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SUSTAINABILITY ASSESSMENT METHODOLOGY FOR BIOMASS ENERGY UTILISATION FOR SMALL AND LARGE SCALE INITIATIVES:

LESSONS LEARNED FROM PILOT STUDIES IN SELECTED EAST ASIAN COUNTRIES

Edited by

ERIA WORKING GROUP ON
"SUSTAINABILITY ASSESSMENT OF BIOMASS UTILISATION IN EAST ASIA"

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FOREWORD AND ACKNOWLEDGEMENT

The ERIA Working Group (WG) on "Sustainability Assessment of Biomass Utilisation in East Asia", sponsored by the Economic Research Institute for ASEAN and East Asia (ERIA), started its activity on sustainability assessment of biomass energy utilisation in the East Asian context since 2007. In the first phase (2007-2008), the WG extracted issues of concern for sustainability assessment of biomass utilisation and summarised a WG report entitled "Sustainable Biomass Utilisation Vision in East Asia", which played an important role for scientific backup for the adoption of the "Asia Biomass Energy Principles" endorsed in the "Second Meeting of Energy Ministers of East Asia Summit" held in 2008. In the second phase (2008-2009), the WG developed a methodology to evaluate sustainability of biomass utilisation based on environmental, economic and social pillars and framed the "Guidelines to Assess Sustainability of Biomass Utilisation in East Asia", incorporating the methodology developed and data required for sustainability assessment for biomass utilisation. Consequently, in the third phase (2009-2010), the WG conducted pilot studies in four selected East Asian countries to field-test the methodology developed and presented in the WG report "Sustainability Assessment of Biomass Energy Utilisation in Selected East Asian Countries".

This report contains the outcome of the research activity of the WG in 2010-2011. The main objectives of the WG for the fourth phase were to summarise the experience gained and lessons learned from the four pilot studies conducted in 2009-2010 and discuss a more comprehensive methodology for biomass sustainability. We hope that this report contributes not only to sustainable utilisation of biomass energy in the East Asian region but also to other frameworks on this topic developed elsewhere in the world.

Finally, we wish to thank ERIA and its officers for providing financial support and generous assistance for various activities of the WG.

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ABBREVIATIONS AND ACRONYMS

Currency conversion rates used in this report:

1 USD = 48 INR = 45 PHP = 32 THB = 9,200 IDR (approximately)

ASEAN	Association of Southeast Asian Nations
CH_4	Methane
CME	Coconut Methyl Ester
CO_2	Carbon dioxide
CO_2eq	CO_2 equivalent
EAS	East Asia Summit
ERIA	Economic Research Institute for ASEAN and East Asia
EROEI	Energy Returned on Energy Invested
GBEP	Global Bioenergy Partnership
GDI	Gender-related Development Index
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
HDI	Human Development Index
ISO	International Organization for Standardization
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
IDR	Indonesian Rupiah
INR	Indian Rupee
LCI	Life Cycle Inventory
LUC	Land Use Change
LULUC	Land Use and Land Use Change
MDGs	Millennium Development Goals
N_2O	Nitrous oxide

PHP	Philippine Peso
SDI	Social Development Indicator
THB	Thai Baht
TNP	Total Net Profit
TVA	Total Value Added
UNDP	United Nations Development Programme
USD	United States Dollar
WG	Working Group

EXECUTIVE SUMMARY

The fourth phase of the working group culminated several years of developing and testing methodology for assessing sustainability of biomass utilisation in East Asia. After review of existing indicators for environmental, economic and social pillars, relevant for biomass systems, one indicator was identified for each of the pillars, based on importance and relevance particular to the East Asian context. Life cycle greenhouse gas (GHG) emissions, total value added (TVA) and the Human Development Index (HDI) of the United Nations Development Programme were the shortlisted indicators of above three pillars, respectively, which were then tested for actual application at four study sites. The studies confirmed the applicability of the indicators but also revealed shortcomings with respect to requirement of extensive data collection for all the indicators and interpretation of results.

In this phase of the working group's effort, discussions were made on the applicability of the indicators for various scales. As the previous case studies were mainly at the project scale, suggestions are made on the applicability of the indicators at the macro scale. Life cycle GHG emissions can easily be applied at the macro scale though the data requirements will increase correspondingly. TVA is amenable to be applied at the macro scale; the sub-indicator foreign exchange in fact being particularly relevant for the macro scale. HDI has been envisaged anyway as a national-level indicator, hence, its applicability at the macro level is obvious. However, for the local level, employment generation and access to modern energy were identified as more

practicable indicators for assessing social impact of biomass energy.

Also, the need for additional indicators for each pillar was identified. For the environmental pillar, biodiversity, energy resource depletion, water resource scarcity, and degradation of air, water and soil quality would be relevant for evaluating biomass systems. For the economic pillar, income (wages), net profit and tax revenue could complement TVA. For the social pillar, as mentioned earlier, employment generation and access to modern energy could complement HDI. These indicators should be field-tested in the near future to identify the practicability of using them as well as to adapt them to the context of East Asia.

An overall observation for the whole exercise of field-testing the sustainability methodology and indicators was that their application requires a certain level of expertise. Hence, it is proposed that “training of the trainers” should be initiated whereby a certain group of personnel from the countries in East Asia are trained to use these indicators; they can then train others in their own countries.

1. INTRODUCTION

1.1. Background

It is generally acknowledged that biomass energy can make a significant contribution to environmental improvement, energy supply diversity from fossil fuels and socio-economic development goals, both in the developed and developing world, owing to the following reasons. Firstly, biomass energy development offers the opportunity for enhanced energy security and access by reducing the dependence upon fossil fuels. Secondly, biomass energy has the potential to contribute to environmental benefits including greenhouse gas (GHG) emissions reduction. Thirdly, biomass energy development can create employment that will positively affect agricultural and rural incomes, poverty reduction and economic growth.

On the other hand, there is a rising concern vis-à-vis life cycle GHG reduction effects of biomass energy, food versus fuel issues and environmental disruption caused by the expansion of biomass resources production and use as energy. In view of these, there is also widespread recognition that biomass energy must be produced and used in a sustainable way, considering all the positive and negative effects from environmental, economic and social pillars of sustainability.

1.2. Review of Initiatives Related to Sustainability of Biomass Energy

There are various initiatives working to develop sustainability criteria and indicators for biomass energy and their feedstocks. These initiatives include regulatory frameworks and voluntary standards. Prominent features of the major initiatives are summarised as follows.

In the Netherlands, sustainability criteria based upon principles and indicators are developed in the "Testing framework for sustainable biomass" (The project group "Sustainable production of biomass", 2007) to inform national policy-making. The framework addresses the sustainability of biomass production and processing for electricity, heat, transport fuel and raw material in chemistry and it covers both domestically-produced and imported biomass. The framework identifies six relevant themes: (1) GHG emissions; (2) competition with food and other applications; (3) biodiversity; (4) environment; (5) prosperity; and (6) social well-being. On these six themes, nine basic principles for biomass sustainability are formulated, including criteria, indicators with minimal requirements and reporting obligations.

In order to meet growing public and policy demand for sustainable production of biofuels and biomass, the German Federal Government has approved a national ordinance upon requirements regarding the sustainable production of biomass to be applied as biofuel in 2007. With this "Biomass Sustainability Ordinance – BioNach V" (German Federal Government, 2007), a series of minimum environmental sustainability requirements for the production of biofuels are defined. The ordinance addresses the following environmental dimensions: (1) sustainable land management; (2) protection of natural habitats; and (3) potential for GHG reduction.

The UK's Renewable Transport Fuel Obligation (RTFO) (UK DfT, 2008) was introduced in 2008 in order to reduce CO_2 emissions from road transport by promoting the supply of renewable fuels. It imposes a legal obligation upon fossil fuel suppliers for road transport to produce Renewable Transport Fuel Certificates (RTFCs), which ensures that a certain amount of biofuel is supplied. In order to receive RTFCs, RTFO requires suppliers of fossil road transport fuel to provide reports on both the net GHG savings and the sustainability of the biofuels they supply. The sustainability reporting scheme, which focuses upon biofuel feedstock production, makes use of existing voluntary agri-environment and social accountability schemes, which have been benchmarked against the RTFO Biofuel Sustainability Meta-Standard. The Meta-Standard comprises seven principles: (1) carbon conservation – biomass production will not destroy or damage large above or below ground carbon stocks; (2) biodiversity conservation – biomass production will not lead to the destruction and damage of high biodiversity areas; (3) soil conservation – biomass production does not lead to soil degradation; (4) sustainable water use – biomass production does not lead to the contamination or depletion of water sources; (5) air quality – biomass production does not lead to air pollution; (6) workers' rights – biomass production does not adversely affect workers' rights and working relationships; and (7) land rights – biomass production does not adversely affect existing land rights and community relations. In addition to these principles, the RTFO Meta-Standard comprises a number of criteria and indicators to assess the extent to which feedstock produced in accordance with each qualifying scheme can be considered sustainable. Some of the criteria are compulsory, while others are simply recommended as best practices. Furthermore, the wider environmental and social principles that are not within the control of the supply chain, including indirect land use change (LUC) and the competition with food prices, will also be monitored and reported.

In 2009, the Council of the European Union (EU) adopted a common set of sustainability criteria through Renewable Energy Directive (European Union, 2009) to achieve significant GHG savings and to prevent negative effects upon biodiversity by the use of biomass energy. The aim of this legislative act is to achieve a 20% share of energy from renewable sources in the EU's final consumption of energy and a 10% share of energy from renewable sources in each member state's transport energy consumption by 2020. According to the Directive, the sustainability criteria relate mainly to the following environmental aspects/issues: (1) biodiversity; (2) the protection of rare, threatened or endangered species and ecosystems; and (3) GHG emission saving. Regarding the socio-economic aspects of sustainability, the Directive required the European Commission to report every two years on the impact of EU biofuels policy on food prices, land rights, and compliance with International Labour Organisation conventions in developing countries.

The U.S. Environmental Protection Agency's Renewable Fuel Standard (RFS) Program aims at increasing national energy security by creating a market for renewable fuels as a substitute for conventional fuels. By incorporating incentives for investing in research and development of renewable fuels, the RFS program also seeks to accelerate the nation's progress towards energy independence. In addition, the RFS program helps to reduce the U.S.'s GHG emissions. The first RFS program (RFS1), created under the

Energy Policy Act of 2005 (EPAct), was revised to address the requirements of the Energy Independence and Security Act of 2007 (EISA) and currently implemented as RFS2 in 2010 (US EPA, 2010). There are two important features of RFS2: (1) it specifies the volumetric requirements for renewable fuels through 2020; and (2) it sets GHG emission thresholds for four biofuel types: advanced biofuel (a renewable fuel other than corn ethanol), cellulosic biofuel, biomass-based diesel and other renewable fuels.

In 2009, the Japanese government released a policy to increase the supply of biofuels under the law of ‘Sophisticated Methods of Energy Supply Structure’, which imposes the energy suppliers on introducing renewable energies including biofuels. In order to define and develop the sustainability standard for biofuels by verifying their contribution to CO_2 emissions reductions from a life cycle perspective (including the clearing of land for cultivation, feedstocks cultivation, biofuel production and transport) and assessing the impact upon competition with food and other aspects, the ministries have jointly organised the “Study Group on Sustainability Standards for the Introduction of Biofuel”. The Study Group report that has been published in March 2010 (ANRE, 2010) highlights the following three aspects of biofuel sustainability: (1) contribution to CO_2 emissions reduction by 50% of the base fuel identified by LCA; (2) supply stability as a source of energy, which should meet at least 50% of biofuel requirements through domestic production as well as development and import from Asia; and (3) coping with competition with food by monitoring the impact of biofuel introduction, analysing the causes of competition to identify solutions and emphasising the development and dissemination of technologies for cellulosic biofuel.

The International Organization for Standardization (ISO) is also considering the development of “Sustainability criteria for bioenergy” by bringing together international expertise and state-of-the-art best practices to discuss the social, economic and environmental use of bioenergy, and identify criteria that could prevent it from being environmentally destructive or socially aggressive (ISO, 2010).

There are also international frameworks to discuss the sustainability of biomass energy.

The Roundtable on Sustainable Biofuels (RSB), a multi-stakeholder initiative hosted by the Energy Center of École Polytechnique Fédérale de Lausanne (EPFL), has developed a global sustainability standard and certification system for biofuel production since 2007. In August 2008, the RSB released its first draft of a generic standard for sustainable biofuels production. After the consultations for their “Version Zero” draft until April 2009, they released their “Version One” of international standard for better biofuel production and processing. In 2010, “Version One” was pilot tested in biofuel supply, namely in Germany, South Africa, Australia, Brazil, Guatemala and Peru, to identify areas in need of further refinement. Based upon this feedback and further consultation, the RSB approved “Version Two” in November 2010 (RSB, 2010). The RSB standard has now become a fully operational biofuel certification standard, which includes principles and criteria, an associated guidance document, detailed compliance indicators and the glossary of terms. The RSB standard is built around the following twelve principles: (1) legality; (2) planning, monitoring and continuous improvement; (3) GHG emissions; (4) human and labour rights; (5) rural and social development; (6) local food security; (7) conservation; (8) soil; (9) water; (10) air; (11) use of technology, inputs, and management of waste; and (12) land rights.

The Global Bioenergy Partnership (GBEP), a forum where national governments, international organisations and other partners seek to facilitate effective policy frameworks and suggest rules and tools to promote sustainable biomass energy development through voluntary cooperation, has been working to develop a set of relevant, practical, science-based voluntary sustainability criteria and indicators under the Task Force on Sustainability since 2008. The criteria and indicators are intended to guide any analysis undertaken of biomass energy at the domestic level with a view to informing decision making and facilitating the sustainable development of biomass energy in a manner consistent with multilateral trade obligations. In May 2011, the GBEP Steering Committee endorsed a set of sustainability indicators for bioenergy defined by the Task Force (GBEP, 2011). A total of twenty-four indicators have been set out under the three pillars of sustainability (environmental, social and economic) and each sub-set of eight indicators is given under its respective pillar.

1.3. Research Activities of ERIA WG on "Sustainability Assessment of Biomass Utilisation in East Asia"

Although there is high biomass energy potential in East Asia, most of the countries in this region are heavily dependent upon fossil fuel imports to meet their energy needs. Governments in this region are looking for various energy alternatives and in this regard biomass energy has emerged on the forefront, which may assure social benefits due to employment generation through its development as well as GHG reduction and energy security.

At the 2nd East Asia Summit (EAS) held in January 2007 at Cebu, the Philippines, the delegates (10 ASEAN members as well as China, Japan, New Zealand, India, South Korea and Australia) signed the “Cebu Declaration on East Asian Energy Security” (ASEAN, 2007), which outlined the potential energy challenges the region could face in the future driven by a number of factors including: the limited global reserves of fossil energy; fluctuating world fuel oil prices; worsening energy related environmental and health issues; and the urgent need to address climate change. To deal with these issues, the EAS leaders agreed to create a working group on energy cooperation, namely the Energy Cooperation Task Force (ECTF), to follow up on the outcomes of the 2nd EAS. Three work streams are established under the EAS ECTF: Energy Efficiency and Conservation (chaired by Japan); Energy Market Integration (co-chaired by Singapore and Australia); and Bio-fuels for Transport and Other Purposes (co-chaired by the Philippines and India).

To support the work of the ECTF, the Japanese government contributed to the Economic Research Institute for ASEAN and East Asia (ERIA) towards energy related research for a few years. For the bio-fuels work stream, ERIA has been running two projects since 2007; an expert Working Group (WG), which has been formed under the support of ERIA to deal with one of the projects, has been conducting research to assess the sustainability of biomass utilisation. The progress of this WG in the previous years can be briefly summarised as follows:

- 2007-2008: Through the reviews of the triple bottom line methods and case studies in East Asian countries, the WG extracted issues to be concerned for sustainability assessment on biomass utilisation and compiled a WG report entitled “Sustainable Biomass Utilisation Vision in East Asia” (Sagisaka, 2008) that played an important role for scientific backup for adoption of “Asia Biomass Energy Principles” endorsed in the “Second Meeting of EAS Energy Ministers of East Asia Summit” in 2008 (ASEAN, 2008).
- 2008-2009: From the discussions on methodology and indices, the WG developed a methodology to evaluate sustainability of biomass utilisation for energy production from environmental, economic and social pillars. The WG prepared a report entitled “Guidelines to Assess Sustainability of Biomass Utilisation in East Asia” (Sagisaka, 2009) in which the methodology developed and data required for sustainability assessment of biomass utilisation were addressed.
- 2009-2010: In order to investigate the differences of biomass utilisation in the EAS region and to field-test the methodology developed, the WG conducted pilot studies in four selected countries (India, Indonesia, Thailand and the Philippines). The evaluation results of sustainability of biomass energy projects utilising various feedstocks were summarised in the WG report “Sustainability Assessment of Biomass Energy Utilisation in Selected East Asian Countries” (ERIA, 2010).

The WG recognises that the advantages of the WG’s milestone project towards other ongoing or existing biomass sustainability initiatives can be addressed as follows: (1) Although the major initiatives of biomass sustainability are mainly led by developed countries, the WG is aiming at developing a sustainability evaluation method for biomass that is suitable for the EAS region where socio-economic situations are quite diverse and biomass resources are abundant. (2) Not only has the WG developed through the discussions a methodology to assess sustainability of biomass utilisation in EAS region but also field-tested the methodology through pilot studies in 2009-2010, which only a few initiatives have experienced.

In the previous report (ERIA, 2010), the WG suggested that the "Guidelines to Assess Sustainability of Biomass Utilisation in East Asia" (Sagisaka, 2009) were robust enough for studies at community, regional and national levels and they might be applied to each country in the East Asian region with minor location-specific modifications. Accordingly in the fourth phase of the WG in 2010-2011, the WG activity aimed at upgrading the WG methodology to assess biomass sustainability in the East Asian context by reflecting on experiences and lessons learned from the four pilot studies conducted in 2009-2010.

Chapter 2 outlines the WG methodology to assess sustainability of biomass utilisation and provides a brief summary of the four pilot studies carried out in selected East Asian countries during 2009-2010. This is followed by the lessons learned from the four pilot studies in Chapter 3. The WG discussions to adjust the methodology to assess sustainability of biomass utilisation as energy both at macro (national/state/province) and micro (community/project) levels and presentation of results for each pillar of sustainability are summarised in Chapters 4 and 5. Conclusions and recommendations derived from this report are summarised in Chapter 6.

2. WG METHODOLOGY AND SUMMARIES OF PILOT STUDIES IN SELECTED EAST ASIAN COUNTRIES

2.1. WG Concept

The WG adopted the definition of “sustainable development” from “Our Common Future” of the United Nations World Commission on Environment and Development report published in 1987 (WCED, 1987), i.e., “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

The triple bottom line approach, focusing upon “people, planet, profit”, is based upon social, environmental and economic criteria. To ascertain the sustainability of biomass energy development, these aspects are necessary and must be considered to overcome and minimise the problems that may occur with the expansion of biomass energy utilisation. In view of these, the WG has developed a methodology to assess sustainability of biomass utilisation in the East Asian context considering environmental, economic and social pillars.

2.2. WG Methodology to Assess Sustainability of Biomass Utilisation

The WG methodology to assess sustainability of biomass utilisation is briefly described in this section. For the details of the WG methodology, please refer to (Sagisaka, 2009).

2.2.1. Environmental Indicator

Life cycle assessment (LCA) is increasingly being promoted as a technique for analysing and assessing the environmental performance of a product system and is suited for environmental management and long-term sustainable development. Although LCA can be used to quantitatively assess the extent of impact of a product system towards environmental issues of concern such as acidification, eutrophication, photo-oxidation, toxicity and biodiversity loss, these impact categories are currently not as much in the limelight as climate change, a phenomenon that is associated with the increasing frequency of extreme weather conditions and disasters. Effects of climate change have been attributed directly to the increased atmospheric concentration of GHG released by anthropogenic activities. Taking other standards or frameworks for biomass energy sustainability into consideration, the WG adopted life cycle GHG emissions that can be quantified through life cycle inventory (LCI) analysis using the collected foreground and background data as the indicator to evaluate the environmental sustainability of biomass energy utilisation.

The system boundary for LCI is comprised of three stages: feedstock cultivation, feedstock collection and biomass energy production. There is a wide recognition that the effect of land use and land use change (LULUC) towards the life cycle GHG emissions could be significant. Although their effect can be calculated using equations and default values proposed by the International Panel on Climate Change (IPCC, 1997), the WG recognises that there is still limited consensus on various aspects of methodology and conversion factors used in the calculations. Studies are still on-going and expected to provide more scientific evidence of the appropriate values that can be adopted to calculate the GHG emissions associated with LUC in future.

Hence the emissions from LUC are excluded from the system boundary of the present WG's methodology. However, future considerations for relevant environmental impacts, especially on losses of carbon stock from land use change (LUC), will be included to complete the sustainability assessment of biomass cultivation and utilisation. Therefore in this report, the concept of GHG emission by LUC and its calculation methods are described in 4.1.2.

The LCI for biomass energy should cover CO_2 and non-CO_2 GHGs, namely CH_4 and N_2O that are released directly and indirectly from agricultural activities. The GHG inventory is calculated as CO_2 equivalent (CO_2eq) and the summation of contribution from non-CO_2 GHGs are based upon the IPCC Fourth Assessment Report (AR4) Global Warming Potential (GWP) values for a 100 year horizon (IPCC, 2007).

2.2.2. Economic Indicator

Economic sustainability of biomass utilisation relates to the exploitation of biomass resources in a manner by which the benefits derived by the present generation are obtained without depriving such opportunity to the future generations. In the assessment of sustainability, it is equally important to determine the actual level and degree of the economic benefits brought about by the biomass industry. Specific economic indices would have taken into consideration to measure the scope of the benefits. Existing methodologies in quantifying such indicators would have to be adopted and evaluated as well. Economic indicators ultimately provide an accurate measurement of the economic performance of a particular industry such as biomass. Based upon the various literature reviewed, the most common economic contributions of biomass utilisation are value addition, job creation, tax revenue generation and foreign trade impacts. The same indicators were taken into consideration to evaluate economic sustainability of biomass energy utilisation in WG's methodology: 1) total net profit accumulated from product conversion or processing; 2) personnel remuneration created by employment at the biomass industry; 3) tax revenues generated from the different entities within the industries; 4) foreign trade impacts in terms of foreign exchange earnings and savings; and 5) total value added, which is the sum of all the previous indicators. Each indicator can be calculated by the following equations:

$$\text{Total net profit (TNP)} = \text{Total returns} - \text{Total costs} \tag{2-1}$$

where

$$\text{Total returns} = \text{Sales from primary output} + \text{Sales from by-products} \tag{2-2}$$

$$\begin{aligned}&\text{Total costs}\\&\quad = \text{Amount of material inputs used} + \text{Labour costs} + \text{Overhead costs}\end{aligned} \tag{2-3}$$

$$\text{Overhead costs} = \text{Taxes and duties} + \text{Interest} + \text{Depreciation} \tag{2-4}$$

$$\begin{aligned}&\text{Personnel remuneration}\\&\quad = \text{Total man-days (Employment)} \times \text{Average wage per man-days}\end{aligned} \tag{2-5}$$

where

Wages = Wage rate × Labour requirement (2-6)

Tax revenue = Total taxable income × Tax rate (2-7)

where

Total taxable income

= Income from main product + Income from by-product (2-8)

Income from main product

= Profit per unit of main product A × Volume of A (2-9)

Income from by-product

= Profit per unit of by-product B × Volume of B (2-10)

Net foreign exchange earnings

= Reduced foreign exchange earnings from product exports

+ Foreign exchange savings from reduced imports (2-11)

where

Foreign exchange earnings

= Price per unit of convertible material × Total volume of exports (2-12)

Foreign exchange savings

= Amount of biomass

× Foreign exchange savings per unit fossil fuel replaced (2-13)

Total value added (TVA)

= Total net profit + Personnel remuneration

+ Tax revenue + Net foreign exchange earnings (2-14)

2.2.3. Social Indicator

Social issues in the growing markets for biomass energy are expected to become prominent as the producers and consumers of biomass energy may belong to different countries. Major social benefits of biomass energy include greater energy security, employment opportunities and improved health from reduced air pollution. On the other hand, possible negative social impacts of biomass energy, such as food insecurity, need to be considered seriously. While there could be some relief on the energy front, the food insecurity and food prices, particularly in developing economies, may aggravate the negative social impact on people.

Measurement of social development differs significantly from economic development. Also, compared to indicators of social development, indicators of economic development are available for most of the countries. However, in many cases, particularly in developing economies, economic indicators often reflect a rosy picture that is far away from the reality. To capture the holistic picture of development across countries, the United Nations Development Programme (UNDP) 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 HDI as the indicator to evaluate social sustainability of biomass energy utilisation. The calculation of HDI can be described as equation (2-15) and Table 2-1. Although the calculation of HDI has changed in the UNDP report published in 2010 (UNDP, 2010), please note here that the WG's calculation is based upon the previous report (UNDP, 2008).

$$\text{HDI} = 1/3 \times (\text{Life expectancy index} + \text{Education index} + \text{GDP index}) \qquad (2\text{-}15)$$

Table 2-1. Calculation of HDI

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

In addition to HDI, some other social development indicators (SDIs) such as Gender-related Development Index (GDI) are also calculated to assess the condition of women in terms of social development as a result of biomass resources utilisation for energy. Please refer to (ERIA, 2010) for the details.

2.3. Target Users of the Methodology and Results

As our WG methodology intends to be used in EAS countries to assess sustainability of biomass utilisation for energy in accordance with the guideline, the situations where the methodology is expected to be used are as follows:

Case 1: Sustainability assessment of a biomass utilisation project being planned.

Case 2: Comparative analysis of sustainability of several options of a biomass project being planned

Case 3: Sustainability assessment of an ongoing biomass utilisation project

Case 4: Comparative analysis of several options to improve sustainability of an ongoing biomass project

The WG methodology aims at both ex ante and ex post evaluation of sustainability utilisation of biomass for energy. In the above cases, users of the results obtained through the WG methodology are the decision makers who have the right to make decisions on whether or not the biomass utilisation initiatives are introduced/carried on, including politicians in charge of biomass project policy and stakeholders such as owners of farms or plantation fields, factory managers, etc.

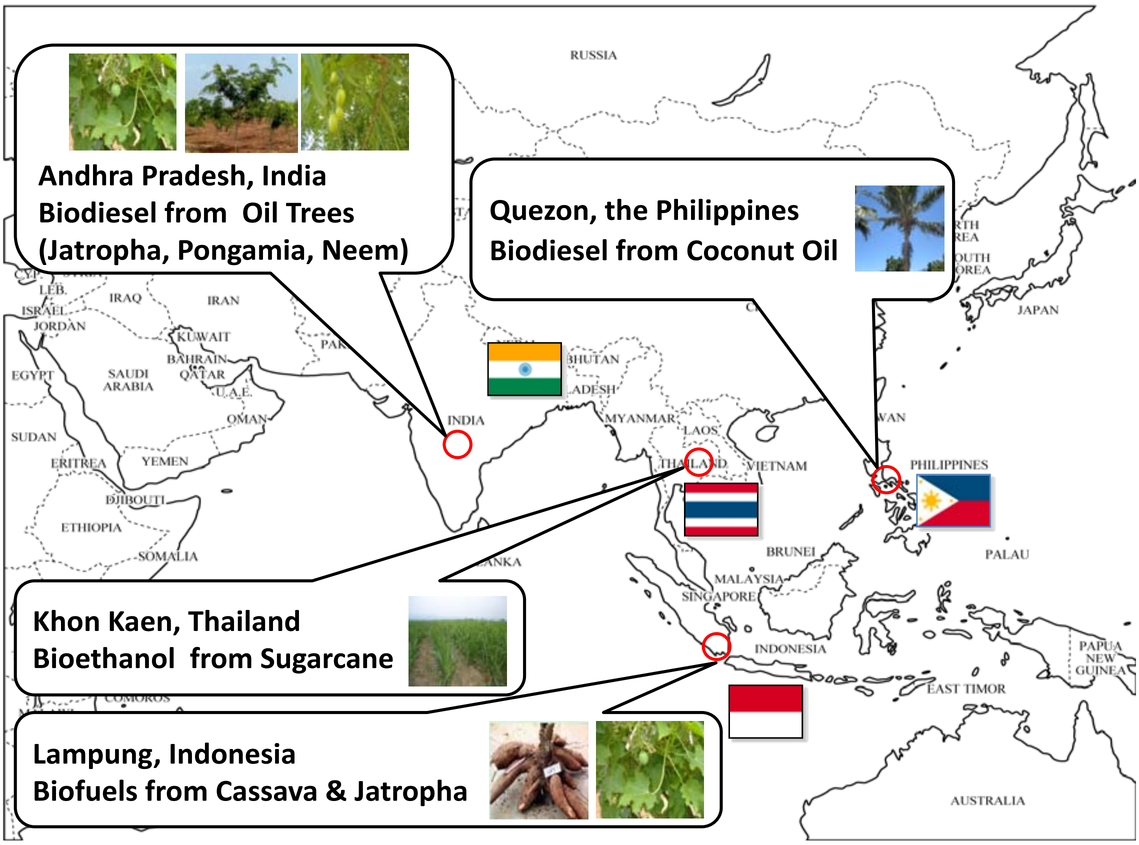
On the other hand, direct users of the methodology, who will be asked by decision makers to assess the sustainability of biomass initiatives and to report the results of the assessment, would be: academics; consultants; and technical officers.

2.4. Brief Summary of Pilot Studies in Selected East Asian Countries

Four pilot studies have been implemented by designated organisations under the ERIA's framework to apply and field-test the assessment methodology developed by the WG. One case study was implemented in each selected East Asian country, namely, India (Andhra Pradesh), Indonesia (Lampung), the Philippines (Quezon) and Thailand (Khon Kaen), as shown in Figure 2-1.

In each pilot study, more than hundred sets of data were obtained through interviews, calculations based upon primary data collected from pilot study sites, and secondary data from elsewhere to calculate the environmental, economic and social indicators of sustainability of biomass energy utilisation according to the WG methodology. The brief summaries of each pilot study are addressed in this section. Please refer to the WG report (ERIA, 2010) for the details.

Figure 2-1. Location of Four Pilot Studies with Different Feedstocks for Biomass Energy



2.4.1. Pilot Study in Andhra Pradesh, India

In case of India, economic assessment indicates that cost incurred during the Jatropha cultivation stage is much higher than the revenue generated, which is not economically viable. At the biodiesel production stage, both total value added (TVA) and total net profit (TNP) are quite attractive, provided the raw material is available at a reasonable price. During the lifecycle of biodiesel production process, a TVA of 80,331 INR or 1,674 USD and a net profit of 39,531 INR or 824 USD per hectare per year were estimated. On the environmental front, companies expect some carbon saving and an additional revenue from carbon credits. GHG saving potential estimated during the process shows a net carbon saving of 2,771,681 t-CO_2eq per year. On the social front, several positive results are visible during various stages of biodiesel production, the main being employment generation for local people increasing their income, which may result in an overall improvement in their living standard.

2.4.2. Pilot Study in Lampung, Indonesia

Biomass energy program in Indonesia was carefully designed but was not running as smoothly as planned originally. It was observed that the cassava utilisation for ethanol in Lampung Province is facing a competition for raw material from tapioca factories. Environmental assessment shows that during bioethanol production GHG emissions depend upon whether the biogas from wastewater treatment is flared or not. Economic assessment indicates that processing cassava for bioethanol increased the value added of cassava by about 950-1,108 IDR or 0.103-0.120 USD per litre of bioethanol or about 146.6-171 IDR or 0.0159-0.0186 USD per kg of cassava. For social assessment, the HDI values for cassava farmers in the study region were estimated to be lower than the HDI values for North Lampung, in general. In case of Jatropha biodiesel, although farmers in the target village receive a very low benefit from cultivation stage, utilisation of Jatropha waste increased their earnings significantly. Environmental assessment indicates that GHG emissions from Jatropha plantation and crude Jatropha oil processing were 59% and 82% of total emissions, respectively. Waste utilisation for biogas production was able to reduce GHG emissions by 41% of total emissions. HDI estimates for Jatropha farmers in North Lampung indicate that quality of life, education, and income for the people in the village were quite low.

2.4.3. Pilot Study in Quezon, the Philippines

Economic analysis of the Philippines study shows that considering the production costs and revenues for each product, the net profit per unit of product is highest for copra production (at 6.76 PHP or 0.150 USD per kg) and lowest for coconut methyl ester (CME, biodiesel from coconuts) production (at 0.122 PHP or 0.0027 USD per litre). The cumulative total profit for all product forms is about 38,000 PHP or 844 USD per ha and the TVA from the biodiesel industry in the province of Quezon would be 13.74 billion PHP or 305 million USD. The use of coconut methyl ester to replace petro diesel will result in net savings or GHG emission reduction of 2,823.97 kg-CO_2eq per ha per year. In terms of social indices, the computed HDI is 0.784 while the change in HDI is 0.004 indicating a higher level of social development. In terms of living standard, the majority (66%) of coconut farmers perceived that there has been an improvement in their living conditions due to coconut farming. In general, the results show that majority of the employees benefited from their respective employment in the biodiesel production chain.

2.4.4. Pilot Study in Khon Kaen, Thailand

In the Thailand study, environmental assessment for the lifecycle of ethanol production indicates that the overall GHG emissions associated with the ethanol production and consumption stages are slightly lower but not significantly different from that of gasoline. Increasing the utilisation of the materials produced during various unit processes in the biorefinery complex results in reducing the GHG emissions. Economic assessment of the overall process of bioethanol production indicates that the TVA for the whole biorefinery complex amounts to 3,715,458,551 THB or 116,108,080 USD and it is economically viable. For social assessment, the HDI of the sugarcane plantation, biorefinery complex, and Khon Kaen were observed as 0.736, 0.797 and 0.763, respectively. Thus, although sugarcane farmers have a lower social development than an average person in Khon Kaen or employee at the biorefinery complex, they still benefit from a steady income as a result of the contract farming, which links them to the sugar mill and guarantees an annual income. Employees at the biorefinery have a higher social development (shown by a positive change of 0.034 in HDI) as compared to the Khon Kaen.

3. LESSONS LEARNED FROM THE PILOT STUDIES

As summarised in the previous chapter, the field-testing of the WG methodology in selected East Asian countries (Sagisaka, 2009) revealed that the methodology could successfully quantify the sustainability of biomass utilisation projects. However, through the experience from the field-testing, the WG recognises that some minor location-specific modifications may be required, while applying the methodology to biomass utilisation projects in other East Asian countries. The WG members also feel that sharing their lessons learned from the pilot studies contributes not only to sustainability assessment of biomass energy utilisation in the East Asian region but also to other biomass sustainability frameworks developed elsewhere in the world.

The lessons learned from the pilot studies in East Asia together with the directions for minor modifications of the WG methodology are addressed in this chapter.

3.1. Lessons Learned from Each Pilot Study

3.1.1. From Andhra Pradesh, India

Some of the issues emerged and lessons learned from the results of the pilot study in Andhra Pradesh, India, are described as follows.

On a small scale, such as village or community level, some good examples of biodiesel production using tree oil are successful. However, major biodiesel producers in the state are not able to procure enough feedstock, i.e. tree borne oils or seeds for biodiesel production. They are surviving on biodiesel production using various other feedstocks such as palm stearin, animal tallow, waste oils, etc. This defeats the basic purpose of the biodiesel producers as well as government policies, which are focused on biodiesel production using tree borne oils. Jatropha curcas was initially considered a miracle plant in India that would grow on any type of soil without irrigation, fertiliser, or any other care. But the pilot study results indicate that Jatropha and other plants, such as Pongamia, need some care for their survival, particularly in the first few years after planting. Also, for a good and sustainable yield, regular irrigation and fertiliser application throughout the life span of plantation is essential. Although the Government of India policies seem to encourage production of biodiesel in the country, the ground realities are different. The targets of biodiesel production (a blending target of 20%), which were earlier set to be achieved by 2011-2012, are now being revised to 2016-2017 as per the National Policy on Biofuels of December 2009 (MNRE, 2010). Based on observations from the field survey, however, achieving the new targets too seems doubtful.

Only a limited success is demonstrated on economic, environmental and social aspects of the biodiesel production chain. Economic analysis indicates that cost incurred during the cultivation stage is much higher than the revenue generated as oil tree growing companies are making a financial loss during this stage. However, economic benefits in terms of total value added (TVA) by the biodiesel producers and foreign exchange savings for the country could be substantial, which confirms that promotion of biodiesel production would result in net economic benefits.

On the environmental front, although data are not sufficient, preliminary estimates from available data indicate a net reduction in greenhouse gas (GHG) emissions during the life cycle of the biodiesel production. Other environmental changes such as impact on local air pollution, water demand, land use change (LUC), etc., may be significant but none of the stakeholders on the sites surveyed collected data to calculate such impacts.

Probably the best performance in all stages of biodiesel chain is shown on the social front. Both during oil tree cultivation and biodiesel production phases, good employment is generated in the surrounding localities. The wages of those employed in the biodiesel production chain are about 50-60% higher than their wages in employment elsewhere. Due to increase in wages, employees are able to spend more on their food, health, education and living standards. Estimation of various social development indicators (SDIs) shows an overall improvement at village or community level. As there is a visible increase in employment and income of individuals employed in oil tree plantations as well as other stages of biodiesel production, promoting these activities would certainly have a positive effect on social development of local people and communities.

For the success of biodiesel programmes, it is necessary to encourage farmers to undertake plantations of Jatropha and other oil trees. This is only possible by ensuring financial gains to them resulting from cultivation of biodiesel crops. Special focus is needed to sustain cultivators during crop gestation period (i.e. no yield period from planting to harvesting). The study supports the idea of initiating ancillary activities such as poultry farming, intercrops, rearing milk producing animals, etc., which were found successful in the field. In addition, introduction of mass awareness and capacity building programs in rural areas, financial and technical supports such as interest free loans or soft loans, easy availability of quality seeds and other inputs, crop insurance, etc., would attract farmers towards biodiesel crops. Among various hurdles, the price of raw material (oil seeds) and final product (biodiesel) was found to be the biggest limitation for promoting tree oil based biodiesel production. It is necessary that price of both oil seeds and biodiesel are kept at such a level that could sustain the biodiesel industry. The pilot study recommended that tree oil seed price should be around 10-15 INR per kg (as against 7-8 INR per kg at present) and biodiesel purchase price should be above 35 INR per litre (as against the governments' present purchase price of 26.5 INR per litre).

The pilot study focused on a very small scale (village or community level) and the story at macro level (state or country level) may be altogether different. Thus, projection and application of the results of this micro level study at macro level would be inappropriate. Instead, it is suggested that more rigorous field work on a larger area, representing a state or the country, as the case may be, should be undertaken for a macro scale assessment. A representative sample size could be coverage of at least 10-15% of total plantation area and about 25% of biodiesel production capacity in the state or country including both small and large scale biodiesel production units.

3.1.2. From Lampung, Indonesia

3.1.2.1. Cassava for Ethanol Production

There are some issues related to production of ethanol fuel that cannot be answered merely by the sum of net profit from the main product and by-products. For example, there will be problems related to productivity of feedstock, efficiency of technology, and production capacity. There may be a question whether ethanol production is energetically favourable or not. Hence, in order to answer these and other issues, it is preferable that other economic parameters like productivity, net energy balance, change in the consumption of fossil fuels and traditional use of biomass, energy diversity, and government policy are included. Enforcement from government is really needed to utilise bioethanol as a biofuel in Indonesia.

The three factors included in the HDI calculation are life expectancy index, education index, and GDP index. The first two indices are nearly constant for a short period. The GDP index, however, is strongly determined by revenue of the farmers which is affected by fluctuation of the cassava price. Therefore, the higher the price of cassava, the better the HDI will be. However, it will be very difficult to significantly increase HDI by changing of cassava price because of logarithmic factor. Therefore, it is required to include other parameters to answer social issues related to ethanol fuel production. For example, because cassava is also used for food and feed, demand of cassava for ethanol production will affect the price and supply of food or feed. Increasing raw material will increase income and affect the allocation and rent of land for cassava production. Therefore, other social parameters like job creation, change in income, access to modern energy, price and supply of food or feed, land allocation and land tenure for bioenergy, should be considered.

3.1.2.2. Jatropha for Crude Jatropha Oil

Using Jatropha wastes such as Jatropha cake to produce biogas and Jatropha peel, wet cake, and sludge for compost will give additional benefit. For this reason, waste management is likely also important to be considered as environmental indicator. However, it is necessary to include other parameters to answer environmental-related issues. The parameters that is likely important to be considered involve soil quality, water quality, water use and efficiency, LUC related to bioenergy feedstock production, and biological diversity in the landscape. It is also imperative to consider other indicators like the change in consumption of fossil fuels and traditional use of biomass as well as energy diversity. Electricity generation using Jatropha biodiesel and biogas production from Jatropha cake will enrich energy diversity available to the people. These energy sources will eventually affect their use of fossil fuels (especially, kerosene and liquefied petroleum gas) and the use of wood energy. When the study group visited the community, it was revealed that electricity is the primary need for the people. They expected to ultimately get electricity by growing and processing Jatropha. Moreover, a unit of generator set has already been equipped in the processing unit. For this reason, ease for the people to access modern energy is an important parameter from social point of view. Global Bioenergy Partnership (GBEP) also listed this as one of the social parameters (GBEP, 2011) in relation to renewable energy development. In fact, electricity is one of the most wanted energy sources by the people.

Even though still lower than HDI of North Lampung district, the Jatropha production and processing activities helped increase HDI. This indicated that Jatropha production and biofuel production from Jatropha and their waste utilisation has positive impact to HDI. However, the people do not directly feel the real benefit of the HDI. It is, therefore, important to include other social parameters to assess sustainability of biomass utilisation.

3.1.3. From Quezon, the Philippines

3.1.3.1. Economics Aspects

The economic indicators that were taken into consideration for calculating the economic impact of the energy project are the following: 1) total net profit (TNP) accumulated from product conversion or processing; 2) wages from employment created out of the biomass industry; 3) tax revenues generated from the different entities within the industries; and 4) foreign trade impacts in terms of foreign exchange earnings and savings. The total value added (TVA) for the industry included the summation of all the value added in each enterprise, which includes personnel remuneration, taxes and duties earned by the government from the enterprises, and the entrepreneur’s net profit. On the other hand, East Asian country members will mostly likely be interested in the net foreign exchange earnings from exported products aside from the reduced importation of fossil fuel products. The other most important reason for the shift to biofuels is the concern on environment.

TVA is merely a measure of economic benefits derived from individual activity conducted, may it be in the production or processing of agricultural products. This shows the additional net profit, additional wages as a result of added employment and added tax revenue paid to the government by both the owners and labourers for the production or further processing of the agricultural products (Tallec and Bockel, 2005). If this activity is not performed, then no further economic benefits will be realized.

TVA alone gives not much meaning to the sustainability of biomass production or processing but knowing the components of the total value added will serve as indicators for the policy makers, private investors, employees/labourers and other players in the biofuel industry to continue or proceed with the program, business or any activity depending on whether it is worth continuing from the economics point of view.

An attractive net profit means good business and so the private investors will then be encouraged to continue the activity while minimal net profit or worse still, negative net profit will discourage them to continue. Substantial wages received from the management will encourage the labourers to work well resulting in better business for the employer. On the other hand, the government will be happy to support the investors due to taxes generated from the business. In the process, the business becomes sustainable. The TVA including its subcomponents namely TNP, wages from employment, and tax revenues generated from the different entities within the industries are appropriate measures to be used as indicators of biomass sustainability.

The other benefit for the economy on a national level includes the net foreign exchange earnings from exported products. Positive net foreign exchange earnings (meaning that the savings for non-importation of fossil fuel for using biodiesel and foregone revenue for non exportation of raw materials such as copra or coconut oil, the raw material for biodiesel production in the Philippine’s case) are good for the economy of the country (Elauria, 2008). Other than this, it will increase the level of energy security of one’s country.

3.1.3.2. Social Aspects

The Human Development Index (HDI) may provide a comprehensive assessment of the social impact of biofuels programmes but it is applicable at macro level, such as national or state/province level. At micro level, such as village or community level, it gives a very vague picture of the real social impact of the biofuels programmes. However, its three subcomponents, viz., life expectancy index, education index and GDP index, provide more meaningful assessment of the social impact of the biofuel business at community or project level. Thus, while HDI may be appropriate to show the change in the social status of each country or each state/province within a country, its three subcomponents are much more appropriate or applicable to the community level. Also, since the three subcomponents of HDI can stand alone, it is not necessary that all the impacts as measured by each subcomponent are positive.

HDI as a social indicator seems to be applicable only at the national level. Even if this social indicator takes into account the measures for life expectancy, education and GDP, these data are only available at the national level or at least in the regional level therefore HDI as measure of social development is more appropriate at the national or regional level. Another social indicator appropriate for the national level is the effect on energy security as a result of the biofuels program of the government. This is a big relief particularly to the transportation sector being heavily dependent on imported fossil fuels.

On the other hand, conflict with food security as a result of using the raw material which may be intended for food may give negative social implication and hence must also be considered.

As for the project or community levels, better and direct measures of social impact are suggested. In case of the biodiesel production from coconut in the Philippines, social impact to the community can be better measured in terms of increased income of the employee, better education for the children, improved health condition and probably improved relationship in the plant or community among others. In the case where the project or community is in a far flung area, the easier access to energy particularly clean energy may also be included.

3.1.3.3. Environmental Aspects

Life Cycle Assessment (LCA) was used in the evaluation of environmental indices. The system boundary was from the cultivation of coconut to the consumption of biodiesel including the sale of the major by-products. The emission investigated is GHGs from the four stages of biodiesel (coconut methyl ester, CME) production (plantation, copra production, oil production and CME production).

Life cycle GHG emissions expressed in terms of CO_2eq as suggested in the WG guidelines (Sagisaka, 2009) have been used. Evaluation of GHG using LCA seems to be the most appropriate approach in assessing the impact of the production of biofuels to the environment since GHG emissions have been directly attributed to the increased atmospheric concentration of GHGs which may consequently lead to change in climate.

3.1.4. From Khon Kaen, Thailand

3.1.4.1. Environmental Assessment

Life cycle assessment is a well-established, standard technique for quantifying GHG emissions. This is useful for calculating possible reductions in GHG emissions from any project as compared to a baseline. However, the issue related to allocation of emissions to co-products remains open to differences in methodological choices which can sometimes significantly affect the results. Narrowing the options for allocation may be a possible way to make the results comparable. Although GHG emissions have been evaluated in this pilot study following the guidelines produced by the WG (Sagisaka, 2009), it is however an option to also include other aspects (mid-point indicators) that might be of relevance depending on the case study assessed. In the context of this particular pilot study other environmental aspects including abiotic resources depletion (including water), eutrophication, acidification, and land use could also be included for the environmental assessment part.

3.1.4.2. Socio-Economic Assessment

Social development as characterized by HDI in this pilot study is mainly affected by the GDP index or in other words by income. However, since HDI only considers aspects of life expectancy, education and income, some other parameters for assessing social development study such as employment opportunity (for employees at the biorefinery complex) and safety of income (for farmers) are not captured by this indicator. Such aspects are important for assessing social development at a community scale. HDI by incorporating aspects of life expectancy, education and GDP indices is suitable for national scale assessment of social development and ranking purposes. However, as seen in this pilot study, it is more difficult to adapt and provides limited information at local scale to evaluate social development/benefits that may have arisen from a particular project.

For future assessments it is imperative that the aspect associated to the nature and scale of the activities assessed be carefully considered to not distort interpretation of results. Also, social and economic assessment results are to be performed in an integrated way. As observed in this pilot study, the results of social and economic assessments are interlinked since social development is influenced by the involvement of people in activities contributing to economic output and generating income. It is imperative that those aspects be recognized to not bias the sustainability results obtained from the social and economic (socio-economic) assessments of an activity.

3.2. Summary of the Lessons Learned

The lessons learned, which are worthy of noting or common to the four pilot studies for each pillar of sustainability, are summarised in this section.

3.2.1. Environmental Pillar

From the lessons learned from the four pilot studies, the WG supports that LCA is a well-established, standard technique for quantifying GHG emissions, which is one of the important role of utilising biomass energy to improve the environment.

However in the current WG methodology to evaluate GHG emissions from life cycle point of view, emissions from land use change (LUC) are not included. At present there exist very few LUC (example, IPCC) models, which poses a big challenge for countries in East Asia to obtain information/data and calculate losses of carbon stock from (any particular cases of) land clearance. However, a comprehensive comparison of data from literature indicates that GHG emissions from LUC (from land with high carbon stocks), if it occurs, can be a significant deciding factor in determining the sustainability of biomass utilisation. Therefore future considerations for such relevant environmental impacts pertaining to any losses of carbon stock from LUC, is essential to complete the sustainability assessment of biomass cultivation and utilisation.

The WG also recognises that the environmental impact caused by biomass energy utilisation is not only climate change induced by GHG emissions. The other environmental impact categories that should be included are;

- impacts on air, water and soil quality
- water use / efficiency of water use
- biodiversity
- issues associated with LUC
- net energy balance
- abiotic resources depletion
- eutrophication
- acidification

3.2.2. Economic Pillar

The economic indicators in most of the pilot studies showed positive results and it indicates that the biomass utilisation projects studied were economically sustainable. However, in order to analyse economic sustainability better, it may be necessary to understand what those economic results mean.

The three subcomponents of the total value added (TVA) are appropriate economic indicators for the business and community level. Total net profit (TNP) is more of business concern; wages derived from employment is for the labourers; while tax revenue generated is for the local and national government. A high TNP alone will not ensure the sustainability of the production nor the high wage of the employees/labourers and also of the high tax paid to the government. The sustainability of biomass utilisation like in biofuel production is anchored on the attractiveness of the business from all the three economic sub-indicators namely TNP, wages and tax generation. The positive impact of these three sub-indicators must be present.

However, the net foreign exchange earnings is only applicable or appropriate on the national level.

3.2.3. Social Pillar

As mentioned in the preceding section, there were difficulties in getting data for HDI calculation at community level. Moreover, the Indonesian pilot study on Jatropha reported a small increase in HDI. Since HDI is calculated by incorporating aspects of life expectancy, education and GDP indices, it seems more suitable for national scale assessment of social development and ranking purposes. To assess social aspect at community level, some studies suggest including more directly measurable parameters such as;

- employment opportunity (for employees at the biorefinery complex)
- safety of income (for farmers)
- income increase
- better education for the children
- improved health condition
- probably improved relationship in the plant or community among others
- energy diversity
- easier access to modern / clean energy / electricity
- employment
- food security (price of food / feed)
- land allocation and tenure
- policy enforcement
- change in the consumption of fossil fuels / traditional use of biomass

On the other hand, some other parameters that should be seen in national level are;

- energy security
- food security

3.3. Other Issues of Concern

To assess sustainability of biomass utilisation for energy, the data required to evaluate each indicator are to be collected based upon the prepared questionnaires as provided in the WG guidelines (Sagisaka, 2009). Through the lessons learned from the pilot studies, however, the WG recognises the limitations of the current methodology. The other issues of concern are summarised in this section.

3.3.1. Data Availability

It was observed in many cases that data to calculate the indicators are unavailable or difficult to collect; Data needed to calculate life cycle GHG emissions such as fuel consumption per trip, number of trips made per year, electricity consumed for the year among others was not easy to collect; Questions on economics particularly cost and revenue data are difficult to collect, for the plant owners/managers/supervisors are quite hesitant in giving pieces of information that may reveal economics or financial aspects of the operation of the plant; Data to calculate HDI such as literacy rate, life expectancy and GDP indices are not available at the community level. Since there are data that can only be collected from the plant records or the target communities to calculate the indicator for each pillar of sustainability, access to these data should be checked in advance.

3.3.2. Data Reliability

From experience, it is not enough to rely on the data given by the respondents particularly technical data such as fuel consumption, efficiency and others. It is important that these technical data collected from the plant and verified from literature.

In the case of coconut shell as fuel used in copra drying in the Philippines case, the respondents gave a very rough estimate of the amount of fuel used per batch of fresh coconut meat to be dried. When the researchers calculated the amount of coconut shell needed to dry a batch of 3,000 nuts of fresh coconut meat, the amount of coconut shell given by the respondents was very far from the calculated value. It means that the respondents gave a very vague estimate. This will not just affect the cost and return in copra processing but also the GHG emission from the burning of coconut shell.

Reliability of data obtained from the questionnaires depends on the manner the questionnaire is prepared and how the questionnaire would be used. Mere distribution and collection of the questionnaire would most likely result in incomplete and inaccurate information. Most company data from the day to day operation of the plant like fuel consumption, distance travelled of vehicle used in the plant, electricity and fuel consumption among others are most of the times not readily available and the one in charge gives estimates which are doubtful. Inaccurate information such as these will affect the calculation of the indicators.

3.3.3. Appropriateness of the Use of Questionnaire

It is important to formulate a single questionnaire for the respondents that will capture the data needed for the calculation of the economic, social and environmental indices of the project/plant. There must be separate types of questionnaires for the producers and processors of biofuels. The respective questionnaires will then be tailored to fit the target respondents so that specific information can then be collected from them. If possible, the person distributing the questionnaire should be properly trained in explaining the intention of the survey to the respondents. The interviewer can then formulate follow up questions on the spot to capture the right information.

3.4. Upgrading the WG Methodology

As described in this chapter, comprehensive lessons were learned from the pilot studies. Those were carefully discussed by the WG in order to improve and upgrade the methodology for the wider range of its application. Based on the discussion, the methodology application for biomass utilisation project at different (small and large) scales will be addressed in the next chapter.

4. INDICATORS APPLICABLE AT DIFFERENT SCALES

4.1. Environmental Pillar

4.1.1. Life Cycle GHG Emissions as an Environmental Indicator

Based upon the lessons learned from the four pilot studies that were carried out in India, Indonesia, the Philippines and Thailand, the following issues are identified for the environmental pillar:

a) The applicability of GHG emissions as an indicator to draw inference on the environmental sustainability of biomass utilisation;

b) The data requirements to ensure representativeness of the GHG emission profile as an indicator for environmental sustainability assessment of biomass utilisation;

c) The appropriate methodology and approach to model GHG emissions in the absence primary data;

d) The viability of applying GHG emission to assess biomass utilisation at the micro and macro level.

4.1.1.1. Applicability of GHG Emission as an Indicator to Assess Sustainability of Biomass Utilisation

The applicability or suitability of using GHG emission as an objective indicator for sustainability assessment of biomass was evaluated for the four pilot studies. The results from these studies are summarised in Table 4-1.

Table 4-1. Comparison of Final Reporting of GHG Emission of Product

Country	**Final form of GHG Results Reporting**	**Unit**	**Life Cycle Stages**
India	GHG emissions emitted for cultivation and production of biodiesel from Jatropha	t-CO_2/yr	Cradle to grave for pure product
	GHG emissions emitted per hectare	t-CO_2/yr	
	GHG savings during consumption	t-CO_2/yr	
Indonesia	CO_{2eq} emission during ethanol/Crude Jatropha Oil production process	kg/litre and kg/GJ-ethanol or crude Jatropha oil	Cradle to gate for pure product
Philippines	Life Cycle GHG emission during Coconut Methyl Ester production	kg-CO_2eq/ha/year	Cradle to grave for pure product
	Net GHG savings	kg-CO_2eq/ha/year	
Thailand	Life cycle results of GWP for system of gasohol 95	kg-CO_2eq	Cradle to grave based on 180 km test run by Toyota 1.5 litre/1996 with gasohol 95 (14.95 litre ethanol)
	GHG emissions for molasses based ethanol production per reference flow (1000 kg of sugarcane)	kg-CO_2eq	Cradle to gate for pure product

As seen in Table 4-1, different forms of GHG results were generated by the four studies. This is not an issue if a study is done primarily for the purpose of life cycle inventory (LCI) analysis to infer hotspots within a product system or to determine GHG savings. However if the GHG emission values are used for comparative assertion, for example to compare GHG profiles between different routes of biomass utilisation, the units of analyses may need to be standardized. Table 4-2 shows the life cycle GHG emission based on two units of quantification: kg-CO$_2$/litre and kg-CO$_2$/MJ that were extracted directly only for the Indonesian study while for the other studies, the values were either inferred or deduced from the data provided in the reports.

Table 4-2. Inference from Four Pilot Studies Based on Actual Practice at Project Site

Country	Type of biomass	Type of end-product	GHG profile of end product	
			kg-CO$_2$/litre	kg-CO$_2$/GJ
India	Jatropha	Biodiesel	0.1143*	-
Indonesia	Cassava	Ethanol	0.2965	88.9923
	Jatropha	Crude Jatropha Oil	0.4374	12.5862
Philippines	Coconut	Coconut Methyl Ester	0.9600*	-
Thailand	Sugarcane /Molasses	Gasohol (Reference flow: 1,000 kg sugarcane to produce 14.95 litre of ethanol)	32.03	
		Ethanol	2.897*	

*Calculated from data extracted from report, other tabulated values are stated as it is in (ERIA, 2010).

In developing the methodology to calculate GHG emissions as an indicator for environmental impact of biomass energy utilisation, only the first two phases of the complete LCA methodology is applied i.e. the study stops at the LCI analysis stage. The LCI analysis is the phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle. As the environmental impact indicator is global warming expressed in relation to GHG emission, the inventory is a carbon footprint currently defined by ISO/CD 14067 as the sum of GHG emission and removals, expressed as net global warming impact in CO_2eq.

In addition to LCA methodology adopted to establish the GHG emissions in the pilot studies, there are a number of steps that should be performed to enable meaningful and objective comparison of products. In the context of biomass energy utilisation assessment, the key areas of comparison include:

a) different forms of bioenergy from the same biomass feedstock (e.g. bioethanol (second generation biofuel), syngas (from gasification) or solid biofuel from empty fruit bunches

b) one type of bioenergy from different biomass feedstocks (e.g. bioethanol from cassava, molasses or sugarcane juice)

c) same form of bioenergy from different technological routes (e.g. second generation bioethanol from cellulosic material that are pre-treated via steam explosion or mechano-enzymatic grinding)

The following items that should be established according to ISO 14040 and ISO14044, before the start of any data collection to determine the GHG emission profile are:

- Goal
  - Intended application of the study
  - Reasons for carrying out the study
  - Intended audience i.e. to whom the results of the study are intended to be communicated
  - Whether the results are intended to be used in comparative assertion
- Scope
  - The product system to be studied
  - The functions of the product system
  - The functional unit
  - The system boundary
  - The allocation procedure
  - Data requirements
  - Assumptions
  - Limitations

Some of the important parameters in the LCA methodology that should be clearly and systematically described in calculating the GHG profile for comparison of biomass utilisation are highlighted herewith:

(i) Product system and Function

The product system function should be clearly described at the onset of any LCA study and this is very important if different types of biomass feedstock or forms of biomass energy are to be compared.

Examples of “Function of biomass energy” or function of the system being studied are;

a) As replacement or partial replacement for fossil fuel in a specific blend of biofuel e.g. gasohol containing 5% bioethanol and 95% gasoline
b) Reduction of GHG emission from co-combustion or co-firing of biomass energy in biopower generation e.g. reduction in GHG emission by 15% from utilisation of biomaterials as feedstock for energy production
c) Generating maximum energy output from combination of crops for a given land area e.g. combination of crops within 1 ha land area for production of feedstock sufficient to generate X MJ energy (considering a base scenario of a known crop)

(ii) Functional unit

Functional unit should be consistent with the goal and scope of the study. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related, which should be clearly defined and measurable.

An example of an explicit functional unit is shown in the Thailand study is the GHG profile produced by a “180 km test run by Toyota 1.5L/1996”. Another form of functional unit applicable to biofuel for use in goods transportation is “use of biofuel to transport specific amount of goods per unit distance by a specific vehicle of known specification” e.g. “transport 1 ton good per km by a 10-ton truck with Euro III engine”.

Based on the functional unit, the reference flow of 1,000 kg sugarcane was selected in the Thailand study. In the ISO 14040 standard, the reference flow is the amount of output or product from the product system that is required to fulfill the functional unit. Examples of function and functional units relevant for cradle to grave are shown in Table 4-3.

Table 4-3. Examples of Function, Functional Unit and Reference Flow

Product	**Bioethanol**	**Biodiesel**	**Pelletised Biomass**
Function	Fuel for transportation	Fuel for transportation	Fuel for power generation
Functional Unit	Per km distance travelled	Per km distance travelled	Per kWh
Performance of Product	X litres of ethanol/km	Z litres of biodiesel/km	W ton pelletised biomass/kWh
Reference Flow	X litre ethanol	Z litre biodiesel	W ton pelletised biomass
Life cycle inventory for GHG emission	kg-CO_2eq/ litre ethanol	kg-CO_2eq/ litre biodiesel	kg-CO_2eq/kWh

(iii) System boundary

It is important that the system boundary applicable to the final GHG profile that will be reported to decision makers have clear system boundaries. Examples of system boundary that can be applied to biomass energy production and utilisation are listed herewith:

a) Cradle to grave: production of feedstock to final bioenergy use (equivalent to well to wheel for conventional fossil fuel studies)

b) Cradle to gate: production of feedstock to production of bioenergy carrier (equivalent to well to tank for conventional fossil fuel studies)

c) Gate to gate: production of feedstock, production of bioenergy carrier, use of bioenergy are separate entities

The coverage of the system boundary depends on the goal of the study. The cradle to gate (well to tank) approach is sufficient when the study is intended to compare various production technologies while cradle to grave (well to wheel) will be required when comparing the use of a type of bioenergy with other types of bioenergy or fossil fuels. Comparisons between systems shall be made on the basis of the same function(s), quantified by the same functional unit(s) in the form of their reference flows.

(iv) Allocation

Allocation which is the partitioning of an output flow, for example the GHG emission from a product system, between the main product and co-products can have a significant effect on the GHG profile of the target or main product depending on the mode of allocation. ISO 14044 provides some guidance on the methods of allocation that can be applied to biomass energy systems.

Allocation methods include partitioning of the main product with co-products by:

- Weight
- Volume
- Energy content

- Monetary/economic value

It is important to consider the choice of allocation method as the GHG emission profile of a type of biomass energy can vary with the method used. For example, mass basis allocation is easy to calculate but it may not be an accurate measure of energy functions. However allocation by energy content also has its limitation if co-products that are not intended for energy purpose (e.g. biofertiliser produced in the bioethanol production system) are substantial outputs. Hence, it is important that the choice of allocation method be considered carefully during the planning stage for a study.

It should also be mentioned here that the final draft of ISO 14067 “Carbon footprint of products – Requirements and guidelines for quantification and communication” supports use of “offsetting” mechanism in calculating the net GHG emission of products. A biomass energy product whose production process at any stage of the life cycle can lead to reduction or removal of GHG in a process outside the boundary of the system should consider including this option in the net GHG profile.

As most of the major parameters in the LCA methodology that are relevant to the development of the GHG emission profile of the biomass energy could not be easily extracted from the four pilot studies, it is recommended that the GHG emission profile should be calculated by LCA practitioners and follow fully the ISO 14040 and ISO 14044 standards, otherwise it is difficult to make objective comparisons and identify the best options.

In conclusion, the life cycle cumulative GHG emission can be systematically calculated and provide values for comparison and is therefore applicable as an indicator for sustainability assessment of biomass utilisation from the environmental perspective. However, the calculation should follow the ISO methodology closely to enable objective and fair comparisons.

4.1.1.2. Data Requirements to Ensure Representativeness of the GHG Emission Profile

All LCA studies include a mixture of sources for data such as directly measured data, direct-reporting data (e.g. interviews), calculated and estimated.

The four studies involved collection of voluminous amount of data. It is noted the foreground data were in most cases primary data obtained directly from the stakeholders e.g. the farmers, the mid-stream and final-stream processors, and even the users. As biomass energy namely biofuels are new industries or new applications of biomass in all four studies, most data sets may not be representative of situations when the processes such as the conversion process has been stabilised or optimised.

As such, it is important that the limitations of the datasets be highlighted in the study with respect to factors such as:

- time-related coverage e.g. monthly data for X months, annual data for Y years, hourly data for Z hours, average price over a period of time or an absolute price established at the time of study, and also whether the data used in the calculation of the GHG profile represents an average of the whole indicated period, or only parts of it;
- geographical coverage e.g. a mill serves more than one plantation/farm or source of feedstock but data were obtained from only one plantation or farm;

- technology coverage (if applicable);
- precision e.g. variance (if applicable);
- completeness which is the percentage of flow that is measured or estimated e.g. more than 95% of the raw materials input has been accounted for in terms of weight;

Based on the available data collected, qualitative assessment of the representativeness of the data in terms of geographical coverage, time period and technology coverage should be mentioned as well as the mode of calculating average (e.g. whether numerical or weighted average) especially for a report that will be used for decision-making eventually.

In view of the volume and complexity of data that is required for a life cycle calculation, it is a good practice to establish the data collection and calculation technique in a proper document before proceeding to do populate the inventory.

If feasible, some simple statistical analysis may be carried out to give an indication of uncertainty such as standard deviation and confidence level.

As a conclusion, detailed planning for collection of data required to develop the LCI is highly recommended to enhance the representativeness of the GHG emission profile for a given biomass energy.

4.1.1.3. Data Treatment Based on Secondary Data and Modelled Estimates

In developing the GHG profile for biomass energy, the background data generally cover the GHG emissions associated with the production of raw materials flowing into the product system including the energy generation process such as electricity generation, fuel for transportation, water treatment and waste disposal. Raw materials pertinent to the production of biomass feedstock at agriculture stage include fertilisers, pesticides, herbicides and packaging materials.

Almost all background data are secondary data sourced from established databases, widely accepted reference sources such as the IPCC reports, manuals and published journal papers.

The hotspots identified by the four pilot studies based on the existing practice are listed in Table 4-4. The agriculture stage generated the highest percentage of GHG for biodiesel in India, and molasses based ethanol from sugarcane in Thailand, while power generation and biodiesel production are the hotspots in the Indonesian and Philippines studies, respectively. The results from the pilot studies showed that different types of biomass energy had different hotspots that are also dependent on the various practices for wastewater and agriculture residue treatment.

Table 4-4. Hotspots in the Life Cycle GHG Inventory of Biofuel in the Four Pilot Studies

Country	**Type of Biofuel and Crop**	**Hotspot stage of the life cycle**
India	Biodiesel from Jatropha	Jatropha cultivation
Indonesia	Bioethanol from Cassava	Power generation
Philippines	Biodiesel from Coconut	Biodiesel production
Thailand	Bioethanol from Molasses of Sugarcane	Sugarcane cultivation

As there is no consistent pattern for the hotspots, the background data for almost every stage in the life cycle GHG emission will be required depending on the type of biomass feedstock and end-product.

Table 4-5 summarises the major input and output flows that should be included in the calculation of GHG emission of biomass energy. The established sources of reference for GHG profiles or conversion factors for these flows if primary data are not available are also summarized below; these activities constitute the background data in the LCI.

Table 4-5. Conversion Factors Required for Input and Output Flows in the Biomass Energy Product System

Material Flow	Stages of life cycle in biomass utilisation for bioenergy			
	Feedstock	Feedstock processing	Conversion	Use
Fertiliser production	✓			
Fertiliser application	✓			
Soil conditioner e.g. lime production	✓			
Soil conditioner application	✓			
Herbicide and pesticide production	✓			
Electricity generation	✓			
Fuel production	✓	✓	✓	
Stationary combustion	✓	✓	✓	
Water supply	✓	✓	✓	
Transportation/Mobile emission	✓	✓	✓	✓
Industrial chemicals production e.g. methanol, acids and alkalis	✓	✓	✓	
Waste and wastewater treatment	✓	✓	✓	
Solid waste disposal		✓	✓	

It is obvious from Table 4-5 that there are several conversion factors for materials, products and electric power that will have an effect on the final GHG emission profile of biomass energy. A suggested hierarchy of possible data sources for conversion factors is:

a) Published and verified data reported by trade associations e.g. Fertiliser Association, Pesticide Association, Petroleum Producers Association, Automobile Association etc.

b) Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventory

c) Established national databases

d) Established commercial databases

e) Journal papers with reported source of data input

f) Seminar, conference papers with un-reviewed data

The selection of the most appropriate datasets is left to the study team to decide based on local conditions, and goal and scope of study.

4.1.1.4. Viability of Calculating GHG Emissions to Assess Biomass Utilisation for Micro and Macro Level Projects

The pilot studies have shown the viability of calculating GHG emission profile of biomass energy at specific project sites and can be considered as micro level. The same approach should be applicable to bigger project sites that can cover district, state or province and national level. The difference between applying the methodology at micro and macro level is mainly in the data collection, data treatment and data integration at the inventory stage. Data collection will be more intensive and averaging the raw data sets may be more suitable based on weighted average especially when yields at plantations or farms differ between different sites within the geographical boundary of the study.

Although the LCI to be developed for macro level projects is expected to be a demanding activity, extrapolation of a study at micro level to the macro level is not recommended.

Finally, it is recommended that the format of reporting a LCA study should follow the ISO 14040 series and ISO14067 for global warming potential measured as GHG emission. The ISO standards are good reference for principles and guidance to implement comprehensive and quality studies to obtain LCA-based GHG emission values that can be used for the sustainability assessment of biomass utilisation.

4.1.2. GHG Emissions due to Land Use and Land Use Change

The first intended general environmental objective of having “green” fuels to replace fossil-based fuels was proposed with the ideal that biomass-derived biofuels are “sustainable”. Most biomass materials come from crops which are grown on land (thus making them “renewable” resources). During its growth period, biomass works as a carbon sink to absorb CO_2. In the carbon neutral theory, it is assumed that the amount of CO_2 absorbed during biomass growth equals the amount of CO_2 released from biofuel combustion [e.g., $CO_{2(combustion)} - CO_{2(biomass)} = 0$]. However, whether or not biomass fuels are “carbon neutral” depends on a lot of factors, and they can in some cases be far more carbon positive than fossil fuels (Johnson, 2009).

Biofuels have proven to bring economic advantages for many countries, causing a significant deforestation problem in many developing countries in the world, particularly Brazil and South East Asian countries (e.g., Wicke et al., 2011). Over the previous years, many studies have been conducted showing major impacts on the environment due to land use change (LUC). Some studies have shown that biofuel production can have larger emissions than fossil fuel burning due to LUC when high carbon stock land is converted to agricultural land for biofuel feedstock cultivation (Fargione et al., 2008; Searchinger et al., 2008).

By analysing the GHG impacts on LUC, the authors intend to propose various land use and production criteria to ascertain the sustainability of biomass utilisation. It is suggested that suitable lands for growing biomass for bioenergy can be an imperative factor in order to make biofuels become more favourable options as compared to fossil-based fuels.

LUC can be allocated into two categories, direct and indirect:

Direct land use change (dLUC): constitutes changes occurring within the system boundary: for example, the replacement of natural vegetation with biofuel crops. If biofuel crop cultivation incurs an upfront loss of carbon as a result of changing land cover, it creates a "carbon debt" (Fargione et al., 2008).

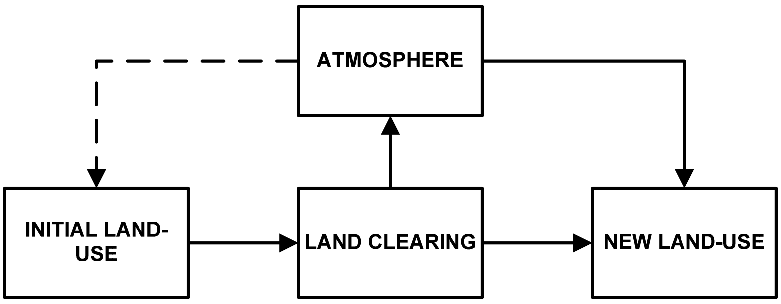
Indirect land use change (iLUC): occurs outside the system boundaries, but is attributable to activities occurring inside those boundaries. For example, if biofuels displace other crops and reduce supplies in the near term, this leads to increased prices that provide motivation for producers in other areas to make up for the shortfall (Bailis and Baka, 2010).

A few scientific communities have been promoting the inclusion of carbon emissions from deforestation, when investigating the environmental performance of biofuels. LUC (dLUC and iLUC) makes up for a significant fraction of world deforestation, annual emissions have been reported to be in the range of 1.0-2.2 Gt-C/yr as a result of this practice (Persson and Azar, 2010).

As good practice, the scope for determining the carbon emitted in biofuels production, should start from the cultivation stage, the production, transport, consumption and the carbon transfer to and from the atmosphere to close the cycle. As shown in Figure 4-1, LUC practice would be considered as an accumulation process of carbon in the atmosphere since the stage involves only carbon emissions. Carbon sequestrated by carbon pools from vegetation and soil is released when land is cleared (Kendall et al., 2009). It works as a one-time output of carbon. The carbon debt generated by this stage is commonly amortised to different life spans. The standard time for amortisation, established by the IPCC is 20 years.

Land clearing removes carbon stocks from initial land due to tillage, land burning, and draining, among others (Figure 4-1). The total amount of carbon stock change will result in emissions to the atmosphere from transformation of the biomass, organic material and carbon in soil that release as CO_2 and other GHGs. When burning, N_2O will have an important influence on GHG emissions.

Figure 4-1. Carbon Flux during LUC. Dotted line represents the carbon assimilation that will not exist after land clearing. New land use will act as a new carbon pool.



4.1.3. Other Environmental Impact Categories

The working group recognises the importance of environmental impact categories other than climate change measured by life cycle GHG emissions or savings. Since those categories also play a vital role on environmental sustainability, this section focuses on the impact categories, particularly those identified as important aspects in Chapter 3. Although the general concept and direction of each impact category are addressed in this section, more discussions and accumulation of research including the preparation of data are required to provide sets of indicators that are suitable for East Asian countries and are useful for the target users of the WG methodology.

Table 4-6 shows the classification and direct causes of the environmental impact categories. Each environmental impact category is not independent; it interacts with other categories in complicated ways, i.e. if a particular practice/operation of biomass utilisation as energy has a large impact on air quality through pollutant emissions, it may damage quality of soil through rainfall or deposition of airborne pollutants, resulting in an impact on quality of water flowing out through soil, ultimately into loss of biodiversity. Since the overall interactions and mechanisms are too complicated to discuss here, the impact categories are addressed separately in this section.

Table 4-6. Classification and Direct Causes of Environmental Impact Categories Identified in the Lessons Learned from Pilot Studies

Type of impact	Impact categories identified in pilot studies	Direct cause in pilot studies
Degradation of ecosystem	Biodiversity	Land conversion into cropland
Energy resource depletion	Net energy balance	Fossil fuel use
Water resources scarcity	Water use	Water use
Degradation of air quality	Air quality, acidification	Biomass burning
Degradation of water quality	Water quality, eutrophication, acidification	Agricultural practice and effluents from processing factories
Degradation of soil quality	Soil quality	Agricultural practice and land conversion into cropland

4.1.3.1. Degradation of Ecosystem

The Millennium Ecosystem Assessment (MA Board, 2005) classifies ecosystem services into 11 groups in the assessment and explains their importance to human well-being. As we highly depend on these ecosystem services, degradation of ecosystem is a critical issue not only for environmental but also social and economic sustainability. Among various aspects of ecosystems, biological diversity (biodiversity) is a necessary condition for the delivery of ecosystem services. In most cases, the supply of ecosystem services depends greatly on biodiversity. By promotion of biomass utilisation for energy, biodiversity can be degraded directly by land conversion into cropland (especially monocrops in many cases) for feedstock production, or indirectly by degradation of air, water, soil quality and excessive use of water and even climate change as well.

The Millennium Ecosystem Assessment also discusses some indicators to quantify biodiversity. The most common indicators for biodiversity are Shannon-Weiner (Weaver and Shannon, 1949) or other similar indicators that are based on species richness such as the number of species and species diversity. However it should be noted that these simple indicators do not capture whole figure of biodiversity. For example, they do not differentiate between native and introduced species and do not focus on species that fulfil significant roles in the ecosystem. The other indicators that integrate multiple aspects of biodiversity are, for example, Index of Biotic Integrity for aquatic systems (Karr and Dudley, 1981) and the Living Planet Index (Loh and Wackermagel, 2004). Effectiveness of these indicators depends on availability of and access to data sets.

The number of species threatened with extinction is also an important indicator of biodiversity trends. In this context, the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2001) is one of the useful indicators.

4.1.3.2. Energy Resource Depletion

Since development of biomass utilisation for energy is intended partly to mitigate non-renewable energy resource consumption, it is of importance to evaluate the performance of energy production that is ultimately linked to energy resource depletion. The indicator commonly used to measure the performance is Energy Returned On Energy Invested (EROEI), or Energy Payback Ratio (EPR), which is the ratio of the amount of usable energy acquired from a particular energy resource to the amount of energy expended to obtain that energy resource (Murphy and Hall, 2010). In production of energy carriers, EROEI of more than one is at least required to ensure that more energy is available for final use than that consumed for the production. EROEI of less than one means that the more energy produced, the more energy would be lost. It is often applied to analyses on the performance of energy producing facilities such as power plants, solar cell systems and biofuel production plants.

4.1.3.3. Water Resource Scarcity

Water discussed here refers to fresh water that is necessary for drinking, agriculture and industries. In recent years, the availability of and access to freshwater have been highlighted as the most critical natural resource issues facing the world (WWAP, 2003). Biomass utilisation for energy sometimes puts more stress on fresh water resources through water consumption by energy crop plantations and feedstock processing. The impacts on availability of and access to fresh water, therefore, should be carefully monitored and managed before and after the biomass project starts so that it does not put more pressure on the water cycle nor compete with indigenous people's demand, particularly in areas where water supply is unstable or becoming scarce.

There are many indicators developed in the past 20 years to quantitatively evaluate water resources vulnerability (Brown and Matlock, 2011). Among them, the water footprint method combining conventional methods and life cycle assessment (LCA) serves as a holistic approach considering environmental, economic and social aspects. However, improvements are required to create a standardised model for quantifying the impact on water resources due to biomass utilisation for energy.

4.1.3.4. Degradation of Air Quality

Air pollutants from biomass energy utilisation are released into the air mainly from the following two activities:

- Open-burning practice in agriculture

There are two cases where open-burning takes place in biomass feedstock cultivation; pre-harvest open burning that makes it easier to harvest crops manually with removal of leaves and spikes before harvesting; and post-harvest open burning to clear residues after harvesting or to control diseases and pests of the crops after harvesting. In both cases, burning of biomass releases pollutants such as particulate matter (PM), nitrogen oxides (NO_x), sulphur oxides (SO_x), volatile organic compounds (VOCs), carbon monoxide (CO), etc. into the air. Among them, a pollutant of special concern is PM that has potential impacts on respiratory diseases in the local population. Since pre-harvest open burning still take place in sugarcane cultivation, some countries have already prohibited open burning of pre- and post-harvest by law.

- Biomass burning in fixed facilities

In cases where agricultural residues or by-products from feedstock processing at fixed facilities such as processing plants are burnt for generating heat or power, pollutants are released into the air by their combustion but some of those are usually captured or filtered by exhaust gas treatment facilities, dust collectors, etc., in accordance with the law associated with factory operations.

Assessment of the environmental impact from the two activities above may be conducted as follows:

a) Compliance with the environmental standards/regulations

When biomass is burnt, the pollutant emissions should at least meet the requirements regulated by the governments and international organisations. The pollutants released should be measured in accordance with the methods provided by the regulations.

b) Risk Assessment of the impacts on air quality

Degradation of air quality may affect human health. Although intensive site-specific data gathering is required for the assessment, the damages to human health caused by low air quality can be evaluated by the combined use of atmospheric diffusion models such as air quality models and risk assessment of human health based on exposure models.

4.1.3.5. Degradation of Water Quality

Water pollutants with relevance to biomass utilisation are mainly classified into two types below in terms of their emission sources.

a) Agricultural Inputs

The oversupply of nutrients (eutrophication) causes negative impacts on water quality particularly in river, lakes and coastal systems through surface runoff and leaching from agricultural lands. As reported in the Millennium Ecosystem Assessment (MA Board, 2005), nutrients addition on the land, including synthetic fertilisers, animal manures, the enhancement of nitrogen fixation by planted legumes and the deposition of airborne pollutants have resulted in approximately a doubling of the natural inputs for reactive nitrogen in terrestrial ecosystems and almost fivefold increase in phosphorus accumulation. In some areas, groundwater is so polluted by nitrates that it is no longer suitable for drinking. In all countries groundwater is an important source of drinking water.

Energy crop plantations in biomass utilisation are sometimes related to intensive fertiliser application for achieving a certain level of crop yield. The study to maximize nutrient uptake by crops from fertilisers for optimum growth and yield may be necessary to minimize the impacts of water quality.

b) Effluent from processing biomass

Feedstock processing in biomass utilisation such as biofuel refinery releases pollutants into water. The pollutant levels are stipulated by environmental standards and regulations in the same manner as air pollutants.

Assessment of the impacts from the two activities above may be conducted in a similar manner to air quality assessment; the emissions to water should meet environmental standards; the movement of pollutants from ground surface through channel networks can be simulated using water quality and soil models to obtain more information of the impact on water quality.

4.1.3.6. Degradation of Soil Quality

Soil quality is determined by three major interacting components, namely chemical, physical and biological characteristics. Soil degradation results from the loss of one or more of these components and induced by soil erosion, loss of organic matter, salinisation and acidification, which are often caused by plant cultivation or poor soil management. Erosion is caused by both wind and water, resulting in the removal of the finer soil particles. It leads to compaction of the soil and makes it difficult to till soil.

Energy crop plantation requires careful soil management for a long-term production. It should meet the environmental standards that stipulate minimum requirement for soil management such as preparation of buffer zone along river and forest, and limitation of planting in areas where slope is beyond a particular critical level. However, it is required to monitor the soil quality and erosion for a long term to minimize soil degradation.

4.2. Economic Pillar

Based on the lessons learned from the pilot studies, the economic assessment can be presented by two levels of indicators: a master indicator and a few sub-indicators. The master indicator is the total value added (TVA) proposed in the WG's guidelines (Sagisaka, 2009). However, we propose a more straightforward way to calculate it.

The sub-indicators are: employment, net profits and tax revenue. Another master indicator is the foreign exchange savings, which has been discussed in our methodology but is put under different usage. 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.

4.2.1. Master Indicator – Total Value Added

TVA is 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 quality and thus becomes TVA per unit of biomass production.

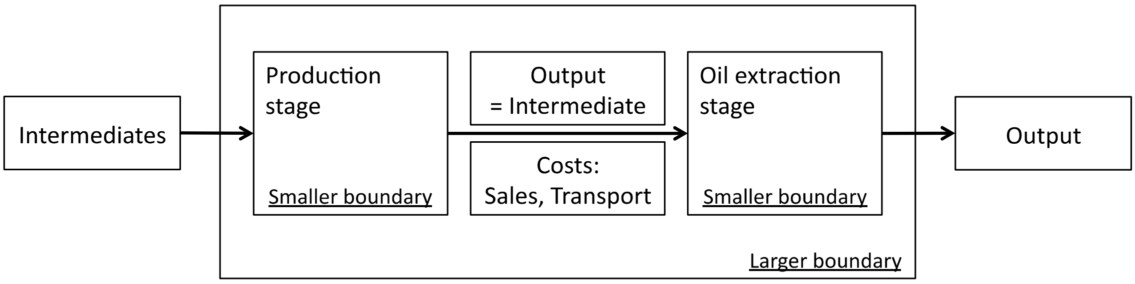
As in national accounts, TVA in this study is also calculated as output value minus costs of intermediates:

$$
\begin{aligned}
\text{TVA} &= \text{Output value (or Gross revenue)} - \text{Cost of intermediates} \\
&= (\text{Price} \times \text{Output quantity}) - \text{Costs of intermediates} \qquad (4\text{-}1)
\end{aligned}
$$

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 that are produced elsewhere in the economy or are imported. It should be noted that land, labour, and capital are primary inputs and are not included among intermediates. This is equivalent to production approach of measuring GDP while the method proposed in the previous report is an income approach, which may be complicated to be used by non-economic professionals.

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 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 4-2, 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 become an "input" in the oil traction stage and thus when calculating the two stages together, one only needs the final output value of biomass oil, while not caring for the output value of biomass.

Figure 4-2. Input-Output Boundaries for TVA Calculation



The boundary in Figure 4-2 can be equally extended to include more stages such as esterification, which are often undertaken in case of producing biodiesel.

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

4.2.2. Sub-Indicators for Economic Pillar

4.2.2.1. Labour Income (Wage)

Labour income or wage is another indicator for assessing the economic impact of the biomass industry and is put as sub-level indicator to supplement the master indicator. Labour 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 utilisation in exchange for their labour. This includes the labour income from both the production stage or plantation and processing of raw material to biofuels. This is computed as equation (4-2):

$$\begin{aligned}&\text{Labour Income}\\&= \text{Total man-days} \times \text{Average wage per man-days}\end{aligned} \tag{4-2}$$

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

4.2.2.2. Net Profit

Net profit is a key indicator that is closely monitored by investors. It is also an indicator to demonstrate the sustainability of 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.

4.2.2.3. Tax Revenues

Tax revenue is the income generated by the government from the entities involved in each production process. Each country may have a different tax portfolio and thus the calculation will be diversified. A typical example is computed as equation (4-3):

$$\text{Tax} = \text{Total taxable income} \times \text{Tax rate} \tag{4-3}$$

Where

$$\begin{aligned} &\text{Total taxable income} \\ &= \text{Income from main product (Profit per unit of product A} \times \text{Volume of A)} \\ &+ \text{Income from by-product (Profit per unit of by-product B} \times \text{Volume of B)} \end{aligned} \tag{4-4}$$

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 coconuts), as can be described as equation (4-5).

$$\text{Tax} = \text{Total taxable income from all processed products} \times \text{Tax rate} \qquad (4\text{-}5)$$

4.2.2.4. Foreign Exchange Savings

Biomass production and processing has positive effects on foreign trade which is determined by two factors, foreign exchange earnings and foreign exchange savings. Foreign exchange earnings arise from the gains of exporting the readily convertible material for biodiesel production. As in the Philippines, the exportable input to biodiesel production is coconut oil. Even before the advent of the biofuel industry, the country is already benefiting from coconut oil exports – one of its major dollar earners. This could likewise be the case for other countries producing biodiesel such rapeseed oil, palm oil, and others. For oil importing countries, the foreign exchange earnings can be calculated as value of import substitute, which is generated from reduced diesel imports with the presence of the energy project.

4.3. Social Pillar

4.3.1. Master Social Indicators Applicable at Different Scales

Social Indicators for assessment of sustainability of biomass energy programs may be different and depend on the scale of operation. The Human Development Index (HDI) measures three social factors, namely, life expectancy at birth, as an index of population, health and longevity; adult literacy rate; and the gross domestic product per capita at purchasing power parity. While HDI could be an indicator of social development at state and national levels, it may not be a suitable measure of observing social changes at local or community level. Based on ERIA WG's experience in conducting the four pilot studies to assess the applicability of the WG guidelines (Sagisaka, 2009), there were difficulties in implementing the social impact assessment based on UNDP's HDI. Calculation of HDI was data intensive requiring inputs on a wide array of parameters that were not readily available at the village or district level. For the pilot studies, secondary data were used adopting available provincial or national data which may not reflect the local situation. In addition, discounting data variability not affecting significantly the calculations, there were other hurdles in isolating the social impacts of biofuels on related activities to overall health, education or even income. There were no comprehensive baseline data to refer to for "before and after" scenarios.

Recognising the difficulty in calculating HDI in the local level, the social indicators such as employment generation and access to modern energy are suggested which could be more relevant to capture local impacts of small-scale biomass energy projects.

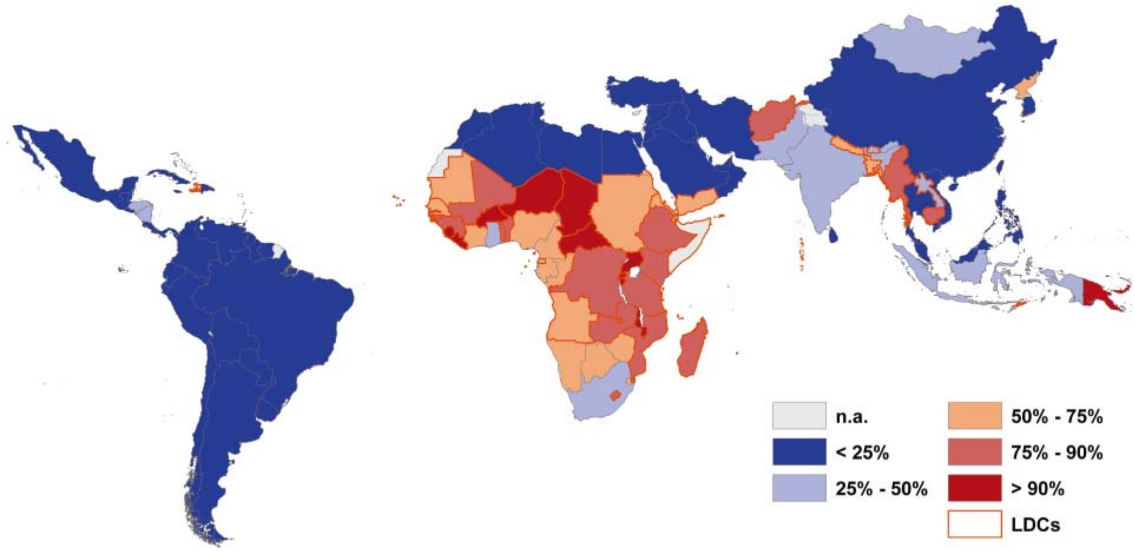
4.3.1.1. Employment Generation

Employment generation, particularly, change in employment and personal income before and after the project, and consequently more spending on basic needs and lifestyle could be some measures of social development at micro level. Thus, master indicator at local level should be the change in personal income that could trigger other social sub-indicators such as change in education, health, gender upliftment, living standard, etc. In cases where there is no change in personal income, indirect benefits like job security, improved working environment or better working time schedule should be noted and taken into consideration.

4.3.1.2. Access to Modern Energy

Provision of reliable and affordable energy access is one of the key Millennium Development Goals (MDGs) of the United Nations which are summarised in Appendix (MDGIs, 2011). It is ironic that despite several modern technological developments around the world in recent times, more than half of the population in developing countries still do not have access to electricity as shown in Figure 4-3. It is estimated that almost a billion people without access to electricity reside in the Asia-Pacific region. The amount and quality of energy consumption has a correlation with poverty, deprivation, social seclusion, access to knowledge and achievements, health, livelihood and security (UNESCAP, 2005).

Figure 4-3. People without Access to Electricity Reside in Asia-Pacific (UNDP/WHO, 2009)



Many developing countries promoted biofuel projects to provide access to energy to remote and rural areas that are not connected to the main grid. In most rural areas relying on biomass for basic cooking, lighting and heating needs, women and children are tasked to gather fuel wood, agricultural residues or dried cow dung. As resources are decreasing, the activity takes more time, leaving less time for other productive work and in some cases making it difficult for children to attend school, so that they can help in household chores (Mencher, 1989). In addition, about 40% of the global infant mortality rates caused by pneumonia occur in Bangladesh, India, Indonesia and Nepal; many of these deaths are caused by pollutants from indoor burning of traditional fuels (ADB, 2002).

Access to modern energy can be an important social indicator, which could be measured in terms of number of households or communities provided with that access. Energy access in rural areas transcends beyond having electricity; it saves lives, empowers women to engage in more productive income generating work and keeps children in school. Modern energy supply must not only be made available to the poor, but should also be made affordable for them before any substantial benefits of human growth or poverty reduction can be realised (ADB, 2006).

In the Indonesian case study, the Jatropha project site has no electricity and not connected to the main grid. One third of Indonesia's population have no access to electricity in spite of the fact that the country used to be an active Organization of the Petroleum Exporting Countries (OPEC) member and has abundant untapped renewable energy sources. About 37 million people or 17% of the total population live below the national poverty line earning less than 14 USD a month. As part of the main strategies to address rural development, the government launched the Energy Self Sufficient Village (ESSV) project targeting 1,000 villages in remote areas and make them self-sufficient in their energy needs by utilising their own local renewable energy resources. Of the 1,000 villages, 500 will produce their own supply of biofuels from Jatropha, cassava or sweet sorghum to run basic equipment for lighting and farm activities, and to replace the use of kerosene for cooking purposes. The other 500 villages will harness their water resources to develop mini- or pico-hydropower and install solar photovoltaics.

It is important to recognize that rural electrification is not an end in itself. Provision of electricity must be integrated with community development to ensure optimum benefits. It is the means to improving the people's livelihood, education, and health towards leading a better quality of life.

4.3.2. Comparison with GBEP Indicator for Social Pillar

Among the various biomass sustainability frameworks, the Global Bioenergy Partnership (GBEP) Task force on Sustainability has developed a set of 24 relevant, practical, science-based, voluntary indicators for bioenergy in May 2011 (GBEP, 2011). While the intention of the WG's main social indicators is to capture social impacts, it is worth examining how it compares with the GBEP's sustainability indicators for social pillar, as well as share some experiences how those indicators were observed at the pilot studies, as shown in Table 1 of Appendix.

4.3.3. Qualitative Sub-Indicators for Social Assessment

In addition to HDI, employment generation and access to modern energy, as the master midpoint indicators, and some other sub-indicators are useful to evaluate endpoint social impacts of utilisation of biomass as energy. Although further discussions are required to decide whether these sub-indicators are applicable and appropriate for East Asian countries or not, the WG had highlighted some sub-indicators, which are based on qualitative parameters of social assessment and may have relevance to GBEP as shown in Appendix.

5. PRESENTATION OF RESULTS

Presentation of results is very important as results of scientific calculations and deliberations need to be conveyed to decision makers (policy makers) in a way that is comprehensible and facilitates the process of decision-making. The working group has given much consideration to this issue. At first, “integration” of the results of sustainability assessment was considered and various existing integration methods reviewed (Sagisaka, 2009). However, it was recognized that combining the results from the three aspects of sustainability – social, economic and environmental – was not very meaningful and attempts to combine these into a single index would result in a loss of information as well as a serious implicit assumption that the three aspects are substitutable. This assumption, in fact, defeats the very purpose of moving towards sustainable development as it could be interpreted to mean for example, that social or environmental costs can be compensated by economic advantages.

When three indicators, one each for social, economic and environmental aspects, were identified as key indicators for sustainability assessment, an attempt was made to develop a methodology for normalizing each of the indicators to a dimensionless number, preferably between 0 and 1, and representing it on a radar diagram (triangular) (ERIA, 2010). The main idea was to present the three indicators in a single diagram and on a dimensionless scale so that the decision makers could see at a glance the impact of an activity on the three aspects of sustainability. As life cycle GHG emissions, human development index and total value added were used as the indicators for environmental, social and economic aspects respectively, the normalization method was proposed as per the following equations (ERIA, 2010):

The Normalized Environmental Indicator (NEnI):

$$NEnI = \frac{GHG_{no-project} - GHG_{project}}{GHG_{no-project}} \tag{5-1}$$

The Normalized Social Indicator (NSoI):

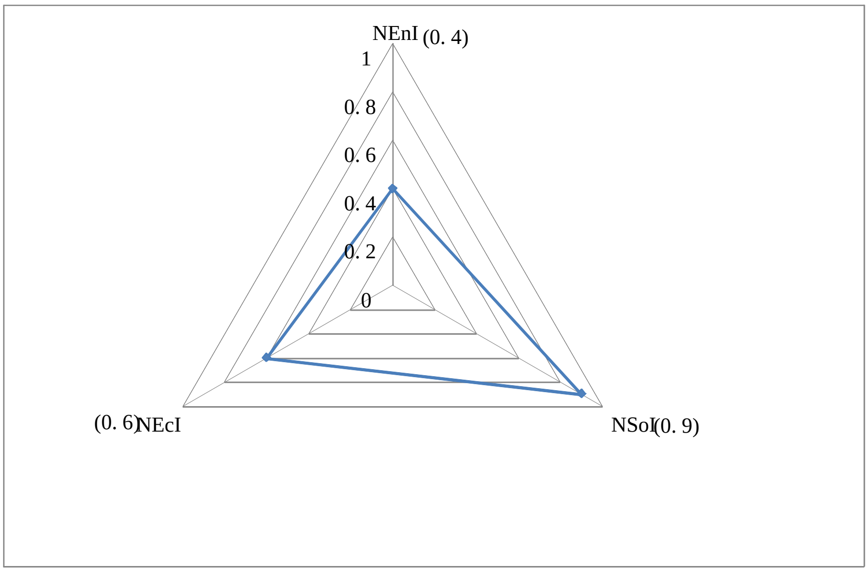
$$NSoI = \frac{HDI_{project} - HDI_{no-project}}{HDI_{\max} - HDI_{no-project}} \tag{5-2}$$

The Normalized Economic Indicator (NEcI):

$$NEcI = \frac{TVA_{project}}{Cost\ of\ the\ project} \tag{5-3}$$

These indicators could be presented in a triangular radar diagram format as shown in Figure 5-1.

Figure 5-1. Presentation of Integrated Results for a Hypothetical Example (NEnI = 0.4, NSoI = 0.9, NEcI = 0.6) (ERIA, 2010)



This method of presentation was then applied to the case studies that were conducted to test the sustainability indicators developed. The normalization part was found to be cumbersome particularly for the economic indicator.

Also, after the latest discussions in the working group, the sustainability indicators have been increased from a total of three indicators to one key master indicator for each aspect of sustainability along with sub-indicators. Presentation of several indicators on the radar diagram is even more complicated. Hence, it is felt that presenting all the indicators in a tabular format would be the most reasonable. This would give all the information available to the decision makers in a single table and relative priorities to various aspects can be assigned by the decision makers themselves based on the context and conditions of the study. However, it may be difficult for the decision makers to assess the relative magnitude of the various indicators, for example, is a global warming potential of 10 t-CO_2eq large or small? For comparative studies this may not be an issue, but for individual studies, some kind of benchmark would facilitate an interpretation of the relative magnitude. This should be considered in further studies; it might eventually also facilitate the reconsideration of a visual presentation format with normalized values as proposed earlier on.

6. CONCLUSIONS AND RECOMMENDATIONS

In the fourth phase of ERIA WG on "Sustainability Assessment of Biomass Utilisation in East Asia" in 2010-2011, the WG summarised the experiences and lessons learned from the four pilot studies in selected East Asian countries (ERIA, 2010) that had been conducted to field-test the WG's sustainability assessment methodology (Sagisaka, 2009).

From the lessons learned from the four pilot studies, the applicability of the indicators as environmental, economic and social pillars of sustainability can be summarised as follows:

- Life cycle assessment (LCA) is a well established, standard technique for quantifying GHG emissions. Life cycle GHG emissions as environmental indicator are applicable for any biomass initiative.
- Total value added (TVA) as economic indicator is also applicable for any biomass initiative. However, TVA alone gives not much meaning to the sustainability of biomass utilisation; understanding the components of TVA, namely, net profit, personnel remuneration, tax revenue and foreign exchange earnings will help decision makers decide whether to proceed with or continue the biomass initiatives or not.
- Human development index (HDI) represents the endpoint social impact by employment. HDI can be used for macro scale (national, state or province level) initiatives but is difficult to assess for micro scale (community or project level)

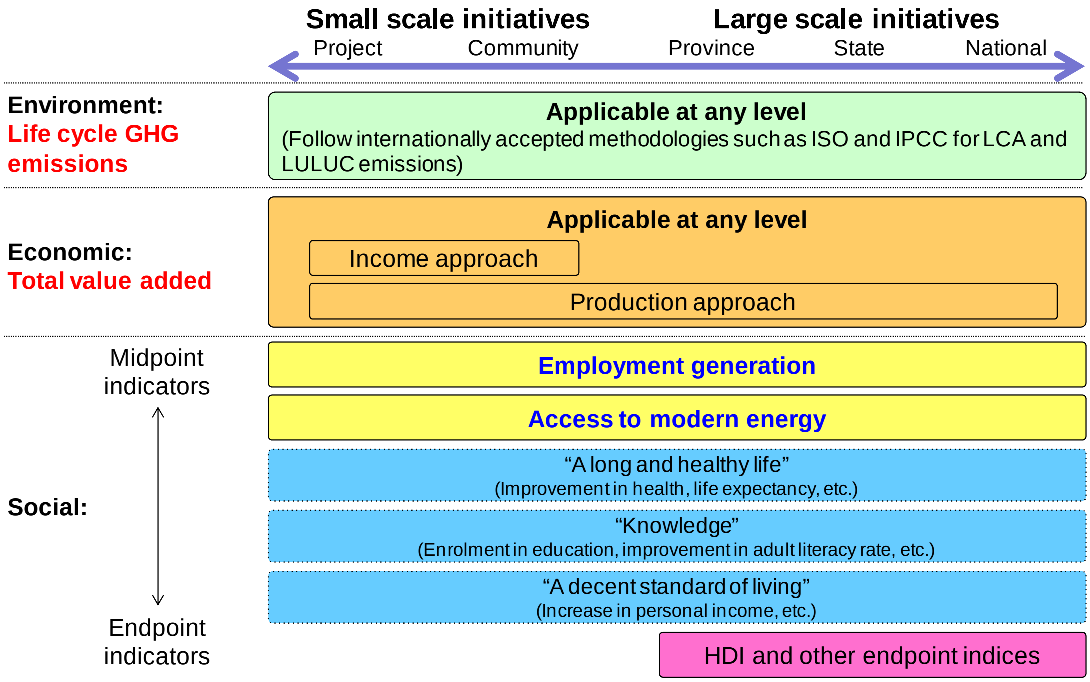
initiatives because of data unavailability. Therefore, midpoint indicators that can directly capture the social benefit by implementing biomass energy utilisation initiatives might be suitable for quantitative evaluation.

By reflecting the lessons learned and the latest worldwide discussions for bioenergy sustainability, the WG proposed an upgraded methodology so that the sustainability indicators for each sustainability pillar could be applied to both small and large scale biomass utilisation initiatives, be more scientific and practical for decision makers in the Southeast and East Asian countries, as can be described as Figure 6-1:

- Life cycle GHG emissions are applicable for both small and large scale initiatives as an environmental indicator. However, it is recommended that the profile should follow internationally accepted methodologies such as ISO for LCA and IPCC for LULUC emissions. Since the environmental impact caused by biomass utilisation as energy is not only global warming, other impact categories can also be quantified by LCA, according to the environmental concerns of the sites where biomass utilisation initiatives are planned or already implemented.
- TVA can quantify economic sustainability for any biomass utilisation initiatives. For small scale initiatives at the community or project levels, the income approach can be used to add up all the income earned by the project or in the community, as had been provided in the WG guideline (Sagisaka, 2009). On the other hand, the product approach that calculates the market value of goods and services produced in the economy can be applied to for both small and large scale initiatives, in the same manner as measuring GDP.

- Although HDI and other indicators can be used as social indicators to evaluate social sustainability at endpoints, they may be only applicable for large scale biomass utilisation initiatives because of the data unavailability at community level. To quantify the social impact by biomass utilisation, the midpoint social indicators such as employment generation and access to modern energy are suggested as more relevant to capture social impacts and that could trigger endpoint social impact such as "a long and health life", "knowledge" and "a decent standard of living" at both small and large scale initiatives.

Figure 6-1. Sustainability Indicators at Different Levels



The final goal of the WG project is to propose a sound and standardised methodology for sustainable biomass utilisation in East Asian countries in line with worldwide trends for biomass sustainability so that it can contribute to policy support on what kinds of biomass utilisations should be implemented in each country.

Among the sustainability indicators shown in Figure 6-1, the WG had already confirmed the applicability of life cycle GHG emissions and TVA using income approach as environmental and economic sustainability indicators and recognised the difficulties for the application of HDI as social indicator at small scale biomass utilisation initiatives, whereas the appropriateness of the other indicators are derived from the lessons learned from the four pilot studies in selected East Asian countries. The WG thinks it important to check the applicability of the other sustainability indicators to biomass utilisation initiatives based upon plan-do-check-act (PDCA) cycle. In addition, since East Asian countries are abundant in biomass resources, the biomass feedstocks to produce energy are not limited to Jatropha, cassava, coconut or sugarcane; other feedstocks such as oil palm and other oil trees or cellulosic biomass have high potential as energy as well. The results of the sustainability assessment are different depending on the feedstocks, technologies adopted in the energy conversion processes or the scale of the initiatives. Therefore it is recommended to accumulate the WG research experience by conducting case studies based upon the upgraded WG methodology and evaluate the sustainability of both small and large scale biomass energy initiatives using various kinds of feedstocks in East Asian countries.

East Asian countries also have high potentials for other renewable energy sources such as hydropower, photovoltaics, wind, geothermal and wave energy. However, it must be noted that the WG's sustainability assessment methodology is tailored only for biomass resources and may not be applicable for comparison with other renewable energy sources. Although sustainability encompasses the environmental, economic and social pillars, the specific indicators and mode of calculations including the boundaries and scope of comparison will differ. It may be imperative to discuss the role of biomass energy within the total energy system in East Asian countries by comparing with the sustainability of other renewable energy sources.

The WG recognises the importance of disseminating the WG methodology. The calculations of all the indicators for the three pillars of sustainability are not an easy task. Without proper training for the users of the WG methodology, the use of these indicators may lead to unreliable results. It is suggested that hands-on training/seminars on the calculation of these indicators be conducted for East Asian country representatives so that there will be transfer of knowledge. These participants will then conduct a trainers' training to disseminate widely the use of the guidelines for the assessment of the sustainability of biomass utilisation in their home countries.

REFERENCES

ADB (Asian Development Bank) (2002), "Asian Environment Outlook 2001", Manila: Asian Development Bank.

ADB (Asian Development Bank) (2006), "Energy for All", Manila: Asian Development Bank.

ANRE (Agency for Natural Resources and Energy), Ministry of Economy, Trade and Industry, Japan (2010), "Report of the Study Group on Sustainability Standards for the Introduction of Biofuel", http://www.meti.go.jp/english/press/data/20100305_02.html, (Accessed 16.07.2011).

ASEAN (Association of Southeast Asian Nations) (2007), "Cebu Declaration on East Asian Energy Security, Cebu, Philippines, 15 January 2007", http://www.asean.org/23313.htm, (Accessed 16.07.2011).

ASEAN (Association of Southeast Asian Nations) (2008), "Joint Ministerial Statement of the Second East Asian Summit Energy Ministers Meeting, Bangkok, 7 August 2008", http://www.aseansec.org/21853.htm, (Accessed 16.07.2011).

Bailis, R.E. and Baka, J.E. (2010), "Greenhouse Gas Emissions and Land Use Change from Jatropha Curcas-Based Jet Fuel in Brazil", Environmental Science and Technology, 44 (22), 8684-8691.

Brown, A., and Matlock, M.D. (2011), "A Review of Water Scarcity Indices and Methodology", The Sustainability Consortium White Paper 106.

Elauria, M.M. et.al.(2008), "Investigation on Sustainable Biomass Utilization Vision in East Asia: Case of Philippines", ERIA Related Joint Research Project Series 2007, No.40.

ERIA WG on "Sustainability Assessment of Biomass Utilisation in East Asia" (2010), "Sustainability Assessment of Biomass Energy Utilisation in Selected East Asian Countries", ERIA Research Project Report 2009 No.12, http://www.eria.org/research/y2009-no12.html, (Accessed 16.07.2011).

European Union (2009), "Directive 2009/28/EC on the promotion of the use of energy from renewable sources", http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF, (Accessed 16.07.2011).

Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. (2008), "Land Clearing and the Biofuel Carbon Debt", Science, 319, 1235.

GBEP (Global Bioenergy Partnership) (2011), "GBEP 24 Sustainability Indicators for Bioenergy", http://www.globalbioenergy.org/programmeofwork/sustainability/gbep-24-sustainability-indicators/en/, (Accessed 16.07.2011).

German Federal Government (2007), "Ordinance on requirements applying to the sustainable production of biomass for use as biofuel (Biomass Sustainability Ordinance – BioNachV)", http://ec.europa.eu/enterprise/tris/pisa/cfcontent.cfm?vFile=120070679EN.DOC, (Accessed 16.07.2011).

IPCC (International Panel on Climate Change) (1997), “The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual”.

IPCC (International Panel on Climate Change) (2007), “IPCC Fourth Assessment Report: Climate Change 2007 (AR4)”.

ISO (International Organization for Standardization) (2010), “ISO standard to make bioenergy sustainable”, http://www.iso.org/iso/pressrelease.htm?refid=Ref1282, (Accessed 16.07.2011).

IUCN (International Union for Conservation of Nature) (2001), “IUCN Red List Categories and Criteria. Version 3.1”, Gland, Switzerland: IUCN.

Johnson, E. (2009), “Goodbye to carbon neutral: Getting biomass footprints right”, Environmental Impact Assessment Review, 29 (3), 165-168.

Karr, J.R. and Dudley, D.R. (1981), “Ecological perspective on water quality goals”, Environmental Management 5: 55-68.

Kendall, A., Chang, B. and Sharpe, B. (2009), “Accounting for Time-Dependent Effects in Biofuel Life Cycle Greenhouse Gas Emissions Calculations”, Environmental Science and Technology, 43 (18), 7142-7147.

Loh, J. and Wackermagel, M. (2004), “Living Planet Report 2004”, Gland, Switzerland: WWF International.

MA Board (2005), “Millennium Ecosystem Assessment”, Washington: Island Press.

MDGIs (Millennium Development Goals Indicators) (2011), “Millennium Development Goals Indicators – The official United Nations site for the MDG Indicators”, http://mdgs.un.org/unsd/mdg/Default.aspx, (Accessed 05.10.2011)

Mencher, J.P. (1989), “Women’s Work and Poverty: Women’s Contribution to Household Maintenance in Two Regions of South India”, in “A Home Divided: Women and Income Control in the Third World” edited by D. Dwyer and J. Bruce, Stanford University Press, 99-119.

MNRE (2010), “Annual Report of Ministry of New and Renewable Energy”, Government of India, New Delhi.

Murphy, D.J. and Hall, C.A. (2010), “Year in review EROI or energy return on (energy) invested”, Annals of the New York Academy of Sciences 1185: 102-118.

Persson, U. M. and Azar, C. (2010), “Preserving the World's Tropical Forests - A Price on Carbon May Not Do”, Environmental Science and Technology, 44 (1), 210-215.

RSB (Roundtable on Sustainable Biofuels) (2010), “RSB Principles & Criteria for Sustainable Biofuel Production (Version 2.0)”, http://rsb.epfl.ch/files/content/sites/rsb2/files/Biofuels/Version%202/PCs%20V2/11-03-08%20RSB%20PCs%20Version%202.pdf, (Accessed 16.07.2011).

Sagisaka, M. (2008), “Sustainable Biomass Utilisation Vision in East Asia”, ERIA Research Project Report 2007 No.6-3, http://www.eria.org/research/no6-3.html, (Accessed 16.07.2011).

Sagisaka, M. (2009), “Guidelines to Assess Sustainability of Biomass Utilisation in East Asia”, ERIA Research Project Report 2008 No.8-2, http://www.eria.org/research/y2008-no8-2.html, (Accessed 16.07.2011).

Searchinger, T., Heimlich, R. and Houghton, R. (2008), “Use of U.S. Croplands for

Biofuels Increases Greenhouse Gases through Emissions from Land-Use Change”, Science, 319, 1238.

Tallec, F and Bockel, L. (2005), “Commodity Chain Analysis: Constructing the Commodity Chain Functional Analysis and Flow Charts”, EASYPol Module 43 to 44_Agricultural policy Support Service, Food and Agriculture Organization of the United Nations.

The project group “Sustainable production of biomass”, the Netherlands (2007), “Testing framework for sustainable biomass”, http://www.lowcvp.org.uk/assets/reports/070427-Cramer-FinalReport_EN.pdf, (Accessed 15.07.2011).

UK DfT (United Kingdom Department for Transport) (2008), “Renewable Transport Fuels Obligation”, http://www.dft.gov.uk/topics/sustainable/biofuels/rtfo/, (Accessed 15.07.2011).

UNESCAP (United Nations Economic and Social Commission for Asia and the Pacific)(2005), “Energy services for sustainable development in rural areas in Asia and the Pacific: policy and practice”, Energy Sources Development Series No. 40.

UNDP (United Nations Development Progamme) (2008), “Human Development Report 2007/2008. Fighting climate change: Human solidarity in a divided world”.

UNDP/WHO (United Nations Development Programme/World Health Organization) (2009), “The Energy Access Situation in Developing Countries: A Review focusing on Least Developed Countries and Sub-Saharan Africa”.

UNDP (United Nations Development Progamme) (2010), “Human Development Report 2010 – 20th Anniversary Edition. The Real Wealth of Nations: Pathways to Human Development”.

US EPA (Environmental Protection Agency) (2010), “Renewable Fuel Standard (RFS)”, http://www.epa.gov/otaq/fuels/renewablefuels/index.htm, (Accessed 16.07.2011).

WCED (World Commission on Environment and Development) (1987), “Our Common Future”, Oxford University Press.

Weaver, W. and Shannon, C.E. (1949), “The Mathematical Theory of Communication”, Urbana, Illinois: University of Illinois.

Wicke, B., Sikkema, R., Dornburg, V. and Faaij, A. (2011), “Exploring land use changes and the role of palm oil production in Indonesia and Malaysia”, Land Use Policy, 28 (1), 193-206.

WWAP (The United Nations World Water Assessment Programme) (2003), “Water for People, Water for Life (WWDR1)”, Oxford, UK: Berghahn Books.

APPENDIX. SUPPLEMENTARY INFORMATION FOR SOCIAL PILLAR

1. Millennium Development Goals (MDG)

The Millennium Development Goals (MDG) and targets originated at the Millennium Declaration, signed by 189 countries, including 147 heads of State and Government, in September 2000 (MDGIs, 2011), and from further agreement by member states at the 2005 World Summit. The goals and targets are interrelated and should be seen as a whole. They represent a partnership between the developed countries and the developing countries "to create an environment – at the national and global levels alike – which is conducive to development and the elimination of poverty".

a) For monitoring country poverty trends, indicators based on national poverty lines should be used, where available.

b) The actual proportion of people living in slums is measured by a proxy, represented by the urban population living in households with at least one of the four characteristics:
   (a) lack of access to improved water supply;
   (b) lack of access to improved sanitation;
   (c) overcrowding (three or more persons per room); and
   (d) dwellings made of non-durable material.

The official list of MDG indicators can be found at: http://mdgs.un.org/unsd/mdg/Default.aspx

2. Comparison with GBEP Indicators for Social Pillar

Table 1 shows the relevance of the GBEP's Sustainability Indicators for social pillar to social factors observed in the pilot studies. Remarks on applicability to East Asian context in terms of quantification or observability are based on first hand experiences after conducting the pilot studies.

Table 1. Comparison with GBEP Indicators for Social Pillar

INDICATOR NAME	INDICATOR DESCRIPTION	EAST ASIAN CONTEXT
Allocation and tenure of land for new bioenergy production	Percentage of land – total and by land-use type – used for new bioenergy production where A legal instrument or domestic authority establishes title and procedures for change of title; and The current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title	Was not observed in the pilot cases
Price and supply of a national food basket	Effects of bioenergy use and domestic production on the price and supply of a food basket, which is nationally defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, and/or household level, taking into consideration: Changes in demand for foodstuffs for food, feed, and fibre; Changes in the import and export of foodstuffs; Changes in agricultural production due to weather conditions; Changes in agricultural costs from petroleum and other energy prices; and	Changes in demand and supply of foodstuffs used as biofuel feedstocks could be observed; data may also be available but were not included in the pilot case study questionnaire

	The impact of price volatility and price inflation of foodstuffs on the national, regional, and/or household welfare level, as nationally-determined	
Change in income	Contribution of the following to change in income due to bioenergy production: Wages paid for employment in the bioenergy sector in relation to comparable sectors Net income from the sale, barter and/or own-consumption of bioenergy products, including feedstocks, by self-employed households/individuals	Observable
Jobs in the bioenergy sector	Net job creation as a result of bioenergy production and use, total and disaggregated (if possible) as follows: Skilled/unskilled Temporary/indefinite Total number of jobs in the bioenergy sector and percentage adhering to nationally recognized labour standards consistent with the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work, in relation to comparable sectors	Observable but problems of double counting could happen especially that biofuel production entails a lot of existing independent activities from growing of the crops to processing May not create new jobs in case of farmers or other skilled workers in processing plants but could enhance “market reliability” as biofuel industry could be an additional market for

		farmers to sell their produce or enhance "job security" for processing employees
Change in unpaid time spent by women and children collecting biomass	Change in average unpaid time spent by women and children collecting biomass as a result of switching from traditional use of biomass to modern bioenergy services	Observable though not critical in pilot cases; collection of firewood were done in their own farms (e.g. fallen leaves of coconut trees) and somewhat integrated to farmer's activities
Bioenergy used to expand access to modern energy services	Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type), measured in terms of energy and numbers of households and businesses Total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional use of biomass	Observable though except for Jatropha farmers, other farmers in the pilot cases were not able to use the end bioenergy product coming from their feedstocks Impact could be as effect of additional income from engaging in biofuel production, they could afford to shift to avail modern energy services
Change in mortality and burden of diseases attributable to indoor smoke	Change in mortality and burden of disease attributable to indoor smoke from sold fuel use, and change in these as a result on the increased deployment of modern bioenergy services, including improved biomass-based cookstoves	From the survey conducted in Jatropha pilot study site in Indonesia, it was difficult to establish the impact of indoor smoke to overall health (especially in cases where smoking

		inside the house for adult males were common) Farm houses in Southeast Asia generally have kitchen windows or use light materials as wall so indoor smoke from cooking escapes though leaving black soot in the wall and cooking utensils
Incidence of occupational injury, illness and fatalities	Incidences of occupational injury, illness and fatalities in the production of bioenergy in relation to comparable sectors	Observable

3. Qualitative Sub-Indicators for Social Assessment

In addition to the results of sustainability assessment of biomass utilisation for social pillar using the HDI and GDI, as have been highlighted in our previous report (ERIA, 2010), some other factors that may affect social changes due to the use of biomass energy were observed in four pilot studies, whose details are addressed again as follows:

- As food need of the growing population in all countries is more important than biofuels' development, it is necessary that enough safeguards be in place. It was observed that governments are careful about the "food versus fuel competition". For example, in India, national policy on biodiesel production focuses on use of waste lands for cultivation of Jatropha and other non-edible tree oils.
- Studies observed that it was difficult to convince farmers to take up the biomass plantation, as it was not economically viable for them. One way to encourage them is to explore the potential of linking biofuel plantation, which depend on energy crop planted, with afforestation measures, which may assign Certified Emission Receipts (CER) benefits to plantation projects resulting in an increase in farmers' income. Other possibility is to provide them financial help to initiate some ancillary activities along with biofuel crops so that they are able to survive during gestation (non-yield) period.
- Both direct and indirect social impacts were observed, although not measured, during the surveys. For example, in the Jatropha project site in Indonesia, women felt empowered to earn a side income and they were proud to be involved in the

government's Self Sufficient Energy Village (SSEV) project, which extends beyond their village. Similarly, the change in Human Development Index (HDI) among farmers at Jatropha plantation of tree oil farms in India may not be that significant but from personal interviews, it was noted that the opportunity to send their children to school was one of the benefits they cited after getting engaged in the farm. Such issues are important aspects of social assessment of biofuel production and should be considered.

- Additional social indices relevant at community level should be added even if they may not be quantified. For example, although the Thailand study found a negative change in HDI for the sugarcane plantation but still farmers involved in the process felt happy as their link with the sugar mill was more or less certain and annual income secured. Some other Social Development Indices (SDIs) at community level could be increased income of the employees, better education for the children, improved health conditions and probably improved relationship in the plant or community, among others.