech—setting conditions to capitalize on the economic potential.

The titles of the chapters (above) well illustrate the book's coverage, but to illustrate further, I have extracted several passages which are quoted below:

> "Because our fossil raw materials derived from prehistoric organic matter are irrevocably decreasing – the end of cheap oil is realistically predicted to occur in the next 2–3 decades, i.e. 2040 at the latest – and because pressure on our environment is building up, the progressive change-over of [the] chemical industry to renewable feedstocks emerges as an inevitable necessity. . . .Thus, carbohydrates, a single class of natural products are – aside from their traditional uses for food, lumber, paper, and heat – the major feedstocks from which to develop industrially and economically viable organic chemicals and materials to replace those derived from petrochemical sources."

> "In a biobased economy, lignocelluloses will most probably be the main source of raw materials.

> First, there are a variety of sources of lignocellulose (e.g. wood, straw, reeds, grass, etc.) and lignocellulose is the abundant continental biomass. There are also other sources, for example cellulose-containing waste materials from public life (recovered paper, hospital waste, municipal waste, etc.) and industrial waste products (e.g. pulp and paper industry).

> Second, lignocelluloses, with their main components cellulose, hemicellulose, and lignin, contain organic structures that serve as source for a variety of derivatives and conversion products. There are almost inexhaustible possibilities in chemistry and biotechnology to use lignocellulose and corresponding derivatives. In addition, industrially established processes and products have already been developed in the past (e.g. saccharification, furfural-based nylon production): unfortunately they could not compete with extremely inexpensive petroleum. Those processes and corresponding experience can be used for further development.

> Third, lignocelluloses are, to a large extent, independent of economic policy (in contrast with agricultural products such as corn, grain, sugar beet, availability of hemicellulose raw materials is not state-controlled); this, together with their reasonable raw material prices, makes lignocelluloses very interesting for industrial use. (Prices for lignocellulose corn stover or straw are approximately 30% of those of corn and grain.)

> Fourth, lignocelluloses can be produced even in environmentally sound less intensive agriculture and forestry which is another positive effect, in addition to the general $CO_2$-neutrality of biomass.

> The main requirement for economic success of lignocelluloses, its technologies and its products seems to be an integrated approach of lignocellulose processing and utilization. By analogy with the extremely successful petrochemistry, it is absolutely essential to improve biorefinery technologies and to develop sustainable and marketable product lines, multiproduct systems, and competitive biobased products."

A chapter authored by Pye of Canada is entitled "Industrial Lignin Production and Applications." The author includes a photograph of an organosolv-based Alcell demonstration plant. Such a description clearly indicates that at least one of these biorefining projects has moved beyond the laboratory.

Kraus at Iowa State University writes the following in Chapter 10:

> "The idea of a biorefinery is modeled after the highly successful oil refinery wherein petroleum is converted into gasoline, oil, and monomers such as ethylene and propylene. . . .The monomers produced by the biorefinery will probably be diols and acids, because the feedstocks are more highly oxygenated than petroleum."

Two more quotes worthy of reproduction in other chapters are as follows:

> "In biorefineries, biomass is used for production of high added-value chemicals, materials, intermediates, and fine chemicals together with the production of energy carriers, preferable in liquid phase, for its higher energy content and easier transport. . . .The industrial sector supplying the most important raw materials are: (1) the sugar and starch sector, which produces carbohydrates such as sugar. . . (2) the oil and fat processing center which produces numerous oleochemical intermediates such as triglycerides, fatty acids, fatty alcohols and glycerol. . . (3) the wood processing sector, in particular the cellulose and paper industry [which produces] mainly cellulose, cellulose derivatives and lignin. . ."

> "In the chemicals and food-processing industries, companies are developing new technology that will enable more cost-effective production of industrial products from biomass. Approximately 5% of chemical sales currently depend on biotechnology, but that figure could jump to 10–20% by 2010."

Reviewing a multi-authored text as I have previously noted is difficult. This series is especially hard because there are just too many well-written, innovative chapters to discuss. I feel that I have done an inadequate job of extracting and reporting on the books' contents. Suffice it to say, this book and its companion volume should be required reading by chemical engineers. The books are not only a superb technical resource tool that illustrates the forthcoming revolution in sustainability, but also would make an excellent text for a course on the topic (aside from the price).

Gary F. Bennett *
*The University of Toledo, Department of Chemical and Environmental Engineering, Mail Stop 305, Toledo, OH 43606-3390, United States*

* Tel.: +1 419 531 1322; fax: +1 419 530 8086.
*E-mail address:* gbennett@eng.utoledo.edu

1 February 2007

Available online 26 March 2007

doi: 10.1016/j.jhazmat.2007.02.038