

Green Energy and Technology

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Biogas Technology in Southeast Asia

 Springer

Green Energy and Technology

Climate change, environmental impact and the limited natural resources urge scientific research and novel technical solutions. The monograph series Green Energy and Technology serves as a publishing platform for scientific and technological approaches to “green”—i.e. environmentally friendly and sustainable—technologies. While a focus lies on energy and power supply, it also covers “green” solutions in industrial engineering and engineering design. Green Energy and Technology addresses researchers, advanced students, technical consultants as well as decision makers in industries and politics. Hence, the level of presentation spans from instructional to highly technical.

****Indexed in Scopus**.**

****Indexed in Ei Compendex**.**

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ISSN 1865-3529

ISSN 1865-3537 (electronic)

Green Energy and Technology

ISBN 978-981-19-8886-8

ISBN 978-981-19-8887-5 (eBook)

<https://doi.org/10.1007/978-981-19-8887-5>

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The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

To the biogas community, let our collective vision for renewable energy, recycled waste and a cleaner environment keep progressing toward a carbon-free future

Preface

This is the first edition of our book, *Biogas Technology in Southeast Asia*. It is authored by Pruk Aggarangsi, Sirichai Koonaphapdeelert, Saoharit Nitayavardhana and James Moran. The authors have worked closely with the editorial team from Springer Nature to publish this book. There are a total of eight chapters covering biogas production, preprocessing, operation, cleaning and end use applications. Each chapter is a self contained unit. It is not necessary to read them all in sequence. Chapter 1 introduces biogas and makes a case for including it in a countries renewable energy mix. Chapter 2 introduces the production process. The biochemical reactions and pathways taken during biogas production are introduced. The terminology associated with biogas digesters is explained. Chapter 3 concerns itself with the wide variety of digesters currently available. Each digester type has unique attributes that make it suitable for a particular feedstock, climate and economic outlay. Particular attention is paid to those that are exclusively designed for use in Southeast Asia. Chapter 4 is a specialized chapter for the pretreatment of lignocellulosic feedstock (biomass) before it can be digested. Since most feedstock in Southeast Asia is wastewater, this pretreatment step is unnecessary. However if crops, grass, wood, etc. are being used to generate biogas, then it becomes necessary to pretreat. Chapter 5 is about the operation and control of the digester. Nowadays, automatic control is only sporadically used, but this is likely to change in the future as our understanding of the complex process broadens. Though each biogas plant is different, they all have some operational procedures in common that ensure a safe and stable digester. Chapter 6 is a post-treatment chapter. The output from the digester includes wastewater (cleaner but still too polluted to release back into the environment) and sludge in addition to biogas. Treating this wastewater so it can be released into the environment and drying the sludge for fertilizer are the processes discussed in this chapter. Chapter 7 introduces the many uses for biogas, from heat production to fuel cells. Several applications require the biogas to be cleaned and/or dried. The level of purity required is dependent on the destination. Chapter 8 concludes with a case study on the design and construction of a biogas digester in the South of Thailand.

The growing importance to develop non-intermittent sources of renewable energies is the driving force behind extracting energy from biomass. Biogas is one such

source and has its own advantages over other biomass energy products, such as bioethanol, because it can be produced from organic waste products. Southeast Asia produces plenty of organic waste but suffers from take-off options for the biogas. Farms and organic producers are located away from population centers, and unlike Europe, Southeast Asia is not networked with gas grids. Transporting biogas economically or using it close to production are challenges. Many biogas plants are constructed due to regulation requiring treatment of this wastewater. The traditional treatment is to place the wastewater in open ponds where the gases produced get released to the atmosphere. Methane has a global warming potential 25 times greater than carbon dioxide, and therefore, every effort should be made to capture and use it productively or at the very least flare it safely.

The aim of this book is to provide a description of techniques, processes and necessary procedures to turn bioproducts into biogas. The microbial reactions that govern the process are discussed early, but the focus of this book is on the engineering required to select and construct biogas digesters. The pre- and post-treatments required for the feedstock and estimating the production rate from the feedstock supply and pollution level. The civil engineering involved in digester construction is a separate topic, not discussed in detail here but left to other dedicated books on this matter. Most of the subject matter comes from the design of biogas plants from agricultural farms across Southeast Asia, in particular Thailand which is where the authors are based.

This book focuses on biogas produced from organic agricultural waste and food processing plants since these are the areas the authors have direct experience with. Biogas from landfill gas, sewage sludge and municipal waste are not discussed in this book mainly because Southeast Asia does not have many of these types of biogas plants. Biogas from these sources is typically more expensive as it contains more impurities that need to be removed prior to combustion.

Several sections of the book deal with economic issues, such as plant construction and operating costs. Chapter 8 is a case study on a plant built in the South of Thailand. The costs are in Thai baht. Costs, especially labor cost, will of course be different elsewhere. Where possible the costs are presented in US dollars at a conversion rate of \$1 = B33. Since this conversion rate fluctuates on a daily basis, prices presented in dollars should be used only as a guide. Technical data here is presented in SI units where possible. In some circumstances when the original data is presented in English units, then it is left as such. Units for production of biomethane are usually expressed as Nm^3/h , which stands for normal cubic meter per hour under standard conditions of 0 °C and 1 atm (101.325 kPa).

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Acknowledgments

The assistance of many individuals who contributed material and suggested improvements is gratefully acknowledged. Thanks are also due to the companies and organizations who graciously provided data and gave permission for reproducing charts and figures. The number of such organizations is too large to permit individual recognition here; however, they are generally identified in the text as the sources of specific data. The authors wish to thank the researchers and staff at the Energy Research and Development Institute Nakorping of Chiang Mai University (ERDI-CMU) who have continuously been conducting research and development into renewable energies with a focus on biogas and its many applications. Special thanks also goes to Mr. Panutat Injaima and Mr. Warut Yuennan for their help with the graphic design. Among the many who have supported and financed this research over the years, special thanks goes to the Energy Conservation Fund (ENCON fund), the Thai Ministry of Energy.

We would like to acknowledge our partners throughout the years include the Thai Biogas Trade Association, Agrikomp GmbH, Chiang Mai Fresh Milk Farm Co., and special thanks to Nam Hong Power Co. for allowing us to share the details of biogas design and construction as a case study for the book.

Other significant contributor to this first edition is Chandra Sekaran our patient editor. Finally, we wish to express gratitude to our families for their support and patience during the preparation of this book. To all fellow researchers in the field of biogas, we wish to extend our deepest gratitude and thanks.

About This Book

Biogas Technology in Southeast Asia is focused on the applications of biogas technology to waste and wastewater management problems commonly experienced in Southeast Asia. The book content is balanced between intensive biological process and the authors' field experience of biogas digester designs and operation. The book begins with basic explanation on anaerobic digestion process of organic matter specifically on waste and wastewater produced from agricultural industries in the region, including swine farms, palm oil mills and tapioca starch factories. Specific biogas yields and digestion conditions are explained and verified using data provided by the Energy Research and Development Institute Nakornping of Chiang Mai University. This book also emphasizes digester selection and design based on feedstock input and other engineering conditions. Readers will be to estimate and visualize the project scale from the major components. Biogas operating conditions are discussed with crucial parameters suggested for monitoring. Lastly, biogas utilization in electricity and heat production are presented based on applicability in the region. This book should be suitable for general audiences up to project developers and plant operators. The authors aim the share existing experience and lessons learned, contributing to the biogas community.

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All authors have published several peer-reviewed papers on biogas, and this book represents an agglomeration of this work.

Nomenclature

\dot{Q}	Wastewater volume flow rate, (m ³ /day)
μ	Volatile solids specific growth rate, (day ⁻¹)
<i>BOD</i>	Biochemical oxygen demand, (mg/L)
<i>C</i>	Substrate concentration, (mg/L)
<i>COD</i>	Chemical oxygen demand, (mg/L)
<i>D</i>	Dissolved oxygen, (mg/L)
<i>d</i>	Water depth, (m)
<i>HRT</i>	Hydraulic retention time, (day)
k_d	Microbe decay rate, (day ⁻¹)
K_s	Monod constant, (mg/L)
k_t	BOD removal constant, (–)
<i>n</i>	Number of moles (–)
<i>n</i>	Porosity, (–)
<i>P</i>	Absolute pressure, (atm)
<i>R</i>	Universal gas constant, (0.082L atm/mol K)
<i>S</i>	Nutrient concentration, (mg/L)
<i>SRT</i>	Solids retention time, (day)
<i>T</i>	Temperature, (K)
<i>TSS</i>	Total suspended solids, (mg/L)
<i>ULV</i>	Upflow liquid velocity, (m/day)
<i>V</i>	Volume, (L)
<i>VSS</i>	Volatile suspended solids, (mg/L)
<i>X</i>	Average microbe concentration, (mg/L)
<i>Y</i>	Biogas yield, (gVSS/gCOD)
<i>OLR</i>	Organic loading rate, (kg COD/m ³ day)

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