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Sustainability of Biofuel Production from Oil Palm Biomass

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Preface

The application of biofuel production systems in solving the global energy crisis has raised controversial issues pertaining to their ecological, thermodynamic, social, economic, political and environmental sustainability. The oil palm industry generates huge amount of biomass every year yet only a small amount is utilized for value-added bioproducts like biofuels, food supplements etc. Sustainability of biofuels from various feedstocks including oil palm biomass are questionable due to many factors such as the heavy use of fossil fuel during production, inefficiency in technological design, generation of large amount of unutilized wastes into the environment etc. However, sustainable energy and resource development should aim for significant reductions on the demand side with greater conservation and improved process efficiency. The major goal of a sustainable production is to effectively utilize resources by minimizing energy and material extraction and throughput per unit of economic output as well as simultaneously improving environmental quality (by minimizing the use of fossil fuel or better still, doing away with them), social well-being of the community while proper policy implementation plans are adhered to.

This book, *Sustainability of Biofuel Production from Oil Palm Biomass* evaluates and discusses the main sustainability challenges encountered during the production of biofuel and other value added bioproducts from oil palm biomass. This book is divided into three main parts with a total of eight chapters.

Chapter 1 gives an overview and comprehensive details on the differences between sustainability and sustainable development with major consideration on biofuels. Biofuels production has various impacts on certain activities such as food production, water quality, biodiversity etc. Thus the choice of raw materials, plantation and harvesting technologies, production process designs, product delivery methods etc. largely determine their sustainability. The dimensions, key issues, initiatives, principles, and criteria for sustainable biofuels production are therefore discussed into details.

Prior to the sustainability assessment of any biofuel production system, there is the need to critically assess technology and the potential of the system to benefit the society. Chapter 2 therefore discusses biofuels in general with great emphasis on biofuel types, production technologies, global production and consumption profiles as well as their market potentials. Biofuels could hold impressive market potentials in the world today and in the future but their production technologies may be sophisticated and costly which could alter its sustainability for sustainable development.

The palm oil industry in the world generates over 190 million tonnes of wastes in the form of solid and liquid residues. Out of this only about 10 % are utilized commercially for value added bioproducts like biofertilizers. Chapter 3 elaborates on the types of oil palm biomass and their specific characteristics as feedstocks for biofuels production. The potential applications of oil palm biomass for other value added bioproducts are also discussed in Chap. 3.

Among the sources of feedstocks for biofuel production currently available and developed in the world, the oil palm is the prime option which fulfills the sustainability criteria for high productivity, efficiency, competitive price discounts, and above all cost effective. Chapter 4 discusses into details the basic and acceptable production criteria for sustainable oil palm and palm biofuels developments. This chapter highlights on some best management practices involving globally accepted initiatives for sustainable oil palm agriculture, palm oil milling, and refining as well as different production routes to palm biofuels production. Integration of different production routes for various types of palm biofuels through effective utilization of wastes toward sustainable development are also elaborated in this chapter.

Chapter 5 discusses about one of the dimensions of sustainability (environmental sustainability) with case studies of different types of palm biofuels. With the aim of minimizing the dependency on fossil fuels while improving the economic viability and environmental performances of oil palm production for biofuels production, emission control from these systems become invincible. However, with best management practices coupled with stringent adherence to basic environmental sustainability principles, these hurdles may be surmounted. The environmental sustainability dimension of the environmental impact assessment for this chapter is based on life cycle assessment (LCA) for common palm biofuels like biodiesel, bioethanol, biomethanol via BtL route, biogas and bioelectricity (bioenergy) from oil palm biomass.

The production of palm biofuels provides the prospects for new wide economic avenues in terms of job creation, investment opportunities etc. for most people in rural communities in developing countries. Chapter 6 of this book assesses the economic sustainability of different types of palm biofuels and the results are compared to those for fossil fuels. Improvement suggestions for a more economic sustainability of palm biofuels are further elaborated in Chap. 6.

In reality, all production processes proceed with the generation of entropy and destruction of useful energy of resource inputs. In view of this, the second law of thermodynamics can be directly linked with sustainability and sustainable development of production systems. In Chap. 7 of this book, case studies for palm biofuels' (biodiesel, bioethanol, biogas, briquettes etc.) thermodynamic sustainability evaluations are carried out using exergy analysis as the major assessment tool. Thermodynamic sustainability considerations in this chapter include feedstock (oil palm biomass) production thus giving a better view of the overall thermodynamic efficiencies of the studied palm biofuel system. Potential causes of inefficiencies and improvement options for sustainable palm biofuels production are also discussed in Chap. 7.

Social sustainability of the palm biofuel industry stresses on the need to produce favorable social and distributional effects like employment, food security, conservation of cultures, equality in sharing between involving parties, technological advancement, and training etc. that would continue to benefit the future generation. The expansion of the oil palm biofuels industry in reaction to the climate change mitigation has necessitated the industry over social, environmental, and political sustainability of palm feedstocks production. Though the production of oil palm biomass and subsequent conversion into biofuels have positive social impacts, some research reports reveal the high rate of unemployment, homelessness and poverty among rural folks who are engaged in oil palm cultivation. Chapter 8 of this book discusses into details the factors that affect the sociopolitical sustainability of palm biofuels and possible improvement suggestions are made.

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Contents

Abbreviations

ADF	Acid Detergent Fiber
AFU	Average Fuel use per Working Hour (l/h)
APROBI	Association of Biofuel Producers
ARE	Federal Office for Spatial Development
AREA	Operating Area (ha)
ASTM	American Society for Testing and Materials
ASTM-D	American Society for Testing and Materials-Draft
BACP	Biodiversity and Agricultural Commodities Program
BMP	Best Management Practices
BOD	Biological Oxygen Demand (ppm)
BP	By-product Credit (US $)
BRDi	Biomass Research and Development
BtL	Biomass-to-Liquid Technology
B5	Biodiesel Blend with Petro-diesel (5 % Biodiesel, 95 % Petro-diesel)
B10	Biodiesel Blend with Petro-diesel (10 % Biodiesel, 90 % Petro-diesel)
B100	Biodiesel in Pure Form
CANMET	Canada Center for Mineral and Energy Technology
CC	Capital Cost ($)
CDIAC	Carbon Dioxide Information Analysis Center
CDM	Clean Development Mechanism
CE	Biodiesel Conversion Efficiency
CERFLOR	Brazilian Program of Forest Certification
CExC	Cumulative Exergy Consumption
CHP	Combined Heat and Power
COD	Chemical Oxygen Demand (ppm)
CPO	Crude Palm Oil
CPKO	Crude Palm Kernel Oil
CPW	Compound Present Worth
CSA	Canadian Standards Association
CSBP	Council on Sustainable Biomass Production
CSPO	Certified Sustainable Palm Oil

DCFRR	Discounted Cash Flow Rate of Return
DEFRA	Department for Environment, Food, and Rural Affair
DM	Dry Matter
DOE	Department of the Environment
ED	Specific Direct Energy Use (fuel) for Field Operation (MJ/ha)
EEA	Eurostat, European Environment Agency
EFB	Empty Fruit Bunch
EIA	Energy Information Agency
EISA	Energy Independence and Security Act
EN	European Standard
EPFL	Energy Center at Ecole Polytechnique Federale de Lausanne
ESMAP	Energy Sector Management Assistance Program
EU	European Union
FAO	Food and Agriculture Organization
FC	Feedstock Cost (US $)
FFA	Free Fatty Acid
FFB	Fresh Fruit Bunch
FGF	First Generation Feedstocks
FGB	First Generation Biofuels
FP	Feedstock Price (US $/tonne)
FSC	Forest Stewardship Council
FU	Feedstock Consumption (tonne)
GBEP	Global Bioenergy Partnership
GCF	Co-product Conversion Factor from Feedstock Oil
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOFBM	Global Oils and Fats Business Magazine
GP	Co-product Price (US $/kg)
GPI	Genuine Progress Indicator
HYSYS	HYprotech SYStems
IAEA	International Atomic Energy Agency
ICCR	Interfaith Center on Corporate Responsibility
ICGP	Interorganizational Committee on Guidelines and Principles
IEA	International Energy Agency
ILO	International Labour Organization
ISO	International Organization for Standardization
ITA	Investment Tax Allowances
IUCN	International Union for Conservation of Nature
JPOI	Johannesburg Plan of Implementation
LABEN	Labor Energy (MJ/ha)
LABENF	Labor Energy Factor (MJ/h)
LABOR	Number of Working laborers
LCA	Life Cycle Analysis
LCC	Life Cycle Cost (US $)

LCSP	Lowell Center for Sustainable Production
LPG	Liquefied Petroleum Gas
MC	Maintenance Cost (US $)
MEMR	Ministry of Energy and Mineral Resources
MPOB	Malaysian Palm Oil Board
MPOWCF	Malaysian Palm Oil Wildlife Conservation Fund
MR	Maintenance Ratio (%)
NBP	National Biofuel Policy
NBPOL	New Britain Palm Oil Limited
NDF	Neutral Detergent Fibre
NEP	National Energy Policy
NGO	Non-Governmental Organizations
NKEA	National Key Economic Areas
NMHC	Nonmethane Hydrocarbons
OC	Operating Cost (US $)
OECD	Organization for Economic Co-operation and Development
OPF	Oil Palm Frond
OPL	Oil Palm Leaves
OPR	Oil Palm Root
OPT	Oil Palm Trunk
OPW	Oil Palm Wastes
OR	Operating Rate (US $/tonne)
PC	Annual Biodiesel Production Capacity (Tonne/year)
PD	Petroleum Diesel
PEU	Specific Energy Value per liter of Fuel (MJ/l)
PFAD	Palm Fatty Acid Distillate
PKS	Palm Kernel Shell
PKC	Palm Kernel Cake
POME	Palm Oil Mill Effluent
PORAM	Palm Oil Refiners Association of Malaysia
POTICO	Palm Oil, Timber, Carbon Offset
PP	Payback Period (Year)
PPF	Palm Pressed Fiber
PPO	Pure Plant Oil
PWF	Present Worth Factor
R&D	Research and Development
RBD	Refined, Bleached, and Deodorized
RC	Replacement Cost (US $)
RED	Renewable Energy Directive
REDD	Reducing Emissions from Deforestation and Forest Degradation
REN21	Renewable Energy Policy Network for the 21st Century
RFA	Renewable Fuels Association
RFS	Renewable Fuel Standard
RMHW	Hamilton Wentworth Regional Council

ROR	Rate of Return
RPKO	Refined Palm Kernel Oil
RPO	Refined Palm Oil
RSB	Roundtable on Sustainable Biofuels
RSPO	Roundtable on Sustainable Palm Oil
RTFO	Renewable Transport Fuels Obligation
RTRS	Roundtable on Responsible Soy
RU	Runs (Number of Application in the Considered Field Operation)
SDC	Swiss Agency for Development and Cooperation
SFI	Sustainable Forest Initiative
SGF	Second Generation Feedstocks
SGB	Second Generation Biofuels
SHF	Separate Hydrolysis and Fermentation
SIRIM	Industrial Research Institute of Malaysia
SNG	Synthetic Natural Gas
SSF	Simultaneous Saccharification and Fermentation
SV	Salvage Value (US $)
SVO	Straight Vegetable Oil
TAX	Annual Total Tax (US $/Year)
TBS	Annual Total Biodiesel Sales (US $/Year)
TGB	Third Generation Biofuels
TGF	Third Generation Feedstocks
TIME	Operating Time (h)
TPC	Annual Total Production Cost (US $/Year)
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Commission on Sustainable Development
UNEP	United Nations Environment Programme
UNDESA	United Nations Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
US $	US Dollar
WCED	World Commission on Environment and Development
WSSD	World Summit on Sustainable Development
WWF	World Wide Fund for Nature
WWI	World Watch Institute

Symbols

C_p	Specific heat capacity (kJ/kmol·K)
d	Deprecation ratio (%)
D^{int}	Internal exergy loss
D^{ext}	External exergy loss

E^{pu}	Produced utilizable exergy
E^{c}	Consumed exergy
En_{in}^{net}	Net energy into a system (MJ)
$E^{\sim}$	Exergy content
E^{tr}	Transformed exergy
$Ex_{destroyed}$	Total exergy destroyed, MJ
$Ex_{efficiency}$	Exergy efficiency
$Ex_{de\text{-}activation}$	Exergy of activation energy used during treatment of wastes (MJ)
$Ex_{emissions}$	Exergy of wastes (MJ)
Ex_{fossil}	Exergy non-renewable energy resources (MJ)
$Ex_{product}$	Exergy of the product
Ex_{total}	Total exergy (MJ)
Ex_i	Exergy of *i*th component (MJ/kg)
$Ex_{ch,i}^{0}$	Standard chemical exergy of *i*th component (MJ/kg)
$Ex_{ch,i}$	Chemical exergy of *i*th component (MJ)
$Ex_{ph,i}$	Physical exergy of *i*th component (MJ)
$Ex_{ch,mixtures}$	Exergy of mixtures (MJ)
Ex_{ch,H_2O}^{0}	Standard chemical exergy of water (MJ/kg)
$Ex_{kin,i}$	Kinetic Exergy (MJ)
$Ex_{pot,i}$	Potential Exergy (MJ)
h	Specific working hours per run (h/ha)
H	Specific enthalpy (kJ/kg)
H_0	Specific enthalpy at T_0, p_0 (kJ/kg)
i	year
I	Irreversibility (MJ)
m_i	Mass of *i*th component (kg)
n	Project life time (year)
N_i	Number of moles of component *i*
p_i	Pressure of *i*th component (kPa)
p_0	Reference pressure = 1 atm = 101.3 kPa
q	Quality of joule (work)
Q	Heat flux (J)
r	Interest rate (%)
R	Ideal gas constant = 8.314 J/mol·K
S	Specific entropy (kJ/kgK)
S_0	Specific entropy at T_0, p_0 (kJ/kgK)
$S_{generation}$	Entropy generation (MJ/K)
T	Temperature (K)
T_0	Reference temperature = 273.15 K
μ_i	Chemical potential of *i*th component (kJ/mol^2)
v_{H_2O}	Mole fraction of water
W_{in}	Net energy into a system
W_{lost}	Lost work (MJ)

ΔG_{fo}	Standard Gibbs free energy of formation (kJ/mol), (kJ/kg)
β	Ratio of chemical exergy to the lower heating value (LHV) or dry organic substances (dimensionless)
λ_i	Mole fraction of *i*th component