- The oxidation of isobutane to methacrylic acid: an alternative technology for MMA production.
- Biocatalysis for industrial green chemistry.

To more deeply explore the topic, I will cite briefly from three of the presentations, one from each of the major sections outlined above.

F.W. Lichtenthaler of the Technishe Universitat of Darmstadt contributed a paper entitled “Carbohydrates as Renewable Raw Materials.” The author notes that the move from utilization of fossil fuels to the use of renewable feedstocks is inevitable. By far the most important class of organic compounds produced by nature are carbohydrates which represent roughly 75% of the annual output of renewable biomass of 180 billion tonnes. Lignin products amount to 20%. Many carbohydrates are used as feedstocks for the chemical industry to produce furfural, D-sorbitol, lactic acid, vitamins and pharmaceuticals. However, the full potential of the feedstock is yet to be realized.

The second paper I will cite is entitled “Ionic Liquids: ‘Designer’ Solvents for Green Chemistry” authored by N.V. Plechkova and K.R. Seddon of the Queen’s University of Belfast, Northern Ireland. Discussed are neoteric solvents with a suggestion that they should be part of the arsenal of solvents used by all synthetic chemists. Distracting, however, in this paper is an extended discussion of global warming which really does not fit the topic.

The third paper is entitled “Seamless Chemistry for Sustainability” by J. Thoen and J.L. Guillaume of Dow Chemical. Given the growing world population and the increasing need for food coupled with the concomitant increase in CO_2 emissions, the need for sustainable development is critical. This problem results in two major challenges for the chemical industry: (1) feedstock availability—or what alternatives exist for nonrenewable fossil feedstocks and (2) energy costs—or what alternatives exist to increasingly expensive nonrenewable fuels. The authors of this paper discuss the potential uses of carbon dioxide as a feedstock in chemical reactions, the use of stranded methane (to produce, for example, methanol, ethylene, benzene, toluene and styrene) and the exploitation of biomass and vegetable oils.

As a group, these are most excellent papers dealing with a very real and growing problem.

Gary F. Bennett*
Department of Chemical and Environmental Engineering,
The University of Toledo, 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

10 September 2007

Available online 14 September 2007

doi:10.1016/j.jhazmat.2007.09.037

Carbon Capture and Sequestration: Integrating Technology, Monitoring and Regulation, F.J. Wilson, D. Gerard (Eds.). Blackwell Publishing, Ames, IA (2007). 289 pp., Price: US$ 179.99, ISBN: 978-0-8138-0207-7

As I began my review of this book, I received a newsletter that noted: “Two Canadian provinces and six western US states are setting mandatory limits for CO_2 emissions by reducing those emissions to 15% below 2005 levels by 2020”. That goal represents a major challenge as the demands for energy provided by coal combustion, in my opinion, will not, indeed cannot, decrease even though major strides may be taken to reduce energy demand through conservation and use of renewable energy resources such as wind and solar. Consequently, carbon capture and disposal will be required.

The contributors thoroughly review the sequestration process and the ultimate disposal of carbon dioxide in deep geological/ocean formations. The editors note that there are “indications” that carbon capture and geologic sequestration (CCS) is a “technically viable option”, but the public (including this reviewer) has serious reservations. The goal of the editors in compiling this book was: “. . . to describe the current state of these technologies and to assess the technical, legal and socioeconomic forces that must coalesce if CCS has to become a viable carbon reduction strategy”.

> “Part one examines separation, capture, and monitoring and verification technologies. There are a number of well-known technical challenges associated with potential leakage and groundwater displacement. The chapters in this section provide an overview of the current technologies, discuss critical challenges and assess technologically feasible and politically realistic solutions. It also broadly identifies further research needs into technical aspects of CCS. Part two expounds on a central theme of the volume—CCS technologies must be implemented within a larger and integrated carbon management system. Costs, regulatory drivers, public acceptance, and legal and environmental issues need to be clarified and factored into the strategy for future energy systems.

The present CO_2 problem is discussed in the first paper in which the contributors note that atmospheric CO_2 concentrations have risen from preindustrial levels of 280 ppm to the current concentration, which is 372 ppm. Limiting CO_2 concentrations to acceptable levels is a major challenge to both technology and society.

> Reduction of CO_2 emissions to stabilize climate warming will “. . . fundamentally transform industrial society. There is no single technological fix that can bridge the gap between current and future energy consumption and simultaneously meet these CO_2 reduction targets. Instead, a menu of options that includes improved technologies, energy conservation and cleaner energy sources is necessary”.

Some of these options have been tested, the author notes. He cites five geologic sequestration demonstration projects conducted under the International Energy Agency's greenhouse gas storage and capture project.

> "The primary goal of this volume is to explore and to understand the technical challenges of carbon capture and sequestration within a larger societal context that encompasses technical, legal, regulatory and societal acceptance factors, all of which will play a crucial role in making GS a feasible and accepted technological option. The first half of this book focuses on the scientific and technical components necessary for large-scale CCS systems, including some of the principal technical challenges that are being addressed (developing monitoring technologies, implications of leakage and seepage). The second half explores the larger context within which CCS systems will be deployed. A number of institutional, regulatory, legal and social components will need to fall in place if CCS has to play a significant role in mitigating greenhouse gas emissions".

The book has the following 11 chapters:

- Carbon capture and sequestration in context: technology, regulation and social acceptance,

  Part I: Technical Overview for Carbon Capture and Sequestration
- Technologies: separation and capture
- Modeling to understand and simulate physico-chemical processes of CO_2 geological storage
- Monitoring geological storage of carbon dioxide
- Risk assessment and management for geologic sequestration of carbon dioxide
- Migration mechanisms and potential impacts of CO_2 leakage and seepage

  Part II: Bridging Technology and Public Policy
- Calculating the costs of electric sector carbon mitigation
- Geologic sequestration under current U.S. regulations: problems and prospects
- Initial public perceptions of deep geological and oceanic disposal of carbon dioxide
- Siting geologic sequestration: problems and prospects
- Property interests and liability of geologic carbon dioxide storage

I was surprised to see, at this early state of technological development, cost data. But some are given. In the first chapter, Wilson and Gerard state that: "Initial energy and economic modeling studies indicate that CCS will be competitive at carbon costs ranging from 25 to 35 US$/ton CO_2 (90–110 US$/tC). For a pulverized coal power plant, for example, capturing carbon would add approximately 1.8–3.4 cents/kWh to the cost of electricity".

Extensive cost data for four types of power plants are found in an early table entitled "Summary of reported CO_2 emissions and costs for new electric power plants with and without CO_2 capture based on current technology (excluding CO_2 transport and storage costs)". The author notes:

- Per cent increase in capital cost with CO_2 capture ranges from 30 to 110%
- Per cent increase in COE with carbon capture ranges from 35 to 74%
- Cost of CO_2 capture ranges from 22 to 41$/ton CO_2
- Energy penalty for CO_2 capture ranges from 15 to 25%

If the reader of this review concludes that I was impressed by this book, he/she is correct. This volume is a fascinating, fact-filled and technologically relevant text, which the book's back cover highlights well with the following paragraph:

> "This book is the first systematic presentation of the technical, legal and economic forces that must coalesce to deploy carbon dioxide capture and geological sequestration as a viable technology within a larger CO_2 reduction strategy. It synthesizes key engineering data and explains the technological, regulatory and legal conditions that must be in place for carbon sequestration to be deployed. The book offers a system of carbon management that takes into account regulation, cost, risk analysis and geological science. The practical information in this book is designed for individuals who need to understand the requirements for achieving CO_2 reduction through carbon capture and sequestration technologies".

Gary F. Bennett*
Department of Chemical and Environmental Engineering,
The University of Toledo, 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

10 September 2007

Available online 14 September 2007

doi:10.1016/j.jhazmat.2007.09.038