Chapter 3

Sustainability Assessment Methodology

2009

This chapter should be cited as

Working Group for Sustainability Assessment of Biomass Utilisation in East Asia (2009), 'Sustainability Assessment Methodology' in Sagisaka, M. (ed.), *Guidelines to Assess Sustainability of Biomass Utilisation in East Asia*, ERIA Research Project Report 2008-8-2, Jakarta: ERIA, pp.15-50.

3. SUSTAINABILITY ASSESSMENT METHODOLOGY

3.1 ENVIRONMENTAL IMPACT - Life Cycle Approach to Develop Greenhouse Gas Inventory -

3.1.1 Introduction

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 sustainability development. Although LCA can be used to quantitatively assess the extent of impact of a product system toward environmental issues of concern such as acidification, eutrophication, photooxidation, toxicity and biodiversity loss, these impact categories are currently not in the limelight as compared to 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.

One of the widely accepted climate change mitigation approach is the propagation of renewable energy for GHG avoidance, and concurrently address the issue of energy security. Biomass that is converted to bioenergy is a source of renewable energy. Hence, the impact of using bioenergy in the transport and power generation sectors will be significant provided the life cycle release is reduced compared to fossil fuel. The cradle to grave life cycle of a type of bioenergy, used for transportation or power generation is shown in Figure 3-1-1.

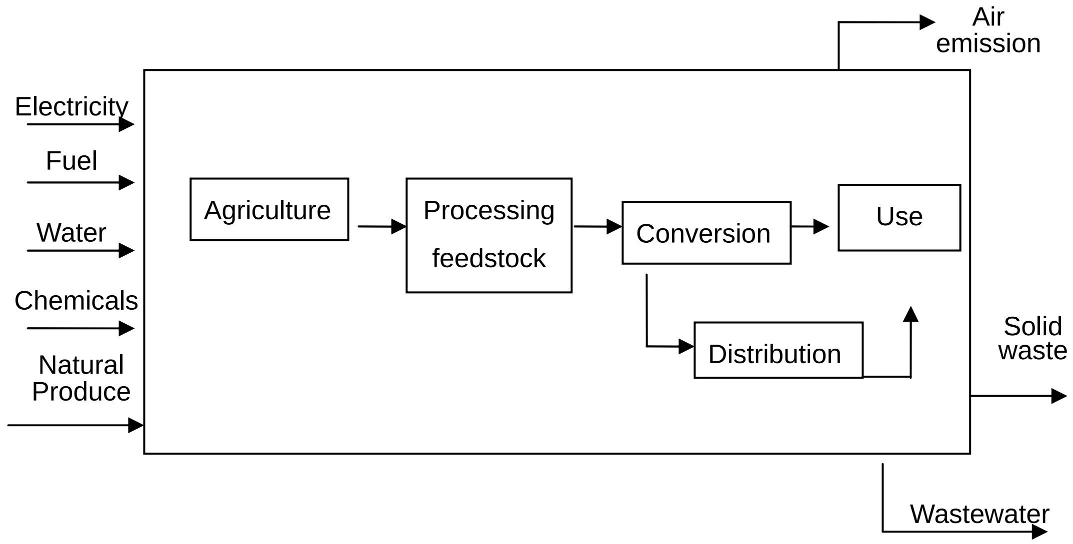


Figure 3-1-1: System boundary for the cradle to grave life cycle inventory of bioenergy

Based on the two main ISO standards on LCA, ISO 14040 and ISO 14044[5], conducting a LCA study consists of four phases. However, in estimating GHG emission specific for biomass energy, only the procedures associated with life cycle inventory (LCI) analysis involving compilation and quantification of inputs and outputs for a given biomass energy throughout its life cycle will be carried out.

The LCI for bioenergy should cover CO_2 and non-CO_2 greenhouse namely CH_4 and N_2O that are released directly or indirectly from agricultural activities. The GHG inventory will be reported as CO_{2equi} and the summation of contribution from non-CO_2 gases will be based on the Global Warming Potential (GWP) for a 100-year time horizon of CH_4 and N_2O at 25 and 298 times, respectively.

3.1.2 Conducting an LCI Analysis of Bioenergy

The life cycle stages of a bioenergy are comprised of the following:

- Agriculture

[5] ISO 14040 Environmental management – Life cycle assessment – Principles and framework
ISO 14044 Environmental management – Life cycle assessment – Requirements and guidelines

- Feedstock processing
- Conversion
- Distribution
- Use

Of the five stages, the cultivation of feedstock materials, summed under agriculture has in most cases contributed to highest emission of GHG. It is in fact highlighted as the stage that requires the most intervention from policy makers. At the same time, it is also the most complex stage where input and output data are not easily measured, and are subjected to estimates and modelling. Hence, the agriculture stage will also be discussed in greater details as compared to the other stages.

(i) Agriculture Stage

The agriculture activities and practices that are contributors to the GHG inventory of bioenergy feedstock materials are:

- Land-use change
- Land fertilisation especially synthetic fertilisers
- Emission from residue degradation in the field
- Emission from soil

There are minimal measured data of the GHG contributions of each of these stages. Most of the studies use equations and default values proposed by the International Panel on Climate Change (IIPCC)[6]. The GHG emissions are primarily related to human activities which:

- Change the way land is used or
- Affect the amount of biomass in existing biomass stocks

(a) Land-Use and Land-Use Change (LULUC)[7]

[6] [Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual]

[7] Intergovernmental Panel on Climate Change: Good Practice Guidance for Land Use, Land-Use Change and Forestry, IPCC National Greenhouse Gas Inventories Programme

There are six Land-Use Categories listed under IPCC: forest land, cropland, grassland, wetlands, settlement and other lands.

Land use change refers to the conversion of one type of land (e.g. forestland) to another (cropland) and leads to changes in carbon in the biomass pools. Table 3-1-1 is a summarised version of the definitions of carbon pools in the terrestrial system according to IPCC, but which can be modified to reflect local conditions.

Table 3-1-1: Brief definition for terrestrial pools based on IPCC guidelines

Pool		Description*
Living biomass	Above-ground biomass	All living biomass (expressed in tonnes dry weight) above the soil including stem, stump, branches, park, seeds and foliage.
	Below-ground biomass	All living biomass of live roots except fine roots <2mm diameter.
Dead organic matter	Dead wood	Includes all non-living woody biomass not contained in the litter and includes wood lying on the surface, dead roots, and stumps ≥10 cm in diameter.
	Litter	Includes all non-living biomass with a diameter < 10cm (e.g.), lying dead, in various states of decomposition above the mineral or organic soil. This includes the litter, fumic, and humic layers.
Soils	Soil organic matter	Includes organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series.

To estimate the changes in GHG emission related to a specific land-use change, three sets of information are critical:

- The carbon stock of the original and changed land-use
- The information on land area affected by the land-use change
- The time frame in which the new land-use change will remain status quo until the next change

The first order approach recommended by IPCC to estimate the GHG emission from land-use change is based on the simple assumptions of:

- the change in carbon stock related to land-use change
- biological responses of vegetation and soils following the land-use change

The input data required to establish the GHG inventory for land-use change will be extracted primarily from the IPCC manual. Of the six categories of land identified under IPCC, land that supplies biomass feedstock materials for use or conversion to bioenery can be referred to as 'cropland'. Within the remainder five categories, it is logical to assume the land-use change will take the form of:

- forest land to cropland
- grassland to cropland
- cropland of one type of crop to cropland of another type of crop
- wetland to cropland
- cropland remaining cropland

Working on the assumption that change in carbon stock is assumed equivalent to carbon loss in the form of GHG emission during land-use change, the following equations can be used to estimate the loss:

$$L_{conversion} = C_{After} - C_{Before} \qquad \text{(Equation 1)}$$[8]

$L_{Conversion}$ = carbon stock change per area for that type of conversion when land is converted, tonnes ha^{-1}

C_{After} = carbon stocks in biomass immediately after conversion, ton C ha^{-1} (cropland)

C_{Before} = carbon stocks in biomass immediately before conversion, ton C ha^{-1} (forest land, grassland, wetland, from one type to another type of cropland)

(b) Land preparation and fertilisation

The two main forms of GHG related to agriculture soil management are nitrous oxide (N_2O) and CO_2. N_2O from managed soils of croplands for biomass feedstock materials are released from anthropogenic N inputs or N mineralisation through two

[8] Equation 3.3.8, IPCC Good Practice Guidance for LULUCF, IPCC, 2003

primary pathways[9]:

o direct emissions from the soil through the natural process of nitrification and denitrification of available N in the soil;

o indirect emissions through the same natural process as above on NH_4^+ and NO_3^- that have deposited in the soil through two routes involving volatilisation, and leaching and runoff.

Figure 3-1-2 summarises some of the default emission factors obtained from 2006 IPCC Guidelines to estimate direct and indirect emissions of N_2O with respect to N inputs.

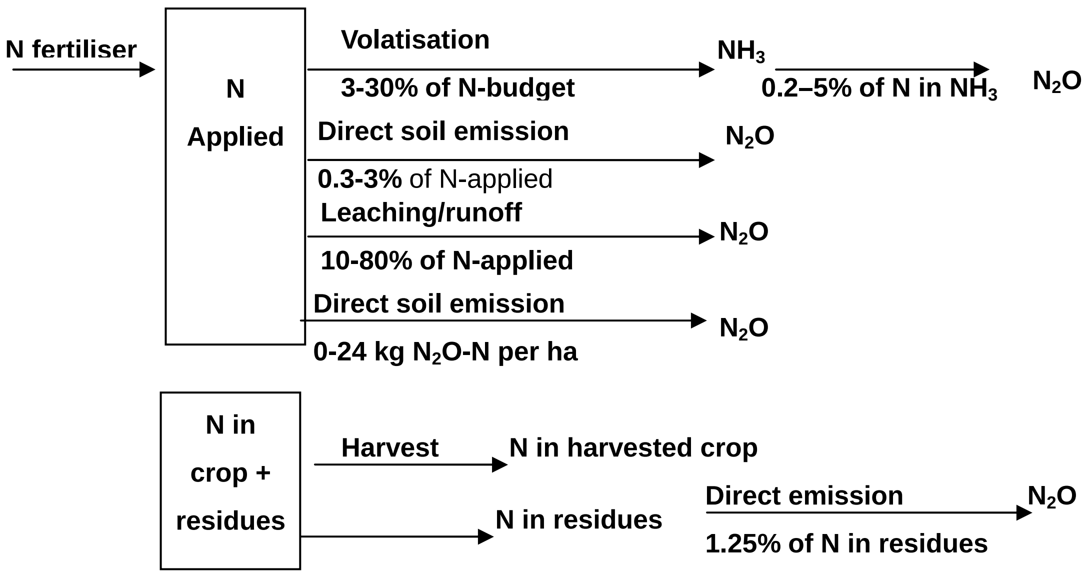


Figure 3-1-2: IPCC method for estimation of N_2O emission based on range of conversion values related to activities and region.

(c) Contribution from liming and other natural events

Agricultural lime (aglime) in the form of crushed limestone (CaCO3) and crushed dolomite ($MgCa(CO_3)_2$) are applied to agricultural soils to increase soil pH. Following the supposition by IPCC that all C in aglime is eventually released as CO_2 to the atmosphere, the CO2 emissions from addition of carbonate limes to soils are estimated based on amount (M_x) and default emission factors (EF_x) of CO_2 for two major types of

9 IPCC Guidelines for National Greenhouse Gas Inventories, Chp. 11, 2006

aglime i.e. limestone and dolomite. The Annual C emissions from lime applications, tonnes C yr^{-1} denoted as CO_2-C *Emission* is estimated as follows:

CO_2-C *Emission* = $(M_{Limestone} * EF_{Limestone}) + (M_{Dolomite} * EF_{Dolomite})$ (Equation 2)

There are two other sources of emission during the agriculture stage namely emission from residue degradation in the field, and emission from soil. Contribution from residue degradation is estimated based on change in carbon stock change and emissions resulting from natural decay or burning during land clearing. However only CH_4 and N_2O, released during these activities is absorbed into the GHG accounting for agriculture activities as CO_2 is emitted is considered neutral.

(d) Emission from soil

Land conversion to cropland that entails intensive management will usually result in losses of C in soil organic matter and dead organic matter. IPCC Guidelines assumes any litter and dead wood pools should be assumed oxidized following land conversion and changes in soil organic matter.

$\Delta C_{LCSoils} = \Delta C_{LCMineral} - \Delta C_{LCorganic} - \Delta C_{LCLiming}$ (All parameters in tonnes C yr^{-1})

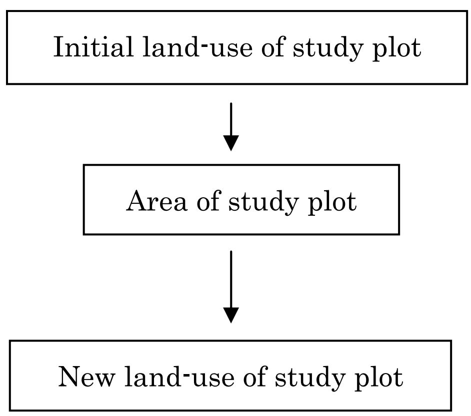
(Equation 3)

$\Delta C_{LCSoils}$ = change in carbon stocks in soils in land converted to cropland

$\Delta C_{LCMineral}$ = change in carbon stocks in mineral soils in land converted to cropland

$\Delta C_{LCorganic}$ = C emission from cultivated organic soils converted to cropland

$\Delta C_{LCLiming}$ = emissions from lime application on land converted to cropland



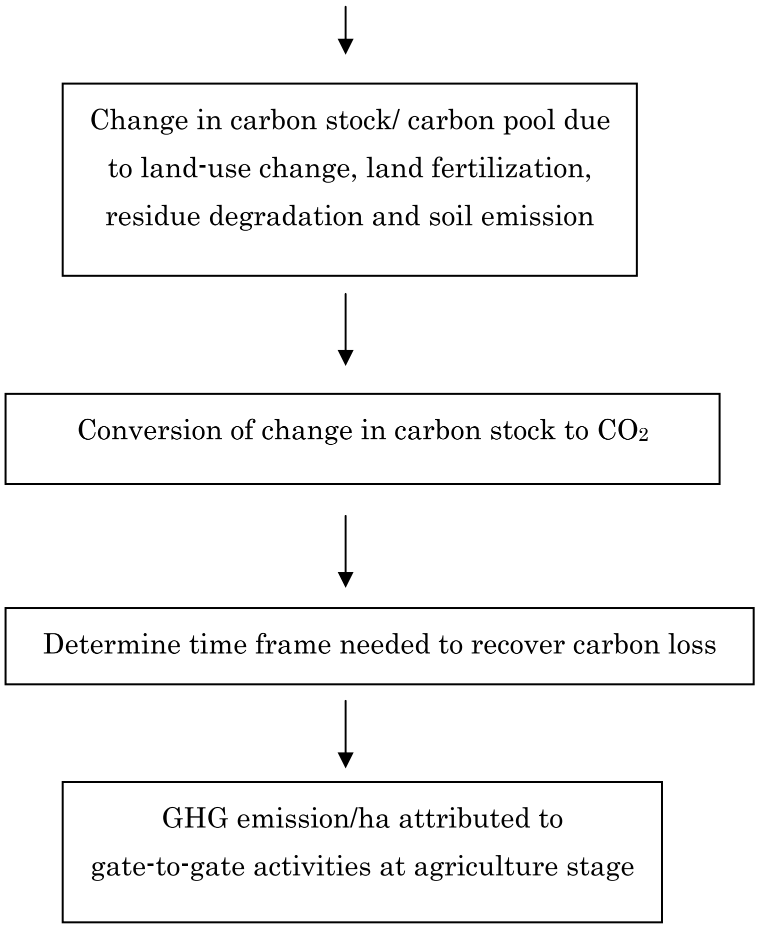


Figure 3-1-3: Flow diagram of data acquisition required to calculate the GHG emission related to land-use and crop management of biomass feedstock materials.

Although a laborious process, the GHG inventory related to agricultural activities beginning with land preparation such as Land Use and Land-Use Change (LULUC) has been viewed as a significant contribution to GHG emission in the cultivation of biomass feedstock material. Its' inclusion in the GHG-LCI of bioenergy is necessary to ensure the carbon footprint values calculated according to this guideline is considered credible. Figure 3-1-3 summarises the steps for estimating the GHG emission for production of biomass feedstock.

In completing the LCI for agriculture stage, emissions related to the production of materials, chemicals, conventional fuels and other manufactures, including fuel for transportation are included, as is normally calculated in the LCA methodology.

(ⅱ) Processing, Conversion, Transformation and Utilisation Stages

The GHG emissions from the production processes generally differ by technologies, efficiencies and management practices. Direct measurements for input and output data are more readily available and less complex than the agriculture stage. Irrespective of the technologies and processes, GHG inventory:

- Resource consumption: fossil fuels, minerals, water, chemicals
- Electricity consumption
- Air pollution (including GHGs) emissions
- Wastewater discharge
- Solid waste generation

Within this product system is the emission from transportation and distribution. Emission from open ponding treatment system may require more tedious measurement to obtain average data. In general, an appropriately structured questionnaire will guide collection of input and output data relevant to develop the LCI of a type of bioenergy from agriculture to the biofuel production stage. The end-of-life stage for biofuel is not included in the LCI as burning of biofuel whether for transportation or power generation is considered CO_2 neutral.

3.1.3 Recommendations

The drivers for the development of Biomass Utilisation as Bionergy in East Asia have been energy security and development of a potential new economic sector. In this respect, environmental criteria of biomass derived fuel has not been emphasised greatly unless required by the export market. Environmental aspects should be given due attention with the rapid expansion of bioenergy, in particular life cycle GHG profile or carbon footprint.

Eight recommendations are forwarded as a result of the ERIA sponsored project on "Investigation on Guidelines for Life Cycle Green House Gas Calculation in the Utilisation of Biomass for Bioenergy".

(i) LCA is a relevant tool to develop the GHG profile or carbon footprint of bioenergy

LCA is one of the relevant methodologies, which can assist policy makers to establish the significance of environmental issues in relation to economical and social factors. The cradle to grave approach incorporates contributions from every source in the bioenergy pathway including emissions from the use of fossil fuels at some stages of the life cycle and also land-use change.

Although the full LCA methodology is not needed since the LCI phase is sufficient to quantify the GHG profile of bioenergy, it is recommended that the implementation of the LCI phase be carried out in accordance with ISO 14040 and ISO 14044 as far as is practicable. Justification should be given for deviation from the standard recommendation.

(ii) Issues on land-use

It is recommended that the six land-use categories introduced by IPCC be adopted by all member countries namely forest land, cropland, grassland, wetland, settlement and other land. This adoption is required to enable comparison of GHG profile of bioenergy from land-use change perspective. However it is pertinent that East Asia establish data on the type of land-use prevalent in the region, including land-use change such as logged over and secondary forest that are being converted to cropland. In spite of the high uncertainty associated with the IPCC emission factors, they will still be used until regional or local data are obtained scientifically.

(iii) Indirect Land-Use Change

There are increasing pressures from some legislative framework, especially from EU to consider indirect land-use change when computing the GHG profile of a bioenergy. Direct land-use change occurs as part of a specific supply chain while ‘indirect’ land use change is a consequence of market forces. Proposed methodologies that quantify GHG emission related to indirect land-use change modify the conventional LCA technique and contain attributes that are more policy-based than science-based. The approach does not fall under the LCA methodology prescribed by the ISO standard and should not be included in the life cycle inventory.

(ⅳ) Peatland Management

In recent years, land-use change for conversion of peatland into cropland such as oil palm plantation has been hotly debated in particular on the potential magnitude of GHG emission. While there is little agreement on emission rate of GHG from converted peatland due to limited measured data, it is accepted that drainage of peatland for agriculture purpose does potentially reduce a carbon reservoir. In view of the existence of substantial areas of peatland in some parts of East Asia, it is recommended that any effort to increase understanding of the CO_2 flux of peatland should be highly supported.

(ⅴ) Carbon sequestration/ capture

IPCC estimates GHG emission from carbon stock change based on rates of carbon losses and gains by a given area of land-use change according to equation herewith:

$$\Delta C = \sum_{ijk} [A_{ijk} * (C_I - C_L)_{ijk}] \quad \text{(Equation 4)}$$

ΔC = carbon stock change in the pool , tonnes Cyr^{-1}

A= area of land, ha

ijk = corresponds to climate type *I*, forest type *j*, management practice *k* etc.

C_I = rate of gain of carbon, tonnes C $ha^{-1}yr^{-1}$

C_L = rate of loss of carbon, tonnes C $ha^{-1}yr^{-1}$

The default assumption in the IPCC Guidelines is that carbon removed in wood and other biomass from forests is oxidised in the year of removal and have provided a rather complicated approach for their conversion to wood products, existing as biogenic carbon or stored carbon. In this respect, PAS 2050 has sought to address this stored carbon or biogenic carbon by assigning a 100-year period of storage.

Since carbon capture or sequestration has a significant impact on the life cycle footprint of biomass derived energy, it is important that this carbon removal cycle at the feedstock supply stage be studied and any principles to be proposed must represent the East Asian region. The importance of biogenic carbon introduced by PAS 2050 is relevant to the development of the GHG estimation system for East Asia especially felled biomass that are not used as fuel but transformed into panels and furniture.

(vi) Reference data/ values at regional level

Development of a regional database on LCI data for bioenergy would assist the carbon footprinting of bioenergy. For example the European Reference Life Cycle[10] Database (ELCD) has under its Energy section data sets on electricity, fuels, thermal energy and pressurised air that can be used quite appropriately for anyone doing LCA within the EU region.

Similarly developing and transition countries of East Asia would require background data and conversion factors to enable them estimate life cycle data of GHG emission or release. The data sharing will also enable some form of standardisation among the 16 countries such as terminologies, methodologies, cut-off criteria, time frame (including for annualising) and fundamentals such as form of reporting, functional units, allocation principles, carbon offsets and capture.

(vii) Tier Approach to Data Collection

It is proposed that data collection follow the IPCC three methodological tiers for estimating GHG emissions and removals by each contributing source. Tiers correspond to a progression from the use of simple equations with default data to country-specific data in more complex national systems. The three general tiers are briefly described in Table 3-1-2.

---

[10] M.A.Wolf et.al., Meeting Among Int. Partners on The International Reference Life Cycle Data System, Nov. 2008, JRC European Commission

Table 3-1-2: Summary of the Three Tier Levels for Estimation of GHG Emissions for Landuse Change[11]

Tier 1	o Applies equation 3 for changes in two carbon pools namely 'aboveground biomass' and carbon in the top 0.3 m of the soil o Carbon accounting required only for wood harvested as biofuels for estimating non-CO_2 gases. o Use default emission factors provided by IPCC (until East Asia values are established). o Use activity data that are spatially coarse, such as nationally or globally available estimates of deforestation rates, agricultural production statistics, and global land cover maps.
Tier 2	Same methodological approach as Tier 1 but applies emission factors and activity data that are country-specific including specialised land-use categories.
Tier 3	Higher order methods are used including models and inventory measurement systems tailored to address national circumstances, i.e. detailed country-specific data. Provides estimates of greater certainty than tiers 1 and 2.

(viii) Reporting vs Targets-Setting

The GHG profile that is eventually calculated should not include offsets for fossil fuels replacement nor report in terms of carbon payback period. Comparative performance based on the GHG profiles of different bioenergy is one of the approaches to encourage improvement of production of feedstock materials, e.g. improved plantation management practices, and improved processing technologies that will reduce use of fossil fuel through energy efficiencies and waste minimisation, including utilisation of process wastes.

For comparative performance, a number of functional units such as kg CO_2/MJ of the fuel should be made available for objective evaluation among different forms of bioenergies and their production methods.

[11] IPCC Good Practice Guidance for Land Use and Land-use Change and Forestry

3.2 ECONOMIC IMPACT - Methodologies Used in the Calculation of Indices for Economic Assessment -

3.2.1 Introduction

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 ascertained without depriving such opportunity to the future generation. 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 to be 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 for an accurate measurement of the economic performance of a particular industry such as biomass.

Previous studies have identified a number of benefits arising from biomass production and processing. For instance, a number of studies have described and estimated these impacts as follows. An article published at the Geo-energy website dated 2005 mentioned that the U.S. geothermal industry supported some 11,460 full time jobs in 2004. Tax revenues from geothermal activities amounted to $12 million supplying 25% of the tax base for a rural town in California. Other economic contributions mentioned in the article were reduction in foreign oil imports, price stability, and fuel supply diversification. The American Solar Energy Society cited that renewable energy and energy efficiency industries created a total of 8.5 million jobs in 2006 throughout the United States. A case study in Columbia County accounted for 170 full time jobs during construction and 39 full time permanent operations jobs generated by the existing wind facilities. Additionally, wind facilities contributed $1.3 million in annual tax revenues. In 2008, an article about the benefits of landfill gas energy stated that cost savings which can be translated to millions of dollar savings could be realized through the replacement of expensive fossil fuels by landfill gas use. In an article entitled "Rural communities can gain big economic benefits from wind energy" in 2001, it was pointed out that wind farms on rural land can earn more money per acre for farmers and ranchers than many traditional agricultural activities.

Based on 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 in establishing the guidelines in economic impact assessment specifically for this study.

3.2.2 Economic Assessment of Biomass Utilisation

(i) Gross Value Added or Total Profit before Taxes

Value addition refers to the increase in worth of a biomass product in terms of profit by undergoing certain processes or conversion to come up with a marketable energy product. Gross value added, as used in this study, is the sum of the value addition or net profit before tax generated out of the main product and the by-products from conversion or processing. The following equation was adopted to compute value addition:

$GVA = VA_a + VA_b$; where,

VA_a – value added from main product

VA_b – value added from by-products

The value added for both the main products and the by-products can be computed using the following equation:

$VA_a = GR_a – TC_a$; and,

$VA_b = GR_b – TC_b$; where,

GR – Gross or Total Revenue

TC – Total Cost

a – Main Product

b – By-products

Quantifying gross revenue was relatively easier as compared to quantifying the total cost. Gross revenue is simply the product of price and quantity (applies to both main product and by-products). Total cost, on the other hand, was calculated in every stage of the conversion process – from the initial up to the final product. This can be better illustrated by dividing the cost calculation into three stages. First stage is regarded as the *Production* stage. This stage accounts for the costs incurred in the actual production process of the raw material or initial product. The costs associated in this stage can be collectively described as the farming costs. The formula adopted is as follows:

TC = Direct Costs + Indirect Costs; where,

Direct Costs – Planting material, fertilizer, direct labor (hauling, transplanting, weeding, fertilizing, and other maintenance operations)

Indirect/Other Costs – Land preparation, harvesting, transportation

The second stage can be termed as *Primary Processing*. In this stage, the raw material or initial product undergoes processing up to the point in which the output is already a convertible material for biodiesel production. The costs associated in this stage can be distinguished as the extraction costs. The following equation was used for calculation:

TC = Direct Costs + Indirect Costs; where,

Direct Costs – Costs of raw material, direct labor

Indirect/Other Costs – Administrative costs, utilities such as electricity and water, miscellaneous overhead such as helper, fuel, fees and local taxes and loan interest, selling cost such as depreciation of fixed assets, and trucking

The third stage is *Secondary Processing*. From the readily convertible material in the second stage of production, certain processes such as esterification are undertaken to produce the final product which is biodiesel. The costs associated in this stage can be referred to as the biodiesel production costs. Total cost was computed as follows:

TC = Direct Costs + Indirect Costs; where, Direct Costs – Raw material costs, Direct operating labor

Indirect/Other Costs – Plant maintenance and repair, operating supplies, utilities, fixed charges such as depreciation, property taxes and insurance, and plant overhead costs

(ii) Employment

Job creation is another indicator for assessing the economic impact of the biomass industry. In a study concerning the sustainability criteria and indicators for bioenergy, it was cited that one of the possible indicators for job creation is the number of jobs or position per unit of energy produced throughout the entire chain of production. The same concept was adopted by this study in determining the employment impact of the biomass industry. The number of jobs generated with the presence of the energy project was computed as follows:

Employment = Total Production x Labor Requirement for every unit produced

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

(iii) Tax Revenues

Government revenues in terms of taxes collected from the different key players of the biomass industry prove to be another economic benefit worthy of valuation. For instance, take into account the coconut industry of the Philippines as the biomass industry under consideration. Mature coconut (*Production* stage) is processed into copra. Copra is then processed into coconut oil (*Primary Processing*). Finally, coconut oil is processed into the final product – coconut methyl ester (*Secondary Processing*). Taxable sectors of the industry may include the farmers and the various sectors in the production chain. However, under the Philippine agrarian reform program, farmers are exempted from paying taxes. Therefore, tax-generating sectors include those players under the primary and secondary processing stages only. The total taxable income under these stages of production shall be multiplied by the prevailing tax rate to obtain the actual amount of tax revenues. This can be further illustrated by the following equation:

Tax = Total Taxable Income x Tax Rate; where,

Total Taxable Income = income from main product (profit per unit x volume) + income from by-product (profit per unit x volume)

(iv) **Foreign Exchange**

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.

Foreign exchange savings can be accumulated from reduced diesel imports with the presence of the energy project. Since biodiesel is expected to at least displace if not replace a fraction of the overall diesel consumption of an economy, eventually imports will decrease. For both foreign exchange earnings and savings, the methods of computation are as follows:

Foreign Exchange Earnings = Price per unit of convertible material x Total volume of exports

Foreign Exchange Savings = Amount (in weight) of biomass x Density of biomass x Forex savings per diesel displacement

In the event that portions of the convertible material are both exported and consumed locally for biodiesel production, a tradeoff occurs. A fraction of the exportable amount would be diverted as input to biodiesel production. As a result, foreign exchange earnings would be reduced. The net effect of this tradeoff or net foreign exchange (Forex) earnings is valuated as follows:

Net Foreign Exchange Earnings = Reduced Forex Earnings + Forex Savings

(ｖ) **Total Value Added to the Economy**

Total value added to the economy refers to the total contribution of the biomass industry to the economy in terms of net profit after tax of stakeholders in the production and processing of biomass; total employment cost or wages and salaries paid to the employees in the biomass industry; tax revenues collected from the different key players of the biomass industry; foreign exchange earnings from exporting the readily convertible material for biodiesel production and foreign exchange savings from reduced diesel imports with the presence of the biomass energy project. The formula is:

Total value added to the economy = net profit after tax + wages and salaries paid + tax revenues + net forex earnings

where net profit after tax is equal to net profit before tax less tax revenues. The formula can be written as:

Total value added to the economy = net profit before tax + wages and salaries paid + net forex earnings

The economic indices, along with the methods of computation enumerated in this section, serve as guidelines in assessing the benefits brought about by biomass production and processing. This study aims to quantify the level and degree of the economic benefits by imputing actual values to provide a concrete overview of such benefits. Consequently, policymakers could have a grasp as to what aspects of the biomass industry are to be addressed in accordance with the purpose of boosting the national economy. A more important case in point is that biomass utilisation practices must gear toward achieving economic sustainability.

REFERENCES

ABLES, R. 2006. CME biodiesel or coco-biodiesel. Philippine Coconut Authority (PCA) Report.

BANZON, J.A. and J. R. VELASCO, Coconut: Production and Utilization, 1982

COCONUT INDUSTRY KIT. 2005.

DOE (Department of Energy) Philippine Energy Plan 2005-2014 (2006 Update)

ELAURIA, J.C., M.L.Y. CASTRO, M.M. ELAURIA, S.C. BHATTACHARYA and P. ABDUL SALAM. Assessment of Sustainable Energy Potential of Non-Plantation Biomass Resources in the Philippines. Volume 29. September 2005. pp. 191-198.

Lower snake river wind energy project. www.snakeriverwind.com/LSRW_031109.html. March 11, 2009.

LOZADA, E. 2002. RDE investments in the processing sector. Coconut Investment Plan 2002.

MAGAT, S. 2007. Coconut-cereal (corn) cropping model: Technology notes. Quezon City: Agricultural Research Management Department, Philippine Coconut Authority.

MAKARYAN, R. Defining community and economic benefits associated with large energy infrastructure projects: LNG Case Study. April 27, 2009.

NSCB (National Statistical Coordination Board). 2007. Regional Statistics.

PARSONS, L. Funding for clean energy projects. www.eesi.org/121708_stimulus. December 17, 2008.

PCA REGION IV-A. Magnitude of the industry: CALABARZON region. Retrieved September 13, 2007 from PCA Region IV on-line database on the World Wide Web: http://www.pcaagribiz.da.gov.ph/r4a/

PIMO(Provincial Information Management Office). 2006. Agriculture. Retrieved September 11, 2007 from Quezon Provincial Government on-line database on the World Wide Web: http://www.quezon.gov.ph/profile/agriculture

PUNCHIHEWA P. and R. ARANCON. 1996. Asian and Pacific Coconut Community (APCC) paper.

QUICOY, C., M. ELAURIA, and C. MAMARIL. 2004. Economic analysis of CME as a fuel additive for diesel engine. Department of Agricultural Economics, CEM, UPLB.

RDEB-PCA (Research, Development and Extension Branch – Philippine Coconut Authority). 2000.

ROSS, J. Benefits of wind energy are mapped out. www.geni.org/globalenergy. January 31, 2009.

SPIK (Samahan sa Pilipinas ng mga Industriyang Kimika). 2003. Oleochemicals industry. Retrieved September 24, 2007 from SPIK on-line database on the World Wide Web: http://www.spik-ph.org/basic_oleochem.html

The British Wind Energy Association. Benefits of wind energy. BWEA Briefing Sheets. July 2004.

The Coconut Committee. 1992. The Philippines recommends for coconut. Los Baños, Laguna: PCARRD, PARRFI, and PCRDF 1993. 234 p. (Philippines Recommends Serires No. 2-B/1993).

The Economic impact of Calpine's Geothermal Development Projects, Siskiyou County. www.geo-energy.org/aboutGE/economicBenefits. Aug 31, 2005.

U.S. ENVIRONMENTAL PROTECTION AGENCY. Benefits of LFG energy. www.epa.gov/lmop/benefits.htm. May 22, 2008.

WILLIAMS, S. K., M. Goldberg and M. Greve. Estimating the economic benefits of wind energy projects using Monte Carlo simulation with economic input/output analysis. Wind Energy, Vol. 11, pp.397-414. March 2008.

WORLD AGROFORESTRY CENTER. Marketing of coconut in Quezon province, Philippines. Date not given.

3.3 SOCIAL IMPACT

3.3.1 Introduction

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

Measurement of social development significantly differs from economic development. Also, compared to social indicators, a plenty of economic indicators are more frequently available for all countries. But in many cases, particularly in case of some developing economies, they reflect a rosy picture which is far away from the reality. For example, looking at the GDP growth rate, India is one of the fastest growing country in the world, but country's social devlopment indicators fall way behind even many small economies. To capture the holistic picture of development across countries, the UNDP has used the Human Development Index (HDI). This essentally take into account the measures for Per Capita Income, Life Expectancy and Literacy. However, it is to be noted that while development of these indices using UNDP system is well defined and uniformly applied to all countries, some of the factors, which could be either region specific for East Asia or country specific for any country within this region need to be considered differently. Further, development of bioenergy has different factors, such as technical, social, economic and policy, for various regions. Hence, using the same yard-stick for assessing the sustainability of bioenergy for all regions of the world may be incorrect.

This section focuses on methodology for estimating social impacts of biomass utilisation for energy production. Taking a case study of biodiesel production from jatropha plantation in India, estimation of social development indicators (SDIs) are made. The methodology suggested here could be helpful in developing guidelines for sustainability of biomass energy in the East Asia region.

3.3.2 HDI and Social Development

As per the UNDP system, the main indicator of social development is Human Development Indicator (HDI), which essentially measures three social factors, namely, life expectancy at birth, as an index of population, health and longevity; adult literacy rate (with two-thirds weighting) and the combined primary, secondary, and tertiary gross enrolment ratio (with one-third weighting); and the gross domestic product (GDP) per capita at purchasing power parity (PPP) in US dollars. These three factors, expressed as respective three sub-indices in HDI. Since values measuring these social factors have different units, it is necessary to standardise them which allows them to be added together. In general, to transform a raw variable, say *x*, into a unit-free index between 0 and 1, the following formula is used:

$$\text{x - index} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

where, $\min(x)$ and $\max(x)$ are the lowest and highest values that variable x can attain, respectively. The Maximum or Minimum values, which these variables can take (known as goalposts in UNDP terms), are given in table 3-3-1.

Table 3-3-1: Goalposts used in UNDP method of HDI

Index	Measure	Minimum value	Maximum value
Longevity	Life expectancy at birth (LE)	25 yrs	85 yrs
Education	Combined gross enrolment ratio (CGER)	0%	100%
GDP	GDP per capita (PPP)	$100	$40,000

Source: **UNDP**

The three sub-indices of HDI and their equations are defined as follows:

(i) Life Expectancy Index

Life expectancy is the average expected lifespan of an individual. In countries with high infant mortality rates, the life expectancy at birth is highly sensitive to the rate of death in the first few years of life. In such cases, another measure such as life expectancy at age one can be used to exclude the effects of infant mortality and reveal the effects of causes of death other than early childhood causes. Quantified life expectancy often called Life Expectancy Index (LEI) and it measures the relative achievement of a country in life expectancy at birth.

$$\text{Life Expectancy Index} = \frac{LE - 25}{85 - 25}$$

(ii) Education Index

The Education Index (EI) comprises of *Adult Literacy Index* (ALI) and *Gross Enrolment Index* (GEI). The EI is measured by the adult literacy rate (with two-thirds weighting) and the combined primary, secondary, and tertiary gross enrolment ratio (with one-third weighting). The adult literacy rate gives an indication of the ability to read and write, while the GE ratio gives an indication of the level of education from kindergarten to postgraduate education.

$$\text{Education index} = \frac{2}{3} \times \text{ALI} + \frac{1}{3} \times GEI$$

$$\text{where, Adult Literacy Index (ALI)} = \frac{ALR - 0}{100 - 0}$$

$$\text{and, Gross Enrolment Index (GEI)} = \frac{CGER - 0}{100 - 0}$$

(iii) GDP Index

GDP Index (GI) is calculated using adjusted GDP per capita (PPP US$). Income is adjusted because achieving a respectable level of human development doesn't require unlimited income. It is measured by the natural logarithm of gross domestic product (GDP) per capita at purchasing power parity (PPP) in United States dollars.

$$\text{GDP Index} = \frac{\log(GDPpc) - \log(100)}{\log(40000) - \log(100)}$$

Finally, the HDI is calculated by taking a simple average of above three indicators:

HDI = 1/3 (Life Expectancy Index + Education Index + GDP Index)

3.3.3 Estimation of SDIS

There is a general lack of data and information on estimation of the social impact of bioenergy, especially in terms of the HDI. Such estimation requires comprehensive data sets for the region where biofuel crops cultivation has been taken up. The data should contain farm level information on production of biofuel crops (such as jatropha, sugarcane, palm, coconut, etc.) and information throughout the value added chain during the whole life cycle of biodiesel production. Considering these facts, this study uses secondary data on waste land in each state of India that are planning jatropha cultivation and which are potentially fit for this biofuel crop. Two micro level data sets have been used to calculate the values of HDI and project them to national level.

3.3.4 Data and Assumptions

Some of the points about the data used for estimation of SDIs and assumptions made are as follows.

- Secondary data give information about the planned cultivation of jatropha or planned production of biodiesel. But in order to calculate the exact impact, the actual data on area under jatropha cultivation and biodiesel production should be considered rather than projected.
- Selection of control group is really difficult, as we need to consider two areas which have same climatic condition, same socio-economic structure and above all successful implementation of jatropha cultivation. This is only possible by conducting a primary pilot survey in such areas.
- For calculating the social impact of jatropha cultivation, the data are available for income generation only. But subsequent relationship between income and life expectancy/education is required, which is not available at micro level. However, this information is available at macro level, which has been used for micro level estimations.
- For calculating gender-related development index, data about political and social status of women is required. There is no data available that can give political or social status of women with jatropha intervention.

3.3.5 Methodology for Estimation

Considering the above limitations of data, social development indicators (HDI and GDI) at micro (district level) and macro (state level) are calculated, which could also be used to project SDIs at India level. In this study a "bottom-up approach" has been followed to estimate the effective social returns on bioenergy production. Two potential districts are identified in India, namely, Adilabad in the state of Andhra Pradesh and Ahmednagar in the state of Maharashtra. The statistics of Jatropha cultivation in these districts is given in the Appendix 1 (Table A). The steps (1 to 8) used to calculate the SDIs at micro and additional steps (9 to 10) are used to project SDIs at macro level are mentioned below.

Step 1: *Calculation of direct employment from jatropha cultivation.*

The direct employment for any district say, A, includes persons employed in site preparation, jatropha plantation and post plantation work. For this district employment in person days per hectare is calculated for consecutive 5 years.

Step 2: *Calculation of indirect employment from jatropha cultivation and biodiesel production.*

This includes employment in post harvest activities such as seed collection, oil extraction, transportation and other related activities. It is also calculated in person days per hectare of jatropha crop.

Step 3: *Aggregating the cost of direct and indirect employment.*

This is done by taking minimum wage determined by International Labour Organization (ILO) and area concerned and summing the cost of steps 1 and 2. This gives us total cost per hectare of jatropha cultivation and total cost per ton of biodiesel production. The conversion factors used here is that "1 hectare of jatropha cultivation produces 1892 litre of biodiesel and 1 ton of biodiesel = 1267 litre." For calculating cost per ton of biodiesel production, the same 5 years' term is taken for cost calculation as in the case of calculating cost per hectare of jatropha cultivation. The calculations of employment in terms of cost and person days are shown in Appendix 1 (Table B).

Step 4: *Calculation of GDP (PPP) per capita*

For calculating GDP (PPP) per capita, data from step 3 (say, Rs. X / ha of jatropha) or (Rs. Y / ton of biodiesel) are used to calculate total income generated from Z ha of land. Therefore, Rs.(XZ) or Rs.(YZ) is divided by total population of the area plus actual GDP of place which gives GDP (PPP) per capita. It can be suitably converted into US dollars

($) to ease the calculation of HDI.

Step 5: *Calculation of HDI*

The HDI can be calculated as HDI = 1/3(LEI+EI+GI)

where, LEI: Life Expectancy Index (data taken from the area).

EI: Education Index; EI = (2/3)*ALI + (1/3)*GEI

ALI: Adult Literacy Index (data taken from the area).

GEI: Gross Enrolment Index (data taken from the area).

GI: GDP index ($) will be given by

$$\text{GDP Index} = \frac{\log(\textit{actualvalue}) - \log(100)}{\log(40000) - \log(100)}$$

Where, actual value is taken from step 4 above. Then, HDI calculation may be made either by taking into account of Rs. per hectare of jatropha cultivation or Rs. per ton of biodiesel production.

Step 6: *Calculation of Gender-related Development Index (GDI)*

The Gender-related Development Index (GDI) is calculated to reflect inequalities between men and women in all the three dimensions used in calculating HDI. The three sub-indices, namely, life expectancy index, education index and GDP index are calculated separately for men and women, as done in the step 5 and an equally distributed index is calculated for each dimension. First, share of men and women is calculated by dividing women population by total population and the same is done for the men. For calculating equally distributed index for three indices the following formulae is used.

Equally Distributed Index = [{(female population share) / (female index)} + {(male population share) / (male index)}] $^{-1}$

Then, the GDI is calculated by taking the average of equally distributed index of all three indices as discussed above. GDI values are presented as percentage of HDI.

Step 7: *Calculation for the other district, Say B*

Step 1 to 6 is repeated for the other district.

Step 8: Calculation of c*hange in HDI*

Average of HDI for district A and district B gives the HDI that incorporates jatropha cultivation. The change in HDI can be calculated by subtracting current HDI for India, which is 0.609 (HDR, 2008).

Based on the above method, the change in HDI for per hectare of jatropha cultivation and per ton of biodiesel production is given in the Appendix 1 (Tables C and D).

Step 9: *Projection of population (male and female)*

The data on actual population for India are available only for 2001 (Census, 2001 data). But other data such as cultivation area, literacy rate, etc. are available for the year 2008. This required population projection for the year 2008 assuming a constant exponential growth rate. Same process is repeated for male and female population taking growth rate constant. Then, the share of male and female population is calculated.

Step 10: *Calculation of HDI and GDI for jatropha cultivation and biodiesel production.*

For macro (state) level calculations the same method is followed as discussed for the micro (district) level. HDI and GDI for jatropha cultivation and biodiesel production were calculated separately.

Finally, overall HDI is calculated by taking average of all states and union territories, and then to find change in HDI = 0.609 (value of HDI for India in 2008) is subtracted from the given value. This gives changes in HDI due to jatropha intervention.

The values of HDI for various states, both in terms of jatropha cultivation and biodiesel production, and the values of GDI are given in the Appendix 1 (Table E).

3.3.6 Summary of Results

This section suggests guidelines for estimating Indicators of Social Impact of

Biomass Utilisation in East Asia. A method of calculating the change in SDIs, due to bioenergy production in India, is mentioned that may be useful for developing guidelines for the East Asian region. In biodiesel production, plantation of jatropha will be the most dominant item of expenditure. It is estimated that an employment of 123 person days per hectare of jatropha plantation in the first year and 322 person days in five years will be generated.

To calculate the change in SDIs, both micro (district) and macro (state) level cases are considered. The case study of Adilabad district of Andhra Pradesh indicates that overall monetary gains, due to employment generation, for the region will be Rs.4221360. The GDP (PPP) per capita with the jatropha intervention and other existing factors gives a value of Rs.21224. This gives a GDP index of 0.420 and fitting the data of life expectancy and education gives a HDI value of 0.647. Thus, the change in HDI is 0.038 (0.647-0.609), where, 0.609 is the value of HDI for India in 2006, as per UNDP estimates. Similarly, the change in HDI when biodiesel production is taken into account comes out to be 0.038. The GDI for Adilabad district is 0.518 in case of only jatropha cultivation and 0.537 for biodiesel production, which is 80% and 82.9% of HDI, respectively.

The case study of Ahmednagar district indicates a total monetary gain for the region, due to the employment generation as Rs.23544562. The GDP (PPP) per capita, with jatropha intervention and other existing factors gives a value of Rs.18054 and a GDP index of 0.376. Fitting the data about life expectancy and education, the HDI for Ahmednagar for jatropha cultivation only comes out to be 0.617. Hence, the change in HDI is 0.008 (0.617-0.609). However, taking into account biodiesel production, HDI is 0.647, which is much higher than the results coming only from jatropha cultivation. Ahmednagar GDI is 94.8 % of HDI when only jatropha cultivation is considered and it is 92.8% of HDI taking into account of biodiesel production.

The aggregate HDI of states (macro level) due to Jatropha cultivation, considering other development indicators constant, comes out to be 0.621. Therefore, the change in HDI due to jatropha cultivation is (0.621-0.609=0.012). Similarly, when biodiesel production is taken into consideration then the total HDI for India comes out to be 0.622, giving a positive deviation of (0.622-0.609=0.013). The GDI value for India is projected as 0.571 which is 91.8 % of the HDI.

3.3.7 Conclusions

A case study of jatropha cultivation in two districts of India indicates that geographical location and field conditions have tremendous effect on survival rates of jatropha plants. Under adverse conditions, survival rate of jatropha plant are very low. On the other hand, some other native oil trees such as Pongamia and Neem may hold promises better. Estimations of HDI due to jatropha cultivation and biodiesel production indicate that the HDI change in whole life cycle of biodiesel production is higher than only in jatropha cultivation.

This study is based on secondary data and to calculate exact change in SDIs, actual data at microscopic level (such as village) are needed. Hence, it is suggested that in the next phase of the project a pilot study on "Estimation of Social impact of Jatropha and other Oil Trees cultivation for Bio-diesel Production in India" is taken up. The pilot study should focus on collecting data and information through survey of various stakeholders involved during various stages of jatropha cultivation and bio-diesel production. Data should be collected through a questionnaire administered to various focus groups. A combination of interview techniques such as face-to-face personal interview, discussion on telephone, correspondence through email, fax and normal mail, etc. will be used for collecting the data and information. A draft of the questionnaire on social issues proposed for the pilot study is given in Appendix [3].

REFERENCES

ADB (2007). Key Indicators 2007. Asian Development Bank, Manila, Philippines

BIS (2006-07): Annual Report of the Bureau of Indian Standards.

CEA (2006): Central Electricity Authority, New Delhi.

HDR, (2008): Human Development Report 2007-2008, United Nations Development Programmes.

Hill J., Tilman, D., and C. Lehman. (2006): Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass.Science 314 (5805): 1598-1600.

Keller, G., M. Mintz, C. Saricks, M. Wang, and H. Ng, (2007): Acceptance of Biodiesel as a Clean-Burning Fuel: A Draft Report in Response to Section 1823 of the Energy Policy Act of 2005, Center for Transportation Research, Argonne National Laboratory, prepared for Office of Freedom CAR and Vehicle Technologies, U.S. Department of Energy, Oct.

MNRE (2007): Annual Report of Ministry of New and Renewable Energy, Govt. of India, 2006-07.

MoEF (2008): Minsitry of Environment and Forest, Govt. of India, website (www.envfor.nic.in).

National Biodiesel Board, 2007, FAQs: How Much Biodiesel Has Been Sold in the U.S.? available at http://www.biodiesel.org/resources/faqs/, accessed Nov. 2007.

Planning Commission (2003): Report of the Committee on Development of Biofuel, Planning Commission, GoI, New Delhi-110 001.

Sagisaka M. (2007) Editor: Report on "Sustainable Biomass Utilisation Vision in East Asia" prepared for JETRO and ERIA.

UN-Energy (2007): A UN document on "Sustainable Bio-energy: A Framework for Decision Makers."

UNCTAD (2006): "An Assessment of the Biofuels Industry in India" prepared by Joseph B. Gonsalves, consultant to United Nations Conference on Trade and Development, Geneva, 2006.

UNDP (2008): Human Development Report 2007-08, United Nations Development Programmes.

WEO (2006): World Energy Outlook, International Energy Agency.

WDR (2008): World Development Report 2008: Agriculture for Development, the World Bank, Washington DC, USA.

Appendix 1: Calculations of HDI

Table A: Jatropha cultivation in Adilabad (AP) and Ahmednagar (MS)

Particulars	Adilabad	Ahmednagar
Sample Village (No)	7	10
Area Proposed (ha)	380.4	2025.6
Area Covered (ha)	312.0	1091.6
Jatropha sown (No.)	1358070	4960230
Plant density (per ha)	4353	4544
Survival (%)	2.19	2.96

Source: GFU, 2005

Table B: Employment from jatropha cultivation and Oil production

S.No	Item	Cost (Rs.)					Employment In person days				
		Year					Year				
		1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th
Direct Employment from Jatropha Cultivation											
	Site Prepartation										
1	Cleaning & Levelling	1100	0	0	0	0	10	0	0	0	0
2	Alignment & Staking	550	0	0	0	0	5	0	0	0	0
3	Digging of Pits	5500	1650	0	0	0	50	15	0	0	0
	Plantation		0								
4	Planting & Replanting	2750	550				25	5	0	0	0
	Post Plantation		0								
5	Irrigation	550	330	330	330	330	5	3	3	3	3
6	Fertilizers	220	110	110	0	0	2	1	1	0	0
7	Pesticides	220	110	110	110	110	2	1	1	1	1
8	Weeding & Soil Working	2200	2200	2200	2200	2200	20	20	20	20	20
Employment Post Harvest											
9	Seed Collection	0	0	0	0	4400	0	0	0	0	40
10	Oil Extraction	0	0	0	0	2200	0	0	0	0	20
11	Transportation	220	0	0	110	550	2	0	0	1	5
12	Others	220	220	220	220	1100	2	2	1	2	10
	Total	**13530**	**5170**	**2970**	**2970**	**10890**	**123**	**47**	**26**	**27**	**99**

Table C: HDI Change based on Area of Jatropha under Cultivation

Item	Adilabad	Ahemednagar
Total Area for Jatropha Cultivation (ha.)	312	2025.6
Total Income (Rs.)	4221360	23544562
GDP/Capita	2.315607 (Due to Jatropha Cultivation)	7.169477
GDP/Capita(Purchasing Power Parities)	21224.32 (Overall)	18054.17
GDP Index	**0.420472**	**0.376618**
Life Expectancy Index	**0.866667**	**0.966667**
Literacy Index	0.645	0.546
Gross Enrolment Index	0.673	0.433
Education Index	**0.654333**	**0.508333**
HDI	**0.647157**	**0.617206**
Change in HDI (Due to Jatroopa Cultivation)	**0.038157 (HDI - 0.609)***	**0.008206 (HDI - 0.609)***

*Note: HDI for India in 2006 = 0.609 (HDR, 2008): India ranked 132nd in 179 countries (in comparison to HDI in 2005 = 0.619 and a rank of 128th in 177 countries)

Table D: HDI Change based upon Biodiesel Production

Item	Adilabad	Ahemednagar
1 (ha.) of Jatropha cultivation produces	1892 (L) = 1.493291 (ton.) Biodiesel	1892 (L) = 1.493291 (ton.) Biodiesel
1.493291 (ton.) requires (in 5 years)	35530 (Rs.)/ha. 23793.08 Rs./ton/ha	30429 (Rs./ha) = 20377.14
Total Area for Jatropha Cultivation (ha.)	312	2025.6
Total Income (Rs.)	7423441	41275928
GDP/Captia	4.072093 (Due to oil Production)	22.64171
GDP/Captia (Purchasing Power Parities)	21226.07 (Overall)	21244.64
GDP Index	**0.420494**	**0.420731**
Life Expectancy Index	**0.866667**	**0.866667**
Literacy Index	0.645	0.645

Gross Enrolment Index	0.673	0.673
Education Index	0.654333	0.654333
HDI	0.647165	0.647244
Change in HDI (Due to Oil Production)	0.038165 (HDI - 0.609)*	0.038244 (HDI - 0.609)*

Table E: HDI and GDI for various States of India

States	Projected Area (ha.)	HDI (Jatropha Cultivation)	HDI (Biodiesel Production)	GDI
Andhra Pradesh	600000	0.620050933	0.620546043	0.568213
Arunachal Pradesh	3000	0.619392242	0.619392869	0.568512
Assam	22000	0.619555337	0.619679358	0.569855
Bihar	195000	0.619545571	0.619662222	0.567756
Chhattisgarh	1000000	0.619874532	0.62023822	0.56964
Goa	60000	0.620132018	0.620687294	0.569279
Gujarat	16000	0.619489263	0.61956337	0.568421
Haryana	1750	0.619397324	0.619401806	0.568249
Himachal Pradesh	45000	0.619530812	0.61963632	0.56759
Jammu & Kashmir	100	0.61939217	0.619392744	0.567874
Jharkhand	300000	0.620018082	0.620488772	0.568383
Karnataka	240000	0.620082686	0.620601376	0.568212
Kerala	60000	0.61940654	0.61941801	0.567896
Madhya Pradesh	1000000	0.619640267	0.619828293	0.568074
Maharashtra	60000	0.619402369	0.619410677	0.567511
Manipur	2000	0.619392059	0.619392549	0.567337
Meghalaya	100	0.619391425	0.619391434	0.568043
Mizoram	500	0.61939148	0.619391531	0.56803
Nagaland	10000	0.619814604	0.620133479	0.570998
Orissa	2000000	0.660555498	0.679139551	0.611049
Punjab	300000	0.619417863	0.619437918	0.56747
Rajasthan	220000	0.619419383	0.619440588	0.567604
Sikkim	1000	0.619396401	0.619400183	0.567618
Tamil Nadu	40000	0.623656067	0.62668608	0.572089
Tripura	200	0.619391456	0.619391488	0.566688
Union Territories	50000	0.619392068	0.619392564	0.620186
Uttar Pradesh	1586000	0.619561951	0.619690963	0.567526
Uttranchal	200000	0.620754094	0.621765931	0.568612
West Bengal	4000	0.619466843	0.61952399	0.568932