Chapter 4

Indicators Applicable at Different Scales

Sustainability Assessment of Biomass Utilisation in East Asia
Working Group

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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).

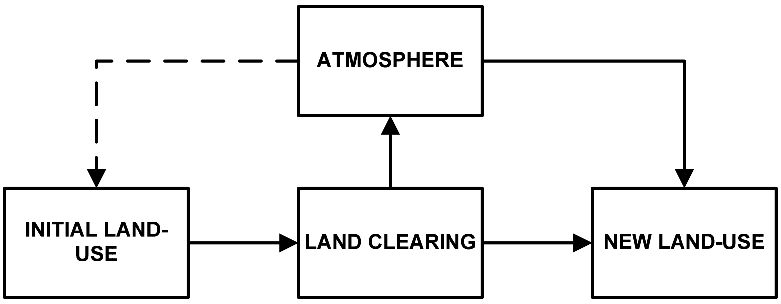
Indirect land use change (iLUC): occurs outside the system boundaries, but is attributable to activities occurring inside those boundaries. For example, if biofuels displace other crops and reduce supplies in the near term, this leads to increased prices that provide motivation for producers in other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

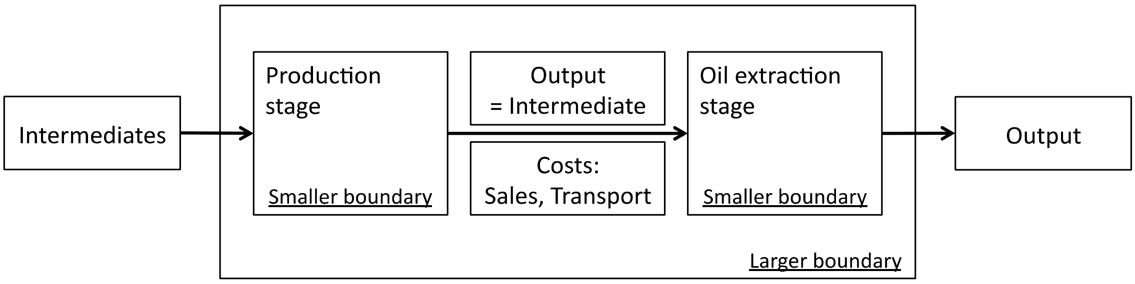
As in national accounts, TVA in this study is also calculated as output value minus costs of intermediates:

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

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):

$$\text{Tax} = \text{Total taxable income} \times \text{Tax rate} \qquad (4\text{-}3)$$

Where

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

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.

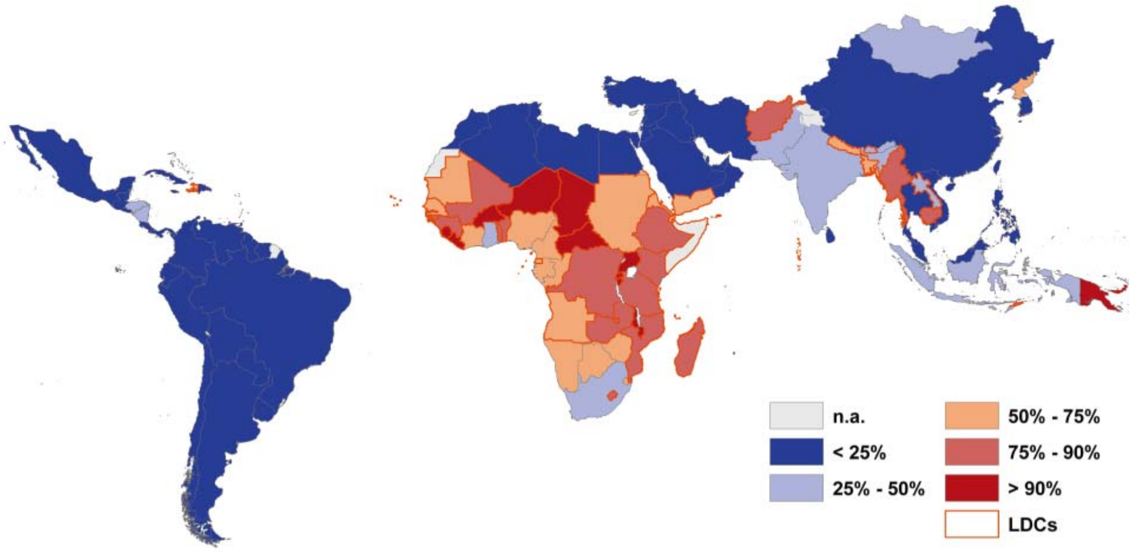
4.3.1.1. Employment Generation

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.