

FAJAR MARENDRA

GREEN ENERGY CIRCULATION:

THE ROLE OF ANAEROBIC DIGESTION
IN A CIRCULAR ECONOMY



Green Energy Circulation: The Role of Anaerobic Digestion in a Circular Economy

Fajar Marendra S.T., M.Sc



Green Energy Circulation: The Role of Anaerobic Digestion in a Circular Economy

Copyright © PT Penamuda Media, 2025

Author:

Fajar Marendra S.T., M.Sc

ISBN : 978-634-7431-19-6

Layout designer:

Tim PT Penamuda Media

Desain Sampul:

Tim PT Penamuda Media

Publisher:

PT Penamuda Media

Editorial:

Casa Sidoarum RT03 Ngentak, Sidoarum Godean Sleman Yogyakarta

Web : www.penamudamedia.com

E-mail : penamudamedia@gmail.com

Instagram : [@penamudamedia](https://www.instagram.com/penamudamedia)

WhatsApp : +6285700592256

First Edition, October 2025

x + 225 Pages; 15 x 23 cm

Copyright protected by law.

Reproduction or distribution of this book in any form or by any means is prohibited without the written permission of the publisher or the author

FOREWORD

Gratitude and praise we offer to the Almighty God, for His boundless mercy and blessings, which have enabled the completion of this book, "Green Energy Circulation: The Role of Anaerobic Digestion in a Circular Economy."

Climate change, the energy crisis, and the accumulation of waste represent the monumental challenges of our century. In this context, the circular economy approach and green technology innovations, such as anaerobic digestion, offer tangible opportunities to create a more sustainable world. This book is presented as a contribution to enriching both academic and practical understanding of how biogas, a product of organic waste processing, can become a crucial pillar in the transition towards a circular economy.

It is hoped that the writing of this book will provide a comprehensive overview of the basic concepts, current technologies, environmental and economic benefits, as well as the challenges and future prospects of biogas development.

I would like to extend my deepest gratitude to all parties who have supported the compilation of this book, including colleagues, practitioners, and academics who have been a constant source of inspiration. May this book serve as a beneficial reference for students, researchers, renewable energy practitioners, and anyone concerned with the sustainability of our planet.

Bogor, April 2025

The Author

TABLE OF CONTENTS

FOREWORD.....	v
TABLE OF CONTENTS.....	vi
CHAPTER 1: THE MODERN-DAY ENVIRONMENTAL AND ENERGY CRISIS.....	1
A. The Pros and Cons of Electric Vehicles: Solution or New Threat?.....	1
B. The Battery Waste Dilemma in the Energy Transition Era.....	18
C. Renewable Energy's Continued Dependence on Fossil Fuels.....	23
CHAPTER 2 GLOBAL WASTE: EXPORTS, IMPORTS, AND INDONESIA'S DILEMMA	26
A. Global Waste Export and Import: Between Economic Interests and Environmental Ethics.....	26
B. The Disarray of Indonesia's Domestic Waste Management	32
C. Regional Inequality and Reliance on Instant Solutions	37
CHAPTER 3 THE URGENCY OF A NEW PARADIGM: TOWARDS A CIRCULAR ECONOMY.....	44
A. The Failure of the Linear Paradigm: Produce–Consume–Discard	44
B. The Circular Economy as a Systemic Alternative	49
C. The Relevance of the Circular Economy in the Indonesian Context.....	54

CHAPTER 4 BASIC CONCEPTS OF THE CIRCULAR ECONOMY	59
A. Background and Urgency of the Circular Economy in the Global Context.....	59
B. Comparison of Linear Economy vs. Circular Economy	64
C. Implications of the Circular Economy for Waste and Energy Management.....	69
D. The Role of Technology in Driving the Transition to a Circular Economy	73
CHAPTER 5 ANAEROBIC DIGESTION: PROCESS AND POTENTIAL	77
A. Understanding Anaerobic Digestion.....	77
B. Biochemical Mechanism of the Anaerobic Process..	80
C. Stages of the Anaerobic Digestion Process	85
D. Factors Influencing Process Efficiency	89
E. Anaerobic Digestion Products: Biogas and Biofertilizer	106
CHAPTER 6 INTEGRATION OF ANAEROBIC DIGESTION IN THE CIRCULAR ECONOMY	110
A. Organic Waste as a Source of Renewable Energy....	110
B. Biogas in the Green Energy Scheme and Energy Decentralization.....	114
C. Biofertilizer: Contribution to Sustainable Agriculture.....	118
D. Biogas Value Chain in the Circular Economy	121
CHAPTER 7 ENVIRONMENTAL AND SOCIO-ECONOMIC BENEFITS.....	127
A. Reduction of Greenhouse Gas Emissions.....	127
B. Conservation of Natural Resources	132
C. Improvement of Local Community Welfare	135

D. Creation of Green Jobs	139
CHAPTER 8 CHALLENGES OF ANAEROBIC DIGESTION IMPLEMENTATION	143
A. Technological and Infrastructure Constraints	143
B. Economic and Financing Challenges	145
C. Regulations and Policies	146
D. Social Acceptance and Public Education	148
CHAPTER 9 CASE STUDIES AND BEST PRACTICES	150
A. Biogas Implementation in Europe	150
B. Biogas Programs in Asia and Latin America	152
C. Comparative Analysis: Success and Failure Factors	153
D. Lessons for Future Development	155
CHAPTER 10: FUTURE DIRECTIONS AND OPPORTUNITIES	161
A. Anaerobic Digestion Technology Innovations	162
B. Biogas Integration with Smart Grids and IoT	165
C. The Role of Anaerobic Digestion in the Net Zero Emissions Agenda	169
D. Strategic Recommendations for Strengthening the Circular Energy System	172
CHAPTER 11 SUPPORTING TECHNOLOGIES AND RECENT INNOVATIONS IN ANAEROBIC DIGESTION SYSTEMS.....	178
A. Integration of IoT and Smart Sensor Technology in Anaerobic Reactors	178
B. Utilization of Bioengineered Microorganisms for High Methane Production	182
C. Biogas Purification Technology: Upgrading and Enrichment.....	186
D. New Generation Reactors: Modular, from Household to Industrial Scale	189

E.	AI and Machine Learning-Based AD Process Modeling and Simulation.....	193
CHAPTER 12 POLICY STRATEGIES AND BUSINESS MODELS TO PROMOTE THE APPLICATION OF ANAEROBIC DIGESTION		
198		
A.	Global Policy Analysis: Lessons from the European Union, China, and the US.....	198
B.	National Policy and Regulatory Reform Recommendations in Indonesia.....	202
C.	Financing Schemes and Economic Incentives	206
D.	Circular Business Models in AD: From Waste to Economic Value	210
E.	Implementation Strategy in the Regions: Collaboration between Local Government, Academia, and Community	213
REFERENCES.....		218
ABOUT THE AUTHOR.....		224

GREEN ENERGY CIRCULATION:

THE ROLE OF ANAEROBIC DIGESTION IN A CIRCULAR ECONOMY

Amidst environmental crises, soaring waste levels, and global dependence on fossil fuels, this book emerges as a significant contribution to redefining the path of sustainable development. Green Energy Circulation provides a comprehensive discussion on how Anaerobic Digestion (AD) technology can serve as a strategic solution for advancing the circular economy and transitioning towards a cleaner, more efficient energy system.

Employing a scientific yet accessible approach, the author outlines the fundamental principles of the circular economy, the biochemical mechanisms of the anaerobic process, the potential of biogas and biofertilizer, and how AD technology can transform organic waste into high-value resources. Furthermore, the book presents global case studies from countries like Germany, Sweden, India, and Brazil, which have successfully implemented AD on a massive scale.

The author emphasizes the critical importance of integrating the latest technologies such as the Internet of Things (IoT), artificial intelligence (AI), and circularity-based business models as keys to the successful implementation of AD, from household to industrial scales. Critical issues such as regulatory challenges, financing, public education, and cross-sector collaboration are also discussed in depth.

This book is highly relevant for students, researchers, policymakers, environmental activists, and renewable energy practitioners. With a reflective yet data-driven presentation style, this book not only offers theoretical insights but also provides a practical roadmap for building a resilient and inclusive circular energy ecosystem for the future.

ISBN 978-634-7431-19-6 (PDF)



9

786347

431196



Penamuda.com

PT Penamuda Media
Casa Sidorum, Ngentak Gedean
penamuda_media