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ELECTROTECHNOLOGY VOLUME 8

BIOTECHNOLOGY AND ENERGY USE

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PREFACE

The objective of this volume is to evaluate the potential impact of bio-industry on industrial energy use. In this survey more than 60 biotechnology applications in key industrial sectors (e.g., food, energy and waste treatment) are reviewed. These applications involve advanced uses of fermentation and enzyme technology. This volume continues the series of studies initiated and sponsored by Electricité de France (EdF), in this case, to study the growth of biotechnology applications in industry and the implications for industrial energy patterns.

There is little doubt that a "revolution" in applied biology is now underway. The most publicized and far-reaching of the developments fostering this revolution is recombinant DNA technology, commonly referred to by the general term "genetic engineering." This technology, which involves transfer of genetic material between biologically divergent organisms, allows scientists to alter cells to perform new functions. The implications of this breakthrough are just starting to be realized in a wide range of industries, including manufacturers in the specialty and commodity chemicals, pharmaceuticals, food processing, energy-related and agricultural industries.

The dramatic increase in the commercial potential of biological processes is not, however, limited to breakthroughs in genetic engineering. More relevant for the near-term are recent developments in biotechnology related to fermentation and the industrial use of enzymes. For example, the global market for industrial enzymes is expected to grow at an annual rate of 8% to a total of approximately $500 million by 1985. Although enzymes have been used in industry for centuries, the projected increase in use can be attributed to biotechnology advances in both production and preparation (e.g., microbial production and development of immobilized enzymes).

One of the most compelling reasons for the broad application of biotechnology in industry is the opportunity to convert processes that consume fossil fuels (either as fuel or raw materials) to new processes that are energy-efficient or that consume renewable/abundant raw materials.

Our objectives in this study are twofold:

1. to identify and describe the range of industrial applications of biotechnologies identified to date; and
2. to identify those applications that have a potential for near-term commercialization and that are likely to affect energy consumption patterns.

What follows in this book is a discussion of the principal tools of biotechnology, the key industrial sectors surveyed, conclusions and brief technical descriptions of individual applications.

For the purposes of this study, bioindustry is a general term, representing a wide range of industrial applications of biological systems (biotechnologies). The emphasis is on the use of microorganisms (whole cells, cellular materials or enzymes) in the manufacture of products or the improvement of processes. At the request of EdF, we have focused our survey on five key industrial sectors: food, energy, waste treatment, chemicals and metals recovery.

It became apparent at an early stage in the project that biotechnology research and development is extensive in the above areas as well as in pharmaceuticals, agriculture and analytical instrumentation. Focusing on these key sectors of interest, we have identified and described applications based on the most recent information available.

We have not included applications based directly on recombinant DNA technology or other aspects of genetic engineering. There are two reasons for this: (1) most proposed commercial applications of genetic engineering are still in the early stages of research and development; and (2) details regarding these processes are considered proprietary business information and therefore are not publicly available.

Computer literature searching is an invaluable tool in surveying a field as diverse and contemporary as bioindustry. The search strategy basically involved matching descriptors relating to food, energy, waste treatment, chemicals and metals recovery with terms relating to microbial processes. A special descriptor, "bioconversion" or "biotechnology," increased the search capability, provided such a descriptor was included in the research citation. The computer literature search is limited, however, in that: (1) it dates back only six to seven years, (2) only widely distributed literature is generally covered, and (3) indexing is sometimes not sufficient to provide comprehensive coverage. We found that, although time-consuming, manual searching and cross-referencing is essential to supplement the computer literature searches and achieve adequate coverage in this field.

Following the literature search, more than 200 citations were scrutinized, and articles or monographs were obtained. In reviewing this information, individual microbial processes were selected for summary if they possessed one or more of the following characteristics either directly or in comparison with a conventional counterpart:

- potential savings in time or materials requirements,
- means for conversion from batch to continuous processing,

- economically significant improvement in product quality,
- capability for production of more than one product simultaneously or serially in the same process,
- commercial feasibility, and
- potential reduction (or increase) in energy consumption.

In most cases, the selected applications meet more than one criterion.

In all cases the objective was to obtain: (1) a basic description of the process (including flow diagrams wherever possible), (2) current stage of development (laboratory, pilot, demonstration, or commercial), and (3) an initial assessment of potential implications for energy consumption. In many cases, the energy implications are stated as "unclear at present." This does not necessarily imply that energy impacts will be nonexistent, but rather that a more detailed analysis is required before a judgment can be made. When questions arose regarding specific aspects of a process, its progress toward commercialization, or its energy implications, researchers or industry representatives were contacted directly.

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Robert J. Clerman is a group leader in the Environment Division of the MITRE Corporation. He received his bachelor's degree in biology from the State University of New York at Fredonia, and has a master's degree in environmental sciences from the University of Virginia. His research interests and publications have covered a wide range of environmental issues. Since joining MITRE, Mr. Clerman has been involved in studies relating to the fate and effects of chemicals in the environment. Projects have included development of a tiered testing system for new chemicals evaluation, design of a residuals monitoring program (both for the Federal Republic of Germany), and evaluation of organic pollutants in water (for the Department of Energy and the National Cancer Institute). Currently he is managing studies of industrial applications of biotechnology.

Rajani Joglekar received her BSc (biology) from the University of Bombay, a MS (biology) and MS (environmental sciences) from Northeastern University and George Washington University, respectively. Her research interests and publications are in the areas of plant growth and development, and development of biological tests for detecting toxic chemicals in the environment. Since 1978, working as a member of the technical staff in the Environment Division of the MITRE Corp., she has been studying the health and environmental effects of energy technologies. These studies have included the health effects of coal and oil shale, health and environmental effects of synthetic fuels, oil and gas-end use, and development of research plans for coal liquefaction technologies. Currently, Ms. Joglekar is involved in evaluating the industrial applications of biotechnology.

Robert P. Ouellette is Technical Director, Environment Division, of the MITRE Corp. Dr. Ouellette has been associated with MITRE in varying capacities since 1969. Earlier, he was with TRW Systems, Hazelton Labs Inc. and Massachusetts General Hospital. A graduate of the University of Montreal, he received his PhD from the University of Ottawa. A member of the American Statistical Association, Biometrics Society, Atomic Industrial

Forum and the National Science Foundation Technical Advisory Panel on Hazardous Substances, Dr. Ouellette has published numerous technical papers and books on energy and the environment and is co-editor, co-author of the Electrotechnology series published by Ann Arbor Science.

Paul N. Cheremisinoff is Associate Professor of Environmental Engineering at New Jersey Institute of Technology. He is a consulting engineer and has been consultant on environmental/energy/resources projects for the MITRE Corp. He has more than 30 years of practical design, research/development and engineering experience in a wide range of industries including pollution control, waste treatment, chemical and process industries. He is author/editor of many Ann Arbor Science publications, including: *Pollution Engineering Practice Handbook*, *Carbon Adsorption Handbook* and *Environmental Impact Data Book*.

CONTENTS