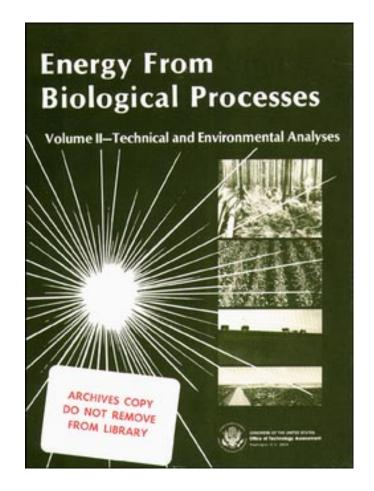
Energy from Biological Processes: Volume II—Technical and Environmental Analyses

September 1980

NTIS order #PB81-134769



Library of Congress Catalog Card Number 80-600118

For sale by the Superintendent of Documents, U.S. Government Printing Office Washington, D.C. 20402 Stock No. 052-003-00782-7

Foreword

In this volume of Energy From Biological Processes, OTA presents the technical and environmental analyses on which the conclusions in volume Lare based. The "Part 1: Biomass Resource Base" includes forestry, agriculture, processing wastes, and various unconventional sources including oil-bearing and aquatic plants. "Part 11: Conversion Technologies and End Uses" considers thermochemical conversions, fermentation for ethanol production, anaerobic digestion, use of alcohol fuels, select energy balances, and a brief description of chemicals from biomass. In each case, appropriate technical, economic, and environmental details are presented and analyzed.

JOHN H. GIBBONS Director

John H. filban

iii

Energy From Biological Processes Advisory Panel

Thomas Ratchford, Chairman Associate Executive Director, American Association for the Advancement of Science

Henry Art

Center for Environmental Studies Williams College

Stanley Barber Department of Agronomy

Purdue University

John Benemann

Sanitary Engineering Laboratory University of California, Richmond

Paul F. Bente, Jr. **Executive Director** The Bio-Energy Council

Calvin Burwell Oak Ridge National Laboratory

Robert Hirsch

EXXON Research and Engineering Co.

Robert Hodam California Energy Commission

Kip Hewlett Georgia Pacific Corp.

Ralph Kienker Monsanto Co.

Dean Kleckner President

Iowa Farm Bureau Federation

Kevin Markey Friends of the Earth

Jacques Maroni

Energy Planning Manager Ford Motor Co.

Michael Neushul

Marine Science Institute

University of California, Santa Barbara

William Scheller

Department of Chemical Engineering

University of Nebraska **Kenneth Smith**

Off ice of Appropriate Technology

State of California

Wallace Tyner

Department of Agricultural Economics

Purdue University

NOTE. The Advisory Panel provided advice and comment throughout the assessment, but the members do not necessarily approve, disapprove, or endorse the report for which OTA assumes full responsibility

Working Group on Photosynthetic Efficiency and Plant Growth

One Bjorkman

Carnegie Institution Stanford University

Glenn Burton Southern Region

U.S. Department of Agriculture

Gary Heichel

North Central Region U.S. Department of Agriculture University of Minnesota

Edgar Lemon

Northeastern Region

U S. Department of Agriculture

Cornell University

Richard Radmer Martin-Marietta Laboratory

Contractors and Consultants

The Baham Corp. Charles Berg California Energy Commission Otto Doering III **Douglas Frederick** Charles Hewett 1 E Associates Larry Jahn Robert Kellison Neushul Mariculture, Inc. Participation Publishers Princeton University, Department of Aerospace and Mechanical Sciences Purdue University, Departments of Agricultural Economics, Agricultural Engineering, and Agronomy

Santa Clara University, Department of Mechanical Engineering

State of California, Office of Appropriate Technology

T B Taylor, Associates

Texas A&M University, Departments of Agricultural Economics and Agricultural

Texas Tech University, Department of Chemical Engineering

University of California at Davis, College of Agricultural and Environmental Sciences University of California, Richmond Field Station

University of Pennsylvania, Department of Chemical and Biochemical Engineering University of Texas at Austin, Center for **Energy Studies**

University of Washington, College of **Forest Resources** Ronald Zweig

Energy From Biological Processes Project Staff

Lionel S. Johns, Assistant Director, OTA Energy, Materials, and International Security Division

Richard E. Rowberg, Energy Program Manager

Thomas E. Bull, Project Director

A. Jenifer Robison, Assistant Project Director Audrey Buyrn*

Steven Plotkin, Environmental Effects
Richard Thoreson, Economics
Franklin Tugwell, Policy Analysis
Peter Johnson, Ocean Kelp Farms
Mark Gibson, Federal Programs

Administrative Staff

Marian Growchowski Lisa Jacobson

Lillian Quigg Yvonne White

Supplements to Staff

David Sheridan, Editor

Stanley Clark

OTA Publishing Staff

John C. Holmes, Publishing Officer

Kathie S. Boss Debra M. Datcher Joanne Mattingly

^{*}Project director from April 1978 to December 1978

Acknowledgments

OTA thanks the following people who took time to provide information or review part or all of the study

Don Augenstein, Flow Laboratories Edgar E. Bailey, Davy McKee Corp. Richard Bailie, Environmental Energy Engineering, Inc.

Weldon Barton, U.S. Department of Agriculture

Charles Bendersky, Pyres, Inc. Edward Bentz, National Alcohol Fuels Commission

Beverly Berger, U.S. Department of Energy Brian Blythe, Davy McKee Corp. Hugh Bollinger, Plant Resources Institute Diane Bonnert, Soil Conservation Service Carroll Bottum, Purdue University Robert Buckman, U.S. Forest Service Fred Buttel, Cornell University

James Childress, National Alcohol Fuels Commission

Raymond Costello, Mittlehauser Corp. Gregory D'Allessio, U S Department of Energy

Ray Dideriksen, Soil Conservation Service Richard Doctor, Argonne National Laboratory

James Dollard, U.S. Department of Energy Warren Doolittle, U.S. Forest Service Ernest Dunwoody, Mittlehauser Corp. Ed Edelson, Pacific Northwest Laboratory Eugene Eklund, U.S. Department of Energy George Emert, University of Arkansas John Erickson, U.S. Forest Service

William Farrell, EXXON Research and Engineering Co Winston C. Ferguson, Conservation Con-

Winston C. Ferguson, Conservation Consultants of New England Kenneth Foster, University of Arizona

Douglas Frederick, North Carolina State
University

Ralph E C. Fredrickson, Raphael Katzen Associates

Tim Clidden, Dartmouth College Irving Goldstein, North Carolina State University

John Goss, University of California Roy Gray, Soil Conservation Service Loren Habegger, Argonne National Laboratory

John Harkness, Argonne National Laboratory

Sanford Harris, U.S. Department of Energy Marilyn Herman, National Alcohol Fuels Commission

Edward Hiler, Texas A&M University
Dexter Hinckley, Flow Resources Corp.
Wally Hopp, Pacific Northwest Laboratory
John Hornick, U.S. Forest Service
William Jewell, Cornell (University
Fred Kant, EXXON Research and Engineer-

J L. Keller, Union Oil of California
Don Klass, Institute of Gas Technology
J. A. Klein, Oak Ridge National Laboratory
Al Kozinski, Amoco Oil Co
Suk Moon Ko, Mitre Corp.
Kit Krickensberger, Mitre Corp.
Barbara Levi, Georgia Institute of

Les Levine, U.S. Department of Energy Edward Lipinsky, Battelle Columbus Laboratory

William Lockeretz, Northeast Solar Energy Center

Dwight Miller, U.S. Department of Agriculture

John Milliken, U.S. Environmental Protection Agency

Larry Newman, Mitre Corp.

Technology

Edward Nolan, General Electric Co John Nystrom, Arthur D. Little, Inc. Ralph Overend, National Research Council of Canada

Billy Page, U.S. Forest Service
R. Max Peterson, U S. Forest Service
David Pimentel, Cornell University
L. H. Pincen, U.S. Department of
Agriculture

Harry Potter, Purdue University
T. B. Reed, Solar Energy Research Institute
Mark Rey, National Forest Products
Association

Robert San Martin, U.S. Department of Energy

Kyosti Sarkanen, University of Washington John Schaeffer, Schaeffer and Roland, Inc. Rolf Skrinde, Olympic Associates Thomas Sladek, Colorado School of Mines Research Institute

Frank Sprow, EXXON Research and Engineering Co.

George Staebler, Weyerhauser Corp.
Terry Surles, Argonne National Laboratory
Robert Tracy, U.S. Forest Service
R Thomas Van Arsdall, U.S. Department
of Agriculture

R. I Van Hook, Oak Ridge National Laboratory

Thomas Weil, Amoco Chemicals Donald Wise, Dynatech R&D Robert Wolf, Congressional Research Service

Robert Yeck, U S Department of Agriculture John Zerbe, U S. Department of

John Zerbe, U S. Department of Agriculture