ERIA Research Project Report 2011, No.19

EXTENDING THE ERIA WG METHODOLOGY FOR SUSTAINABILITY ASSESSMENT OF BIOMASS UTILIZATION IN EAST ASIAN COUNTRIES

Edited by
ERIA WORKING GROUP ON
"SUSTAINABILITY ASSESSMENT OF BIOMASS UTILIZATION IN EAST ASIA"

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February, 2013

PREFACE AND ACKNOWLEDGEMENT

The ERIA Working Group (WG) on "Sustainability Assessment of Biomass Utilization in East Asia" started its research activity in 2007. In the first phase (2007-2008), the WG summarized the concept of sustainability and issues related to biomass utilization in East Asian countries. In the second phase (2008-2009), the WG developed "Guidelines to Assess Sustainability of Biomass Utilization in East Asia". The WG's third phase research activities (2009-2010) involved conducting four pilot studies to test the methodology developed under the guidelines; and the research of the fourth phase (2010-2011) upgraded the methodology based on the lessons learnt from the pilot studies.

This report is to summarize the outcome of the fifth phase (2011-2012) of the research activity, in which the WG constructed the basic concept of a decision support tool based on the methodology, and also extended the methodology.

Our sincere thanks first go to all the members of the WG for their tremendous efforts to complete this research activity. They contributed valuable ideas, opinions, suggestions and even lessons. Secondly, we would like to express our appreciation to ERIA for its financial support. Finally, we would like to thank all the colleagues who supported our research activities.

AIST Research Team

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ABBREVIATIONS AND ACRONYMS

AHP	Analytic Hierarchy Processes
ASEAN	Association of Southeast Asian Nations
CA	Conjoint Analysis
BAP	Budget Allocation Processes
BEFSCI	Bioenergy and Food Security Criteria and Indicators
CAPEX	Capital Expenditure
	Carbon dioxide
	equivalent
CPO	Crude Palm Oil
CV	Calorific Value
dLUC	Direct Land Use Change
EFB	Empty Fruit Bunch
EISA	Energy Independence and Security Act
EMP	Employment Rate
EPB	Employment in Bioenergy Sector
ERIA	Economic Research Institute for ASEAN and East Asia
FAO	Food and Agriculture Organization of the United Nations
FFB	Fresh Fruit Bunch
GBEP	Global Bioenergy Partnership

GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNI	Gross National Income
GREET	The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model
GWP	Global Warming Potential
GVA	Grass Value Added
HDI	Human Development Index
iLUC	Indirect Land Use Change
IPCC	Intergovernmental Panel on Climate Change
ISCC	International Sustainability & Carbon Certification
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LC-GHG	Life Cycle Greenhouse Gas
LCI	Life Cycle Inventory
LUC	Land Use Change
MDGs	Millennium Development Goals
MF	Mesocarp Fibers
MJ	Mega Joule
MWh	Mega Watt hour
MYR	Malaysian Ringgit

NHBE	Number of Households with any Modern Bioenergy
NHME	Number of Households with any Modern Energy
NIR	National Greenhouse Gas Inventory Report
NPE	Number of Persons Employed in all activities
NPEB	Number of Persons Employed in Bioenergy
OPEX	Operational Expenditure
OPF	Oil Palm Fronds
OPS	Oil Palm Shells
OPT	Oil Palm Trunk
QA	Quality Assurance
RCA	Responsible Cultivation Areas
RFS	Renewable Fuel Standard
RSB	Roundtable on Sustainable Biofuels
SDI	Social Development Indicator
TLF	Total Labor Force of the village/community
TNHH	Total Number of Household in village/community
TVA	Total Value Added
UCM	Unobserved Components Models
UNDP	United Nations Development Programme
USD	United States Dollar
VA	Value Added

WG	Working Group
WPC	Wood Polymer Composite

EXECUTIVE SUMMARY

The activities of the ERIA WG during 2011-2012 were mainly aimed at two objectives; (1) checking the indicators developed by the WG for assessing sustainable biomass utilization with other international efforts such as the Global Bioenergy Partnership (GBEP) and the Roundtable on Sustainable Biofuels (RSB) and (2) developing an ex-ante decision support tool for assessing the sustainability of biomass utilization systems.

Vis-à-vis the first objective, the sustainability indicators of biomass utilization identified in the international initiatives were considered and compared with those selected for the ERIA WG methodology. The sustainability indicators in the ERIA WG methodology were found to be consistent with those in GBEP and RSB. In the case of environmental assessment, life cycle greenhouse gas (GHG) emissions are considered relevant. As an additional indicator to be included in the ERIA WG's methodology, soil quality was reviewed. In the case of economic assessment, Total Value Added (TVA) was seen to capture the most important consideration for the East Asia context, even though the other international initiatives included more indicators. In the case of social assessment, Employment and Access to modern energy, as identified in the earlier report by the ERIA WG, were considered as the relevant indicators.

To meet the second objective, a decision support tool to make ex-ante sustainability assessments on biomass utilization was developed, and the relevance

of the indicators developed by the ERIA WG was discussed. Life cycle GHG emissions, TVA (using the production approach) and employment were identified as the indicators most suitable for use in the ex-ante decision support tool. The tool was then tested using a case study of the utilization of empty fruit bunches from palm oil mills in Malaysia for producing pellets (energy carrier) and biofiber composite profiles (biomaterials). It was seen that the tool could be successfully used for assessing the sustainability of the two utilization pathways.

CHAPTER 1

Introduction

1. Sustainability of Biomass Utilization

Biomass utilization for energy or fuels has been attracting the world's attention due to its potential to contribute to rural development and employment generation. It may also help diversify energy supply and decrease dependency on fossil fuel based energy, particularly in East Asian countries. However, there are some negative issues recognized through the increased demand of feedstock for bioenergy and implementation of policies for an enhanced use of bioenergy. These issues are mainly related to environmental or social concerns about increase in Greenhouse Gas (GHG) emissions, loss of biodiversity, unwanted impacts on livelihoods of local communities, food insecurity, etc.

With increasing concerns on the above issues, several initiatives on the assessment of sustainability bioenergy have emerged in recent years. These initiatives are working on developing the sustainability criteria, indicators, certification systems and legislations for the processing of bioenergy feedstock and production and consumption of bioenergy.

2. Initiatives on Assessment of Sustainability

Some of the well-recognized initiatives on the sustainability of bioenergy could be classified into three categories. The first category is those initiatives established to provide the guidelines for sustainability, covering all significant elements of sustainability from environmental, economic and social points of view, and prepare comprehensive indicators and checklists to propose a best practice or a goal. The second category is designed for a certification system, which certifies that an organization within the supply chains of bioenergy, e.g., a grower or a processer of biomass feedstock, satisfies a specific standard of sustainability. To become certified, the organization must meet the requirements prepared by these initiatives and prove its continuous efforts on sustainability by undergoing annual audit. Such initiatives usually provide standards, checklists, methodologies and tools for their sustainability certification process. The third category comprises the sustainability standards used in legislation or policies associated with bioenergy. For example, bioenergy legislation in some developed countries specifies volumetric requirements of biofuel use, aiming at GHG emissions reduction to mitigate climate change. This category of initiatives stipulates rigid sustainability standards, including a specific percentage of lifecycle GHG emissions reductions of bioenergy compared with that of fossil energy, and provides calculation methodologies, tools and databases for the calculations.

3. Activities of ERIA's Working Group

ERIA's expert working group (WG) on "Sustainability Assessment of Biomass Utilization in East Asia" comprises researchers specialized in any one or more aspects of sustainability and working in the East Asian Countries. The WG started its activities on "Sustainable Biomass Utilization" in 2007 with the support of the Economic Research Institute of ASEAN and East Asia (ERIA). Since then the WG has been involved in conducting studies on the sustainability assessment of biomass utilization for energy. As there were no well-established sustainability initiatives on bioenergy at that time, the WG started with discussions on a "Sustainable Biomass Utilization Vision in East Asia" in 2007-2008 (Sagisaka, 2008), suggested policy recommendations and framed the "Asian Biomass Energy Principles", which were endorsed by the Energy Ministers Meeting of the East Asian Summit in Bangkok in August 2008. In response to the request from the energy ministers of the region to develop a methodology to assess the environmental, economic and social impacts of biomass utilization for energy by taking into account specific regional circumstances, the WG started investigations toward "Guidelines for Sustainability Assessment of

Biomass Utilization in East Asia" in 2008-2009 (Sagisaka, 2009), in which the WG identified indicators for each aspect of sustainability. Subsequently, in 2009-10, the WG tested its guidelines through field studies by conducting four pilot studies, one each in India, Indonesia, Thailand and the Philippines, and investigated the sustainability of a variety of feedstocks being utilized for bioenergy in these countries (ERIA, 2010).

Application of the ERIA WG methodology to the above pilot studies indicated that extensive data collection was required for use of all the indicators suggested by the methodology, and interpretation of results. In 2010-2011, based on the lessons learned from the pilot studies, the WG discussed the applicability of the indicators and proposed some specific and practical indicators to assess environmental, economic, and social aspects of sustainability of biomass energy utilization for both small and large scale initiatives (ERIA, 2011).

In this phase of the ERIA project (2011-2012), with increased worldwide activities in development of a variety of sustainability assessment initiatives, the WG has reviewed the methodologies of some major initiatives and extended its methodology from an ex-post assessment tool to an ex-ante assessment tool, so that it could support appropriate decision making and ensure the sustainability of biomass projects at the planning stage.

This report summarizes the outcome of the WG's activities in 2011-2012 and starts with the review of sustainability indicators developed by other sustainability initiatives in Chapter 2. Chapter 3 outlines the direction and sustainability indicators of the ERIA WG methodology, which were based on discussions in a series of WG meetings in 2011-2012. The means of quantification for additional social indicators that were proposed in the previous report were set out here. Towards a more practically-relevant ERIA WG methodology, Chapter 4 proposes the framework of a "decision support tool" that was prepared in response to the needs for ex-ante assessment of the sustainability of biomass utilization. As a preliminary exercise, a case study in Malaysia was conducted to test the framework of the "decision support tool".

CHAPTER 2

Review of Environmental, Economic and Social Indicators

Various initiatives related to the sustainability of biomass utilization have emerged in recent years. The BEFSCI Project of the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2011) conducted a review of 23 of these sustainability initiatives and classified the sustainability aspects/issues addressed under the initiatives into 24 categories. Among these initiatives, the WG focused on the environmental, economic and social indicators of the Global Bioenergy Partnership (GBEP, 2011) and the Roundtable on Sustainable Biofuels (RSB, 2010). In the following sections, in addition to the review of indicators of the above two initiatives, some other initiatives were also taken up as appropriate.

1. Review of Environmental Sustainability Indicators

This section looks over the environmental impact categories and corresponding indicators taken into consideration in two well-recognized initiatives, GBEP and RSB. In addition, the issue of direct and indirect land use changes, a controversial topic in estimating life cycle GHG emissions from bioenergy, was taken up in order to look into how the GHG emissions associated with land use change are dealt with in other sustainability initiatives.

1.1. GBEP's Environmental Indicators

As indicated below, among 24 sustainability indicators of GBEP, 8 are related to environmental aspects.

- Indicator 1: Life cycle GHG emissions

Life cycle GHG emissions reported using the GBEP common methodological framework

- Indicator 2: Soil quality

  Area and percentage of land with specific soil carbon conditions
- Indicator 3: Harvest level of wood resources

  Volume and percentage of harvested wood, etc.
- Indicator 4: Emissions of non-GHG air pollutants, including air toxics

  Emissions in comparison with other energy sources
- Indicator 5: Water use and efficiency

  Volume / percentage of water withdrawn from specific water resources
- Indicator 6: Water quality

  Percentage of pollutant loadings in the watershed
- Indicator 7: Biological diversity in the landscape

  Area and percentage of land with high conservation values
- Indicator 8: Land use and land use change related to bioenergy feedstock production

  Total land area, percentage of land area with specific land conditions, net annual rates of conversion

Just as the ERIA WG methodology employs life cycle GHG emissions as an environmental sustainability indicator, it was also considered important in GBEP's framework. GBEP provides a common methodological framework for estimating GHG emissions so that it can cover fundamental emission sources step by step.

Other than GHG emissions, as reported in the ERIA WG report of the previous phase (ERIA, 2011), the WG conducted a review of several environmental impact categories (e.g. climate change, impacts on air, water and soil, and biodiversity) that were found to be important issues in the pilot studies. GBEP also includes these categories in its guideline.

In addition to these categories, it also pays particular attention to wood resources and land use change. The indicator for wood resources is intended to assess whether forests are being harvested beyond their ability to renew themselves. The indicator for land use change is to assess the impacts of bioenergy production and use on land use, and land use change that may trigger environmental, economic and social issues. This is to be reviewed, as these issues were not observed in the WG's pilot studies.

1.2. RSB's Environmental Indicators

RSB has 12 principles for sustainable biofuel production, among which six are related to environmental sustainability. These principles and corresponding indicators are as follows.

- Principle 3: GHG emissions

  Whether biofuels contribute to climate change mitigation by significantly reducing lifecycle GHG emissions, as compared to fossil fuels (average 50% lower).
- Principle 7: conservation of biodiversity and ecosystems

  Whether biofuel operations avoid negative impacts on biodiversity, ecosystems, and conservation values.
- Principle 8: soil

  Whether biofuel operations implement practices that seek to reverse soil degradation and /or maintain soil health.
- Principle 9: Water

  Whether biofuel operations maintain or enhance the quality and quantity of surface and ground water resources, and respect prior formal or customary water rights.
- Principle 10: Air

  Whether air pollution from biofuel operations is minimized along the supply chain.
- Principle 11: Use of technology, inputs and management of waste

  Whether the use of technologies in biofuel operations seek to maximize production efficiency and social and environmental performance, and minimize the risk of damage to the environment and people.

As RSB principles are designed for certification systems, these indicators are used to check whether or not they meet the certification requirements. The environmental indicators of RSB also cover GHG emissions in Principle 3, impacts on air, water and soil in Principles 8 to 10, and biodiversity in Principle 7. In addition to these impact categories, RSB focuses on risks associated with use of technologies including genetically engineered plants or micro-organisms.

1.3. GHG Emissions Associated with Land Use Change

1.3.1. Emissions from Direct Land Use Change (dLUC)

The pilot studies conducted in the previous WG activities did not estimate GHG emissions from direct Land Use Change (dLUC) because none of the four pilot study sites had been converted from other land use in the past few decades. However, as some studies and reports have pointed out, dLUC emissions have a large impact on the life-cycle greenhouse-gas (LC-GHG) emissions of biomass utilization for energy. The emissions greatly depend on what the previous land use was prior to biomass feedstock cultivation. There are even some cases where the dLUC emissions alone may possibly be larger than the LC-GHG emissions of fossil based energy if lands with high carbon stock were converted into croplands for biomass feedstock. As a methodology to quantify these emissions, many initiatives for bioenergy sustainability including the ERIA WG methodology refer to the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines Vol.4 (IPCC, 2006). Although these guidelines are designed for compiling the National Greenhouse Gas Inventory Report (NIR), they are applicable to analyses of LC-GHG emissions of bioenergy. The Tier 1 methodology in the IPCC guidelines provides default values and methods for estimating carbon stocks for various land use types. Without directly measuring carbon stock in biomass and soil, the dLUC emissions could be computed with this method and default values with a particular uncertainty (Fritsche *et al.*, 2010). Some certification systems or legislations have simplified this methodology and prepared their own dLUC calculation methodologies and the databases necessary for the calculations. Table 1 summarizes how the dLUC emissions are dealt with or considered in selected initiatives.

The European Union (EU) Directive 2009/28/EC and some certification systems provide methods to calculate dLUC GHG emissions and the databases necessary for calculations whereas the GBEP's guideline for bioenergy sustainability provides a framework to describe how LUC was taken into account.

The ERIA WG also addressed the calculation methodology based on the IPCC guideline in a previous report (Sagisaka, 2009). The recent WG discussion concluded that the LUC GHG emissions should be counted in LC-GHG emissions analyses with the description of uncertainty.

Table 1: Selected Bioenergy Sustainability Initiatives that Deal with dLUC

	Name	How dLUC GHG emissions are dealt with
Guideline	GBEP (Global Bioenergy Partnership)	The guideline refers to the common methodological framework for GHG lifecycle analysis of bioenergy, which helps users of the guidelines describe how the dLUC emissions are taken into consideration, e.g. reference period, scenarios, system boundaries, baseline, methodological approach for estimating the emissions etc.
Certification System	RSB (Roundtable on Sustainable Biofuels)	The certification has its own GHG calculation methodology developed based on IPCC guidelines. There are some differences from the methodology of EU Renewable Energy Directive 2009/28/EC.
	ISCC (International Sustainability & Carbon Certification)	The certification requirement for the production of biomass stipulates that the biomass feedstock should not be produced (as of January 2008) from • land with high biodiversity value • highly biodiverse grassland • land with high carbon stock • land that was peatland GHG emissions from dLUC that took place after 1 January 2008 are counted with the calculation methodology of Directive 2009/28/EC.

Source: WG compilation.

1.3.2. Emissions from Indirect Land Use Change

Indirect Land Use Change (iLUC) effects indicate a variety of environmental and social impacts, which are indirectly induced by the expansion of feedstock cultivation for bioenergy. For example, even if the feedstock for biofuel were to be cultivated on land where dLUC effects might not be critical (e.g. conversion of crop land to land for an energy crop), it might result in the subsequent conversion of other lands to biofuel feedstock cultivation. iLUC is often referred to as “unintended negative impacts induced from indirectly induced land conversion, particularly increases in GHG emissions”. As there is no well-established calculation methodology for iLUC GHG emissions, not all the bioenergy sustainability initiatives take account of this complicated issue, although some of them have had intensive discussions on how iLUC could be quantified in their certification system or guidelines. Table 2 shows selected initiatives that officially address the iLUC GHG emissions. Although the WG currently does not address iLUC in its methodology, GHG emissions from iLUC will be included in future if calculation models become well-established with sufficient scientific evidence.

Table 2: Selected Bioenergy Sustainability Initiatives that Deal with iLUC

	Name	How iLUC GHG emissions are dealt with
Guideline	GBEP (Global Bioenergy Partnership)	The guideline refers to the common methodological framework for GHG lifecycle analysis of bioenergy, which helps users of the guidelines describe how the iLUC emissions are taken into consideration, e.g. reference period, scenarios, system boundaries, baseline, methodological approach for estimating the emissions, etc.
Certification System	RSB (Roundtable on Sustainable Biofuels)	The RSB standard currently does not address indirect impacts. However, an expert group was formed in 2009 to examine the indirect impacts of biofuel production and has published a “Draft for Public Consultation” (RSB, 2012), which shows five potential options for dealing with the indirect impacts of biofuel. • Do nothing about indirect impacts • Add-on certification of low-risk biofuels for indirect impacts • Criteria to minimize the risk of indirect impacts • Implementation of an iLUC factor in lifecycle GHG calculations • “Indirect impacts fund” / indirect impacts mitigation outside the project boundary
Legislation	RFS-2 (US Renewable Fuel Standard)	Energy Independence and Security Act (EISA) 2007 stipulates that greenhouse gas emissions assessments must evaluate the aggregate quantity of greenhouse gas emissions, including direct emissions and significant indirect emissions such as significant emissions from land use changes. It sets GHG emissions reduction thresholds for the four biofuel categories. To determine which fuel pathways meet this threshold, EPA is preparing GHG emissions assessments (including iLUC) for different pathways of several biofuels. The calculation model of GHG emissions consists of LCA models (GREET), economic models, satellite images and carbon stock maps to estimate international and domestic land use change emissions.

Methodology	RCA (Responsible Cultivation Areas) Methodology	RCA Version 1.0 is an open methodology that is designed to be used by all interested parties to identify and certify feedstock production with a low risk of indirect effects. It explains how to set the baseline and system boundary and how to prove the “additionality” that is a key to preventing bioenergy feedstock production from displacing other provisioning services of land.

1.4. Summary of Environmental Indicators

The environmental sustainability indicators of GBEP and RSB include life cycle GHG emissions in a similar way to the ERIA WG methodology. Other than GHG emissions, RSB and GBEP include environmental impact categories that were reviewed in the previous ERIA WG report (ERIA, 2011), i.e. climate change, impacts on air, water and soil, and biodiversity. In addition to these categories, GBEP takes into consideration wood resources and land use change while RSB includes the risk of new technology use, including genetically engineered plants or micro-organisms.

GHG emissions associated with land use change were also reviewed. The GHG emissions from dLUC are taken into consideration by GBEP, RSB and other sustainability initiatives, with frameworks for estimating the GHG emissions, but concrete methodology to estimate the emissions from iLUC is addressed in only one set of legislation.

The WG is reviewing the evaluation methodologies of these impact categories suitable for East Asian countries to include them and extend the ERIA WG methodology.

2. Review of Economic Sustainability Indicators

In order to enhance the ERIA WG methodology, the economic indicators of the Global Bioenergy Partnership (GBEP) and the Roundtable on Sustainable Biofuels (RSB) have been assessed. These are well-recognized initiatives.

2.1. GBEP's Economic Indicators

The GBEP sustainability indicators for biomass utilization for energy are similar to the ERIA WG methodology and other frameworks of bioenergy sustainability, and are categorized into environmental, economic and social pillars. The following 8 indicators belong to the economic pillar:

- Productivity
- Net energy balance
- Gross value added
- Change in consumption of fossil fuels and traditional use of biomass
- Training and re-qualification of the workforce
- Energy diversity
- Infrastructure and logistics for distribution of bioenergy
- Capacity and flexibility of use of bioenergy

2.1.1. Productivity

The indicator applies to biomass utilization for energy and to all bioenergy feedstock and pathways. Increases in productivity resulting in more efficient use of all inputs, including land and other resources, would mean reduced quantities of all inputs, resulting in increased profit and reduced burden on the environment.

Productivity is another indication of economic sustainability, but the ultimate measure of economic benefit could be expressed in terms of net profit derived from the production of bioenergy feedstock and/or processing of feedstock into bioenergy. Net profit is a component of Gross Value Added (GVA), an economic indicator already used in the ERIA WG methodology. Therefore there may not be a need to include productivity as another economic indicator.

2.1.2. Net Energy Balance

GBEP describes net energy balance as the net energy ratio of the bioenergy value chain, including energy ratios of feedstock production, processing of feedstock into bioenergy, bioenergy use, and/or life cycle analysis. It applies to biomass utilization for energy, biomass conversion into energy, use of bioenergy and to all bioenergy feedstocks, end-uses, and pathways. It is generally expressed in terms of the ratio of energy output to the total energy input from all the stages of biomass utilization for energy. An energy ratio greater than one means that the energy that can be derived from the bioenergy production is more than what is needed to produce the energy. Efficient production of bioenergy will result in a higher net energy balance and hence will lead to energy savings, which in large volume may improve energy security. The energy input may be in the form of fossil fuel or renewable energy. If the energy input is from fossil fuel, a higher net energy balance indicates a reduced consumption of, and hence reduced dependence on, fossil fuel.

Net energy balance would be better expressed in terms of the difference between the energy content of bioenergy and the total energy input used in the production of feedstock and processing to bioenergy. The unit could be expressed in terms of MJ/ha, MJ/ton of feedstock or MJ/year.

Net energy balance could be included in the list of economic indicators under the ERIA WG methodology. A positive net energy balance would make the biomass utilization for energy sustainable as there will be more energy output than used in the process. If biomass utilization for energy were to be a significant quantity then this could enhance the energy security of the country concerned.

2.1.3. Gross Value Added

Gross Value Added (GVA) is one of the GBEP economic indicators, and is defined as the value of output less the value of intermediate consumption. It is a measure of the contribution to GDP made by an individual producer, industry or sector. GVA provides a monetary value for the amount of goods and services that have been produced, less the cost of all inputs and raw materials that are directly attributable to that production. GVA is equivalent to the TVA (Total Value Added) of the ERIA WG methodology.

2.1.4. Change in consumption of fossil fuels and traditional use of biomass

This is described as the substitution of fossil fuels with domestic bioenergy, measured by energy content and in annual savings of convertible currency arising from reduced purchases of fossil fuels. The former is measured in terms of MJ per year and/or MWh per year while the latter is measured in terms of USD per year.

The use of locally produced biomass for energy can displace the consumption of fossil fuels, consequently reducing a country's dependence on imported fossil fuel, and might therefore have a significant impact on energy security if large volumes were involved. The non-importation of fossil fuels would also bring about savings in dollar reserves.

This economic indicator is included in the ERIA WG methodology separately as foreign exchange savings.

2.1.5. Training and re-qualification of the workforce

This is described as the percentage of trained workers in the bioenergy sector out of the total bioenergy workforce, and the percentage of re-qualified workers out of the total number of jobs lost in the bioenergy sector.

Although this indicator can be a factor to ensure sustainable production and use of bioenergy, the WG regards it as a non-direct measure of the sustainability of bioenergy.

2.1.6. Energy diversity

This is described as the change in diversity of total primary energy supply due to bioenergy. It is measured in terms of MJ of bioenergy per year in the total primary energy supply. The indicator applies to biomass utilization for energy, and to all bioenergy feedstocks, end uses and pathways. The production and use of bioenergy improve the diversity of energy supply and can make a contribution also to the country's energy security if large volumes are involved.

Energy diversity applies only to a macro-level biomass utilization for energy, hence there may not be a need to include this as another economic indicator in the ERIA WG methodology.

2.1.7. Infrastructure and logistics for distribution of bioenergy

This is described as the number and capacity of routes for critical distribution systems, and is expressed in terms of number of infrastructure facilities and total bioenergy in MJ or volume of bioenergy safely and reliably distributed per year. Safe, reliable, cost-effective, appropriate available infrastructure will help ensure adequate and secure energy supplies, that will facilitate sustainable bioenergy development. It is not, however, a direct measure of the sustainability of biomass utilization for energy.

2.1.8. Capacity and flexibility of use of bioenergy

This is described as the ratio of capacity for using bioenergy with actual use for each significant utilization route, or the ratio of flexible capacity which can use either bioenergy or other fuel sources, to total capacity. This indicator refers primarily to energy security, and infrastructure and logistics for distribution and use.

Again, just like the other economic indicators mentioned above, this is not a direct measure of the sustainability of biomass utilization for energy.

2.2. RSB's Economic Indicators

The Roundtable on Sustainable Biofuels (RSB) sets Principles and Criteria that provide guidelines on the best practices for sustainable biofuels production.

The only economic indicator under RSB is wages, and this is reported as one of its socio-economic indicators together with employment and labor conditions.

The RSB Principles, specifically Principle 4- Human and Labor Rights- is intended to ensure that biofuel operations do not violate human or labor rights, and in fact promote decent work and the well-being of workers. This includes wages which are to be provided in cash, or some other form acceptable to farmers, at a pay rate based on the legal minimum wage or comparable regional wage, whichever is higher.

The RSB also emphasizes the importance of the principle that economic viability of biofuel operations should not entail sacrificing the social and environmental aspects of its development. However, it does not specifically mention measure(s) of economic viability.

2.3. Summary of Economic Indicators

Among the economic indicators listed under GBEP and RSB only net energy balance could be included in the list of economic indicators under the ERIA WG methodology. However, instead of being expressed as the energy ratio of the bioenergy value chain in comparison with other energy sources, it would be better expressed in terms of the difference between the energy content of bioenergy and the total energy input used in the production of feedstock and processing to bioenergy. The unit could be expressed in terms of MJ/ha, MJ/ton of feedstock or MJ/year. A positive net energy balance would make the biomass utilization for energy sustainable, as there will be more energy produced than used in the process.

3. Review of Social Sustainability Indicators

Development of bioenergy is associated with a broad range of social issues. While its benefits include accelerated rural development, increased employment, mitigation of climate change and access to modern energy services, it may also result in certain risks, including deforestation, food and fuel conflict, biodiversity loss, water scarcity, and land degradation due to increased use of agricultural inputs.

To have a broader view of the social impacts and their indicators, two of the existing sustainability guidelines, namely, the Global Bioenergy Partnership (GBEP) and the Roundtable for Sustainable Biofuels (RSB) are covered in this sub-section. The Millennium Development Goals (MDGs) are also discussed, recognizing the situation of many developing countries in Asia.

3.1. The GBEP Social Indicators

Among the 24 sustainability indicators proposed by the GBEP, eight are for the assessment of social impacts, considering various criteria such as access to land, water and other natural resources, the national food basket, labor conditions, rural and social development, access to energy, and human health and safety. The corresponding social impact indicators are

- Allocation and tenure of land for new bioenergy production
- Prices and supply of the national food basket
- Change in personal incomes
- Jobs in the bioenergy sector
- Change in unpaid time spent by women and children collecting biomass

- Bioenergy used to expand access to modern energy services
- Change in mortality and burden of disease attributable to indoor smoke
- Incidence of occupational injury, illness and fatalities.

The indicators are value-neutral, do not feature directions, thresholds or limits and do not constitute a standard, nor are they legally binding. The indicators are intended to inform policy making and facilitate the sustainable development of bioenergy, and shall not be applied so as to limit trade in bioenergy in a manner inconsistent with multilateral trade obligations. The GBEP indicators do not provide answers or correct values of sustainability, but rather present the right questions to ask in assessing the effect of modern energy, biomass utilization for energy, and use of bioenergy in meeting nationally defined goals of sustainable development.

3.2. The RSB Social Indicators

The RSB standard is built around the following 12 principles: (i) legality, (ii) planning, monitoring and continuous improvement, (iii) greenhouse gas emissions, (iv) human and labor rights, (v) rural and social development, (vi) local food security, (vii) conservation, (viii) soil, (ix) water, (x) air, (xi) use of technology, inputs and management of waste, and (xii) land rights. The social impacts are combined with economic impacts addressing the following concerns.

- Land tenure, access and displacement
- Rural and social development
- Access to water and other natural resources
- Employment, wages and labor conditions
- Human health and safety
- Energy security and access
- Good management practices and continuous improvement.

The RSB standard identifies four types of operators subject to different sustainability requirements within it. These include “feedstock producers”, “feedstock processors”, “biofuel producers” and “blenders”. Throughout the standard the requirements that apply to each of theses operators are identified. The criteria included in the RSB standard address only the direct activities that farmers and producers can undertake to prevent unintended consequences from biofuel production.

3.3. The MDG Social Indicators

The Millennium Development Goals (MDGs) were declared in 2000 and their progress was reviewed by the United Nations in 2010, when world leaders agreed that some concrete strategies and actions would be taken up to meet the eight MDGs by 2015 (United Nations, 2010). The MDGs represent human needs and the basic rights that every individual around the world should be able to enjoy. They are classified into eight categories, namely; freedom from extreme poverty and hunger; quality education; productive and decent employment; good health and shelter; the right of women to give birth without risking their lives; and a world where environmental sustainability is a priority, and women and men live in equality and develop a global partnership for development to achieve these universal objectives.

Most of the MDGs are thus related to social development, and employment and access to modern energy are built into them.

3.4. Summary of Social Indicators

The GBEP sustainability indicators provide guidance on how to promote wider production and use of bioenergy, particularly in developing countries. These indicators could be modified by country, region or community to suit their nationally or regionally defined needs and circumstances. The RSB standard, however, is a certification system for biofuels that demands strict compliance to its principles and criteria to obtain certification.

The common social concerns in the GBEP and RSB sustainability criteria and guidelines are the following:

- Resource rights and use
- Labor rights and employment conditions
- Food security
- Human health and safety
- Rural and social development
- Benefits for women, youth, indigenous and vulnerable people

- Access to modern energy services

Both GBEP and RSB have tried to consider the realities in developing countries and regions of poverty, where traditional use of biomass is still prevalent. The indicators, measured over time, could show progress towards or away from a nationally defined sustainable development path. However, it would require a huge and diverse amount of data and expertise to come up with a holistic description and context of socio-economic conditions, which may not be available at the local level.

A variety of data sources would be needed to analyze the wide range of socio-economic issues mentioned above, in a qualitative and quantitative manner. While it is preferable to be comprehensive in addressing social impacts, in the end the data challenge will dictate the necessary trade-off in prioritizing indicators which are easily observable and important to the community such as “increase in income” and “access to modern energy”.

ERIA through its WG has developed its own methodology which uses various social development indicators (SDIs) to express the social aspects of bioenergy, both qualitatively and quantitatively. The WG has compared the ERIA WG methodology with the GBEP methodology and the MDGs and such comparisons raised many questions, which need to be answered. For example, many of the GBEP indicators are not included in the ERIA WG methodology and it was felt necessary to give an explanation for this.

Data for estimating employment and access to modern bioenergy were not collected in pilot studies, and these may be required in future studies through more extensive field surveys of the study regions.

Although GBEP’s methodology is comprehensive, it seems difficult in implementation in developing countries. As the GBEP method has very many indicators, data collection could be difficult for researchers, and data understanding could be difficult for policy makers

The MDGs aim at halving poverty in the world’s poorest countries by 2015, which is a daunting task. While some of the world’s poor countries have seen tremendous success in poverty reduction over the past decades and are on track to achieve the MDGs, many others are lagging. It would be worthwhile to address the role of energy services in meeting the MDGs in the lagging countries. Energy services are essential to both social and economic development, and much wider access to energy services is critical in achieving all of the MDGs.

In view of the above comments, the ERIA WG methodology may not include some of the GBEP indicators nor some aims of the MDGs, and our methodology may not be the best available, but it could be an appropriate one to apply at the local level, particularly in East Asian countries. However, the WG is still not sure about its methodology being recognized or applied in all East Asian countries, and feels that it is necessary to disseminate the ERIA WG methodology widely in these countries. One of the future goals of the ERIA WG will thus be to establish a comprehensive database, containing the data necessary for carrying out a sustainability assessment and possibly including data and information on GBEP and MDG concepts and indicators.

CHAPTER 3

Towards Extending the ERIA WG Methodology

The sustainability indicators currently employed in the ERIA WG methodology are summarized in Appendix I. Since the development of the ERIA WG methodology in 2009 (Sagisaka, 2009), the WG has been trying to improve the methodology so that it could be practically applied to a variety of biomass utilization projects, from small to large scale biomass projects, and in both ex-ante and ex-post assessments.

This chapter first explains the current direction of the ERIA WG methodology and then outlines the updates of sustainability indicators of environmental, economic and social aspects. In the final section of this chapter, the latest discussion about presentation of results is summarized.

4. Direction of the ERIA WG Methodology

A variety of initiatives on sustainability of biomass utilization have emerged worldwide in recent years. Although intensive discussions on sustainability are currently underway around the world, it is not an overstatement to say that the countries of East Asia are not at forefront of those discussions in spite of abundant biomass resources to be utilized in this region. In this context, the task of the WG aims at development of a methodology to assess the sustainability of biomass utilization, taking into considering the context of the East Asian countries.

The WG methodology is neither to establish certification systems for verifying the sustainability of biofuels, nor to propose vast and comprehensive ideas that cover all the considerable sustainability elements for biomass utilization. The ERIA WG methodology was designed to support decision making with the aid of scientifically-sound and practical indicators that quantitatively measure the degree of sustainability of biomass utilization projects. The indicators have been carefully selected from existing ones so that they could be applied to sustainability assessment from community to national level biomass utilization projects being planned or in operation.

The users of the assessment results are expected to be those who are in a position to make a decision on whether a project should proceed, or which technology or biomass feedstocks among several potential candidates should be chosen in terms of long term sustainability. The people who make such decisions could be policy makers rather than business managers.

This decision making situation is faced by policy makers not only when checking the sustainability of on-going policies or projects, but also, and perhaps more often in East Asian countries, when planning a new national biomass policy or a new biomass project. Although the WG conducted pilot studies to check the applicability of the ERIA WG methodology in existing biomass projects (ex-post assessment), the methodology has not yet been applied to biomass utilization projects being planned (ex-ante assessment). The WG has therefore started preparing a "decision support tool" for ex-ante assessments. The WG has established the basis of the framework of the tool, and then tested it in a case study. This tool and the case study are discussed in the next chapter.

5. Environmental Aspect: Soil Quality

The WG recognized from the outset the importance of other environmental impact categories that are currently not considered in the ERIA WG methodology. The previous report (ERIA, 2011) summarized some of those categories, which include impacts on air, water and soil quality, and biodiversity. Among those categories, the WG looked into soil quality to explore a possible indicator to be considered in the ERIA WG methodology. This is summarized in Appendix II.

6. Economic Aspect: Production Approach for TVA

In the ERIA WG methodology, the economic aspect is represented by Total Value Added (TVA). As in national accounting, TVA is calculated as output minus intermediates:

$$\begin{aligned} TVA &= \textit{Output value} \text{ (or } \textit{Gross revenue}\text{)} - \textit{Cost of intermediates} \\ &= \sum \textit{Price} \times \textit{Output quantity} - \textit{Cost of intermediates} \end{aligned}$$

where gross revenue is simply the product of price and quantity (applies to both main product and by-products), and intermediates include goods and services, other than fixed assets, used as inputs into the production process using biomass produced elsewhere in the economy or imported. This is equivalent to the production approach for measuring GDP.

Generally, intermediate goods are: material inputs (fertilisers, seeds, pesticides, purchased energy), manufacturing fees excluding VA (Value Added) items, sale fees excluding VA items, management fees excluding VA items, and interest. VA items are costs paid to labor (including wages, salary, benefits, employee insurance, tax) and depreciation. From this calculation, it can be seen that TVA can be closely approximated by return to labor (Total Labor Expense), return to capital (Operating Profit before Depreciation), and payment to government (net tax, i.e. taxes minus subsidies), which is an income approach as proposed in the ERIA WG methodology (Sagisaka, 2009).

As a comparison, in the income approach TVA is equivalent to Revenue less Outside Purchases (of materials and services). It is very closely approximated by Total Labor Expense (including wages, salaries, and benefits) plus "Cash" Operating Profit (defined as Operating Profit plus Depreciation Expense, i.e. Operating Profit before Depreciation). The first component (Total Labor Expense) is a return to labor and the second component (Operating Profit before Depreciation) is a return to capital (including capital goods, land, and other property).

In the income approach, indirect taxes have to be counted as a part of TVA. It must be noted that apart from income tax, the government may also levy other kinds of taxes during the production process, which will be deducted from the profits. Therefore, government indirect tax should also be counted as a part of TVA. However, such taxes could be levied on companies that provide intermediate goods and cannot be easily counted.

7. Social Aspects: Employment and Access to Modern Energy

The pilot studies conducted as a part of the WG activities revealed that although Human Development Index (HDI) is an appropriate indicator that takes into account three essential end-point components of the social aspect, there were some difficulties in implementing the methodology for assessment. For example, estimation of HDI was data intensive, requiring inputs on a wide array of parameters. However, the pilot studies found that such data were not readily available at village or district level. In addition, it was difficult to dissociate the social impact of a biomass project from the impact of other activities, particularly at community level. This is because HDI is more suitable for large scale assessment of social development and for the purpose of ranking countries.

The data demands of the HDI pale in comparison with the full requirements of social impact assessment following the GBEP and RSB methodologies. GBEP is in the process of field-testing their sustainability guidelines in selected countries, while RSB has been used to certify biofuel projects in developed countries. It remains to be seen if their social indicators could be applied in developing countries and regions of poverty wherein the data required for the assessment may not be available.

Recognizing the difficulty in calculating HDI, other social indicators such as job creation or employment and access to modern energy were proposed which may prove to be more fitting to capture local impacts of small-scale bioenergy projects in developing countries and regions of poverty in Asia. Looking at the GBEP and RSB social indicators, employment and access to modern energy are placed high as “core” indicators complementing other indirect impacts. Keeping in view the trend in other sustainability guidelines and limitations of applying HDI at project / community level, the WG decided to use “Employment” and “Access to Modern Bioenergy” as the two indicators for assessing the social impact of bioenergy projects at community level, as explained in the following paragraphs.

7.1. Employment

7.1.1. Employment in Biomass Utilizations

Bioenergy programs are important for employment generation and may assist in poverty alleviation and sustainable development. A study conducted in Malawi indicates that with the current estimated wood energy consumption in sub-Saharan Africa, approximately 13 million people could be employed in commercial biomass energy (Openshaw, 2010).

The type of bioenergy crop to be used may be objective-specific and maximizing one objective (say, employment generation); this may impact other objectives of the bioenergy promotion as found for the European Union (EU). For example, while climate change mitigation proposes the use of lignocellulosic biomass in the stationary sector, employment generation requires biofuels for transport based on traditional agricultural crops (Berndes and Hansson, 2007).

Many of the jobs are expected in feedstock production, which could invigorate rural development and the agriculture sector. Agriculture remains the backbone of developing countries for sustainable attainment of food security, employing a significant part, ranging from 30 to over 50 percent, of the total work force. However, bioenergy development may not directly translate into creating new jobs. In some cases the benefits are indirect yet equally important. It may enhance "market reliability" as the bioenergy industry could be an additional viable market for farmers seeking to get a better price for their produce, resulting in increased income or enhanced "job security" for employees of processing plants.

7.1.2. Quantification of Employment

Employment is calculated as a ratio of the employed people to the total labor force of the economy; children and dependent people in the population are not considered in the labor force. The concept of under-employment, the employment of a person below his/ her capacity, is also used in the literature. For example, a person wants to/can work for more than eight hours a day but he/ she can only find paid work for 2 hours a day. This kind of employment is considered under-employment. But he/she will still be considered as employed and not unemployed.

Measurement of the total labor force and the employed labor force of an economy is complex, and may be country-specific and based on several other factors. In India, for example, it is the availability and the willingness of a person to work/join the labor force. In the US, the term "labor force" refers to the number of people of working age (above 16 years) and below retirement age who are actively participating in the work force or are actively seeking employment. The number excludes people who are active-duty members of the U.S. Armed Forces, are in institutions such as jail, or are younger than 16 years of age. In the previous WG report (ERIA, 2011), employment had already been discussed and to some extent it was also quantified. For example, the person-days employed per hectare of bioenergy crop plantation or per ton of feedstock processing were calculated. The number of people employed in the bioenergy supply chain was also quantified.

Rather than expressing the absolute number of people employed, it would be better to calculate the percentage of people employed in various stages of the bioenergy supply chain. With the above definition of employment, quantification of employment in the bioenergy chain could be as follows.

Total Labor Force of the Village/ Community = TLF
(Number of people willing to work)
Number of People Employed in All Activities = NPE
*Employment Rate (%) (EMP) = (NPE/TLF)*100*
Number of People Employed in Bioenergy = NPEB
*Employment (%) in Bioenergy Sector (EPB) = (NPEB/ TLF)*100*

7.2. Access to Modern Energy

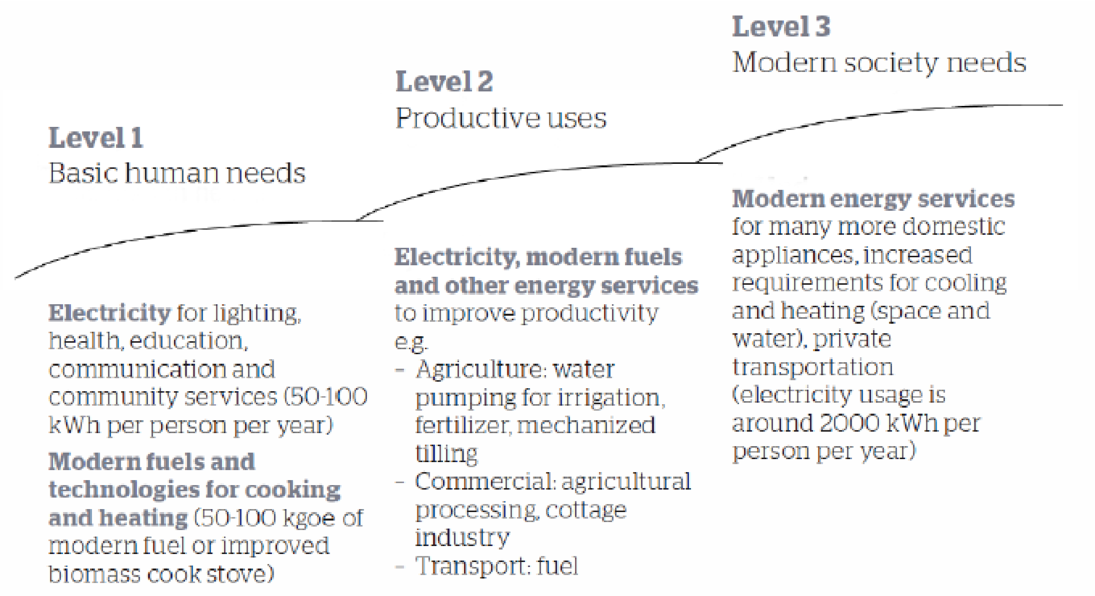
7.2.1. Access to Modern Energy in Biomass Utilizations

The term "Energy services" refers to the services that energy and energy appliances provide, and includes lighting, heating for cooking and space heating, power for transport, water pumping, grinding, and numerous other services that fuels, electricity, and mechanical power make possible.

Modern energy services are crucial to human well-being and to a country's economic development. Yet, globally, over 1.3 billion people are without access to electricity, and 2.7 billion people are without clean cooking facilities. More than 95% of these people are either in sub-Saharan Africa or developing Asia, and 84% are in rural areas (IEA, 2011). The United Nations declared the year 2012 as the "International Year of Sustainable Energy for All."

Figure 1 illustrates the incremental levels of access to energy services. Bioenergy development in rural areas is expected to bring a significant change in access to modern energy, either in the form of electricity or as modern fuels for cooking, heating and mechanical power to improve productivity.

Figure 1: Incremental Levels of Access to Energy Services (AGECC, 2010)



Level 1
Basic human needs

Electricity for lighting, health, education, communication and community services (50-100 kWh per person per year)
Modern fuels and technologies for cooking and heating (50-100 kgoe of modern fuel or improved biomass cook stove)

Level 2
Productive uses

Electricity, modern fuels and other energy services to improve productivity e.g.

- Agriculture: water pumping for irrigation, fertilizer, mechanized tilling
- Commercial: agricultural processing, cottage industry
- Transport: fuel

Level 3
Modern society needs

Modern energy services for many more domestic appliances, increased requirements for cooling and heating (space and water), private transportation (electricity usage is around 2000 kWh per person per year)

Different forms of clean and modern energy, which can be generated by utilization of biomass, are liquid biofuels, heat, electricity and gas. In many East Asian countries, for example in India, access to biogas generated through anaerobic digestion of biomass, is quite an "old" application, and people in rural areas have been using biogas since the early 1970s. However, heat and electricity generation through thermal gasification of biomass has been historically used by only a few companies, and their use by the general public is comparatively new. Access to modern energy services is defined as household access to electricity and clean cooking facilities. Modern bioenergy is provided through utilization of biomass for energy, such as clean cooking fuels and stoves, advanced biomass cooking stoves and biogas systems, bio-power, etc.

*7.2.2. Quantification of Access to Modern Energy*The percentage of households of the total population using modern energy services is considered as the ratio of population (number of households) accessing modern energy services. People using traditional biomass energy sources are not considered to have access to modern energy services

With the above definition, the quantification of access to modern energy could be as follows.

Total Number of Households in Village/ Community = TNHH
Number of Household with any Modern Energy = NHME
Household (%) with Modern Energy = (NHME/TNHH)*100
Number of Households with Modern Bioenergy = NHBE
Household (%) with Access to Modern Bioenergy = (NHBE/TNHH)*100

8. A Way of Presenting Results, and Methods of Integration

The development of indicators for the three aspects of sustainability – environment, economy and society has been discussed in the previous sections. Much effort has gone into the identification and refinement of appropriate sustainability indicators to evaluate biomass utilization systems in East Asia. Scientific discussions among researchers were conducted over several years for identifying and then field-testing and finally refining the indicators to arrive at a robust set that could be used for assessing biomass utilization at large, as well as small scale initiatives. However, it must be remembered that these indicators have been developed to assist policy makers in the region, not all of whom are scientists. Care must therefore be taken to present the results to them in a way that helps them understand the issues being considered in assessing the sustainability of biomass utilization initiatives.

Decision-making would be much easier if there were only a single index that would somehow include all the aspects of sustainability. Comparison of the sustainability of systems would almost be trivial should such an index exist. However, as seen in the earlier sections, a suite of indicators has had to be developed for assessing the environmental, economic and social aspects of sustainability for biomass utilization initiatives. The development of a single index integrating all the identified indicators would thus require a systematic method of aggregation. As the different indicators for environmental, economic and social aspects of sustainability are in widely varying units, integration would first require some form of normalization to bring the indicators to the same unit, followed by weighting to allow for the difference in relative importance/seriousness of the various indicators, after which they could be aggregated into a single index.

Many methods for normalization exist as summarized in Table 1. Also, a number of weighting techniques exist; some are derived from statistical models, such as factor analysis, data envelopment analysis and unobserved components models (UCM), or from participatory methods like budget allocation processes (BAP), analytic hierarchy processes (AHP) and conjoint analysis (CA). Regardless of which method is used, weights are essentially value judgments. While some analysts might choose weights based only on statistical methods, others might reward (or punish) components that are deemed more (or less) influential, depending on expert opinion, to better reflect policy priorities or theoretical factors. Weights may also be chosen to reflect the statistical quality of the data. Higher weights could be assigned to statistically reliable data with broad coverage. However, this method could be biased towards the readily available indicators, penalizing the information that is statistically more problematic to identify and measure.

Table 1: Examples of Methods for Normalization (OECD, 2008)

Method	Equation
1. Ranking	$I_{qc}^t = Rank(x_{qc}^t)$
2. Standardisation (or z-scores)	$I_{qc}^t = \dfrac{x_{qc}^t - x_{qc=\bar{c}}^t}{\sigma_{qc=\bar{c}}^t}$
3. Min-Max	$I_{qc}^t = \dfrac{x_{qc}^t - \min_c(x_q^{t_0})}{\max_c(x_q^{t_0}) - \min_c(x_q^{t_0})}$.
4. Distance to a reference country	$I_{qc}^t = \dfrac{x_{qc}^t}{x_{qc=\bar{c}}^{t_0}}$ or $I_{qc}^t = \dfrac{x_{qc}^t - x_{qc=\bar{c}}^{t_0}}{x_{qc=\bar{c}}^{t_0}}$
5. Categorical scales	Example: $I_{qc}^t = \begin{cases} 0 & \text{if } x_{qc}^t < P^{15} \\ 20 & \text{if } P^{15} \le x_{qc}^t < P^{25} \\ 40 & \text{if } P^{25} \le x_{qc}^t < P^{65} \\ 60 & \text{if } P^{65} \le x_{qc}^t < P^{85} \\ 80 & \text{if } P^{85} \le x_{qc}^t < P^{95} \\ 100 & \text{if } P^{95} \le x_{qc}^t \end{cases}$
6. Indicators above or below the mean	$I_{qc}^t = \begin{cases} 1 & \text{if } w > (1+p) \\ 0 & \text{if } (1-p) \le w \le (1+p) \\ -1 & \text{if } w < (1-p) \end{cases}$ where $w = x_{qc}^t / x_{qc=\bar{c}}^{t_0}$
7. Cyclical indicators (OECD)	$I_{qc}^t = \dfrac{x_{qc}^t - E_t(x_{qc}^t)}{E_t(\lvert x_{qc}^t - E_t(x_{qc}^t)\rvert)}$
8. Balance of opinions (EC)	$I_{qc}^t = \dfrac{100}{N_e}\sum_{e}^{N_e} \operatorname{sgn}_e(x_{qc}^t - x_{qc}^{t-1})$
9. Percentage of annual differences over consecutive years	$I_{qc}^t = \dfrac{x_{qc}^t - x_{qc}^{t-1}}{x_{qc}^t}$

Note: x_{qc}^t is the value of indicator *q* for country *c* at time *t*. $\bar{C}$ is the reference country. The operator *sgn* gives the sign of the argument (*i.e.* +1 if the argument is positive, -1 if the argument is negative). N_e is the total number of experts surveyed. P^i is the i-th percentile of the distribution of the indicator x_{qc}^t and *p* an arbitrary threshold around the mean.

One of the normalization techniques, "Min-Max" (No. 3 in Table 1) was attempted earlier on for bringing the indicators into the range [0,1] so that they could be visually presented as a radar diagram (ERIA, 2009). However, after initial testing and discussions in the WG, this method was discarded (ERIA, 2010). One of the major reasons for discarding it was the increase in number of indicators from the initial three due to the inclusion of sub-indicators. The normalization techniques developed for the initial three indicators were already somewhat arbitrary, because they were not comparable amongst themselves. This limitation would actually be true for any normalization scheme. Additional indicators would only compound this shortcoming. It was therefore decided to revert to a simple tabular presentation of results, since it provided all necessary information to decision makers without introducing any bias from researchers.

The WG considered one possible process to normalize the indicators which could hold appeal especially for non-scientists, namely monetization of all the indicators. However, finding monetary equivalents for environmental and social externalities would be a significant challenge. Even for a commonly used indicator such as greenhouse gas (GHG) emissions, there are several values used internationally, which means that it would be difficult to select a unique value. For other indicators, such monetary values do not even exist. Much resource and time would be required to develop such a scheme for use with the indicators selected for assessing the sustainability of biomass utilization initiatives. And even such a scheme would still suffer from uncertainty and subjectivity, as with other normalization methods.

A tabular presentation therefore remains the preferred choice. Future efforts may look at providing some reference values for each indicator that may help the reader somehow get a sense of the relative magnitude of the numbers. This would also indirectly be a kind of normalization effort, even though the normalized values would not be calculated. Intensive discussions in the WG would be needed following any investigation in this direction.

CHAPTER 4

Framework of a “Decision Support Tool”

1. Introduction

In the processing of bioenergy feedstocks, the private sector often makes the decisions, which causes uncertainty in reaping the benefits of bioenergy. Public and private decision makers are likely to have different concerns. Private decision makers often focus on economic returns, while leaving out social and environmental issues as externalities, because these are impacts that do not appear in private companies’ accounting systems. Public decision makers, on the other hand, are supposed to take social and environmental aspects into consideration.

Whether or not bioenergy development can deliver the desirable results depends on an institutional settlement, which should be set by Government. Once the appropriate regulations are in place, externalities would be internalized, and thus the private decisions would be as inclusive as public decision. Decision makers therefore face the challenge of setting the right institutional regulations to make sure that private decisions will deliver results consistent with national policy and public interest. To maximize benefits and minimize risks from the development of bioenergy, policy makers at all levels need to understand the potential impacts of various investment proposals when they are deciding bioenergy development strategy or approving investment options.

To make an appropriate regulatory regime, Government needs to understand the potential impact of bioenergy development before the development activities take place. The ERIA sustainability assessment method, which is good for post-project evaluation, can also be used for this ex-ante assessment. In the ex-ante case, the assessment method serves as a decision support tool for decision makers to decide which option would be in their best interests. The tool will calculate a variety of indicators in economic, social and environmental aspects for each option. Such calculations rely on a hypothetical scenario for each option. Data for the calculation will come from the literature, or pilot testing. However, it should be noted that it is unlikely that all three aspects would give the same preference and thus trade-offs would have to be made by the policy makers.

This chapter will illustrate how the ERIA WG methodology can be used for supporting ex-ante assessment. An illustrative example will be presented to demonstrate how the methodology is applied. After this introduction, the next section (Section 2) will discuss the framework of the decision. Section 5 presents a demonstrative case study on choosing the best option to dispose empty fruit bunches (EFB) of oil palm in Malaysia.

2. The Framework

In applying the methodology, some issues have to be defined before the tool can be used. The first would be policy objectives. If reasonable options have to be specified, then these options would be the targets of the tool. At the technical level, a boundary of the assessed system has to be decided.

2.1. Defining Policy Objectives

There are two frequently-discussed policy targets. The first is effective optimization of the use of an existing piece of land to obtain bioenergy. The second is efficient disposal of biomass, in particular, waste from bioenergy production.

Policy makers need to decide which bioenergy crops should be planted on a particular land area after they decide to develop bioenergy feedstocks on that land, since there is a large variety of feedstocks. Such issues could be faced by both governments and NGOs. Governments usually need to make such decisions on a large area of land, as in the case of industrial planning. However, in many countries, such decisions are made by the private sector. Governments, however, still needs to understand the issue in order to set the regulatory system.

In the case of bio-waste disposal, the government also needs to assess sustainability in order to set the right regulatory framework and incentives which will lead the private sector to move to the desirable direction.

2.2. Identifying Options

For every policy target, there are numerous potential options. However, considering the limitations of time, financial resources, and for other reasons, decision making has to be based on limited options. There should therefore be a step to identify candidate options. For example, in the case of producing bioenergy carriers from a given land area, the master options would be different kinds of feedstocks.

It should be noted that these options do not represent all the possible real scenarios. For example, even for a given feedstock, the use of different amounts of fertilizer will lead to different emission results. We should also therefore decide the level of aggregation of options, to avoid being swamped with details. Usually, in each master option, the WG suggests the use of an average or standardized scenario. For example, the use of fertilizer will be assumed to be at a certain level so that it will not cause different emissions results. This has a real advantage, in that we do not need too many details. Some details, such as exactly how much fertilizer could be used, would be useful but not cost-effective, since they will not provide additional information for choosing the right option.

The standardized scenario is particularly important for the feedstock processing step, with different scales of factory, different amount of capital investment, etc. All the differences will lead to differences in processing costs. It is recommended that some standardized factory be assumed, which will be represented as constant process costs.

2.3. Defining System Boundary

In order to calculate TVA, the boundary of the project has to be defined properly, because if the production chain extends, the TVA will surely grow. For example, in the case of disposing of empty palm-fruit bunches (EFB), if board made from EFB is further used to produce furniture, the TVA will become larger. The TVA approach will always prefer a longer production chain to a shorter one. Moreover, the value of the furniture will not be able to be standardized, since the prices of the furniture could be very diverse due to factors such as brand and types of furniture.

For the calculation of GHG emissions, the boundary setting is also important. A different boundary setting will lead to different GHG emissions. For example, the GHG emissions vary greatly with whether more downstream processes are included or whether the produced biomaterials substitute the existing materials. It should be carefully checked that the system boundary as defined gives an appropriate answer to the target of the study. Similarly, for calculating social indicators, boundary definition also matters. Therefore, clear, transparent and reasonable definitions of the project boundary are essential.

2.4. Application of Indicators

Following the ERIA WG methodology, the decision tool should have three aspects: environmental, economic and social. However, considering the many differences between ex-ante forecasting and post-project evaluation, the following points should be noted in applying the indicators of the ERIA WG methodology.

2.4.1. Environmental Indicator

The WG environmental sustainability indicator, life cycle GHG emissions, will remain valid in ex-ante assessments.

In all these three aspects, calculations may be simplified by omitting the common parts of the biomass utilization value chain across all options, if the assessment focuses only on comparison between options. For example, land preparation can be omitted in the case of selecting bioenergy feedstocks for a given land area. In this case, the evaluation needs to focus only on what is relevant for comparison purposes; that is the differences between the options.

2.4.2. Economic Indicator

It is more practical and feasible to use the production approach than the income approach. One advantage of the production approach over the income approach is that, in the ex-ante decision, disaggregated data for TVA, including labor costs and profits, are not available. It is thus not possible to calculate TVA using the income approach. For the production approach, on the other hand, we only need the costs of intermediates, which are available in the market.

In the case of applying the production approach, where the production chain is relatively straightforward, it can be assumed that there is an integrated company, which can produce bioenergy carriers from land. Such a vertically integrated company will have control of the whole supply chain for bioenergy, including plantation, processing and sales. The production approach thus will not consider costs occurring inside the company, such as processing costs. Instead, it needs to subtract the value of goods and services bought outside the company (these are intermediate goods) from the final sales values. It should be noted that land, labor, and capital are primary inputs, which are not included among intermediate inputs[1].

2.4.3. Social Indicator

Employment generation is a relevant and suitable social parameter. The employment generated by a bioenergy project may be different for various biomass feedstocks. It is, therefore, necessary to assess the labor intensity (person hours generated per unit of land). Practically, it is important to find out how many more jobs can be created by each type of feedstock.

3. Interpretation of Results

In general, the three indicators may not necessarily give the same preference. If that happens, policy makers need to decide trade-offs among the three indicators. Unfortunately, the assessment methodology itself cannot help very much in suggesting a weight among the three aspects, because that will depend on the priority of the decision makers in each case.

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[1] In the production process, intermediate goods either become part of the final product, or are changed beyond recognition in the process. In other words, intermediate goods must be consumed during the production process.. Source: ILO, IMF, OECD, Eurostat, UNECE, World Bank, 2004, Producer Price Index Manual: Theory and Practice, International Monetary Fund, Washington DC.

CHAPTER 5

A Case Study for Application of the "Decision Support Tool"

1. Introduction

Over the last decade, the interest in biomass as a renewable resource has grown rapidly, for both energy and material applications. Biomass for energy has been a primeval practice, where woody plants served as firewood for fuel. Today, modern uses of biomass as fuel or bioenergy adopt various technologies that convert biomass to briquettes, pellets or a gaseous mixture known as "synthesis gas", commonly abbreviated to "syngas", to enhance their calorific value and thus combustion efficiency. An example is the need to transform whole Empty Fruit Bunches (FFB) to a form of energy carrier to enhance their efficiency of conversion to energy, which has been reported to be around 20% (15-25%) when EFBs are directly combusted in boilers to produce heat and steam (Rahman, *et al.* 2004).

Although the sector where biomass use has been widely discussed at the global level is energy, biomass is also a renewable feedstock for product development in biomaterials and bio-chemicals. Bio-composites production, comprising biomass fibers bound in synthetic or in-situ natural polymeric resins, is a well-established industrial process producing wood polymer composites for building materials and furniture making. Research is ongoing towards commercial-scale bioprocesses to transform biomass into biochemicals such as polylactic acid, polyhydroxyalkanoates and polyamides. These would be competing uses of biomass.

The National Biomass Strategy of Malaysia (AIM, 2011) has projected that by year 2020, there will be an additional 20 million tons of palm biomass to be exploited. Through concerted efforts by government agencies and private companies in realizing the biomass potential as feedstock for biomaterials, bioenergy and biochemicals, it is estimated that the biomass value chains will enhance the Malaysian Gross National Income (GNI) by 30 billion Malaysian Ringgit (MYR) or

4.7 billion US dollar (USD) (using the approximate currency conversion rate of 1 USD = 6.4 MYR) and in tandem, support new employment of 40,000 high skill and 27,000 low skill workers.

Palm biomass, like all biomass, is hence a renewable feedstock with two established applications and one up-coming potential application in the forms of bioenergy, biomaterials and biochemicals. For a given biomass feedstock, decision makers in both the public and private sectors will be presented with options such as type of utilization and technology systems. At the same time, for a given end-use, there are multiple options on the type of biomass feedstock to be mass produced.

The objective of the case study is to apply the sustainability assessment methodology developed under ERIA to identify the most sustainable utilization of oil palm biomass (EFB) as biomaterial or bioenergy, as against the existing practice of in-situ or on-site fertilization, based on life cycle assessment (LCA) and socio-economic benefit using indicators to represent social impact, economic impact and environmental impact (specifically climate change).

2. Biomass from the Palm Oil Industry

The palm oil industry not only provides palm oil and palm kernel oil for food, industrial and consumer products utilization. The industry also generates a huge amount of biomass from its agriculture and milling activities. The importance of biomass in the palm oil industry is reflected by the fact that oil is only 10% of the total produce of an oil palm plantation. The rest is biomass, comprising predominantly oil palm wastes from milling such as oil palm shells (OPS), mesocarp fibers (MF) empty fruit bunches (EFB), and residues left in the field during replanting, namely oil palm fronds (OPF) and oil palm trunks (OPT). EFB is the residue left after oil is extracted from fresh fruit bunches (FFB).

Although OPF and OPT are good sources of woody biomass and have been used for animal feed and as logs for furniture, these two sources of woody biomass are still relatively untapped due to limited accessibility in terms of transporting them to processing sites. EFB on the other hand is a milling residue generated at all palm oil mills and poses a disposal problem that can be overcome by using this accumulated agro-waste for commercial applications such as bioenergy or biomaterials. Most palm oil mills that are located in close proximity to oil palm plantations will send a certain portion of the EFB back to the plantations for mulching. EFB is an agro-residue with many choices of utilization. This biomass is a good material to apply the sustainability assessment methodology to, evaluating the various options in a holistic approach.

3. Properties of EFB

For every ton of FFB that is processed, about 22% of its weight is left as EFB. The average yield of FFB in the typical oil palm plantation in Malaysia is 20 ton FFB/ha or 4.4 ton EFB/ha. In 2009, Malaysia had a total oil palm plantation of 4,691,160 ha (MPIC, 2010), which means that for that particular year, about 21 million ton of EFB was produced in the country.

The nutrient contents of EFB, although variable, are significant. The nitrogen content has been reported to range between 0.34 – 0.66%, with a mean of 0.54%; phosphorus 0.03-0.10% with a mean of 0.06%; potassium 1.20 - 2.40% with a mean of 2.03%; and magnesium 0.17-0.20% with a mean of 0.19% (Heriansyah, 2011). Hence EFB is a good source of organic matter and plant nutrients.

The most prevalent practice at the palm oil mills is to send some of the EFBs back to the oil palm plantations for mulching. Mulching is the practice of applying biomass such as EFB on the soil surface to reduce temperature and conserve moisture, in addition to supplying varying amounts of nutrients as they degrade. It has been reported that EFB mulching at about 27 ton/ha is equivalent to current practices of applying mineral (inorganic) fertilizers (Loong *et al.*, 1987).

Tables 1 and Table 2 illustrate the importance of EFB in improving soil condition and productivity (Mannan, 2012).

Table1: Fertilizer Equivalence of 1 ton EFB

Type of Fertilizer	Equivalent quantity of nutrient
Urea	3.8 kg
Rock phosphate	3.9 kg
Muriate of potash	18.0 kg
Kieserite	9.2 kg

Table 2: Nutrient Equivalence of 1 ton EFB

Type of Nutrient	Composition as a percentage of dry matter
Nitrogen (N)	0.44
Phosphorous (P)	0.144
Potassium (K)	2.24
Magnesium (Mg)	0.36
Calcium (Ca)	0.36

Aside from agricultural applications, including use in animal feed supplement, EFBs are also increasingly used for bioenergy. One of the main reasons for the inability to use all of the EFBs for mulching in the plantations is the transportation distance. It is not economic to move the EFBs to plantations beyond a certain distance.

Non-agricultural applications of EFB include conversion to biomaterials for the following end-products:

- a material for composite wood-based products (particle boards, medium density fiberboards, biofiber composite profiles)
- pulp & paper
- filler material for pipes and conduits

Feedstock for conversion into bioenergy existing in various forms of energy carriers such as:

- Pellets
- Bioethanol
- Syngas

One of the unique properties of EFB, even when converted into fibrous material, is the presence of lignin with an adhesive property. It has been reported that biofiber materials, and pellets produced from fibrous EFB, do not need external adhesive to bind the fibers. Appropriate heating is able to just melt the lignin to take on the adhesive function.

4. Sustainability Assessment Methodology

The past case studies conducted by the ERIA WG have shown the viability of using the sustainability assessment methodology to evaluate the utilization of biomass for fuel or bioenergy. It is the intention of this case study to test the suitability of the assessment methodology to evaluate the utilization of a biomass feedstock for applications in two different domains i.e. bioenergy and biomaterials.

Sustainability assessment methodology on the utilization of woody biomass will be based on life cycle GHG emissions for environmental impact, job creation for social impact, and total value addition for economic impact for the two different domains.

The production and utilization of any form of biomass as energy carrier or as material for further downstream applications as in furniture or building materials cover three major stages, namely:

- feedstock supply
- processing
- conversion

EFB is generated as long as crude palm oil is produced. The supply of EFB is therefore dependent on the yield at the plantation, irrespective of its subsequent utilization. Although many types of EFB utilizations are reported or known, EFB is still considered as a form of agro-waste and does not fetch a good price in the unprocessed form. The processing of EFB includes removal of residual oil, shredding and desizing to short fine fibers, and these processes are common for both bioenergy and biomaterial applications.

The increasingly popular form of EFB biofuel is in the form of pellets, while EFB can also be converted to boards or profiles for use in furniture-making. In assessing the sustainability of the two routes of utilization for the same feedstock, the divergence occurs only from the conversion stage onwards. The sustainability assessment to evaluate utilization of EFB as pellets for fuel or as biomaterials will have similar input for the two stages of feedstock supply and processing as illustrated in Figures 5-1 and 5-2. As there are many types of biomaterials, the specific type that will be described in this study is the biofiber wood composite profiles produced from extrusion of a mixture of EFB-fiber and resins using a typical extruder (hereinafter referred to as biofiber composite profiles).

Figure 1: System Boundary for Conversion of EFB to Pellets for Use as Fuel.

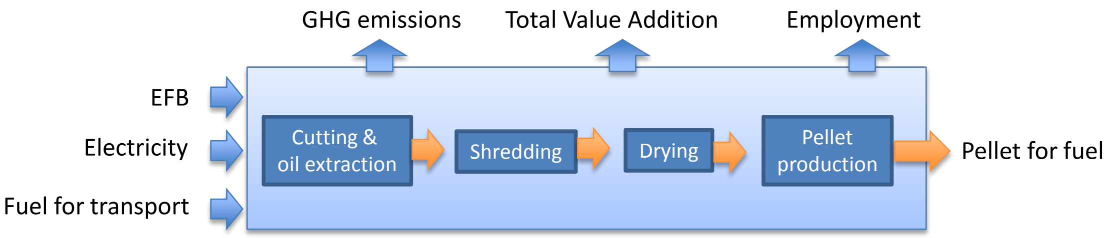
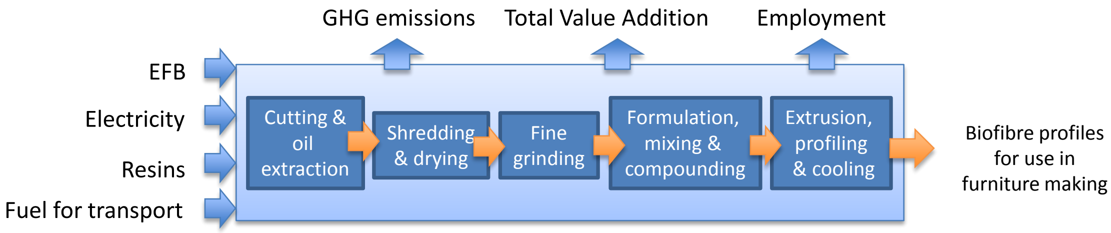


Figure 2: System Boundary for Conversion of EFB to Biofiber Composite Profiles (Wood Plastic Composite Containing 70% Biofiber) for Use in Furniture Making.



4.1. Environmental Indicator

For this study, the environmental indicator for the sustainability assessment of EFB is the life cycle greenhouse gas profile. The surge in interest in biomass has been attributed largely to the perception that it is not only a renewable resource but also contributes to a reduction in greenhouse gases based on the concept of carbon neutrality at the point of combustion. However, from the life cycle perspective, there are net emissions related to land-use change, agricultural practices, logistics, processing and conversion of the biomass to different forms of bioenergy.

Although EFB has been used for diverse applications, it is still considered an agro-waste in the production of crude palm oil and palm kernel oil. EFB is therefore not allocated any environmental burden from the upstream processes in the life cycle system boundary (land use change, oil palm cultivation, transportation of FFB and palm oil milling). In other words, EFB as a raw material by itself does not carry any CO_2eq burden. The emission associated with the use of EFB will come mainly from transportation of the material from point of generation to the point of use and subsequent processing.

Based on this background scenario, the life cycle inventory analysis of EFB for the two routes of application is tabulated in Table 3.

Table 3: Life Cycle Inventory Analysis for Conversion of EFB to Pellets and Biofiber Composite Profiles.

Parameter	Description
Goal of study	To establish the greenhouse gas emission of two different EFB-based products. The greenhouse gas emissions of the two EFB-based products will be compared with respect to the EFB consumed and used for a specific utilization.
Function	• Pellets produced from EFB for use as fuel – for the system boundary illustrated in Figure 5-1 • Biofiber composite profiles produced from EFB for furniture making - for the system boundary illustrated in Figure 5-2
Functional Unit	1 ton of EFB consumed to produce the specific product (pellets or biofiber composite profiles).
System Boundary	Pretreatment of EFB to fibrous material and conversion to different forms as pellets and biofiber composite profiles. The system boundaries are shown in Figures 5-1 and 5-2.

4.2. Economic Indicator

Based on the latest version of the ERIA WG methodology presented in ERIA Research Project Report 2010, No. 22 (November 2011), the economic assessment can be presented by two levels of indicators: a master indicator and a few sub-indicators.

The master economic indicator to calculate the economic impact of a particular form of biomass utilization is the Total Value Addition (TVA), while the sub-indicators are: employment, net profits and tax revenues.

TVA in the ERIA WG methodology is calculated per unit mass of biomass production as shown in Equation (5-1):

$$\begin{aligned} TVA &= \textit{Output value } (\text{or } \textit{Gross revenue}) - \textit{Cost of intermediates} \\ &= \sum \textit{Price} \times \textit{Output quantity} - \textit{Cost of intermediates} \qquad (5\text{-}1) \end{aligned}$$

- Gross revenue applies to income from the main products (pellets and biofiber composite profiles) and by-products (none for both system boundaries)
- Intermediates include goods and services, other than assets used as inputs in the production of pellets and biofiber composite profiles namely whole EFBs from the mills, and EFB fibers, additives and utilities.
- Total returns of primary output and by-products will be based on market sale prices e.g. current market price for pellets and biofiber composite profiles.
- Total cost of intermediates will be based on market sales prices of input materials and utilities.

The sub-indicators include:

- Labor income
- Net profit
- Tax revenues

- Foreign exchange earnings

Capital costs, although a significant component of any investment will be reported but not included as an indicator.

The eventual TVA and sub-indicator values are reported as per unit of EFB consumed instead of per unit of pellets or biofiber composite profiles produced. This is because both end-products require different amount of EFB, comparison based on the same amount of EFB consumed will refer to the same baseline.

The parameters where information is required to calculate TVA and sub-indicators for both types of EFB utilizations, are listed in Table 4.

Table 4: Data Required for Calculating TVA and Sub-indicators of EFB Utilisations.

Parameter	Pellets	Biofiber Composite Profiles
Gross Revenue		
Sales of primary output	Pellets	Profiles (for furniture assembly)
Sales of by-products	None	None
Cost of Intermediates		
Materials input (cost is at ex-factory gate for whole EFB and EFB fibers)	Whole EFB	Whole EFB
	EFB Fibers	EFB Fibers
		Polypropylene
		Additive
Services input	Electricity	Electricity
	Transport	Transport
Labor income (wages)		
Labor costs (only for converting EFB to fibrous material, pellets, fiber boards and furniture)	Monthly wages of manual workers + production engineer	Monthly wages of manual workers + production engineer
Net Profit = Total Returns – Total Costs (overhead included on top of cost of intermediates and labor income)		
Overhead costs (only for stages in the value chain relevant to conversion of EFB to specific end-product)	25% of direct cost of pellets (20% for corporate tax and 5% for duties, interest and depreciation)	30% of direct cost of profiles (20% for corporate tax and 5% for duties, interest and depreciation)
Tax Revenues		
Taxable income	Taxable income (profit) from sales of pellets at tax rate of 25% of net profit	Taxable income (profit) from sales of profiles (exclude furniture as the range of furniture possible is too broad) at tax rate of 25% of net profit
Foreign Exchange Earnings (not included in this study)		
Export (earnings)	Export of pellets	Export of profiles
Savings (import substitution)	None	None

4.3. Social Indicator

The social Indicator will be based mainly on job creation analyzed as follows:

- Number of jobs created compared to “business-as-usual” scenario i.e. current handling and usage of EFB
- Number of jobs that are applicable to both sexes
- Type of jobs created, whether increase at operator or professional level

5. A Case Study - Processing of EFB to Target End-Products

5.1. Scenario Setting

As this study is going to compare two forms of utilization of EFB, it is important to define clearly the common activities in their respective production, and the point where the processed EFB material will divert to different routes. The stages in the value chain production of pellets and biofiber composite profiles for use in furniture making are summarized in Table 5 together with hardware and material inputs.

The following assumptions are made in setting the scenario for eventual comparison:

- The EFB produced in a year by the generic palm oil mill will be consumed either for producing pellets, or biofiber composite profiles for furniture-making (as EFB is required for mulching in most plantations, only half of what is produced at the mill will be consumed for bioenergy or biomaterials).
- The pre-treatment of EFB to fibrous material that serves as raw material for pellets and biofiber composite profiles for furniture assembly will be carried out at the mill. This is a logical approach as transportation of wet and unprocessed EFB incurs high transportation cost.
- Transportation impact will be considered only from the mill to the factories that are converting the fibrous EFB material to pellets or biofiber composite profiles. The transportation distance from mill to the respective destination for conversion to pellets or biofiber composite profiles is assumed the same.

Secondary data will be obtained and used for the input-output approach as shown in Table 5-5. The modeling will be done on a 60 ton/hour capacity plant operating 280 days/year for an average of 16 hours per day. The plant will generate ~54,000 ton EFB/year at dry weight or ~162,000 ton EFB/year containing 70% moisture.

It should also be noted the plant capacities, in particular the designated capacities at the conversion stage, are not realistic. For comparison, it is assumed that the plant is designed to handle half the daily production of the total EFB produced at the 60 ton/hour capacity palm oil mill, which will be consumed either as bioenergy or biomaterial. Some capital goods, especially key equipment, are included to enable estimation of operational cost and operational emissions, for example from electricity. Construction of plant and all other civil structure requirements to house the production plants are not considered.

Table 5: Stages in the Value Chain Production of Biofiber Composite Profiles and Pellets[1]

No.	Parameters	Biofiber Composite Profiles	Pellets
1.	Feedstock Supply (as whole EFB with ~70% moisture)		
	Source:	Palm Oil Mill	Palm Oil Mill
	Amount /year (half of total produced at mill):	80,640 ton	80,640 ton
	Price/ton (market price):	20 MYR/ton	20 MYR/ton
	Cost of raw material/year	1.613 million MYR (0.25 million USD)	1.613 million MYR (0.25 million USD)
2.	Production of EFB fiber (30,000 ton/year capacity) at the mill		
2.1	Final form required: Conversion of EFB to EFB fiber requires two different items of equipment (*based on system supplied by Muar Ban Lee Sdn. Bhd. of Malaysia* (Muar Ban Lee Sdn. Bhd., 2012))	Shredded of size <1/2", 15% moisture content	Shredded of size<1/2 " 15% moisture content
	Single Barrel Press to reduce moisture content from 70% to 50%	Number of machines: 1 Capacity: 12 Mton/hour	Number of machines: 1 Capacity: 12 Mton/hour
	EFB Shredder (Size reduction break cutter) which includes screening and recycling system to reduce size of EFB to below ½" and 45% moisture	Number of machines: 4 Capacity: 6 Mton/hour	Number of machines: 4 Capacity: 6 Mton/hour
	Dryer using biomass as fuel to reduce moisture content to 15%	Number of dryers: 1	Number of dryers: 1
	Total capital investment inclusive of all ancillary parts and components for pre-treatment and desizing of EFB to form fiber	[2]3.3 million MYR (0.52 million USD)	3.3 million MYR (0.52 million USD)

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[1] The values are estimated on annual production that varies in work schedule e.g. it can be 8-10 hour/day and 5-6 days/week for 52 weeks

[2] All prices given are approximate values and are provided as a general guide and for the purpose of the study

No.	Parameters	Biofiber Composite Profiles	Pellets
2.2	Total power consumption for producing EFB fiber	Power: 2,386 MWh	Power: 2,386 MWh
2.3	Waste (residual oil) generation: (Sold as low quality palm oil at 1/3 current price of crude palm oil (CPO), assume 1% recovery from EFB)	1,300 ton/year 1,000 MYR (156 USD)/ton residual oil	1,300 ton/year 1,000 MYR (156 USD)/ton residual oil
2.4	Jobs created (to mobilize, operate pre-treatment machinery, shredders and dryer) No. of persons (not part of mill)	15 technicians for 3 shifts and 1 supervisor	15 technicians for 3 shifts and 1 supervisor
	Gross salary/year	211,200 MYR (33,000 USD)/year	211,200 MYR (33,000 USD)/year
	Output - Weight of EFB fiber -[3]15% moisture content	40,000 ton/year	40,0000 ton/year
	Selling price of EFB fiber: MYR/ton (USD/ton) Million MYR/year (Million USD/year)	 120 (18.8) 3.415 (0.53)	 120 (18.8) 3.415 (0.53)
3.	Conversion to final form for target use		
3.1	Transportation distance to conversion site using 5 ton lorry:	50 km	50 km
	Number of trips/year	5,700 trips/year	5,700 trips/year
	Cost of transportation of 5 ton/truck travelling 100 km on 2-way trip @ 350 MYR (54.7 USD)/trip and diesel consumption @ 5km/liter	1.755 million MYR (0.27 million USD)/year	1.755 million MYR (0.27 million USD)/year
3.2	Production process	Fine grinding, compounding and extrusion to produce extruded profiles4	Processing, pelletizing and cooling to produce pellets for fuel5
	Equipment required for plant capacity to handle 40,000 ton/year. (details not provided as part of confidentiality agreement with operating entities)	Equipment for compounding and extrusion line	Equipment for automated pelletization processing line with pollution controls
	Capital investment (million MYR(USD)): Capacity (ton/year:) Total power consumption (MWh/year):	226 (3.4) 40,000 1250	10 (1.6) 40,000 3600
3.3	Consumables:	Polypropylene: 12,860 ton/year Additive: 900 ton/hour	None
	Total Cost (million MYR(USD)/year):	84.7 (13.2)	None
3.4	Wastes	Process residue (10% feedstock lost as process waste)	None

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[3] MS 1408 :1997 (P) - Specification for oil palm empty fruit bunch fiber.

[4] Data modeled from a pilot plant producing wood polymer composite (WPC) furniture using rice husk, EFB fiber replaces rice husk in the study (Syed Mustafa Syed Jamaludin, 2012)

[5] Data modeled from a private operating entity involved in the pelletizing business using diverse biomass feedstock supply (Builders Biomass Sdn. Bhd., 2012)

[6] For the sake of comparison, an unrealistic plant capacity of 40,000 ton WPC compounding mix/year was designed for the study in order to make a fair comparison with the alternative usage for pellets that has also been assigned a production capacity of 40,000 ton/year

No.	Parameters	Biofiber Composite Profiles	Pellets
3.5	Jobs created		
	No. of person months:		
	Type of Job and Salary (MYR (USD)/person month)	12 technicians @ 1,500 (234)	3 technicians @ 1500 (234)
	Type of Job and Salary (MYR (USD)/person month)	3 line leaders and 2 QA@ 2,800 (438)	1 line leader and 1 QA @ 2,800 (438)
	Type of Job and Salary (MYR (USD)/person month)	6 engineers @ 3,300 (516)	2 engineers @ 3,300 (516)
	Gross salary (thousand MYR (USD)/year):	Total: 620 (97)	Total: 200 (31)
3.6	Output: Product	22,000 ton extruded profiles (ready to be used for furniture assembly)	27,000 ton Pellets (CV>4,500 kcal/kg)
	Selling price of product:	4,000 MYR (625 USD)/ton extruded profiles	400 MYR (64 USD)/ton pellets

5.2. Findings of Study

The estimated values of the three sustainability indicators were calculated using the material, monetary and human resource input and output, and are summarized in Table 6.

Table 6: Indicator Values for Conversion of EFB to Biofiber Composite Profiles vs Pellets

	Sustainable Indicator	Biofiber Composite Profiles	Pellets
Environmental	GHG emissions for end-product	752 kg CO_2/ton profile	84 kg CO_2/ton pellet
	GHG emissions for 1 ton EFB consumed to make a target end-product	203 kg CO_2/ton of EFB consumed	27 kg CO_2/ton of EFB consumed
Economic.	Main indicator: Total Value Addition (TVA)	687 MYR (107 USD)/ton profile 186 MYR (29 USD)/ton EFB consumed to produce profile	86 MYR (13 USD)/ton pellet 28 MYR (4.4 USD)/ton FFB consumed to produce pellet
	Sub indicators: Labor income:	43 MYR (6.7 USD)/ton profile 12 MYR (1.9 USD)/ton EFB-consumed	12 MYR (1.9 USD)/ton profile 4 MYR (0.6 USD)/ton EFB-consumed
	Net profit:	643 MYR (100 USD)/ton profile 174 MYR (27 USD)/ton EFB-consumed	74 MYR (11.6 USD)/ton profile 24 MYR (3.8 USD)/ton EFB-consumed
	Tax revenue:	161 MYR (25 USD)/ton profile 43 MYR (6.7 USD)/ton EFB-consumed	18 MYR (2.8 USD)/ton profile 6 MYR (0.9 USD)/ton EFB-consumed

	Sustainable Indicator	Biofiber Composite Profiles	Pellets
Social	Job Creation[7]	30 new jobs compared to business-as-usual i.e. sending some proportion of EFB back to the field. Due to manual handling of large volume of materials, the production is expected to employ mostly males. Ratio of executive to operator level is 30:70. Indirect employment such as transportation of EFB fibers is not included.	11 new jobs created compared to business-as-usual i.e. EFB sent to field for mulching. Due to manual handling of large volume of materials, the production is expected to employ mostly males. Ratio of graduates to operator level is 20:80. Indirect employment such transportation of EFB fibers is not included.

From Table 6, it can be inferred that:

- EFB consumed as pellets produce less GHG compared to biofiber composite profile, due mainly to the inclusion of propylene and additive to produce the biomaterial (biofiber composite profiles).
- EFB consumed as pellets gave lower TVA compared to biofiber composite profiles. Although a higher TVA is achieved for biofiber composite profiles, the specific utilization of EFB fiber require higher CAPEX (Capital Expenditure) and OPEX (Operational Expenditure) compared to pellet production.
- EFB consumed as pellets also gave lower values for all three economic sub-indicators i.e. labor wages, net profit and tax revenue.

5.3. Conclusion and Recommendations

It must be noted that the choice of another type of biomaterial that does not require the addition of plastic resins will generate a different set of results. The results generated in the case study are all modeled from existing facilities that are not exactly doing the activities described e.g. the pellet production plant uses a range of feedstocks. However, the case study assumes pellets are produced primarily from EFB fibers. The same applies to biofiber composite profiles where the modeling is based on a pilot plant using rice husks. Hence the figures produced from the

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[7] "Jobs created" relates only to full employment for a specific activity in the value chain of the target product and do not include administrative staff of the company or, transportation, logistics, laboratories and machine maintenance employees of other companies.

calculations are not necessarily precise, but are sufficiently comprehensive to give a representative picture.

In using the sustainability assessment methodology for ex-ante studies, the following pre-requisites should be carefully considered:

- The form of the raw material should be the same at the starting point of comparison for the two different applications, in this case EFB from the palm oil mill.
- Input for utilities should be based on an annual production schedule for easier accounting. In this case study, half of the EFB generated by a mill of 60 ton/hour capacity was consumed by either forms of EFB utilization.
- The input of auxiliary materials will differ in the consumption of 1 ton of EFB for the two different routes of application, resulting in end-products that are different in weight but yet have consumed 1 ton of EFB, including losses in the particular production process.
- Assumptions are clearly defined, as the market situation changes rapidly with demand.

Ex-ante studies will have to depend on secondary information from reliable sources namely:

- Existing facilities that are involved in similar business (although not always exactly the same)
- Existing facilities involved in activities that are part of the value chain in the production of a product containing EFB
- Equipment suppliers who are able to give ball-park figures of capital and operating costs based on a known plant capacity
- Public domain information such as pricing and tariff data for electricity consumption published on the web
- Private communication with relevant stakeholders to provide general insights of the proposed project's activities

The case study on evaluating alternative uses of EFB using the sustainability assessment methodology showed that it is possible to compare ex-ante activities by creating well-defined scenarios. Although not performed in this study, it is recommended that uncertainty and sensitivity analyses be conducted to increase the level of confidence in the results produced by the methodology.

Finally, a concern that has surfaced recently, particularly from the plantation owners, is that the removal of oil palm biomass from the field should be studied carefully with respect to maintaining the soil's organic carbon levels, preserving or enhancing productivity and reducing the impact of soil erosion before making decisions (Hashim *et al*., 2012). In this respect, the sustainability assessment methodology should still be able to address the functional unit of consumption of (1 ton) EFB for use in mulching as against its use for biomaterials or biomass utilization for energy.

Although this case study showed that ex-ante figures could be obtained by using the assessment methodology on bioenergy and biomaterials, the exercise has also raised concerns that should be investigated further to strengthen the approach. These concerns are:

- The result of the sustainability assessment indicates that biofiber composite profiles earn more social and economic benefits than pellets. On the other hand, given the magnitude of GHG emissions, biofiber composite profiles produce more emissions than pellets within the system boundary set in this study. It is to be noted that the result would give different figures and information if the system boundary or the function of the biomass-based products was set differently. It is imperative that, at the outset of the study, boundary and functions should be clearly defined so that the assessment result can provide the target of the study with appropriate information.
- Uncertainty and sensitivity analyses may also be considered to enhance the reliability of the study and the level of confidence in its result, but this would be an additional step.

Assessments on the potential utilization of EFB for bioenergy versus biomaterial usage are becoming more important as competing uses of biomass emerge, and biomass feedstock is also reducing with competing land use. More case studies should be carried out to strengthen the methodology as a decision support tool for ex-ante activities.

CHAPTER 6

Conclusions

The ERIA WG has been working progressively on the development of indicators for assessing the sustainability of biomass utilization systems. First, suitable indicators were identified and quantification methods defined for the environmental, economic and social assessment of biomass utilization systems. These indicators were then field-tested and in the process, refined to suit the conditions and context of East Asia. During the period of the ERIA WG's activities, several international initiatives, such as GBEP and RSB also published their own sets of indicators. It was therefore imperative to check the methodology that had been developed and tested by the ERIA WG. This was one of the major tasks achieved by the WG in the current phase (2011-2012). In general, though the ERIA WG methodology used fewer indicators for the assessment of the environmental, economic and social aspects of biomass utilization than GBEP or RSB, the indicators used were nevertheless identified as being relevant and robust. Thus, for case of environmental assessment, life cycle GHG emissions was retained as the main indicator, noting also the importance of emissions from land use change (particularly direct land use change) as well as other impact categories including impacts on air, water and soil. Among other categories, soil quality was picked up to explore a possible indicator to be considered in the ERIA WG methodology. In the case of economic assessment, TVA, as selected earlier on, was considered adequate. The production and income approaches to estimating TVA have been outlined in this report. In the case of social assessment, the two indicators identified in the previous report (ERIA, 2011) – "Employment" and "Access to modern energy" – have been confirmed. These indicators have been further described and methods for their quantification presented.

The other important issue considered in this report is the development of a framework for a decision support tool for ex-ante assessments of biomass utilization projects and policies. The need for such a tool had been identified earlier on to facilitate evaluation of planned biomass utilization projects before they have actually been implemented. To this end, the indicators for sustainability assessment were once again tested for relevance and applicability, first on a theoretical basis and then by means of a case study. Life cycle GHG emissions, TVA (using the production approach) and employment were identified as adequate indicators for ex-ante assessments. A case study on utilization of empty fruit bunches from palm oil mills in Malaysia for pellets (energy carrier) and biofiber composite profiles (biomaterial) was conducted. The decision support framework for ex-ante assessment was successfully tested in this case study. The study revealed that, using data from existing systems that were not necessarily identical to the proposed systems, reasonably accurate estimations could be made ex-ante. Uncertainty and sensitivity analyses would enhance the reliability of the study. It is also observed that the assessment result would give different information if the system boundary or the functions of products were set differently. This implies that boundary and functions should be clearly defined so that the assessment result could provide the target of the study with appropriate information.

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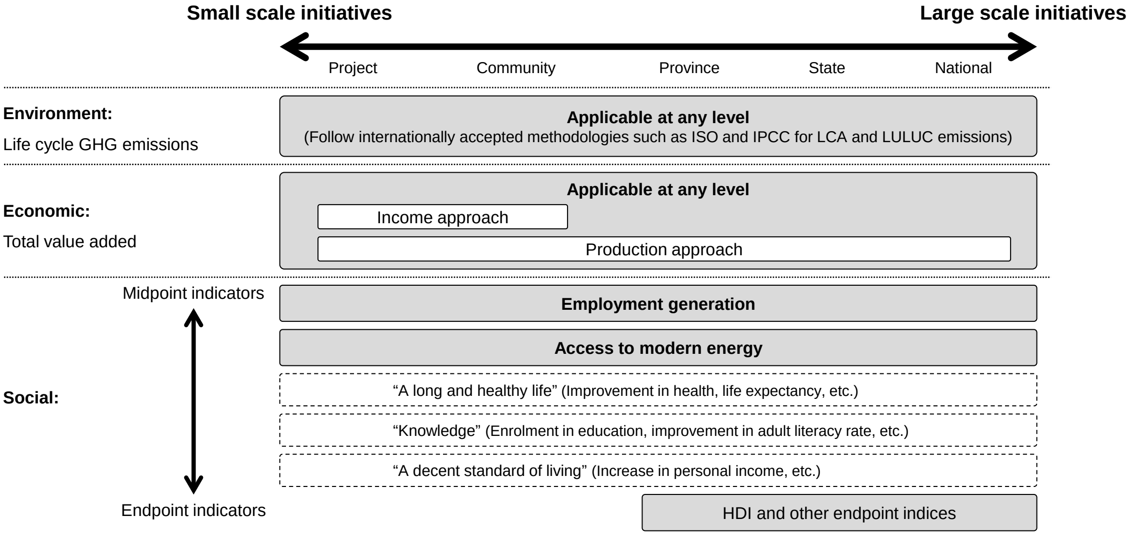
Appendix I. Sustainability Indicators of ERIA WG Methodology

The sustainability indicators currently employed in the ERIA WG methodology are summarized in Figure A1-1. These indicators were carefully selected from existing indicators so that they could be applied to a variety of biomass utilization projects, ranging from small to large scale, in both ex-ante and ex-post assessments. Each indicator is summarized in the following sections.

Figure A1-1. Indicators of Sustainability of the ERIA WG methodology



1. Environmental Sustainability Indicator

Although the WG recognizes the importance of other environmental impact categories, such as such as impacts on air, water and soil quality, and biodiversity, the concept of Life Cycle GHG (LC-GHG) emissions, or their savings, is employed as the WG environmental sustainability indicator in the ERIA WG methodology. This is because climate change caused by GHG emissions is one of the most important concerns, affecting all countries in East Asia.

In order to quantify the emissions of GHGs, including carbon dioxide and other gases, it is necessary to take each step of the Life Cycle Assessment (LCA) standardized in ISO 14040s.

The material and energy inputs and outputs necessary for estimating GHG emissions, the so called Life Cycle Inventory (LCI) data, are gathered based on the goal and scope defined at the beginning of a study. Then the quantities of GHGs are computed with use of GHG emission factors that are, for example, prepared nationally, provided by IPCC (default values) or experimentally-measured. The amounts of the respective GHG emissions are aggregated into the quantity of carbon dioxide equivalent weight of greenhouse gases (kg- or tons-) with use of GWP (Global Warming Potentials) (IPCC, 2007). This calculation can be expressed by Equation (A1-1).

$$LCGHG = \sum_{i,j} \left(GHG_{i,j} \times GWP_i \right) \qquad \text{(A1-1)}$$

where *i* is the greenhouse gas (e.g. carbon dioxide, methane and/or nitrous oxide) *j* is the life cycle stage of biomass utilization for energy (e.g. feedstock cultivation, feedstock collection and conversion process of biomass into energy), *LCGHG* is life cycle GHG emissions [/FU], $_{,j}$ is the amount of the GHG *i* in the stage j [/FU], is the global warming potential for the GHG *i* and FU is the functional unit (e.g. per hectare per year, per 1 kiloliter or GJ of bioenergy carrier, etc.).

In case a biomass-derived product is comparable and replaceable with fossil-based product, e.g. the case that bioethanol replaces gasoline, GHG savings is a more convenient indicator to understand how much GHG emissions could be reduced by the replacement. This is computed with Equation (A1-2).

$$S = LCGHG_{Fossil} - LCGHG_{Biomass} \qquad \text{(A1-2)}$$

where S is GHG savings, is life cycle GHG emissions from a fossil-based product and is life cycle GHG emissions of a biomass-derived product.

2. Economic Sustainability Indicators

There are two levels of indicator: a master indicator and multiple sub-indicators. The sub-indicators are: employment, net profits and tax revenues while master indicators are TVA (Total Value Added) and the foreign exchange savings. All these indicators can be applied to any scale, from project to national level, except for foreign exchange savings which is only relevant at the national level.

2.1. Master Indicator – Total Value Added

TVA was originally used in national accounts as a measure in economics of the value of goods and services produced in an area, industry or sector of an economy. TVA as used in this study is the sum of the value added generated out of the development of biomass, including, production, further conversion or processing, and by-products. In the economic assessment, the TVA is rescaled by production quantity and thus becomes TVA per unit of biomass production.

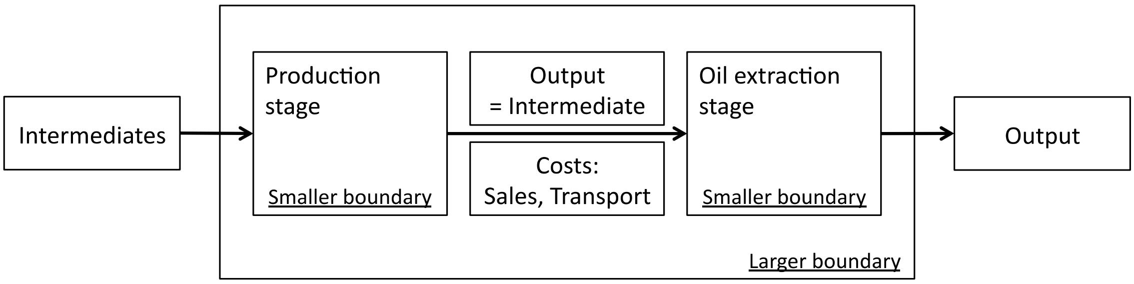
As in national accounts, TVA in this study is also calculated as output value minus costs of intermediates:

$$\begin{aligned} \text{TVA} &= \text{Output value (or Gross revenue)} - \text{Cost of intermediates} \\ &= \sum \text{Price} \times \text{Output quantity} - \text{Cost of intermediates} \qquad \text{(A1-3)} \end{aligned}$$

where gross revenue is simply the product of price and quantity (applies to both main product and by-products), and intermediates include goods and services, other than fixed assets, used as inputs into the production process of biomass, which are produced elsewhere in the economy or are imported. It should be noted that land, labor, and capital are primary inputs and are not included among intermediates. This is equivalent to the production approach of measuring GDP while the method proposed in the previous report was an income approach, which may be complicated for use by professionals not having a background in economics.

This TVA measure can be applied to any stage of biomass production and can include any step of biomass production. The user only needs to know the value of intermediate input and the output value generated out of the boundary. Anything inside the boundary is a “black box” and does not need to be calculated. The boundary can be defined by the user. For example, as shown in Figure A1-2, the boundary can contain only production of biomass, or both production of biomass and oil extraction. In the later and larger boundary, the “output” value of biomass becomes an “input” in the oil extraction stage and thus when calculating the two stages together, one only needs the final output value of biomass oil, while not caring about the output value of biomass.

Figure A1-2. Input-Output Boundaries for TVA Calculation



The boundary in Figure A1-2 can be equally extended to include more stages, such as esterification, which are often undertaken in the case of producing biodiesel.

The master indicator can be supplemented by a few sub or component indicators, such as labor income, net profit, tax revenues and foreign exchange savings.

2.2. Sub-Indicators for Economic Pillar

2.2.1. Labor Income (Wage)

Labor income or wage is another indicator for assessing the economic impact of the biomass industry and is put as a sub-level indicator to supplement the master indicator. Labor income, or wage, or personnel remuneration refers to the total salaries and wages paid to the employees in the different firms or activities involved in the biomass utilization in exchange for their labor. This includes the labor income from both the production stage and the plantation and processing stages of raw material to bioenergy. This is computed as Equation (A1-4):

$$\text{Labor Income} \\ = \text{Total person-days} \times \text{Average wage per person-day} \qquad \text{(A1-4)}$$

In most cases, the labor requirement is expressed in terms of person-days. As such, the necessary conversion may be done to express person-days as number of persons hired. The resulting figure is a more concrete representation or estimation of the employment impact.

2.2.2. Net Profit

Net profit is a key indicator that is closely monitored by investors. It is also an indicator used to demonstrate the sustainability of a biomass business. If a negative profit is consistent, investors will finally pull out of the biomass business and the industry cannot be sustained.

Profit can be influenced by the government, and thus it is also of interest to the government. If government finds that the profit is not attractive to private investors, it can reduce taxes or provide subsidy to the biomass industry.

2.2.3. Tax Revenues

Tax revenue is the income generated for the government from the entities involved in each production process. Each country may have a different tax portfolio, and thus the calculation will be diverse. A typical example is computed as Equation (A1-5):

$$\text{Tax} = \text{Total taxable income} \times \text{Tax rate} \qquad \text{(A1-5)}$$

Where

Total taxable income

= Income from main product (Profit per unit of product A × Volume of A)

+ Income from by-product (Profit per unit of by-product B × Volume of B) (A1-6)

Taxes generated from the biomass industry can be obtained by multiplying the prevailing tax rate by the total taxable income of each sector (i.e. copra, unrefined oil, and coconut methyl ester producers in the case of biodiesel production from coconut), as can be described as Equation (A1-7).

$$\text{Tax} = \text{Total taxable income from all processed products} \times \text{Tax rate} \qquad \text{(A1-7)}$$

3. Social Sustainability Indicator (Human Development Index)

Among the social sustainability indicators of the ERIA WG methodology, the basic concepts of employment and access to modern energy are already addressed in Chapter 3.4. This section deals with the Human Development Index (HDI).

Social issues in the growing markets for biomass energy utilization are expected to become prominent as the producers and consumers of bioenergy may live in different countries. Major positive social impacts of bioenergy include enhancing energy security, creating job opportunities, etc. On the other hand, negative social impacts expected in biomass energy utilization are food insecurity, land use conflicts with indigenous inhabitants, exploitative working conditions, etc. To capture the holistic picture of development across countries, the United Nations Development Programme (UNDP, 2011) has used the Human Development Index (HDI). This essentially takes into account the measures for living a long healthy life (by life expectancy), being educated (by adult education and enrolment at primary, secondary and tertiary levels) and having a decent standard of living (by purchasing power parity, PPP). The WG adopted the HDI as the indicator to evaluate the social sustainability of biomass energy utilization. Although the pilot studies conducted by the WG (ERIA, 2010) found difficulty in applying HDI to biomass projects at the small scale or community level, HDI could be applied to projects at large scale or national level. The calculation of HDI can be described as Equation (A1-8) and Table A1-1.

$$\text{HDI} = 1/3 \times (\text{Life expectancy index} + \text{Education index} + \text{GDP index}) \qquad \text{(A1-8)}$$

Table A1-1: Calculation of HDI

Index	Measure	Minimum value	Maximum value
Life expectancy	Life expectancy at birth (LE) LE index = (LE-)/(-)	25 years	85 years
Education	Education index = ALI×2/3+GEI×1/3 Adult literacy index (ALI) = (ALR-)/(-) where ALR: Adult literacy rate [%] Gross enrolment index (GEI) = (GER-)/(-) where GER: Gross enrolment ratio [%]	0%	100%
GDP	GDP index = {ln(GDP)-ln( )}/{ln( )-ln( )} where GDP: GDP (PPP) per capita [USD]	100 USD	40,000 USD

Appendix II. Soil Sustainability

Soil quality and sustainability evaluation is a fundamental concept bridging between the utilization and protection aspects of soil-use planning. Sustainability analysis of soil-use can performed for any individual soil function or groups of soil functions in defined land use systems in a comparative manner, taking the potential effects of degradation into account (Tóth, *et al*., 2007).

Decline of soil fertility, carbon, and biodiversity, lower water retention capacity, disruption of gas and nutrient cycles and reduced degradation of contaminants are among the results of the soil degradation processes. Soil degradation has a direct impact on the environmental quality that prevents the soil from performing its services to society and ecosystems at required levels, such as:

- Biomass production
- Storing, filtering and transforming nutrients, substances, and water
- Biodiversity pool such as habitats, species, and genes
- Source of raw materials
- Acting as carbon pool

The maintenance of the fertility of the soil is the first condition of any permanent system of agriculture. To ensure the sustainability of biomass energy utilization, International Sustainability & Carbon Certification (ISCC) announced that biomass should be produced in an environmentally responsible way (ISCC, 2011). This includes the protection of soil, water and air, and the application of Good Agricultural Practices (GAP). To address the impacts of biomass energy utilization on soil sustainability, the following GAP principles should be considered.

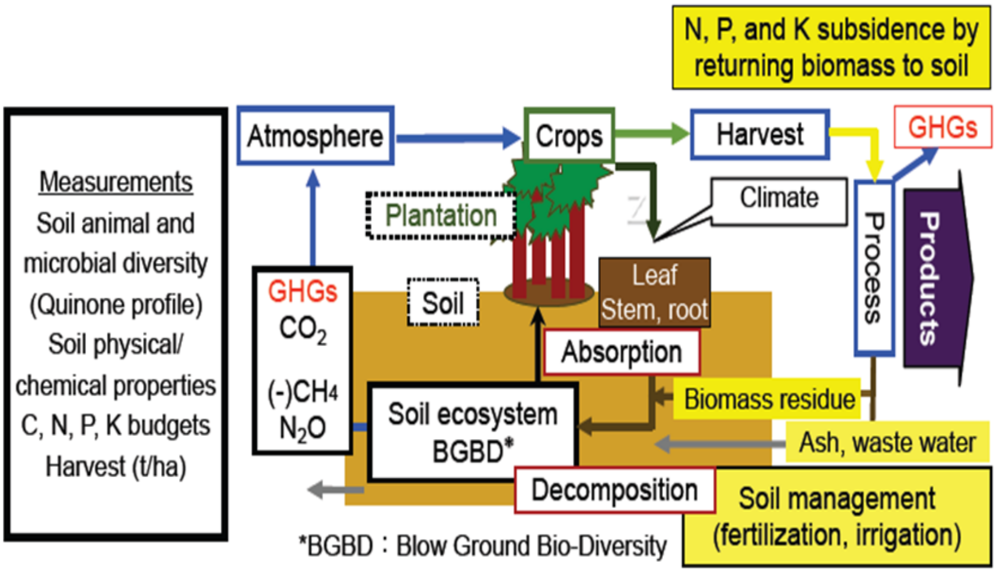
- Field cultivation techniques are used to reduce the possibility of soil erosion
- Soil organic matter is maintained/preserved
- Organic matter, if used, is evenly spread throughout the production area
- There is a restriction on burning of organic matter as a part of the cultivation process
- Techniques have been used that improve/maintain soil structure, and avoid soil compaction.

The sustainable use of soil resources depends on three factors: soil characteristics, related environmental (climate, hydrologic etc.) conditions and land use. These factors interact in a systems-based fashion, where the change in one factor causes alteration in the others. Therefore the sustainable use of soil resources is a dynamic category. It is important to assess our soil resources from this standpoint and to consider soil as the prime object of sustainable use in relation to land management under given (changing) natural conditions. The sustainability of soil-use can be achieved by practical methods of management and can only be guaranteed if the material and energy flow associated with soil processes are controlled and positively influenced. This means the management and maintenance of certain level of soil characteristics, which eventually embrace soil quality as well (Tóth, *et al*., 2007).

The GBEP (Global Bioenergy Partnership) sustainability indicator for bioenergy considered soil quality as an indicator in its environmental pillar. The description of this indicator is “Percentage of land for which soil quality, in particular in terms of soil organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested”. In this sustainability indicator, the term “soil quality” is described particularly only as soil organic carbon. Actually, to describe the soil quality comprehensively, the chemical, physical, and biological properties of soil should be measured. In terms of chemical soil quality, the C, N, P, and K contents are usually used as general indicators. Soil animal and microbial diversity can be used as parameters of biological soil quality. Soil erosion and compaction or soil structures are often used to measure physical soil quality. Figure A2-1 describes the relationship between cultivation and productivity and the measurement parameters for evaluate soil quality.

Society needs simple measurements to compare the options for utilizing soil functions and measuring the risk of that particular utilization leading to soil degradation processes. Soil quality assessment can serve as a basis of this comparison and should be one of the main criteria for planning and practicing sustainable soil-use (Tóth, *et al*., 2007).

Figure A2-1: Relationship between Cultivation and Productivity and the Measurement Parameters for Evaluating Soil Quality.

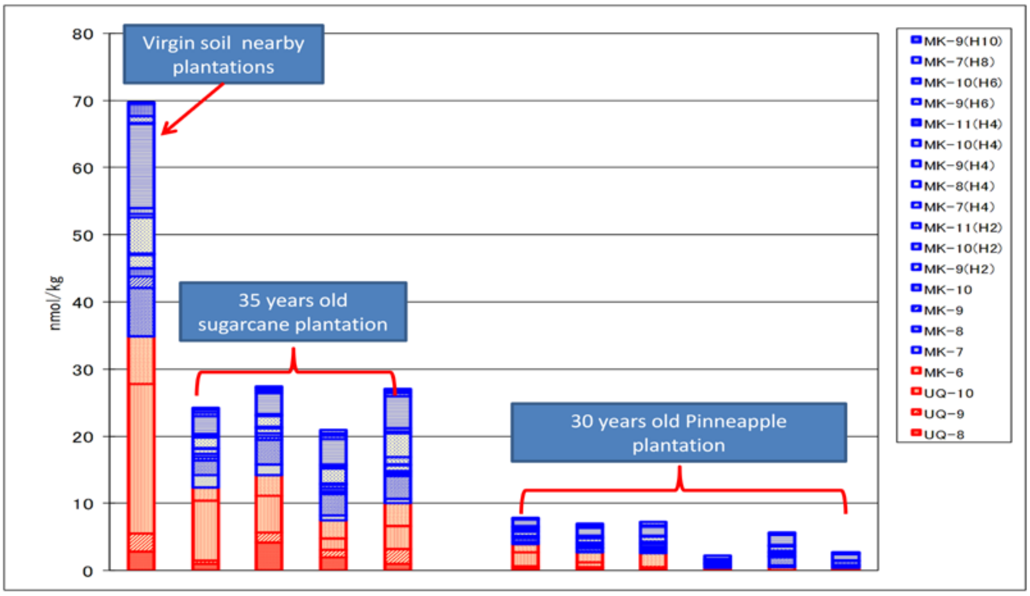


To measure all indicators of soil quality is not easy. Soil organic carbon and the soil's microbial community have a close relationship to soil quality. In living soil around 100 elements and billions of microorganisms work together in synergy. Microorganisms are precisely what differentiate a living soil from a dead soil. Microorganisms decompose and ferment organic matter into humus, containing nutrients and hormones that facilitate plant growth. Typically, microorganisms are responsible for providing hormones, nutrients, and minerals in a useable form to the plants via the root ecology. Microorganisms cohere with soil particles and soil structure, retaining nitrogen and other fertilizing compounds.

Microorganisms have been known to contribute to environmental conservation via organic matter which is predominantly degraded through microbial processes in ecosystems (Baker and Herson, 1994; Fujie, *et al*., 1998; Katayama, *et al*., 1998). The capacity of an ecosystem to degrade organic matter and its response to the changes in environmental conditions not only depend on the total population of microorganisms present in that system but also depend on microbial community structure of that system (Hu, *et al*., 1999; Hasanudin, *et al*., 2004).

The microbial community structure in natural mixed cultures such as soil can be used as an indicator of soil conditions such as: fertility, biodiversity, and the structural condition of soil. Soil organic carbon has a close correlation with microbial community structure, but soil which has a high concentration of organic carbon does not always have high number and species of microbes. Microbial communities in the soil need not only organic carbon for growth and multiplication, but also other organic matter such as nitrogen (N) and phosphorus (P). Therefore, microbial community structure can be promoted as a more representative indicator of soil quality than soil organic carbon. The quinone profile or other microbial identification systems can be used to describe microbial community structure in soil and can therefore be used as an indicator of soil quality. Figure A2-2 shows the effect of sugar cane and pineapple plantation in Lampung Province, Indonesia on the number and diversity of microorganisms, using quinone as an indicator. The concentration of quinone (mmol/kg of soil) can be used as an indicator of the number of microorganisms and species of quinone (Ubiquinone (UQ) and Menaquinone (MK)) can be used as indicators of the diversity of microorganisms in the soil. This result shows that after several years of soil utilization for cultivation, the number and diversity of microorganisms decreased significantly. This information is very useful for describing soil conditions (soil fertility and structure) and the productivity of soil for producing biomass. Based on this information, microbial community structure using quinone profiles can describe soil quality. Soil quality is very important in ensuring the sustainability of biomass production, and quinone profiles can be used as an evaluation index of bioenergy sustainability.

Figure A2-2: Effect of Land Utilisation for Plantations on Microbial Community Structure in the Soil Using Quinone Profile Indicator.



The sustainability of soil-use and preservation of soil resources depends on (i) the ability of soil to perform and maintain its function and (ii) the capacity of soil to respond to impacts over time under the changing pressure of soil degradation threats. Therefore matching soil quality and degradation characteristics over a time period helps in evaluating soil sustainability. Soil sustainability analysis is performed on the basis of numerical indices of a Soil Quality Index (SQI) and a Cumulative Degradation Effect (CDE). A Soil Sustainability Index (SSI), can therefore be defined as Equation (A2-1)

$$\text{SSI} = \text{SQI} \times (100 - \text{CDE}) \qquad \text{(A2-1)}$$

Where:

- *SQI* is the Soil Quality Index, which can be used as an indicator of the "goodness" of soil with regards to functions and responses.
- *CDE* is the Cumulative Degradation Effect (the gradient of the degradation processes), which is scaled inversely, on a proposed 100 point scale. Inverse

scaling in this equation helps to identify the effect of degradation on the function, and provide a realistic SSI (Tóth et.al., 2007).

Based on this equation, soil sustainability is determined by SQI and CDE, which can be explained by concentration and diversity of quinone in the virgin and the present soil condition (calculated from and).

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