Chapter 7

Pilot Study on Sustainability Assessment of Biomass Utilization in Thailand

Shabbir H. Gheewala
The Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi

Sebastian Bonnet

Pariyapat Nilsal

Kritana Prueksakom

September 2010

This chapter should be cited as
Gheewala, S. H., S. Bonnet, P. Nilsalab and K. Prueksakom (2010), 'Pilot Study on Sustainability Assessment of Biomass Utilization in Thailand', in ERIA WG on 'Sustainability Assessment of Biomass Utilisation in East Asia' (eds.), *Sustainability Assessment of Biomass Energy Utilisation in Selected East Asian Countries*. ERIA Research Project Report 2009-12, Jakarta: ERIA. pp.1-39;1-43.

PILOT STUDY ON SUSTAINABILITY ASSESSMENT OF BIOMASS UTILIZATION IN THAILAND

A case study report by:
The Joint Graduate School of Energy and Environment
Assoc. Prof. Dr. Shabbir H. Gheewala, Dr. Sébastian Bonnet, Ms. Pariyapat Nilsalab, Mr. Kritana Prueksakom

---

EXECUTIVE SUMMARY

In this report, the sustainability of biomass utilization has been assessed for a sugar biorefinery complex in Khon Kaen, Thailand. It is composed of several units including: sugarcane cultivation, sugar production, bioethanol production from molasses, power production from bagasse and organic fertilizer from filter cake. Environmental, social and economic impacts were investigated and the main findings are reported below.

For environmental assessment of the sugar biorefinery complex (including sugarcane cultivation) global warming potential (GWP) was considered as the main impact category and evaluated following the IPCC 2007 method. The reference flow is 1,000 kg of sugarcane. The system boundary includes the cultivation stage of sugarcane up to final utilization of the main products from the biorefinery complex i.e. sugar and ethanol and by-products i.e. filter cake, bagasse, and molasses.

From the energy analysis, the largest share (about 50%) of the total energy use is contributed by the sugar production process (sugar mill) from the use of steam. About 84% of the steam used for the sugar production process is from the facility for power generation that is located within the sugar mill and 16% from the power plant. Less than 1% of the total energy use is from the process of power generation and fertilizer production. For the life cycle of ethanol production, the burning ratio of cane trash in the sugarcane plantation contributes to significantly affect GWP for this stage. It was found GWP could vary as much as 47% if burning ratio was changed from 0% to 70% (open burning of 70% of the cane trash in the plantation is currently being practiced at the pilot study site). The overall

life cycle greenhouse gas (GHG) emissions associated to ethanol production (production plus use stage) are slightly lower. The maximization of utilization of the materials produced from the various units of the biorefinery complex is contributing to reducing GHG emissions and therefore the GWP associated to the various processing units of the biorefinery complex. However, the open burning of cane trash, although not significantly contributing to affect the life cycle GHG emissions associated to ethanol production, should still be discouraged and alternative use, for energy purposes for instance, considered. This could help providing additional GHG emission credits for the biorefinery complex and hence to further benefiting the environmental performance of ethanol as compared to gasoline. To further assess the sustainability of biomass utilization in the pilot study of Khon Kaen, socio-economic impacts were investigated.

For social assessment, the notion of Human Development Index (HDI) was introduced to evaluate the impacts of the overall biorefinery complex including sugarcane plantation on social development. Factors including life expectancy index, education index and gross domestic product (GDP) were investigated. For comparative purposes, HDI was determined at the level of the province of Khon Kaen in order to assess the extent of social development achieved at the level of the sugarcane plantation and biorefinery complex. The HDIs of the sugar cane plantation, biorefinery complex, and Khon Kaen are equal to 0.736, 0.797 and 0.763 respectively. Those results indicate that although farmers are characterized by a lower social development than an average person in Khon Kaen or employees at the biorefinery complex, they still benefit from receiving a steady income as a result of their contract (contract farming) with the sugar mill and which guarantees the selling of their sugarcane to the factory in a given year. Employees at the biorefinery complex receive an income that is on average higher than that of the provincial level. Hence, social development is higher as shown by the positive change in HDI (+0.034) obtained for this category of people as compared to Khon Kaen.

For the economic assessment, total value added was introduced as an indicator. Total net profit, wages (employment), tax revenues and foreign trade earning are the four factors that were considered to assess total value added. The economic assessment was performed at the level of the sugarcane plantation and the biorefinery complex. The results obtained from the economic assessment for the overall complex (including plantation) indicate that annual total net profit, annual wage paid, annual tax revenue, and annual foreign exchange amount to 1,350,394,033 THB, 1,468,935,095 THB, 371,120,493 THB, and 525,008,930 THB respectively. Hence, the annual total value added for the whole bioefinery complex amounts to 3,715,458,551 THB.

1. INTRODUCTION

1.1 Background and objectives of the research

Biomass utilization such as that for biofuel is expected to enable reducing greenhouse gas emissions in the world and to contribute to socio-economic development of biomass rich countries. However, negative impacts on biodiversity and food security are pointed out. Research on sustainable biomass utilization has been conducted by a WG of ERIA since 2007. In 2007, the WG discussed sustainable biomass vision in East Asia and produced seven policy recommendations. "Asia Biomass Energy Principles" endorsed by the recommendations were adopted at the EAS Energy Minister Meeting in Bangkok in August 2008. Following the Minister Meeting, the WG expanded its discussion to develop and publish guidelines to assess the sustainability of biomass utilization in East Asia".

The WG is now planning to support the ERIA pilot study that will be implemented by designated organizations under the ERIA's framework to implement the assessment methods developed in 2008. While performing the study, the WG will implement the methodologies required for the assessment and produce policy recommendations based on the results obtained from the pilot study. The location of the pilot study is in Khon Kaen, Thailand.

Khon Kaen province has a very strong agriculture base with abundant rice, cassava and sugarcane farming. Thus, there are a lot of biomass resources, some of which are being used for non-food applications (fuel and fertilizer). There are already factories producing ethanol from cassava and sugarcane molasses and which have been in operation for several years. This study will however focus on sugarcane utilization for ethanol (via molasses) and for electricity (via bagasse) production. A company group in Khon Kaen producing sugar (and molasses) from sugarcane as well as electricity and fertilizer will be selected as the case study.

Various scenarios about sugarcane resources utilization will be considered and sustainability investigated by the study team. The base case scenario is the conventional utilisation system and will be defined the local investigation team in consultation with the WG members.

The investigations for each production stage i.e. sugarcane farming, sugar factory, power plant, ethanol factory, organic fertilizer factory, and all transportations, to assessing the sustainability of biomass resources utilization in the East Asian region and come up with policy recommendations, will be performed as reported below:

Condition of the field: At the site of the pilot study, geographical/economic information, production/consumption data of the target biomass, agro-related industry information, national policy of the biomass utilisation, etc. will be investigated and reported.

Environmental Aspects: Life cycle assessment (LCA) will be adopted for evaluating various scenarios of sugarcane resources utilisation. The system boundary will be from the cultivation stage of sugarcane to final utilization of main products (sugar and biofuels) and by-products (filter cake, bagasse, molasses). The emissions to be investigated are Greenhouse Gases (GHGs). However, other emissions of pollutants will also be considered based on available data.

Economic Aspects: The parameters and methods detailed in the guidelines developed by the WG will be adopted for this evaluation. Total Net Profit, Wages (employment), Tax Revenues and Foreign Trade are the four factors that will be considered as part of this economic assessment to determine Total Value Added. The economic assessment will be performed at the level of the sugarcane plantation and the biorefinery complex. The results will then be summarized to determine the overall total value added of this pilot study.

Social Aspects: The parameters and methodology developed by the WG will be adopted for this evaluation. Human Development Index (HDI) is introduced as a measure to assess social development by combining indicators of life expectancy index, education index and gross domestic product (GDP). Data will be collected from farmers (sugarcane plantation) and from the biorefinery complex via interview and questionnaire surveys. For comparative purposes, HDI will also be determined at the level of the province of Khon Kaen in order to assess the extent of social development achieved at the level of the sugarcane plantation and biorefinery complex.

1.2 Overview of Each Production Stage

1.2.1 Sugarcane plantation

Sugarcane is any of six to thirty-seven species (depending on taxonomic system) of tall perennial grasses of the genus *Saccharum*. They have stout, jointed, fibrous stalks that are rich in sugar, and measure two to six meters tall. Sugarcane is grown in over 110 countries. About 50 percent of world sugarcane production occurs in Brazil and India. In 2008 an estimated 1,743 million metric tons of sugarcane were produced worldwide as shown in Table 1.1. From the processing of sugarcane, there are several by-products that can be utilized for various purposes other than food. The products and by-products manufactured from sugarcane are sugar, molasses, rum, ethanol, etc. The bagasse that remains after sugarcane crushing can be burned to provide heat and electricity. Because of its high cellulose content, it can also serve as raw material for paper, cardboard, and eating utensils (Wikipedia, 2010).

Figure 1.1 Sugarcane plantation (Wikipedia, 2010)

Table 1.1 Top ten sugarcane producers in 2008 (Wikipedia, 2010)

Rank	Country	Production (Ton)
1	Brazil	648,921,280
2	India	348,187,900
3	People's Republic of China	124,917,502
4	Thailand	73,501,610
5	Pakistan	63,920,000
6	Mexico	51,106,900
7	Colombia	38,500,000
8	Australia	33,973,000
9	Argentina	29,950,600
10	United States	27,603,000
11	World	1,743,092,995

Sugarcane cultivation requires a tropical or temperate climate, with a minimum of 60 cm. of annual moisture and a minimum of 1,500 mm of rainfall (The Junior Encyclopedia Project, 1997). In prime growing regions, such as India, Brazil, Australia, etc. sugarcane can produce 20 kilograms for each square meter (32 ton/rai; 1 hactare = 6.25 rai) exposed to the sun (Wikipedia, 2010). From survey in Thailand, sugarcane planting in fertile soil can produce 20-25 ton/rai. Presently, amount of sugarcane yield (and sweetness) has been decreasing since the nutrients accumulated over millions of years in soil are rapidly exploited. Therefore, after harvesting, soil is often nourished and prepared by planting many kinds of beans and mixing them with filter cake, organic fertilizer and soil before primary tillage (ploughing), secondary tillage (harrowing), furrowing, etc. On average, plantation area, yield quantity, yield price and income in Thailand for 2000-2007 of sugarcane are shown in Table 1.2.

Table 1.2 Planted area, yield quantity, yield rate, yield price and income 2000-2007 (OAE, 2008)

Year	Planted area (1,000 rai)	Production (1,000 tons)	Yield per rai (Kgs.)	Farm price (THB per ton)	Farm value (Million THB)
1999	5,735	50,332	8,777	496	24,964
2000	5,710	54,052	9,466	445	24,053
2001	5,481	49,563	9,042	514	25,475
2002	6,320	60,013	9,496	435	26,106
2003	7,121	74,259	10,429	469	34,827
2004	7,012	64,996	9,269	368	23,918
2005	6,670	49,586	7,434	520	25,785
2006	6,033	47,658	7,899	688	32,789
2007	6,314	64,365	10,194	683	43,962
2008	6,590	73,502	11,153	557	40,940

*Remark: *1 rai = 1,600* m^2

Areas for sugarcane cultivation in Thailand are mainly in 47 provinces of Central, North-eastern and Northern regions. Table 1.3 shows ten of provinces having the highest sugarcane production in descending order (OAE, 2008).

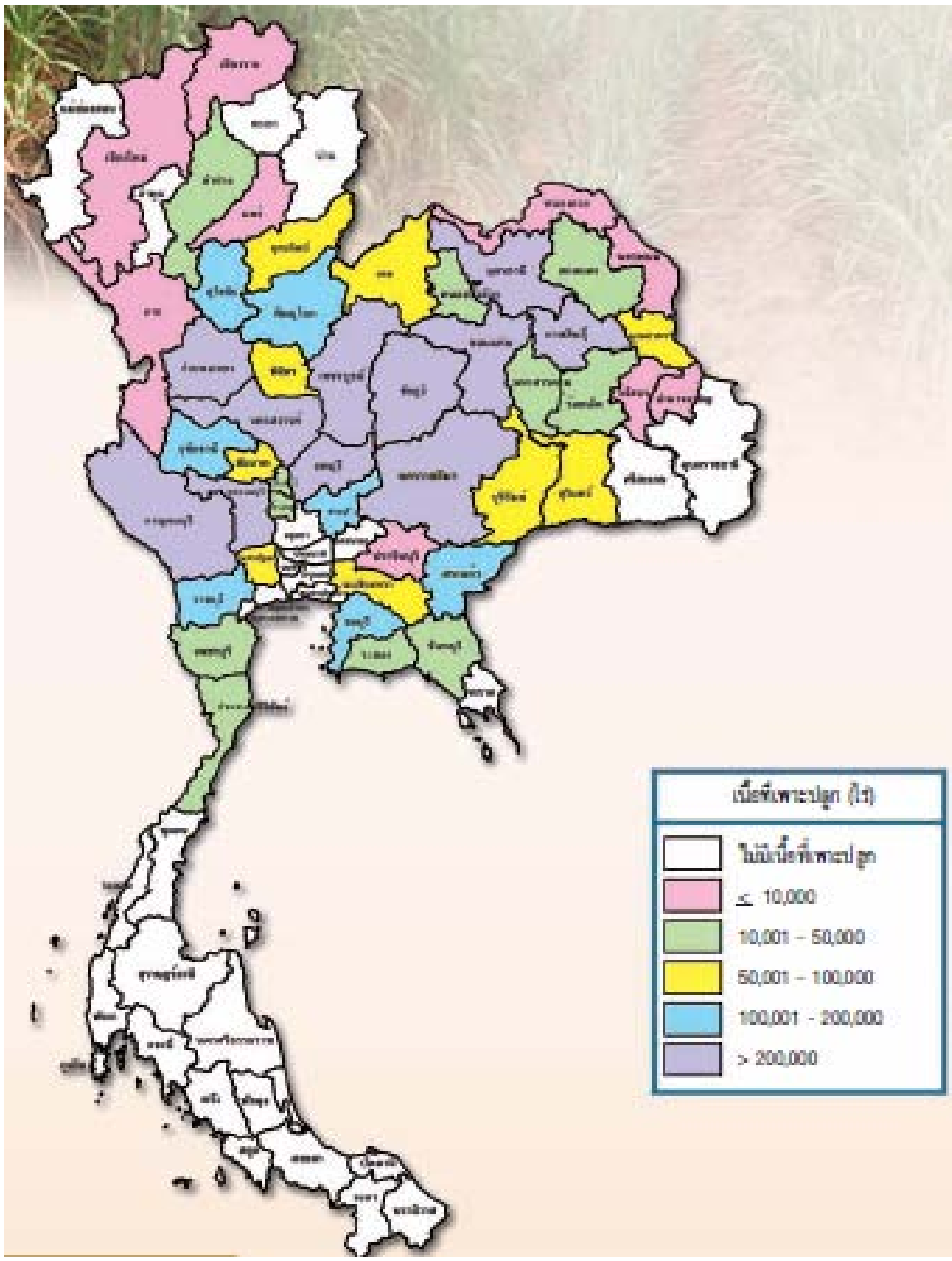


Figure 1.2 Sugarcane plantation areas in Thailand (OAE, 2007)

Table 1.3 Planted area, yield quantity and yield rate by province 2005-2007 (OAE, 2008)

Region/Province	*Planted area (Rai)*	*Region/Province*	*Quantity (Tons)*	*Region/Province*	*Yield per rai (kg)*
Kanchanaburi	1,883,525	Kanchanaburi	19,013,197	Kamphaeng Phet	32,208
NakhonSawan	1,568,156	Nakhon Sawan	16,531,960	Nakhon Sawan	31,667
NakhonRatchasima	1,429,489	Khon Kaen	14,165,541	Nakhon Pathom	30,997
Khon Kaen	1,377,336	NakhonRatchasima	13,642,390	Ang Thong	30,671
Suphan Buri	1,299,197	Suphan Buri	12,994,587	Phetchabun	30,639
KamphaengPhet	1,173,286	KamphaengPhet	12,805,725	Khon Kaen	30,621
Udon Thani	1,121,025	Udon Thani	9,802,847	Kanchanaburi	30,375
Chaiyaphum	884,918	Chaiyaphum	8,556,771	Suphan Buri	30,262
Lop Buri	780,707	Kalasin	7,726,663	Kalasin	30,204
Kalasin	760,264	Lop Buri	7,426,843	Chon Buri	30,012

In Thailand, there are 2 periods of time for planting sugarcane i.e. from May to July (start of rainy season) and from December to February (end of rainy season). Time to plant mainly depends on the rain if the planting area is far from irrigation-service area. Farmers in North-eastern region regularly plant sugarcane during May to July because this period takes lower time before harvesting because of matching with the crushing season of factory. However, cane planting in this period has several disadvantages e.g. problems from weed, water useless from the rain to young tree, low yield from water shortage during growing period (4-8 months after planting), etc (The Junior Encyclopedia Project, 1980).

Modern stem cutting has become the most common method to plant although sugarcanes produce seeds. Cuttings are sometimes hand-planted. If each cutting contains 3 buds, there should be just 2,000-4,000 of cutting per rai with suitable crop density (The Junior Encyclopedia Project, 1980). In the United States and Australia, advanced technology like billet planting is common. Billets harvested from a mechanical harvester are planted by a machine opening and recloses the ground. Once planted, a stand can be harvested several times. Anyway, there may be some failed cases that sugarcane cannot grow up. Replanting process is required in this case within 3-4 weeks after planting (Wikipedia, 2010).

Crop maintenance after planting (about 1 year) of sugarcane is the key factor to the amount of yield; comprising weeding, pest-disease control, irrigating, fertilizing and applying other special soil-improving materials. Labor, fuel, machine, water, and chemicals are required for such activities depending on budget and availability of cultivator as well as condition in farm; for example, irrigation is always done once there is a symptom from sugarcane indicating dehydrated condition caused by circumstance.

Harvesting period is around 5-6 months since December to April or May. The pinnacle is around January to February. The percentage of harvest for each month is shown in Table 1.4. After each harvest, the cane sends up new stalks, called ratoons. Successive harvests give decreasing yields in later years until eventually replanting is justified. Suitable times for ratooning in Thailand are just 2-4 times (OEA, 2007).

Table 1.4 Period and percentage of harvest in Thailand (OAE, 2007)

2006					2007					
Aug	Sep	Oct	Nov	Dec	**Jan**	**Feb**	Mar	Apr	May	Jun
				18.10	**31.78**	**27.08**	19.48	3.29	0.27	
Harvesting period					**Peak of harvesting period**					

Sugarcane can be harvested both by hand and mechanically. Hand harvesting accounts for more than half of production, and is dominant in the developing world. In hand harvesting the field is first set on fire. The fire burns dry leaves, and kills any lurking venomous snakes, with little harming the quality of water-rich stalks and roots. Harvesters then cut the cane just above ground-level using cane knives or machetes. A skilled harvester can rip cane leaves, cut and bind cane trunk approximately 500 kilograms of sugarcane per hour or almost one rai/man-day. Hence, several ten thousands labor/season/factory are needed which is very difficult. Then, farmers always burn cane before harvesting because it is easier and can reduce time about one-third but air emissions and soil deterioration are the problems bothering nearby resident. Meanwhile, mechanical harvesting uses a combine, or chopper harvester. The machine cuts the cane at the base of the stalk, strips the leaves, and deposits the cane into a transporter, while blowing the trash cane back onto the field. Such machines can harvest 100 tons each hour and avoid burning of trash but the machine has very high cost and hard to work in some soil characteristics (Wikipedia, 2010).

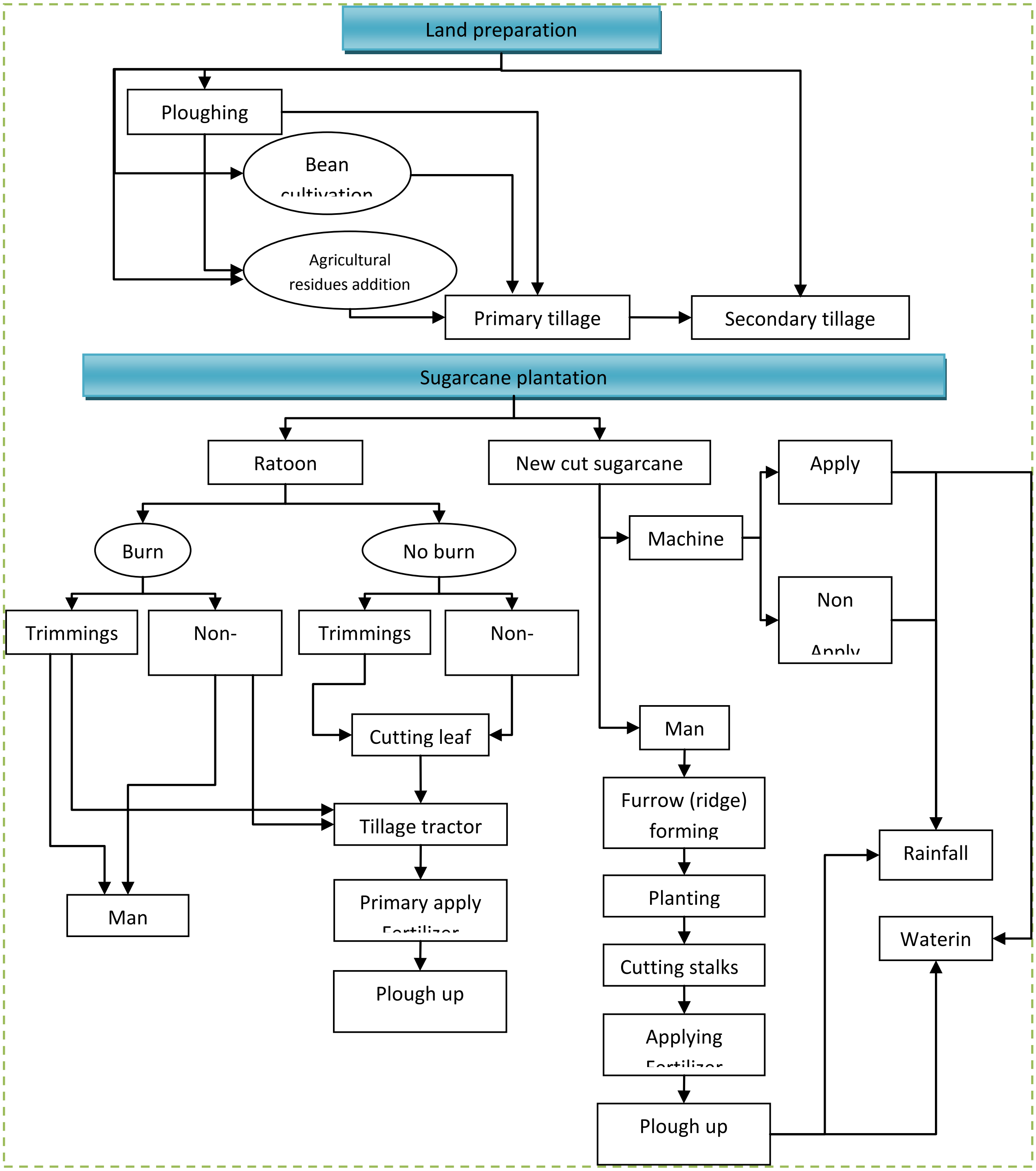


Figure 1.3 Flowchart of sugarcane plantation (Land preparation and Sugarcane plantation) (TEI, 2007)

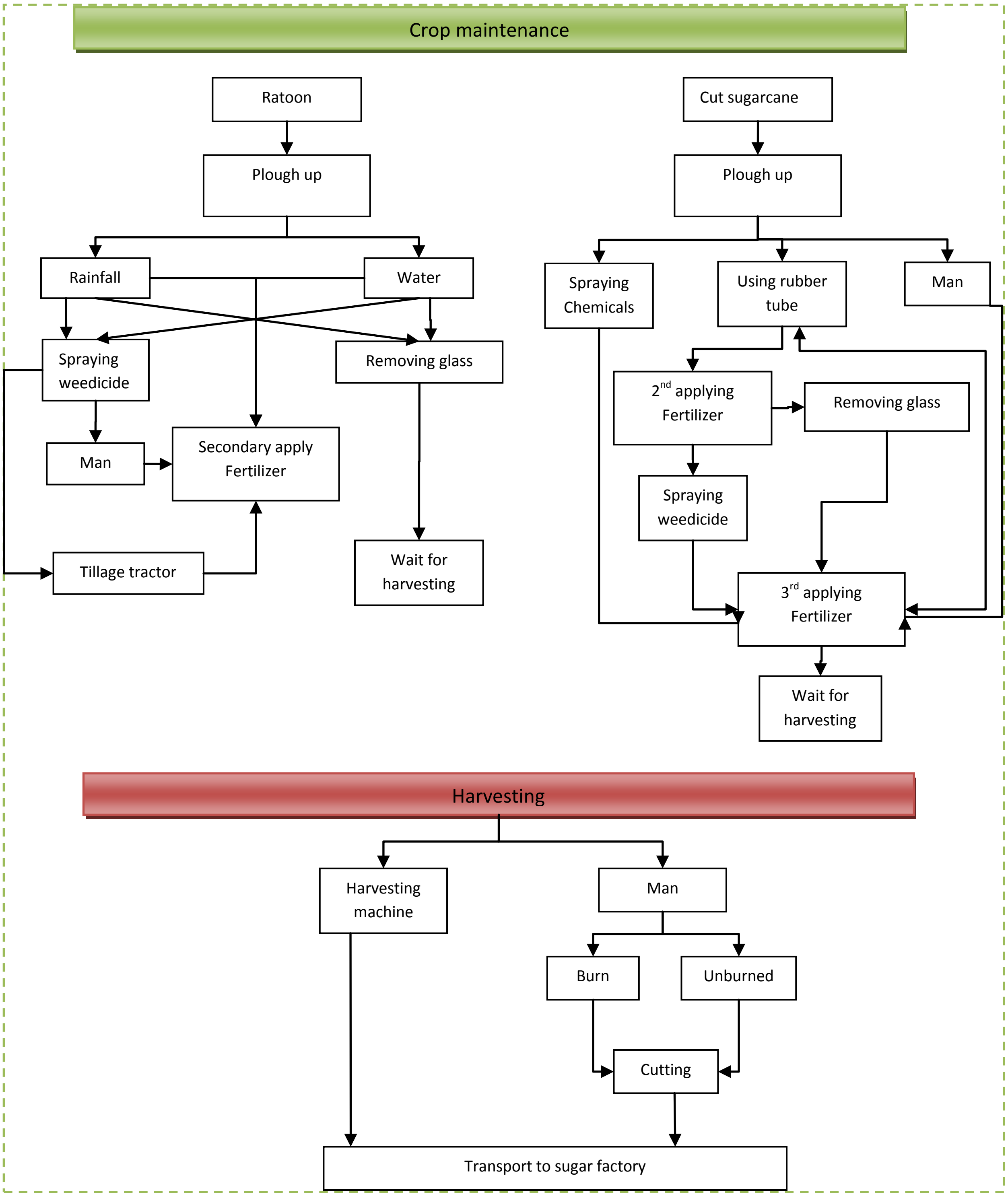


Figure 1.4 Flowchart of sugarcane plantation (Crop maintenance and Harvesting) (TEI, 2007)

1.2.2 Cane sugar processing

1.2.2.1 Milling (K-Patents Process instruments, 2008)

After sugarcane has been harvested it must be processed within less than 24 hours to avoid sugar loss by inversion to glucose and fructose. The process is shown as Figure 1.5.

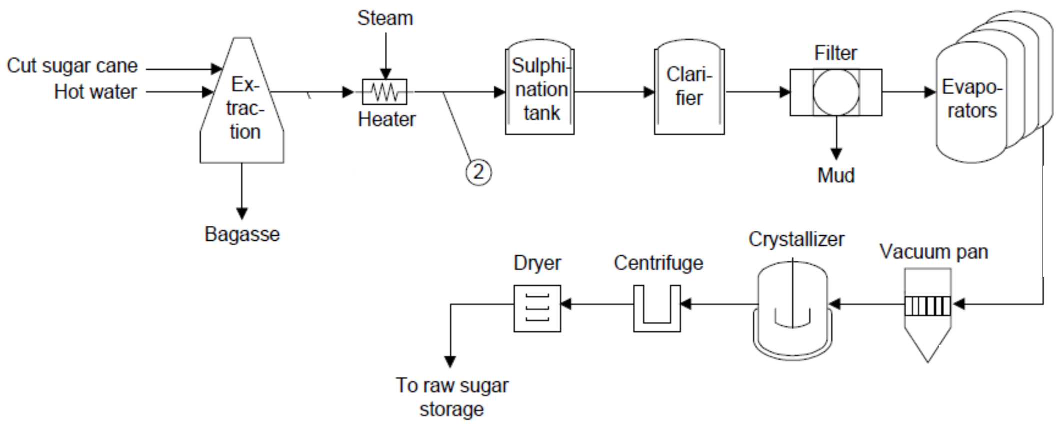


Figure 1.5 Cane sugar process (Milling) (K-Patents Process instruments, 2008)

Preparation and Extraction: The cane carried from farm is first washed to remove mud and debris. Then the cane is chopped and shredded in huge roller mills for extracting the juice. About 90-96% of the juice is extracted depending on the efficiency of machine. Water and weak juice from the last mill is added to help to macerate the cane and to aid in the extraction. The spent cane, called bagasse is either used as fuel, as raw material for paper or hardboard, or as insulating material.

Heating: The juice is sent to multiple heaters where the sugar content is increased to 16-17 Brix. Degrees Brix (symbol °Bx) is unit representative of the sucrose content of an aqueous solution by weight. One degree Brix corresponds to 1 gram of sucrose in 100 grams of solution.

Sulphitation and Clarification: Sulphitation is the practice of adding sulphur dioxide (SO_2) to the juice to remove impurities and for decolourisation. After that, lime is added to precipitate impurities and to help removing colouring matter, organic acids and other suspended material. The limed juice is sent to clarification to settle. The clear juice goes to the evaporation plant. Rotary filters are generally used to recover the sugar from the settled-out mud.

Evaporation: The filtrate is evaporated in triple or quadruple-effect evaporators to a thick pale-yellow juice of about 60 Brix.

Crystallization: The thick juice goes to the vacuum pans where it is evaporated to supersaturation. When the predetermined degree of supersaturation is reached, seeding takes place and the crystals are grown to the required size. The massecuite is discharged to a crystallizer where the crystallization is completed.

Centrifuging and Drying: The massecuite is sent to a centrifuge where the syrup is separated from the crystals. After drying of the crystals, the light brown raw sugar is ready for shipping to a refinery. The molasses is often used for fermentation products, cattle feed, citric acid etc.

1.2.2.2 Refining (K-Patents Process instruments, 2008)

The raw sugar received by a refinery contains 96.5 to 98.5% sucrose and therefore 1.5 to 3.5% impurities which comprise organic matter, inorganic compounds, water and microorganisms. The raw sugar is also highly coloured. The process is shown as Figure 1.6.

The first step in refining is called affination, wherein the raw sugar crystals are treated with heavy syrup (typically 60-80 Brix) in order to remove the film of adhering molasses. This strong syrup dissolves little or none of the sugar but softens or dissolves the coating impurities. The mixture, called magma, is spun in centrifuges and washed with hot water to remove the adhering molasses film. The washed raw sugar crystals are then dissolved in water and diluted to about 54 Brix.

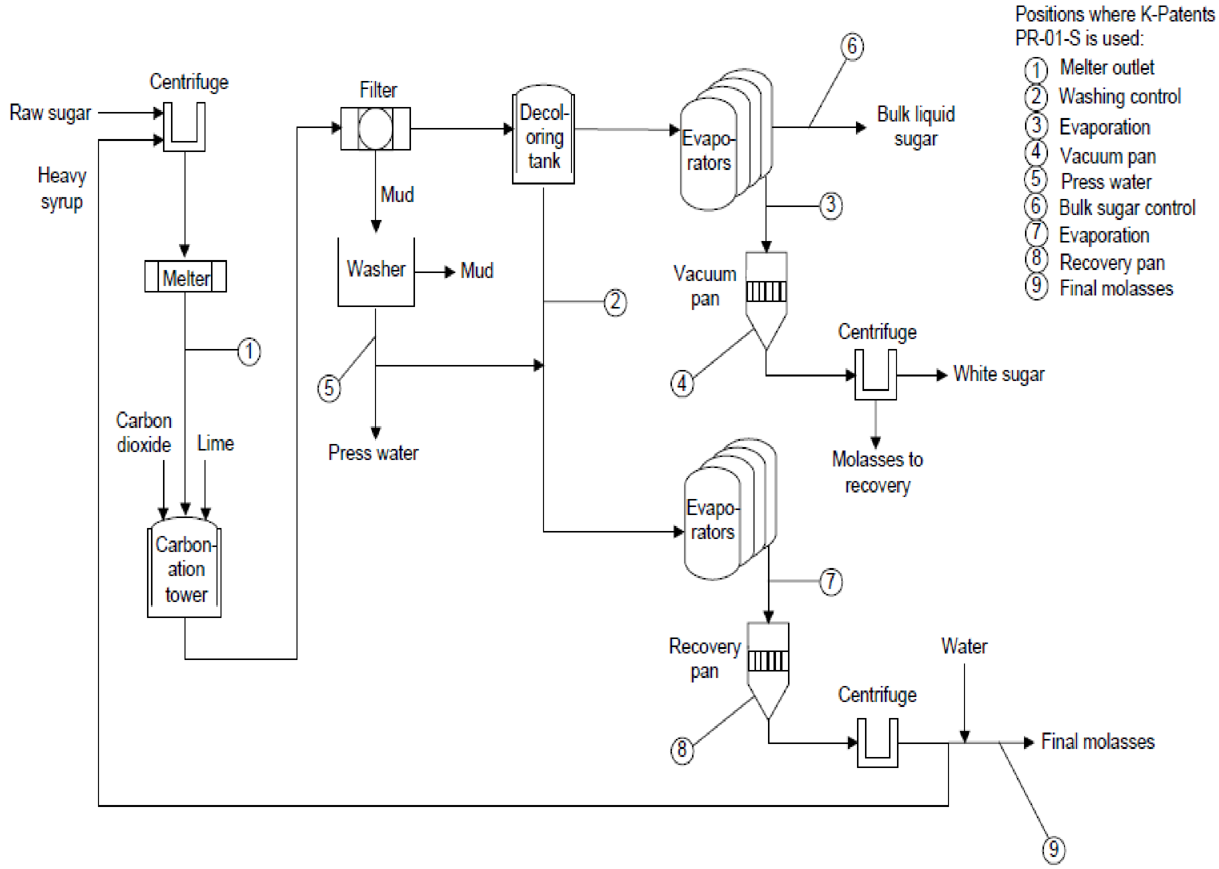


Figure 1.6 Cane sugar process (Refining) (K-Patents Process instruments, 2008)

During carbonation the syrup is mixed with milk of lime and reacted with carbon dioxide to produce a precipitate of calcium carbonate (chalk). The chalk precipitate entraps organic non-sucrose and inorganic impurities. Pressure filters are then used to remove the chalk precipitates and to produce clear, light brown syrup.

The brown syrup is then passed over series of acrylic and styrene resin columns and granular activated carbon columns. The resulting low colored syrup (fine liquor) is used for crystallization of white sugar or for the production of bulk liquid sugar.

The fine liquor, after reduction of its water content by multiple effect evaporation, is fed to vacuum boiling pans. Crystallization is initiated by seeding the concentrated liquor with slurry. The process is continued until the crystals reach the desired size. The resultant mixture of crystals and mother liquor is fed in centrifugals and the sugar crystals are washed with hot water to remove any adhering syrup.

1.2.3 Ethanol production

The most currently used biofuel for transportation worldwide is bioethanol. There are several priorities for bioethanol to be introduced both for developing and industrialized countries (Demirbas, 2007). Ethanol production is, in addition, viewed as several countries' long-term strategy for the following examples of benefits (Nguyen, 2007).

Reduction in oil demand: Pure ethanol can replace gasoline in modified spark-ignition engines, or it can be blended with gasoline at up to 10% concentration to fuel unmodified gasoline engines.

Agricultural benefits: Ethanol production from food crops can help create rural employment and develop flexible markets for surplus agricultural commodities.

Vehicle performance benefits: The quality of gasoline can be improved by blending ethanol with gasoline so as to increasing the octane level. Lead is now banned and methyl tertiary butyl ether (MTBE) is also being discouraged.

Reduction in greenhouse gas (GHG) emissions: There is scientific proof that use of ethanol could provide reductions in GHG emissions compared to gasoline. The concept is common for biomass fuels; the combustion of plant biomass at a rate equal to the rate in which new plants absorb CO_2 during their growth completes a closed cycle.

Air quality benefits: When used, ethanol generally produces lower tailpipe emissions of CO, SO_2, HC and PM.

The bioethanol production use food crops to be the raw materials mainly which are different in regions and classified as sugar-based feedstocks, starch-based feedstocks and lignocellulosic biomass-based feedstocks. 95% of the crop produced in Brazil comes from sugarcane. In the United States, corn production is several times greater than wheat. In the EU, in contrast, wheat production is three times higher than corn production (IEA, 2004-A). With concerning on food crops use to produce fuel, there is increasing interest in the production of ethanol from lignocellulosic feedstocks, especially those collected from the agricultural residues (e.g., corn stover and sugarcane bagasse), forestry wastes (e.g., sawdust and paper sludge), and herbaceous and woody energy crops (Gnansounou, 2005). If process technology to transform these waste products into high-quality fuels on a commercial scale is available, it provides not only a safe measure to dispose of the waste but also a means to salvage energy stored in biomass. Anyway, the scope of this study covers just the production of ethanol from sugar-based feedstocks in Khon Kaen, located in North-eastern region of Thailand.

1.2.3.1 Situation of bioethanol production in Thailand

Sugarcane is the important materials for producing bioethanol in Thailand. In February 2008, a number of ethanol factories were expected to start operation within 2008 with 1.5 million L/day of total designed capacities. Parts of them were the sugarcane-based ethanol production factories as Figure 1.7. Moreover, considering to demand of people, there was the report that gasohol was totally sold around 7.3 million L/day in February 2008 (0.7 million L/day of ethanol demand – 106% increasing from January 2007) (DOEB, 2008). In addition, the government established a policy to support ethanol use seriously and aimed to produce 2.4 million L/day of ethanol in 2011.

From literature, 1 ton of sugarcane can approximately produces 104 kg of sugar and 45 kg of molasses (Natthakrit, 2009). Considering to Table 1.2 & 1.5, in the year 2007, Thailand would be, therefore, able to produce 7,383,155 kg of molasses/day and 1,919,580 liters of ethanol 95%/day approximately. According to the government aim, to produce 2.4 million liter/day in the year 2011, amount of ethanol output was quite less than the plan. Especially this amount was not included the amount of molasses used in the other types of industry, signifying that using only molasses to produce ethanol was not sufficient.

The production of cassava in the year 2007 was 26,411,000 tons. Calculated by information in Table 1.5, it meant that Thailand would be able to produce 2,604,921 liters of ethanol per day by using cassava. Therefore if cassava was considered, Thailand would be able to autonomous in ethanol production.

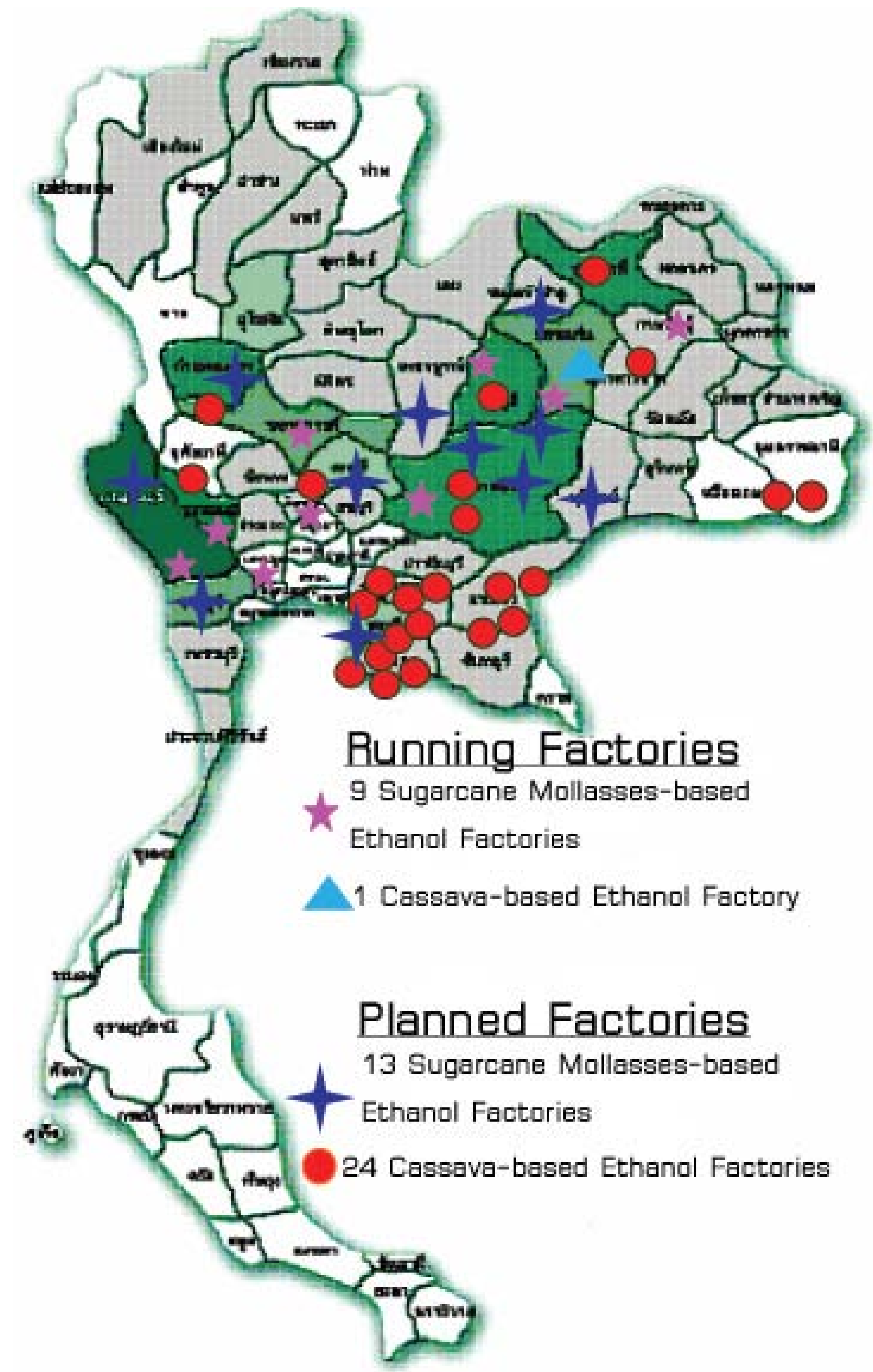


Figure 1.7 The sites of sugarcane molasses-based ethanol production factories and cassava-based ethanol production factories in Thailand (DOEB, 2008)

Table 1.5 Amount of ethanol output from various kinds of feedstocks (Natthakrit, 2009)

Feedstocks (1 ton)	95% of ethanol (liter)
Sugarcane molasses	260
Sugarcane	70
Cassava	180
Sorghum	70
Cereal (rice, corn)	375
Coconut oil	83

In year 2009, there were 15 running ethanol factories with 2.3 million L/day of total designed capacities. as shown in Table 1.6 (DEDE, 2009-A). This progress from the year 2008 could show the high potential to reach the target of Thai government at 2.4 million L/day in 2011. Moreover, there are 8 factories preparing to start the operation within these few years with over 3.4 million L/day of total designed capacities (DEDE, 2009-A).

Table 1.6 Name of operating ethanol factories and capacity (DEDE, 2009-A)

No.	Name of company	Location	Designed capacity (L/day)	Main raw material	Start date
1	Pornwilai International Group Trading Co., Ltd.	Ayutthaya	25,000	Molasses	Oct 2003
2	Thai Agro Energy Co., Ltd.	Suphan Buri	150,000	Molasses	Jan 2005
3	Thai Alcohol Co., Ltd. (Plc)	Nakhon pathom	200,000	Molasses	Aug 2004
4	Khon Kaen Alcohol Co., Ltd.	Khon Kaen	150,000	Molasses	Jan 2006
5	Thai Nguan Ethanol Co., Ltd.(Plc)	Khon Kaen	130,000	Cassava	Aug 2005
6	Thai Sugar Ethanol Co., Ltd.	Kanchanaburi	100,000	Molasses	Apr 2007
7	K.I. Ethanol Co., Ltd.	Nakhon	100,000	Molasses	Jun 2007

		ratchasima			
8	Petro Green Co., Ltd	Kalasin	200,000	Molasses	Jan 208
9	Petro Green Co., Ltd	Chaiyaphum	200,000	Molasses	Dec 2006
10	Ekarat Pattana Co., Ltd.	Nakhon Sawan	200,000	Molasses	Mar 2008
11	Thairungreung power Co., Ltd.	Saraburi	120,000	Molasses	Mar 2008
12	Ratchaburi Ethanol Co., Ltd.	Ratchaburi	150,000	Cassava	Jan 2009
13	E.S. Power Co., Ltd.	Sakaeo	150,000	Molasses	Jan 2009
14	Mae Sod Clean Energy Co.,Ltd.	Tak	200,000	cane juice	May 2009
15	Sapthip Co., Ltd.	Lopburi	200,000	Cassava	May 2009
	Total designed capacity		2,275,000		

1.2.3.2 Conversion technology

Ethanol can be produced from any biological feedstocks that contain appreciable amounts of sugar or materials that can be converted into sugar such as starch or cellulose. Bioethanol production can be mainly categorized by feedstocks to three types; sugar, grain/tuber, and cellulosic biomass. Fundamental production process of bioethanol is different in feedstock as summarized in Table 1.7.

Table 1.7 Ethanol production steps by feedstock and conversion technique (IEA, 2004-B)

Feedstock	Harvest technique	Feedstock conversion to sugar	Process heat	Sugar conversion to alcohol	Co-products
Sugar crops (cane)	Cane stalk cut, mostly taken from field	Sugar extracted through bagasse-crushing, soaking, chemical treatment	Primarily from crushed cane (bagasse)	Fermentation and distillation of alcohol	Heat, electricity and molasses
Cellulosic	Full plant	Cellulose	Lignin and	Fermentation	Heat,

crops (grasses, trees)	harvested; grasses cut	conversion to sugar via saccharification (encymatic hydrolysis); lignin use for process energy	excess cellulose	and distillation of alcohol	electricity animal feed, bioplastics, etc.
Grain and Tuber crops (wheat, corn, cassava)	Starchy parts of plants harvested; stalks mostly left in the field	Starch separation, milling, conversion to sugars via enzyme application	Typically from fossil fuel	Fermentation and distillation of alcohol	Animal feed (e.g. distillers dried grains), sweetener (from corn feedstock)

Sugar to ethanol: More explanation for Table 1.7, the first process of ethanol production from sugar crops is removing the sugar (such as through crushing, soaking and chemical treatment). The sugar is then fermented to alcohol using yeasts and other microbes. The final step is purifying the ethanol to the desired concentration and usually removes all water to produce "anhydrous ethanol" that can be blended with gasoline. The process of sugarcane molasses-based ethanol production is shown as Figure 1.8.

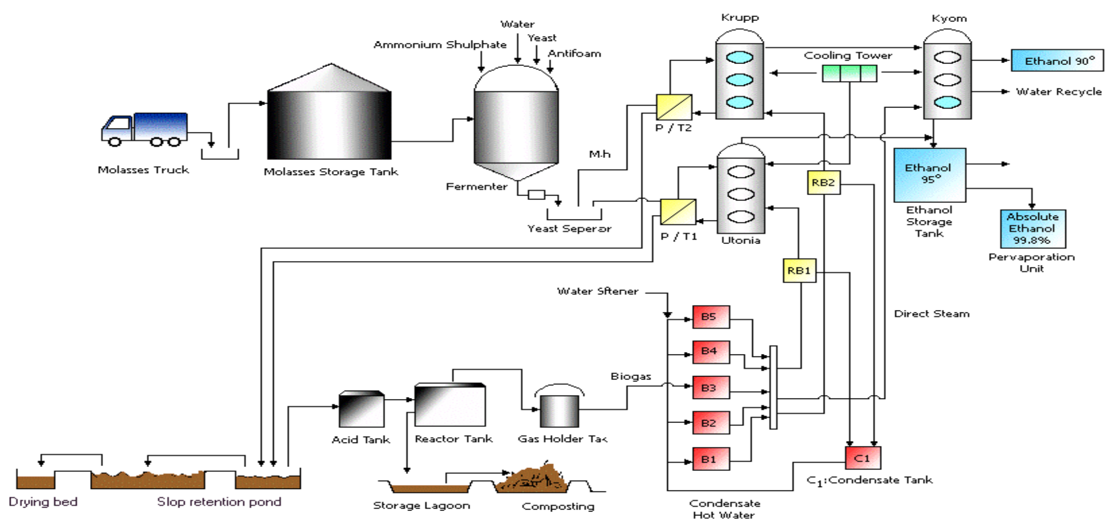


Figure 1.8 Process of sugarcane molasses-based ethanol production (The Liquor Distillery Organization, 2008)

Cellulosic biomass to ethanol: The first step in converting biomass to ethanol is pre-treatment, involving cleaning and breakdown of materials. Some hemicelluloses can be converted to sugars in this step, and the lignin removed. Next, the remaining cellulose is hydrolyzed into sugars, the major saccharification step. Common methods are dilute and concentrated acid hydrolysis. As sugars are produced, the fermentative organisms convert them to ethanol.

Grain/Tuber to ethanol: The process of grain to ethanol is separating, cleaning and milling (grinding up) the starchy feedstock. Milling can be "wet" or "dry", depending on whether the grain is soaked and broken down either before the starch is converted to sugar (wet) or during the conversion process (dry). For wet milling process, only starch enters the process. For dry milling, all components of the grain (starch, fiber, proteins, fats, minerals) are involved in the process. In both cases, the starch is converted to sugar, typically using a high-temperature enzyme process (Cardona, 2007).

Three basic steps involved in the conversion of biomass to ethanol are listed as follows (Nguyen, 2007):

a) Hydrolysis: It is a process of converting biomass (starch, cellulose) to a fermentable sugar, using a variety of different process technologies depending on type of feedstock.

$$(C_6H_{10}O_5)n + nH_2O \xrightarrow{\text{enzyme}} nC_6H_{12}O_6$$

b) Fermentation: This process relies on yeasts or other microbes to convert six-carbon sugars (mainly glucose) to ethanol and carbon dioxide.

$$C_6H_{12}O_6 \xrightarrow{\text{yeast/bacteria}} 2C_2H_5OH + 2CO_2$$

c) Distillation and dehydration: The fermentation product is a relatively dilute aqueous solution of ethanol, about 5-10% weight per volume. Ethanol at this concentration is separated from the fermentation product by distillation. Conventional distillation yields hydrous ethanol, a mixture of about 95% alcohol and 5% water. The production of anhydrous ethanol requires a dehydration step which could be accomplished in one of three ways: Azeotropic distillation, Molecular sieve separation and Membrane evaporation.

c-1) Azeotropic distillation technology uses a third solvent added to the ethanol/ water mixture. This changes the boiling characteristics of the solution taking advantage of the formation of another azeotrope which allows separation of anhydrous ethanol. Benzene was first used as entrant of choice of ethanol dehydration but now considered a powerful carcinogen. In those factories that employ this technology to produce ethanol, benzene has been replaced by a less hazardous substance, e.g. cyclohexane.

c-2) Molecular sieve dehydration technology works on the principle of pressure swing adsorption. Water is first adsorbed on the surface of "molecular sieves" and then cyclically removed under certain conditions. Molecular sieves are composed of synthetic zeolites. The structure of zeolites is able to absorb or reject material based on molecular size. Water molecule can enter the sieve and be adsorbed there, whilst larger alcohol molecule cannot and thus will pass through the bed. There can be 2-3 beds working in parallel.

c-3) Membrane pervaporation process is a form of ultra-filtration where water is filtered out from the alcohol-water mixture via a hydrophilic membrane. Ultra filtration, nano-filtration and reverse osmosis principles are applied here.

Summarily, the information in Table 1.7 can be abridged as shown in Figure 1.9. From 3 main lines of feedstocks, sugarcane is sugar-based feedstock.

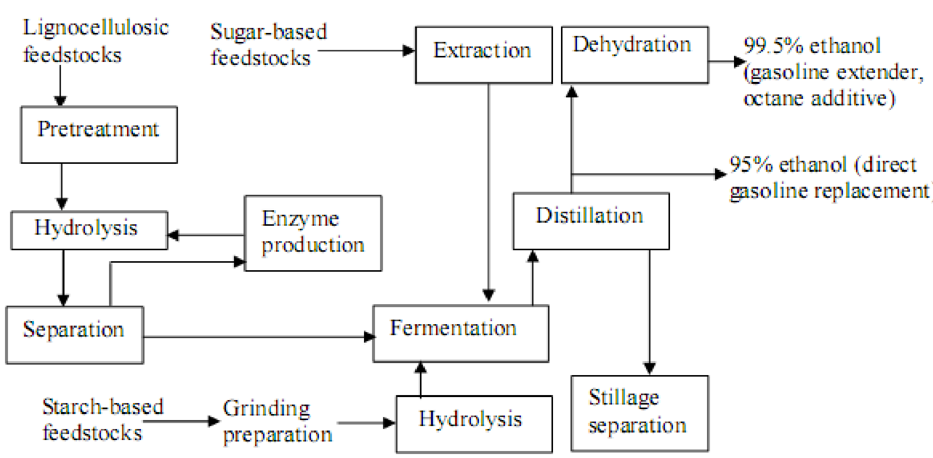


Figure 1.9 Schematic representation of principal steps in ethanol conversion process (Nguyen, 2007).

1.2.4 Biomass power plant

1.2.4.1 General information and situation of biomass power plant in Thailand

Agricultural residues like bagasse – byproduct from sugar production – can be directly combusted to produce heat, steam, and electricity. Length of bagasse fibril is around 10-20 cm. with moisture about 50%. Moreover, about 10 million tons of cane leaf with moisture content just 10% is equivalent to 3,800 million liter of fuel oil. Therefore, if cane leaf is not uselessly burned and is collected from farm to factories, the following profit will be obtained (Wangkanai Group, 2008).

1. **Lower price of feedstock in power generation:** this kind of green energy can be approximately transferred to 1,200 MWh of electricity.
2. **High quality of feedstock in sugar production:** without burning leaf before harvesting, sugarcane yield is certainly fresh with high sweetness.
3. **Better atmosphere:** environmental problem from burning leaf is diminished.

However, it is difficult task to collect sugarcane leaf from farm. In year 1991, “USAID” provided fund to study the potential of using sugarcane leaf as feedstock for power generation. This found that the cost to collect leaf within 20 km from power plant was about 750 THB/ton almost equal to the cost to collect fresh sugarcane. Furthermore, collecting leaf from agricultural area was obstructed by land characteristic of sugarcane farm (big rock, hole, knoll, etc.). This project was consequently failed but if there is some technique to collect sugarcane leaf with low cost, it will be considerable source of energy production (Wangkanai Group, 2008).

Other biomasses are always searched to reach the target of power production if bagasse and sugarcane leaves are not sufficient. Not like diesel, gas, etc.; biomass is widely scattered around country and hard to investigate the certain amount. The quantity will be estimated by ratio of residues to agricultural products.

Quantity of biomass = Quantity of agricultural product x residue ratio

Residue ratio is ratio between biomass left after harvesting or milling agricultural product; for example (Biomass One-Stop Clearing House, 2006).

- 1,000 kg of paddy is milled to 540 kg of rice, 130 kg of rice broken, 110 kg of bran, and 220 kg of husk. Therefore, ratio of husk to paddy is 220/1000 or 22%.
- Per 1 rai, amount of paddy and straw is 800 and 390 kg. Therefore, ratio of straw to paddy is 390/800 or 49%.

Type, amount, and heating value, total energy from agricultural residues; as potential to produce electricity in Thailand; averaged from amount of agricultural products in each year is shown in table 1.8. However, the utilization of biomass in term of energy is unquestionably less than the potential because some types has too high moisture content while some types is not worth to collect from field. Location and quantity of electricity generation from biomass power plant (SPP & VSPP) in Thailand is shown in Figure 1.10.

Table 1.8 Potential of biomass in Thailand: year 2001/2002 (Biomass One-Stop Clearing House, 2006)

Type	Yield (kg)	Residue (kg)		Heating value (MJ/kg)	Energy (TJ)	Oil equivalent (MT)	Electricity (MW)
Sugarcane	60,013.00	Bagasse	3,615.00	14.40	52,056.04	1.23	764.21
		Leaf	17,870.19	17.39	310,762.62	7.36	4,105.92
Rice	26,514.00	Husk	3,006.42	14.27	42,901.65	1.02	566.83
		Straw	8,106.60	10.24	83,011.61	1.97	1,096.78
Palm	4,089.00	Empty Fruit Bunch	1,022.05	17.86	18,253.88	0.43	241.18
		Fiber	80.55	17.62	1,419.21	0.03	18.75
		Palm shell	7.41	18.46	136.85	0.00	1.81
		Palm leaf	10,647.76	9.83	104,667.44	2.48	1,382.91

		male flower bunch	952.74	16.33	15,558.20	0.37	205.56
Corn	4,466.00	Corncob	816.88	18.04	14,736.44	0.35	194.71
Peanut	129.00	Shell	41.67	12.66	527.50	0.01	6.97
Cotton	36.00	Trunk	116.35	14.49	1,685.94	0.04	22.27
Soybean	292.00	Trunk and leaf	590.97	19.44	11,488.51	0.27	151.79
Sorghum	145.00	Trunk and leaf	117.64	19.23	2,262.18	0.05	45.14
Wood chips	10,268.00	Branch and stem	2,669.68	14.98	39,991.81	0.95	528.39
Coconut	1,396.00	Coconut bark	300.68	16.23	4,880.11	0.12	64.48
		Coconut shell	84.43	17.93	1,513.83	0.04	20.00
		coconut bunch	57.66	15.40	888.03	0.02	11.73
		Coconut leaf	254.11	16.00	4,065.71	0.10	53.72
Cassava	16,868.00	Trunk	604.14	18.42	11,128.34	0.26	147.03
Total amount			48,293.26	Total energy	721,935.91	17.10	9,630.18

Theoretically, size of biomass power plant is always not bigger than 10 MW because cost to collect biomass directly varies to the distance while bigger size of fossil power plant is worthier because cost of operation and construction per unit of energy produced is lesser. Gas is transported by pipeline or coal is transported by vessel with enormous volume.

Limitations of biomass power plant are listed as following (Biomass One-Stop Clearing House, 2006):

High moisture content: size of chamber has to be bigger and some devices to reduce moisture must be designed in case of very high moisture content affecting to cost.

Low melting point of ash: ash of some kinds of biomass has low melting point. If temperature in chamber is too high, ash may be melted. This makes problems and reduces the efficiency of steam production.

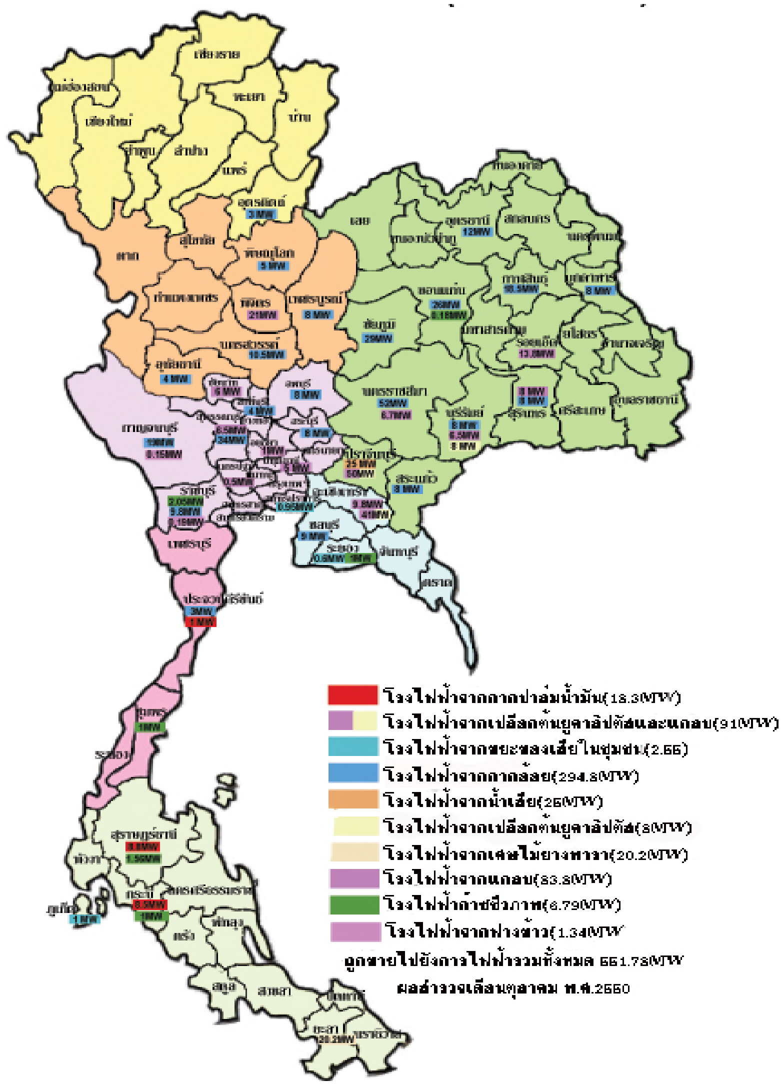


Figure 1.10 Location and quantity of electricity generation from biomass power plant (SPP & VSPP) in Thailand (EFE, 2008-A)

Uncertainty of supply in each year: amount of biomass is up to the agricultural yield according to the season. During harvesting season, the quantity is definitely high while the quantity during out of harvesting season is low. The price is then higher. This cycle will be happen every year.

Difficult to predict the amount and price for long term: the amount of biomass depends on several factors such as trend of farming caused by market price of agricultural product, policy of government, environmental condition of area, etc. Therefore, long-team plan for producing energy is hard to design. This is different to fossil fuels that can be obviously predicted and reserved.

No credit for purchasing: to purchase this kind of energy feedstock, only cash is admitted, not like other industrial product that can be paid by credit at 5-6 months.

Demand of other industries: if many kinds of industries also need biomass in their processes. Price of biomass will be certainly higher by demand increased.

Low density: with the same volume, weight of biomass is basically lower. Therefore, per energy obtained, number of trip to carry biomass affecting to cost is so higher than to carry fossil fuel. In addition, number of trip means to number of truck running around the area. This can also cause to the traffic problem.

Table 1.9 Average weight of products carried by 10-wheel truck (40 m^3) (EFE, 2008-A)

No.	Biomass	Average weight of product (Ton)
1	Rice husk	7
2	Off-Cut Para Rubber Wood	17
3	Saw dust	10
4	Palm shell	16
5	Rice straw	5
6	Cassava root	10
7	Empty fruit bunch	15

There are several technologies of electricity production but just one technology suitable and in trend for biomass power plant in Thailand is mentioned here that is boiler and steam turbine.

1.2.4.2 Boiler and steam turbine (EFE, 2008-B)

The system of this technology is to produce steam from burning energy feedstock and then send the steam into turbine to produce electricity. It is a basic technology of general power plant and its detail is given as follows:

There are several structures of chamber depending on type of fuel and effieciency of burning. The examples of structure using in Thailand are as following:

Incline/ Fixed grate stoker: earthen grate is fixed with simple structure. Therefore, its cost is quite cheap. Disadvantage is low efficiency, hard to remove ash, fuel is sometime remained in the middle of earthen grate and then its efficiency of burning is lower. This structure is widely used in many sugar factories, palm factories, and rice mill.

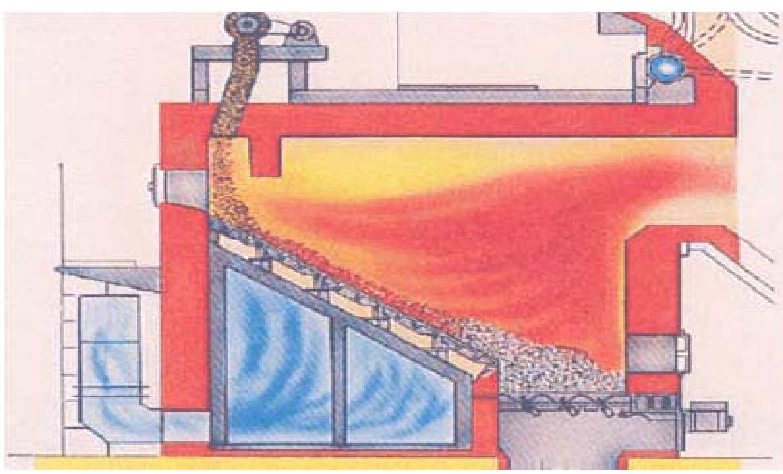


Figure 1.11 Inclined/ Fixed grate stoker (EFE, 2008-B)

Traveling grate stoker: structure of earthen grate will move all the times like tank's wheel. This is suitable for fuel with the same size and high ash ratio like husk. However, this structure is not appropriate to use with many kinds of fuel in the same time because they will not be burnt out together.

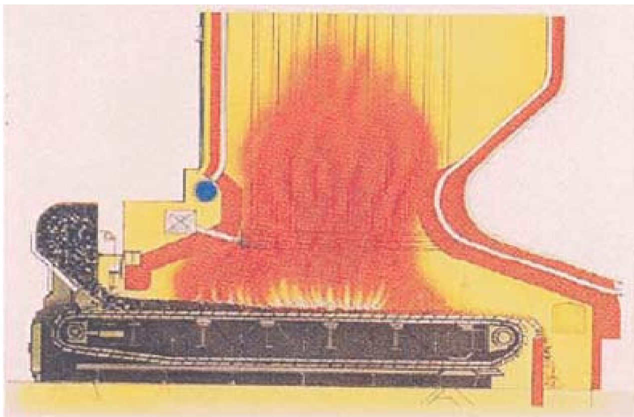


Figure 1.12 Traveling grate stoker (EFE, 2008-B)

Spreader stoker: this structure is developed from Traveling grate stoker by grinding fuel and then feeding to stove. Its efficiency is better than Incline (fixed) grate stoker & traveling grate stoker because there is more surface area of fuel touching with air but construction cost is also higher. It has the other name called **Suspension-fired**.

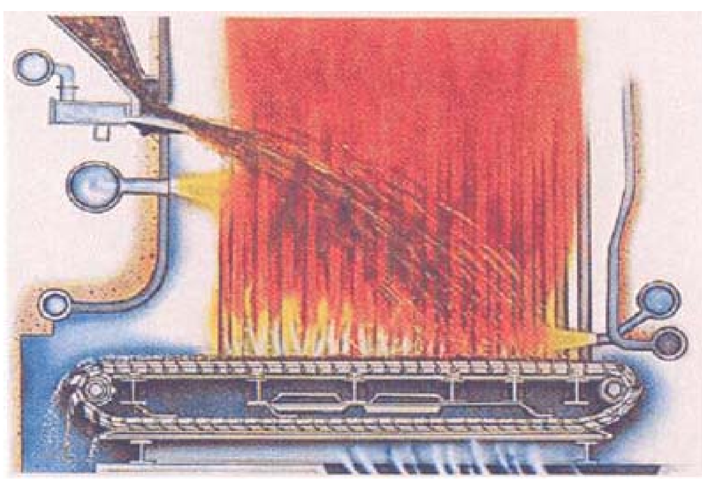


Figure 1.13 Spreader stoker (EFE, 2008-B)

Step grate stoker: its body structure is ladder. Fuel is pushed to each step of ladder. So, fuel has chance to turn around and its efficiency will be better. This structure is suited with various kinds of fuel.

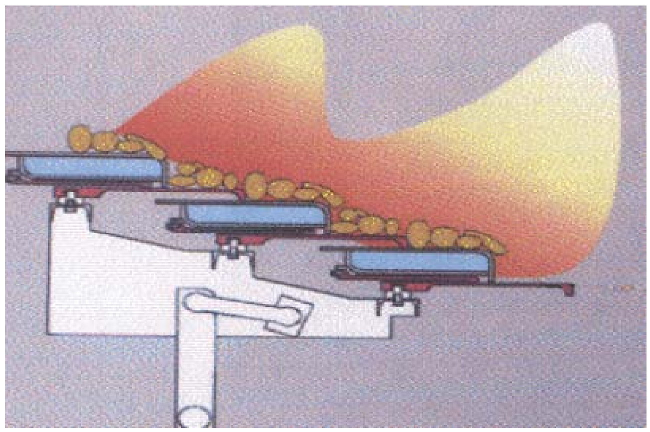


Figure 1.14 Step grate stoker (EFE, 2008-B)

Fluidized bed: media must have good qualification in dispersing heat. Sand is the recognized media. Its well-capability to make temperature of this system can drive out high moisture and burn low-quality fuel. This system can simultaneously burn several types of fuel. It is also better than fixed grate stoker in controlling quality, temperature, and air emissions e.g. NO_X and CO. However, its construction and maintenance cost is quite higher than that of fixed grate stoker (EFE, 2008-B).

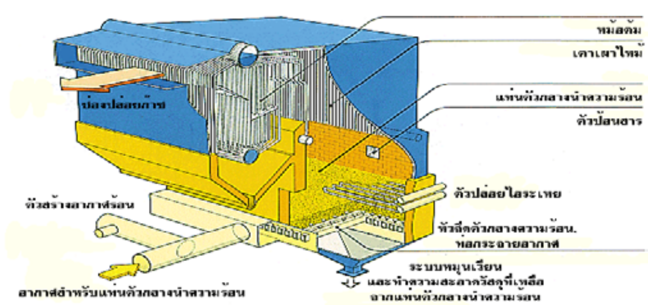


Figure 1.15 Fluidized bed (EFE, 2008-B)

Vibrating grate stoker: earthen grate will be vibrated so that ash can better go down to increase efficiency of burning.

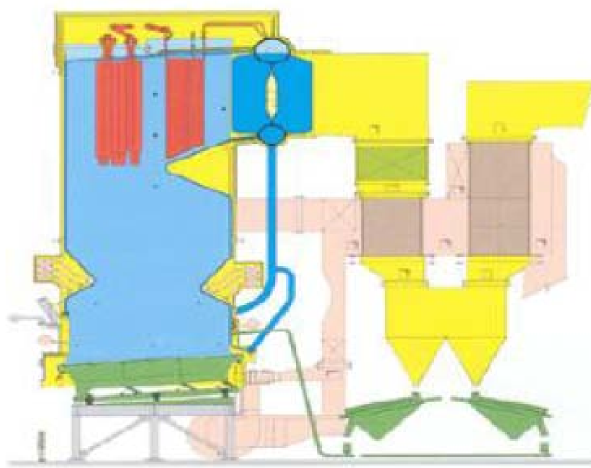


Figure 1.16 Vibrating grate stoker (EFE, 2008-B)

Therefore, main factors to select type of system are investment budget, type of fuel, and price of fuel.

Water pressure in boiler can be divided into 3 levels according to the pressure:

1. Pressure > 20 bar: construction cost is low. It is found in many sugar and raw palm factories. The system is mainly cogeneration (steam is together used in production system). Efficiency in producing electricity is about 5%.

2. Pressure 20-40 bar: this size is mostly found in Thailand. Construction cost is about 1.0-1.2 million dollar U.S. Its total efficiency is around 20-23%.

3. Pressure > 60 bar: Construction cost is about 2 million dollar U.S. Its total efficiency is around 25-28%.

Price of fuel is the main factore whether high pressure of biomass power plant is suitable in Thailand. There are 2 turbine structures according to the characteristic.

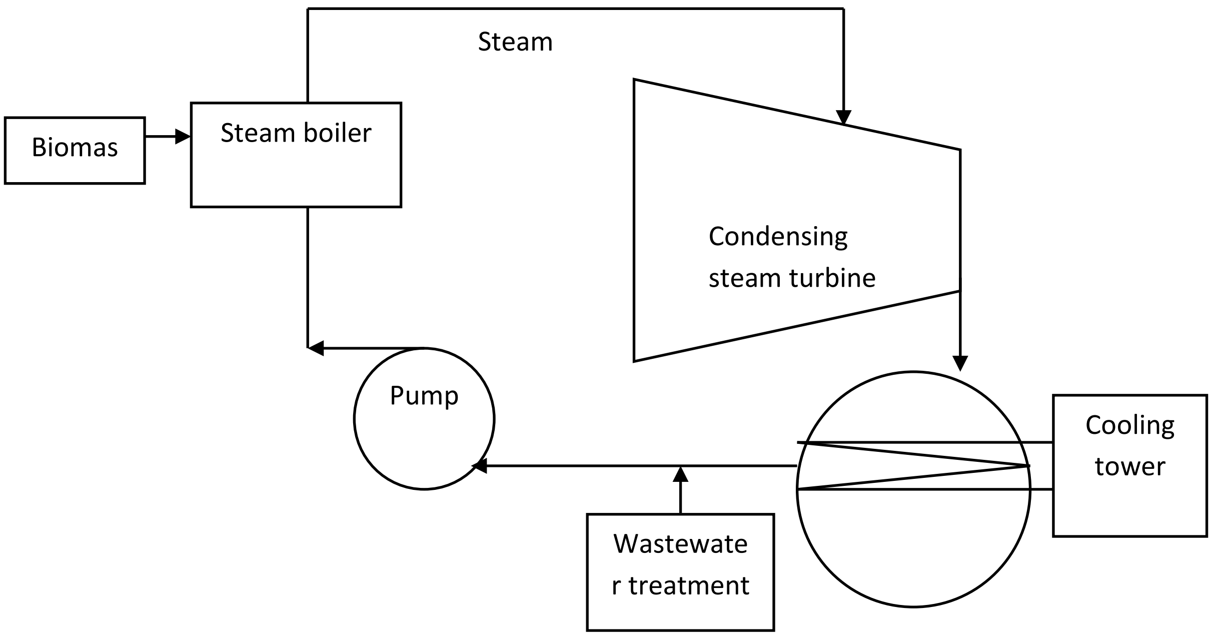


Figure 1.17 Flowchart of boiler system and condensing turbine (EFE, 2008)

Condensing turbine: Firstly, water is brought to treat and pass the standard of quality. Then, water is sent by Boiler feed pump to Boiler. Water heated in boiler become steam and flow into condensing turbine so that electricity can be produced by circulation. Water from Turbine now have lower pressure but still be in steam condition. It must be passed into Condenser and Cooling tower to be water condition. Then, that water will be pumped back into boiler again as cycle. Efficiency of system is 15-20%.

Back pressure turbine: concept of this system is a bit different from condensing turbine. There is no condenser and cooling tower. Steam from turbine will have high pressure so that it can be exploited in production process. This is called back pressure which is able to control steam pressure according to the demand of production process. Nevertheless, electricity produced is lesser. This kind of technology is suited to the factories requiring steam as main energy such as sugar factory, palm extraction factory, etc. Therefore, demanded steam and electricity must be well balanced. The efficiency of system is over 50% relying on how design to bring back heat and steam to utilize in production process.

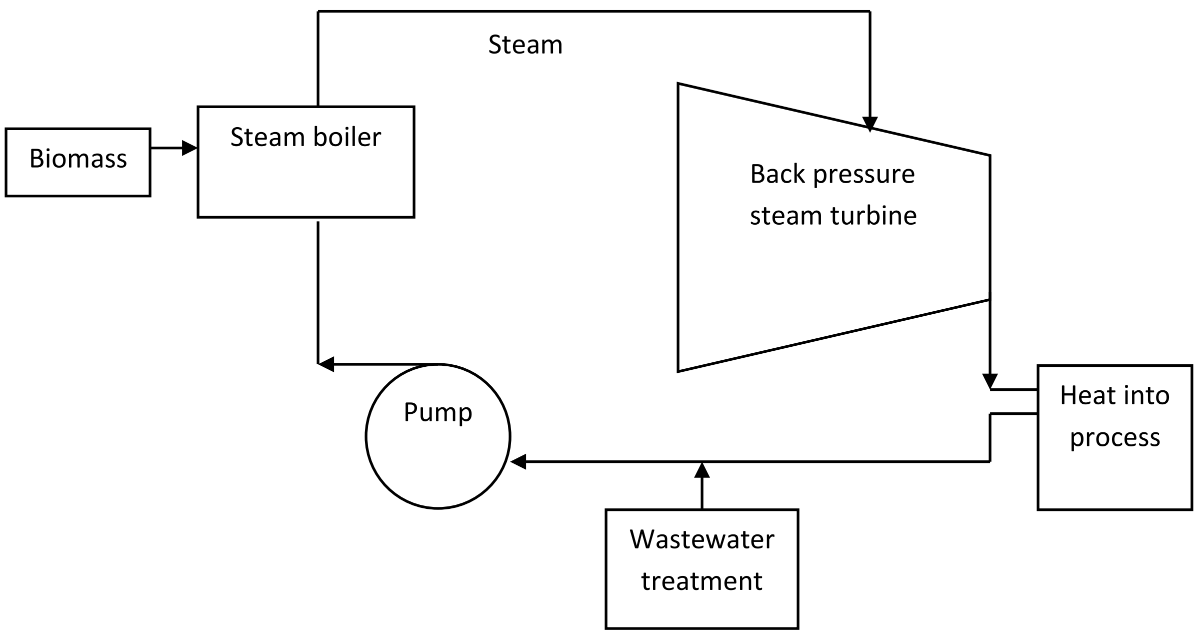


Figure 1.18 Flowchart of boiler system and back pressure turbine (EFE, 2008)

2. OBJECTIVE, SCOPE OF THE RESEARCH & METHODOLOGY

For overall understanding, the linkages between the four main stages leading to molasses based ethanol production for our pilot study are illustrated in Figure 2.1. Based on this information, environmental, economic, and social assessment related to the five main production units leading to molasses based ethanol production and which include: sugarcane plantation, sugar mill, ethanol plant, biomass power plant and fertilizer plant as well as all transportations activities, were performed in this study. The methodologies related to such assessments are detailed in the sections below.

2.1 Environmental Assessment

2.1.1 Background information

The environmental assessment was performed by assessing in a life cycle perspective the GHG emissions associated to the biorefinery complex including the sugarcane plantation. The environmental impact was assessed in term of global warming potential. To this end input-output data, or so called "Life Cycle Inventory" (LCI) data, were collected for each production unit of the biorefinery complex including, sugarcane plantation nearby the sugar mill, sugar mill, biomass power plant, fertilizer plant, and ethanol plant in Khon Kaen.

To perform this assessment the *reference flow* (RF) chosen for the study is 1,000 kg of sugarcane. The system boundary, as already mentioned above and shown in Figure 2.1, includes the sugarcane cultivation and harvesting, sugarcane mill, ethanol production, bagasse-based power generation, fertilizer production. Data gaps (transportation distances between various production units for instance) were resolved based on academic assumptions made upon data available from the study site or values retrieved from the literature. The scope of this study is gate-to-gate.

In the environmental analysis, the assessments of environmental emissions associated to facilities construction e.g. manufacturing machines, irrigating structures, buildings, infrastructures, vehicles, etc. as well as to manual labor e.g. new planting, pruning, harvesting, machine operating, driving etc., were excluded. Also it is suggested that the information reported for the environmental assessment is only valid within Thailand for a period of 5 years based on the assumptions that the farming practices and ethanol conversion technologies will not change significantly over this period of time. The information to accomplish the analysis is opened for any available sources (Published journals, textbooks, technical reports, government publications and online articles) both Thai and foreign literature. Primary data collected from the pilot study site was compared with information published in the literature, as necessary, and presented in the report and appendices. As the site in the pilot study in Khon Kaen is specific, names of factories and confidential data do not appear in the report.

The GWP assessment was conducted based on mid-point indicator and the characterisation factors from the IPCC 4th assessment report published in 2007 (IPCC, 2007). The allocation of environmental burdens between the co-products was performed based on recommendation from the WG members. Allocation by energy was selected first based on energy content. In some cases, allocation was avoided when expansion of system boundary was possible. In cases when no databases for environmental calculation were available, 1% was considered to be acceptable as negligible as cut-off rule.

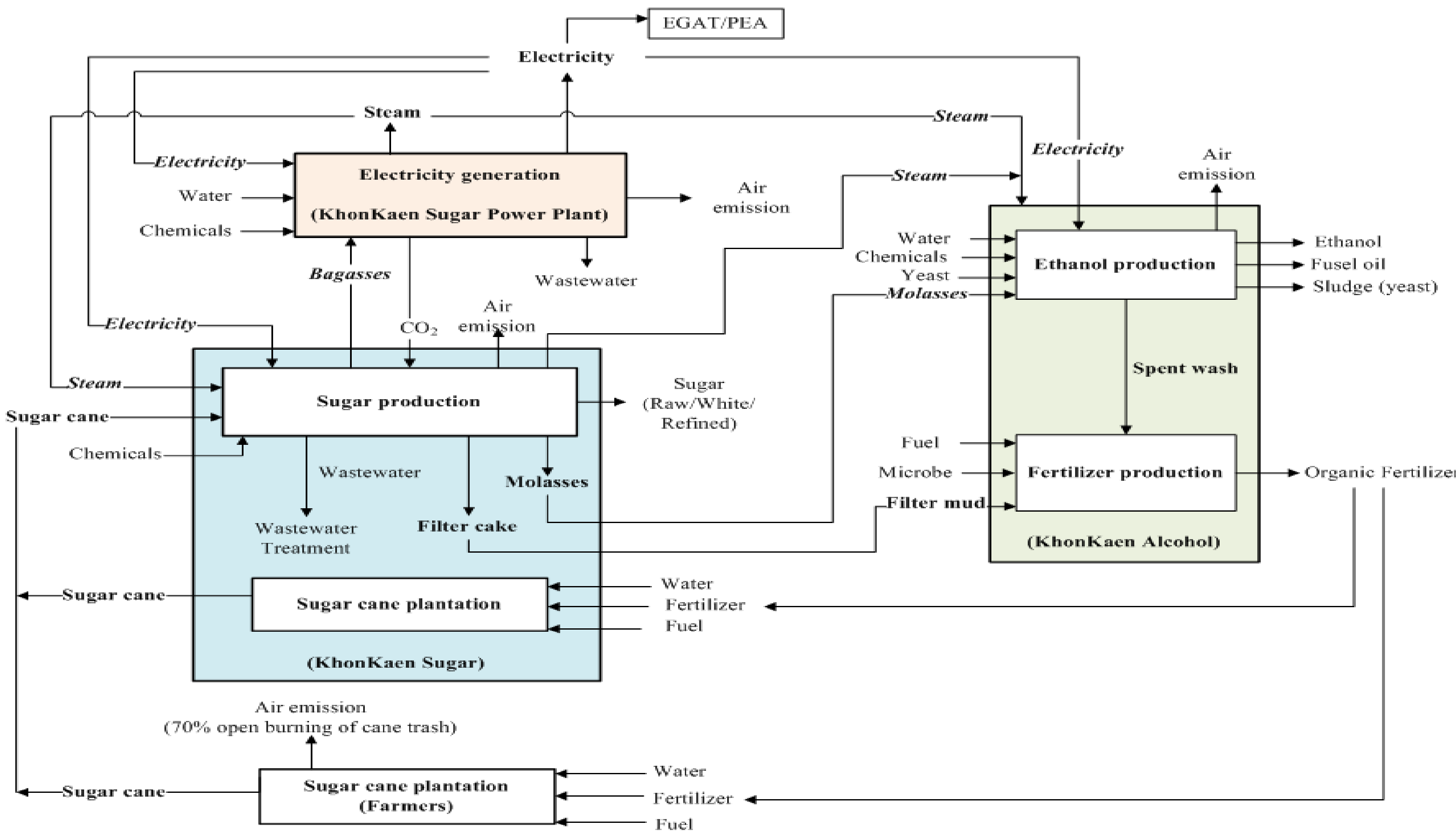


Figure 2.1 Linkages between the four main stages of molasses based ethanol production

2.1.2 Inventory analysis

Although data was mainly collected from Khon Kaen, some information was also retrieved from other sources since some activities are operated outside Thailand, such as for instance chemical fertilizers production. Also data were collected from the literature in order to be able to compare the results obtained in this study with that from other sources. Details of all data collected in this study are reported below.

2.1.2.1 Data collection from the literature

The data collected from literature review include:

- Data related to sugarcane cultivation and products' output
- Data related to ethanol production process such as molasses production for instance
- Current method of commercial production of ethanol, including data on waste management
- Transportation data related to sugarcane production and ethanol conversion (transport method, loading, distance, and frequency of transport).

2.1.2.2 Data collection from study site

Primary data was collected from sugarcane plantation, transport, ethanol factories and relevant governmental organizations through visits, interviews and questionnaire surveys. This data would be of primary importance for the life cycle inventory (LCI) and life cycle impact assessment (LCIA).

Sugarcane plantation:

For the farming stage, main data were collected from farms nearby the sugar mill. Existing data from earlier studies could also be used for sugarcane production for comparative purposes.

Data collection from factories:

Production of sugar, ethanol, electricity and fertilizer**:**

- Method and process of production

- All input-output inventories
- Utilisation of product output
- Emissions to air, water, soil, and waste management

Transportation data:

For the transportation stage, relevant data include types of transport, amount and type of fuel used. Based on availability of information, data was also retrieved from literature sources whenever applicable.

In Table 2.1. are summarized the type, sources and method of collection of the life cycle inventory data for molasses-based ethanol production, from sugarcane plantation to ethanol conversion and use.

Table 2.1 Life cycle inventory data - Type, sources and collection method

Main unit process	Data required	Data sources	Collecting method
Sugarcane production	- Fuel use - Fertilizer use - Herbicide use - Cane trash burning	- Sugarcane farmers - Thai & foreign research reports	- Questionnaire - On-site interview - Literature review
Sugar/Molasses production	- Production capacity - Fuel use - Electricity use - Surplus electricity sold to the grid - Chemical use - Waste management/ Utilization	- Sugar factory - Thai & foreign research reports	- Questionnaire - On-site interview - Literature review - Factory report
Ethanol conversion	- Production capacity - Fuel use - Electricity use - Chemical use - Waste management/ Utilization such as biogas	- Ethanol factory - Thai & foreign research reports	- Questionnaire - Interview - Literature review - Factory report

Biomass power plant	- Production capacity - Fuel use - Electricity use - Surplus electricity sold to the grid - Chemical use - Waste management/ Utilization	- Power plant - Thai & foreign research reports	- Questionnaire - Interview - Literature review - Factory report
Fertilizer production	- Production capacity - Fuel use - Electricity use - Chemical use - Waste utilization	- Fertilizer production unit - Thai & foreign research reports	- Questionnaire - Interview - Literature review - Factory report
All transportation activities involved in the system	- Distance - Transport - Mode/Capacity	- Sugarcane farmers - Bulk terminal company - Sugar factory - Ethanol factory - Thai & foreign research reports - Assumptions	- Questionnaire - Interview - Literature review

2.1.3 Impact assessment

The environmental impact category considered in this study is global warming potential (GWP). It can be determined from the equation shown below (Wenzel, 1997);

$\Sigma EIP = \Sigma (Q_{(x)} \times EF_{(x)})$

Where:

EIP: Environmental impact potential

$Q_{(x)}$: Quantity of substance “x”

$EF_{(x)}$: Emission factor of substance “x”

The calculations are based on the reference flow defined in the study (1,000 Kg of sugarcane). The characterization factors used for the calculations are based on the IPCC

2007 report and GWP is expressed in terms of CO_2 equivalent per unit of reference flow. Additional explanations relating to calculations of GWP are provided below.

Greenhouse Gas Emissions (TEF, 2007):

Greenhouse gas emissions are (consisting of CO_2, CH_4, N_2O, etc.) based on raw materials/fuel use and emission measurements from the factories studied. Details about the hypothesis and methods of GHG emissions calculations are presented below for various cases.

Case 1: Calculation of GHG emissions from cane leaves burning prior to harvesting and cane trash burning for land preparation. The greenhouse gases considered include CH_4 and N_2O based on IPCC methodology for GHG emission estimation from agricultural residues burning.

Step 1 Calculation of carbon released/ ton cane

Carbon released/ ton cane	=	Amount of cane trash (kg/ton cane)
		× Dry Matter fraction of cane trash
		× percentage of cane trash burned in field
		× fraction oxidized
		× carbon fraction

determine;

Percentage of cane trash burned in the field	=	50%
Fraction Oxidized	=	0.9
Carbon fraction	=	0.50 kg C/kg residue (DM)
Dry matter fraction (of cane leaves)	=	0.45%

The assumption taken in this case is that combustion is complete. Hence the carbon emitted for calculation is carbon dioxide.

Step 2 Calculating CH_4 released/ton cane and N_2O released/ton cane

CH_4 released (kg CH_4 /ton cane) = Carbon released (kg C/ton cane)

× Emission ratio of CH_4 (= 0.005)

× Conversion Ratio (= 16/12)

N_2O released (kg N_2O/ton cane) = Carbon released (kg C/ton cane)

× Nitrogen-Carbon ratio (= 0.015)

× Emission ratio of N_2O (= 0.007)

× Conversion ratio (= 44/28)

N/C Ratio is 0.010-0.020

Emission Ratio: Reference to Intergovernmental Panel on Climate Change (IPCC, 2007).

Case 2: Calculation of GHG emissions from fossil fuel. In case that fossil fuel is used, CO_2 is also to be included in the emission calculations. If a factory selects biomass as a source of energy, the CO_2 released from the combustion of that biomass can be omitted (carbon neutral concept). The assumption is that because trees absorb CO_2 as they grow, the net amount of CO_2 added to the atmosphere from biomass energy use can be reduced through the use of biomass based power as long as the trees are replanted. However, non-CO_2 greenhouse gas emissions still need to be assessed, since these gases (N_2O or CH_4 for instance) are not absorbed during photosynthesis.

Case 3: At the sugar mill, the surplus of electricity generated from biomass and sold to the grid is considered, via allocation as co-product, to help decreasing GHG emissions on the basis of corresponding amount of fossil based electricity that is substituted.

Case 4: CO_2 released as a result of the fermentation process leading to ethanol production is not included for calculation of the GWP since it is regarded as CO_2 occurring naturally (released from microbial respiration).

Case 5: To determine the amount of GHGs and air emissions released from industrial factories (such as ethanol factory and sugar mill), the emissions will be those monitored at the stack, point where the air pollutants are released to the atmosphere.

2.1.4 Interpretation

This study will be assessed and interpreted to the step of classification and characterization that are the mandatory elements of Life cycle impact assessment according to the provison of ISO 14040. Comparison of scenarios will be done to find out the key factors of this study. The steps of normalization, grouping, and weighting as the optional elements are avoided due to the completion of project objectives since the step of characterization.

2.2 Social assessment

Social development of each country is related to its economic development and there are several indicators available for assessing social and economic impacts. According to the method developed by UNDP (Human Development Report Office, 2008), Human Development Index (HDI) is introduced as a measure of social development by combining indicators of life expectancy index, education index and gross domestic product (GDP).

HDI = 1/3(Life Expectancy Index + Education Index + Gross Domestic Product Index)

This formula provided by UNDP was applied to estimate social development from the sugarcane cane plantation and biorefinary complex in Khon Kaen (Human Development Report Office, 2008).

Data were collected on site via interview and questionnaire surveys, and from reports provided by the biorefinery complex including the sugar factory, biomass power plant, and alcohol factory (including ethanol and fertilizer plants). Details are as follows:

1. Data were obtained from the biorefinery complex in Khon Kaen and from farmers supplying sugarcane to the sugar factory via interview and questionnaire surveys.
2. Human development Index was determined both at the level of the sugarcane plantation (framers) and biorefinery complex (employees). Also the HDI for Khon Kean was investigated in order to serve as a basis for comparison with the results obtained from the plantation and biorefinery complex.
3. Gross Domestic Product (GDP), one of the indicators to calculate HDI, was replaced with the Gross Provincial Product (GPP) of Khon Kaen. GPP at current market prices was collected from the National Statistic Office of Thailand (TNSO).

4. GDP (PPP or Purchasing Power Parity) per capita for the sugarcane plantation and biorefinery complex is referred to as income per capita in term of purchasing power parity for this study.

5. Conversion factors were applied to calculate the GDP index at the level of the plantation and biorefinery complex. The PPP factor was obtained by dividing the GDP of Thailand with the GDP (PPP) of Thailand.

6. National level data were used for Life Expectancy Index, Education Index, Literacy Index, and Gross Enrollment Index since the information was unavailable at provincial level but could be representative for Khon Kaen.

HDIs for Khon Kaen, the sugarcane plantation and the biorefinery complex were determined via the following steps:

Step 1: Calculation of employment from sugarcane plantation

Employment refers to persons employed at the sugarcane plantation and includes all aspects related to land preparation, planting, fertilization and weeding. The data were collected from farmers that are either employed or owning the plantation via interview and questionnaire surveys.

Step 2: Calculation of employment from biorefinery complex

This refers to persons employed at the sugar factory, biomass power plant, alcohol factory (ethanol and fertilizer plants) as mentioned earlier. Data were obtained from annual and daily operation reports, environmental and environmental impact assessment reports, and from interviews and questionnaire surveys.

Step 3: Aggregating the cost of employment

The total cost of employment in term of person days per area for sugarcane plantation and the biorefinery complex were calculated based on the reference flow of 0.1 rai (area corresponding to production of 1,000 kg of sugarcane).

Step 4: Calculation of GDP (PPP) per capita

The total cost of employment from the previous steps is referred to as total income for employees at the level of the sugarcane plantation and biorefinery complex. The income per capita for sugarcane plantation and biorefinery complex was calculated by dividing the total income with total employment for each case. The corresponding income per capita (PPP) was determined for each case by converting it from THB to USD and multiplying with PPP factor.

Step 5: Calculation of GDP Index

GDP index can be calculated using the following formula from UNDP (Human Development Report Office, 2008);

GDP Index = [Log (GDP (PPP) per capita in USD)-Log (100)] / [Log (40,000) - Log (100)]

Step 6: Calculation of HDI

HDIs for sugarcane plantation and biorefinery through life expectancy index, education index and GDP index by given formula HDI = 1/3(LEI+EI+GI) for the area. These two indicators are obtained at national level whereas only GDP index is taken from step 5.

2.3 Economic assessment

For economic assessment, four factors are taken into consideration namely total net profit, wages (employment), tax revenues and foreign trade earnings. Those factors are investigated at the level f the sugarcane plantation and the biorefinery complex. From this information total value added is calculated for each level and for the whole complex (sugarcane plantation plus biorefinery complex).

Total Net Profit:

Total Net Profit (TNP) is the sum of the net profit generated from main products and by-products from production after deduct tax and cost of operation.

Total Net Profit = Total Income - Taxes - Total Costs and Expenses

Based on annual sugarcane production, total net profit is calculated for the sugarcane plantation and the biorefinery complex.

For the sugarcane plantation, total income from plantation is estimated by multiplying the annual amount of sugarcane sold with its selling price. For taxes, the tax rate is defined at 0.75% as withholding tax. The total costs and expenses for sugarcane plantation are projected by multiplying total area for plantation with total cost per area. The annual net profit is calculated by subtracting taxes and costs for plantation from total income. Data for calculation were collected via interview and questionnaire surveys.

For the biorefinery complex, annual net profit was collected from annual report. Net profit is calculated by deducting total income (total revenues from operations and other incomes) with corporate income tax at 35% and total costs and expenses.

Wages (salaries paid):

In this study, employment at the sugarcane plantation and biorefinery complex were investigated and expressed in terms of man-days. Based on availability of data, some conversions were performed to express man-days into number of persons hired and estimate wages paid.

Wages (salaries paid) = Wage rate x Labor Requirement

Tax revenue:

This is the income generated by the government from the entities involved in each production process. Tax revenue for this study includes sugarcane plantation from the farmers who are selling their sugarcane to the biorefinery complex and from the biorefinery complex itself. However, it is important to point out that in Thailand alcohol factory producing ethanol and fertilizer and biomass power plant are exempted from paying taxes for a certain number of tear which is applicable for this pilot study. Therefore, taxes are only coming from the production stage of sugarcane and the sugar mill. As reported earlier, for the sugarcane plantation there is a withholding tax of 0.75%, while for the biorefinery complex there is a corporate income tax of 35%.

Foreign trade earning:

This factor is determined by dollar earnings from product export and dollar savings from reduced product imports. Biomass production and processing has positive effects on foreign trade which is determined by two factors; foreign exchange earnings and foreign exchange savings. In this study, foreign exchange is considered by way of substitution of gasoline with ethanol. This factor is calculated the amount of money saved from the corresponding amount of gasoline that is substituted (and hence, not imported)

3. HISTORY, BACKGROUND, AND LIFE CYCLE INVENTORY OF EACH PRODUCTION UNIT

All the information and data for each production unit, that are necessary to interpret the results obtained for this pilot study, as well as background and history, are detailed in this chapter.

3.1 Sugarcane plantation

Average pH of sugarcane plantation area is around 5-5.5. In 2009, the quantity of rain received in this area ranges from 50.00-129.80 mm. From records provided by the sugar factory, during 2009-2010 4 thousand farmers passed a contract (contract farming) with the sugar mill to sell their sugarcane. This represents a total weight of sugarcane of more than 2 million tons. In reality about 1.87 million tons were sent to the factory (89.30% from contract farms). The largest amount per contract was 60,000 tons of sugarcane but this farm was able to submit about 45,701 tons of sugarcane while the highest amount submitted from one particular farm located nearby the sugar mill was about 76,000 tons (contract: 50,000 tons of sugarcane). The distance between the farms and the sugar mill does not exceed 50 km radius. The average amount of sugarcane per contract farm is about 515 tons but the real amount sent to the mill is about 460 tons. The average distance between the farms and the mill is in the range 25-50 km. The flow diagram and LCI data for cultivation stage are shown in Figure 3.1 and Table 3.1. The data reported in Table 3.1 was extracted from questionnaires that were sent to a sample of 42 sugarcane farms.

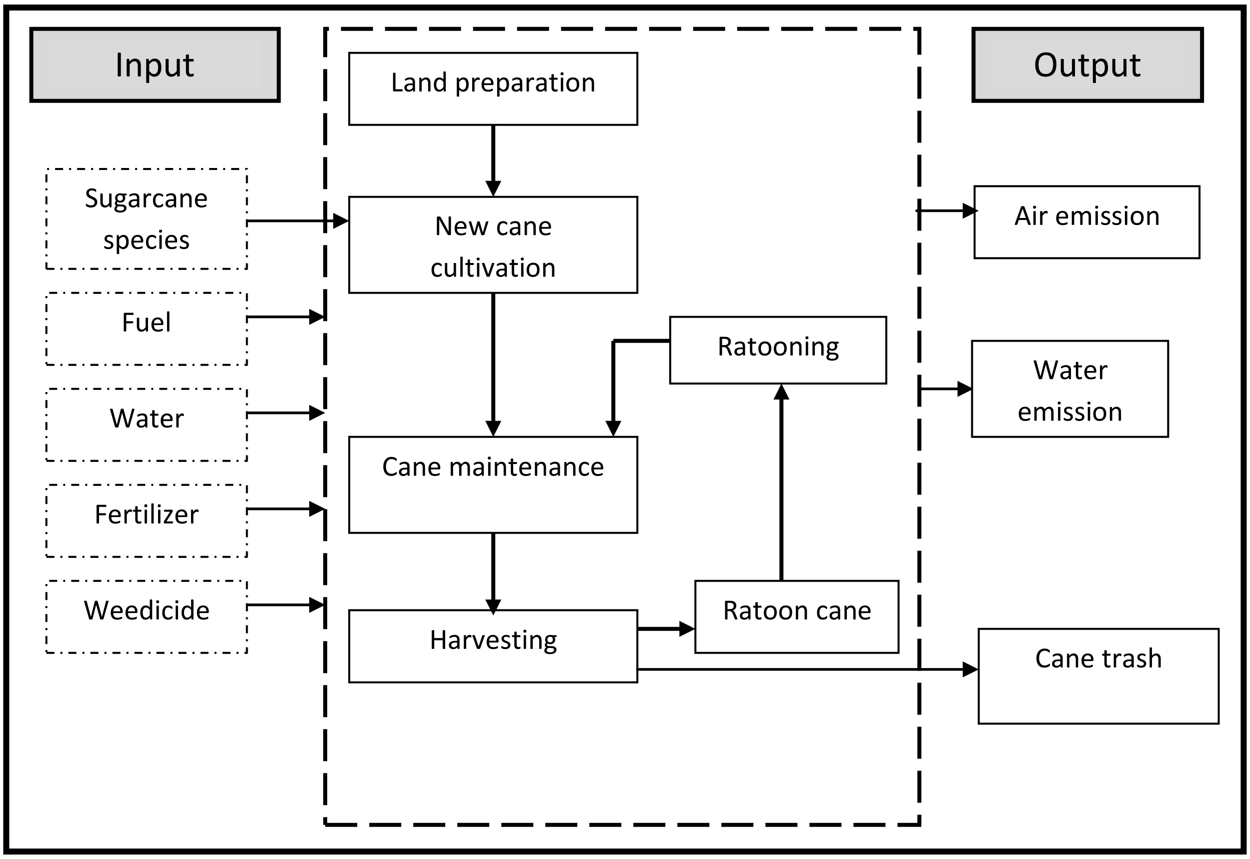


Figure 3.1 Sugarcane plantation stage

Table 3.1 Input and output data for the stage of sugarcane plantation per reference flow (cane 1,000 kg)

SUGARCANE PLANTATION			
Input		**Quantity**	**Unit**
Land		0.10	Rai*
Fertilizer	N	9.15	kg
	P	7.58	kg
	K	7.01	kg
Diesel	Farm operation	2.59	L
Pesticide		0.17	kg

*Remark: *1 Rai = 1,600 m^2*

Table 3.1 Input and output data for the stage of sugarcane plantation per reference flow (cane 1,000 kg) (Con't)

SUGARCANE PLANTATION			
Output		**Quantity**	**Unit**
Product	Sugar cane	1000	kg
Wastes	Cane trash	172.04	kg
	Cane trash burning	111.18	kg

3.2 Sugarcane processing

Main products from sugar factory are raw sugar, white sugar, refined sugar and molasses. Raw sugar is produced after evaporation and crystallization. Raw sugar has a color index higher than 1,500 ICUMSA (International Commission for Uniform Method of Sugar Analysis: a measurement standard for color index used in the sugar industry – sugar with a higher color index will be darker in color than sugar with a lower color index). It has dark brown color, high dirt index and low purity index. It is possible to store raw sugar in bulk for long periods of time in the warehouse. This sugar cannot be consumed unless it is further refined and purified. Generally, the company melts raw sugar and refines and purifies it, even during the off season, to produce white and refined sugar. White sugar is the normal sugar that people consume and is used in certain food industries. Its purity is higher, the color index is between 46-200 ICUMSA and the polarization is not less than 99.50 degrees.

The company sells white sugar to the domestic food industries and also exports to other countries. Refined sugar has higher purity than white sugar. The color is white and clear. The color index does not exceed 45 ICUMSA. This refined sugar is of high purity. It is sold to industries that require high purities such as pharmaceuticals, beverages and energy drinks. The company sells refined sugar to the domestic pharmaceutical, food and beverages industries and exports to several countries. Flow diagram, input, and output data for stage of sugar production are shown in Figure 3.2, Table 3.2 respectively.

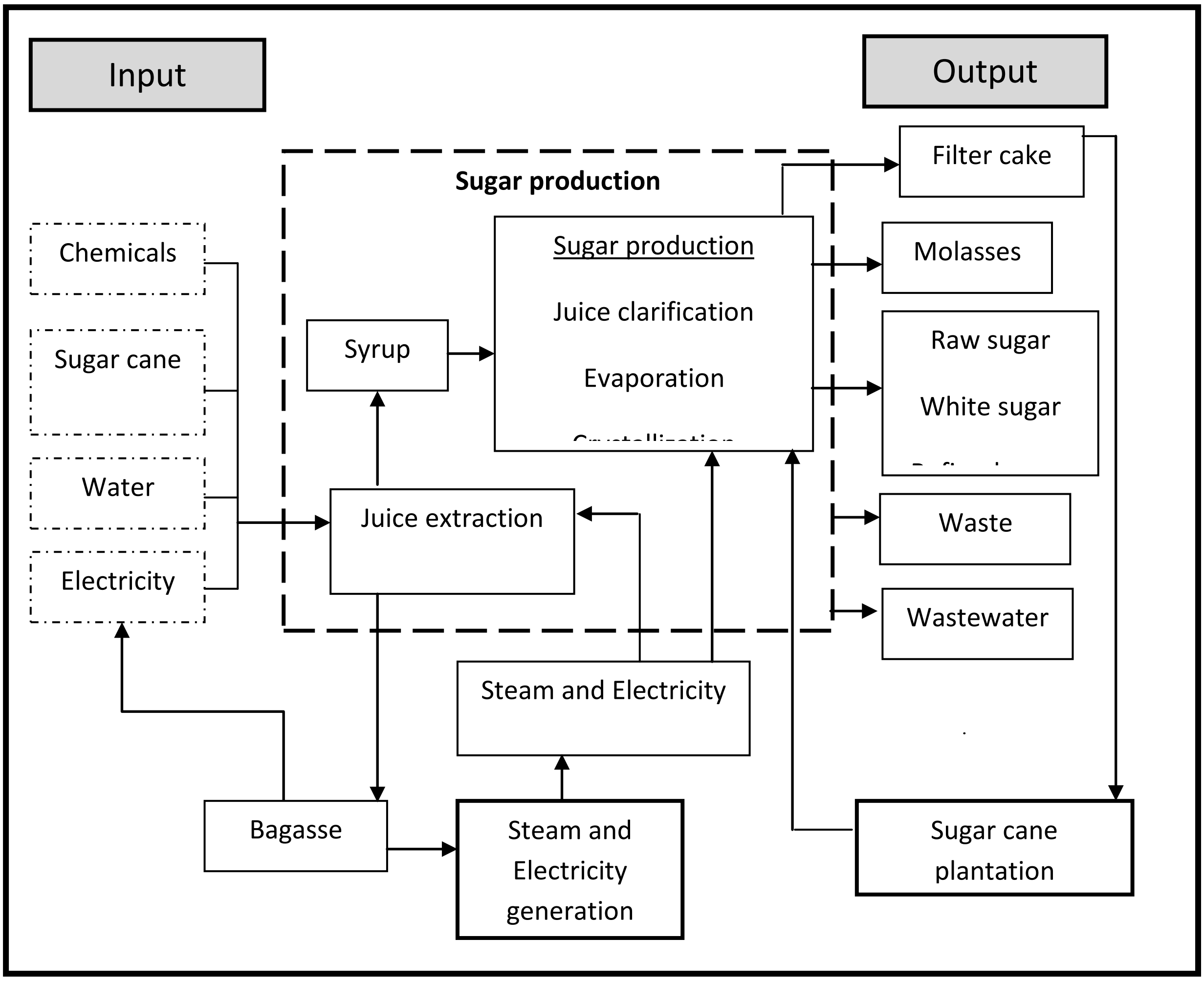


Figure 3.2 Sugar production stage (Sugar factory)

Table 3.2 Input and output data for the stage of sugar production per reference flow (cane 1,000 kg)

SUGAR PRODUCTION (SUGAR FACTORY)				
Input			**Quantity**	**Unit**
Raw material		Sugarcane	1000	kg
Chemicals				
	Chemical usages	Lime	517.96	g
		Flocculants	4.65	g
	Refinery	Phosphoric	99.08	g
		Filter aid	19.85	g
		Lime	2,683.98	g

	Sodium Chloride (NaCl)	8,883.03	g
	Caustic Soda	2.54	g
	Hydrochloric acid	4.59	g
Cleaning and pH adjusting	Caustic Soda (B)	0.01	g
	Caustic Soda (E)	48.91	g
Boiler	Phosphate	1.72	g
	Sulphite	0.07	g
Water treatment	Alum	27.20	g
	Sodium Chloride (NaCl)	1,881.23	g
Miscellaneous		108.24	g
Energy			
Biomass Power Plant (Purchase)	Electricity	5.87	kWh
	Steam	92.79	kg
Sugar factory (Electricity generation unit)	Electricity	25.95	kWh
from bagasse 210.99 ton/ton cane	Steam	489.49	kg

Table 3.2 Input and output data for the stage of sugar production per reference flow (cane 1,000 kg) (Con't)

SUGAR PRODUCTION (SUGAR FACTORY)			
Output		**Quantity**	**Unit**
Products	Total sugar	99.62	kg
	Raw sugar	10.45	kg
	White sugar	45.03	kg
	Refined sugar	44.14	kg
By-products	Molasses	42.08	kg
	Bagasse	275.49	kg
	Excess bagasse (Total bagasse – Bagasse)	64.50	kg
Emissions			
Air*	Particulate	8.88	g
	NOx as NO_2	8,785.53	g
	SO_2	585.03	g
	CO	40,748.66	g
Wastewater	Temperature	33.30	C
	pH	6.98	
	COD	0.77	g
	BOD	0.10	g
	SS	0.17	g
	TS	2.94	g

*Remark: *From electricity generation unit of sugar factory during in-season (105 days = 2,531.2 hrs.)*

3.3 Ethanol and fertilizer production process

Molasses is a by-product obtained as a residue from the sugar manufacturing process. It is viscous and brownish black in color. It has low sugar content and it is uneconomical to extract sugar from it. Molasses are a valuable by-product from the sugar refining process and contains various ingredients, typically, water 20%, sucrose 30%, invert sugar 32%, non-sugars 12%, and ash 6%. One ton of sugarcane processed yields about 45-50 kilograms of molasses. The amount of molasses produced in a year depends on the quantity of sugarcane processed that year. Molasses have wide ranging applications in the biochemical industry.

Fertilizer production unit is sub-unit process in Ethanol factory. Filter mud is obtained by filtering the sediment from the clarifiers under vacuum. Filter mud can be used to produce general purpose fertilizers. Presently, the company gives filter mud to the cane-growers, who supply sugarcane, for use in their farmland to support the sugar plantations in the nearby areas. In the near future, this filter mud will be useful to the company in its alcohol and chemical projects as a total waste utilization system. The waste water from the alcohol plant will be processed and mixed with filter mud to produce fertilizers which are suitable for use in sugarcane fields. This makes the business totally environment friendly. Flow diagram for stage of ethanol & fertilizer production is shown in Figure 3.3 while LCI data of fertilizer and ethanol production are shown in Table 3.3and 3.4 respectively.

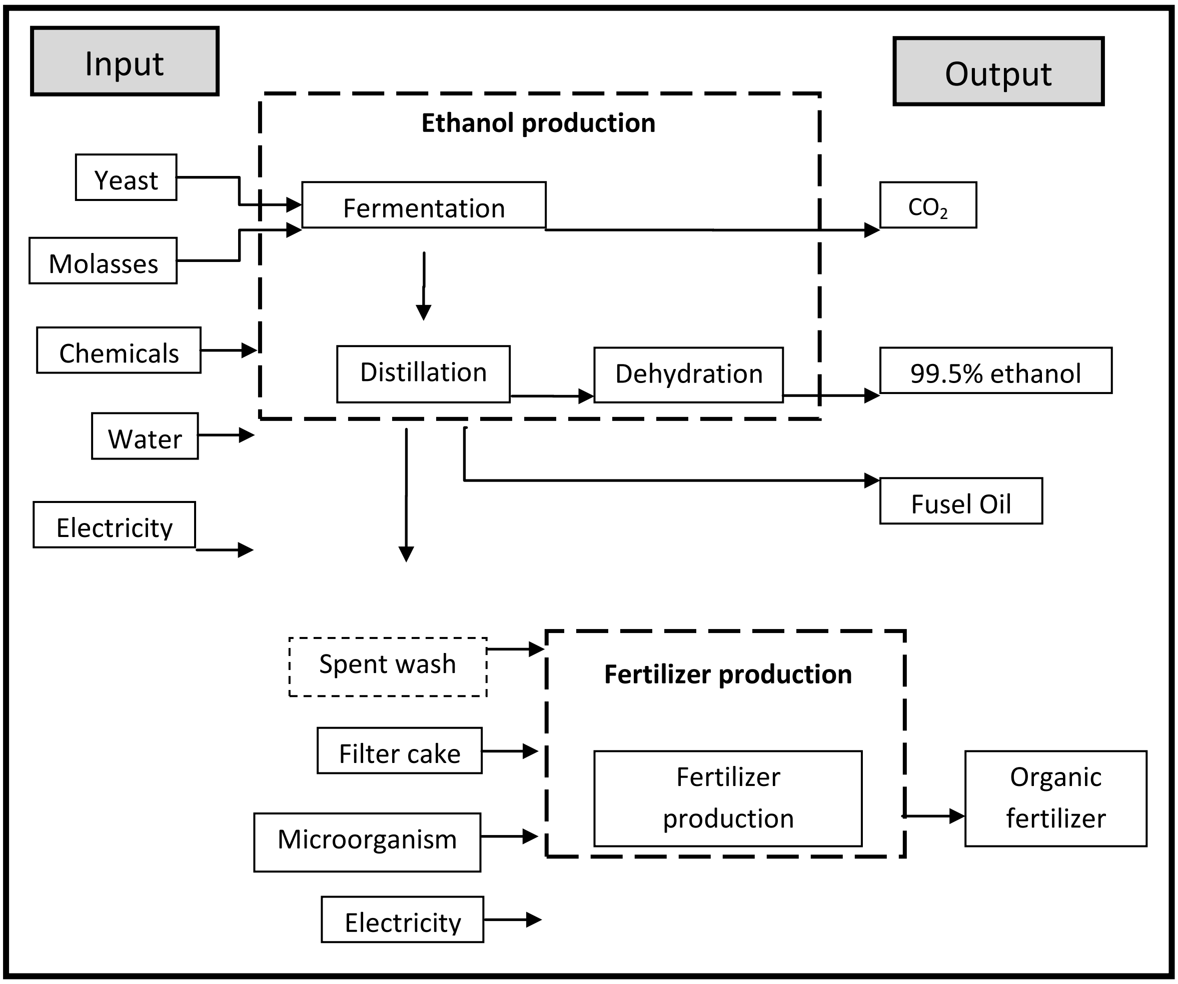


Figure 3.3 Ethanol production stage (Alcohol factory)

Table 3.3 Input and output data for the stage of fertilizer production per reference flow (cane 1,000 kg)

FERTILIZER PRODUCTION (ALCOHOL FACTORY)			
Input		**Quantity**	**Unit**
Raw material	Filter cake (Sugar factory)	45.29	kg
	Microorganism	0.05	kg
	Spent wash	90.58	L
Energy	Electricity (PEA*)	0.19	kWh
	Biodiesel (B5)	0.41	L
Output		**Quantity**	**Unit**
Product	Organic fertilizer	18.12	kg

*Remark: *PEA is a Provincial Electricity Authorization*

Table 3.4 Input and output data for the stage of ethanol production per reference flow (cane 1,000 kg)

ETHANOL PRODUCTION (ALCOHOL FACTORY)			
Input		**Quantity**	**Unit**
Fermentation			
Raw materials	Molasses	42.08	kg
	Actual molasses (used)	55.83	kg
	Purchased molasses	13.75	kg
Chemicals	Diammonium phosphate (DAP)	1.60	g
	Sulfuric acid (98%)	320.34	g
	Urea	160.17	g
	Caustic soda (50%)	26.70	g
Energy	Electricity	1.20	kWh
Water	Process water	104.65	L

Table 3.4 Input and output data for the stage of ethanol production per reference flow (cane 1,000 kg) (Con't)

ETHANOL PRODUCTION (ALCOHOL FACTORY)				
Input			**Quantity**	**Unit**
Distillation				
	Chemicals	Caustic soda (50%)	5.34	kg
		Miscellaneous	11.48	g
	Energy	Electricity	1.196	kWh
		Steam	37.37	kg
	Water	Soft water	179.39	L
Output			**Quantity**	**Unit**
Product		Ethanol	14.95	L
Wastes		Stillage	39.87	L
		Fusel oil	0.10	L
		Sludge (yeast)	0.27	g
		Wastewater	0.02	L
Emissions				
	Wastewater	BOD	7.82×10^{-4}	mg
		COD	1.80×10^{-3}	mg

3.4 Biomass power plant

Bagasse is what remains of the sugarcane after the last crushing mill. At present the company uses a part of the bagasse as a source of energy to produce electricity and steam which are used in the sugar manufacturing process. The remaining bagasse is sold as raw material to Biomass Power Plant which produces electric power to supply to the national electricity grid of the Electricity Generation Authority of Thailand (EGAT) and also supplies steam and electricity to the sugar factory and alcohol factory. Flow diagram and LCI data for stage of ethanol production are shown in Figure 3.4 and Table 3.5.

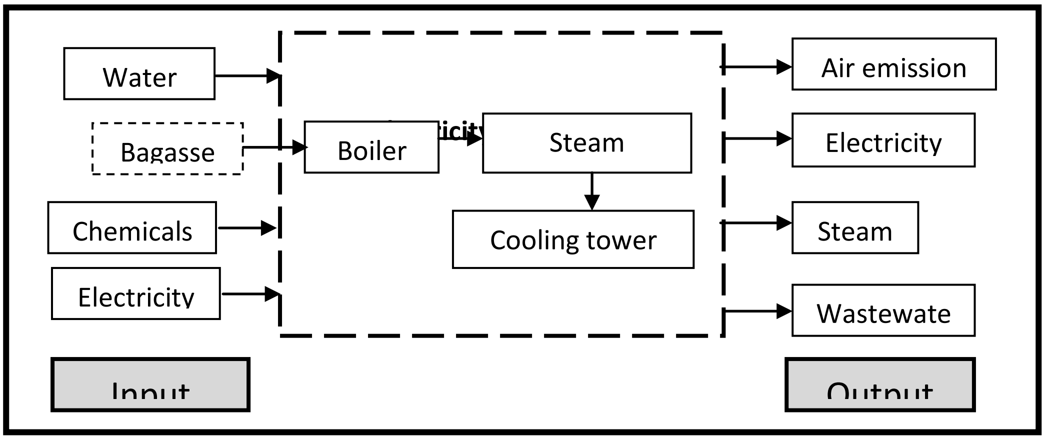


Figure 3.4 Energy production stage

Table 3.5 Input and output data for the stage of biomass power plant per reference flow (cane 1,000 kg)

ELECTRICITY GENERATION (BIOMASS POWER PLANT)			
Input		**Quantity**	**Unit**
Raw material	Excess bagasse (Sugar factory)	64.50	kg
	Actual bagasse (used)	163.54	kg
	Purchased bagasse	99.04	kg
Chemicals	NaOH (50%)	52.32	g
	HCl (35%)	29.90	g
	Sodium hypochlorite	10.68	g
	Sulfuric acid	8.01	g
	Phosphoric acid	0.80	g
	Miscellaneous	5.97	g
Energy	Electricity	9.61	kWh
Water	Water	0.27	L

Table 3.5 Input and output data for the stage of biomass power plant per reference flow (cane 1,000 kg) (Con't)

ELECTRICITY GENERATION (BIOMASS POWER PLANT)			
Output		**Quantity**	**Unit**
Products	Electricity	111.48	kWh
Co-Products	Steam	307.53	kg
Wastes	Fly ash (20%)	0.4	kg
	Bottom ash (80%)	3.20	kg
	Used resin	0.09	ml
	Used oil	0.10	ml
	Wastewater sludge	1.33	g
	Wastewater	5.45	L
Emissions			
Air (Boiler)	Particulate	5.06	mg
	SO_2	1,299.67	mg
	NOx as NO_2	9,845.95	
Wastewater	TDS	3,224.40	mg
	BOD	51.74	mg
	COD	341.73	mg
	Oil & Grease	6.17	mg

3.5 Transportation

All materials (fertilizers, stem cuttings, etc), fuels (rice husk, furnace oil, etc), products (sugarcane molasses), intermediate products (sugarcane stalks), and others involved in the life cycle of Molasses-based Ethanol are hauled by different transport facilities through varying distances. From the reference, data associated with this segment were collected in three ways: 1.) information exchange via personal interviews, 2.) model, and 3.) educated assumptions or estimations, if necessary. Life cycle inventory (LCI) for this sub-process within the scope of search for stage of transportation is then summarized in Table 3.6.

Table 3.6 Data for the stage of transportation per reference flow (cane 1,000 kg)

TRANSPORTATION			
Route	**Product**	**Energy**	**Quantity (L)**
Plantation to Sugar factory*	Sugar cane	Diesel	9.66
Sugar factory to Plantation (free load)	-	Diesel	4.66
Sugar factory to Fertilizer facility	Filter cake	Diesel	0.01
Fertilizer facility to Sugar factory (free load)	-	Diesel	0.01
Biomass power plant to Sugar factory	Ash	Diesel	9.41×10^{-5}
Sugar factory to Biomass power plant (free load)	-	Diesel	7.02×10^{-5}
			Quantity (kWh)
Sugar factory to Alcohol factory (pipe line)	Molasses	Electricity	0.10
Sugar factory to Biomass power plant (conveyor)	Bagasse	Electricity	0.02
Alcohol factory to Fertilizer facility	Stillage	Electricity	0.89

*Remark *Data from real site, there are around 1,100 vehicles for transporting sugarcane stalks to sugarcane factory consisting of 60% or 660 six wheels trucks/day, 30% or 330 ten wheels trucks/day, 5% or 55 trailers/day, and 5% or the other vehicles (e.g. Tracker)/day.*

4. RESULTS AND DISCUSSION

4.1 Environmental assessment

4.1.1 Allocation process

The life cycle inventory data reported in Chapter 3 were obtained from the biorefinery complex and, when not available, from the literature. They provide information on inputs and outputs from each process but cannot directly inform about the environmental burden of a particular product. Allocation – one methodological aspect in LCA – enables to share environmental load among various products and by-products by ratio. Energy allocation was used in this study, whenever applicable, since focus is on molasses based ethanol production for use as transportation fuel. This would enable standardize calculations for evaluating GWP whenever allocation is to be used.

4.1.1.1 Energy allocation to all products from all processes

Allocations can be used in LCA calculations when a process provides more than one product. In normal case, allocation is done process by process so as to reasonably share the environmental load. In this case, allocation is done together at a same time to all final products from all processes because the overall system has some intricacy to allocate step by step. Some intermediate products e.g. ashes, spent wash, filter cake, bagasse, etc. may not receive a share of the environmental burden associated to the upstream processes that have lead to their production if they are unused and therefore considered as waste. However, if they are considered as a by-product of a process and therefore used to satisfy some other functions e.g. electricity from biogases or fertilizer from filter cake, then they should carry a share of the environmental burden from the upstream processes that have lead to their formation. In this study, for each unit of the biorefinery complex, there is a maximization of use of the by-products to maximize profit in utilizing them.

As shown in Figure 4.1, if a raw material is brought from a previous production unit to satisfy a particular function in the next production unit and which function is provided back to the former unit, a loop system, the allocation process would be rather complicated since convergence would occur and would have to be worked out to resolve the allocation of environmental burden between the various products and by-products.

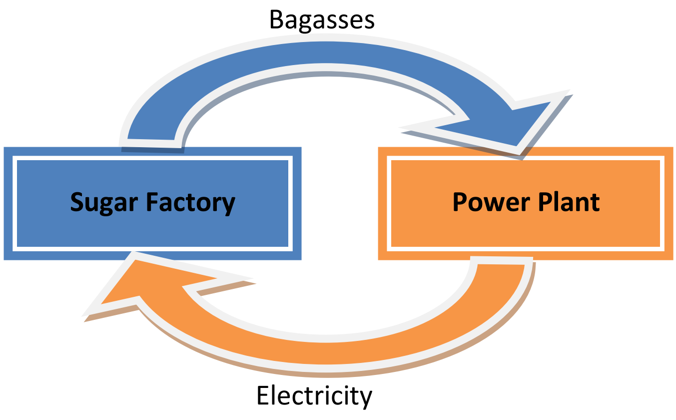


Figure 4.1 Example of circulation of products between each process

The allocation of environmental burden to only ethanol production is 11.0% from total load as shown in Table 4.1.

Table 4.1 Energy allocation in sugar production process and calculation method per RF (1000 kg of sugarcane)

Product	Amount	Heating value	Total energy value from process	Environmental load (%) $(X_i \times 100)/\sum X^* = \text{Load}$
Sugar	99.62 kg	15.76 MJ/kg**	99.62 × 15.76 = 1,570.0 (X_1)	(1,570.0 × 100)/2,823.4 = 55.6
Electricity	93.79 kWh	10 MJ_{pr}/kWh	93.79 × 10 = 937.9 (X_2)	(937.9 × 100)/2,823.4 = 33.2
Ethanol	14.95 L	21.1 MJ/L	14.95 × 21.1 = 315.5 (X_3)	(315.5 × 100)/2,823.4 = 11.2

Remark:
*$*\sum X = X_1 + X_2 + X_3 = 2{,}823.4$
***Nutrient Data Laboratory (2010); Though there are many types and quantities of sugar e.g. refined sugar, white sugar, brown sugar, caloric content is supposed to be the same for all*
**** Calculation factor obtains as credit from reducing chemicals (NPK) fertilizer*

4.1.1.2 Energy allocation to products imported from other sources

As insufficient amount of molasses and bagasse are produced at the biorefinery complex, a certain amount of those materials is also imported from outside to satisfy demand for ethanol production and electricity generation at the biorefinery complex. The evaluation of energy and environmental burden at other sites producing those materials is too wide a scope for this pilot study and therefore the assumption taken is that the burden for those two products is equal to that of the corresponding products at the study site.

Allocation is performed for 2 production units i.e. sugar factory and power plant. Calculation for this aspect is to be performed prior to the allocation process described in the previous section (4.1.1.2). It is reported here for ease of understanding to the reader.

A) Energy allocation in sugar mill process

The allocation explained here is based on energy output of product at the sugar mill. The purpose of this allocation is to assess the burden carried by molasses that are imported from other study sites. The summary of allocation is shown in Table 4.2. The other product in this stage to be allocated is sugar. Other intermediate by-products are cane trash, excess of bagasse, and filter cake. The environmental burden to only molasses production is 23.72% from total load.

Table 4.2 Energy allocation in sugar mill

Product	**Amount**	**Caloric content**	**Total energy value from process**	**Environmental load (%)** (X_i × 100)/ ∑X* = Load
Sugar	99.62 kg	15.76 MJ/kg	99.62 × 15.76 = 1,570.01 (X_1)	(1,570.01 × 100)/2,058.14 = 76.28
Molasses	42.08 kg	11.6 MJ/kg**	42.08 × 11.6 = 488.13 (X_2)	(488.13 × 100)/ 2,058.14 = 23.72

Remark:
**∑X = X_1 + X_2 = 2,058.14*
*** sugar ratio in molasses = 54%*

B) *Energy allocation in electricity generation process*

Although the energy content of bagasse from sugar factory is similar to that of sugar and molasses, it is always neglected when it comes to sharing environmental load among the products. Therefore, this consideration will be skipped to process of electricity generation. The two main products in this process are electricity and steam. Each type of power plant has a different ratio of energy output from electricity and steam. It depends on the objective of use. The summary of allocation is shown Table 4.3. The environmental load from only electricity and steam generation is 56.76 and 43.24% respectively from the total load.

Table 4.3 Energy allocation in biomass power plant

Product	Amount	Heating value	Total energy value from process	Environmental load (%) $(X_i \times 100)/\sum X^*$ = Load
Electricity	111.48 kWh	10.0 MJ_{pr}/kWh	111.48 × 10.0 = 1,114.8 (X_1)	(1,114.8 × 100)/1,963.89 = 56.76
Steam	307.53 kg	2.76 MJ/kg	307.53 × 2.76 = 849.1 (X_2)	(849.1 × 100)/1,963.89 = 43.24

Remark: $*\sum X = X_1 + X_2 = 1,963.89$

From Life Cycle Inventory in the previous chapter, the scenarios for study of molasses-based ethanol production and the results of their energy and environmental load are summarized in Topic 4.1.2:

4.1.2 Life cycle impact assessment and interpretation

From the data of inventory analysis, the life cycle impacts resulting from emissions for all production processes of 1,000 kg sugarcane are assessed and presented here. Two impacts categories are considered in this study, energy consumption and global warming potential (GWP).

4.1.2.1 Energy results

Net energy gain (NEG) and net energy ratio (NER) of molasses-based ethanol, including the energy use in each process, are summarized in Table 4.4.

From the energy analysis, the largest share (about 50%) of the total energy use is contributed by the sugar production process from the use of steam. Around 84% (1,572 MJ) of steam for the sugar production process is from the facility for power generation inside sugar factory itself and 16% (257 MJ) from the power plant. Lower than 1% of total energy use belongs to the process of power generation and fertilizer production. The main energy use for power plant is from electricity use (35 MJ or 94.5%) to operate the system while for fertilizer factory it is from the use of B5 (19 MJ or 90.8%) to mix components of manure. NER from literature (1.1) is lower than that from this study (1.36) due to the utilization of wastes from all processes are turned to byproducts.

Table 4.4 Energy input, energy output, NEG, and NER of scenarios for molasses based ethanol production per RF (1000 kg of sugarcane) and comparison with literature

No.	Stage	Energy input (MJ)	Percentage
1	Plantation	1,233	30.3
2	Sugar production	2,020	49.5
3	Power plant	37	0.9
4	EtOH factory	122	3.0
5	Fertilizer factory	20	0.5
6	All transportations	642	15.8
	Total energy input	4,075	100
	Total energy output	5,549	
	Total energy gain	1,474	
	NER	1.36	
	NER from Literature (TEI, 2007)	1.1	

4.1.2.2 Environmental assessment

The various scenarios considered for assessing the environmental life cycle impacts of molasses-based ethanol production in terms of GWP are summarized in Table 4.5:

According to data from the LCI stage and appendix as well as the scenarios reported in Table 4.4, GWP for molasses-based ethanol production and other related production systems are summarized in Table 4.6. The GHG emissions from the production and use phase for both gasohol 95 (ethanol 5%) and gasoline 95 are shown in Table 4.6 so as to compare and present sustainability in terms of environmental impacts.

Table 4.5 Summary of scenarios in study

No.	Topic interest	Base scenario	Variation
1	The guideline for allocation based on ISO recommendation to expand the system if possible.	System expansion of fertilizer	Heating value
2	Consideration of left-over steam	Waste (real situation)	Co-product

3	Burning ratio of cane trash in sugarcane farm	70% (real situation)	0%	35%

Table 4.6 Life cycle results of GWP for each scenario for the system of gasohol 95 and compared to gasoline 95

Phase	Gasohol 95 (kg CO_2 eq)					Gasoline 95 (kg CO_2 eq)
	Base Scenario	Scenario 1	Scenario 2	Scenario 3		
				0%	35%	
Production	_3.97_	3.91	3.74	3.22	3.46	_3.45_
Use	_28.06_	28.06	28.06	28.06	28.06	_30.82_
Total	_32.03_	31.97	31.80	31.28	31.52	_34.27_

Remark: 180 km test run by Toyota 1.5 L/1996 with gasohol 95 (14.95L) and gasoline 95 (14.78L)

Some values shown in Table 4.6 refer to the literature (TEF, 2007). The factors used for calculating GWP are different. However, to ensure the quality of comparative results the error (checked by the calculation) accruing from the difference of factor is lower than 1%.

The LCA (use and production) from base-case scenario, scenario 1, and scenario 2 show rather similar amount of GHG emissions while for scenario 3 (0 and 35% of burning ratio of cane trash in sugarcane farm) slightly lower amount of GHG emissions are observed. System expansion is used for base-case scenario to avoid allocation as much as possible as recommended by ISO 14040. However, overall it can be seen that the variation in the results due to the various scenarios is within 2%; hence the base case results are robust and can be used for further analysis.

Scenario 1 is set up to compare results obtained with base-case scenario. The difference in GWP is due to the fact that the expansion of system by substitution of NPK (chemical fertilizer) with organic fertilizer (base-case) give a lower result of GHG emissions as compared to allocation based on the heating value of organic fertilizer from total energy (scenario 1). Therefore, the allocation of burden to ethanol for the base-case scenario is higher.

Scenario 2 is considered in order to assess the reduction in GWP as a result the use of the total volume of steam produced (total energy from steam), i.e. including left-over steam.

In scenario 3, two sub-scenarios related to cane trash burning are assessed in terms of their influence on GWP. It is observed that it is the only scenario for either sub-cases i.e. 0 and 35% of cane trash open burning, that GHG emissions are slightly lower than that of gasoline 95. In the base case scenario, the open burning of 70% of cane trash in the plantation is one of the main contributors to GWP. The GWP results for each process are shown in Table 4.7.

Table 4.7 Environmental results of base-case scenario for each process of molasses based ethanol production per RF (1000 kg of sugarcane)

Stage		GHG emissions (kg CO_2 eq)	%
Plantation		124.0	102.27
Sugar production		4.6	3.80
Power plant		-58.5	-48.26
Alcohol factory		7.4	6.06
	Ethanol production	-0.7	-0.56
	Fertilizer production	44.5	36.69
Transportation		121.2	100
Total		124.0	102.27

The main contributors to GHG emissions are the processes of sugarcane plantation and transportation. GHG emissions from power plant and fertilizer plant have a negative value. This means that the GHGs emitted from those production processes are lesser than the GHGs credited from the products produced in each stage. The activities contributing to the major emitting GHG processes are reported in Table 4.8.

Table 4.8 Contribution of activities to the major GHG emitting processes

Process	Activity	Contribution of activity to the process (%)
Cane plantation	Fertilizer (NPK) production and use in sugarcane farm	49.95
Cane plantation	70% Cane trash burning	43.56
Transportation	Transportation from farm to mill	99.82

From the above, it is observed that improvements to reduce environmental impacts are limited since many improvements have already been made over the years to maximize the use of materials at the biorefinery complex. However, with regards to cane trash burning some alternative options need to be investigated in order to avoid such practices and make use of a resource which could find useful application for instance as s feedstock for energy purposes just as bagasse is being used at the power plant for electricity generation. There should support from all stakeholders that may be concerned, including, farmers, labors, investors, factory staff and employees and the government.

4.1.2.3 Interpretation

With regards to the results obtained over the entire life cycle of ethanol production, the burning ratio of cane trash at the sugarcane plantation contributes to significantly affect GWP for this stage. GWP could vary as much as 47% if burning ratio was changed from 0% to 70%. However, the overall life cycle greenhouse gas (GHG) emissions associated to ethanol production (production plus use stage of gasohol) is not significantly different from that of gasoline, although slightly lower since only a 10% blend of ethanol is used. The maximization of utilization of the by-products coming out from the various units of the biorefinery complex is contributing to reducing GHG emissions and therefore GWP associated to the various processing units of the biorefinery complex. However, the open burning of cane trash, although not contributing to significantly affect the overall life cycle GHG emissions associated to ethanol production, should still be discouraged, and alternative use for energy purposes considered. This could help providing additional GHG emission credits for the biorefinery complex and hence further benefit to the environmental performance of ethanol as compared to gasoline.

4.2 Social assessment

Human Development Index or HDI is introduced as a measure of social development as mentioned in Chapter 2. HDI index for this study is calculated for Khon Kaen and sugarcane based biorefinery complex. For this later, HDI for both the sugarcane plantation and the biorefinery complex (sugar factory, biomass power plant, alcohol factory) were assessed.

According to the formula, life expectancy index and education index are obtained at national level whereas GDP index is considered at provincial level. Consequently, GDP index is determined for Khon Kaen, sugar cane plantation and biorefinery complex in order to estimate HDI.

GDP Index and Employment

To obtained GDP index, total cost for employment is required for estimating total income of farmers in the sugar cane plantation and employees in the biorefinery complex.

For the sugar cane plantation, standard employment wages relevant for Khon Kaen were collected and compared with information collected from interview and questionnaire surveys. Total farmers in the sugar cane plantation amounts to 15,035 person/year. The total annual cost of employment amounts to 708,125,095 THB. For the biorefinery complex, total expenses amounting to 760,810,000 THB where paid as salaries for a total of 5,395 employees over a year during the production and normal period as reported in the annual report.

The results of total cost for employment of these two areas are reported in term of cost per area (reference flow) in Table 4.9. Total costs for employment at sugar cane plantation and biorefinery complex are referred to as income of employment. Therefore income per capita for sugar cane plantation and biorefinery complex is calculated by dividing total cost for employment with employment in person year. The income per capita for sugar cane plantation and biorefinery complex amounts to 47,100 THB and 141,021 THB, respectively.

According to the method mentioned in Chapter 2, Purchasing Power Parity (PPP) is reported in term of US dollars (USD) to calculate the GDP Index. So, income per capita of these two areas is converted into USD. In addition, the PPP factor is used to convert income per capita (USD) into income per capita (PPP). The GDP Index has been determined for both the sugar cane plantation and the biorefinery complex as shown in Table 4.10.

Table 4.9 Employment from sugarcane plantation and biorefinery complex

	Cost	Employment	
	(THB/Year)	(in person days)	(person year)
Sugarcane plantation			
Land preparation Planting Fertilization Weeding	708,125,095	4,510,351	15,035
TOTAL PER AREA*	378.07	2.408	
Biorefinery complex in Khon Kaen			
Sugar (Sugar Factory) Electricity (Biomass Power Plant) Ethanol (Alcohol Factory)	760,810,000	1,212,960	5,395
TOTAL PER AREA*	406.20	0.6476	

*Remark: *Reference flow = 0.1 rai (1 rai = 0.16 ha)*

Table 4.10 Calculation of GDP index of Khon Kaen and for plantation and biorefinery complex

			GDP Index
Gross Provincial Product per capita of Khon Kaen	76,055	THB	
Gross Provincial Product (PPP) per capita for Khon Kaen	5,637	USD	0.673
Income per capita for sugarcane plantation	47,100	THB	
Income per capita (PPP) for sugarcane plantation	3,491	USD	0.593
Income per capita for biorefinery complex	141,021	THB	
Income per capita (PPP) for biorefinery complex	10,452	USD	0.776

Remarks: 1USD = 33.38 THB (Google finance, 2010);

PPP factor for Thailand is 2.47 (NationalMaster, 2010)

For comparative purposes the GDP index for Khon Kaen due to biorefinery complex located in Khon Kaen. When comparing the results, GDP Index of Khon Kaen is higher than sugar cane plantation but it is lower than biorefinery complex.

Human Development Index (HDI)

HDI is calculated through life expectancy index, education index and GDP index in formula of HDI = 1/3(LEI+EI+GI) as mentioned in Chapter 2. Only GDP index is taken from previous results while life expectancy index and education index are obtained from national data of Thailand. HDI is computed for Khon Kaen, sugar cane plantation and biorefinery complex as shown in Table 4.11.

HDI of the biorefinery complex is higher than that of Khon Kaen and the sugar cane plantation whereas the lowest HDI is for the sugar cane plantation. When compared to Khon Kaen, the change in HDI is negative for sugar cane plantation and positive for the biorefinery complex.

Table 4.11 Calculation of HDI

SOCIAL ASSESSMENT	Khon Kaen	Plantation	Bio-energy production
Life Expectancy at birth Indicator (LEI)	0.728*	0.728*	0.728*
Education Index (EI)	0.888*	0.888*	0.888*
GDP Index (GI)	0.673**	0.593	0.776
HDI	0.763	0.736	0.797
CHANGE IN HDI	-	- 0.027	+ 0.034

Remarks:
**National data from UNDP (Human Development Report Office, 2009);*
***GI calculated based on GPP of Khon Kaen (Human Development Report Office, 2008)*

Farmers in Khon Kaen benefit from a steady income each year as a result of the selling of their sugarcane to the sugar mill via contract farming. This has certainly contributed to improve their living conditions. The negative change in HDI observed for this group of farmers just indicates that they still belong to a lower class of the society (lower income) and are therefore characterized by a level of social development that is lower than the provincial or national level. On the other hand, employees at the biorefinery benefit from higher income and therefore living conditions which translate into a HDI that is higher than that of the province.

The biorefinery complex set in Khon Kaen has enabled to provide farmers and workers in the area with steady income (job opportunity) translating into better social development. Even though farmers appear to not reach a level of social development equivalent to that of the provincial level, it is important to point out that the biorefinery complex has certainly contributed to improve their living conditions as compared to others.

4.3 Economic assessment

For the economic assessment of the biorefinery complex, including sugarcane plantation, Total Value Added was calculated both for the sugarcane plantation and the biorefinery complex.

The first factor is total net profit. Based on the annual amount of sugarcane required by the biorefinery complex 1,872,981 ton/year with a production yield 1,000 kg/0.1 rai, the total area of sugarcane cultivated is 187,931rai/year. The average cost for sugarcane farming is approximately 7,500 THB/rai, therefore, the annual cost for the whole area amounts to 1,423,110,604 THB including material cost and overhead cost, and the annual gross revenue is 1,816,792,036 THB. The net profit from sugar cane plantation amounts to 393,681,432 THB. Data for sugarcane plantation was collected via interview and questionnaire surveys.

For the biorefinery complex, costs of materials plus overheads for sugar production, electricity generation, ethanol production, and fertilizer production amount to 11,113,781,852 THB/year. The annual revenue is 12,070,494,453 THB. Hence the net profit for the biorefinery complex amounts to 956,712,601 THB.

The total annual net profit for the whole biorefinery complex, including sugarcane, is 1,350,394,033 THB. Financial data for the biorefinery complex were extracted from the annual report. The results are presented in Table 4.12.

The second factor is wages (salaries paid). This factor is defined based on the annual labor requirement for sugar cane plantation and biorefinery complex. Wages paid for the sugar cane plantation is based on provincial standard wages amounting to

157 THB/persons/day. The labor requirement is around 15,035 persons/year. Thus annual wages paid are about 708,125,095 THB for the sugar cane plantation.

For the biorefinery complex, labor requirement is divided into two periods: production period and normal period. The biorefinery complex requires 3,142 of permanent labor over a whole year and requires additional labor force during the production period (120 days), about 2,253 of temporary labor. Therefore annual wages paid for the biorefinery complex are approximately 760,810,000 THB. Consequently, the total amount of annual wages paid for the biorefinery complex, including sugarcane plantation, amounts to 1,468,935,095 THB for a total of 5,723,311 man-days (see Table 4.13).

The third factor is tax revenue. This factor is subtracted from total income from the sugar plantation and biorefinery complex. The tax rate (withholding tax) for the sugar plantation is 0.75% of total income. The total income from selling 1,872,981.48 ton cane/year at 970 THB/ton cane is 1,816,792,035.60 THB/year; accordingly, the annual tax paid is 13,625,940 THB. For the biorefinery complex, the annual tax paid is 357,494,554 THB which corresponds to 35% of corporate income tax. The results regarding total profit before tax for both the sugar cane plantation and the biorefinery complex are also reported in Table 4.14 along with their corresponding Tax revenue.

Table 4.12 Annual cost and returns for plantation and biorefinery in Khon Kaen

PLANTATION		QUANTITY	COST/UNIT (THB)	COST/TOTAL AREA (RAI) (THB)
MATERIAL	Seedling and planting materials			
	Fertilizer, Pesticides and Other Chemicals		7,500/rai	1,423,110,604
OVERHEAD	Transportation/ Delivery Cost, Tax			
TOTAL COST				1,423,110,604
				REVENUE/TOTAL

			AREA (RAI) (THB)
TOTAL GROSS REVENUE (From sugarcane plantation)	1,872,981 ton/year	970/ton	1,816,792,036
SUB-NET ROFIT			393,681,432

BIOREFINERY COMPLEX IN KHONKAEN		COST/YEAR (THB)
MATERIAL	Total cost of operation	8,680,081,437
OVERHEAD	Miscellaneous (Financial cost, selling and administrative expenses, fee, tax, etc.)	2,433,700,415
TOTAL COST		11,113,781,852
		TOTAL/YEAR (THB)
TOTAL REVENUES from Operation (From sugar, electricity, ethanol and fertilizer)		11,688,514,083
OTHER INCOMES (Dividends income, profit sharing, etc.)		381,980,370
SUB-NET ROFIT		956,712,601
TOTAL NET PROFIT		**1,350,394,033**

Remark: 1 rai = 0.016 ha

Table 4.13 Annual labor requirement and wages paid by product form

PRODUCT FORM	LABOR REQUIREMENT (m-days/per total area (rai)-year)	WAGE RATE (THB/m-day)	**WAGES PAID (THB/year)**
Sugar cane (plantation)			
Land preparation Planting Fertilization Weeding	4,510,351	157	708,125,095
Biorefinery complex			
Production season period Normal period	270,360 942,600	-	760,810,000
TOTAL	5,723,311		1,468,935,095

Table 4.14 Annual tax revenue generated by product form

PRODUCT FORM	TOTAL PROFIT (THB-year)	TAX REVENUE (THB-year)
Sugar cane (plantation)	407,307,372	13,625,940
Biorefinery complex in Khon Kaen		
Sugar (Sugar Factory)		
Electricity (Biomass Power Plant)	1,314,207,155	357,494,554
Ethanol + Fertilizer (Alcohol Factory)		
TOTAL	1,721,514,527	371,120,494

The last factor is foreign exchange earning. This factor is considered by mean of substitution of gasoline with ethanol. Due to the lower heating value of ethanol (100%) as compared to gasoline, the substitution ratio of gasoline with ethanol is 1: 1.56 Liter (Table 4.15).

Table 4.15 Substitution ratio for gasoline with ethanol

Fuels	Specific gravity*	Avg. Density (kg/m^3)	Lower heating value* (MJ/kg)	Lower heating value* (MJ/m^3)	Lower heating value* (MJ/L)	Ratio (L)	Price** (THB/L)
Gasoline	0.75	750	44	33,000	33	1.00	19.30
Ethanol	0.785	785	26.9	21,116.5	21.12	1.56	

*Remark: * Heywood, 1988*
*** DEDE, 2010*

Thus, the amount of ethanol produced by the Alcohol factory is 42,510,380 Liter/year. From this amount, the corresponding amount of gasoline that is displaced by ethanol is 27,202,135 Liter/year. This translates in a saving from avoid importation of gasoline amounting to 525,008,930 THB/year (Table 4.16).

Table 4.16 Annual foreign exchange earnings from substituting imported gasoline by ethanol

PRODUCT FORM	QUANTITY (Liter/year)		
Ethanol produced by the Alcohol factory	42,510,380		
		COST PER UNIT (THB/Liter)	**TOTAL COST (THB/year)**
Gasoline substituted by Ethanol	27,202,134.52*	19.30	525,008,930
TOTAL			525,008,930

*Remark: *Substitution ratio at 1 L of gasoline: 1.56 L of Ethanol (based on energy content)*

All financial parameters detailed above are summarized in Table 4.17 and the total value added for the bioenergy complex including the sugarcane plantation amounts to 3,715,458,551 THB for a year.

Table 4.17 Total value added per year from sugarcane cultivation and biorefinery

ECONOMIC ASSESSMENT	PRODUCT FORM		TOTAL VALUE ADDED (THB/Year)
	Plantation (THB/Year)	KhonKaen Biorefinery complex (THB/Year)	
Total Net Profit	393,681,432	956,712,601	1,350,394,033
Wages Paid	708,125,095	760,810,000	1,468,935,095
Tax Revenue	13,625,940	357,494,553	371,120,493
Foreign Exchange	-	525,008,930	525,008,930
TOTAL VALUE ADDED			3,715,458,551

5. CONCLUSION

In this study environmental and socio-economic assessments related to molasses based ethanol production were investigated for a system including sugarcane plantation and biorefinery complex in Khon Kaen, Thailand. Main findings from the investigations performed in this pilot study are presented below.

An energy assessment was carried out while assessing the environmental performance of the biorefinery complex. It was found that the net energy ratio (NER) from the whole production system is 1.36 implying that there is energy profit. For environmental assessment, Global Warming Potential (GWP) was considered as the main impact category for this study. GHG emissions from the production and use stage of gasohol 95 for all scenarios considered range from 31.28 to 32.03 kg CO_2 equivalent for the same driving distance (180 km) in the same passenger vehicle (Toyota 1.5L/1996) while GHG emissions from production and use of gasoline 95 are 34.27 kg CO_2 equivalent. Therefore in terms of environmental performance with regards to GWP, gasohol 95 performs better than gasoline 95 though the difference is not as pronounced since only a 10% blend of ethanol is used. Since the utilization of materials produced at the biorefinery complex has been maximized, options for improvement are limited. Still the open burning of cane trash at a level of 70% should be avoided and alternative usage of the biomass feedstock encouraged. Cane production in Thailand has traditionally led to serious environmental degradation as sugarcane fields are frequently burned before or after harvest, resulting in reduced soil fertility. Reduced soil fertility has led to lower cane yields, and consequently, higher application rates of fertilizers. Additionally, cane production in upland areas causes erosion, resulting in the siltation of water bodies. Ground water can also be contaminated by the high application rates of nitrogen fertilizer and persistent herbicides. Also trash burning contributes to reducing biodiversity, harming populations of snakes, wildcats and ground nesting birds. At last, air quality deteriorates with burning, leading to respiratory ailments, eye disease and increased incidence of cancer among sugar workers.

With regards to social assessment, Human Development Index (HDI) was used as indicator and calculations made for the sugarcane plantation and biorefinery complex. Based on available data, it was found that the HDI of farmers was lower than that of employees at the biorefinery complex. Still, social development for this category of farmers is likely to have improved as a result of the steady income received from contract farming with the sugar mill. For employees of the biorefinery complex, the change in HDI as compared to Khon Kaen is positive reflecting a higher social development than the average for the province. The biorefinery complex has therefore contributed to bring social benefits to farmers who belong to a lower income category in Thailand and to employees of the refinery who benefit from higher income as a result of higher educational level.

In relation to the economic assessment, total net profit, employment impacts, tax revenue, were considered. With regards to taxes, it is important to highlight that based on the Thailand Board of Investment regulation on biomass utilization, ethanol factories and biomass power plants are exempted from paying taxed for 8 years. The results obtained for the pilot study indicate that for the overall complex (including plantation) the annual total net profit, annual wage paid, annual tax revenue, and annual foreign exchange earning amount to 1,350,394,033 THB, 1,468,935,095 THB, 371,120,493 THB, and 525,008,930 THB respectively. Hence, the annual total value added for the whole bioefinery complex amounts to 3,715,458,551 THB.

APPENDIX

Table 1 Outputs management

Outputs	Source	Management
Cane trash	Sugarcane plantation	Burning in the field
Bagasse	Sugar factory (milling)	Feedstock for generating electricity
Molasses	Sugar factory (centrifugals)	Raw material for producing ethanol
Filter Cake	Sugar factory (vacuum filter)	Raw material for producing fertilizer
Ash (fly and bottom)	Biomass power plant (burning)	Soil covering in factory
Used resin	Biomass power plant	Sent to disposal by outsource
Used oil	Biomass power plant	Sent to disposal by outsource
Stillage	Alcohol factory (Ethanol production)	Raw material for producing fertilizer
Fusel oil	Alcohol factory (Ethanol production)	Sent to perfume industry
Sludge (yeast)	Alcohol factory (Ethanol production)	Raw material for producing fertilizer
Wastewater sludge	Wastewater treatment system	Soil conditioning in factory

Table 2 Factors for energy calculation along the life cycle of bioethanol production

Subject	Energy factor (MJ/kg)	Reference
Fertilizers production		Pimentel, 1992
Nitrogen (N)	87.9	
Phosphorus (P)	26.4	
Potassium (K)	10.5	
Pesticide production	237	Sharma and Campbell, 2003 (generic averages for insecticides)
Ethanol		
Heating value	21.2	TEF, 2007
Diesel use		* TEI, 2001 ** IFAS, 1991 *** Sharma and Campbell, 2003
Fuel energy per kg of diesel	43.098 (36.418 MJ/L)*	
Energy for producing diesel	9.594 (8.107 MJ/L)**	
(specific gravity of diesel = 0.845 kg/L)***		
Electricity use Energy losses during electricity generation in Thailand are about 64%. That is 100 MJ of primary energy are required to produce 36 MJ (or 10 kWh) electricity		TEI, 2003

Table 3 Factors for environmental calculation for production and use of inorganic fertilizers and pesticides (Sharma and Campbell, 2003)

Phase	Emission	Nitrogen (N)	Phosphorus (P)	Potassium (K)
	CO_2 (kg/kg)	3.96	1.76	1.36
production	N_2O (g/kg)	0.0177	0.0659	0.00547
	CH_4 (g/kg)	7.1278	5.052	0.8344
Use	N_2O (g/kg)	12.5	-	-

Remark: generic averages for herbicides and insecticides

Table 4 Global Warming Potential (GWP) factors for production and use of vehicle fuels

GWP factors	kg CO_2 eq	References
Electricity (Production)	0.56	Hinchiranan, 2007
Gasoline 95 (1,000 L)	233.28	TEF, 2007
Biodiesel (1,000 L)	670	Pleanjai, *et al.*, 2009

Examples for the calculation of GHG are shown below.

1) <u>Example of GWP calculation from cane trash burning</u>

If Amount of cane trash from farming = 2.22 kg

Percentage of cane trash burned in field = 50%

From the formula as shown in topic 7.1.3.4.2,

Carbon released = (2.22) × (50/100) × (0.9) × (0.50) × (45/100)

~ 0.225 kg

CO_2 released ~ 0.825 kg

(Assumed all carbon released is converted to CO_2 only)

CH_4_released (kg CH_4) = Carbon released (kg C)

× Emission ratio of CH_4 (= 0.005)

× Conversion Ratio (= 16/12)

~ (0.225) × (0.005) × (16/12)

~ 0.0015 kg

N_2O_released (kg N_2O) = Carbon released (kg C)

× Nitrogen-Carbon ratio (= 0.015)

× Emission ratio of N_2O (= 0.007)

× Conversion ratio (= 44/28)

~ (0.225) × (0.015) × (44/28) × (0.007)

~ 0.0000371 kg

2) <u>Example of GHG calculation from wastewater system</u>

If COD from process = 7,100 mg/L (~ average)

Quantity of wastewater = 26.26 L/L of bioethanol

Per liter of ethanol, COD = 7,100 × 26.26 = 186,446 mg = 0.186 kg

COD equivalence of CH_4 (in wastewater pond):

1 g COD destruction is equivalent to 0.25 g of CH_4 @ 35°C (Speece, 1996)

0.186 kg COD destruction is equivalent to 0.186 × 0.25 / 1 = 0.047 kg of CH_4

Table 5 Emission factors for production and use of gasohol 95

Life cycle stage	Gasohol 95 : 1,000L (Ethanol from molasses) [kg CO_2 eq]
Crude oil extraction	68
Crude oil transportation	15
Ethanol transportation (Truck)	5
Refining and blending process to produce gasohol	69
Gasohol transportation to terminal	13
Gasohol transportation from terminal to petro station	6

Source: TEF, 2007

Energy use and GHG emissions from the production of chemicals and raw materials used for all processes are extracted from SimaPro database and their contribution to GWP is just 0.4 and 3.9% respectively from only the production of ethanol. The list of those numerous references for those minute percentages is therefore avoided.

Chapter 8

Indices of Sustainability of Biodiesel (Coco Methyl Ester) Production

Marilyn M. Elauria

Patricia Lei P. Almazan

Russel M. Manuba

Arvin Joseph M. Elauria

Jessie C. Elauria
Institute of Agricultural Engineering, College of Engineering and Agro-industrial Technology, University of the Philippines

September 2010

This chapter should be cited as
Elauria, M. M., P. L. P. Almazan, R. M. Manuba, A. J. M. Elauria and J. C. Elauria (2010), 'Indices of Sustainability of Biodiesel (Coco Methyl Ester) Production', in ERIA WG on 'Sustainability Assessment of Biomass Utilisation in East Asia' (eds.), *Sustainability Assessment of Biomass Energy Utilisation in Selected East Asian Countries*. ERIA Research Project Report 2009-12, Jakarta: ERIA. pp.44-109.

INDICES OF SUSTAINABILITY OF BIODIESEL (COCO METHYL ESTER) PRODUCTION

PHILIPPINE PILOT STUDY

Submitted by:

Dr. Marilyn M. Elauria (Team Leader), Ms. Patricia Lei P. Almazan, Mr. Russel M. Manuba, Engr. Arvin Joseph M. Elauria, Dr. Jessie C. Elauria (Field Manager)

EXECUTIVE SUMMARY

The Philippines is a major producer of coconut. As of 2008, 3.38 million hectares or 28% of total agricultural lands are devoted to coconut. This provides livelihood to more than three million coconut farmers. The industry contributes an annual average of 5.97% to Gross Value Added (GVA) and 1.14% to Gross National Product (GNP). Regarded as a dominant sector of Philippine agriculture, the coconut industry is one of the major dollar earners of the country, averaging US$800 million or roughly PhP40 billion annually according to the Department of Agriculture (DA). Among the coconut-based provinces in the country, Quezon has the largest volume of production and is heavily dependent on coconut, accounting for almost 9% each year to overall national production based on the data by the Bureau of Agricultural Statistics. Moreover, Quezon had the biggest land area in coconut production contributing 7.4% to the country's total harvest.

A pilot study was conducted in Quezon to test the methodologies for the calculation of economic, social and environmental indices of sustainability of biodiesel production from coconut (Coco Methyl Ester). The economic indicator used was the value added for the industry which included the entrepreneur's net profit, personnel remuneration, taxes and duties earned by the government from the enterprises and foreign exchange earnings from exported products. In the determination of the value added, the different product forms of coconut in Quezon were considered. In the production of the final product which is CME, mature dehusked coconut is used for copra production. Coconut oil, which is extracted from copra, is the primary input in CME manufacturing.

Throughout the conversion process, by-products are generated namely copra meal, glycerin, fatty acid, glycerin and acid oil.

The social sustainability of the biomass project was assessed using the Human Development Index. Life Cycle Assessment (LCA) was used in the evaluation of environmental indices. The system boundary was from the cultivation of coconut to the consumption of biodiesel including the sale of the major by-products. The emission investigated is GHGs from the four stages of biodiesel (CME) production.

Analysis of the production costs and revenues for each product form from the primary input to the final product, that is from dehusked nut to biodiesel shows that from the 6432kg of dehusked nut produced per hectare per year, the biodiesel output produced amounts to 1,329.91 liters. Due to the additional activities done on the input product, the production cost of the output product increases as the product changes from PhP2.08 per kg of nut to PhP43.878 per liter of CME. Net profit per unit is highest for copra at PhP6.76/kg and lowest for CME at PhP0.122/liter. Including the revenue from the by-products, the same trend is observed with copra production giving the highest total profit. The cumulative total profit for all product forms is almost PhP 38,000 per hectare.

Employment refers to the number of jobs that can be generated with the presence of the biomass project starting from the production of the raw material up to the final product which is biodiesel while personnel remuneration is the value of total salaries and wages paid to the employees in the different firms or activities involved in the biomass utilization. The labor requirement on a per hectare mature nut production up to processing into amounts to 53 mandays per hectare per year valued at PhP 13,764.

Total tax revenue for the biomass project amounts to PhP 7,859.38 per year with copra production registering the highest tax since it also generated the highest profit on a per hectare basis. However, due to the low volume of CME production at the provincial level, it is assumed that the net foreign exchange savings will not be significant. Moreover, the value of foregone dollar earnings from the amount of refined oil that was used for CME can just be offset by the opportunity cost of CME in terms of the value of imported fossil fuel substituted it substituted. Thus the net foreign trade effect is zero.

The total enterprise profit amounts to PhP 37,999 with total wages paid of PhP 13,764 and generating a tax revenue of PhP 7,859 per year per hectare. The total value added generated for all the value adding activities from the per hectare production of mature nut up to processing into biodiesel or CME amounted to PhP 59,623 per hectare per year with dehusked mature nut production contributing the highest amount (44.5%) followed by copra production (38.5%). Considering that around 230,440 hectares in the province of Quezon are planted to coconut, the total value addition from the biodiesel industry would be PhP 13.74 billion if the mature nuts production in the province will be processed into biodiesel.

In terms of social indices, the computed HDI is 0.784933 while the change in HDI is 0.003933. In terms of the effects of the biomass project specifically coconut production on their level of living condition, the majority (66%) of coconut farmers perceived that there has been an improvement in their living condition due to coconut farming and 76 percent reported that their income increased and they were able to provide better education for their children. Moreover, majority (57%) of employees perceived that there has been an improvement in their living condition due to their employment in their respective biomass project. The employees of the copra plant registered the highest satisfaction where around 93% experienced improvement in their level of living due to their copra employment. In general, it could be seen from the results that majority of the employees benefitted from their respective employment in the biomass production and processing into biodiesel. Thus a major social impact of the biomass project can be measured in terms of the improvement in the level living of living conditions of the stakeholders in the biomass project.

Results of the computed GHG emissions from different stages of CME production from coconut show a total GHG emission of 1,267.13 kgCO_2/year/ha. The use of CME to replace petrolic diesel fuel will result to net savings or GHG emission reduction of 2,823.97 kgCO_2/year/ha. Among the four stages involved in the life cycle of CME production, the most GHG emission comes from the production of CME from refined oil. This amounts to 637.2 kgCO2/year/ha representing 50.287% of the total GHG emission. The second greatest source of GHG emission is from the CNO production from copra with 329.6 kgCO2/year/ha representing 26.011%. This is followed by the GHG emission from the production of copra with GHG emission amounting to 193.38

kgCO2/year/ha representing 15.261% of the total GHG emission. GHG emission from the cultivation and nursery management are 7.062 and 1.379 percents of the total GHG emission contribution in the whole of life cycle of coconut for CME production, respectively**.**

The sustainability of biomass utilization can be looked at the different levels such as national level (from the point of view of the country or state), regional or province level (from the point of view of the region or province) and community level. At the pilot study area, the economic indices of biomass sustainability showed positive results. However, data needed in the computation of social indices are only available at the national level or at least in the regional level therefore HDI as measure of social development is more appropriate at the national or regional level. HDI cannot be used to calculate the social impact from the four stages of coconut production for CME. Evaluation of GHG using LCA seems to be the most appropriate approach in assessing the environmental impact of the production of biofuels since GHG has been directly attributed to the increased atmospheric concentration resulting into the change in climate.

1. BACKGROUND, RATIONALE AND OBJECTIVES OF THE STUDY

Dubbed as the "tree of life", coconut is second to rice in the four major products in agriculture, others being corn and sugar. According to Bureau of Agricultural Statistics, area planted or harvested of coconut has an increasing trend from 1990 of about 3.1 M ha to about 3.38 M ha in 2008. In between these years, the average area planted to coconut is about 3.17 M ha. Of the average 3.17 M ha planted to coconut, about 11 percent of these came from Region IV-A, the CALABARZON area, which on the average (1990-2008) has 346,314 ha planted to coconut alone. Of these land area, about 68% is located in Quezon alone. From 1990 to 2008, the province covered majority of the area planted to coconut in CALABARZON, consistent at 67% to nearly 70%.

In terms of production, at the national level, increase in production goes along with the increase in land area. The country is producing an average of 14.88 million nuts annually from 2005 until 2007, increasing at an average of 0.79% per year (Bureau of Agricultural Statistics, BAS, 2009). Of the average national coconut production, an average of about 10% is contributed by Region IV-A, CALABARZON area, with an average annual production of 1.36 million MT. Of the 1.36 million, 80% was produced in Quezon, with variation of about 2% every year from 1990 to 2008.

Meanwhile, average copra production from 2003 until 2007 was 2.50 million metric tons (MT) per year, equivalent to 13.09 million nuts (Philippine Coconut Authority, PCA, 2009). Thus, high percentage of coconut produced in the country is utilized for copra production. Also, the coconut oil exportation covers 21% of the total agricultural exports. Domestic consumption, on the other hand, was 0.52 million metric tons. Average exportation from 2001 until 2007 is 1.99 million metric tons, in copra terms. In 2007, the country exported 1.61 million metric tons of copra and 888.85 thousand metric tons of coconut oil giving the country US $ 733.81 million worth of foreign exchange earnings. In April 2009, the Philippine coconut oil export increased by 125.5% bringing $147.97 M to the country's foreign reserves (http://www.asianjournal.com).

The coconut industry's importance can also be signified by the fact that 25 million Filipinos are directly or indirectly dependent on the industry, 3.5 million of those directly dependent are the coconut farmers (Philippine Coconut Authority, PCA). Quezon has been known as a major coconut-producing province in CALABARZON. Since it is a major source of raw material, thus it has relatively more coconut oil milling factories and other coconut processing firms. As of 2006, there are at least 20 coconut oil mills operating in the province (PCA, Quezon I). Thus, a significant percentage of its population is directly or indirectly affected by the industry. However, during the past years, three of the four oil millers had ceased their operation due to insufficient supply of copra in the area due to low supply of coconut. Even the oil milling companies in Quezon and Laguna had to source out their inputs of whole coconut from Mindoro, Marinduque and Bicol provinces due to the insufficient local supply. Since importing copra or purchasing from outside provinces is costly, thus oil millers resort to shutting down their companies.

The increasing number of substitute products for coconut oil had caused the demand for coconut oil to decrease. These had also led the farmers to cut down the trees for lumber aside from the numerous senile and unproductive trees. Thus, it gave an undesirable impression to coconut farmer, in terms of profitability.

The coconut oil industry started to suffer economic instability due to its low and fluctuating price trend and instability of coconut supply. This had lead coconut farmers to shift into other higher income alternative industries like agro-livestock, cottage and fishing industry (Sariaya.net, 2008).

With some literature implying that coconut industry can now be classified as a sunset industry with no promising benefits in the future, many coconut stakeholders already gave up their enterprise without analyzing further if their investment were really bringing them gains or losses. This is also true to the local government, which could bring hundreds or even thousands of people with no source of income. These situations impose a great threat to the coconut oil industry since its production depends on the coconut production.

The study aims to test the methodologies for the calculation of indices for sustainability of biomass utilization specifically biodiesel production from coconut in Quezon. This will help determine the issues and constraints by the stakeholders in biodiesel production which can help the policy makers to establish policies and programs that would really answer the needs of the industry's stakeholders. It also aims to help the key players'/agents to determine whether there is a need to improve, change, or adopt new technologies for a better outcome of the industry.

The general objective of the study is to test the methodologies for the calculation of indices of sustainability of biodiesel production in Quezon. The specific objectives are:

1. To describe and analyze the value-adding activities performed by processors in the biodiesel industry in Quezon;
2. To calculate the value added in the biodiesel industry in terms of net profit, employment generation, tax generation and foreign exchange earnings;
3. To calculate the human development index and other social benefits from the biomass project; and
4. To calculate the environmental effects of the biomass project using LCA

2. METHODOLOGY AND DESCRIPTION OF THE PILOT AREA

The study was conducted in an area where biomass is known to have high production level and there is high concentration of biomass-based industries. The province of Quezon was selected based on the following reasons: (1) Among the coconut-based provinces in the country, Quezon has the largest volume of production and is heavily dependent on its two major agricultural products, rice and coconut; (2) Having several rice and coconut-based industries, Quezon has the potential of increasing the value addition generated from biomass production; and, (3) With the mandate of the Biofuels Act of 2006 of implementing a higher percentage mix of biodiesel to diesel fuel in the coming years, Quezon's production of coconut methyl ester is likewise expected to increase since there are three major CME plants located in the province.

Situated at the eastern coast of Luzon (as shown in **Figure 1)**, Quezon has a total land area of 870,660 hectares or 8,706.6 sq. km. – an equivalent of 18.6% share in Region IV. In terms of land area, Quezon province is the second largest in the Southern Tagalog region and the sixth largest province in the Philippines. It is composed of 40 municipalities which are divided into four political districts, 1,242 barangays, and an urbanized city (Lucena) which serves as its capital. The total population of the province amounts to 1,679,030 with Lucena as the most populous area accounting to 11% of Quezon's population (NSCB, 2007).

The major agricultural products of Quezon are palay, coconut, corn, banana, vegetables and root crops. Fish and marine products are primarily sourced out from the vast offshore waters and inland fish ponds of the province. Its logging industry, which includes forest products, lime manufacture, and desiccated coconut, is supported by Quezon's thickly forested and mountainous areas.

Despite the Philippine Coconut Authority's (PCA) order to regulate the cutting of coconuts, clearing of significant numbers of coconut trees still persists in the province for coco-lumber and conversion to other uses such as subdivisions or new population centers. However, it served as the main source of livelihood in the province. In Region IV, Quezon still has the greatest coconut production with an average of 1,099,459 metric tons per year from 1992-2008 – 80% of the region's coconut production.

Figure 1. Philippine map showing the location of Quezon

Primary data were utilized in the study. These data were obtained by interviewing selected coconut oil industry stakeholders, consisting of coconut farmers, copra processor, oil miller and biodiesel processor in Quezon. Information regarding value-adding activity they performed, revenues and costs they received from such activities by each key player were gathered. Employees of these firms were also interviewed to test the methodologies for the social sustainability of biomass utilization. Secondary data were also gathered from the Philippine Coconut Authority (PCA), Department of Energy (DOE), and Bureau of Agricultural Statistics of Department of Agriculture (BAS-DA).

Descriptive analysis was used to describe key players in the biodiesel industry, including the process adopted in each activity. These were enhanced through the use of tables showing the different costs and revenues, and other pertinent data to summarize the discussion. Figures such as line graph and bar graphs are used to show the percentage of each cost item in the different value-adding activity relative to the total cost to determine which directly affect the costs in each process, respectively.

2.1 Methodology for the Calculation of Economic Indices of Biomass Sustainability

The economic indicators that were taken into consideration for calculating the economic impact of the energy project are the following: 1) total net profit accumulated from product conversion or processing; 2) employment impacts created out of the biomass industry; 3) tax revenues generated from the different entities within the industries; and 4) foreign trade impacts in terms of dollar earnings and dollar savings.

Total Net Profit

Costs and Returns Analysis was used to determine the net profit of the key enterprises in biodiesel industry for the year 2010. To determine the profitability, total production costs were deducted from the returns gained from the enterprise. Returns in the enterprise include revenue from sales of the primary output and sales from by-products. Total costs, on the other hand, include value of material inputs or materials and supplies used in the production process, such as purchasing costs of mature coconut for copra processors, copra and other chemicals for coconut oil producers, and others. In addition to the value of intermediate inputs, labour costs including wages and salaries are also included, as well as the various taxes and duties charged in the production process, and other costs items. To determine the profit, the following formulas were used:

Total Returns = Sales from Primary Output + Sales from By-products

Total Costs = Value of material inputs used + Labor costs + Overhead Costs

Overhead Costs =Taxes and Duties + Interest + Depreciation

Net Profit = Total Returns – Total Costs

Total net profit is the sum of the net profit generated from both the main product and the by-products.

The calculation for the total cost is divided into three stages. First stage is the *Production*. This stage accounts for the costs incurred in the actual production process of the raw material or initial product. This involves the farming costs. For coconut, *Production* stage corresponds to mature nut production which is the initial product for biomass processing.

Second stage is the *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. This involves the extraction costs. *Primary Processing* for coconut involves copra and refined oil production. Mature coconut serves as the input in copra processing.

Third stage is the *Secondary Processing.* From the readily convertible material in the second stage, certain processes such as esterification are undertaken to produce the final product which is biodiesel. This involves the biodiesel production costs. A readily convertible material for biomass production such as refined oil undergoes *Secondary Processing,* specifically the process of esterification, to arrive at the final product which is biodiesel.

Employment Generation and Personnel Remuneration

Employment impact is the number of jobs that can be generated with the presence of the energy project which is computed as follows:

Employment = Total Production x Labor Requirement for every unit produced

If labor requirement is in terms of man-days, necessary conversion will be done such that the computed value could be translated into number of jobs created to provide a more concrete view of the employment impact of biomass production and processing.

The extent of the economic impact with the presence of the biomass industry can be measured through the number of jobs that can be hired by the industry. To estimate this, the total number of man-days required for each stage all throughout the production process was computed. The value is then translated in terms of the number of laborers employed.

Employment = Total Production of Mature Coconut/Copra/Refined Oil/Coconut Methyl Ester x Labor Requirement per unit of Mature Coconut/Copra/Refined Oil/Coconut Methyl Ester produced

Personnel remuneration on the other hand refers to the total salaries and wages paid to the employees in the different firms or activities involved in the biomass utilization. This is computed as:

Personnel remuneration = total man-days x average wage per man-day.

Tax Revenue

Tax revenue is the income generated by the government from the entities involved in each production process. This is computed as follows:

Tax = Total Taxable Income x Tax Rate; where,

Total Taxable Income = Income from main product (Profit per unit of product A x Volume of A) + Income from by-product (Profit per unit of by-product B x Volume of B)

Taxes generated from the coconut industry can be obtained by multiplying the prevailing tax rate by the total taxable income of each sector (i.e. copra, unrefined oil, and CME producers). However, coconut farmers are exempted from paying taxes as stipulated under the Comprehensive Agrarian Reform Program of the Philippines. Thus, no taxes are generated from the farming sector.

Tax = Total Taxable Income from copra, unrefined oil, and coconut methyl ester production x Tax Rate

Foreign Trade

Foreign trade impact is determined by two factors, (i) dollar earnings from product export and, (ii) dollar savings from reduced diesel imports with the presence of the energy project. The computations for each are as follows:

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

$ Savings = Amount (in weight) of biomass x Density 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 trade-off occurs. Dollar earnings from exports will then be reduced with domestic consumption. The net effect of this trade-off can be computed as follows:

Net Effect= Reduced $ Earnings + $ Savings

Coconut oil is one of the top dollar earners of the country and represents the $ earnings for the coconut industry. With the adoption of CME, a portion of the total volume of production of unrefined oil will be dedicated to CME production. As a result, the volume of exports is lessened - dollar earnings are reduced. On the contrary, dollar savings arises from CME adoption in lieu of diesel imports. Thus, a trade-off occurs. The net effect of this trade-off can be quantified by adding the reduced dollar earnings from unrefined oil exports and the dollar savings from displaced diesel by CME.

Reduced $ Earnings = (Price per unit of coconut oil exports x Total volume of exports) x % to be used for CME production

$ Savings = [(Metric tons of unrefined oil produced x % to be used for local consumption)/Density (kg/li)] x Forex savings per liter of displaced diesel by CME*

*a constant estimated by the Department of Energy

Net Effect = (Reduced $ earnings from unrefined oil exports) + $ savings from reduced diesel imports

Total Value Added

The total value-added for the industry included the summation of all the value-added in each enterprise, which include personnel remuneration, taxes and duties earned by the government from the enterprises, foreign exchange earnings from exported products, and the entrepreneur's net profit. Thus total value added for the industry is given by the formula:

Total Value Added = Net Profit + Personnel Remuneration + Tax Generated
+ Foreign Exchange Earnings

2.2 Methodology for the Calculation of Social Indices

The social sustainability of the biomass project was assessed using the Human Development Index. Human development, as described in Chapter I of the Human Development Report 1990 of the United Nations Development Programme (UNDP), is a process of enlarging people's choices, most critical of which are to lead a long and healthy life, to be educated and to enjoy a decent standard of living.

The Human Development Index (HDI) conceptualized by the UNDP in 1990 attempts to measure human development. Recognizing the complexity of human development, the HDI may not be that comprehensive to be able to capture all the facets of human development. The UNDP, however, stressed that a simple composite measure of human development can already draw attention to the issues quite effectively.

The provincial HDI for the pilot area is constructed using the average of three development outcomes for each province. These include: (1) health as measured by life expectancy; (2) level of knowledge and skills as measured by the weighted average of functional literacy and combined elementary and secondary net enrolment rate; and (3) access to resources as measured by the level of real per capita income.

The HDI is measured by taking the average of (1) life expectancy; (2) weighted average of functional literacy and combined elementary and secondary net enrolment rate; and (3) real per capita income. That is,

$$\mathbf{HDI = (I_1 + I_2 + I_3) / 3}$$

Where:

I_1 = life expectancy index

I_2 = education index

I_3 = income index

2.3 Methodology for the Calculation of Environmental Indices

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

Both primary and secondary data were used in the determination of the raw material inputs in the four stages of biodiesel production. Secondary data were mostly taken from the Philippines Recommends for Coconut and book on Coconut Production and Utilization. Secondary data taken was fertilizer requirements during the nursery management and management of coconut plantation. Primary data requirements includes fuel for transport of raw materials, other material inputs, main products and by-products in the four stages of production; fuels used in the boiler; electricity used and other raw materials. These data were actually taken from the results of personal interview and questionnaires distributed to the respondents.

Total GHG emissions were then calculated from each stage of production (plantation, copra production, oil production and CME production) and from the fuel used in the transportation in each of these four stages.

3. THE COCONUT INDUSTRY IN THE PHILIPPINES

The Philippine Coconut Authority states that coconut is a dominant sector of Philippine agriculture; 68 out of 79 provinces produce coconut. On a national level, area planted to coconut increased from 3.36 million hectares in 2007 to 3.38 million hectares in 2008. The number of bearing trees increased from 338.72 million trees in 2007 to 339.36 million trees in 2008 (BAS, 2009). The country has a 59% share in world coconut exports and is the world's second largest producer of coconut products after Indonesia, which produces mainly for domestic consumption. As of 2008, the Philippine Coconut Authority (PCA) data accounts that 3.38 million hectares out of the 12 million hectares of farmlands are devoted to coconut – 28% of total agricultural land. This provides livelihood to more than three million coconut farmers. About 25 million Filipinos are dependent both directly and indirectly on the coconut industry. The industry contributes an annual average of 5.97% to Gross Value Added (GVA) and 1.14% to Gross National Product (GNP). Regarded as a dominant sector of Philippine agriculture, the coconut industry is one of the major dollar earners of the country, averaging US$800 million or roughly PhP 40 billion annually according to the Department of Agriculture (DA). The Philippines is the world leader in coconut oil production, supplying 64% of the global requirement (Teves, 2003). Approximately 80% of domestic coconut production is exported mostly to the US and Europe.

A lot of foreign market opportunities for the national coconut industry exist. World demand for coconut oil is increasing due to coconut oil's high lauric fatty acid content, for use primarily in the detergent and cosmetic industries and in the production of other environment-friendly products. A large international market exists for coco chemicals like fatty acids and alcohol, methyl esters, tertiary amines, alkanolamides, and glycerin.

Local and export demand for virgin coconut oil (VCO) for health purposes are increasing.

Figure 2 exhibits the material balance of coconut in the country. Of the estimated 15 million metric tons of coconut produced in the country per annum, about 90% is processed into copra. Annual copra production is estimated at two million MT. The remaining portion (10%) of the total coconut production is devoted to the manufacture of desiccated coconut (5%) and other coconut products namely coconut milk, *buko*, and for household purposes (5%). Out of the total amount of copra produced, 62% is processed into crude CNO – 60% of which goes to exports while 40% is left for domestic consumption. Copra cake or meal which is the by-product of copra production constitutes the remaining 34% (Lozada, 2002).

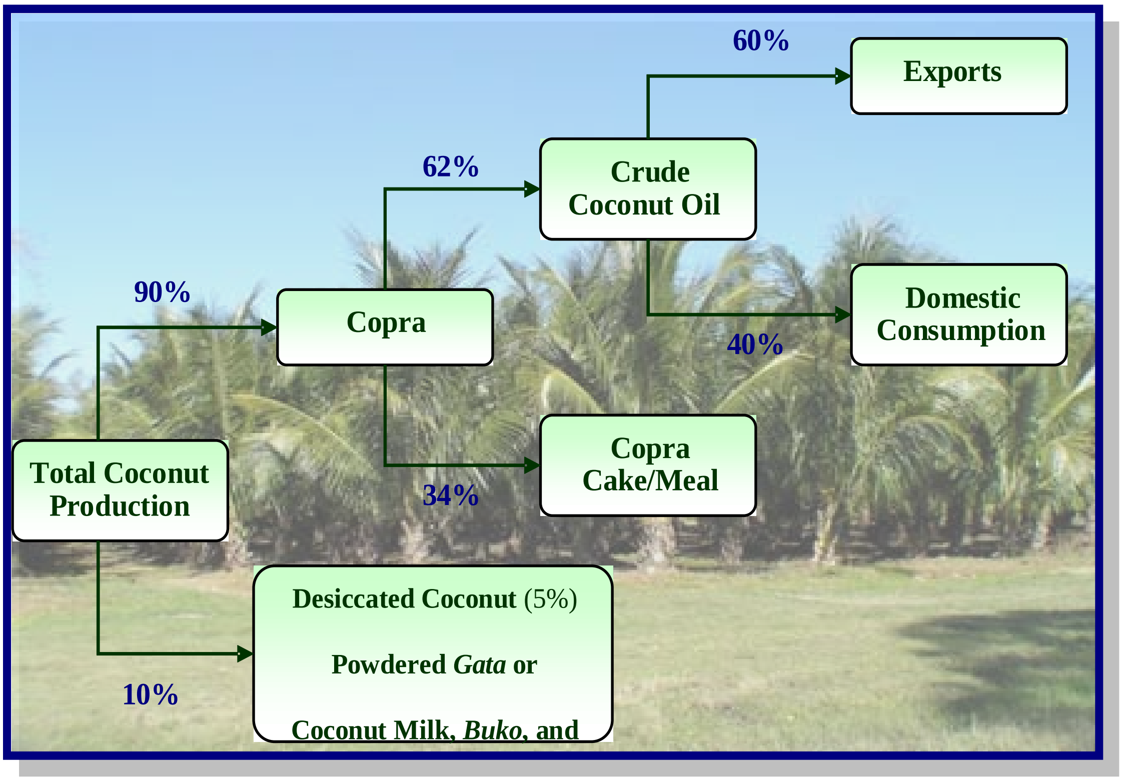


Figure 2. Coconut material balance in the Philippines (Lozada, 2002)

3.1 Coconut Industry in Quezon

The province of Quezon had been one of the major producers of coconut nationwide, accounting for almost 8% each year to overall national production based on the data by the Bureau of Agricultural Statistics from 1992-2008. In 2008, the province contributed 1.09 million MT or 7% of the total coconut production (see **Figure 3**).

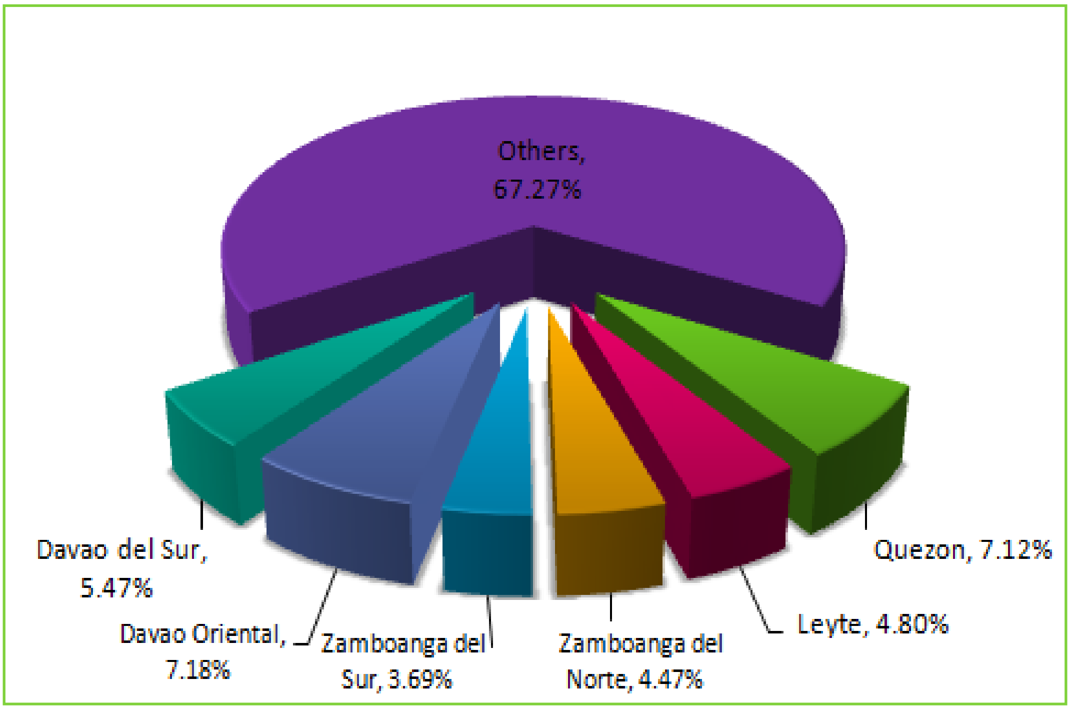


Figure 3. Coconut production volume distribution by province, Philippines, 2008

Depicted in **Table 1** is a situationer for the national, regional, and provincial coconut accounts for 2008. Of the total area planted to coconuts, 10% is situated in Region IV-A, the CALABARZON region. Out of this 10% contribution to national coconut hectarage, 67% is located in Quezon province.

Moreover, Quezon had the biggest land area in coconut production contributing 6.8% to the country's total harvest. For a more detailed account of Quezon's coconut industry, refer to **Table 2**. Over time, the area planted to coconut in the province has remained relatively stable. However, a significant decrease in the volume of production could be observed during 1996 but eventually recovered in the following years. The number of bearing trees exhibits a declining trend through time.

Table 1. Coconut statistics in Quezon and in the Philippines, 2008.

ITEM	Philippines		Region IVA – CALABARZON		Quezon	
	Value	%	Value	%	Value	%
Area Planted (in has)	3,379,741	100	343,578	10.17	230,440	67.07
Volume of Production (in MT)	15,319,527	100	1,362,852	8.90	1,090,941	80.05
Number of Bearing Trees	339,357,206	100	41,750,811	12.30	32,554,563	77.97

Source: Bureau of Agricultural Statistics, 2009

Table 2. Coconut statistics in Quezon province, 1992-2008.

YEAR	AREA PLANTED (in has)	VOLUME OF PRODUCTION (in MT)	NUMBER OF BEARING TREES	YIELD PER HECTARE (in MT/ha)	YIELD PER BEARING TREE (in kgs)	VALUE (in M PhP)
1992	235,722	1,166,254	38,260,570	4.95	30.48	2,332.51
1993	235,618	1,130,068	37,282,130	4.80	30.31	2,260.14
1994	234,780	1,126,964	37,274,674	4.80	30.23	2,253.93
1995	234,529	1,105,388	36,747,603	4.71	30.08	2,210.78
1996	233,524	768,262	36,547,603	3.29	21.02	1,536.52
1997	227,524	1,162,935	36,000,000	5.11	32.30	2,325.87
1998	232,934	1,094,011	34,346,147	4.70	31.85	2,188.02
1999	235,398	955,124	34,600,600	4.06	27.60	1,910.25
2000	239,780	959,351	34,689,608	4.00	27.66	1,918.70
2001	243,658	970,220	34,694,000	3.98	27.97	1,940.44
2002	241,221	1,296,689	34,274,321	5.38	37.83	2,593.38
2003	241,221	1,255,072	34,274,321	5.20	36.62	2,510.14
2004	241,171	1,236,076	34,246,282	5.13	36.09	2,472.15
2005	230,730	1,206,761	32,763,660	5.23	36.83	2,413.52
2006	230,460	1,190,722	32,560,450	5.17	36.57	2,381.44
2007	230,449	975,960	32,556,563	4.24	29.98	1,951.92
2008	230,440	1,090,941	32,554,563	4.73	33.51	2,181.88

Source: Bureau of Agricultural Statistics, 2009

4. Economic Indices of Sustainability of Biodiesel Production from Coconut

The sustainability of biomass utilization was assessed using the indicators of the economic benefits that have been identified. The methodologies that were used for the calculation of economic indices of biomass utilisation were tested using actual data from coconut farmers, copra processors, oil mills, and coconut methyl ester (CME) manufacturers.

In the determination of the value added, the different product forms of coconut in Quezon were considered. Primary coconut products include mature dehusked coconut, copra, coconut oil, and CME. By-products include copra meal, coconut shell, coconut husk, glycerin, and fatty acid.

In the production of the final product which is CME, mature dehusked coconut is used for copra production. Coconut oil, which is extracted from copra, is the primary input in CME manufacturing. Throughout the conversion process, by-products are generated namely copra meal, glycerin, fatty acid, glycerin and acid oil (refer to Figure 4).

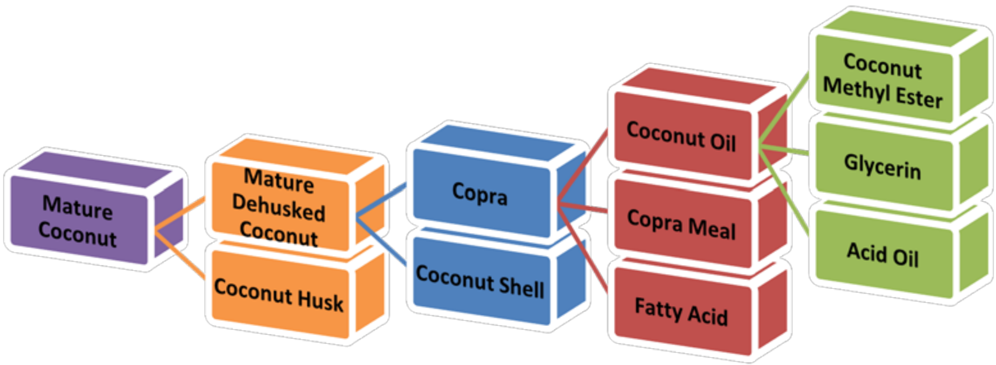


Figure 4. Product flow of coconut

4.1 Total Net Profit

In the computation for the costs and returns as well as the value added or net profit generated for each conversion process, the product flow was divided into four stages. First stage is the ***Production of mature dehusked coconut***. This stage accounts for the costs incurred in the actual production process of the raw material or initial product which is the mature dehusked coconut. Second stage is the *Copra Production.* This stage involves the processing of the mature dehusked nuts in to copra Third stage is the *Coconut Oil production.* This stage involves the processing of copra into crude coconut oil and further processing of crude coconut oil into refined coconut oil, specifically RBD which is refined, bleached and deodorized coconut oil. The final stage is the CME or biodiesel production. This involves esterification of the refined oil to produce the final product which is biodiesel. **Table 3** lists the recovery rates of each product form.

Table 3. Recovery rates per coconut product form

PRODUCT FORM	RECOVERY RATE
Mature dehusked nut	67% of mature husked nut
Husk	33% of mature husked nut
Copra	33% of mature dehusked nut
Shell	22.4% of mature dehusked nut
Crude coconut oil	61.5% of copra
Copra meal	32% of copra
Refined coconut oil	92.5% of crude oil
Fatty acid	4.9% of crude oil
CME	100% of refined oil
Glycerin	12.5% of refined oil
Acid oil	0.55% of refined oil

Using the recovery rates in **Table 3,** the quantity of output per process is computed on a per hectare per year production of mature nuts. The results are shown in **Figure 5.** The amounts of by-products generated in each stage are also shown. The quantities of inputs, primary outputs and by-products are used in the computation of costs and returns per stage.

Figure 5. Coconut products and by-products production per hectare per year

4.1.1 Production of Mature Dehusked Coconut

First stage is the *Production of mature dehusked nut*. This stage accounts for the costs incurred in the actual production process of the raw material or initial product which is mature dehusked coconut. This involves the farming costs or the operational costs. For this stage, the case of Alvarez Enterprise's coconut plantation was taken into consideration.

Profile of Alvarez Coconut Plantation

The Alvarez family owns a 5-hectare coconut farm situated in Lutucan I, Sariaya, Quezon, considered as one of the largest in the municipality. The land was acquired by the family since 1975, including the tenanted lands. Of this, 1.25 hectares is owned by one of the children, Dante Alvarez, the farm has about 100 coconut bearing trees per hectare. Average production is at 10 nuts per tree or 1,000 nuts per harvest per hectare. Farm assets include vehicles used in harvesting the mature nuts such as the carabao-driven cart. Just like any other coconut farms in the area, the minimal investment in production inputs such as fertilizer and chemicals is reported.

Activities and Input Requirements

The production stage's output is mature dehusked coconut. Coconut utilization starts with harvesting. The harvesting cycle practiced in the farm is a 45-day period with a yield of 1,000 nuts per hectare. There are two common methods of harvesting coconuts, the pole and the climbing methods. The pole method makes use of a long bamboo pole to reach for the coconuts and detach them from the tree. The climbing method, on the other hand, is practiced when trees are relatively shorter and fewer in number. The climbing method is less preferred over the pole method as it is riskier in terms of safety. Bunches of nuts which fell to the ground are then piled up. These will then be hauled by a carabao-driven cart. The farm prefers the pole method of harvesting.

Post-harvest and primary processing practices (seasoning of partially immature nuts for 7 –10 days or "ripening", dehusking and copra processing) are common in small to medium scale farms. If sold to coconut desiccating plants, dehusked nuts are immediately marketed. Coconut husks await decortication or defibering, while coconut shells are converted to charcoal and sold to activated carbon processors (Magat, 2007). The volume of transported mature coconuts is seasonal. During the eight peak months from May to December, volume transported reaches 80 tons per day. In lean months, this goes down to 10 to 15 tons per day for six days a week.

Dehusking is often done to put a premium on the farmers' saleable output. The equipment used in dehusking mature nuts is some sort of a vertically-positioned blade. Furthermore, additional income could be derived from the sale of coconut husks or further processing of output into copra. While some farmers opt to do these, others may opt to sell the harvested nuts in husked forms, so as to avoid any incremental processing costs. This depends on the volume of nuts harvested. For small volumes, immediate selling is preferred. For large volumes, further processing is preferred.

Labor costs incurred are for harvesting dehusking, loading and unloading of coconut. The farm incurs PhP 1,000 per hectare for these activities. Delivery cost is

PhP 300 per 1,000 nuts for 3-4 km distance from the farm to the copra plant. Mode of transportation is via a truck with capacity of 6,000 nuts.

Net Profit from Mature Dehusked Nut Production

Table 4 presents the costs and returns computation based on a 1000-mature nut production per hectare per harvest. One mature nut weighs 1.2 kg on the average. Harvesting is done every 45 days so there are 8 harvests per year. Material cost amounts to PhP 1,200 per year which accounts for the 1-bag fertilizer application. Labor cost includes payment for maintenance operations of PhP 3,000 per year and contract labor for harvesting, dehusking and hauling of the dehusked nuts to the delivery vehicles at PhP 1,000 per harvest. Transportation cost involves the delivery cost to the copra plant valued at PhP 0.30 per nut. Total costs amount to PhP 13,400 per year or PhP 2.08/kg of dehusked nut.

Mature dehusked nuts are sold at PhP 4.50 per kg. Since there are 8,000 nuts per hectare, one hectare would yield 9,600kg of mature nuts using the weight of a mature nut which is 1.2 kg. Using the recovery rates of 33% for husk and 67% for duhusked nut, total yield is 6,432 kg of dehusked nut resulting to a total revenue of PhP 28,944.00. The value of coconut husks is negligible (only PhP 0.06 per kg) and they are not normally sold.

Net profit amounts to PhP 15,544 per hectare per year or PhP 2.42 per kg of dehusked nut.

Table 4. Costs and returns in mature dehusked coconut production

	ITEMS	QUANTITY/ HECTARE	COST/UNIT (in PhP)	COST/ HECTARE (in PhP)
MATERIAL	Fertilizer and Other Chemicals	1 bag/yr	1200/bag	1200
LABOR	Weeding, Fertilizing, and Other Maintenance	12 mandays/yr	250/m-day	3000
	Harvesting, Dehusking and Hauling	8000 nuts	1,000/harvest	8000

OVERHEAD	Transportation/Delivery Cost	8000 nuts	300/1000 nuts	2400
TOTAL COST				**13400**
			PhP/KG	**PhP/HA**
TOTAL mature nut (1.2 kg)		9600kg	**1.40**	**13,400**
TOTAL dehusked nut (67% recovery)		6432	**2.08**	**13,400**
PRICE of dehusked nut			**4.50**	**28,944**
NET PROFIT			**2.42**	**15,544**

Note: There are 8 harvests in a year, average yield is 10 nuts per tree per harvest

4.1.2 Copra Production

The second stage is the processing of mature dehusked nut, specifically the coconut meat into copra. 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. This involves the processes and extraction costs of copra from mature coconut. The case of Alvarez Enterprise's coprahan was taken into consideration.

Profile of Alvarez Coprahan

Together with the coconut plantation, the Alvarez family has been in the copra processing business for 52 years. Its copra processing adopts the "tapahan" method and 500 sq.m. or 0.75 hectares of land is devoted for the tapahans. The family started with the copra venture as it was the only form of saleable product to coconut oil mills at the time of establishment. Enterprise asset includes 2 10-wheeler trucks, an elf, a loader, and a jeep; some are also included in the trading enterprise. Copra produced is sold to oil mills such as Tongsan Industrial Development Corporation (Candelaria), Josefa Yu Oil Mills, and Tantuco Oil Mills (Lucena).

Activities and Input Requirements

Copra is dried coconut meat from which coconut oil is obtained. The mature coconuts are split open using a *bolo* then undergoes a drying process using dryers like the "tapahan" method. Drying is the method of producing copra. Sun-drying takes 2 days to complete and requires a large area. However, the copra plant has 12 units of copra dryer. A dryer can carry around 3,500 to 4,000 nuts. The process of drying is characterized by the "dissolving" of moisture, which comes from the coconut meat, by air. The equilibrium moisture content of copra is about 5% which implies that good quality copra is attained when moisture content is at this level. The plant's fuel requirement to carry out the drying activity is about 500 kg of coconut shell per batch.

After initial drying for eight hours, the meat can be easily scraped out. The coconut shell is collected and used as fuel for the earthen dryers. Scraped meat is dried for another three hours. Lastly, the copra meat is weighed, placed in jute sacks, and are kept on elevated pallets in warehouse prior to sale.

Recovery rate of copra from mature dehusked coconut is 33%. Production capacity follows a seasonal pattern in which the peak is dated from May through December while lean is from January through April. During the peak season, 4 tons of copra is produced per day; while during the lean season, 5-6 tons is produced every two weeks.

On the average, the plant employs 20 to 30 workers for peak season and the labor requirement is three laborers per three batches wherein each batch processes 3,500 to 4,000 nuts. The transportation cost incurred in delivering copra to the oil mill is PhP 300/ton. During peak months, the plant delivers 5 tons of copra three times a day for every two weeks. Aside from transportation, other indirect cost is depreciation. This includes the depreciation of the tapahan valued at PhP 15 per ton.

Net Profit from Copra Production

Table 5 summarizes the costs and returns in copra production from per hectare of mature nut production per year. The amount of input is the quantity of dehusked nut produced from 1-hectare valued at its market value or selling price. Total cost amounts to PhP 32,344. The amount of copra produced at 33% recovery is 2,122,56 kg resulting to a unit cot of PhP 15.24 per kg of copra. Copra is sold at PhP 22.00 per kg on the average thus revenue from copra sales is valued at PhP 46,696 and net profit is PhP 6.76 per kg.

Table 5. Costs and returns in production of copra from one hectare coconut production

	ITEMS	QUANTITY	COST PER UNIT (PhP)	TOTAL (PhP)
Direct Costs	Mature Dehusked Coconut Input	6432 kg	4.50/kg	28,944
	Labor	6 m-days	300/m-day	1,800
	Trucking		300/ton	600
	Sub-Total			**31,344**
Overhead	Miscellaneous (helper, fees and local taxes, selling and administrative)			1,000
	TOTAL COST			**32,344**
TOTAL OUTPUT, kg (33%)		**2122.56**		**46,696**
COST PER KG			**15.24**	
SELLING PRICE PER KG			**22.00**	
NET PROFIT			**6.76**	**14,352.32**
BY PRODUCT	Coconut Shell (22.4%)	1440 kg	3/kg	4320
	Less shell used as fuel	1000 kg		3000
	Sales of shell	440 kg		1320
TOTAL PROFIT			**7.38**	**15,672.32**

A by-product of copra processing is coconut shell which can be used as charcoal or even as water filter. Coconut shell recovery is 22.4% of the dehusked nut. The coprahan uses 1,000 kg of shell as fuel and only the remaining 440 kg is sold. Coconut shell is sold at PhP 4.00 per kg during lean months while PhP 2.50-PhP 3.00 during peak months, the average of PhP 3 per kg was used as the selling price. The resulting value is then added to net profit from copra to get the total profit of PhP 15,672 per year. Net profit per unit is PhP 7.38 per kg of copra.

4.1.3 Coconut Oil Production

The third stage is the processing of copra into crude coconut oil and further processing of the crude oil into refined oil. In this stage, crude oil undergoes processing up to the point in which the output is already a convertible material for biodiesel production which is the RBD or refined, bleached and deodorized oil. This involves the processes and extraction costs of oil from copra. The case of Tantuco Oil Mill was taken into consideration.

Profile of Tantuco Oil Mill

Tantuco Oil Mill is located at Maharlika Highway, Iyam District, Lucena City, Quezon with a total land area of 22,251 sq.m. Owned by Edwin Tantuco, the oil mill was established on August 31, 1965. It continued its operations until 1981. It ceased operations for a few years and was later reinstalled in 1986. Major products are crude coconut oil (CNO) and refined oil (RBD) which account for 45% and 32% of the company sales, respectively.

Plant capacity is 300 metric tons of copra per day from which 61.5% is crude coconut oil, 32% is copra meal, and 4% is fatty acid. Crude coconut oil is further processed into refined, bleached, and deodorized (RBD) oil with a 92.5% recovery rate. Processing copra to crude coconut oil takes about an hour. The plant operates 24 hours a day, 7 days per week. The mill employs 90 regular employees.

Activities and Input Requirements

In obtaining the commercially valuable product from coconut which is the oil using the dry process, it is necessary to convert coconut meat to copra (Banzon and Velasco, 1982). Coconut oil can either be crude or refined. Refined oil is the form fit for human consumption while biodiesel production may either utilize crude or refined oil. Originally, coconut oil (CNO) was used as fuel for lamps, then for food, and as a material for soap making. Coconut oil is a very saturated oil with over 90% of its fatty acid content as saturated. Thus, CNO is particularly desirable for bakery goods as "spray oil" in maintaining stability with respect to flavor change, for bath soaps, and for the production of white leather. CNO has a heat value of about 9,000 kcal/kg (Banzon and Velasco, 1982). It is now widely promoted as a diesel fuel additive termed as coco-biodiesel for a more environment-friendly and economically advantageous fuel nationwide.

In order to produce refined coconut oil, also known as refined, bleached, and deodorized (RBD) coconut oil, copra has to undergo oil extraction before undergoing refining and deodorizing process. Copra, sourced from within Quezon and Bicol province, is stored in a warehouse – a well-structured, well-roofed, and well-ventilated structure. Stored copra can last for a maximum of two weeks.

From the warehouse, copra is transferred by pay loaders to the loading area aided by conveyors (**Figure 6**). However, manual picking of foreign materials is done prior to loading. At the same time, conveyors have built-in magnets to separate metallic foreign materials. The conveyors will lead copra to the grinding section where it will be mashed. After grinding, the mashed copra will then proceed to the cracking roll to reduce the material into finer pieces, and flaker to expose more surface. From the flaker, flaked copra will be dried before subjecting to the expander. The expander renders flaked copra under steam to swell and expose oil cells. Steamed copra will proceed to the cooker and conditioner. After conditioning, copra will proceed to the expeller press, where actual oil extraction takes place. This process will eventually produce copra cake or copra meal, as its by-product, alongside unrefined coconut oil. Copra meal is the residue resulting from the extraction of oil from copra. It is mainly used as a livestock feed ingredients because of its high protein content. It is a major component for various poultry feeds such as starter, layer and broiler mixture. Recovery rate from copra is 61.5% unrefined oil, 32% copra meal, and 4% fatty acid. The actual diagram for the CNO extraction at Tantuco oil mill is illustrated in **Figure 7**.

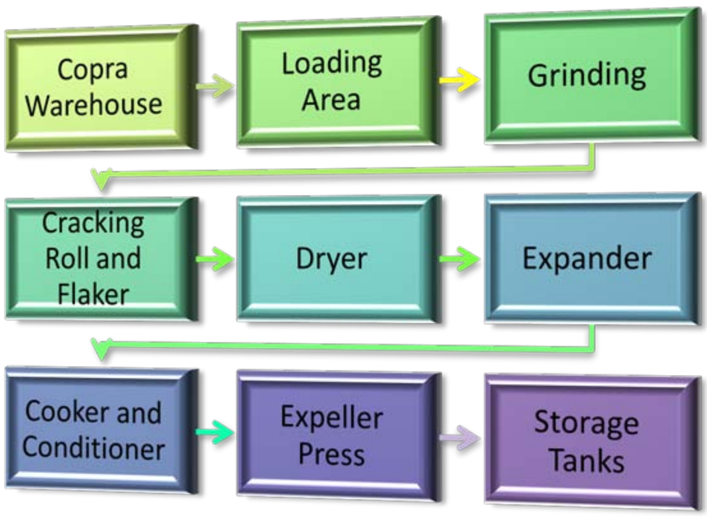


Figure 6. Process flow of unrefined oil production

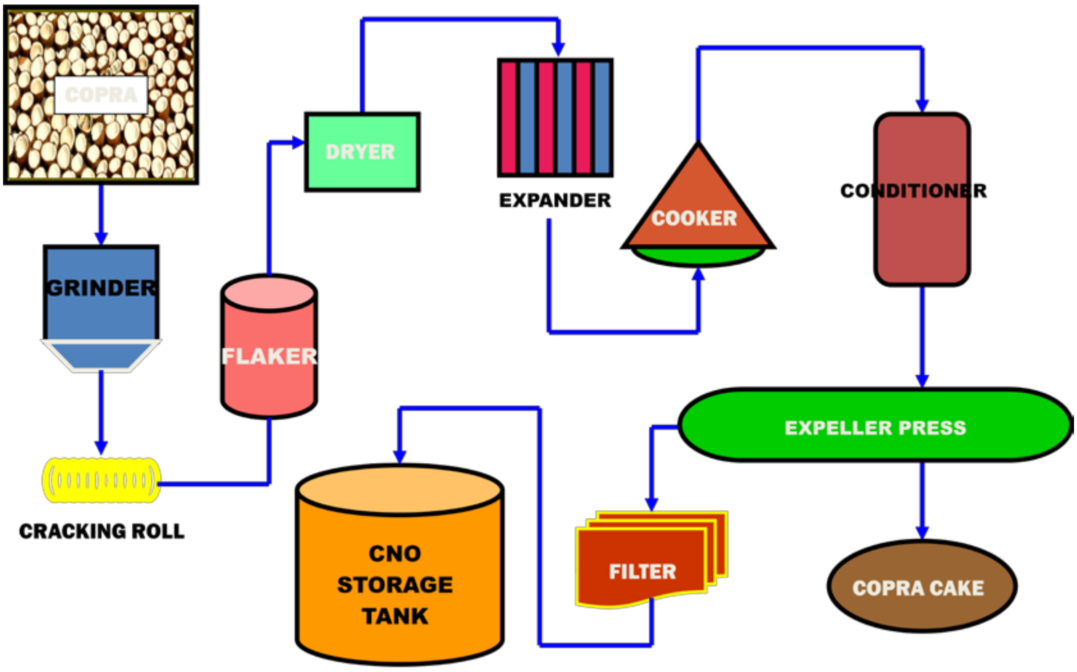


Figure 7. Extraction of crude coconut oil from copra at Tantuco Oil Mill

Refining is done through physical method and subdivided into three processes: degumming, bleaching, and deodorizing; all of which are mechanized and controlled in a control room. Degumming is the process of subjecting the coconut oil to phosphoric acid and water. Degumming usually takes about 30 minutes to process 5,000 liters of coconut oil. Bleaching likewise takes 30 minutes and is aided by activated carbon and bleaching earth. The time allocated for bleaching, however, is indefinite since the color of oil varies depending on its composition. Deodorization does not employ additional inputs since the process only requires settling of the bleached oil for two hours. This allows the separation of coconut fatty acid from the bleached oil as the fatty acid is the one responsible for the strong odor. The final product is the clear, viscous, and odorless edible oil. On the average, refining process takes three hours to produce an average of 30,000 liters of RBD. Recovery rate of RBD from unrefined CNO is 92.5 %. Thus, the remaining 7.5 % of coconut oil is fatty acid. Aside from fatty acid, another by-product is used activated carbon, a grayish substance with sand-like appearance used by cement industries. After production, RBD is packaged and labeled for distribution in local markets (**Figure 8).**

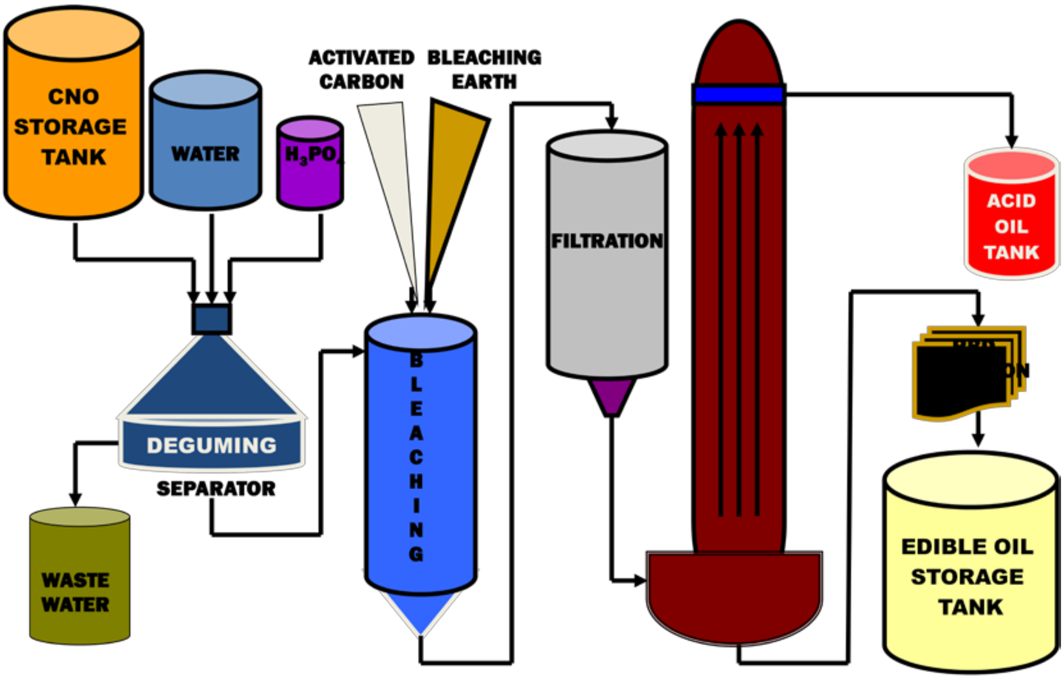


Figure 8. Refining of crude coconut oil (CNO) into RBD

Net Profit from Refined Coconut Oil Production

The amounts of material inputs required to process the copra produced from one hectare nut production into refined coconut oil along with the corresponding costs are shown in **Table 6**. Consumption of other material inputs is as follows: phosphoric acid is 0.05% of crude CNO, activated carbon is 0.3% of crude CNO, and bleaching earth is 1.2% of crude CNO. The labor requirement is one man-day with a wage rate of PhP 350.

Total cost in processing the copra input from one hectare amounts to PhP 49,212 producing 1,305.65 kg of CNO. With 92.5% recovery from CNO, RBD output is equivalent to PhP 1,207.72 kg, thus the computed cost per kg of RBD is PhP 40.75.

Refined coconut oil is sold at PhP 42 per kg. The total amount of refined oil produced was based on 2,123 kg of copra input in which 61.5% of which is crude oil and 92.5% of crude oil is refined oil. Total revenue from RBD sales is PhP 50,724. Net profits per hectare and per kg amount to PhP 1,512 and PhP 1.25, respectively.

Revenues are also generated from the sales of by-products in oil production namely copra meal and fatty acid. The quantity of copra meal was derived by getting 32% of copra input. Copra meal is sold at PhP 3.50 per kg. Copra cake or meal is sold to feed millers. Oil refineries produce coconut fatty acid as its by-product which is sold to feed mills and sometimes exported as an ingredient in soap making. Coconut Fatty Acid (CFA) can be sold at PhP 23.00 per kg. Recovery rate of fatty acid is 4.9% from refined oil. Returns from the by-product sales of copra meal and fatty acid amount to around PhP 3,849.22.

Combined net profit from RBD and by-products amounts to PhP 5,361.56 per hectare or PhP 4.439 per kg of RBD.

Table 6. Costs and returns in refined coconut oil production

ITEMS		QUANTITY	COST PER UNIT (PhP)	TOTAL (PhP)
MATERIALS	Copra Input (kg)	2123	22/kg	46,706
	Phosphoric acid (.05%)	0.653	18/kg	12
	Activated carbon (.3%)	6.369	34.35/kg	219
	Bleaching earth (1.2%)	25.476	16.7/kg	425
LABOR	Labor (man-days)	1 m-day	350/day	350
	Sub-Total			**47,712**
Overhead	Miscellaneous (helper, fuel, fees and local taxes, loan interest)			1,500
			PhP /Kg	
TOTAL COST				**49,212**
CNO OUTPUT, kg (61.5%)		1305.65	37.69	
RBD OIL OUTPUT, kg (92.5%)		1207.72	40.75	
COST PER KG of RBD			40.75	
SELLING PRICE OF RBD			42.00	50,724
NET PROFIT			**1.25**	**1,512**
BY-PRODUCTS	Copra meal (32%)	679.36	3.5	2377.76
	Fatty acid (4.9%)	63.977	23	1471.46
	TOTAL BY- PRODUCT SALES		**3.187**	**3849.22**
TOTAL PROFIT			**4.439**	**5361.56**

4.1.4 Biodiesel (Coco Methyl Ester) Production

A readily convertible material for biomass production such as refined oil undergoes *Secondary Processing*, specifically the process of esterification, to arrive at the final product which is biodiesel. The case of Tantuco Enterprise's biodiesel plant was taken into account.

Profile of Tantuco Biodiesel Plant

Tantuco's biodiesel plant was constructed in November 2006 and became operational in March 2008. It is located at Barangay Isabang, Tayabas, Quezon. It got its Department of Energy (DOE) accreditation in September of the same year. The plant employs 12 regular and 12 contractual employees paid at an average wage rate of PhP 350 per man-day. With a total land area of six hectares, 600- square meter area is allotted for esterification and the CME production plant operates at 24 hours a day with six operation days in a week. Production capacity is 116,000 liters of CME per day but actual production is 10,000 liters per day.

It is not only engaged in manufacturing of CME but the plant also refines glycerin. To reduce production cost, biodiesel manufacture is scheduled every two weeks. The company's main contractors for biodiesel are Petron, PTT Philippines and Jetti Oil.

Activities and Input Requirements

Coconut oil is the primary input in ester production. Biochemically, coconut oil is composed of two main components – fatty acids and glycerin. Fatty acid has the same characteristics as the diesel fuel. However, glycerin envelopes fatty acid that makes fatty acid volatility suppressed, which is necessary for energy combustion in engines. Thus, in biodiesel production, it is essential that glycerin be separated from the fatty acid, a process known as esterification – the process of transforming coconut oil into diesel fuel. In order to effectively separate glycerin from fatty acids, a catalyst such as caustic soda and methanol are necessary in the process. After methanol and glycerin were removed from the initial mixture, the only substance left is methyl ester (Diaz, 2007).

The basic esterification (**Figure 9**) of coconut oil and methanol with the presence of caustic soda as the catalyst can be done in a reactor at 60°-80°C with continuous agitation. After one hour, agitation is stopped and separation is seen. To neutralize the caustic soda, hydrochloric acid is added. After neutralization, crude glycerol settles at the bottom. This serves as the by-product of the process. The remaining layer of crude coconut methyl ester is transferred to a wash tank and further purification process to remove excess glycerin, water, methanol, and acid such that the current Philippine National Standard (PNS) is met.

Coconut methyl ester can be derived either from refined, bleached, and deodorized (RBD) oil or from low acid oil. But aside from RBD and LAO, methyl ester can also be produced from coconut fatty acid (CFAD), known as the Fatty Acid Methyl Ester (FAME). CME production from RBD or LAO and from CFAD applies the same process as the production from (CFAD). From CNO, CME production can be segregated into four processes: esterification, methanol extraction, settling, and filtration. In producing CME from RBD and LAO, methanol and catalyst are combined with RBD or LAO to better facilitate esterification. Methyl ester produced is subjected to further methanol extraction and washing; while, methanol and glycerin undergo acidulation to further extract acid oil. Foul methanol produced from methanol extraction and recovery is subjected in another process to further recover the remaining methanol. Methyl ester undergoes settling to facilitate separation from water. Separated methyl ester is then filtrated, dehydrated, and stored in tanks.

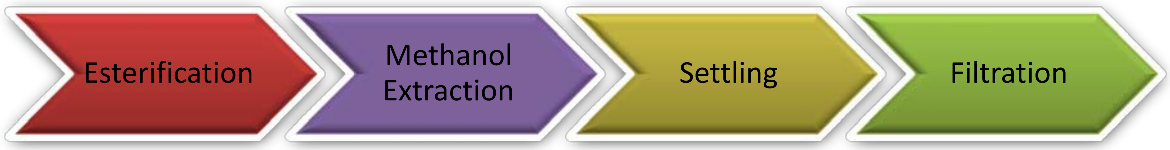


Figure 9. Basic esterification process

Meanwhile, methyl ester production using CFAD as feedstock undergoes more processes compared to methyl ester extraction from RBD and LAO. Initially, catalyst and methanol are added to CFAD and undergo esterification reaction and distillation. At the end of the process, methanol is separated. After esterification, the main product undergoes neutralization through the aid of water and soda ash. Glycerin produced undergoes acidulation and acid oil is separated. After the mixture has been neutralized, methanol and catalyst are added for trans-esterification where glycerin is recovered after. After trans-esterification, methanol is extracted from the mixture. Methanol extracted goes through another process where foul methanol is recovered. CME, on the other hand, is washed and undergoes settling where water is separated. Then, CME is filtered, dehydrated, and stored in the designated tank.

Other CME plants use crude coconut oil while Tantuco uses low fatty oil as feedstock. The process flow of processing low acid oil into CME is illustrated in **Figure 10**. Approximately, 16 tons of oil is consumed for CME production per operation. In esterification, 100 liters of CNO is combined with 3.16 liters of methanol and 1.16 kg of potassium hydroxide (as catalyst) and 6.7 kg of another catalyst in a 31 cu. m chemical reactor. A 20-hp reactor is used. The actual amount of methanol per batch was obtained by getting 14.5% of CNO input converted on a per liter basis using density of 0.915 kg/L. From the reactor, CME goes to another chemical reactor with 27 cu. m capacity for methanol extraction.

After methanol has been extracted, the remaining solution is a composition of water and methyl ester. To separate water from CME, the solution flows through the settling tanks with capacity of 25.6 cubic meters each. Pure CME from settling proceeds to filtration. CME filtration makes use of a 3-hp plate and frame filter press that is capable of filtering 5,000 liters of CME per hour or 43.5 tons of CME per day.

After filtration, CME will undergo dehydration to remove excess water. Dehydration is done through a 27-hp flash vaporizer capable of dehydrating 43.5 tons of CME per day. After moisture had been removed, CME will proceed to CME storage tanks ready for distribution. It takes 6 hours to process CNO to CME.

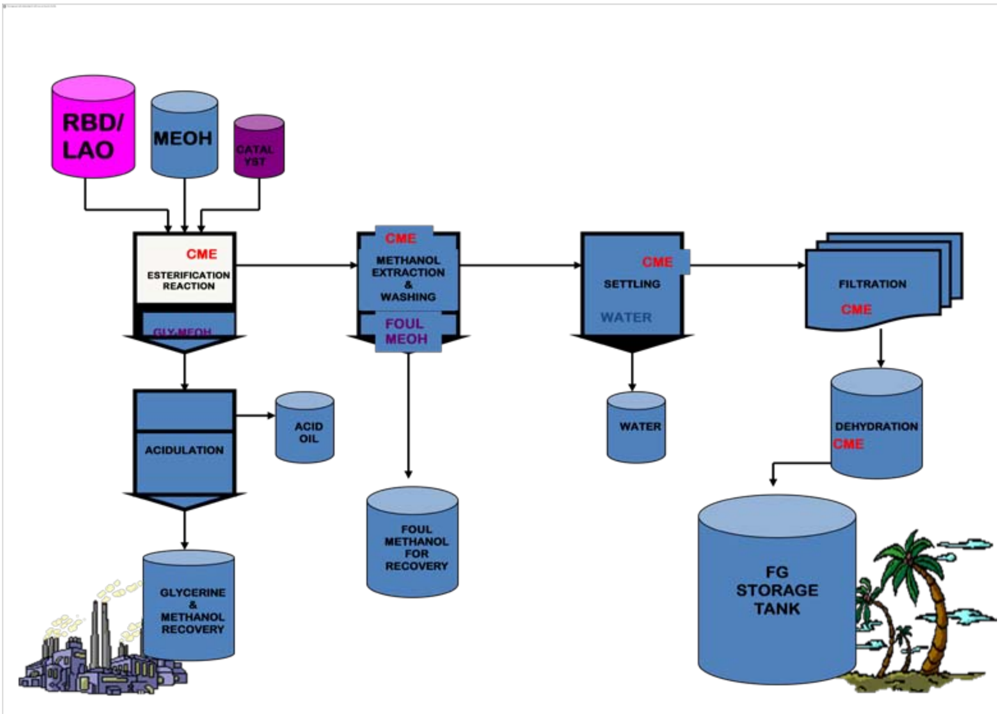


Figure 10. Processing of low acid oil into CME at Tantuco Enterprises

Net Profit from Biodiesel (CME) Production

Table 7 summarizes the costs and returns incurred in producing CME from one hectare nut production and per liter of output. The primary input is the RBD produced from copra amounting to 1,319,91 liters using the RBD density of 0.91kg/li. Other inputs include 191.388 liters of methanol and 8.843 liters of catalyst. Labor requirement is 1.33 mandays per 1000 liters and overhead cost amounts to PhP 2.00 per liter of CME. Total costs amount to PhP 57,915 producing 1,319.91 liters of CME or PhP 43.88 per liter of CME.

Since CME has a 100% recovery rate from RBD, the amount of RBD input was just converted to kg terms in order to arrive at the saleable quantity of CME. CME is sold at PhP 44.00 per liter resulting to a total revenue of PhP 58,076.23. Net profit from CME is only PhP 160.63 or PhP 0.12 per liter. However additional returns are derived from the by-products. The amounts of by-products generated by the process are 150.96 kg of glycerin and 6.64 kg of acid oil. Both glycerin and acid oil are sold at PhP 8 per kg. Total returns from by products amount to PhP 1,260.86 per batch or PhP 40.96 per liter.

With the costs and returns figures at hand, an accumulated net profit of PhP 1.08 per li was recorded and PhP 1,421.49 per batch operation.

Table 7. Costs and returns in CME production

ITEMS		QUANTITY	COST/ UNIT (PhP)	TOTAL (PhP)
MATERIALS	RBD Oil, li (.915 kg/li)	1319.91	42/kg or 38.43/li	50,724
	Methanol (14.5%	191.388	19.00/li	3636.36
	Catalyst (.67%)	8.843	34.00/li	300.68
LABOR	Labor	1.76	350/md	614.42
Sub-Total				**55,275.77**
	Overhead Costs		2.00	2639.83
TOTAL COST				**57,915.60**
OUTPUT, li CME		1319.91		
			PhP/li	
TOTAL COST of CME			**43.878**	
SELLING PRICE of CME			**44.00**	**58,076.23**
NET PROFIT from CME			**0.122**	**160.63**
BY- PRODUCTS	Glycerin, kg (12.5%)	150.96	8/ kg	1207.72
	Acid oil, kg(0.55%)	6.64	8/ kg	53.14
	TOTAL		**0.96**	**1260.86**
TOTAL PROFIT			**1.082**	**1421.49**

4.1.5 Total Profit for all Product Forms

The production costs and revenues for each product form from the primary input to the final product, that is from dehusked nut to biodiesel are summarized in Tables 8a and 8b. **Table 8a** shows that from the 6,432 kg of dehusked nut produced per hectare per year, the biodiesel output produced amounts to 1,329.91 liters. Due to the additional activities done on the input product, the production cost of the output product increases as the product changes from PhP 2.08 per kg of nut to PhP 43.878 per liter of CME.

Net profit per unit is highest for copra at PhP 6.76/kg and lowest for CME at PhP 0.122/liter as shown in **Table 8b**. Including the revenue from the by-products, the same trend is observed with copra production giving the highest total profit. The cumulative total profit for all product forms is almost PhP 38,000.

Table 8a. Summary of production cost and selling price per unit by product form

PRODUCT FORM	OUTPUT QUANTITY	UNIT	PRODUCTION COST (PhP/unit)	SELLING PRICE (PhP/unit)
Dehusked Nut	6,432	Kg	2.08	4.50
Copra	2,122.56	Kg	15.24	22.00
Refined Oil	1,207.72	Kg	40.75	42.00
Biodiesel (CME)	1,319.91	Liter	43.878	44.00

Table 8b. Summary of net profit per unit and per hectare by product form

PRODUCT FORM	NET PROFIT (PhP)		BY-PRODUCT SALES (PhP/Ha)	TOTAL PROFIT (PhP/Ha)
	Per unit	Per batch (ha)		
Dehusked Nut, kg	2.42	15,544.00	0	15,544.00
Copra, kg	6.76	14,352.32	1,320.00	15,672.32
Refined Oil, kg	1.25	1,512.33	3,849.22	5,361.56
Biodiesel (CME), li	0.122	160.63	1,260.86	1,421.49
TOTAL		**31,569.29**	**6,430.08**	**37,999.37**

4.2 Employment and Personnel Remuneration

Employment refers to the number of jobs that can be generated with the presence of the biomass project starting from the production of the raw material up to the final product which is biodiesel while personnel remuneration is the value of total salaries and wages paid to the employees in the different firms or activities involved in the biomass utilization. **Table 9** shows the labor requirement on a per hectare mature nut production up to processing into CME. Total number of laborers employed amounts to 53 mandays per hectare per year valued at PhP 13,764.

Table 9. Annual labor requirement per hectare and wages paid by product form

PRODUCT FORM	LABOR REQUIREMENT (in m-days)	WAGE RATE (PhP/mday)	WAGES PAID (PhP)
Dehusked Mature Nut	44	250	11,000
Copra	6	300	1,800
Refined Oil	1	350	350
Coconut Methyl Ester	1.76	350	614
TOTAL	**53**		**13,764**

4.3 Tax Revenue

Tax revenue is the income generated by the government from the entities involved in each production process. However, coconut farmers are exempted from paying taxes as stipulated under the Comprehensive Agrarian Reform Program of the Philippines. Thus, no taxes are generated from the farming sector. Total tax revenue for the biomass project amounts to PhP 7,859.38 per year with copra production registering the highest tax since it also generated the highest profit on a per hectare basis (**Table 10**).

Table 10. Annual tax revenue generated by product form

PRODUCT FORM	TOTAL PROFIT (PhP/Ha)	TAX REVENUE (PhP/Ha)
Dehusked Nut	15,544.00	exempted
Copra	15,672.32	5,485.31
Refined Oil	5,361.56	1,876.54
Biodiesel (CME)	1,421.49	497.52
TOTAL	**37,999.37**	**7,859.38**

4.4 Foreign Trade

Foreign trade impact is measured in terms of dollar earnings from product export and dollar savings from reduced diesel imports with the presence of the biodiesel project. In the event that portions of the convertible material are both exported and consumed locally for biodiesel production, a trade-off occurs. Dollar earnings from exports will then be reduced with domestic consumption. Coconut oil is one of the top dollar earners of the country and represents the $ earnings for the coconut industry. With the adoption of CME, a portion of the total volume of production of unrefined/unrefined oil will be dedicated to CME production. As a result, the volume of exports is lessened - dollar earnings are reduced. On the contrary, dollar savings arises from CME adoption in lieu of diesel imports. Thus, a trade-off occurs. The net effect of this trade-off can be quantified by adding the reduced dollar earnings from unrefined oil exports and the dollar savings from displaced diesel by CME.

However, due to the low volume of CME production at the provincial level, it is assumed that the net foreign exchange savings will not be significant. Moreover, the value of foregone dollar earnings from the amount of refined oil that was used for CME can just be offset by the opportunity cost of CME in terms of the value of imported fossil fuel substituted it substituted. Thus the net foreign trade effect is zero.

4.5 Total Value Added

The total value-added for the industry included the summation of all the value-added in each enterprise, which includes wages paid or personnel remuneration, taxes and duties earned by the government from the enterprises, foreign exchange earnings from exported products, and the entrepreneur's profit from main and by-products. Since the net foreign trade effect is zero, total value added for the industry is the summation of the total profit, wages paid and tax revenue at different product form.

Table 11 shows the summary of the total value added per product form generated from the per hectare production of mature nut up to processing into biodiesel or CME. The total enterprise profit amounts to PhP 37,999 with total wages paid of PhP 13,764 and generating a tax revenue of PhP 7,859 per year per hectare. The total value added for all the value adding activities amounted to PhP 59,623 per hectare per year with dehusked mature nut production contributing the highest amount (44.5%) followed by copra production (38.5%).

Considering that around 230,440 hectares in the province of Quezon are planted to coconut, the total value addition from the biodiesel industry would be PhP 13.74 billion if the mature nuts production in the province will be processed into biodiesel.

Table 11. Total value added per year by product form per hectare of biomass utilization

PRODUCT FORM	TOTAL PROFIT (PhP/Ha)	WAGES PAID (PhP/Ha)	TAX REVENUE (PhP/Ha)	TOTAL VALUE ADDED (PhP/Ha)
Dehusked Mature Nut	15,544.00	11,000.00	exempted	26,544.00
Copra	15,672.32	1,800.00	5,485.31	22,957.63
Refined Oil	5,361.56	350.00	1,876.54	7,588.10
Biodiesel (CME)	1,421.49	614.42	497.52	2,533.44
TOTAL	**37,999.37**	**13,764.42**	**7,859.38**	**59,623.17**

5. SOCIAL INDICES OF SUSTAINABILITY OF BIODIESEL PRODUCTION FROM COCONUT

5.1 Human Development Index

Operationally, any progress or change in human development is measured by an index called the “Human Development Index” or HDI. This index attempts to measure the complex concept of human development by tracking the progress of three selected aspects of human life mentioned above. As an index that tries to capture and simplify description of human development, it can evolve through time depending on the availability of data and emerging needs.

In the Philippines, the Human Development Network (HDN) started the computation of the HDI in 1994 down to the regional level. Three years later, the HDN came out with provincial HDI estimates for 1990 and 1994. After the launch of the 1990 and 1994 HDI by province, the then President Fidel V. Ramos instructed the

National Statistical Coordination Board (NSCB) to include the HDI in the system of designated statistics to ensure regular release of the index. In May 1997, a Memorandum of Understanding was signed between the NSCB and the HDN to effect the transfer of responsibility for the computation and publication of the HDI to NSCB. Thus, in March 2000, the NSCB released its first report on the HDI (Report on the 1997 Philippine Human Development Index), for the year 1997 and updates for 1994.

In the Philippines, the HDI is measured by taking the average of (1) life expectancy; (2) weighted average of functional literacy and combined elementary and secondary net enrolment rate; and (3) real per capita income(**Adopted from NSCB Technical Notes).** That is,

$$\mathbf{HDI = (I_1 + I_2 + I_3) / 3}$$

Where:

a) I_1 = life expectancy index

$$I_1 = (H - H_{min}) / (H_{max} - H_{min})$$

where

H = life expectancy at birth (in years) by province

H_{max} = 85 years

H_{min} = 25 years

The minimum and maximum values adopted for life expectancy at birth are based on the values being used by UNDP and HDN. Using the data for Quezon shown in **Table 12,** the life expectancy index is computed as 0.75.

Table 12. Quezon statistics as of 2007

	Male	Female
Proportion to total population	51%	49%
Life expectancy at birth (years)	67.33	72.89
Weighted average for Quezon (years)	70.05	
Literacy rate	96.8	96
Weighted average for Quezon	96.4	
Combined Gross Enrollment Rate (CGER)	87.5	88.9
Weighted CGER	88.19	
Income	16,430.167	13,917.75
Weighted average Income	15,148.83	

Source: NSCB 2007

Substituting the values:

$I_1 = (70 – 25) / (85 – 25)$

$\mathbf{I_1 = 0.75}$

b) I_2 = education index

$I_2 = 2/3 (E_1) + 1/3 (E_2)$

where

$E_1 = (Lit – Lit_{min}) / (Lit_{max} – Lit_{min})$ = index for functional literacy by province

$Lit_{max} = 100$

$Lit_{min} = 0$

Substituting the values:

$E_1 = (96.4 – 0) / (100 – 0)$; where Quezon's functional literacy rate is 96.4%

(*Source:* *://www.quezon.gov.ph/profile/education.htm*)

$E_1 = 0.964$

$E_2 = (Enrol – Enrol_{min}) / (Enrol_{max} – Enrol_{min})$ = index for combined elementary and secondary net enrolment rate by province

$Enrol_{max} = 100$

$Enrol_{min} = 0$

Substituting the values:

E_2 = (88.19 – 0) / (100 – 0); where 88.19% is the index for combined elementary and secondary net enrolment rate for the Philippines (no data for Quezon)

(Source: DepEd 2009)

E_2 = 0.8819

I_2 = 2/3 (0.964) + 1/3 (0.8819)

I_2 = 0.937

c) I_3 = income index

I_3 = (logGDP_{pc} – log100) / (log40000 – log100)

where

Y = real per capita income by province

Substituting the values:

I_3 = 0.6678

The maximum and minimum values set for the income indicator are the highest and lowest values of real income per capita actually attained by the provinces for a particular reference year. As suggested by the Human Development Network (HDN), the National Capital Region was treated as one of the provinces in determining the maxima and minima. Hence, the NCR real income figures were adopted as the maximum values in the computation of the HDI for all provinces for the three reference years.

Using all the computed values and substituting in the formula, the computed HDI is now 0.784933.

HDI = (I_1 + I_2 + I_3) / 3

HDI = (0.75 + 0.937 + 0.6678) / 3

HDI = 0.784933

The percent change in HDI in Quezon is calculated by subtracting the current HDI for Philippines which is 0.771 from the calculated HDI in Quezon.

Percent Change in HDI = 0.784933 – 0.771 = 0.003933

2.1 5.2 Gender-related Development Index

The gender-related Development Index (DGI) is calculated to reflect inequalities between men and women in all the three dimensions in HDI. For calculating equally distributed index for three in the following formula 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 discussed earlier. Using the formula used earlier for both male and female and the data in Table 12, yield the values in Table 13.

Table 13. Indexes for male and female in Quezon

ITEM	MALE	FEMALE
Percentage share	51	49
Life Expectancy Index (LEI)	0.7055	0.798167
Adult Literacy Index	0.968	0.96
Gross Enrolment Index	0.875	0.889
Education Index (EI)	0.937	0.936
GDP Index (GI)	0.784108	0.784933
Equally Distributed LEI, EDLEI	0.748056075	
Equally Distributed EI, EDEI	0.9365097	
Equally Distributed Income Index, EDII	0.667759641	

Using all the equally distributed indexes in Table 13, the computed GDI is now 0.7841085.

GDI = (EDLEI + EDEI + EDII) / 3

GDI = (0.748056075 + 0.9365097 + 0.667759641) / 3

GDI = 0.7841085

5.3 Other Social Indicators

To determine the social impact of the biodiesel project, coconut farmers and employees of the case enterprises for the different product stages were interviewed. The socio-demographic characteristics of the coconut farmer-respondents are shown in **Table 14.** Coconut farmer-respondents are generally old having an average age of 56.56 years. Majority of the coconut farmer are males, married and have low levels of educational attainment (7 years of formal schooling) and average household size of 4 family members.

The coconut farmers have been engaged in coconut farming for 24 years on the average and average farm size is 3 hectares with majority (48%) of the farmers having small farms (1 – 2 has). Seventy six percent are owners of the coconut farms while 56% have other sources of income such as other crops for 28% of the respondents and employment or trading business for 20% of the farmer-respondents (**Table 15**).

Table 14. Socio-demographic characteristics of 25 coconut farmers in Quezon

CHARACTERISTIC	NUMBER	PERCENT
Age (in years)		
31 to 40	4	16
41 to 50	4	16
51 to 60	8	32
60 to 80	9	36
Average	***56.56***	
Gender		
Male	17	68
Female	8	32
Civil Status		
Married	21	84
Widow/Widower	4	16
Household Size		
1 to 2	4	16
3 to 4	10	40

5 to 7	11	44
Average	***4***	
Years spent in school		
6 years and below (primary)	17	68
7 – 10 (secondary)	4	16
Above 10 (college)	4	16
Average	***7.2***	

Table 15. Farm characteristics of 25 coconut farmers in Quezon

CHARACTERISTIC	NUMBER	PERCENT
Years in coconut farming		
Below 10	5	20
10 – 20	8	32
21 to 30	6	24
31 to 50	6	24
Average	***24.4***	
Tenure status		
Owner	19	76
Tenant	6	24
Farm size (ha)		
1 to 2.0	12	48
> 2 to 4	9	36
> 4 to 8	4	16
Average	***3.05***	
Other sources of income		
Crop Farming	7	28
Livestock/poultry farming	2	8
Employment/trading business	5	20
None	11	44

The socio-demographic characteristics of the employees of the different firms involved in the production of the biodiesel are presented in **Table 16**. A total of 47 employees were interviewed. Majority of the employees belong to the 41 to 60 age group with oil mill employees registering the oldest average age of 51 years. Results also show that the biodiesel industry is a man's domain where 85% of the employees are males. Due to the technical expertise required for the oil and CME production, majority of the employees in these two firms are college graduates. Majority of the employees are married and the average household size is 3 members.

Table 17 shows the monthly salary of the employees in the three firms. Employees are receiving low income, where majority of the respondents reported an average income of only PhP 6,000 to 10,000 per month. Around 30%, however, reported other sources of income.

Table 16. Socio-demographic characteristics of employees of biomass projects

CHARACTERISTICS	COPRA (N=14)	CME (N=7)	OIL MILL (N=26)	TOTAL (N=47)	PERCENT
Age (years)					
21 to 40	8	5	6	19	40.43%
41 to 60	6	2	19	27	57.45%
60 and above	0	0	1	1	2.13%
Average	*39*	*38*	*51*		
Gender					
Male	14	3	23	40	85.11%
Female	0	4	3	7	14.89%
Educational Attainment					
Elementary	7	0	5	12	25.53%
High School	4	0	5	9	19.15%
Vocational	0	0	4	4	8.51%
College	3	6	11	20	42.55%
Post Graduate	0	1	1	2	4.26%
Civil Status					
Single	4	3	2	9	19.15%
Married	10	4	24	38	80.85%
Household Size					
1 to 2	2	3	8	13	27.66%
3 to 4	6	3	6	15	31.91%

5 and above	6	1	12	19	40.43%
Average	*4.07*	*3*	*3.62*	*3.49*	

Table 17 .Monthly salary and involvement of employees of the biomass projects

ITEM	COPRA (N=14)	CME (N=7)	OIL MILL (N=26)	TOTAL (N=47)	PERCENT
Salary (PhP/mo)					
1,000 to 5,000	3	0	1	4	8.51%
6,000 to 10,000	8	4	24	36	76.60%
11,000 to 15,000	0	0	1	1	2.13%
16, 000 and above	3	3	0	6	12.77%
Other information					
Has other source of Income	5	3	6	14	29.79%
Member of an Organization	0	1	3	4	8.51%
Involved in the community Activities	1	0	2	3	6.38%

In terms of the effects of the biomass project specifically coconut production on their level of living condition, the majority (66%) of coconut farmers perceived that there has been an improvement in their living condition due to coconut farming as shown in **Table 18**. On the other hand, **Table 19** enumerates the benefits gained by the farmer-respondents from coconut farming. Seventy six percent reported that their income increased and they were able to provide better education for their children. Majority (84%) of the farmers experienced improvement in their relationship with other workers or farmers in the community.

Table 18. Coconut farmers' perception on their level of living

LEVEL OF LIVING	NUMBER	PERCENT
Better than before the biomass project	19	76%
Same as before the biomass project	5	20%
Worse than before the biomass project	1	4%
Total	**25**	**100%**

Table 19. Benefits of the coconut farmers from the biomass project

BENEFITS	NUMBER		PERCENT	
	Yes	No	Yes	No
Increased income	19	6	76%	24%
Improved health condition	18	7	72%	28%
Better education for the children	19	6	76%	24%
Improved relationship w/ other Laborers	21	4	84%	16%

On the other hand, in terms of the effects of employment in biomass project on the level of living condition, **Table 20** shows that majority (57%) of employees perceived that there has been an improvement in their living condition due to their employment in their respective biomass project. The employees of the copra plant registered the highest satisfaction where around 93% experienced improvement in their level of living due to their copra employment. On the other hand, majority of the CME and oil mill employees reported no change in their living conditions.

Table 20. Employees' perceptions on their level of living

LEVEL OF LIVING	COPRA (N=14)		CME PLANT (N=7)		OIL MILL (N=26)		ALL	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Better than Before	13	92.86%	2	28.57%	12	46.15%	27	57.45%
Same as Before	1	7.14%	3	42.86%	12	46.15%	16	34.04%
Worse than Before	0	0.00%	2	28.57%	2	7.69%	4	8.51%

Tables 21 to 23 enumerate the benefits gained by the employees of the different firms in the biodiesel project. All the copra employees reported that their income increased and they experienced improvement in their relationship with other employees (**Table 21**). Majority of the copra employees also reported improved health conditions and provision of better education for their children as the benefits from their employment in the copra plant.

Table 21. Benefits of the employees from the copra plant

BENEFITS	YES		NO	
	Number	Percent	Number	Percent
Increased income	14	100.00%	0	0.00%
Improved health Condition	12	85.71%	0	0.00%
Better education for the Children	11	78.57%	2	14.29%
Improved relationship w/ other laborers	14	100.00%	0	0.00%

On the other hand, **Table 22** shows that only 58% and 54% of the oil mill employees reported improvement in their health condition and better education for their children resulting from their employment in the oil mill, respectively. However, majority experienced improved income and relationship with other employees.

Table 22. Benefits of the employees from the oil mill

BENEFITS	YES		NO	
	Number	Percent	Number	Percent
Increased income	22	84.62%	4	15.38%
Improved health Condition	15	57.69%	11	42.31%
Better education for the Children	14	53.85%	12	46.15%
Improved relationship w/ other laborers	25	96.15%	1	3.85%

In the case of employees of the CME plant, only 57% of the employees reported increased income and better education for their children as their benefits from their employment in the firm, although around 86% experiences improved relationship with other employees. However, results in **Table 23** also show that 71% of the employees reported that their health condition did not improve at all.

Table 23. Benefits of the employees from the CME biodiesel project

BENEFITS	YES		NO	
	Number	Percent	Number	Percent
Increased income	4	57.14%	3	42.86%
Improved health Condition	2	28.57%	5	71.43%
Better education for the Children	4	57.14%	3	42.86%
Improved relationship w/ other laborers	6	85.71%	1	14.29%

In general, it could be seen from the results that majority of the employees benefitted from their respective employment in the biomass production and processing into biodiesel. Thus a major social impact of the biomass project can be measured in terms of the improvement in the level living of living conditions of the stakeholders in the biomass project.

6. ENVIRONMENTAL INDICES OF SUSTAINABILITY OF BIODIESEL PRODUCTION FROM COCONUT

Life Cycle Assessment (LCA) has been suggested in the Guidelines as the indicator in assessing the environmental impact of biofuels. LCA as suggested in the Guidelines is limited to the quantification of greenhouse gases (GHG) expressed in terms of kilogram of CO_2 equivalent.

Figure 11 shows the material inputs and the corresponding emissions from these inputs in all the four stages of production including the fuels used in the transportation of these inputs and that of the finished products and electricity used in the processing plant. Emission for the production of mature coconut comes from the use of fertilizer while emissions for the processing of mature coconut to copra, copra to refined oil and refined oil into CME come from the fuels and electricity used in the processing and diesel fuel in transportation.

Table **24** shows the power generated from various sources of electricity and the range of efficiencies of each power plants. These are actual data taken from the Philippine Energy Plan 2007-2014. These data were used as basis in the calculation of GHG emission in kgCO2eq/kWh from each source. The total GHG emission from Grid accounts to 0.561 kg of CO_2.

Table 25a shows the data used in the calculation of life cycle GHG emissions from each fuel type. **Table 25b** shows the different GHG emissions from each fuel type in the form of carbon dioxide, methane and nitrous oxide. It also shows the value of GHG emission from each fuel type expressed in kg of CO2eq/L. **Table 25c** reflects the life cycle GHG emissions for gas oil, fuel oil and coal used in the plant.

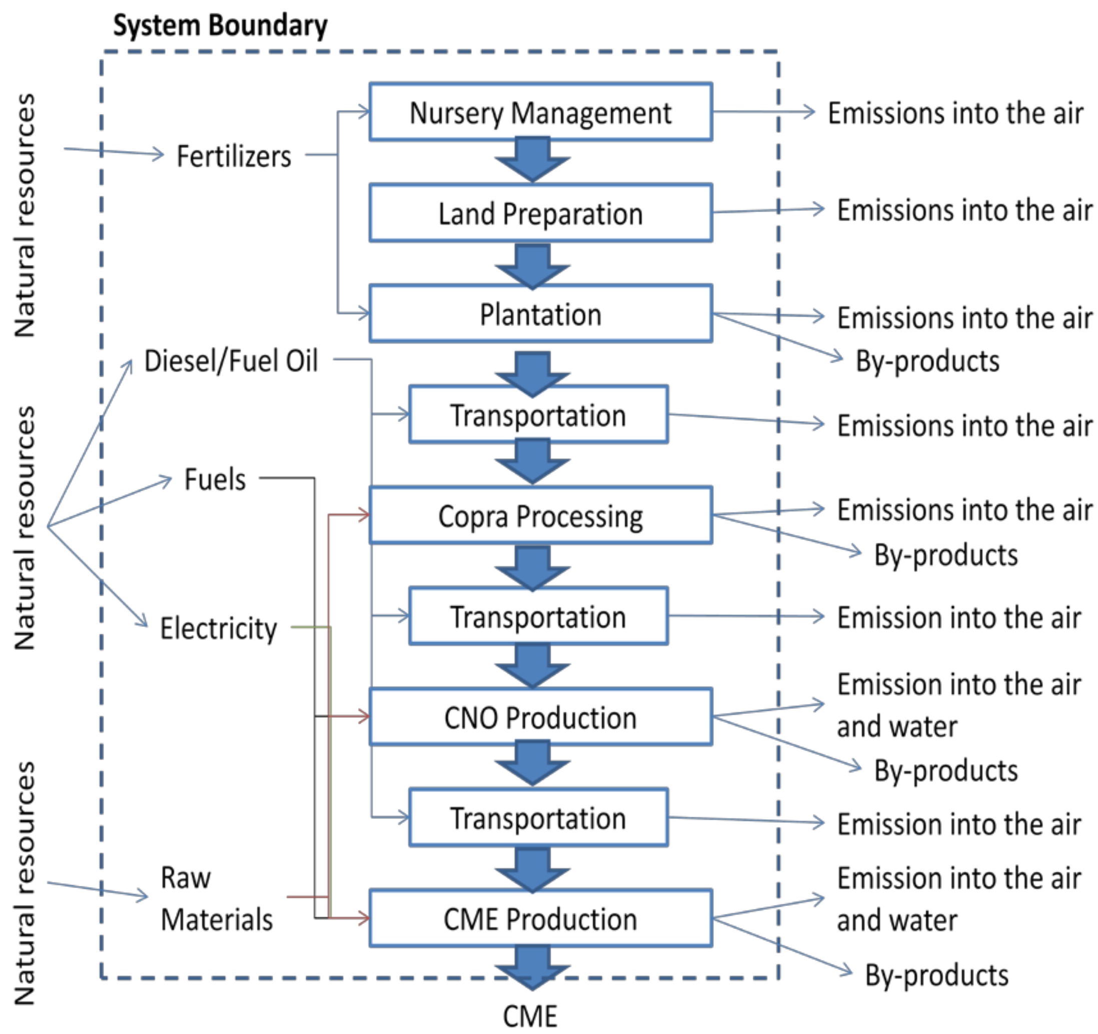


Figure 11. System boundary in CME production

Assumptions

- Life span of coconut plantation is 80 years.
- GHG emissions from Land Use Change (LUC) are ignored because LUC happened 80 years ago and it is beyond the time scope which is usually taken into account for GHG emission estimates.
- One plantation site supplies all the necessary amount of mature coconuts to the copra processing plant although mature coconuts are actually supplied from several sites.
- One copra processing plant supplies all the necessary amount of copra to the CNO processing plant although copra is actually supplied from several plants.

Table 24. Power generated, efficiency and green house gas emission of grid electricity by power source

Power Source	Power Generated kWh	Mean Efficiency %	HV (Mean) MJ/kg	Life Cycle GHG kgCO2eq/kWh	Conditions for GHG Emission per kWh	GHG kg
Coal	13,503,727	32.5	28.5	0.96612	Efficiency:39.55% Power:1000MW	13046221
Oil	1,928,244	32.5	43.6	0.76555	Efficiency:38.42% Power:1000MW	1476167
Natural gas	19,575,855	47.5	51.9	0.51883	Efficiency:44.61% Power:1000MW	10156541
Geothermal	3,729,921	47.5		0.01503	Availability:60% Power: 55MW	56060.71
Hydro	5,400,402	85		0.01126	Availability:45% Power: 10MW	60808.53
Wind	61,386	23		0.029493	Efficiency:20% Power:300 kW	1810.448
Total	**44,199,534**				GHG emissions from GRID-→	0.561038

Reference: Evaluation of Power Generation Technologies based on Life Cycle CO2 Emissions, Socio-economic Research Center, Reo. No.Y99009,Petroleum Energy Center, PEC-1999R-13

Table 25a. Data for Life Cycle GHG Emissions of Fuels

Fuel Type	Heating Value (MJ/kg)	Density (kg/L)	Heating Value (MJ)	GHG Emission Mining & T (kgCO
			MJ/L	
Gas oil	44.7	0.85[1]	37.995/L	[illegible]
Fuel oil(bunker)	42.6	0.92[2]	39.192/L	[illegible]
Coal (bituminous)	23-34.0	-	28.5 MJ/kg	0

References:
[1]*Wikipedia http://en.wikipedia.org/wiki/Diesel_fuel*
[2]*DMC in ISO8217(2005) from Wikipedia ://en.wikipedia.org/wiki/Fuel_oil*
[3] *P.47-48, Evaluation of Power Generation Technologies based on Life Cycle CO2 Emissions, Socio-economic Research Center, Reo. No.Y99009 Petroleum Energy Center, PEC-1999R-13*
[4] *P.54, Evaluation of Power Generation Technologies based on Life Cycle CO2 Emissions, Socio-economic Research Center, Reo. No.Y99009 Petroleum Energy Center, PEC-1999R-13*

Table 25b. GHG Emissions from Fuel Consumptions

Fuel Type	GHG Emissions from Fuel Consumption [/TJ][1]			GWP[2]		
	kgCO2/TJ	kgCH4/TJ	kgN2O/TJ	kgCO2/kg CO2	kCO2/kg CH4	kgCO2/kg N2O
Gas oil	74100	10	0.6	1	21	310
Fuel oil(bunker)	77400	10	0.6	1	21	310
Coal (bituminous)	94600	10	1.5	1	21	310

References:
[1] *Table 2-2, 2-3 and 2-4, Default Emission Factor for Gas/Diesel Oil, IPCC 2006*
[2] *Page 212, AR4, IPCC 2006*

Table 25c. Life Cycle GHG Emissions from each Fuel Type

Fuel Type	GHG Emissions from Fuel Consumption [/L]			GHG Emissions from Consumption [kgCO2eq/L]	Life Cycle GHG Emissions
	kgCO2/L	kgCH4/L	kgN2O/L	CO2kgeq/L	CO2kgeq/L
Gas oil	2.8154295	0.00037995	0	2.83047552	3.014908853
Fuel oil(bunker)	3.0334608	0.00039192	0	3.048980832	3.293914165
Coal (bituminous)	2.6961	0.000285	0	2.7153375	2.777670833

Estimates of GHG Emissions from Each Stage of CME Production

A. Nursery Stage

Table 26 shows the amount of fertilizer applied in the nursery stage.

Table 26 Fertilizer applied in the nursery stage

N (a)	P (b)	K (c)	Unit	Number of times (d)	Total (a + b + c) x d, [kg]
0.5	0.25	0.3	kg/tree/time	2	2.1

GHG emissions from fertilizer are divided into two parts;

- GHG emissions from fertilizer production
- GHG emissions from fertilizer application

GHG emission factor of fertilizer production is 0.576 kg-CO2eq / kg-fertilizer (Ref. IDEMAT 2001 with Simapro 7.1).

The GHG emissions from fertilizer production are:

2.1 kg-fertilizer/tree x 0.576 kg-CO2eq/kg-fertilizer

= 1.2096 kg-CO2eq / tree……..(Eq.A-1)

According to IPCC (Ref. EB33 Report, Annex 16, CDM Executive Board, UNFCCC), N_2O emissions released from fertilizer applications are:

0.5 (kg-N/time/tree) x 2 (times) x (1-0.1) x 0.01 x 44/28 x 310

= 4.38 kg-CO2eq/tree……….(Eq.A-2)

Where

Value	Meaning	Unit
310	Global warming potential	kg-CO2eq/kg-N2O
44/28	the conversion factor from N2 into N2O	Kg-N2O/kg-N2
0.01	Default emission factor in IPCC 2006 guideline for emissions from N input	-
0.1	Default value in IPCC 2006 guideline for the fraction of synthetic fertilizer that are emitted as NO_X and NH_3 (It is assumed here that the type of fertilizer applied is synthetic.)	-
2	N-contents in the fertilizer	kg-N

The total GHG emissions from fertilizer production and application are:

(Eq.A-1) + (Eq.A-2) = 5.5896 kg-CO2eq/tree…….(Eq.A-3)

The number of trees planted in 1 hectare is 250 trees.

The GHG emissions per 1 hectare is:

(Eq. A-3) x 250 = 1397.4 kg-CO2eq/ha……..(Eq.A-4)

The life span of the plantation is 80 years. The GHG emissions per hectare and per year is:

(Eq. A-4) / 80 = 17.4675 kg-CO2eq/ha/year……..(Eq.A-5)

B. Cultivation Stage

Table 27 shows the amount of fertilizers applied in the cultivation stage.

Table 27 Fertilizer applied in the cultivation stage

Period	N	P	K	Unit	Total [kg]
1st and 2nd year	42	20	140	g/tree	0.304
3rd and 4th year	42	90		g/tree	0.132
5th year and up	56	6.67	140	g/tree	1.216

The GHG emissions are estimated in the way as in the nursery stage.

The GHG emissions from fertilizer production are:

For 1st and 2nd years:

0.202 kg-fertilizer/tree x 0.576 kg-CO2eq/kg-fertilizer

= 0.1164 kg-CO2eq / tree……..(Eq.B-1)

For 3rd and 4th years:

0.132 kg-fertilizer/tree x 0.576 kg-CO2eq/kg-fertilizer

= 0.07603 kg-CO2eq / tree……..(Eq.B-2)

From 5th year:

0.20267 kg-fertilizer/tree x 0.576 kg-CO2eq/kg-fertilizer

= 0.1167 kg-CO2eq / tree (Eq.B-3)

The total GHG emissions from fertilizer production over 80 years of the life span are

(Eq.B-1) x 2 + (Eq.B-2) x 2 + (Eq.B-3) x (80 - 4) = 9.257 kg-CO2eq/tree...(Eq.B-4)

The annual average GHG emissions per 1 ha (250 trees/ha) from fertilizer production are:

(Eq.B-4) x 250 / 80 = 28.93 kg-CO2eq/ha/year...(Eq.B-5)

N_2O emissions released from fertilizer applications are:

For 1st and 2nd years:

0.042 (kg-N/tree) x (1-0.1) x 0.01 x 44/28 x 310

= 0.1840 kg-CO2eq/tree……….(Eq.B-6)

For 3rd and 4th years:

0.042 (kg-N/tree) x (1-0.1) x 0.01 x 44/28 x 310

= 0.1840 kg-CO2eq/tree……….(Eq.B-7)

From 5th year:

0.056 (kg-N/tree) x (1-0.1) x 0.01 x 44/28 x 310

= 0.2453 kg-CO2eq/tree……….(Eq.B-8)

The total GHG emissions from fertilizer application over 80 years of the life span are:

(Eq.B-6) x 2 + (Eq.B-7) x 2 + (Eq.B-8) x (80 - 4) = 19.38 kg-CO2eq/tree...(Eq.B-9)

The annual average GHG emissions per 1 ha (250 trees/ha) from fertilizer application are:

(Eq.B-9) x 250 / 80 = 60.55 kg-CO2eq/ha/year...(Eq.B-10)

The total GHG emissions from fertilizer production and application are

(Eq.B-5) + (Eq.B-10) = 89.48 kg-CO2eq/ha/year...(Eq.B-10)

Mature coconuts are harvested by hand. The harvested coconuts are dehusked by hand. There are no more energy and material inputs in harvesting and dehusking. The products from this stage are dehusked coconuts and husks. As dehusked coconuts and husks are usually used not only for energy, but also for foods, raw materials, etc., the GHG emissions are allocated to each product by the economic value based allocation method. However, as the price of coconut husks are sometimes negligibly small, all the GHG emissions from stage is allocated to dehusked coconuts.

C. Copra Processing Stage

Dehusked coconuts are transported by diesel trucks to the copra processing plant. The necessary data for estimating GHG emissions from the transport are as follows:

- The diesel consumption is 8 L/trip.
- The number of trips per year is 795 trips/year.
- The amount of copra processed in the plant is 1.728 x 10^7 kg/year.
- The plantation area required to produce the amount of copra above is 2686 ha.
- GHG emissions from diesel oil production and consumption are 3.1 kgCO2eq/L-diesel (Ref. RTFO).

The GHG emissions from the transport are:

8 [L/trip] x 795 [trips/yr] x 3.1 [kgCO2eq/L] / 2686 [ha]

= 39.57 [kgCO2eq/ha/year]…….(Eq.C-1)

Dehusked coconuts are separated by hand into copra, shell and water. A Part of shells are used for drying copra. Although CO_2 emissions from burning shells are ignored according to the concept of carbon neutral, CH_4 and N_2O emissions should be taken into account. According to IPCC 2006 Guideline, CH_4 and N_2O default emission factor from the stationary combustion of 'other primary solid biomass' are 300 and 4 kg of GHG / TJ, respectively.

The heating value of copra shells is 19.808 MJ……..(C-3)

The amount of shells used for drying copra is 1,000 kg/year/ha……..(C-4)

The heat generated by shells is:

(C-3) x (C-4) = 19,808 MJ = 0.019808 TJ………(C-5)

The CH_4 and N_2O emissions from shells combustion are:

300 x (C-5) = 5.9424 kg-CH_4……(C-6)

4 x (C-5) = 0.07232 kg-N_2O……..(C-7)

The CH_4 and N_2O emissions from shells in kg-CO2eq are:

(C-6) x 25 = 148.56 kg-CO2eq……(C-8)

(C-7) x 298 = 23.611136 kg-CO2eq……..(C-9)

The GHG emissions from shells are:

(C-8) + (C-9) = 172.171136 kg-CO2eq……..(Eq.C-2)

Water from dehusked coconuts is left on the ground or evaporated by heat. There are no GHG emissions from water.

The total GHG emissions from transport of dehusked nuts and coconut shell used as fuel are Eq C–1 + Eq C-2 = 211.74 kg-CO2eq/ha/year (Eq.C-3).

The products from this stage are eventually copra and shells. Copra is not used for energy whereas shells for fuel. The GHG emissions are, therefore, allocated to these two products by the economic value based allocation method.

The price of copra and shells are 46706 and 4320 [PHP/year/ha], respectively.

The GHG emissions allocated to copra are:

211.74 x 46706 / (46706 + 4320) = 193.38 [kgCO2eq/year/ha]…….(Eq.C-4)

D. Coconut Oil Production Stage

Copra is transported by diesel trucks to the CNO production plant. The necessary data for estimating GHG emissions from the transport are as follows:

- The diesel consumption is 226 L/trip.
- The number of trips per year is 2500 trips/year.
- The amount of Copra processed in the plant is 300 ton/day.
- The plantation area required to produce the amount of copra above is 49468 ha.
- GHG emissions from diesel oil production and consumption are 3.1 kgCO2eq/L-diesel (Ref. RTFO).

The GHG emissions from the transport are

226 [L/trip] x 2500 [trips/yr] x 3.1 [kgCO2eq/L] / 49468 [ha]

= 34.44 [kgCO2eq/ha/year]……..(Eq.D-1)

The main energy input in the copra processing stage is coal for steam generation. The necessary data for estimating GHG emissions from coal are as follows:

- Coal consumption per year in the plant is 14,000 kg/day.
- The GHG emission factor of coal is 2.778 kgCO2eq/kg.
- The number of days for the plant operation is 350 days/year.
- The copra production in the plant is 300 ton/day.
- The plantation area required to produce copra 300 ton/day is 49468 ha.

The main inputs in this stage are coal for steam generation and phosphoric acid.

The GHG emissions from coal are

14,000 [kg/day] x 2.778 [kgCO2eq/kg] x 350 [days/year] / 49468 [ha]

= 275.1 [kgCO2eq/year/ha]…….(Eq.D-2)

The GHG emissions from phosphoric acid is

75,400 [kg / truck] x 1[truck / month] x 12 [month/year] = 904800 [kg/year]

904800 [kg/year] x 1.1017 [kgCO2/kg] / 49468 [ha]

= 20.15 [kg/ha/year]…….(Eq.D-3)

GHG emission factor of phosphoric acid:1.1017 kgCO2/kg…..(Ref. ETH-ESU 96)

The GHG emissions from CNO production stage is

(Eq.D-1) + (Eq.D-2) + (Eq.D-3) = 329.69 [kgCO2eq/year/ha]…….(Eq.D-3)

The products from this stage are CNO, copra meal/cake, fatty acid and waste water. Since these are not used for energy, economic allocation is applied to allocate GHG emissions to CNO.

The prices of each product are shown in the table below.

Table 28 The Prices of Products from CNO Production Stage

Product/Byproduct	Price [PHP/ha/year]
CNO	50,724.00
Copra meal/cake	2,377.76
Fatty Acid	1471.46

One of byproducts, waste water, is excluded from the allocation because it is not sold.

The GHG emissions for CNO is:

309.54 x 50724 / (50724 + 2377.76 + 1471.46) = 287.7 [kgCO2eq/year/ha]

E. CME Production Stage

Table 29 shows Feedstock/fuel transported to the CNO production plant.

Table 29 Feedstock/Fuel Transported to the CNO Production Plant.

Type of Feedstock	Type of Transport	Type of Fuel	Fuel Consumption [L/trip]	The Number of Trips [trips/year]	Total fuel consumption [L/year]
CNO	Tanker	Bunker fuel	2	480	960
Methanol	Tanker	Bunker fuel	16	84	1344
Bunker fuel	Truck	Diesel oil	16	144	1560

- The GHG emissions from bunker oil are 3.015 kg-CO2eq/L.
- The amount of CNO processed in the plant is 9510 ton/year.
- The plantation area required to process the amount of CNO above is 7876 ha.

The GHG emissions from these transports are

{(960 + 1344) x 3.015 + 1560 x 3.1} /7876 = 1.496 [kgCO2eq/year/ha] (Eq.E-1)

The feedstock/energy inputs in this stage are shown in **Table 30**.

Table 30. Feedstock and Energy Inputs in CME Production Stage

Feedstock/Energy	Amount [/month]	Amount [/year/ha]
Methanol	110600 kg	168.5 kg
Bunker	19200 L	52.11 L
Water	631800 L	1612 L
Electricity	40000 kWh	69.10 kWh

The GHG emission factors of methanol, water and electricity are 1.57 kgCO2eq/kg, 0.1083 kgCO2eq/L and 0.561 kgCO2eq/kWh.

The total GHG emissions from feedstock and energy inputs are:

168.5 x 1.57 + 52.11 x 3.015 + 1612 x 0.1083 + 69.10 x 0.561

= 649.5 [kgCO2eq/year/ha]

The products from this stage are CME, glycerin and acid oil. Since glycerin and acid oil are not used for energy, economic allocation is applied again to allocate GHG emissions to CME.

The prices of each product are shown in **Table 31**.

Table 31 The Prices of Products from CNO Production Stage

Product/Byproduct	Price [PHP/ha/year]
CME	58076.23
Glycerin	1207.729
Acid oil	53.14

The GHG emissions for CME is

(1.496 + 649.5) x 58076.23 / (58076.23 + 1207.729 + 53.14)

= 637.2 [kgCO2eq/year/ha]

The GHG emissions from each stage are summarized in **Table 32**.

Table 32. Life Cycle GHG Emissions of CME Production

Stage	GHG Emission [kg-CO2eq/ha/year]	Percentage [%]
Nursery	17.47	1.379
Cultivation	89.48	7.062
Copra Processing	193.38	15.261
CNO Production	329.6	26.011
CME Production	637.2	50.287
Total	1267.13	100.00

The largest GHG emissions are from the CME production stage and the second the CNO production. The emissions are from feedstock productions and energy consumptions. A total of 1,319.91 L of CME produced from 1 ha of plantation. It is assumed here that 1L of CME is able to replace 1 L of petrolic diesel. GHG emissions avoided by replacing 1319.91 L of petrolic diesel is

1319.91 x 3.1 = 4091.7 [kgCO2eq/ha/year]

The net GHG saving is

4091.7 – 1267.13 = 2823.97 [kgCO2eq/ha/year]

It is concluded from the results that CME production contributes GHG emission reductions.

7. CONCLUDING REMARKS

7.1 Assessment of Indices of Sustainability of Biomass Utilisation

7.1.1 Economic Indices

1. There are four economic indicators identified in the Guidelines developed to assess economic sustainability of biomass utilisation. These are the following: annual net profit, employment and personal remuneration, tax revenue and net foreign trade impact.
2. These four (4) indicators are general indicators that can be used to evaluate economic sustainability of biomass utilisation for biofuels.
3. The sustainability of biomass utilisation can be looked at the different levels such as national level (from the point of view of the country or state), regional or province level (from the point of view of the region or province) and community level.
4. In either of the three levels of biomass utilisation, there must always be a business component. As a business, the biomass utilisation should be profitable and that can be measured using the by the net profit as indicator.
5. Employment and personal remuneration; and tax revenue can be used as indicators in all the three levels as well.
6. As for the four (4) plants evaluated in the Philippines, tax revenue applies only to Copra Processing Plant, Oil Processing Plant and CME Plant. Owners of the coconut plantation and farmers employed in the business are exempted from payment of taxes as part of the government's incentive to coconut growers.

7. Foreign trade impact applies only to regional and national levels.

8. The situation in the Philippines is unique. There are two businesses involved in the sales of biodiesel namely the biodiesel (CME) producers and the oil companies selling the CME blended diesel to the consumers. For the biofuel producers, net profit should be positive to be economically sustainable and hence there will be positive value addition in terms of net profit. For the oil companies, they buy the biofuels at a price higher than the cost of imported diesel therefore there is negative net profit and there is no added return to the investment. This is so because the oil companies need to comply with the law requiring the sales of diesel blended with CME at 2% blend. Although the oil companies incur small losses in the purchase of CME for blending of 2% in diesel they compensate the loss with their profit on the sale of 98% diesel in the blended diesel. With this small negative value addition they will be able to comply with the Philippine law hence they can still operate and still get positive net profit in the business as a whole.

7.1.2 Social Indices

1. The Guidelines proposed Human Development Index (HDI) as an overall measure of social development. This social indicator takes into account the measures for Per Capita Income, Life Expectancy at Birth and Adult Literacy Rate.

2. HDI is calculated by getting the average of Life Expectancy Index (LEI), Education Index (EI), and Gross Domestic Product (GDP) Index

3. LEI is based on Life Expectancy (LE) at birth, EI is based on Adult Literacy Index (ALI) and Gross Enrolment Index (GEI) while GDP Index is based on GDP per capita.

4. LE, ALI, GEI and GDP data are only available at the national level or at least in the regional level therefore HDI as measure of social development is more appropriate at the national or regional level. HDI cannot be used to calculate the social impact from the four stages of coconut production for CME.

5. More direct measures of social development is recommended to be used at the project or community level such as that of the coconut production, copra processing, oil processing and CME processing.

6. Some of the recommended social indicators in the project or community level are increased income of the employee, better education for the children, improved health condition and probably improved relationship in the plant or community among others.

7.1.3 Environmental Indices

1. Life Cycle Assessment (LCA) has been suggested in the Guidelines as the indicator in assessing the environmental impact of biofuels.
2. LCA as suggested in the Guidelines is limited to the quantification of greenhouse gases (GHG) expressed in terms of kilogram of CO_2 equivalent.
3. Evaluation of GHG using LCA seems to be the most appropriate approach in assessing the impact of the production of biofuels to the environment since GHG has been directly attributed to the increased atmospheric concentration resulting into the change in climate.

7.2 General Observations on the Appropriateness and Use of the Questionnaires

1. It is important to formulate a single questionnaire for the respondents that will capture the data needed for the calculation of the economic, social and environmental indices of the project/plant.
2. There must be separate type of questionnaires for the producers and processors of biofuels. The respective questionnaires will then be tailored fit to the target respondents hence specific information can then be collected from them.
3. It is important that respondents must be properly informed of the real purpose of the questionnaires in order to get the right information.
4. If possible, the person distributing the questionnaire should be properly trained in explaining to the respondents the intention of the survey.
5. It has been found that the use of the questionnaire alone was not sufficient to gather all the necessary data needed in the evaluation of economic, social and environmental impacts of the utilisation of biomass for biofuels. Whenever possible personal interview should be done in order to explain the questions and make follow up questions in order to capture the right information.

6. Questions on economics particularly cost and revenue data are difficult to collect from the plant. Plant owners/managers/supervisors are quite hesitant in giving information on economics of the operations of the plant.
7. Social development data such as literacy rate, GDP, life expectancy are not available in the community level and so survey needs to be done to collect these data from the community.
8. Data needed for the LCA such as fuel consumption per trip, number of trips made per year, electricity consumed for the year among others was also not easy to collect. These are information that you can only get from the plants record book. Without an access to these records it would be difficult to get accurate information.
9. From experience it is not enough to rely on the data given by the respondents particularly technical data such as fuel consumption, efficiency and others. It is important that these technical data collected from the plant be verified from the literatures.
10. The calculation of all the indicators namely net profit, tax revenue, salaries/wages and foreign trade for the economics; HDI for the social impact and LCA for the environmental impact is not an easy task to do. Without proper training of personnel, the use of these indices will be a futile exercise. It is suggested that hands-on training/seminar on the calculation of these indicators be done for ASEAN member country representatives so that there will be transfer of knowledge. These participants will then conduct a trainors training to disseminate widely the use of the guidelines for the assessment of the sustainability of biomass utilisation.

ACKNOWLEDGEMENT

The authors would like to thank the Economic Research Institute for ASEAN and East Asia (ERIA) for sponsoring this case study. We recognize the invaluable support given by the director and staff of ERIA during the conduct of the study. We also recognize the invaluable support of the ERIA Working Group under the leadership of Dr. Sagisaka. We also thank the cooperators for this study, the Alvarez family and the Tantuco Enterprises for their cooperation during the fields visits and interviews.

Chapter 9

Assessment of Sustainability of Biomass Utilisation System in Indonesia

University of Lampung Research Institute

September 2010

This chapter should be cited as
University of Lampung Research Institute (2010), 'Assessment of Sustainability of Biomass Utilisation System in Indonesia', in ERIA WG on 'Sustainability Assessment of Biomass Utilisation in East Asia' (eds.), *Sustainability Assessment of Biomass Energy Utilisation in Selected East Asian Countries*. ERIA Research Project Report 2009-12, Jakarta: ERIA. pp.110-159.

ASSESSMENT OF SUSTAINABILITY OF BIOMASS UTILISATION SYSTEM IN INDONESIA

By:
University of Lampung Research Institute

University of Lampung Research Institute:

1. Dr. Udin Hasanudin — Head of Dept. of Agro-Industrial Technology
2. Dr. Agus Haryanto — Researcher at Dept. of Agriculture Engineering
3. Mr. Zainal Abidin, M.Sc. — Researcher at Dept. Of Agriculture Social Economic
4. Dr. Sugeng Triyono — Researcher at Dept. Of Agriculture Engineering

Starch Technology Centre, Agency for the Assessment & Application Technology (BPPT):

1. Dr. Agus Eko Tjahjono — Director of Starch Technology Centre
2. Mr. Sigit Setiadi, M.Sc. — Researcher at Starch Technology Centre
3. Mr. Bambang Triwiyono, M.Sc. — Researcher at Starch Technology Centre
4. Mr. Nurul Rusdi — Researcher at Starch Technology Centre

EXECUTIVE SUMMARY

Based on President's Regulation (Peraturan Presiden) No.5/2006 on the National Energy Policy of Indonesia, it is expected that by 2025 the share for oil should be reduced to 20% of the national energy consumption. In the same time, the share of biofuels should be increased to at least 5% in the national energy mix. According to the Blueprint of National Energy Management, bioethanol and biodiesel are biofuels to be developed among other fuel types. Various initiatives for biofuel development has been carried out by numerous stakeholders, private, NGO, government, as well as communities.

In the Blue Print and Roadmap of Bioenergy Development of Lampung Province (2006), *Jatropha curcas* was selected as prime bioenergy due to not compete with food production, possible grown as intercropped crop with other traditional crops existing in the village that land use competition can be avoided, and easy to grow in many types of lands that minimum management is required. Cassava is another source that can be developed for biofuel (ethanol) in the near future. Currently, however, cassava in Lampung is dedicated mainly for tapioca starch and food production. Cassava and Jatropha have high potential as sources to produce bioethanol and biodiesel, respectively.

Lampung Province has promoted jatropha under scheme of Self Sufficient Energy Village (SSEV) program as the first program implemented in 2006–2007. The program was carefully designed from site planning to program implementation. However, the execution was not running as smoothly as it was originally planned. Cassava utilization for bio-fuel in Lampung Province was started by operated a pilot scale ethanol plant at a capacity of 8 KLD (kilo liter per day) since 1982. A commercial scale factory with a capacity of 180 KLD has been operated since 2008. Cassava roots were supplied by farmers around the factories, both with or without partnership. Competition between ethanol factories as bio-energy producers and tapioca factories as food and feed producers caused insufficiency of raw material in bio-energy producers. Therefore, it is important to assess the sustainability of biomass utilization, in particular for energy source (ethanol from cassava and biodiesel from jatropha as well as biogas generated from their waste).

The purpose of this study was to test the sustainability assessment methodology on the utilization of Cassava and Jatropha for bio-energy in Lampung Province, Indonesia. The

Guidelines to Assess Sustainability of Biomass Utilization in East Asia which established by ERIA Working Group on "Sustainability Assessment of Biomass Utilization in East Asia" (ERIA Research Project Report No.8-2) was used as a method of assessment. Study teams investigated the sustainability of Cassava and Jatropha utilization for bio-energy from Environmental, Social, and Economic aspects.

Guidelines to Assess Sustainability of Biomass Utilization in East Asia which established by ERIA Working Group on "Sustainability Assessment of Biomass Utilization in East Asia" (ERIA Research Project Report No.8-2) was successfully used as a assessment method for assess the sustainability of ethanol production from cassava and biodiesel from jatropha as well as biogas generated from their waste in community level from the point of view social, economic, and environment aspects.

Cassava farmer received profit about 6,235,744 IDR/ha/year for contract farming system and 4,995,916 IDR/ha/year for non contract farming system. Processing cassava for bioethanol increased the value added of cassava about 950-1108 IDR/L bioethanol or about 146.6-171 IDR/kg cassava. Fluctuation of cassava price significantly affected to economic sustainability of bioethanol production.

Sustainability assessment of cassava utilization for bioethanol revealed that HDI for the case of cassava farmer was 0.542 or 54.2% with GDI of 0.5416 or 54.16%. This is far below the HDI of North Lampung in general. The low of HDI is strongly affected by GDP index, which determined by low GDP of cassava farmer. From environmental side, production of bioethanol was promoted the utilization of biofuel to substitute fossil fuel. If biogas from waste treatment is barely flared, CO_2 emission from ethanol production system is 0.2965 tCO_{2e}/kL ethanol (14.0491 kg/GJ). Almost two third of the CO_2 emission was released from power plant. Utilization of biogas in the power plant reduces the CO_2 emission to 0.2680 tCO_{2e}/kL ethanol or 12.6974 kg CO_{2e}/GJ. The utilization of biogas from wastewater treatment plant gives highest sustainable indicator from economic, social, and environmental point of views.

Jatropha farmer received benefit about 699,077 IDR/ha/year and profit about (-1,610,369 IDR/ha/year) from their jatropha farming system. It is very low benefit and not profitable. The utilization of jatropha waste has successfully increased their revenue will be 4,781,638 IDR/ha/year. Therefore, the economic benefit is improved to be 1,453,569 IDR/ha/year. This was not a bad economic activity given that jatropha is planted as intercropping. It should be pointed out that by planting jatropha as merely an additional activity the community is able to produce bioenergy for itself without any reduction on the income.

Sustainability assessment of jatropha utilization for CJO revealed that HDI for the case of jatropha farmer was 0.3534 or 53.34% with GDI of 0.351 or 35.1%. The HDI for jatropha farmer was much lower than the HDI for North Lampung in general. This implied that life quality, education, and income for the people in Way Isem were quite low. The low of HDI is strongly affected by GDP index, which determined by low GDP of jatropha farmer.

On a basis kilo liter of CJO being produced, it can be demonstrated that total emission of CO_2 equivalent resulted from CJO production is 0.4374 tCO_{2e}/kL CJO or 12.5862 kg CO_{2e}/GJ. CO_2 emission from plantation and jatropha processing was 59% and 82%, respectively. Waste treatment reduces the CO_2 emission by 41% of the total emission. In this case jatropha cake, waste from CJO processing, was anaerobically digested to produce biogas. The biogas was then utilized as fuel for kitchen stoves, replaced kerosene or woods.

Sustainability of cassava and jatropha utilization for bioenergy would be increased through utilization of waste or by product from each step of processing. The utilization of waste biomass increased gross value added and created new job, and decreased GHGs emission. Development of close system in plantation and biofuel industry is very much recommended to increased the sustainability of soil, reduce environmental impact, and optimized social and economic benefit.

Implementation of this assessment method at macro level, such as province level, should be evaluated. Output of this study could be useful for sustainability assessment at national or East Asian region.

Dissemination of Guidelines on Sustainability Biomass Utilization to other East Asian Countries is needed. Experiences in the assessment of sustainability in the pilot studies can serve as guide in the efforts of other East Asian Countries and other international organization such as GBEP and ISO in biomass assessment.

1. INTRODUCTION

1.1.Background

Indonesia is blessed with numerous energy sources such as oil, coal, natural gas and renewable sources like solar, hydro, wind, geothermal and biomass. In order to reduce oil dependence, Indonesia has taken an important step to increase renewable energy contribution in the national energy supply by releasing President's Regulation (Peraturan Presiden) No. 5/2006 on the National Energy Policy. Based on the regulation, it is expected that by 2025 the share for oil should be reduced to 20% of the national energy consumption. In the same time, the share of biofuels should be increased to at least 5% in the national energy mix. According to the Blueprint of National Energy Management, bioethanol and biodiesel are biofuels to be developed among other fuel types.

In relation with initiatives for finding more sustainable energy sources as pointed out in the President's Instruction (Inpres) No. 1/2006, the local government of Lampung Province has recently initiated a program called Desa Mandiri Energy (DME) or Self Sufficient Energy Village (SSEV). In fact, various initiatives for biofuel development has been carried out by numerous stakeholders, private, NGO, government, as well as communities.

According to National Team for Biofuel Development (Tim Nasional Pengembangan BBN, 2006), DME is designed to:

1. Promote labor absorption, inclusion of the poor, and to satisfy local energy demand.
2. Include poor fishermen villages, remote areas, and transmigration villages.
3. Obtain supporting institutions and cooperative units, as well as small and medium scale entrepreneurs.
4. Have additional support by local government, such as subsidy on seeds, seedlings tools, or other facilities, shown in the approved local (province and district) budget.

Lampung is targeted to grow 53.000 ha of jatropha (Tim Nasional Pengembangan BBN, 2006). In the Blue Print and Roadmap of Bioenergy Development of Lampung Province (2006), *Jatropha curcas* was selected as prime bioenergy due to several considerations, such as:

1. Unlike other potential biofuel sources such as palm oil, cassava, corn, or sugarcane, jatropha is non edible crop that will not divert other end use, especially food production. Therefore, all jatropha products will be designated for biofuel production.
2. The plant is generally grown as intercropped crop with other traditional crops existing in the village. This means that land use competition can be avoided.

3. The people are already familiar with such sufficient knowledge to the plant that minimum effort can be taken for socialization the plant.
4. The plant is easy to grow in many types of lands that minimum management is required and does not require lot of inputs.
5. The plant is growing even in poor/marginal land. A study in India concluded that jatropha farming is beneficial when it is incorporated in the development strategy for marginal lands (Francis *et al*., 2005).

Cassava is another source that can be developed for biofuel (ethanol) in the near future. Currently, however, cassava in Lampung is dedicated mainly for tapioca starch and food production. Therefore, it is important to assess the sustainability of biomass utilization, in particular for energy source (ethanol from cassava and biodiesel from jatropha as well as biogas generated from their waste).

In the case of cassava utilization for bio-fuel, a pilot scale plant at a capacity of 8 KLD (kilo liter per day) has been operated since 1982 to produce bio-ethanol and a commercial scale factory with a capacity of 180 KLD has been operated since 2008. Ethanol factories, however, have not enough plantations to supply cassava tubers as a raw material. Therefore, cassava roots were supplied by farmers around the factories, both with or without partnership. Even so, the supply of cassava roots as a raw material to ethanol factories was not sufficient to fulfill design capacity of the factories. Competition between ethanol factories as bio-energy producers and tapioca factories as food and feed producers caused insufficiency of raw material in bio-energy producers. The competition between biomass utilization for food and for energy has become hot issue on the sustainability of cassava utilization in Lampung.

For Jatropha case, under scheme of SSEV program, Lampung has promoted jatropha as the first program implemented in 2006–2007. It was established in two different districts, i.e. North Lampung and South Lampung Districts. Association of jatropha farmers was established to diffuse the program into the whole community. The program was carefully designed from site planning to program implementation. However, the execution was not running as smoothly as it was originally planned. Several challenges hampered the program achievement, such as: (1) land used competition with other commodities, (2) lack of skill of the farmers to really implement the program, (3) public doubt regarding the jatropha itself in terms of market value and market channel, and (4) poor institutional setting.

Abidin (2008) has calculated jatropha farming in South Lampung District using Policy Analysis Matrix. The study suggests that Jatropha farming is profitable as it does not require lot of inputs. However, its profitability is less competitive compare to other dry land crops predominant in the area, such as: corn and cassava. A study by Francis, et al (2005) on Jatropha in India also suggested that Jatropha is profitable and could support India's effort to provide bioenergy by utilizing marginal lands.

Some private sectors have also expanded Jatropha farming for the purpose of extending seeds availability. Under partnership with private sectors, many farmers participated in Jatropha farming as seeds farmers. The Jatropha market is then still dominated with seeds market. Supply of Jatropha for local industry as well as local energy needs has not established yet.

In light of complex needs of farmers, and competition of other land uses, Jatropha farming posed serious challenges to provide local energy needs as well as to establish local industry for bio-energy, set out under independent energy village scheme.

Lampung, located in south part of Sumatra Island, is one province in Indonesia blessed with a lot of biomass resources, especially from agro-industries activities, such as Cassava, Palm Oil, Sugarcane, Pineapple, Corn, and Jatropha. They can be used as feedstock of biofuels. Cassava and Jatropha have high potential as sources to produce biofuels; bioethanol and biodiesel, respectively. As a result of transmigration in the past, Lampung is now the most populated province in Sumatera. Lampung is also the home of various ethnic groups with Javanese to be the majority and Lampungese is the second. With 12 districts and 2 municipalities, Lampung is inhabited by around 7 million people. Lampung has 3,3 million ha area in which around 1,04 million ha is forest zone. However, the condition of the forest has always been under intense pressure from human activities such as agricultural development, human settlement, transportation facilities, etc. According to the Forestry Agency, more than 60% of state forest areas have been degraded and that trend is likely to continue for the near future.

Income per capita of Lampung province has significantly increased from US$ 513 in 2003 to around US$ 967 in 2007 (based on current price). It, however, was far lower than the national average of around US$ 1,600 at the same time. This makes Lampung Province be among the poorest provinces in the nation.

Lampung's economy relies heavily on agricultural sector as was clearly demonstrated by Regional Statistics. Although more than 50% of its labor force involved in agricultural production sector, yet agricultural sector contribution to regional income was merely around 35% in 2007 (BPS, 2009). Agroindustries play major roles and several large scale agroindustries have been established for more than thirty years such as: tapioca industries, sugar industries, feedstock industries, pineapple industry and various food production industries.

Expenditure for household consumption, especially for food and non-food is the largest contributor of Lampung expenditure which was 56% followed by expenditure for export and import expenditures. This means that domestic consumption plays major roles for Lampung's economy between 2003 and 2007 and it prolongs till now.

Human Development Index of Lampung Province corresponds with economic performance. Figure 1 indicated that HDI of Lampung Province is the lowest among province in Sumatra. Lampung HDI is merely 68,8 which is almost the same as Nangroe Aceh Darrussalam (NAD), a Province which has just barely recovered from tsunami tragedy in 2004. Lampung HDI is even lower than Bengkulu Province, a poor and more isolated province from main economic activities of Indonesia. The strategic location of Lampung as the gate to and from Java, has not give significant advantage for economic and human development. There is strong connection between poor economy and human development index.

Figure 1. Human development index (HDI) in Sumatra, Indonesia *(Source: BPS 2009)*

Our study area for cassava-based ethanol production and jatropha-based SSEV was located in North Lampung district. According to BPS (2009), HDI of North Lampung district was 69.4 and ranked the sixth. There is no significance improvement of HDI in North Lampung for the last five years. In addition, as shown in Table 1, the percentage of poor population in North Lampung was the highest. This implies that the study area is considered as less developed in terms of human development.

Table 1. Human Development Index (HDI) and percentage of the poor population by districts and municipalities in Lampung (2005-2008).

Districts	2005	2006	2007	2008*	Poor population (%)	Cassava plantations (ha) 2006**
West Lampung	66	66.8	67.74	68.21	24.47	427
Tanggamus	67.7	69	69.62	70.19	22.17	2,596
South Lampung	67.2	67.8	68.39	68.79	26.94	12,436
East Lampung	67.90	68.60	69.23	69.68	27.21	41,253
Central Lampung	68.8	69.1	69.40	69.93	22.07	88,575
North Lampung	68.00	68.50	68.97	69.40	32.16	29,976
Way Kanan	67.40	68.10	68.46	68.98	25.96	17,600
Tulang Bawang	67.80	68.20	68.63	69.14	13.03	90,441
Pesawaran	na	na	na	68.73	n.a	n.a
Bandar Lampung	73.50	73.80	74.29	74.86	9.44	181
Metro	75.20	75.20	75.31	75.71	11.53	159
Province (all)	68.80	69.40	69.78	70.30	22.19	283,430

*Sources: *BPS 2009*
***BPS 2008*

1.2.Objective

The purpose of this study was to test the sustainability assessment methodology on the utilization of Cassava and Jatropha for bio-energy in Lampung Province, Indonesia. The Guidelines to Assess Sustainability of Biomass Utilization in East Asia which established by ERIA Working Group on "Sustainability Assessment of Biomass Utilization in East Asia" (ERIA Research Project Report No.8-2) was used as a method of assessment. The study team investigated the sustainability of Cassava and Jatropha utilization for bio-energy from Environmental, Social, and Economic aspects.

1.3.Methodology

To assess the sustainability of cassava utilization for ethanol production, the study was conducted at an ethanol factory which uses cassava as raw material and some cassava farmers as supplier of the raw material. Location of this study is in Prokimal area, North Lampung district, Lampung Province, Indonesia. The sustainability of Jatropha utilization was assessed in Way Isem Village, It is a SSEV developed in 2007 located in sub district Abung Barat, district North Lampung, Lampung Province, Indonesia.

1.3.1. Economic Aspects

Gross value added (GVA) was calculated and compared for base and proposed scenarios. Necessary data for the calculation, such as total costs of inputs for the biofuel production, and total revenue from selling of products were investigated. The practical parameters and methods shown in the guideline of the economic index developed by the WG was adopted for this evaluation.

The impact of target biomass utilization to the economic community was investigated using GVA (Gross Value Added). Gross Value Added was calculated based on priced and recorded at basic prices. It is the net result of output valued at basic prices less intermediate consumption valued at purchasers' prices. Gross value added at current basic prices and current exchange rates. The basic price is the price receivable by the producers from the purchaser for a unit of a good or service produced as output minus any tax payable on that unit as a consequence of its production or sale (i.e. taxes on products), plus any subsidy receivable on that unit as a consequence of its production or sale (i.e. subsidies on products).

Based on the various literature reviewed, the most common economic contributions of biomass utilization 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.

1. 3.2. Gross Value Added

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 generated out of the main product and the value addition generated out of the by-products of conversion or processing. The following equation was adopted in computing for 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 *Processing Stage*. In this stage, the raw material or initial product undergoes processing to produce the intermediate or final product of biofuel production. The costs associated in this stage can be referred to intermediate or final product of biofuel production costs. The following equation was used for calculation:

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

1.3.3. 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 × 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.

During the *Production* stage, employment generation can be generated from activities such as hauling, transplanting, weeding, fertilizing, and other maintenance operations. The resulting value is expressed in terms of man day per hectare of production. This can be estimated as follows:

Employment = (Output per Hectare ÷ Total Output) × Man days per Total Output

The same formula can be applied to compute for the employment generated during the *Processing* stage.

Total value added to the economy refers to the total contribution of the biomass energy industry or activities to the economy in term of net profit or benefit in the production and processing of biomass to bioenergy.

1.3.4. Social Aspects

Social development index was investigated as shown in the guideline of the social index developed by the ERIA WG on “Sustainability Assessment of Biomass Utilization in East Asia”. 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 weighing) 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 value measuring these social factors have different units, it is necessary to standardize them which allow them to be added together. In general, to transform a raw variable, say *x*, into a unit-free index between 0 and 1 (which allows different indices to be added together), the following formula is used:

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

where min (χ) and max (χ) 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 the Table 2.

Table 2. Goalposts used in UNDP method of HDI

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

Source: UNDP

1.3.5. Sub-Indices of HDI (UNDP Method)

The sub-indices used in HDI are expressed as follows:

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

Education Index = $\dfrac{2}{3}\times ALI+\dfrac{1}{3}\times GEI$

Adult Literacy Index (ALI) = $\dfrac{ALR-0}{100-0}$

Gross Enrollment Index (GEI) = $\dfrac{CGER-0}{100-0}$

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

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

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

Lampung Demographic Data at Community (Village), Sub-district, District, Provincial as well as National level were used in the assessment of social impact. The data included Adult Literacy Rate, Gross Enrollment Ratio, Life Expectancy and Health Status. To estimate Adult Literacy Rate (ALR), sample tests at local area and historical/statistical analysis of ALR will be done. Gross Enrolment Ratio (GER) will be calculated from Community (Village) statistics that can be obtained from Village and Statistical Bureau or Education authority of the area. GDP per capita will be estimated from provincial I/O table analysis. Also, GDP at Community (Village) level was calculated using primary data from community's survey. Using historical death data of Village profile and Health Department of Lampung Province, life expectancy was estimated. To estimate the effect of Cassava and Jatropha base's industries, local Human Development Index (HDI) parameters were investigated at self sufficient energy village and cassava villages nearby ethanol factory. Gender related Development Index (GDI) was also calculated to reflect inequalities between men and woman in all the three dimensions used in calculating HDI. Equally Distributed Index for three indices was calculated using the following formula:

$$\text{Equally Distributed Index} = \left[\frac{\text{female population share}}{\text{female index}}+\frac{\text{male population share}}{\text{male index}}\right]^{-1}$$

The GDI was calculated by taking the average of the equally distribution index of all three indices, life expectation index, education index, and GDP index.

1.3.6. Environmental Aspects

Life Cycle Assessment (LCA) is increasingly being promoted as a technique for analyzing and assessing the environmental performance of a product system and is suited for environmental management and long term sustainability development. Also, LCA is relevant methodologies that can assist policy makers establish significance of environmental issues in relation to economic and social factors. 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 the extreme weather conditions and disasters. Effects of the climate change have been attributed directly to the increased atmospheric concentration of Green House Gases (GHG) related by anthropogenic activities.

One of the widely accepted climate change mitigation approach is the propagation of the 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 the fossil fuel. The general system boundary for the cradle to grave life cycle inventory of a type of bioenergy is shown in Figure 2. Due to some limitation of data in the field, LCI was conducted until processing stage of cassava for ethanol and Jatropha for crude Jatropha oil (CJO) as well as biogas generated from their waste.

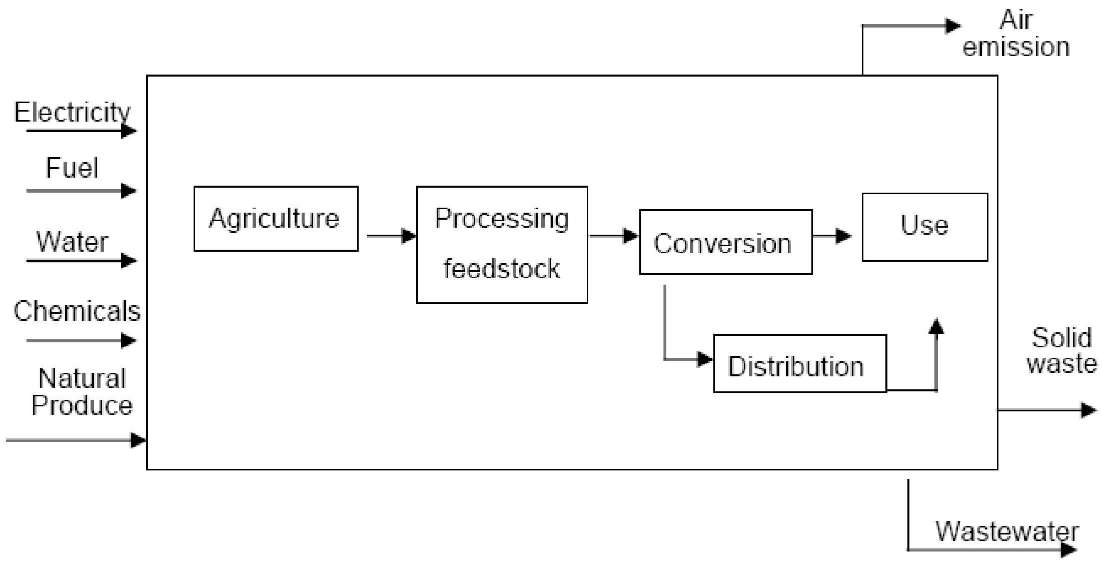


Figure 2. System boundary for the cradle to grave life cycle inventory of bioenergy
Source: ERIA Research Project Report 2008 No. 8-2 (2009)

GHG emission for specific biomass energy was estimated through life cycle inventory (LCI) analysis involving compilation and quantification of inputs and outputs for a given biomass energy throughout its life cycle. The LCI of bioenergy covered CO_2 and non CO_2 green house gases namely CH_4 (methane) and N_2O (Nitrous Oxide) that are released directly from agricultural activities. The GHGs inventory will be reported as CO_{2equi} and the summation of contribution from non CO_2 gases was calculated based on the Global Warming Potential (GWP) for a 100-year time horizon of CH_4 and N_2O at 21 and 298 times, respectively. The life cycle stages of bioenergy production from Cassava and Jatropha are comprised of the following: agriculture (farming) including transportation of feedstock to processing plant and feedstock processing. Comparative performance based on the GHGs profiles of different bioenergy is one of the approaches to encourage improvement of the 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 minimization, including utilization of process waste.

CASE A. CASSAVA FOR ETHANOL

Even though there was a pilot scale of ethanol factory with capacity 8 KL/day operated since 1982, ethanol production from cassava at a commercial scale is quite new in Indonesia. The first ethanol factory using cassava as raw material with capacity 180 KL was operated since 2008 in North Lampung. The objective of developing cassava-based ethanol is triggered by decreasing of fossil fuel reserve, increasing fossil fuel price, and global warming issue.

The production ethanol from cassava have directly affected to the increasing of cassava price due to competition with tapioca factories. The increasing of cassava price, however, has a positive effect to the farmer to increase production by expanding cassava farming area. Table 3 shows that cassava farming increase in term of area and productivity during 3 years later in Lampung province. Considering to this condition, the existence of ethanol factory has given a positive impact in improving farmer revenue through increasing production and keeping a better price of cassava. However, this condition has increased the production cost of cassava-based products, such as tapioca, citric acid, and bio-ethanol.

Generally, cassava farmer in Lampung planting two type of cassava species, Kasetsrat and Thailand species. The original seeds were imported from Thailand several years ago and followed by extensive breeding in Indonesia. Kasetsrat species can be harvested after 10-12 months after planting with productivity 30-40 tons/Ha and high starch content. Thailand species can be harvested after 7-10 months with lower productivity 20-25tons/Ha and relative lower starch content. The number of seeds/ha are about 17,500 to 25,000 with price 60-100 IDR/seed. For ethanol production, factory recommended farmers to plant Kasetsrat species. In general, Urea and NPK are used for fertilizer in cassava farming. Few farmers use KCl, TSP/SP-36/SP-18, and compost to increase productivity. The average utilization of fertilizer per hectare per season are 192.02 (kg/Ha) for Urea, 185.54 (kg/Ha) for NPK and 273.46 (kg/Ha) for compost.

Table 3. Area and production of cassava in Lampung province at 1998-2008

Year	Area(ha)	Production (ton)	Productivity(ton/ha)
1998	174745	1951590	11.17
1999	264178	3028605	11.46
2000	257506	2924418	11.36

2001	316979	3584225	11.31
2002	295156	3471136	11.76
2003	298989	4984616	16.67
2004	266586	4673091	17.53
2005	252984	4806254	19.00
2006	283430	5499403	19.40
2007	316806	6394906	20.19
2008	316.019	7649536	24.21

Sources: Lampung Statistical Bureau, 2008 and Central Statistical Bureau, 2008

The cassava roots are transported to the ethanol factory after harvesting. The distance from field to the factory varies from 0 to 40 km (average 6 km). Beside need transport cost, transportation activities also release CO_2 to the atmosphere as a GHGs emission. Cassava is processed at ethanol factory through several processes, such as washing, rasping, liquefaction, saccharification, fermentation, and distillation. Schematic diagram of ethanol production are shown at Figure 3.

In these stages, energy was needed and CO_2 was also released to the atmosphere. Beside bio-ethanol as main product, the ethanol factory also produced wet cake, cassava peels, some soil as solid waste, and thin slop that is high concentration of organic matter. The solid wastes can be utilized as a raw material to produce compost. The factory collaborates with third parties to handle these solid wastes and producing compost. This utilization system was developed to prevent environmental pollution and generate additional income. Utilization of compost as an organic fertilizer for contract farmers' land will improve the soil quality and increase productivity. The system can also reduce the consumption of chemical fertilizers which will reduce GHGs from fertilizer production and transportation stage. Other by-product or waste from ethanol processes is thin slop. This wastewater contains high concentration of organic matters

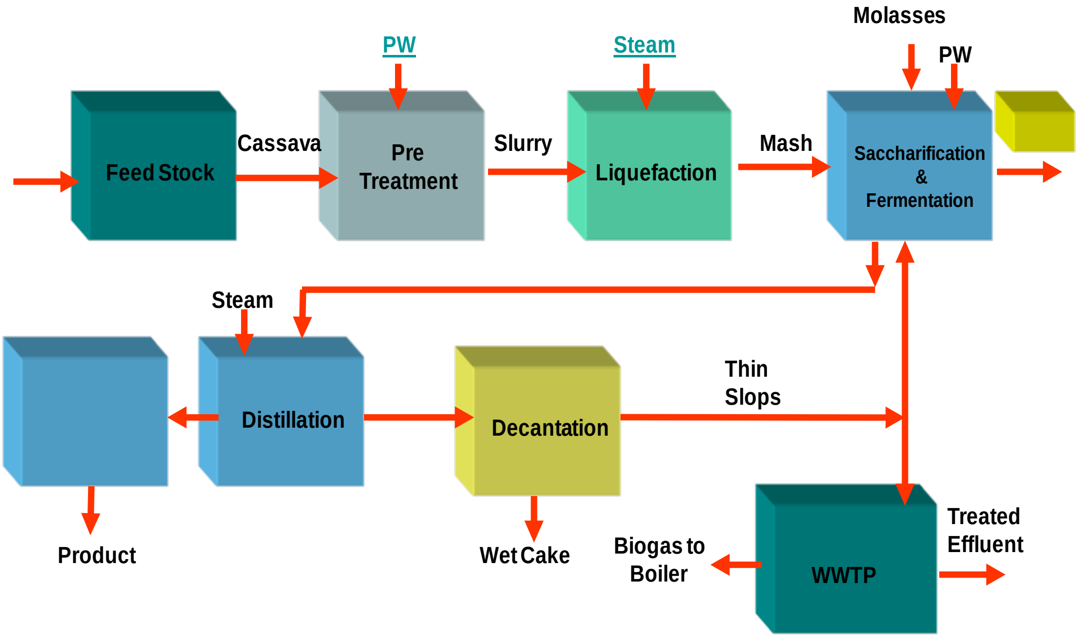


Figure 3. Schematic diagram of ethanol production
Source: from survey results

and has high potential to produce methane gas (biogas) through anaerobic digestion. The ethanol factory has utilized the thin slop as a raw material to produce biogas. Until now, the biogas was only flared, not utilized as fuel yet. This condition has decreased the GHGs emission because effect of methane (CH_4) emission on global warming was 21 times higher than CO_2. However, the utilization of biogas as fuel for power plant in the ethanol factory will also reduce coal consumption and will automatically reduce carbon CO_2 emission. The boundary of study system in ethanol factory is shown at Figure 4. Figure 5 depicts material balance on cassava-based ethanol production.

The ethanol production also has give impact to the social condition of the people which stay in the surrounding the factory. Increasing of income from cassava farming and widely job opportunity of the people nearby factory has been improving social condition of people in that area.

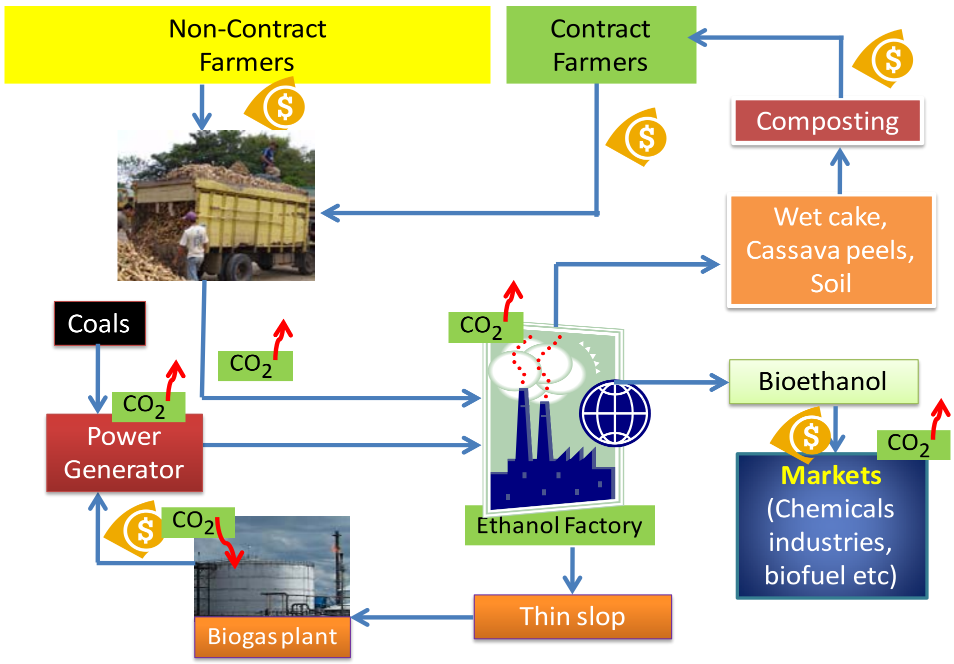


Figure 4. Boundary of study system in ethanol factory
Source: from survey results

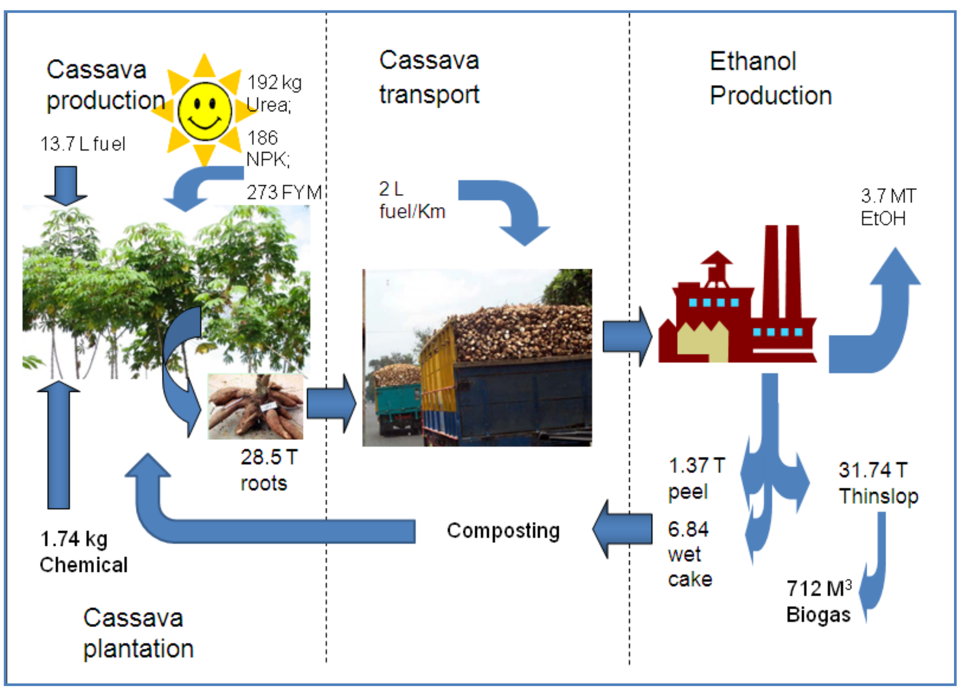


Figure 5. Material balance on cassava-based ethanol production (based on a ha of plantation)
Source: from survey results

2.A. ECONOMIC IMPACT OF PRODUCTION AND PROCESSING OF CASSAVA

It is worthy to note that in the economic analysis, cash income is usually distinguished with accounted income. Cash income or benefit is defined as production value (revenue) subtracted by all costs that are actually incurred by the farmer including cost for production facilities, labor costs outside the family, and taxes. Accounted income or profit, on the other hand, is defined as the production value subtracted by cash costs and calculated costs as well. Calculated costs considered for economic evaluation include land rental, labor cost inside the family, depreciation, and seeds. Table 4 shows a breakdown of cost and revenue of cassava production, both for partnership and non partnership cassava farmers.

It can be showed that partnership farmers got significantly higher benefit from cassava production than that of non partnership farmers. In part this was caused by fact that partnership farmers produced higher cassava roots (28,490 kg/Ha) than non partnership farmers who produced (24,670 kg/Ha). This was likely resulted from land quality which is implied by its tax cost. The higher cost for land preparation (machinery rent) as well as manpower for non partnership farmers also reflected that the land quality is lower than that of partnership farmers. Refraction, which is 0-5% penalty due to starch content, is another important factor. Refraction for non partnership farmers (945,628 IDR/Ha) was considerably higher than that of partnership farmers (626,807 IDR/Ha). This might be resulted from either their low quality cassava roots or a particular policy acted for non partnership farmers so that they received higher refraction.

The most important factor affecting farmers' benefit is cassava price. In the analysis, the price of cassava tuber for partnership farmers was 439.25 IDR/kg and it was not significantly different to that of non partnership farmers (449.75 IDR/kg). It was about the normal price for cassava roots. The benefit-cost ratio (B/C) was 1.32 for partnership farmers and 1.03 for non partnership farmers. In conclusion it can be wrapped up that cassava cultivation for partnership farmers is a better economic activity than that of non partnership farmers.

Table 4. Costs and returns in cassava production for partnership farmers

ITEMS		QUANTITY/ HA	COST/UNIT (in IDR)	COST/HA (in IDR)
MATERIAL	Seed, Fertilizer, compost, and	1 package	1,187,950	1,187,950

	Chemicals			
LABOR	Weeding, Fertilizing, and Other Maintenance	28.05 days	25,000	701,328
MACHINE	Land preparation	1 package	294,498	294,498
	Harvesting and Transportation	28,49 ton	69,545	1,981,338
OVERHEAD	Tax, and rent, refraction			2,135,280
TOTAL COST				**6,300,394**
TOTAL fresh cassava root		28,490kg	**439.25**	**12,536,138**
NET PROFIT				**6,235,744**

Table 5. Costs and returns in cassava production for non-partnership farmers

	ITEMS	QUANTITY/ HA	COST/UNIT (in IDR)	COST/HA (in IDR)
MATERIAL	Seed, Fertilizer, compost, and Chemicals	1 package	1,027,716	1,027,716
LABOR	Weeding, Fertilizing, and Other Maintenance	37.31 days	25,000	832,811
MACHINE	Land preparation	1 package	478,172	478,172
	Harvesting and Transportation	24,67 ton	74,897	1,847,716
OVERHEAD	Tax, and rent, refraction			1,823,862
TOTAL COST				**6,110,277**
TOTAL fresh cassava root		24,670 kg	**449.75**	**11,106,193**
NET PROFIT				**4,995,916**

On March 2010, however, the cassava price at the ethanol factory was 710 IDR. The high price for cassava roots reflected that there was a tough competition for cassava in the market. This condition was good for farmers in term that they got increased benefit by 13,443,992 IDR/Ha and 10,014,104 IDR/Ha for partnership and non partnership farmers, respectively. Nevertheless, it was difficult situation for ethanol plant because the high cassava price resulted in a much higher production cost. The structure of production cost of ethanol from cassava more than 65% is attributed to raw material (cassava tubes) cost.

Processing cassava into ethanol is expected to bring about value added for cassava farming. It is required 6.48 kg of fresh cassava to produce every liter of ethanol. At investment cost for ethanol plant 45 million US dollar, our observation found that ethanol production cost was 150-160 US$/KL ethanol or 15 to 16 cent per liter excluding raw material (cassava). At cassava price of 439.25-449.75 IDR/kg and exchange rate of 9200 IDR a dollar, the total cost of ethanol production will be in the range of 4231 to 4388 IDR per liter. Currently, ethanol price is 580 US$/KL ethanol or 5336 IDR a liter. The value added resulted from ethanol processing was 950-1108 for every liter ethanol being produced. In other word, ethanol processing has resulted in value added of 147-171 IDR a kilo cassava. Figure 6 shows the value added resulted due to ethanol processing from cassava tubers. Table 6 details cost and returns for ethanol production as well as additional profit from waste management.

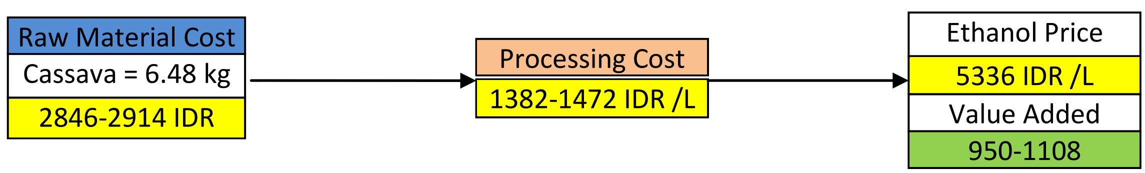


Figure 6. Value added resulted from processing cassava tubers into ethanol on a liter ethanol basis
Source: from survey and calculation results

The utilization of ethanol for biofuel needs additional process to remove remaining water. The fuel grade bio-ethanol will have price higher than 580 US$/KL ethanol or 5336 IDR a liter. It is difficult to utilize bioethanol as a biofuel in Indonesia because until now gasoline price still subsidized by government. The subsidized price for gasoline (premium) is 4500 IDR, much cheaper than bioethanol prices and almost similar with production cost. Subsidy system should be adopted on bioethanol production if Indonesia wants to implement bioethanol as a biofuel mixed with premium. Enforcement from government is really needed to utilized bioethanol as a biofuel.

Table 6. Costs and returns in production of ethanol from one hectare cassava production

ITEMS		QUANTITY	COST/UNIT (IDR)	TOTAL (IDR)
TOTAL COST		4,466 L	**4,231**	**18,895,646**
TOTAL OUTPUT, L		4,466 L	**5,336**	**23,830,576**
SELLING PRICE PER L			**5,336**	
NET PROFIT				**4,934,930**
BY PRODUCT	Biogas	712 M^3	4,200	2,990,400
	Compost	1.37 T	700,000	959,000
ADDITIONAL PROFIT				**3,949,400**
TOTAL PROFIT				**8,884,330**

3.A. SOCIAL IMPACT OF PRODUCTION AND PROCESSING OF CASSAVA

Social impact is measured using HDI that is influenced by three parameters, namely life expectation index, GDP index, and education index. Our field study revealed that number of population was 7820 with 49.2% females and 50.8 males. Some important social factor for cassava farmer was depicted in Table 7.

Table 7. Social parameters on cassava production in North Lampung

Item	Quantity
Number of population	7820
Number of family (NF)	1872
Average age of dead people (year)	61.89
Income per capita (US$/year)	635.8
Number of illiterate people	102
Number of preschool pupils	34
Number of basic school student	397

Number of junior high student	470
Number of senior high student	333
Number of diploma student	19
Number of university student	0

Life Expectation Index = $\frac{61.89-25}{85-25}$ = 0.6148

Number of adult people =

2 * NF + HS + DS + US = 2(1872) + 333 + 19 + 0 = 4096

ALR (Adult Literacy Rate) = 100 % * (4096 – 102)/4096 = 97.5 %

ALI (Adult Literacy Index) = $\frac{ALR-0}{100-0} = \frac{97.5-0}{100-0}$ = 0.975

GEI = $\frac{(34+397+470+333+19)}{7820}$ = 0.16

EI (Education Index) = 2/3 (ALI) + 1/3 (GEI) = 2/3 (0.975) + 1/3 (0.16) = 0.70

GDP Index = $\frac{\log(GDP_{pc})-\log(100)}{\log(40000)-\log(100)} = \frac{\log(635.8)-\log(100)}{\log(40000)-\log(100)}$ = 0.309

HDI = (LEI + EI + GDPI)/3 = (0.615 + 0.700 + 0.309)/3 = 0.542

It is revealed that HDI for the case of cassava farming is 0.542 or 54.2%. This is far below the HDI of North Lampung in general. The HDI of North Lampung District at 2008 is 69.4. There are three factors affecting HDI, namely Life Expectation index, Education Index, and GDP index. The first two indices are nearly constant for some short period. The GDP index, however, is strongly determined by fluctuation of the cassava price. Therefore, the higher the price of cassava, the better the HDI will be. However, it will be very difficult to significantly increase HDI by changing of cassava price because of logarithmic factor. Recently, for instance, the price for fresh cassava climbs to about IDR.900. If this is the case, the income per capita will increase to 897 USD. HDI will change to 56.1 compared to 54.2 at an average price of IDR.445 for cassava. Productivity improvement on cassava farming systems was also important to make significant increased of GDP. Government support to improve education enrollment through scholarship program is imperative.

If cassava farming was assumed as additional activities and previous GDP was assumed equal to GDP of Lampung Province (734.78 US$), Cassava farming increased income per capita of farmers 162.3 and 130.0 US$ for partnership and non partnership system, respectively. The case partnership of cassava farming increased GDP index from 0.309 to 0.366 and increased HDI about 3.5% to 56.1 and the case non partnership cassava farming increased GDP index from 0.309 to 0.360 and increased HDI about 3% to 55.9, respectively. Even though still lower than HDI of North Lampung district, the cassava farming activities was successfully to increase HDI in partnership and non partnership system. The HDI in partnership farming system increased higher than HDI in non partnership farming system, this indicated that ethanol factory as a partner of cassava farmer was successfully to increase HDI in the surrounding area of the factory. It is also mean that the biofuel production from cassava has positive impact to increased HDI.

The same indices were separately calculated for male and female to estimate Equally Distributed Index (EDI). Gender-related Development Index (GDI) was then calculated by simply taking unweighted average of those three EDIs. The calculation and resulted GDI was tabulated in Table 8. It was revealed that Gender-related Development Index for cassava farmers in the field studied was 0.5416.

Table 8. Equally Distributed Index calculation along with resulted Gender-related Development Index for cassava farming

Gender	LEI	EDI-LE	EI	EDI-E	GDPI	EDI-I	GDI
Female	0.5867	0.6141	0.6887	0.7073	0.285	0.3074	**0.5416**
Male	0.6433		0.7178		0.333		

4.A. ENVIRONMENTAL IMPACT OF PRODUCTION AND PROCESSING OF CASSAVA

Table 9 shows environmental effect of ethanol production process using cassava roots started from plantation to waste treatment. Regarding to methane gas released from waste treatment, there are three scenarios considered in the table: (1) biogas gas is flared to release carbon dioxide (CO_2) to the atmosphere, (2) biogas gas is merely released to the atmosphere, and (3) biogas is used to generate electricity by burning it in the power plant station.

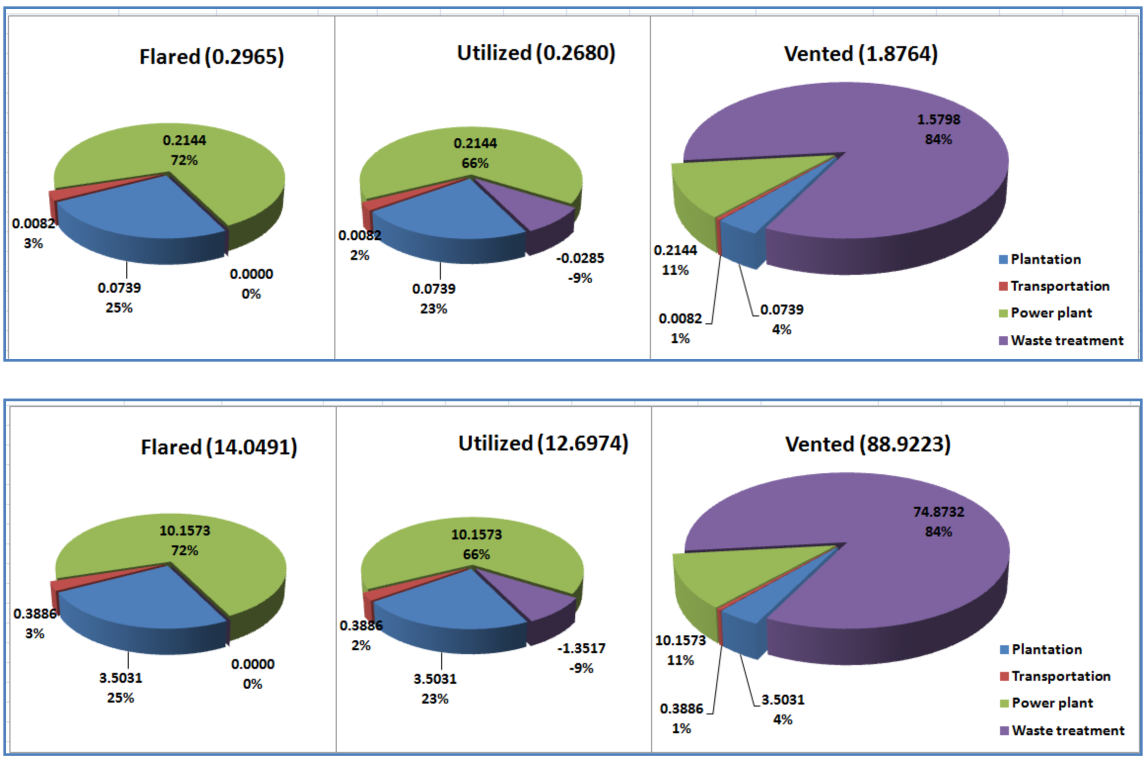
Table 9. CO_2 emission during ethanol production process

Process	Source	Unit*	Quantity	CO_{2e} Emission	
				(kg/L Ethanol)	(kg/GJ)***
Plantation	Diesel fuel	L/ha	13.7	0.0097	0.4597
	Urea	Kg/ha	192	0.0400	1.8957
	NPK (15-15-15)	Kg/ha	185.5	0.0173	0.8199
	Herbicides	Kg/ha	1.747	0.0739	0.3249
Transportation	Diesel fuel	L/ton	0.41		
		L/KL ethanol	2.658	0.0082	0.3886
Processing	Coal	Ton/Day	210		
		MW/KL ethanol	0.032	0.2143	10.1564
	CO_2	M3/day	0**	0	
Waste treatment	CH_4, flared	M3/day	0**	0	
	CO_2	M^3/day	0**	0	
	CH_4, vented	M^3/day	18957.9	1.5798	74.8720
	CH_4, utilized	M^3/day	18957.9	-0.029	-1.3744
TOTAL CO2 EMISSION (SCENARIO 1, FLARED)				0.2965	14.0491
TOTAL CO2 EMISSION (SCENARIO 2, VENTED)				1.8764	88.9223
TOTAL CO2 EMISSION (SCENARIO 3, UTILIZED)				0.2680	12.6974

**) every ha produces 4.394 KL ethanol*
***) neutral*
****) Low Heating Value of Ethanol = 21.1 MJ/L (.bioenergy.ornl.gov/papers/misc/energy_conv.html)*

On a basis kilo liter of ethanol being produced, it can be demonstrated from Table 9, that total emission of CO_2 equivalent resulted from ethanol production is 0.2965 ton per KL ethanol (14.0491 kg/GJ) if the biogas resulted from waste treatment is flared. As can be seen from

Figure 7, CO_2 released from power plant contributes the highest emission, accounted for 72% of total emission. If the biogas resulted from waste treatment is utilized to generate electricity in the power plant, the total CO_2 emission slightly decreases to 0.2680 ton/KL (12.6974 kg/GJ). Although no much difference in term of CO_2 emission, using biogas in power plant will reduce coal consumption significantly. Our calculation reveals that the use of biogas may replace around 28 ton coal per day (13.3%). The CO_2 emission will be worst if the gas released from the ethanol processing waste is merely vented to the atmosphere. Our calculation showed that CO_2 emission in the last case was 1.8764 ton/KL ethanol or 88.9223 kg/GJ.



(a) (b) (c)

Figure 7. CO_2 emission ethanol production in ton CO_2e/KL ethanol (top) and kg CO_2e /GJ (bottom) for different biogas treatment: (a) flared, (b) utilized in the power plant, (c) vented to the atmosphere as it is. ***(Source: from survey and calculation results)***

Based on result of economic, social, and environmental impact calculation, an integration indicator can be described in Figure 8 below. Increment of HDI was calculated as a ratio of the improvement HDI due to biomass (Cassava) production and utilization to original HDI. The ratio of CO_2 emission reduction from ethanol to gasoline production was used as an environmental indicator. Net Profit in thousand US$ was used as economic impact indicator. Figure 8 clearly shown that the utilization of biogas from wastewater treatment plant give highest sustainable indicator from economic, social, and environmental point of views.

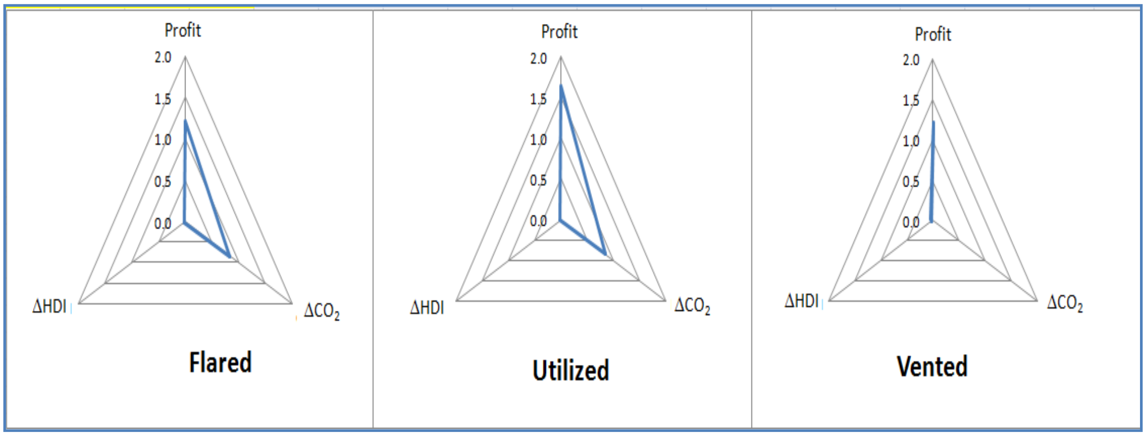


Figure 8. The change of integration indicator in a hectare basis due to cassava-based ethanol production with partnership farmers (Profit is in thousand US$, other indicators are in unitless decimal).
Source: from survey and calculation results

CASE B. JATROPHA FOR CRUDE JATROPHA OIL

Jatropha is developed under a concept called Desa Mandiri Energi (DME) or Self-Sufficient Energy Village (SSEV). The SSEV pilot based on jatropha has been established in Way Isem, a village located in Sub District of Sungkai Barat, North Lampung District. The village located about 3 hours driving (160 km) from Bandar Lampung or about 44 km from district city (Kotabumi), and 17 km from subdistrict city (Sungkai Barat). The village is occupied by 1.443 peoples with 739 (51,21%) male dan 704 (48,79%) female under 361families. Most of them are working in the farm. Energy consumption of the villagers is basically for cooking and lighting and is supplied by wood and kerosene. So far, no electricity grid is installed at the village. The wood is gathered from the garden or farm for free; while kerosene is bought from the local supplier. Total area of this village is about 1.350,867 ha.

The SSEV pilot project was sponsored by Eka Tjipta Foundation as a manifestation of CSR (Corporate Social Responsibility) from Sinar Mas group. It was initiated in 2007 when two representatives from Eka Tjipta Foundation visited Way Isem and introduced the SSEV concept based on jatropha. The foundation provided 100 kg seed for the whole community or 0.8 kg for each family. Jatropha seed can be processed to produce jatropha oil and the oil is used to run generator set for electricity production. Later on, the foundation also provided 20 units of anaerobic digester to produce biogas fuel from the jatropha cake. Other biomass waste from peeling and pruning is returned back to the field as compost. Based on this concept, the boundary system of Way Isem SSEV is depicted in Figure 9.

The people in Way Isem were interested to cultivate jatropha because they thought that jatropha will benefit them with many uses. Jatropha is easy to cultivate and practically no fertilizer is required for the plant. So far, the pilot involved a plantation area about 40 Ha. It is required at least 7 months for jatropha to produce seed (1 month in poly bag and 6 months in the field). The production of jatropha is around 1 kg of fresh fruit per tree. The seed can be harvested twice a week. After peeling, 6 kg of fresh fruit gives 1 kg seed. The oil is extracted using a mill and every 4 kg seed produce 1 liter CJO (crude jatropha oil) which then sold through Eka Tjipta. There should be something wrong because, if at all possible, the oil should be used by the community to produce energy (electricity).

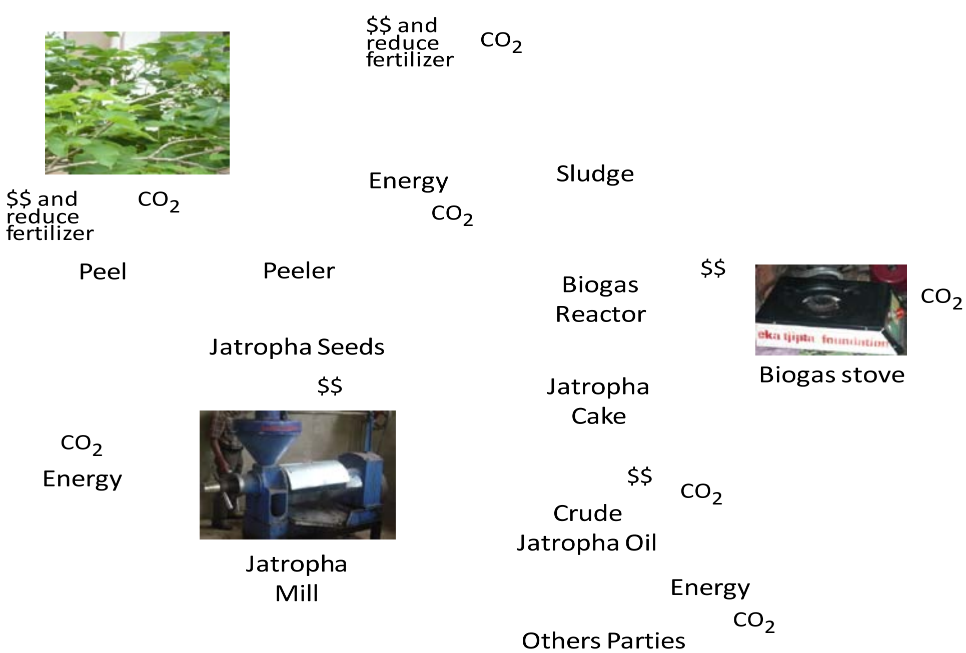


Figure 9. The concept development of Way Isem SSEV, North Lampung
Source: from survey results

The community is organized under a cooperative unit (Koperasi) functioning as a bridge for the people to sell jatropha seed. The cooperation is lead by the head of the village. The villagers collect and peel jatropha nuts, and then sell the seeds to the Koperasi at a price of IDR 1000/kg seed. The Koperasi processes the seed to extract CJO. All the processing equipments like generator set, jatropha mill, oil filter and degummer have been provided by Eka Tjipta. To produce 1 liter CJO requires 3.3 kg of jatropha seed. Figure 10 shows material balance on CJO production.

The CJO is sold to Eka Tjipta at a price of IDR 10.000 per liter. Therefore, the Koperasi gets IDR 4000 gross profit that is used to pay the cost for jatropha processing and to run the Koperasi. Small part of the profit will be returned to the Koperasi members as dividend.

To manage the waste resulted from jatropha processing in a more beneficial way, Eka Tjipta also provided twenty units of anaerobic digester to the village. The digester is run using jatropha cake to produce biogas fuel. The biogas is used to replace fire wood in cooking. Digester volume is 1200 liter and need to be filled with 2 kg of jatropha cake mixed with 18 liter water. The biogas generation system was practical and innovative one, but the villagers had minimal knowledge on the safety precautions.

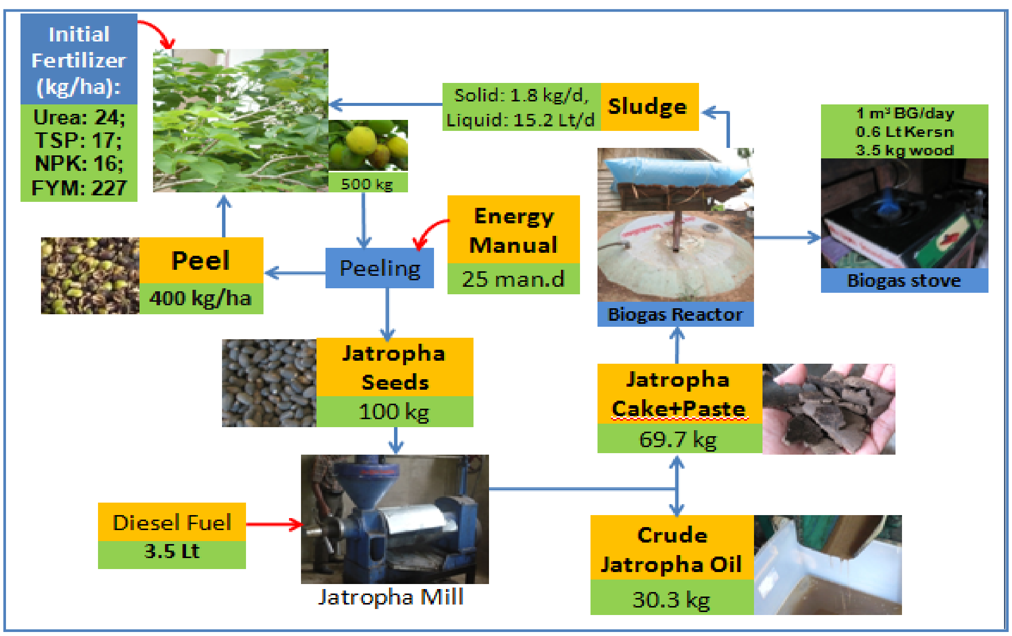


Figure 10. Material balance on 100 kg seed basis of CJO production
Source: from survey and calculation results

2.B. ECONOMIC IMPACT OF PRODUCTION AND PROCESSING OF JATROPHA

Table 10 showed economic evaluation for jatropha cultivation in Way Isem, North Lampung. It was revealed that jatropha cultivation was not profitable. The cultivation is laborious. Seed price, on the other hand, is low. According to the Village Head, the selling price of jatropha seed at IDR 1000/kg is too cheap because a person will get lower money than that he (she) can get by working as labor. Currently, the daily wage of a laborer is IDR 30,000. Therefore, a farmer will have to harvest and produce at least 20 kg seed to match the wage he gets by working as a laborer. In fact, it is difficult to realize this quantity, which is equivalent to 120 kg of fresh nuts, because the cooperation accepts only seed with no skin. Furthermore, the nuts have to be peeled before it is handed to the cooperation. So far, removing the peel is laborious and is conducted manually. These problems have decreased the attraction of jatropha to the community.

Table 10. Costs and returns in jatropha seed production

ITEMS		QUANTITY/ HA	COST/UNIT (in IDR)	COST/HA (in IDR)
MATERIAL	Seed, Fertilizer and Other Chemicals, Compost	1 package		214,648
LABOR	Land preparation, planting, Fertilizing, and Other Maintenance	64.11 day	24011	1,539,345
	Harvesting, peeling and Hauling	26.92 day	24011	646,376
TOTAL COST				2,400,369
TOTAL seed		790 kg	**1,000**	**790,000**
NET PROFIT				**-1,610,369**

The Village Head has proposed to Eka Tjipta to also provide a mechanical 'fruit peeler' to the Koperasi that will reduce the manual work required to peel the jatropha nuts. He expected that a worker working with mechanical peeler would produce at least 50 kg seed. Simple mechanization of removing the skin of the fruits was seen as the only way to make the jatropha planting a feasible economic activity. Another way that could possibly increase the interest of the people is to install more biogas digester. The idea is that the Koperasi will return back the jatropha cake for free to the people only when the people bring jatropha seed to the Koperasi.

Based on our observation, it is strongly recommended that jatropha has to be cultivated as intercrop plant. In fact, company such as Wellable Indonesia suggested that jatropha should be planted only for extra earning through mix or intercropping with other main crops. It is also important to reorientation people's perception about jatropha cultivation in particular and SSEV in general. So far, the people have already been fulfilled with a high expectation on jatropha. Even, they thought to replace the existing important plants such as pepper, coffee, or woody plant, with jatropha if jatropha really give better income. It should be pointed out that by planting jatropha as merely an additional activity the community is able to produce bioenergy for itself without any reduction on the income.

Processing jatropha into CJO is expected to result in value added for jatropha production. Every 5 kg of jatropha nuts was peeled to produce a kilo jatropha seeds. The seeds then were processed into CJO and required 3 kg to produce a liter CJO. Our observation found that CJO production cost was about 1000 IDR/L CJO excluding raw material (seeds). Currently, CJO is sold a price of 10,000 IDR/L. The value added resulted from CJO processing was 1000 IDR/kg seed (Figure 11).

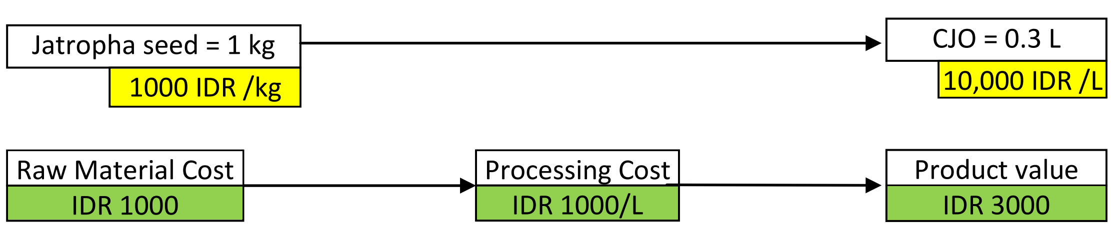


Figure 11. Value added resulted from processing jatropha seeds into CJO on a kg seed basis
Source: from survey and calculation results

Economic benefit of jatropha production can be optimized by using all jatropha waste such as jatropha cake to produce biogas and jatropha peel, wet cake, and sludge for compost (Figure 12). Assuming the price for simple organic fertilizer at around Rp.700/kg, our analysis on a hectare basis revealed a significant additional economic benefit resulted from optimum waste utilization (Table 11).

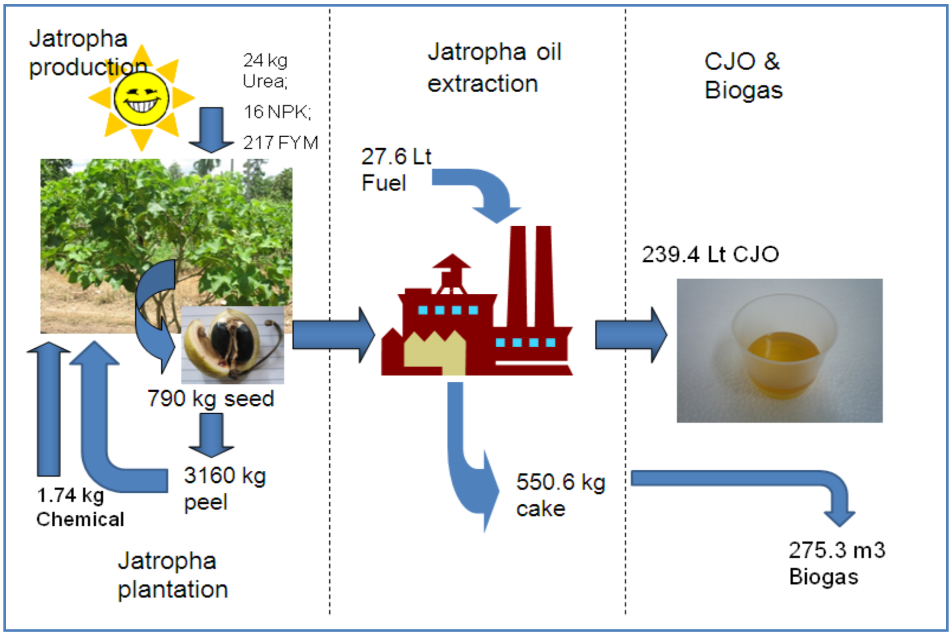


Figure 12. Material balance of Jatropha processing based on a ha of plantation
Source: from survey and calculation results

With CJO yield of 239.4 L/ha and CJO price of IDR.10,000 it can be showed that total revenue will be 4,781,938 IDR/ha. Therefore, the economic benefit is improved to be 1,453,569 IDR. This was not a bad economic activity given that jatropha is planted as intercropping.

Table 11. Costs and returns in production of CJO from one hectare jatropha production considering a maximum use of waste

ITEMS		QUANTITY	COST/ UNIT (IDR)	TOTAL (IDR)
Direct Costs	Seed input cost	790 kg	1,000/kg	790,000
	Labor cost	790 kg	1,000/kg	790,000
	Fuel	27.6 L	5,000/L	138,000
	Sub-Total			**1,718,000**
Overhead	Miscellaneous (helper, fees and local taxes, selling and administrative)			0

TOTAL COST				**1,718,000**
TOTAL OUTPUT, L CJO		**239.4**	**10,000**	**2,394,000**
NET PROFIT				**676,000**
BY PRODUCT	Jatropha peel (0.4 factor)	1264 kg	700	884,800
	Biogas from jatropha cake*	275.3 m^3	4200	1,156,260
	Solid/sludge fertilizer	550.6 kg	630	346,878
ADDITIONAL PROFIT				**2,387,938**
TOTAL PROFIT (IDR/Ha) from processing				**3,063,938**
TOTAL PROFIT (IDR/Ha) from farming and processing				**1,453,569**

**) 1 m^3 biogas is equivalent to 0.6 L kerosene*

3.B. SOCIAL IMPACT OF PRODUCTION AND PROCESSING OF JATROPHA

Our field study revealed some important social factor for Jatropha farmer depicted in Table 12.

Table 12. Social parameters on jatropha farmers in Way Isem, North Lampung

Item	Quantity
Number of population	1443
Number of family (NF)	361
Average age of dead people (year)	31
Income per capita (US$/year)	321.7
Number of illiterate people	44
Number of preschool pupils	0
Number of elementary school student	468
Number of junior high student	37
Number of senior high student	74
Number of diploma student	5
Number of university student	0

Life Expectation Index = $\frac{31-25}{85-25}$ = 0.100

Number of adult people = 2 * NF + HS + DS + US = 2(361) + 74 + 5 + 0 = 801

ALR (Adult Literacy Rate) = 100 % * (801 – 44)/801 = 94.5 %

ALI (Adult Literacy Index) = $\frac{ALR-0}{100-0} = \frac{94.5-0}{100-0}$ = 0.945

GEI = $\frac{584}{1443}$ = 0.404

EI (Education Index) =

2/3 (ALI) + 1/3 (GEI) = 2/3 (0.945) + 1/3 (0.404) = 0.7647

GDP Index = $\frac{\log(GDP_{pc})-\log(100)}{\log(40000)-\log(100)} = \frac{\log(321.7)-\log(100)}{\log(40000)-\log(100)}$ = 0.195

HDI = (LEI + EI + GDPI)/3 = (0.100 + 0.7647 + 0.195)/3 = 0.3534

It is revealed that HDI for the case of jatropha farmer was 0.3534 or 35.34 %. Again, the HDI for jatropha farmer was also far below the HDI for North Lampung in general. This implied that life quality, education, and income for the people in Way Isem were quite low. Therefore it is important for them to work hard to improve their life expectation and income as well. Government support to improve health quality by establishment local health center (Puskesmas) is also imperative.

If jatropha production and processing were assumed as additional activities and previous GDP was assumed equal to GDP of Lampung Province (734.78 US$), jatropha production and processing increased income per capita of farmers 38.9 US$. The jatropha production and processing increased GDP index from 0.195 to 0.342 and increased HDI about 13.8 % to 40.2. Even though still lower than HDI of North Lampung district, the jatropha production and processing activities was successfully to increase HDI, this indicated that jatropha production and processing activities biofuel production from jatropha and their waste utilization has positive impact to increased HDI.

The calculation and resulted GDI was tabulated in Table 13. It was revealed that Gender-related Development Index for jatropha farmers in the field of study was 0.351.

Table 13. Equally Distributed Index calculation along with resulted Gender-related Development Index for jatropha farming

Gender	LEI	EDI-LE	EI	EDI-E	GDPI	EDI-I	GDI
Female	0.0817	0.0993	0.7503	0.7726	0.1549	0.1877	**0.351**
Male	0.1250		0.7950		0.2352		

4.B. Environmental Impact of Production and Processing of Jatropha

Table 14 shows environmental effect of CJO production from jatropha started from plantation to waste treatment. On a basis kilo liter of CJO being produced, it can be demonstrated from Table 14, that total emission of CO_2 equivalent resulted from CJO production is 0.4374 ton per kilo liter CJO or 12.58.62 kg/GJ. CO_2 emission from plantation and jatropha processing was 59% and 82%, respectively (Figure 13). Waste treatment to produce biogas is a very good practice because it is able to reduce CO_2 emission by 41% of the total emission. In this case jatropha cake, waste from CJO processing, was anaerobically digested to produce biogas. The biogas was then utilized as fuel for kitchen stoves, replaced kerosene or woods. Our observation revealed that a family produced about one cubic meter biogas a day that is equivalent to 0.6 L kerosene or 3.5 kg woods.

Table 14. CO_2 emission during CJO production

Activity	Source	Unit	Quantity*)	CO_{2e} Emission	
				(kg/L CJO)	(kg/GJ)**
Plantation	Urea	Kg/ha	24	0.0920	2.6464
	NPK (15-15-15)	Kg/ha	16	0.0275	0.7914
	TSP (0-36-0)	Kg/ha	17	0.0087	0.2505
	Herbicide	Kg/ha	1.00	0.0721	2.0759
	Pesticide	Kg/ha	0.74	0.0588	1.6914

Processing	Diesel fuel	L/ha	27.6	0.3076	10.3012
Waste treatment	CH_4, utilized	M^3	178.9	-0.1797	-5.1707
TOTAL CO_2 EMISSION				**0.4374**	**12.5862**

**) based on a hectare jatropha production*
***) Heating Value of Jatropha Oil = 37.8 MJ/kg (Augustus, et.al., 2002)*

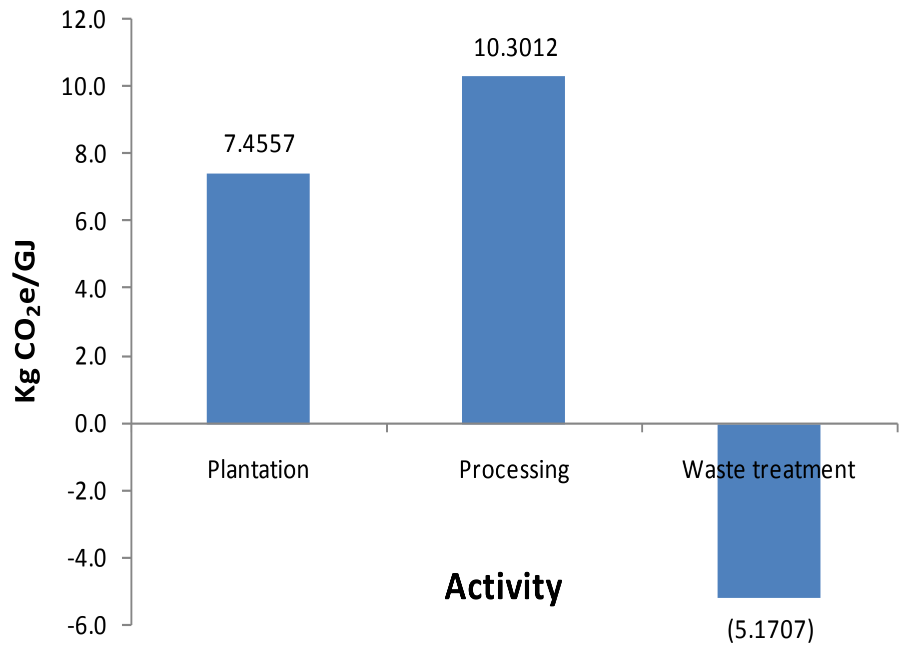


Figure 13. CO_2 emission from CJO production process.
Source: from survey and calculation results

Based on result of economic, social, and environmental impact calculation, an integration indicator of jatropha production and utilization can be described in Figure 14 below. Net Profit from production and utilization (thousand US$) was used as an economic impact indicator. As a social impact indicator, increment of HDI was calculated as a ratio of the improvement HDI due to biomass (Jatrpoha) production and utilization to original HDI. The ratio of CO_2 emission reduction from ethanol to gasoline production was used as an environmental indicator. Figure 14 clearly shown that production and utilization of jatropha as bioenergy feedstock give high impact on social and environmental aspects, due to increased of HDI and CO_2 emission reduction. From economic impact point of view, this activity is not interesting yet because give only little additional profit.

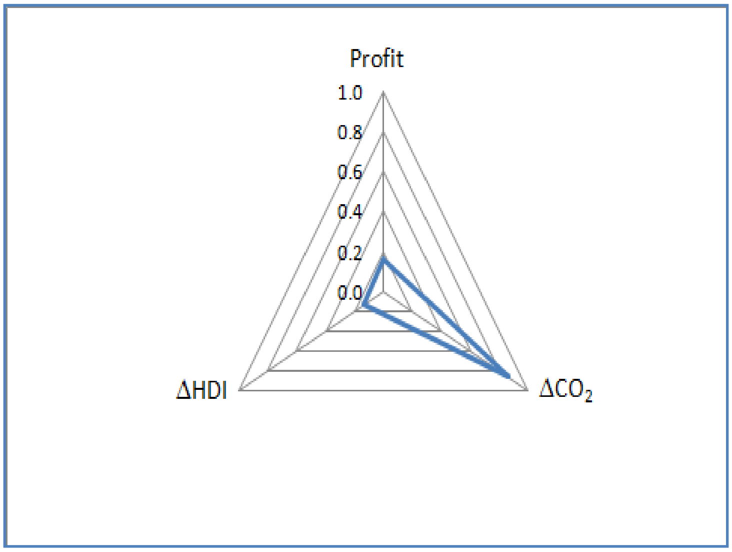


Figure 14. The change of integration indicator in a hectare basis due to CJO production and utilization (Profit is in thousand US$, other indicator are in unitless decimal).
Source: from survey and calculation results

5. CONCLUSION AND RECOMMENDATION

Guidelines to Assess Sustainability of Biomass Utilization in East Asia which established by ERIA Working Group on "Sustainability Assessment of Biomass Utilization in East Asia" (ERIA Research Project Report No.8-2) was successfully used as an assessment method for assessing the sustainability of ethanol production from cassava and CJO from jatropha as well as biogas generated from their waste in community level in term of social, economic, and environment point of view.

Cassava farmer received profit about 6,235,744 IDR/ha/year for contract farming system and 4,995,916 IDR/ha/year for non contract farming system. Processing cassava for bioethanol increased the value added of cassava about 950-1108 IDR/L bioethanol or about 146.6-171 IDR/kg cassava. Fluctuation of cassava price significantly affected to economic sustainability of bioethanol production.

Sustainability assessment of cassava utilization for bioethanol revealed that HDI for the case of cassava farmer was 0.542 or 54.2% with GDI of 0.5416 or 54.16%. This is far below the HDI of North Lampung in general. The low of HDI is strongly affected by GDP index, which determined by low GDP of cassava farmer. From environmental side, production of bioethanol was promoted the utilization of biofuel to substitute fossil fuel. If biogas from waste treatment is barely flared, CO_2 emission from ethanol production system is 0.2965 tCO_{2e}/kL ethanol (14.0491 kg/GJ). Almost two third of the CO_2 emission was released from power plant. Utilization of biogas in the power plant reduces the CO_2 emission to 0.2680 tCO_{2e}/kL ethanol or 12.6974 kg CO_{2e}/GJ. The utilization of biogas from wastewater treatment plant gives highest sustainable indicator from economic, social, and environmental point of views.

Jatropha farmer received benefit about 699,077 IDR/ha/year and profit about (-1,610,369 IDR/ha/year) from their jatropha farming system. It is very low benefit and not profitable. The utilization of jatropha waste has successfully increased their revenue will be 4,781,638 IDR/ha/year. Therefore, the economic benefit is improved to be 1,453,569 IDR/ha/year. This was not a bad economic activity given that jatropha is planted as intercropping. It should be pointed out that by planting jatropha as merely an additional activity the community is able to produce bioenergy for itself without any reduction on the income.

Sustainability assessment of jatropha utilization for CJO revealed that HDI for the case of jatropha farmer was 0.3534 or 53.34% with GDI of 0.351 or 35.1%. The HDI for jatropha farmer was much lower than the HDI for North Lampung in general. This implied that life quality, education, and income for the people in Way Isem were quite low. The low of HDI is strongly affected by GDP index, which determined by low GDP of jatropha farmer.

On a basis kilo liter of CJO being produced, it can be demonstrated that total emission of CO_2 equivalent resulted from CJO production is 0.4374 tCO_{2e}/kL CJO or 12.5862 kg CO_{2e}/GJ. CO_2 emission from plantation and jatropha processing was 59% and 82%, respectively. Waste treatment reduces the CO_2 emission by 41% of the total emission. In this case jatropha cake, waste from CJO processing, was anaerobically digested to produce biogas. The biogas was then utilized as fuel for kitchen stoves, replaced kerosene or woods.

Sustainability of cassava and jatropha utilization for bioenergy would be increased through utilization of waste or by product from each step of processing. The utilization of waste biomass increased gross value added and created new job, and decreased GHGs emission. Also, utilization of waste biomass from cassava and jatropha for biogas and biofertilizer reduced fossil fuel and chemicals fertilizer consumption, created clean energy sources, and made people in rural village easier to get energy and fertilizer. Development of close system in plantation and biofuel industry is very much recommended to increased the sustainability of soil, reduce environmental impact, and optimized social and economic benefit.

5.1. Policy Recommendations

Guidelines to Assess Sustainability of Biomass Utilization in East Asia which established by ERIA Working Group on “Sustainability Assessment of Biomass Utilization in East Asia” (ERIA Research Project Report No.8-2) was successfully used as a assessment method for assess the sustainability of ethanol production from cassava and biodiesel from jatropha as well as biogas generated from their waste in community level. Implementation of this assessment method at macro level, such as province level, should be evaluated. Output of the above studies could be useful for sustainability assessment at national or East Asian region.

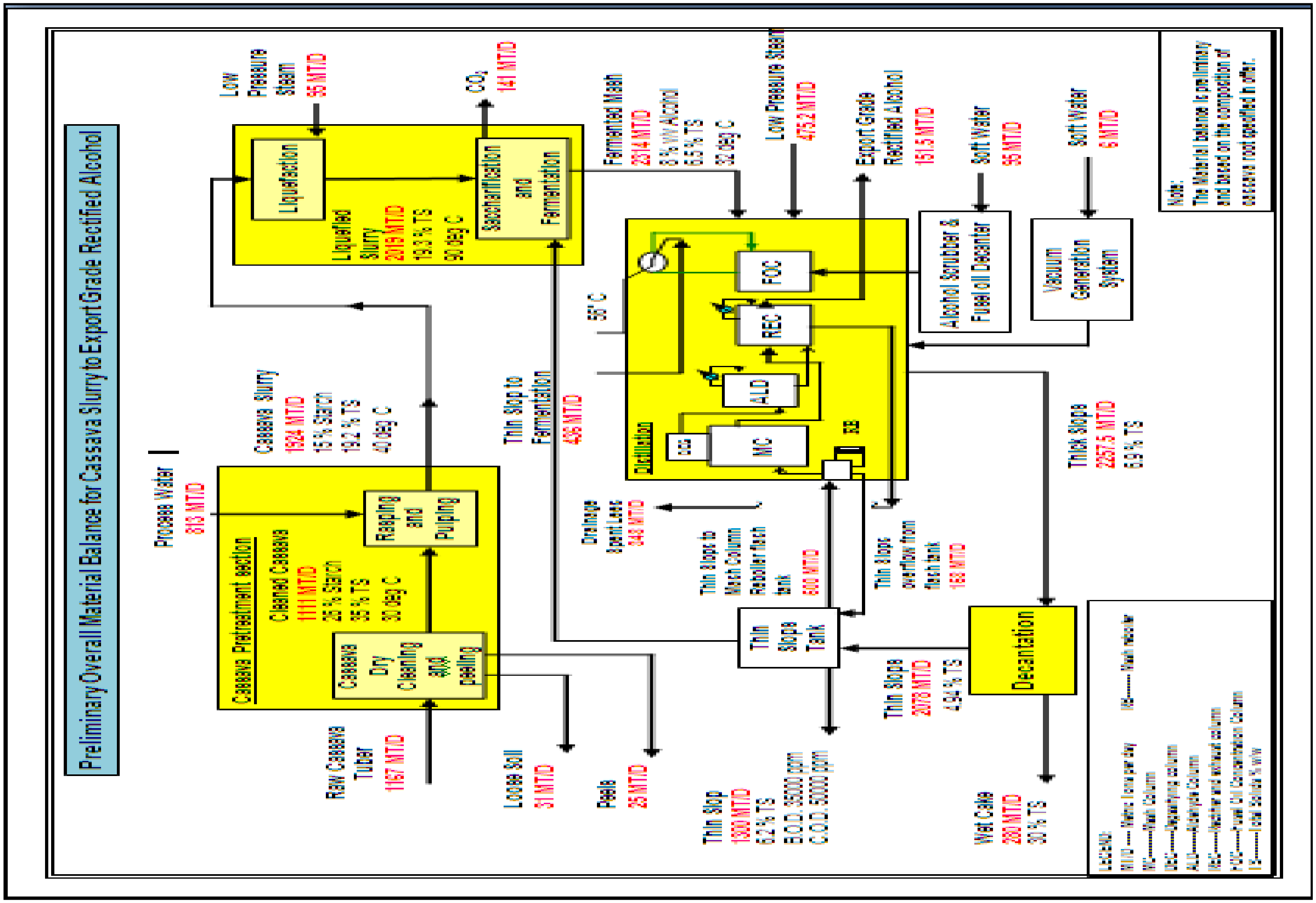
Dissemination of Guidelines on Sustainability Biomass Utilization to other East Asian Countries is needed. Experiences in the assessment of sustainability in the pilot studies can serve as guide in the efforts of other East Asian Countries and other international organization such as GBEP and ISO in biomass assessment.

Costs and returns in cassava production in North Lampung for partnership and non partnership farmers.

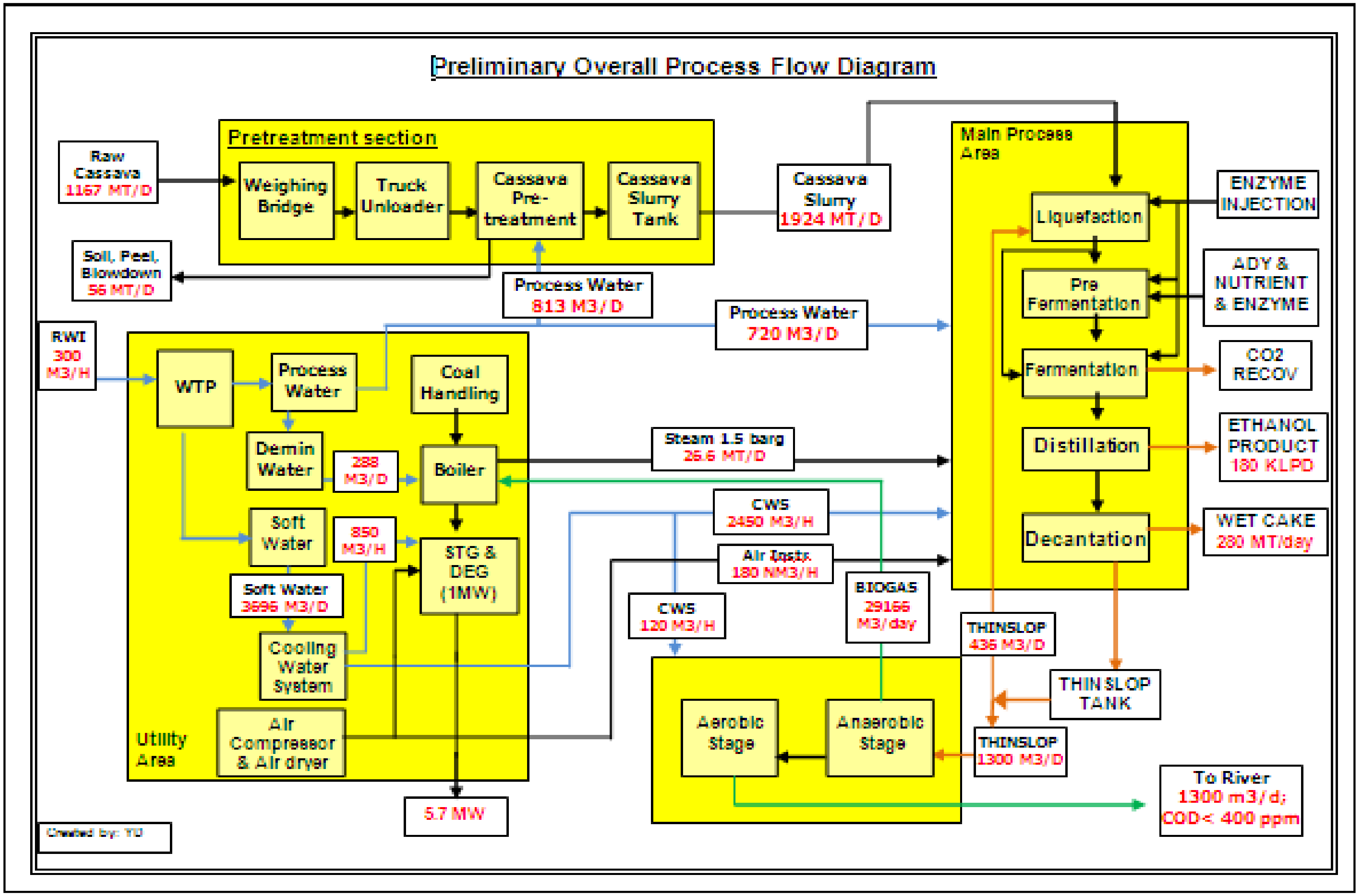
Item	Unit	Partnership	Non partnership
GENERAL:			
* Average plantation area	Ha/family	1.159	1.231
* Average yield per family	kg	33,012.5	30,375
	Kg/Ha	28,490	24,670
* Cassava price	IDR/kg	439.25	449.75
* Average Revenue per family	IDR	14,526,250	13,674,500
	IDR/Ha	12,536,138	11,106,193
INCURRED COST:	IDR/Ha	4,246,381	4,791,415
* Man power (outside family)	IDR/Ha	303,776	653,706
* Fertilizer and Compost	IDR/Ha	920,324	828,772
* Chemicals	IDR/Ha	103,020	25,178
* Machinery	IDR/Ha	294,498	478,172
* Harvesting + Transportation	IDR/Ha	1,981,338	1,847,716
* Tax	IDR/Ha	16,618	12,244
* Rafraction	IDR/Ha	626,807	945,628
ACCOUNTED COST:	IDR/Ha	2,054,013	1,364,112
* Man power (inside family)	IDR/Ha	407,551	293,604
* Seed	IDR/Ha	154,606	167,766
* Land rent	IDR/Ha	1,447,357	865,990
TOTAL COST	IDR/Ha	6,255,896	6,110,277
BENEFIT	IDR/Ha	8,334,255	6,360,028
PROFIT	IDR/Ha	6,280,242	4,995,916

Costs and returns in jatropha production in Way Isem, North Lampung Lampung

Item	Unit	Value
GENERAL:		
* Average plantation area per family	Ha	0.95
* Average yield per family (dry seed)	Kg/Ha	790
* Jatropha seed price	IDR/kg	1000
* Average revenue per family	IDR/Ha	790,000
INCURRED COST:	IDR/Ha	133,298
* Man power (outside family)	IDR/Ha	0
* Fertilizer	IDR/Ha	133,298
* Machinery	IDR/Ha	0
* Tax	IDR/Ha	0
ACCOUNTED COST:	IDR/Ha	2,242,349
* Man power (inside family)	IDR/Ha	2,185,752
* Seed	IDR/Ha	1,029
* Chemicals	IDR/Ha	80,290
TOTAL COST	IDR/Ha	2,400,369
BENEFIT	IDR/Ha	699,077
PROFIT	IDR/Ha	(1,610,369)



Source:obtained from the company surveyed.



Source:obtained from the company surveyed.

PAC DOSING

CAUSTIC DOSING

CLHORIN DOSING

PROCESS WATER DISTRIBUTION

PROCESS WATER DISTRIBUTION

STATIC MIXER

RAW WATER

CLARIFIER

SAND FILTER

ACF FEED PUMP

PROCESS WATER STORAGE TANK

ACF TANK

LAGOON (SCOPE BY OWNER)

TREATED WATER TANK

RO PUMP

HCL DOSING

DEMIN WATER DISTRIBUTION

RO MODULE Cap. 12 m^3/HR

INTERMEDIATE TANK

MIXBED PUMP

MIXBED SYSTEM

REGEN PUMP

DEMIN WATER TANK

DISTRIBUTION PUMP

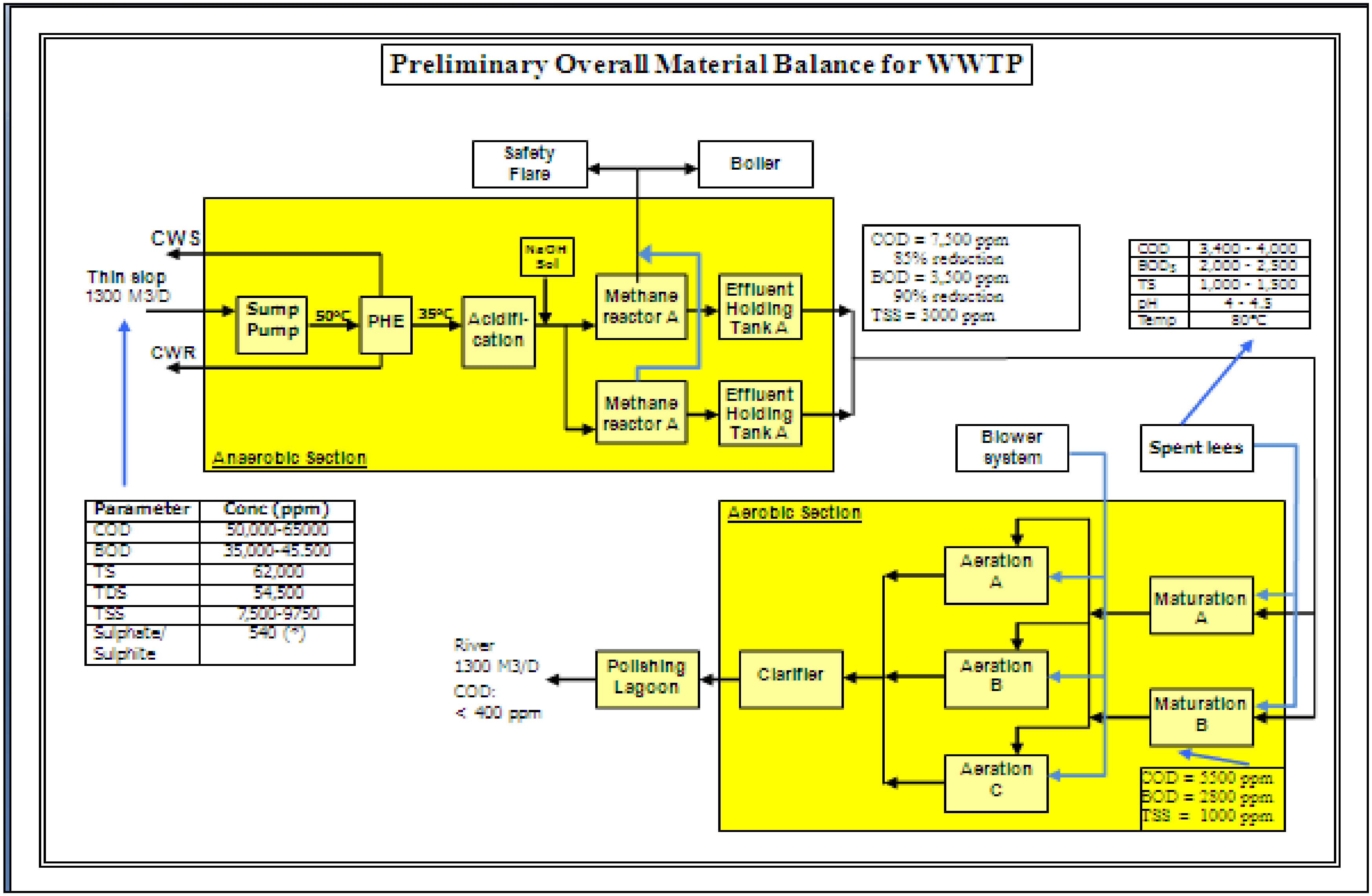
COMPRESSOR

NaOH DOSING

Produk WTP :

1. Clear Water
2. Process Water
3. Soft water
4. Demin Water

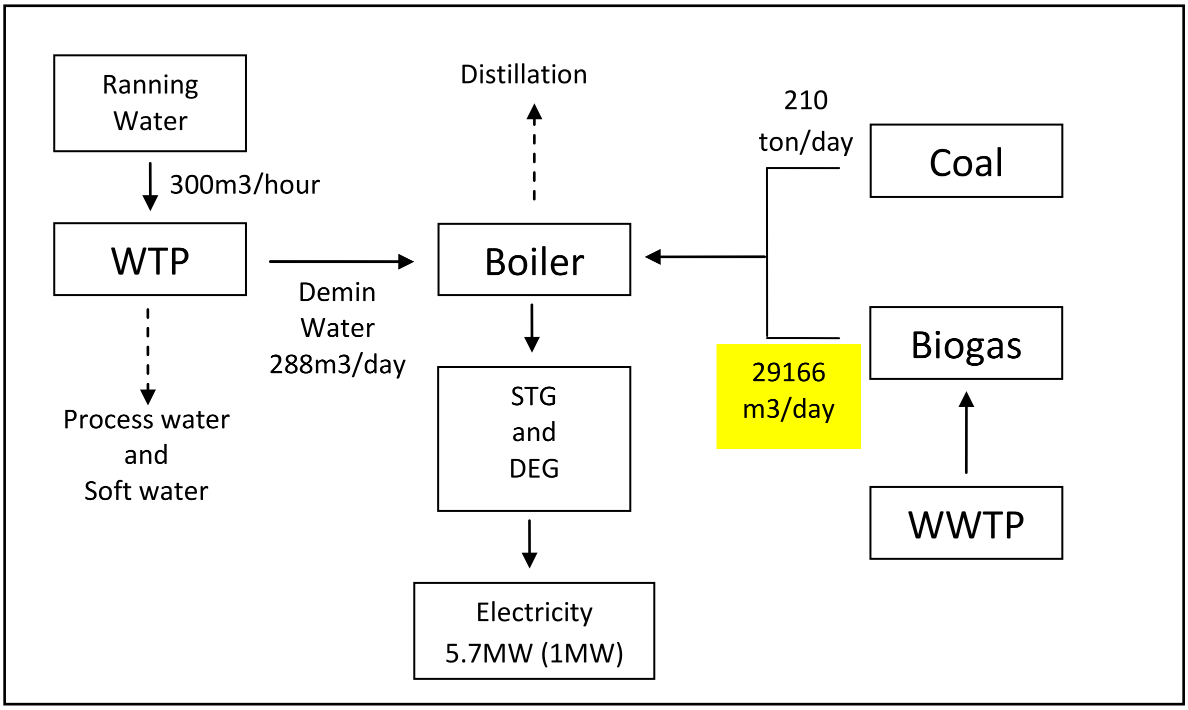
Source:obtained from the company surveyed.



Source:obtained from the company surveyed.

Utility Area

2010.1.30



Boiler

Steam Capacity: 40t/hours

Pressure: 40bar.

STG (*Steam Turbine Generator*)

Capacity:5.7MW

Used to generate electricity and low pressure steam for main process.

DEG (*Diesel Engine Generator*)

Capacity: 1MW (from diesel)

Used to start up, shutdown and emergency back up.

Source:obtained from the company surveyed.

Conversion factor used to calculate emission in this report*

Carbon dioxide emissions from fossil fuels

Primary fuel	At point of fuel combustion[a] (kg C/GJ)	Due to production and transport (kg C/GJ)	Total from fuel use (kg C/GJ)
Primary fuel			
Motor gasoline	18.34	2.93	21.27
Distillate fuel (diesel)	18.92	3.03	21.95
Residual fuel	20.19	3.23	23.42
Liquified petroleum gas	16.11	2.58	18.69
Petroleum coke	26.41	4.23	30.64
Naphtha	18.84	3.01	21.85
Coal	24.43	0.73	25.16
Natural gas	13.72	0.82	14.54
Waste fuel			
Tires	22.19	0.07	22.27
Wood	25.32	0.12	25.44

Carbon dioxide emissions from generation of electricity

Primary fuel	At point of fuel combustion (kg C/kWh_e)	Due to production and transport (kg C/kWh_e)	Total from fuel use (kg C/kWh_e)
Coal	0.274	0.008	0.282

Carbon dioxide emissions from pesticides (kg C/ton)

Pesticides	
Herbicide	4702.38
Insecticide	4931.93
Fungicide	5177.52

*) West TO and Marland G. (2002). A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: comparing tillage practices in the United States. *Agriculture, Ecosystems and Environment* **91**: 217–232.

Carbon dioxide emissions from fuel combustion (kg-CO_2/GJ)**

Primary fuel	Extraction and Processing	Transport	Refining	Emission Factor	Total
Diesel fuel	3.7	0.9	8.6	73.2	86.4
Gasoline	3.6	0.9	7.0	73.3	84.8

***) RTFO*

Carbon dioxide emissions from synthetic fertilizers *)**

Fertilizer	**Emission factor (kg CO2e/ton)**
Nitrogen (N)	1,991
Phosphate (P_2O_5)	340
Potassium (K_2O)	408

****) IPCCC, 2006*

Integration indicators for cassava-based ethanol production

Indicators	**Biogas**		
	Flared	**Vented**	**Used**
Partnership Farmer			
Profit (x 1000 US$)	1.214	1.214	1.644
Δ CO2	0.83	-0.05	0.85
Δ HDI	0.035	0.035	0.035
Non Partnership Farmer			
Profit (x 1000 US$)	1.079	1.079	1.509
Δ CO2	0.83	-0.05	0.85
Δ HDI	0.03	0.03	0.03

Integration indicators for CJO production

Indicators	**Value**
Profit (x 1000 US$)	0.158
Δ CO2	0.86
Δ HDI	0.138

Chapter 10

Assessment of Sustainability of Biodiesel Production Using Jatropha and other Tree Oils in India

National Ecology and Environment Foundation (NEEF), Mumbai, India

September 2010

This chapter should be cited as
National Ecology and Environment Foundation (NEEF) (2010), 'Assessment of Sustainability of Biodiesel Production using Jatropha and other Tree Oils in India', in ERIA WG on 'Sustainability Assessment of Biomass Utilisation in East Asia' (eds.), *Sustainability Assessment of Biomass Energy Utilisation in Selected East Asian Countries*. ERIA Research Project Report 2009-12, Jakarta: ERIA. pp.160-270.
ERIA. pp.103-109..

ASSESSMENT OF SUSTAINABILITY OF BIODIESEL PRODUCTION USING JATROPHA AND OTHER TREE OILS IN INDIA

Prepared by
National Ecology and Environment Foundation (NEEF)
Mumbai, INDIA

ACKNOWLEDGEMENTS

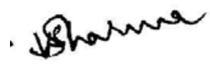
This report contains the outcome of a Pilot Study on "Assessment of Sustainability of Biodiesel Production using Jatropha and other Tree Oils in India," sponsored by the Economic Research Institute for ASEAN and East Asia (ERIA), Jakarta, Indonesia.

We are grateful to the ERIA and its officers Mr. Hidetoshi Nishimura, Executive Director and Mr. Koshi Yamada, Financial Director for supporting this study. We sincerely thank Dr. Masayuki Sagisaka, Leader, Material & Energy Sustainability Assessment Group, Research Institute of Science for Safety & Sustainability, National Institute of Advanced Industrial Science and Technology (AIST), Japan, for guiding us throughout the project. Unfortunately, during this project, Dr. Sagisaka faced some health problems but during his absence the role of Dr. Yuki Kudoh, Dr. Tomoko Konishi and Dr. Yoshie Murata of AIST has been commendable. We acknowledge the help of concerned staff members of ERIA, including Mr. Shinya Kawamura, Deputy General Manager, Mr. Sho Oishi, Senior Financial Officer for financial matters, and Mrs. Rahayu Dhini, Ms. Maria Anastasia and Mr. Hanif Rusdian for logistics.

Primary data and information was collected through field visits of various organisations. In this regard, cooperation of Mr. Srinivas Ghatty and Mr. Rajeshwar Rao of Tree Oils India Pvt. Ltd., Zaheerabad; Mr. C. S. Jadhav of Nandan Biomatrix Pvt. Ltd. Hyderabad; and Mr. Brahmanand Reddy of Southern Online Biotechnologies India Ltd., Nalgonda is highly appreciated. We also acknowledge the help of Dr. Willima Dar, Director General, Dr. S. P. Wani and Mr. Murali Sharma of ICRISAT, Patencheru, for sharing their research on the biodiesel. Role of Shri Sandeep Chaturvedi, President of BDAI and Shri US Pandey, Secretary of BDAI in the project is highly appreciated. Local team members of NEEF, namely, Dr. Ramanand Shukla, Ms.

Purnima Jhariya, Ms. Rituja Mokal, Mr. Narendra and Mr. Shone helped in data collection and report preparation.

During the meetings of the working group (WG) of the ERIA, many experts gave useful comments and suggestions, which helped in improving the report. We express our thanks to WG members including Dr. S. Chen, of Environment & Bioprocess Technology Centre, SIRIM, Malaysia; Dr. J.C. Elauria of College of Engineering & Agro-Industrial Technology, University of the Philippines, The Philippines; Dr. Shabbir Gheewala of JSGEE, University of Technology, Thonburi, Thailand; Dr. Yucho Sadamichi of Life Cycle Management Centre, Chiang Mai University, Thailand, Dr. Jane Romero of IGES, Japan, Dr. Khoo Hsien Hui of Institute of Chemical and Engineering Sciences, Agency for Science, Technology and Research (A*STAR), Singapore. Dr. Vinod K. Sharma, WG members of ERIA and Professor of Indira Gandhi Institute of Development Research, Mumbai, India, provided guidance in the field work for data collection, management and analysis and report preparation.



Sangeeta V. Sharma
Team Leader, India Pilot Study
ERIA-AIST-NEEF Project

ABBREVIATIONS AND ACRONYMS

1 Lakh (or Lac)	=	100,000
10 Lakhs (or Lacs)	=	1 Million
1 Crore (or 100 Lacs)	=	10 Millions
47 INR or Rs. (Indian Rupees)	=	US$ 1

AIC	Agriculture Insurance Company of India Limited
AIST	National Institute of Advanced Industrial Science and Technology
AP	Andhra Pradesh (an Indian State)
BDAI	Biodiesel Association of India
BIEZ	Bio Investment Eco Industrial Zone
BIEP	Bio Investment and Eco-Industrial Park
BREL	Bharat Renewable Energy Limited
CACP	Commission for Agriculture Cost and Prices, India
CCI	Chemical Construction International (P) Ltd.
CER	Certified Emission Receipts
CDM	Clean Development Mechanism (CDM) scheme.
ERIA	Economic Research Institute for ASEAN and East Asia
EIA	Energy Information Agency, USA
GDI	Gender-related Development Index
GDP	Gross Domestic Product
GEI	Gross Enrolment Index
GHI	Green and Happiness Index, Thailand
GoI	Government of India
HDI	Human Development Indicator
HDR	Human Development Report
ICRISAT	International Crops Research Institute for Semi-Arid Tropics

IEA	International Energy Agency
IREDA	Indian Renewable Energy Development Agency
JIC	Jatropha Information Center
LEI	Life Expectancy Index
MLQI	Malaysian Quality of Life Index
MNRE	Ministry of New and Renewable Energy Sources, GoI
MoEF	Ministry of Environment and Forests, GoI
MoP&NG	Ministry of Petroleum and Natural Gas, GoI
MoU	Memorandum of Understanding
MPCE	Monthly Per Capita Expenditure
MT	Million Tones
Mha	Million Hectares
NNMB	National Nutrition Monitoring Board, India
NBM	National Biodiesel Mission, GoI
NBL	Nandan Biomatrix Limited
NBL	Naturol Bioenergy Limited, India
NPC	Nursery Production Center
NREGS	National Rural Employment Guarantee Scheme
NSS	National Sampling Survey, India
PCRA	Petroleum Conservation and Research Association, India
P4	Public Private Panchayat Partnership
PPAC	Petroleum Planning and Analysis Cell, New Delhi.
SDI	Social Development Indicator
SBTL	Southern Online Bio Technologies Limit
TBOs	Tree Borne Oilseeds
TOIL	Tree Oils India Limited

EXECUTIVE SUMMARY

India's crude oil imports are continuously rising, which are not only increasingly the financial burden on national economy but also threatening country's energy security. Indian oil marketing companies are incurring a huge financial loss by providing a subsidy to end users of petroleum products. Production of biofuels, particularly biodiesel, which can be blended with the fossil fuel, may provide some relief on above fronts. With this objective, the government of India has initiated production of biodiesel from various Tree Borne Oils such as Jatropha and Pongamia on a large scale. Being an agro-based industry, biomass derived biodiesel would also generate employment in rural areas and be a source of additional income to the farmers. Thus, energy security and employment generation are two main reasons for promoting biodiesel production in India.

This pilot study is carried out in the state of Andhra Pradesh and is based upon the data and information collected from three companies involved in plantation of Jatropha and other oil trees, research and development activities on Jatropha, biodiesel production using TBOs and other feed stocks. Estimation of economic, environmental and social impacts during various stages of biodiesel production was carried out using primary data and information obtained from the field survey of these companies and other stakeholders affected by projects initiated by the companies. Secondary data and information from the literature and elsewhere were also used.

The results of the study indicate that presently none of the three companies studied is able to generate enough feedstock of tree born oils, which can meet the demand of the biodiesel production by the company. Economic analysis indicates that cost incurred during the cultivation stage is much higher than the revenue generated, and hence, concerned companies are making a financial loss during this stage. On environmental fronts, companies themselves have not been able to generate data for GHG or any other type of emissions but have future plans to analyse the net carbon savings from their activities and expect some additional revenue from carbon credits. Based upon the limited data available and use of information from secondary sources, GHG saving potential by the companies during the life cycle of the biodiesel production has been estimated and preliminary results show a net carbon saving potential in the process.

On social fronts, several positive results are visible during various stages of biodiesel production. Both during oil tree cultivation and biodiesel production phases a good employment is generated in the surrounding localities. The rise in income has resulted in more spending on food, health and education and rising in the living standards of people affected by the project initiated by the companies. Estimation of various social development indicators (SDIs) such as the HDI, GDI and other SDIs indicates an overall improvement in the locality.

It is suggested that biodiesel production using tree borne oils could prove a boon for the country as it has potential to meet all three aspects of sustainability, viz., economic, environmental and social. However, many steps are required to make the process sustainable in the long run. Farmers and companies will be attracted towards Jatropha cultivation and biodiesel production from TBOs, respectively, if the purchase price Jatropha seeds from farmers and biodiesel from companies are realistic and provides them a good return on their investment. Given the different agro-climatic conditions of various regions in the country, an intensive research on Jatropha and other oil trees is required so that the varieties of oil trees suitable for a particular condition could be developed. Research on increasing yield of seeds and oil content of seeds may be accelerated as it would improve the economic viability at the cultivation of oil trees.

The scale of the pilot study undertaken in this research, both in spatial and temporal terms, was too small to make some meaningful projections at state, region on country level. It is suggested that a large scale study for a longer period, say, for a duration of 3 to 5 years, and covering a larger area, say, a whole state or region covering several stages may be taken up in future. This would ensure an accurate assessment of the long term impacts, and hence, sustainability of biodiesel production in India

1. INTRODUCTION

1.1 Background

Promotion of bioenergy in India is aimed at achieving energy security and gaining from various socio-economic and environmental benefits of this renewable energy. India is endowed with vast natural and environmental resources, which possess a huge potential for renewable energy. Encouraging the use of biomass and other natural resources would help India achieve its growth targets with much lesser negative impact on society and the environment. Biodiesel and bioethanol are two major liquid biofuels that are currently being promoted in the country. Other forms of bioenergy such as power from biomass thermal gasification and biogas from waste decomposition are also being promoted. Development of biofuels may satisfy growing energy needs of the country by supplying clean, economic and eco-friendly fuels. Among the liquid biofuels, as diesel forms a major portion of fuels for rail and road transport, the production of biodiesel is considered at a much larger scale than any other fuel.

In a country like India, where a major part (more than 70%) of fossil fuels are being imported, promotion of biofuels makes both economic and ecological senses. Rising crude oil prices are putting extra financial burden on the economy and their increased use is also deteriorating the environmental quality in the country. Both of these problems, could be tackled to a great extent, if biofuels are blended with the fossil fuels and used in transportation and other activities.

Biodiesel is a fatty acid of ethyl or methyl ester and produced by transesterification of vegetable oils, both edible and non-edible, and can be used in vehicles up to 20% blending with fossil diesel without any modifications. Biodiesel is derived from various biological sources such as seed oils (e.g., soybeans, rapeseeds, sunflower seeds, palm oil, Jatropha seeds), waste cooking oils and animal fats. In most of the developed and even in some developing countries, edible oils have been used as raw material for producing biodiesel. But, in India, due to high cost and demand of edible oils, only non-edible oils have been proposed for production of biodiesel. Further, due to increased food demand of the growing population, diversion of agriculture land for biofuel crops is not possible in India, and hence, focus is on growing non-edible oil trees on waste lands.

The process for production of biodiesel is country specific and depends upon the availability of raw material, technology and skilled manpower in the country. For example, in the United States, a majority of biodiesel is produced from soybean oil. In recent years, the sales volume for biodiesel in the United States has increased dramatically from about 2 million gallons in 2000, to 75 million gallons in 2005, to 250 million gallons in 2006 (National Biodiesel Board, 2007). In European countries (especially in Germany), biodiesel is produced primarily from rapeseeds.

India has a large number of species yielding edible and non-edible oils. The Botanical Survey of India has identified 36 non-edible oil-yielding varieties of plants but most used plants for production of biofuels are Jatropha curcas and Pongamia pinnata. The estimated potential for tree borne oil seeds (TBOs) in India is 50 lakh tonnes annually of which only about 10% is exploited (MoA, 2006).

Biodiesel in India is produced by the transeterification of vegetable oils and since the demand for edible vegetable oil exceeds the supply, non-edible oil from Jatropha Curcas, Pongamia Pinnata and some other tree oils is being promoted as main feedstock. Although the demand for diesel is five times higher than the demand for petrol, in comparison to mature ethanol industry, the biodiesel industry is still at its early stage in India. The GoI has formulated an ambitious National Biodiesel Mission (NBM) to meet 20 per cent of the country's diesel requirements by the years 2011-2012.

This pilot study focuses on "Assessment of sustainability of biodiesel using Jatropha and other tree oils in India." Through a case study of biodiesel production from Jatropha and other oil seeds, an estimation of economic, environmental and social Impact is undertaken. The study is being supported by the Economic Research Institute for ASEAN and East Asia (ERIA), Jakarta, Indonesia, and assisted by an expert work group (WG) of the ERIA. The WG consists of experts and researchers form various countries in the East Asian region. It is a part of the larger project being coordinated d by the AIST, Japan in four countries viz., India, Indonesia, The Philippines and Thailand. The Indian pilot study includes detailed study of three sites in the state of Andhra Pradesh. Two tree oil plantation farms situated near Zaheerabad town in Medak district and a biodiesel plant located in Nalgonda district were selected as case studies. More details of these sites are given in the subsequent sections.

1.2 Objectives

The objective of this research is the "Assessment of Sustainability of Biodiesel Production using Jatropha and other Tree Oils in India." To achieve this objective, a pilot study was conducted at micro level in the state of Andhra Pradesh in India. Data and information were collected through field surveys of three companies involved in Jatropha cultivation and biodiesel production. A questionnaire, prepared for the purpose of survey of all stakeholders (farmers, labourers, company owners producing biodiesel and users of biodiesel) was used to gather information and data. Concerned stakeholders were interviewed through various modes such as personal interaction of stakeholders by the field team, telephonic, email and postal responses. Based upon the responses from various stakeholders, the economic, environmental and social impacts of biodiesel production were estimated. Due to limitation of the funds and time, it was not possible to conduct a comprehensive life cycle assessment, and hence, impacts were estimated during the limited life cycle of biodiesel production only.

1.3 Methodology

Broadly, the methodology involved in assessment of three major aspects of sustainability, viz. economic, environmental and social, used the internationally accepted norms. In particular, the methodology followed in this study uses the guidelines developed by the experts work group (WG) members of the ERIA. For example, for assessment of social aspect, Human Development Indicator (HDI), developed by the UNDP, has been used as the main indicator of social development. The UNDP method uses three measures to calculate HDI, 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 natural logarithm of gross domestic product (GDP) per capita at purchasing power parity (PPP) in US dollars.

But it was observed by the WG that while HDI may be a good index for inter-country comparison, some aspects of social development may not be captured it. Hence, it was proposed that alongwith the estimation of HDI, some other forms of social development indicators (SDIs) such as increase in living standard, access to basic necessities, spending on health and education, etc. may also be necessary. Similarly, for assessment of economic and environmental aspects, estimation of gross value added (GVA) and savings in the green house gases (GHG), respectively, have been used. Details of the methods used for analysis are given in subsequent sections.

1.4 Coordinating Organisations

AIST

The National Institute of Advanced Industrial Science and Technology (AIST) started working as an independent administrative institution in April 2005 with a status of non-government affliliation. Staff members and researchers of AIST are no longer government officers, so diverse employment patterns and work styles are available. This allows each researcher to work in a manner that brings out his/her best, which in turn, will promote research activities.

The fundamental goals of the AIST are as follows:

- To improve our society by advancing industrial science and technology in Japan
- To strengthen the international competitiveness of the Japanese industry and
- To achieve a sustainable society.

Since its establishement, AIST has worked diligently on promoting an effective research methodology for industrial science and technology and has developed the concept of "Full Research." This system allows researchers from different backgrounds to solve specific research issues.

AIST plays the role of a mediator, an innovation hub, to bring together academia and industry through the integration of human resources, systems, and organizations. AIST advances Full Research through the multilayered network of research sectors, regions, and countries, as well as among industry, academia, and government. More details of the AIST are available at (http://www.aist.go.jp/).

The ERIA

In its "Global Economic Strategy" released in April 2006, Japan's Ministry of Economy, Trade and Industry (METI), in a bid to further enhance economic integration in East Asia, stressed the importance of the creation of an institute that can function like an Asian OECD. In line with this, Japan made a proposal at the Second East Asia Summit held in Cebu in January 2007 to establish the Economic Research Institute for ASEAN and East Asia (ERIA). The

Institute for Developing Economies (IDE) played a key role in ERIA's creation, through conducting joint surveys with foreign research institutions and universities, and disseminating survey results through seminars and publications. ERIA aims at intellectually contributing to the regional efforts for East Asian Economic Integration in wide-ranging policy areas from Trade/Investment to SMEs, Human Resource development, Infrastructure, Energy, etc. ERIA's main task is to provide the policy analyses and recommendations to Leaders/Ministers in strong partnership with the ASEAN Secretariat and existing research institutes. Capacity Building aimed at strengthening policy research capacities especially in the less developed countries is another important issue for ERIA. More details of ERIA are available at (://www.eria.org/).

NEEF

National Ecology and Environment Foundation (NEEF) was established in 1997 as a not-for-profit, non-governmental organization (NGO) and a public trust with its head office at Mumbai. NEEF has collaborative agreements with several organizations in other parts of the world including Australia, Europe, Japan and USA. Through promotion of activities of ISLCA, NEEF contributes to the Life Cycle Initiative of the United Nations Environment Programme (UNEP). The Foundation has been promoted by well-known experts in the fields of engineering, science, and humanities and has a wide network of its affiliates, which includes Centre Heads, Consultants, Life-Members and Volunteers. The NEEF provides a neutral forum, where all viewpoints of the environmental management and development issues i.e. technical, scientific, economic, social, and political can be addressed. More details of NEEF are available at (http://www.neef.in).

2. BIODIESEL: FACTS AND FIGURES

According to the U.S. Energy Information Administration and the International Energy Agency, fossil fuels will continue to provide a major part, about eighty percent, of global energy supplies and demand for liquid fuels will increase by more than fifty percent in the year 2030. An assessment by IPCC indicates that the global oil demand will rise from 75 million barrel per day in the year 2000 to 120 million barrel per day in 2030. Almost three quarters of this increase in demand will be from the transport sector and oil is going to remain the fuel of choice in road, sea and air transportation. This has spurted the demand for biomass derived biofuels and biodiesel and ethanol have emerged as major transport fuels. As the demand for diesel is much more than the petrol, production of biodiesel is being given more importance than ethanol, globally.

2.1 Biodiesel at Global Level

In view of the above, biomass derived fuels (BDF) such as biodiesel are being promoted worldwide. Various reasons for large scale promotion of BDFs are energy security from fluctuating fossil fuel prices, environmental benefits of reduced emissions, and large scale generation of employment in rural areas. Biodiesel can be blended with conventional diesel fuel in any proportion and used in diesel engines without significant engine modifications. Biodiesel can be derived from various biological sources such as seed oils (e.g., soybeans, rapeseeds, sunflower seeds, palm oil, Jatropha seeds), waste cooking oils and animal fats, etc. However, the process for production of biodiesel is country specific and depends upon the availability of raw material, technology and skilled manpower available in the country.

For promoting biodiesel, local levels of taxation and national tax exemptions have lead to different marketing decisions, for instance use as a heating oil in Italy, a 5% blend in fossil diesel in France, a 20% blend and 100% neat in the US, and 100% use in Austria and Germany targeting the environmentally-sensitive areas such as water protection areas or smog-risk cities. In 2004, the US signed into law a bill containing the first biodiesel tax incentive- a provision that is expected to increase domestic energy security, reduce pollution and stimulate the economy. In countries like Austria, France, Germany, Italy, Malaysia, Nicaragua, Sweden, and the US, biodiesel activities have led commercial projects. It is reported that global biodiesel demand will rise from 5 billion gallons in 2009 to 14.4 billion gallon in 2015, in volume terms, and from 7.5 billion US$ in 2009 to 43.2 billion US$ in 2015, in value terms (ALTP, 2010). Biodiesel production is rapidly growing in Europe and the United States and in many Asian countries.

Different countries use various raw materials for biodiesel production such as palm oil, coconut, jatropha seeds, etc. Some of the feed stocks used in various countries/ region of the world are listed in Table 2.1. Selection of raw material mainly depends upon the sustained availability and price of oil seeds.

Table 2.1: Global Feedstocks for Biodiesel Production

Country/Region	Feedstock
USA	Soybeans
Europe/EU	Rapeseed, Sunflower
Africa	Jatropha
India	Jatropha, Pongamia
Malaysia / Indonesia	Palm
Philippines	Coconut
Spain	Linseed Oil
Greece	Cottonseed

Source : ALTP(2010)

2.2 Biodiesel in India

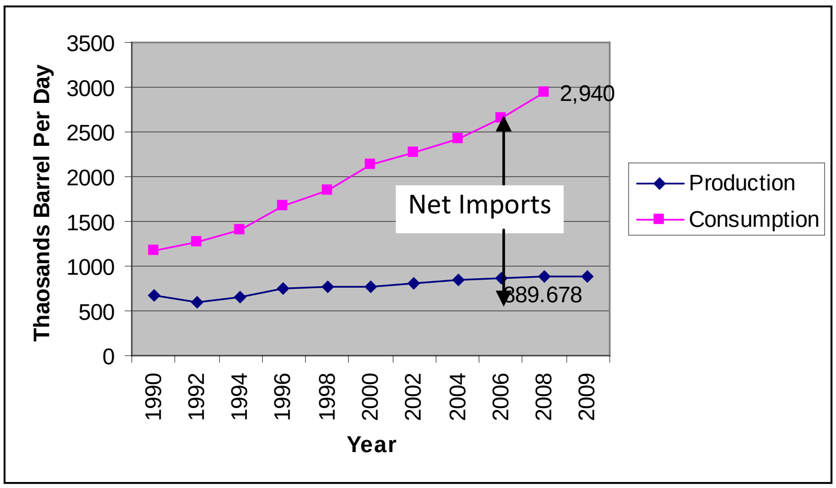
In India, biodiesel is produced by the transeterification of vegetable oils and since the demand for edible vegetable oil exceeds the supply, non-edible oil from Jatropha Curcas, Pongamia Pinnata and similar other tree oils is being promoted as main feedstock. Policies of Government of India are promoting production of biodiesel using Jatropha, and therefore, many public and private companies have started cultivating Jatropha plantation in different parts of the India. The GoI recognizes the potential of biofuels, which can offset the country's energy and transport needs and also offer social benefits in terms of creating significant rural employment. The National Biodiesel Mission has introduced 5% blend of biodiesel, which may gradually increase to 20% in 2011-12. In order to achieve this through domestic production, the government hopes to bring a minimum of 2.19 million hectares under plantation by oilseed feedstock in 2006-7, rising to 11.2 million hectares by 2011-12. Tax incentives for the production and use of biodiesel and guaranteed minimum purchase prices by the state oil companies for all biodiesel products are being considered (IBFC, 2008).

Recently, the GoI has deregulated the price of diesel and other petroleum products (announced on June 25, 2010). In the free market, this may increase the price of these products. However, this may be a good opportunity to promote the BDFs in the country in which production of biodiesel may play a major role in the Indian economy.

Production and Consumption

India is highly dependent on imports of fossil fuels and as much as more than 70% of total consumption of petroleum products is being imported. This results in a large amount of foreign exchange spending on such imports and also creates energy insecurity. As depicted in Figure 2.1, there is a huge gap (about 76%) in demand and in-house supply of oil consumption in India (EIA, 2008). This is responsible for a large amount of net imports and foreign currency spending on such imports.

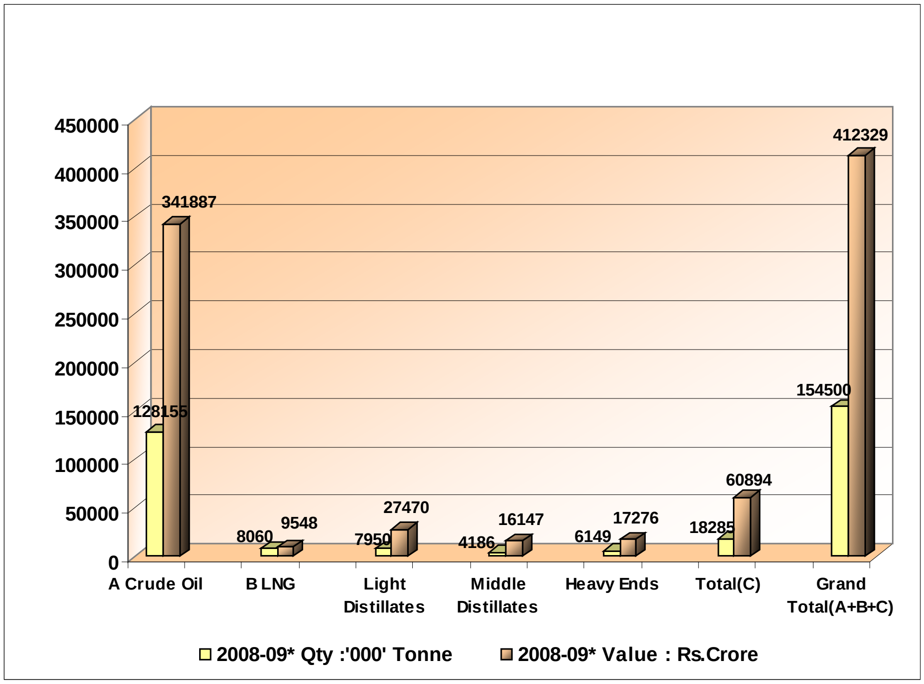
Figure 2.1: Year-wise Production and Consumption of Oil in India



Source: EIA, USA

Figure 2.2 shows that India in 2008-09 spent about Rs.4123 billion on imports of all petroleum products.

Figure 2.2: Gross Imports of Crude Oil and Petroleum Products in India (2008-09)



Source: PPAC, India

It is reported that sector-wise diesel consumption in India for the year 2008-09 was as shown in Figure 2.3 (ET, 2010). This indicates that, in total, as much as 70% of diesel was consumed by transport sector and of that 64% by road transport only. As transport sector is one of the major contributors of the GHG emissions and several other forms local pollution in the country, increased blending of biodiesel may be beneficial for environment.

India imports crude oil from various countries and Saudi Arabia is largest contributors (at 23%) to countries crude oil imports. Also, of total imports, as much as 71%, comes from middle east countries with minor contributions from Nigeria (11%) and Malaysia (4%) as shown in Figure 2.4.

Figure 2.3: Sector-wise Diesel Consumption in India, 2008-09

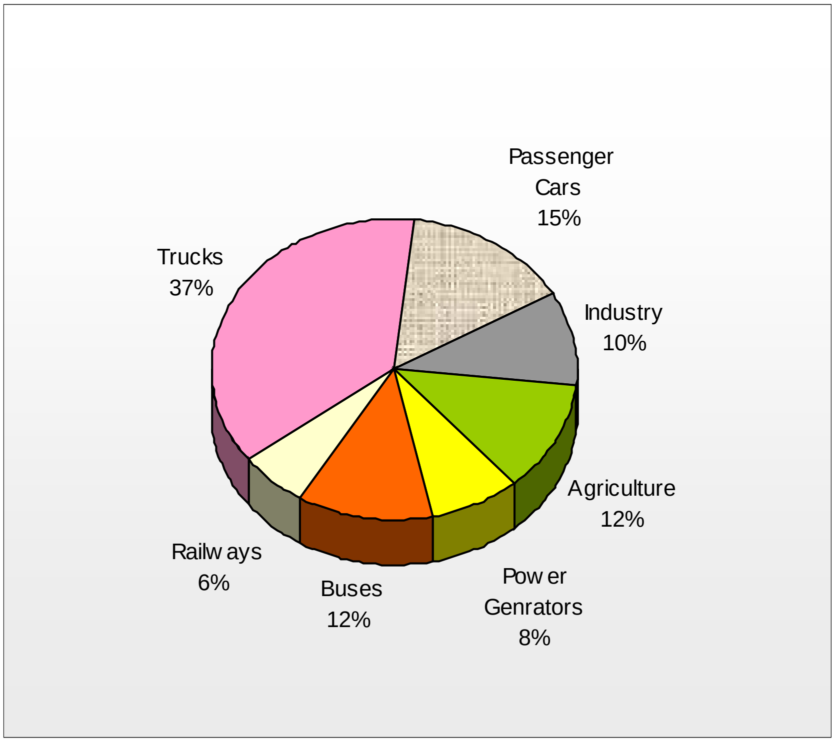
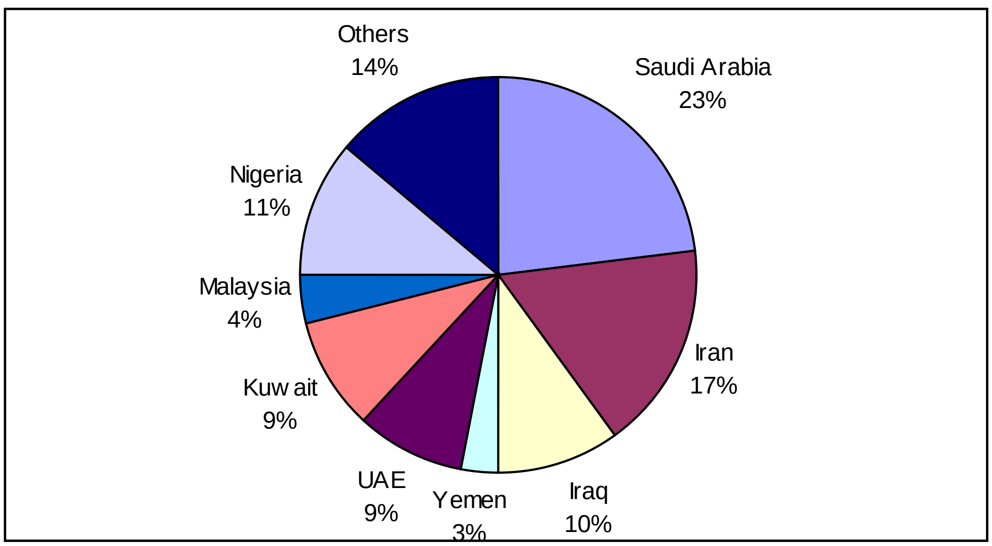


Figure 2.4: Sources of Oil Imports in India, 2007

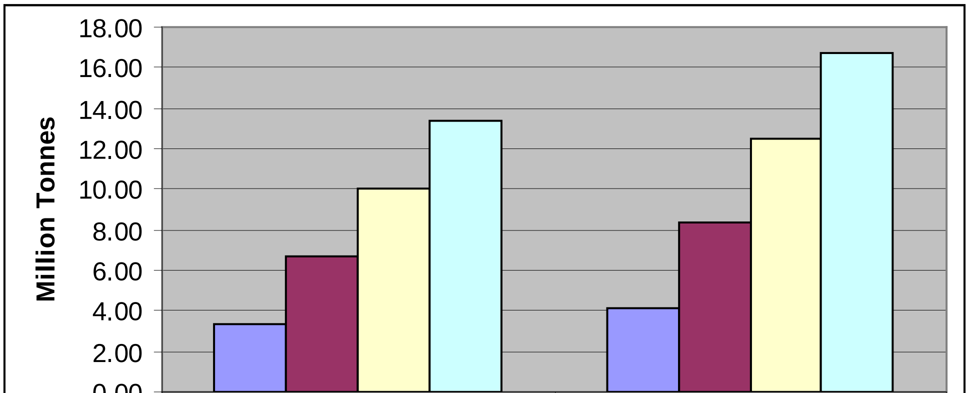


Data Source: EIA, USA

Demand Projections

As per the GoI projections the demand for diesel in the years 2011-12 and 2016-17 may be about 66.9 and 83.6 million tonnes (MT), respectively. Accordingly, the demand for biodiesel at various blending rates is shown in Figure 2.5

Figure 2.5: Biodiesel Demand at various Blending Rates



	2011-12 (Diesel=66.9 MT)	2016-17 (Diesel=83.6 MT)
5%	3.35	4.18
10%	6.69	8.36
15%	10.04	12.54
20%	13.38	16.72

Date Source: Committee on Biofuels, GoI; Note: Area calculated on the basis of plantation density of 2500 per hectare, seed production of 1.5 kg per tree or of 3.75 T of seed per hectare corresponding to 1.2 T of oil per hectare of plantation.

Considering the facts presented above, large scale production of bio-diesel may prove to be a boon for the country, and therefore, the Biodiesel Policy, 2009 of the GoI envisages 20% blending by 2017.

Some of the advantages of promotion of biodiesel in India are the following.

Bio-diesel can reduce crude imports by 5% in 2015 and 10% in 2020 (assuming a 10% blending mandate and 20% blending mandate in 2015 and 2020, respectively.

Bio-diesel value chain can create up to 9 million jobs in rural areas as early as the year 2015. Bio-diesel production process is eligible for carbon credits (or certified emission receipts, i.e. CERs) under Kyoto Protocol’s Clean Development Mechanism (CDM) scheme.

Bio-diesel is less polluting and eco-friendly than conventional fossil fuels. As compared to the conventional fuel, 20% blended bio-diesel emits 20% less Carbon monoxide, 22% less particulate matter, 20% less Sulphates, 20% less PAH (Polycyclic Aromatic Hydrocarbons) & 50% less Nitrated PAH.

Looking at the potential of Bio-diesel, the Ministry of New and Renewable Energy (MNRE), Government of India has declared the ‘National Policy on Biofuels’ in December, 2009 with ambitious target of 20% biodiesel blending by year 2017. Some of the salient features of this policy are as follows (MNRE, 2010).

The focus for development of biofuels in India will be to utilize waste and degraded forest and non-forest lands only for cultivation of shrubs and trees bearing non-edible oil seeds for production of bio-diesel. This would ensure that food versus fuel crisis does not occur.

Along with cultivators, farmers, landless labourers, etc., corporates will also be enabled to undertake plantations that provide the feedstock for bio-diesel through contract farming by involving farmers, cooperatives and Self Help Groups, etc., in consultation with Gram Panchayats, where necessary.

Such cultivation / plantation will be supported through a Minimum Support Price for the non-edible oil seeds used to produce bio-diesel.

Appropriate financial and fiscal measures will be considered from time to time to support the development and promotion of biofuels and their utilization in different sectors.

Employment provided in plantations of trees and shrub bearing non edible oilseeds will be made eligible for coverage under the National Rural Employment Guarantee Programme (NREGP).

The blending would have to follow a protocol and certification process, and conform to Bureau of Indian Standards (BIS) specification and standards, for which the processing industry and Oil Marketing Companies (OMCs) would need to jointly set up an appropriate mechanism and the required facilities. Section 52 of the Motor Vehicles Act already allows conversion of an existing engine of a vehicle to use biofuels. Further, engine manufacturers would be encouraged to suitably modify the engines to ensure compatibility with biofuels, wherever necessary.

In the determination of bio-diesel purchase price, the entire value chain comprising production of oil seeds, extraction of bio-oil, its processing, blending, distribution and marketing will be taken into account.

Plantation of non-edible oil bearing plants, the setting up of oil expelling/extraction and processing units for production of bio-diesel and creation of any new infrastructure for storage and distribution would be declared as a priority sector for the purposes of lending by financial institutions and banks. National Bank of Agriculture and Rural Development (NABARD) would provide re-financing towards loans to farmers for plantations. Indian Renewable Energy Development Agency (IREDA), Small Industries Development Bank of India (SIDBI) and other financing agencies as well as commercial banks would be actively involved in providing finance for various activities under the entire biofuel value chain, at different levels.

Biofuel technologies and projects would be allowed 100% foreign equity through automatic approval route to attract Foreign Direct Investment (FDI), provided biofuel is for domestic use only, and not for export. Plantations would not be open for FDI participation.

To assure standard quality, development of test methods, procedures and protocols would be taken up on priority along with introduction of standards and certification for different biofuels and end use applications. The Bureau of Indian Standards (BIS) has already evolved a standard (IS-15607) for Bio-diesel (B 100), which is the Indian adaptation of the American Standard ASTM D-6751 and European Standard EN-14214. BIS has also published IS: 2796: 2008 which covers specification for motor gasoline blended with 5% ethanol and motor gasoline blended with 10% ethanol.

The above features of the "National Policy on Biofuels" declared by the Government of India show the seriousness of the government to take the production and consumption of biofuels at a rapid pace. This makes it more relevant to study how sustainable would be this ambitious plan on bio-diesel promotion for energy security, rural empowerment and alleviation of negative environmental impacts.

2.3 Benefits of Biodiesel

Reduction in GHG Emissions

Several researchers have reported environmental benefits of biodiesel (Prueksakorn and Gheewala,, 2006; Whitaker and Heath, 2009) as indicated in Tables 2.2 to 2.4. As shown in Table 2.2, in case of both diesel and biodiesel, more than 90% of GHG emissions emanate from the end use of these products. The GHG emissions from biodiesel are less than 25% of the GHG emissions from diesel. The main reason for this is the fact that CO2 emissions from the combustion of biodiesel are considered GHG neutral, being of biomass origin and are absorbed by Jatropha plants during the cultivation stage.

Table 2.2: GHG Emissions during entire Life Cycle of Biodiesel as compared to Diesel

(kgCO2 equivalent)					
	Production	**Transportation during Production**	**Product Transport**	**End Use**	**Total**
Diesel	8.5	0.5	0.2	236.9	246.1
Biodiesel	5.1	0	0.2	51.4	56.7

Source : Prueksakorn, K.; Gheewala, S.H. (2006)

Tables 2.2 and Table 2.4 show that the use of the fertilizers at cultivation stage is the major source of GHG emissions. This is so because of the Nitrogen compounds from the manufacturing process and use of the Nitrogen based compounds create N_2O which is a highly potent greenhouse gas.

Table 2.3: GHG Emissions during Biodiesel Production

(kgCO2 equivalent)		
	kgCO2	**%**
Cultivation Phase		61.3
Land Preparation	0.2397	4.7
Cultivation Phase	0.0102	0.2
Irrigation	1.3311	26.1
Fertilisers	1.5453	30.3
Oil Extraction Phase		14.4
Cracking	0.153	3
Oil Pressing	0.5559	10.9
Filtering	0.0255	0.5
Biodiesel Conversion Phase		24.3
Transesterification	1.2393	24.3
TOTAL	5.1	100

Source: Whitaker M.; Heath G. (2009)

Table 2.4: GHG Emissions during the entire Life Cycle of Jatropha Biodiesel

Process	Diesel	B5	B10	B20	B100
Consumption	**89%**	**87%**	**85%**	**81%**	**0%**
Crude Oil Production and Transport	**10%**	**10%**	**9.9%**	**9.4%**	**0%**
Jatropha Cultivation	**--**	**0.83%**	**1.7%**	**3.7%**	**44%**
N2O Release from Fertilizer	--	0.32%	0.66%	1.4%	17%
Irrigation	--	0.53%	1.1%	2.4%	28%
Fertilizer Application and Offset	--	<-0.1%	<-0.1%	<-0.1%	-0.83%
Jatropha Oil Extraction	**--**	**<0.1%**	**<0.1%**	**<0.1%**	**0.93%**
Hexane Production	--	<0.1%	<0.1%	<0.1%	0.93%
Transesterification	--	**-0.42%**	**-0.87%**	**-1.9%**	**-22%**
Methanol Production	--	0.13%	0.26%	0.56%	6.7%
Potassium Hydroxide Production	--	<0.1%	0.10%	0.22%	2.7%

Glycerine Offset	--	-0.60%	-1.2%	-2.7%	-32%
Supporting Processes	**--**	**1.4%**	**2.8%**	**6.1%**	**72%**
Electricity	--	0.78%	1.6%	3.4%	40%
Truck Transport	--	<0.1%	0.16%	0.35%	4.2%
Steam Production	--	0.53%	1.1%	2.4%	28%

Source: Whitaker M.; Heath G. (2009)

Reduction in Other Emissions

Use of biodiesel also reduces other emissions such as particulate matter emissions are 30% lower than fossil diesel, Hydrocarbon exhaust emissions are 93% lower than fossil diesel, Nitrogen oxide emissions can be effectively managed and efficiently eliminated from bio-diesel, Overall ozone forming hydrocarbon emissions are 50% less than diesel fuel, Carbon dioxide emissions reduces by 78% compared to petroleum diesel, etc. Thus, biodiesel reduces over all exhaust emissions by clean burning and it is a renewable fuel, which is indigenously produced and creates local employment.

The U.S. Environmental Protection Agency (EPA) has surveyed a large body of biodiesel emissions studies and averaged the health effects' testing results with several other relevant studies. The emissions related results are as follows:

- The ozone (smog) forming potential: This is 50% less than the diesel fuel.
- Carbon Monoxide: These are 48% lower than the diesel.
- Sulphur emissions: These are essentially eliminated compared to the diesel.
- Particulate Matter: These emissions are 47% lower than overall particulate matter.
- Hydrocarbons: These emissions are 67% lower than that of diesel.
- Nitrogen Oxides: These are 10% higher than that of diesel.

Some India Specific Advantages

Biofuel crops in India are planned on marginal and waste lands and hence the "food versus fuel issues" may not be of much concern in the country. Although gestation period of TBOs in India is longer in comparison to annual crops used elsewhere for biodiesel production but once the system is in place, it may ensure long term benefits to farmers and other stakeholders. The two main TBO crops promoted in India are Jatropha and Pongamia. Jatropha, being a shrub with shorter gestation period than Pongamia, has received much attention. Jatropha being is a non-edible variety and sturdy plant that can grow on almost all kinds of soils with much lesser care than other crops, it is possible to grow it on non-arable lands, and thus, there is no competition from food crops. In addition to biodiesel production, the oil from the Jatropha seeds can be used directly for several other purposes such as soap production, home lighting, fuel for cooking and as fuel in diesel engines.

3. DETAILS OF PILOT STUDY

Indian pilot study was implemented in the state of Andhra Pradesh (AP), near Hyderabad district. Andhra Pradesh is one of the foremost Indian states, which has initiated biodiesel production using various non-edible tree oils, the major being Jatropha Curcas. Other reason for selecting AP as the study area was a good response and cooperation of the three companies selected as the case studies within the pilot study.

3.1 About Andhra Pradesh

Andhra Pradesh is the fifth largest State in India both in terms of area as well as population. The total area of the State is 2,75,045 Sq. Kms of which a major part (2,70,589 Sq. Kms) is categorised as rural and balance as urban area. The population of state is 75,727,541 with a population density of 275 persons per sq km as per 2001 census. The rural population of the State in 2001 was is 55,223,944 (73%) and urban population was 20,503,597 (27%).

Physiologically, the State is divided into three zones of Coastal plains, Eastern Ghats, and the plains. The climate in the State is tropical, mostly hot and humid, particularly in the coastal belt. Most of the Andhra Pradesh is in the semi-arid zone and rainfall is concentrated in a few months in the year. The average temperature during the cooler months of December and January is 28^{o}C, and in the summer months of May and June the temperature reaches above 40^{o}C. Most parts of the state in summer are hot and humid. The annual average temperature is 31.5^{o}C.

Agriculture provides employment to about 68% of the work force in the State and 22.74% of Andhra Pradesh's income (1997-98) comes from agriculture. The principal crops grown (in terms of area) are rice, oil seeds, groundnut, pulses, other cereals and millets, cotton, jowar, sugarcane, castor, and tobacco. About 500 sq. km of the forest area (0.78%) is reported to be under shifting cultivation. More than 60% of the net sown area in the State is dependent on rainfall as it has no assured irrigation facilities.

Agriculture and industrial sectors are the biggest users of commercial energy in the State followed by the domestic and the commercial sectors. Electricity in rural areas has problems of poor voltage and intermittent supply. About 91.5% of rural households depend on fuel wood for cooking followed by 3.37% who use cow dung cakes as the cooking fuel. Use of woodstoves affects the health of the rural poor, especially women who are the main users of biomass fuels mainly due to carbon monoxide in the smoke generated.

Promotion of Biofuels in AP

Andhra Pradesh is a densely populated and partly, a drought prone state. Considering the great dependence on biomass fuels for cooking, and the poor quality of rural supplies, alternative energy sources including oil tree plantations and usage of biofuel seems to be a good choice. Despite being one of the pioneering states in adopting Jatropha cultivation for biodiesel production in 2005, the state had some discouraging experiences with the promotion of Jatropha. Due to this experience, the state also brought in focus promotion of Pongamia, and, more recently, on Simaruba. Pongamia is a local species in the state, the leaves of which have long been used as organic manure. The goal of the state government is to achieve 100,000 acres of biodiesel plantations in 13 districts of the state respectively in order to make productive use of degraded land.

To effectively promote biodiesel, the state of Andhra Pradesh has created a dual organisational structure. The Rain Shadow Areas Development Department is responsible for policy-making, monitoring and promoting entrepreneurship while the Department for Panchayati Raj and Rural Development is dealing with the implementation of the programme. A State Level Task Force Committee is also entrusted with monitoring the programme. Biodiesel plantations are promoted on specified private land and on forest land, putting emphasis on association with private entrepreneurs.

The state has been assigning small plots of revenue land to landless people since 1960s, granting them ownership rights over the produce of that land. Most of the revenue land has been already assigned. However, in most of the cases, the land remains degraded and making negligible or no change in the condition of poor farmers. To rehabilitate this land and provide additional income for the farmers, the biodiesel programme initially focussed on these assigned farmers. In 2006, the department for Panchayati Raj and Rural Development extended the programme to all small and marginal farmers with landholdings below five acres.

To motivate more farmers and provide them with better training and material and supply, the state also promotes private partnership in the sector. The state extends full NREGS support to all small and marginal farmers under buy-back agreements with the company. The material component of NREGS is transferred to the bank accounts of the farmers, so that they are free to purchase the inputs, including the seedlings, from the company. In turn, companies are required to ensure 90% survival of grafted plants by the end of the third year of plantation and to procure the seeds at the market price or, at least, at the minimum support price as decided by the state. They are also required to set up expelling and transesterification units within their area of operation.

All farmers have the option to sell to the Andhra Pradesh Oil Federation or, in tribal areas, to the state-owned Girijan Cooperative Corporation at the minimum support price set by the Rainshadow Areas Development Department. In order to enhance demand, Andhra Pradesh has reduced the Value-Added Tax (VAT) for biodiesel to 4%.

3.2 Description of Sites Selected

As mentioned earlier, for the pilot study, three case studies were selected, which are Tree Oils India Limited (TOIL), Nandan Biomatrix Limited (NBL) and Southern online Bio Technologies Limited (SBTL). Each of these companies are involved in atleast one stage of biodiesel production chain and were identified to capture, as much as possible, the major part of the life cycle of biodiesel production i.e. from Jatropha cultivation to biodiesel production. A brief introduction of the companies is given as follows.

3.3 Tree Oils India Limited (TOIL)

In 2003, TOIL purchased about 120 acres of waste land in Medak District of Andhra Pradesh, which is about 115-120 kms from Hyderabad and about 14 kms from Zaheerabad town. The land was almost barren with rocky soil and almost nothing was growing on the land. This land has been used by the company for cultivation of Jatropha, Pongamia, Simaruba and other oil tree plants.

The plantation is located nearer to National Highway No. 9 for easy transport of seed and oil. Dry region of Deccan Plateau is selected to encourage the farmers and corporates, who own large tracts of dry and waste lands in the area, to raise the plantations of Jatropha and Pongamia with an agreement to buy the seed. As the company proposes to operate in the states of Andhra Pradesh, Maharashtra and Karnataka, the proposed location facilitates easy operation in all the three states

The farm land has been divided into different parts for growing various plantations as follows.

Pongamia: 60 acres (plants are 4.5-5 yrs old)

Jatropha- 40 acres ((plants are 4.5-5 yrs old)

Amla – 15 acres (plants are 5 yrs old)

Simaroba, Madhuca, Neem, Soapnut, Calophyllum, Chinese talo, candle nut & Camelina (like yellow mustard) -5 acres.

Thus, maximum focus is on Pongamia and Jatropha plantations. Apart from the above, various vegetables like cabbage, tomato, chilly etc. are also being grown as intercrops, which improve biodiversity, mitigate risk and ensure regular income from first year itself.

TOIL was established to build up environment friendly and sustainable energy system based on plant sources, contribute to waste lands utilisation and rural women employment and promote ethics and self reliance. TOIL plans to manufacture the biodiesel from non-edible tree oils such as Jatropha and Pongamia. It proposes to supply eco-friendly fuel to the transport sector and organic manure to the farm sector. Company also facilitate the research on non-edible oil trees and to promote organic farming by making de-oiled cake available to farmers. TOIL believes that with the increased production and use of biodiesel, the country will gradually reduce its dependence on huge imports of crude fossil oil and become self-sufficient in auto fuel in about 20 years.

Presently the company is mainly involved in plantation, has a small scale oil extraction unit and uses the oil within its in-house facilities and also sells it in the market. The company has plans to set up 2 TPD Biodiesel Plant in a central location of the cluster of villages. The company also proposes to establish Rural Energy Centres (RECs) across India. This includes plans to establish 50 RECs in different parts of the country and network them to create 100 TPD Biodiesel production capacity. Most of the Biodiesel produced could be consumed in that area itself by the Transport Operators and Farmers and the surplus can be taken to the nearby Distribution Centre. The company is also looking forward to set up seed collection centres with 250 Kg/day oil expeller units in the surrounding villages, within a radius of 50 km. These can be established by unemployed youth and landless labourers. They will also be selling points for saplings, deoiled cake and Biodiesel. The company has involved villagers in the project and intends to create such projects as viable options for the farmers and villagers. The company also plans to tie up with farmers through contract farming and execute plantation projects on turnkey basis with profit sharing basis.

In addition to main product, i.e. oil seeds, the company has developed several ancillary activities on the farm which include apiculture, animal raring, poultry, vermiculture, composting, biogas from animal dung, etc. These activities, on one hand, are catering to the daily needs of farm workers, these are generating some revenue for the company, on the other hand.

Survival rate of Jatropha is more than 80% Jatropha seeds sourced from Chattisgarh. It starts giving fruits from 2nd yr but economically viable yield from 5th year. The company has planted various varieties of Jatropha brought from Brazil, China, Australia, etc., and also from different parts of the country. Company also advocates that oil tree Pongamia (locally known as Karanja) is better suited as its yield per plant is up to 50 kg/tree and it requires no water for irrigation or fertilizer. However, gestation period for seeds is 6 to 7 yrs). Company sells vegetable oil from Jatropha and other oil seeds @ Rs. 50 per liter to universities and research institutes. Further, it is looking for oil use for power generation, local transport & public vehicles. Company is already using oil after filtration to run Diesel Generators for electricity for families at farm. Seed cakes composting is used as manure for plantation.

3.4 Nandan Biomatrix Limited (NBL)

NBL's head office is located at Hyderabad and its main research and development (R&D) facility is located at Zaheerabad. The company was started 12 yrs back with cultivation of herbal plants and selected Jatropha as one of such plants. The company has 10000 acres of medicinal plant cultivation across the country through contract farming. Gradually, as Jatropha was being promoted as a promising plant for bio-diesel, the company focused on Jatropha cultivation. Though Jatropha was initially selected as a medicinal plant for uses in medicines for toothache, stomach-ache, etc., the company did extensive field work on various aspects of bio-mass and biodiesel plantations in its endeavour to bring in more benefits to the farming community and contribute to the cause of economy.

NBL has a target to produce 2.5 million tonnes of biodiesel within five to seven years and aims at occupying at least 15% market shares of country's total requirement of biodiesel by 2017. It has developed Jatropha hybrid varieties, which may give upto 7 tons yield of seeds per hectare and upto 3 tonnes of oil per hectare. NBL has been awarded four global patents for Jatropha varieties, viz., High Seed Yield, High Oil Content, High Oleic Acid content, Interspecific Hybrid and Developed Superior Selected Varieties. The company is utilising advanced approaches of crop improvement like mutagenesis (radiation induced and chemical induced), hybridization of high oil seed yielded lines and development of proper agronomical practices.

NBL is involved in Contract Farming, Direct benefit through Estate Farming, Partnership with Panchayat and Farming in forest lands. Farmers have potential to earn a stable income Rs 45000 per hectare from fifth year onwards by adopting NBL's hybrid cultivation. Company is constantly providing many support services to the farmers as follows.

High quality planting material and cultivation technology

Finance assistance crop cultivation through UBI tie up

Crop insurance through AIC tie up

Continuous monitoring of the crop and buy back

NBL has divided its plan into two phases in which phase I includes Rajasthan, Odissa, Gujarat, Madhya Pradesh and Andhra Pradesh. Phase II covers the states of Maharashtra, Karnataka, Chhattisgarh, Jharkhand and Tamil Nadu. This programme fits well to the National Biofuels Policy, 2009 of the GoI. Company is planning to expand to other countries like South East Asia, Africa and South America. NBL, BPCL and Shapporji Pallonji have formed a JV to implement the project in Uttar Pradesh. This model, known as BREL, operates through Public Private Panchayat Partnership (P4) Approach. Degraded lands and local below poverty line (BPL) population for labour are being used in the project. NBL has a flagship project called as "Project Triple One", which has the following objectives.

To bring in one lakh hectares of marginal lands under Jatropha cultivation

To generate employment to one lakh people

To produce two lakh tons of biofuel per annum

Adopting BREL model and scaling up the same in other states in phases

NBL has signed a MoU with the state government of Gujarat during “Vibrant Gujarat” summit for project implementation. Company has also established Nursery Production Center (NPC) and Jatropha Information Center (JIC) in the premises of Sardar Krishinagar Dantiwada Agricultural University (SDAU) for collaborative research in Jatropha. For this state, NBL is planning to get approval for 20,000 hectares estate farming and to cultivate 1,00,000 hectares in the next five years for producing 2.1 lakh MT of Crude Jatropah Oil (CJO) and up to 300 MW of power production from seedcake.

In Rajasthan, NBL has a partnership with Biofuel Authority of the State and running research projects in Jatropha with Maharana Pratap Agricultural University, Udaipur. Company is waiting approval to form a PPP for the implementation of Bio Investment Eco Industrial Zone (BIEZ) focusing on all renewable sectors; biofuels, solar, wind and biomass. Project will develop 550 MW of renewable power, 2.1 lakh MT of biofuel for a total investment of Rs.7,500 crore. Estate and Contract Farming activities are currently in progress in the state.

Company has tied up with Odissa University of Agriculture and Technology for collaborative research. It has established Nursery Production Center and Jatropha Information Center and operation across 22 districts of the State with a functional regional office and an 11 member team. NBL is targeting small and marginal farmers possessing degraded marginal lands.

Madhya Pradesh is a role model for NBL's Corporate Jatropha Farming. NBL has signed a MoU with Madhya Pradesh Agro Industries Corporation during Gwalior Investors Meet, 2008. Numerous projects are under pipeline with the State Government. Estate farming activities are underway in the district of Shoepur (5000 Acres) and suitable lands for such purposes have been discovered in other districts of the State.

Andhra Pradesh is a success story for NBL's tripartite contract farming. Contract farming activities are commenced in the district of Nellore and achieved 1000 acres in a time span of 3 months. They have plans to scale up the operations in the districts of Cuddapah and Prakasam. NBL is associated with the Bank of Maharashtra for Tripartite Contract Farming Model.

NBL is planning for Bio Investment Eco Industrial Zone (BIEZ). BIEZ will be an integration of the entire value chain of biofuel and other renewable energy production. It is an investment region for bioenergy and renewable energy within an area with a diameter of approximately 300 km. The components are the Catchment Area for bioenergy crop cultivation and renewable energy projects with a smaller park area in the interior, the Bio Investment and Eco-Industrial Park (BIEP). Company has got principle approval for the implementation of the concept from Government of Rajasthan and Orissa. NBL has Signed an MoU for the implementation with the State Government of Gujarat and State Government of Karnataka.

NBL has formed a Joint Venture with a German company, Alphakat GmBH for commercializing a second generation biodiesel production technology. The technology is Catalytic Depolymerization (KDV), which converts the biomass along with the Jatropha seeds into Biodiesel. The company is planning to commercialize the technology in India.

3.5 Southern online Bio Technologies Limited (SBTL)

Initially, this company was started as first private internet service provider in Andhra Pradesh and then diversified into bio-diesel production. SBTL is located at Village Narayan Samasthan in district Nalgonda, which is about 63 kms from Hyderabad. The Biodiesel plant is spread in 12 acres of land and situated in an area, which has access to the availability of raw materials such as Pongamia and Jatropha and also various alternate raw oils such as non-edible vegetable oils, etc. The plant also has sufficient water availability for its requirement from the ground water. The plant has recently got a certification of ISO 9001 for Production of Biodiesel. The plant has been awarded "best cleaner production and waste minimization techniques" for the year 2009-2010 by the Andhra Pradesh Pollution Control Board in Nalgonda.

The bio diesel plant of the company (designed by LURGI/Germany and built by their Indian licensee, CCI) was commissioned in July 2007. Present production capacity of the plant is 40000 litre per day. The plant uses multi-feedstock for bio-diesel production with common raw materials as Palm Sterean oil and Animal Talo. The Company is constructing its second and larger bio diesel unit in Vishakhapatanam with a production capacity of 250 tons and also has plans for more plants in future.

The company projects itself as an eco-friendly greenfield company, which is involved in biodiesel production by developing wastelands and employing tribal and rural folks and thereby generating rural employment, saving foreign exchange on diesel imports and reducing pollution levels by substituting biodiesel for the fossil diesel. SBTL is also working on a public-private partnership project with ICRISAT to teach farmers on biodiesel seed collection and nursery plantations. However, the farmers will be asked to sell the produce to SBTL.

SBTL also plans to establish a third biodiesel plant by the end of 2009. The proposed plant will be built in Anantapur, Kurnool or Chittoor district and serve to markets in Tamil Nadu and Karnataka. The plant will have a crushing capacity of 500 tonnes per day. The company has signed a memorandum of understanding with a Singapore-based company to identify around 50,000 acre for raising biodiesel plantations along with local farmers. The company will offer a buy-back arrangement of the crop at the prevailing market price and also establish a crushing unit in Singapore. It will sell the oil cake in the local markets there and import the oil to India. The plant would have a crushing capacity of 250 tonne per day. It will produce 275,000 litre biodiesel per day. It will procure around 75% of the feedstock requirements from local resources and import some non-edible oils. The plant also produces omega fatty acids, agri-products, glycerine apart from biodiesel that will be sold in the domestic market.

During the survey the company reported that the availability Jatropha or other oil tree seeds for the plant at Nalgonda was not enough and cost effective, hence, as an alternative to, presently the company uses combination of various feed stokes such as non-edible vegetable seed oils, fish oils, animal fats, fatty acid and used cooking oil to produce biodiesel and glycerine.

4. METHODOLOGY FOR ASSESSMENT

The methodology used for the assessment of various impacts of biodiesel production using Jatropha and other tree oils is based on the guidelines developed by the expert WG of the ERIA. Attempt has been made to estimate the impact during each stage of the life cycle of biodiesel production represented by selected case studies. Accordingly, using the WG method, the impacts on three aspects of sustainability, viz., economic, environmental and social have been estimated during the cultivation stage (for Tree Oils India Limited) and biodiesel production stage (for Southern Online Biotechnologies).

4.1 Economic Impact

Economic sustainability of biomass utilisation relates to the exploitation of biomass resources in such a manner that the benefits derived by the present generation are ascertained without depriving such opportunity to the future generations. In the assessment of sustainability, it is 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. Based on the methodology of WG and literature reviewed, the most common economic contributions of biomass utilisation are value addition, job creation, tax revenue generation, and foreign trade impacts. For Indian case study, the same indicators were taken into consideration for the assessment of economic impact of biodiesel production.

The WG of ERIA has developed following indices for economic assessment of biomass utilization.

i) Gross Value Added (GVA) 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 in computing for value addition.

GVA = VAa + VAb

where,

VAa – value added from main product

VAb – value added from by-products

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

VAa = GRa – TCa; and,

VAb = GRb – TCb; where,

Where,

GR – Gross or Total Revenue

TC – Total Cost (suffix "a" refers to main product and suffix "b" refers to byproduct)

(ii) Employment

Job creation is another indicator for assessing the economic impact of the biomass industry. The quantum of jobs created per hectare of plantation or per ton of biodiesel production is a good indicator for assessing the impact of biomass industry on employment generation. The number of jobs generated with the presence of the bio-energy project is computed as follows.

Employment = Total Production x Labour Requirement for every unit produced

Or Job Created per unit of output = total production / no. of person employed.

(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. In India, agricultural income is fully exempted from paying taxes. Bio-ethanol already enjoys concessional excise duty of 16% and biodiesel is exempted from excise duty. No other taxes and duties are proposed to be levied on bio-diesel or bioethanol.

(**iv) Foreign Exchange**

Biomass production and processing has positive effects on foreign trade which is determined by two factors, viz., foreign exchange earnings and foreign exchange savings. Foreign exchange earnings arise from the gains of exporting the readily convertible material for biodiesel production. 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 fully, a fraction of the overall diesel consumption of an economy, which would eventually decrease imports of fossil diesel. 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

(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.

Thus,

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.

Or,

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 utilization practices must gear toward achieving economic sustainability.

Based on the above concepts, step wise economic analysis of various stages of biodiesel production is given as follows.

a) GVA in Cultivation Stage

Step 1: Total cost of production of Jatropha seeds per hectare is estimated at current prices (actual/estimated) after taking into consideration the inputs used.

(COP) cult = Cost of production of Jatropha seeds per Hectare

= Labour Cost + Cost of Seedlings + Cost of Fertilizers + Cost of irrigation

Step 2: Jatropha seeds output yield per Hectare is estimated

(O/P) seeds = output yield of Jatropha seeds in tonnes per Hectare

Step 3: Using the market price of Jatropha seeds, the sales proceeds are calculated from the Jatropha seeds per hectare.

(MP) seeds = Market price of Jatropha seeds per tonne

(Sales) seeds = (MP) seeds * (O/P) seeds

Step 4: Given the sales realization and the cost of production per hectare, the gross value added per Hectare during the cultivation stage.

(GVA) cult = (Sales) seeds - (COP)cult

b) GVA in Oil Extraction Stage

Step 1: The total cost of oil extraction per hectare is estimated at current prices (actual/estimated) after taking into consideration all the inputs used. The Jatropha seed input is valued at the market price.

(COP) oilext = Cost of production of Jatropha oil per hectare

= Cost of Jatropha Seeds+ Cost of Power + Cost of Steam + Labour Cost

Step 2: The output yield of Jatropha oil (@ 25% of seeds quantity) and Oilcake is estimated per Hectare.

(O/P) oil = output yield of Jatropha oil in tonnes per Hectare

(O/P) oilcake = output yield of oilcake in kg per Hectare

Step 3: Using the market price of Jatropha oil and oil cake, the sales proceeds from the Jatropha oil per Hectare are estimated.

(MP) oil = Market price of Jatropha oil per tonne

(MP) oilcake = Market price of oilcake per kg

(Sales) oilext = (MP) oil * (O/P) oil + (MP) oilcake * (O/P) oilcake

Step 4: Given the sales realization and the cost of production per hectare, the gross value added per Hectare during the oil extraction stage is given as follows.

(GVA)oilext = (Sales) oilext - (COP) oilext

c) GVA in Transesterification Stage

Step 1: The total cost of transesterification per Hectare is estimated at current prices (actual/estimated) after taking into consideration all the inputs used. The jatropha oil input is valued at the market price.

(COP) trans = Cost of transesterification per hectare

= Cost of Jatropha Oil + Cost of Steam + Cost of Power + Cost of Chemicals + Cost of Labour + Cost of Water

Step 2: The output yield of biodiesel and glycerol is estimated per Hectare .

(O/P) biodiesel = output yield of biodiesel in tonnes per Hectare

(O/P) glycerol = output yield of glycerol in tonnes per Hectare

Step 3: Using the market price of biodiesel and glycerol, the sales proceeds per hectare is estimated.

(MP) biodiesel = Market price of biodiesel per tonne

(MP) glycerol = Market price of glycerol per tonne

(Sales) trans = (MP) biodiesel * (O/P) biodiesel + (MP)glycerol * (O/P)glycerol

Step 4: Given the sales realization and the cost of production per hectare, the gross value added per hectare during the transesterification stage is estimated.

(GVA) trans = (Sales) trans - (COP)trans

Total GVA per Hectare

The total gross value added per hectare during all the three stages is given by:

(GVA) total = (GVA)cult + (GVA) oilext + (GVA)trans

4.2 Environmental Impact

Biofuel from oil trees like Jatropha is also being viewed as a means to offset CO_2. The results of a study conducted by the USEPA on the emissions produced by biodiesel show that except for nitrogen oxides (NOx), regulated and non regulated emissions from both B100 (100% biodiesel) and B20 (20% biodiesel) are significantly lower than for conventional petroleum based diesel. However, the entire life cycle needs to be assessed to ascertain the environmental impact of biodiesel, from cultivation of oil trees till biofuel utilization.

For assessment of the environmental impact, WG has developed eco-index based on which the impact has been estimated at farm level and at the biodiesel producing stage at plant level. The steps of GHG Index methodology are given as follows.

GHG Index Methodology

Step 1: Estimate the emission levels of 100% diesel (DE) as an aggregate across the entire life cycle of diesel.

Step 2: Estimate the emission levels of 100% biodiesel (BDE) as an aggregate across the entire life cycle of diesel.

Step 3: Arrive at the various blending levels of biodiesel (%BD) and diesel (%D)

Step 4: Compute the GHG Index as

GHG Index = (%D * DE + %BD * BDE) /DE

Using the above steps, the GHG Emissions Index, at various blending levels, are given in Table 4.1. As the data on emission of other pollutants such as oxides of nitrogen and sulphur, particulate matter, etc., are not available, they have not been estimated in this study.

Table 4.1: GHG Emissions Index at Various Blending Levels

	GHG Emissions			GHG Index
	Diesel Component	**Biodiesel Component**	**Total**	
Diesel	246.1	0	246.1	100.00
5% Blending	233.795	2.835	236.63	96.15
10% Blending	221.49	5.67	227.16	92.30
15 % Blending	209.185	8.505	217.69	88.46
20% Blending	196.88	11.34	208.22	84.61
Biodisel	0	56.7	56.7	23.04

4.3 Social Impact

For sustainability aspect of biodiesel production, social impacts are as important as economic and environmental impacts. Thus, it is necessary that the cultivation of Jatropha and other oil tress is socially acceptable. This can only happen when farmers are convinced that their involvement in biofuel crops plantation and other stages will economically benefit them and results in raising their standard of living.

At global level, the social development is measured by the Human Development Index (HDI) calculated as per UNDP method. However, there is a general lack of data and information on estimation of the social impact of bio-energy, especially in terms of the HDI. Such estimation requires compressive data set for the region where bio-fuel crops cultivation has been taken up. The data should contain farm level information on production of bio-fuel crops (such as Jatropha) and information throughout the value added chain during the life cycle of biodiesel production.

Some of the problems with the data and information available and assumptions made in estimation of HDI are stated as follows. 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, etc., 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.

Therefore, in addition to see the change in the HDI, it was considered that other social development indicators (SDIs) at micro level should also be estimated. GDP per capita, Education and Health aspects will be captured through social parameters such as Employment, Life Expectancy, GER, etc. Some other SDI to see the conditions of women, socially deprived groups, etc, gives an overall assessment of social development. However, it is to be noted that estimation of SDIs have many issues, which at micro or macro level may give biased results. Also, other SDIs may not be comparable at international level and same SDI may carry different meaning. For example, National Sampling Survey (NSS) of India categorises households into various monthly per capita expenditure (MPCE). The standard of living is considered higher among the number of households per 100 households that fall in a particular category of MPCE. If this number of households have three amenities, viz., water, latrine and electricity within their premise, it is considered a higher standard of living. However, similar definition of living standard may not be true in case of other East Asian countries.

Estimation of HDI

HDI 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($\mathbf{X}$) and max($\mathbf{X}$) 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 4.2.

Table 4.2: 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.

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

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.

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

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

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

iii) GDP Index

GDP Index (GI) is calculated using adjusted GDP per capita in US dollar. 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)

The steps used to calculate the HDI at micro level are mentioned below.

Step 1: Estimate the direct employment from Jatropha cultivation that includes persons employed in site preparation, Jatropha plantation and post plantation work. This direct employment in person days per hectare is calculated for consecutive 5 years.

Step 2: Estimate the indirect employment from Jatropha cultivation and biodiesel production that 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 per hectare of jatropha plantation, which is multiplication of person days of employment created and salary per person at the location.

Step 4: For calculating GDP (PPP) per capita, data from step 3 (say, Rs. X / ha of Jatropha) are used to calculate total income generated from Z ha of land. Therefore, Rs.(XZ) is divided by total population of the area and added to the original GDP of place which gives GDP per capita, which can be converted into US dollars i.e. GDP (PPP).

Step 5: The HDI can be calculated by given formula HDI = 1/3(LEI+EI+GI) as earlier.

Where,

LEI: Life Expectancy Index; Life expectancy data was taken from the area.

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

ALI: Adult Literacy Index; data taken from area.

GEI: Gross Enrolment Index; data taken from area.

GI: GDP index ($) will be given by

$$GDP\ Index\ (GI) = \frac{Log\ (actual\ value) - Log\ (100)}{Log\ (40000) - Log\ (100)}$$

Where actual values are taken from step 4 above.

Step 6: The change in HDI is calculated by subtracting HDI at the local site and the HDI for India for that particular year

Stagewise Estimation of HDI

Stepwise estimation of impact on various sub-indices of HDI during various stages of biodiesel production are calculated as follows.

i) Impact on literacy

a) Cultivation Stage

Step 1: Estimate the employment generated in person days with a plantation of one Hectare.

(EPH)cult = Employment Generated per Hectare during cultivation stage

Step 2: Assuming a certain number of working days per year, estimate the total no. of persons employed throughout the year with one hectare of plantation.

Ncult = (EPH) cult / NWD

Where, Ncult = No. of persons employed in cultivation

NWD = No. of working days in a year

Step 3: Estimate the monthly per capita income generated based on the number of working days per month and the minimum wage rate.

Δ MI = Increase in the monthly per capita income generated

Step 4: From the NSS data, estimate the rise in literacy level (per 1000 persons) on account of increase in per capita income.

Δ LL = Rise in literacy level per 1000

Step 5: Estimate the increase in literacy on account of the one hectare of plantation.

$\Delta LITcult = (\Delta LL * Ncult)/ 1000$

b) Oil Extraction Stage

Step 1: Estimate the employment generated in person days with a plantation of 1 Hectare.

Step 2: Assuming a certain number of working days per year, estimate the total no. of persons employed throughout the year with 1 Ha plantation.

$Noilext = (EPH)oilext / NWD$

where Noilext = No. of persons employed in oil extraction

NWD = No. of working days in a year

Step 3: Estimate the monthly per capita income generated based on the number of working days per month and the minimum wage rate.

ΔMI = Increase in the monthly per capita income generated

Step 4: From the NSS data, estimate the rise in literacy level (per 1000 persons) on account of increase in per capita income.

ΔLL = Rise in literacy level per 1000

Step 5: Estimate the increase in literacy on account of 1 Ha plantation.

$\Delta LIToilext = (\Delta LL * Noilext)/ 1000$

4.3.1.1.1

4.3.1.1.2 c) Transesterification Stage

Step 1: Estimate the employment generated in person days with a plantation of 1 Hectare.

(EPH)trans = Employment Generated per Hectare during transesterification stage

Step 2: Assuming a certain number of working days per year, estimate the total no. of persons employed throughout the year with 1 Ha plantation.

$Ntrans = (EPH) trans / NWD$

where Ntrans = No. of persons employed in transesterification

NWD = No. of working days in a year

Step 3: Estimate the monthly per capita income generated based on the number of working days per month and the minimum wage rate.

ΔMI = Increase in the monthly per capita income generated

Step 4: From the NSS data, estimate the rise in literacy level (per 1000 persons) on account of increase in per capita income.

Δ LL = Rise in literacy level per 1000

Step 5: Estimate the increase in literacy on account of 1 Ha plantation.

$\Delta LITtrans = (\Delta LL * Ntrans) / 1000$

Overall impact

The overall increase in the literacy levels per hectare of plantation is given by:

$\Delta LIT = \Delta LIT\ (cult + oilext + Trans)$

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. It is to be noted that, as per UNDP's goal posts for GDI, maximum and minimum values of life expectancy for women are 87.5 and 27.5 and for men are 82.5 and 22.5, respectively.

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.

Methodology for computing GDI

Step1. Unit free indices between 0 and 1 are calculated for females and males in each of the following areas- Life Expectancy , Education and Income.

Life Expectancy Index of Gender = (Life Expectancy of Gender – min (Life Expectancy of Gender))/ (max(Life Expectancy of Gender)- min (Life Expectancy of Gender))

Adult Literacy of Gender = (Adult Literacy of Gender – min (Adult Literacy of Gender))/ (max(Adult Literacy of Gender)- min (Adult Literacy of Gender))

Income Index of gender:

$$\frac{log(\text{earned income of gender}) - log(100)}{log(40,000) - log(100)}$$

Step 2: For each area, the pair of gender indices are combined into an Equally Distributed Index that rewards gender equality and penalizes inequality. It is the harmonic mean of two gender specific indices.

Equally Distributed Index =

$$\left(\frac{\text{female share of population}}{\text{female-index}} + \frac{\text{male share of population}}{\text{male-index}}\right)^{-1}$$

Step 3: The GDI is the average of the three Equally Distributed Indices viz. Equally Distributed Life Expectancy Index, Equally Distributed Education Index and Equally Distributed Income Index.

SDIs and MPCE Classes

National Sampling Survey of India (NSS) has categorises households in rural India in terms of monthly per capita expenditure (MPCE) and its effect on various social development indicators (SDIs). The impact on these SDIs with rise in MPCE is described as follows.

a) Impact on Literacy

The literacy levels (per 1000) across the Monthly Per Capita Expenditure (MPCE) classes in the rural India, as per the NSS Report 2004-05 are as in Table 4.3 Due to rise in income and expenditure, the number of households falling under a particular MPCE class will change, which can be found from the following Table 4.3.

Table 4.3: MPCE Class and Literacy Levels

MPCE Class	No. per 1000 households with no literate person above 15 years in all members
less than 235	444
235 -270	436
270 -320	382
320 – 365	352
365 – 410	306
410 – 455	292

455 – 510	271
510 - 580	243
580 – 690	209
690 – 890	186
890 -1155	141
1155 & above	88
all classes	261

Source: NSS Report

Methodology

Step 1: Estimate the employment generated in person days with a plantation of 1 Hectare**.**

EPH = Employment Generated per Hectare

Step 2: Estimate the total employment generated in person days by the proposed plantation as mentioned above.

EMP = EPH * NH

where, EMP = total employment generated in person days

NH = No. of Hectares of the proposed plantation

Step 3: Assuming a certain number of working days per year, estimate the total no. of persons employed throughout the year with the proposed plantation.

N = EMP/ NWD

where N = No. of persons employed

NWD = No. of working days in a year

Step 4: Estimate the monthly per capita income generated based on the number of working days per month and the minimum wage rate.

Δ MI = Increase in the monthly per capita income generated

Step 5: From the NSS data, estimate the rise in literacy level (per 1000 households) on account of increase in per capita income.

Δ LL = Rise in female literacy level per 1000

Step 6: Estimate the increase in literacy on account of the proposed plantation as mentioned above.

$\Delta LIT = (\Delta LL * N)/ 1000$

b) Impact on Female Literacy

Methodology

The steps followed for total employees are now considered for female employees only and the employment of females generated is estimated following steps 1 to 6 to get employment of females in person days per hectare of cultivation.

The female literacy levels (per 1000) across the Monthly Per Capita Expenditure (MPCE) classes in the rural India, as per the NSS Report 2004-05 are as in Table 4.4.

Table 4.4: MPCE Class and Female Literacy Levels

MPCE Class	No. per 1000 households with no literate person above 15 years in female members
less than 235	644
235 -270	711
270 -320	681
320 – 365	632
365 – 410	583
410 – 455	574
455 – 510	543
510 - 580	496
580 – 690	436
690 – 890	385
890 -1155	302
1155 & above	182
all classes	500

Source: NSS Report

c) Impact on Type of Dwelling

Methodology

Step 1: Estimate the employment generated in person days with a plantation of 1 Hectare.

EPH = Employment Generated per Hectare

Step 2: Estimate the total employment generated in person days by the proposed plantation across India as mentioned above.

EMP = EPH * NH

where EMP = total employment generated in person days

NH = No. of Hectares of the proposed plantation

Step 3: Assuming a certain number of working days per year, estimate the total no. of persons employed throughout the year with the proposed plantation.

N = EMP/ NWD,

where N = No. of persons employed and NWD = No. of working days in a year

Step 4: Estimate the monthly per capita income generated based on the number of working days per month and the minimum wage rate.

Δ MI = Increase in the monthly per capita income generated

Step 5: From the NSS data, estimate the rise in the persons (per 100 persons) staying in the type of dwelling units on account of increase in per capita income.

Δ DW = Rise in persons staying in a type of dwelling per 100

Step 6: Estimate the increase in the persons staying in a type of dwelling unit on account of the proposed plantation, as mentioned above.

$\Delta DWT = (\Delta DW * N)/ 1000$

As per NSS reports, the persons staying in type of dwelling unit (per 100) across the Monthly Per Capita Expenditure (MPCE) classes in the rural India, as per the NSS Report 2002 are as in Table 4.5.

Table 4.5: MPCE Class and Details of Dwelling Units

MPCE (Rs.)	Pucca	Katcha
0 - 225	22	33
225 -255	23	32
255 - 300	25	28
300 -340	26	29
340 - 380	29	25
380 -420	31	23

420 -470	35	22
470 - 525	38	18
525 -615	42	17
615 - 775	48	13
775 - 950	53	9
950 or more	64	5
not reported	35	28
all classes	21	67

Source: NSS Report

Due to income from Jatropha biodiesel production, there is an expected rise in income and expenditure, the number of person falling in a particular MPCE class can be calculated and change in dewelling units could be estimated.

d) Impact on Standard of Living

As per NSS norms the standard of living is estimated by finding out the rise in the persons (per 100 persons) staying in the dwelling units, where they have access to three basic amenities, viz., drinking water, electricity and latrine within the premises. If there is change in this value on account of increase in per capita income, it is considered that living standard is improving.

Methodology

Step 1: Estimate the employment generated in person days with a plantation of 1 Hectare.

EPH = Employment Generated per Hectare

Step 2: Estimate the total employment generated in person days by the proposed plantation across India as mentioned above.

EMP = EPH * NH

where EMP = total employment generated in person days

NH = No. of Hectares of the proposed plantation

Step 3: Assuming a certain number of working days per year, estimate the total no. of persons employed throughout the year with the proposed plantation.

N = EMP/ NWD

where N = No. of persons employed

NWD = No. of working days in a year

Step 4: Estimate the monthly per capita income generated based on the number of working days per month and the minimum wage rate.

Δ MI = Increase in the monthly per capita income generated

Step 5: From the NSS data, estimate the rise in the persons (per 100 persons) staying in the dwelling units, where they have all the three amenities such as drinking water, electricity and latrine within the premises, on account of increase in per capita income.

Δ SL = Rise in persons staying in a dwelling having all the three amenities per 100

Step 6: Estimate the increase in the persons staying in dwelling having all the three amenities on account of the proposed plantation across India as mentioned above.

$\Delta SLT = (\Delta SL * N)/ 1000$

As per NSS reports, the persons staying in a dwelling unit with all three amenities (per 100) across the Monthly Per Capita Expenditure (MPCE) classes in the rural India, as per the NSS Report 2002 are as in Table 4.6.

Table 4.6: MPCE Class and Details of Standard of Living

MPCE Class	Houses with all 3 amenities	Houses with none of the above amenities
0 - 225	3	52
225 - 255	1	49
255 - 300	2	44
300 - 340	3	41
340 - 380	5	35
380 - 420	5	33
420 - 470	8	28
470 - 525	8	24
525 - 615	15	21
615 -775	19	14
775 -950	27	11
950 or more	43	7
not reported	11	36
all classes	11	30

Source: NSS Report

Due to income from Jatropha biodiesel production, there is an expected rise in income and expenditure, the number of person falling in a particular MPCE class can be calculated and change in living standards based on three amenities in their dewelling units could be estimated.

Local Sub-Indices of HDI

Since data on literacy and life expectancy at local level are not available an alternative method for assessment of HDI is proposed here. For each country, the rise in per capita income and its relationship with change in literacy and life expectancy is available either at state level or province level or district level. For example in India, National Sampling Survey (NSS), data provide such kind of relationship at state level.

i) Life Expectancy Index

The increase in life expectancy is estimated as mentioned above, As shown in Table 4.7, which gives the state-wise life expectancy, a regression model is used to find the change in life expectancy due to rise in PCI.

Table 4.7: State-wise Life Expectancy and Per Capita Income

State/UT	Population		
	2006	Life Expectancy (in years)	Per Capita Income (Rs.)
Andhra Pradesh	75730000	62.8	16373
Assam	26640000	59	10467
Bihar	82890000	65.7	5108
Gujarat	50600000	63.1	19228
Haryana	21080000	64.6	23742
Karnataka	52740000	62.4	18041
Kerala	31890000	71.7	19463
Madhya Pradesh	60380000	59.2	10803
Maharashtra	96750000	66.8	23726
Orissa	36710000	60.1	8547

Punjab	24290000	69.8	25048
Rajasthan	56470000	62.2	11986
Tamil Nadu	62110000	67	19889
Uttar Pradesh	166060000	63.5	9721
West Bengal	80220000	66.1	16072

Source: ://www.indiastat.com

Based on the data available for LE at the state-level, we can calculate the rise in LE due to rise in PCI as follows.

LE = 62.8 * (PCI at State Level+ Rise in PCI)/ PCI at State Level

Where,

LE = Life Expectancy and

PCI = Per Capita Income

ii) Adult Literacy Rate

The increase in Adult Literacy Rate s estimated as mentioned above. As shown in Table 4.8, which gives the state-wise ALR, a regression model is used to find the change in ALR due to rise in Per Capita Income (PCI).

Table 4.8: States-wise Adult Literacy Rates and Per Capita Income

State/UT	**Population**		
		Adult Literacy Rate	**Per Capita Income (Rs.)**
Andhra Pradesh	75730000	44.87	16373
Assam	26640000	69.18	10467
Bihar	82890000	36.81	5108
Gujarat	50600000	61.04	19228
Haryana	21080000	57.82	23742
Karnataka	52740000	52.54	18041
Kerala	31890000	89.47	19463
Madhya Pradesh	60380000	47.52	10803
Maharashtra	96750000	66.82	23726

Orissa	36710000	51.35	8547
Punjab	24290000	62.59	25048
Rajasthan	56470000	42.1	11986
Tamil Nadu	62110000	61.67	19889
Uttar Pradesh	166060000	44.52	9721
West Bengal	80220000	62.46	16072

Source: ://www.indiastat.com

Based on the data available for ALR at the state-level, we can calculate the rise in ALR due to rise in PCI as follows.

ALR = 44.87 * (PCI at State Level+ Rise in PCI)/ PCI at State Level

Where,

ALR = Adult Literacy Rate and

PCI = Per Capita Income

iii) Gross Enrolment Ratio

The increase in Gross Enrolment Ratio is estimated as mentioned above. As shown in Table 4.9, which gives the state-wise gross enrolment ratio, a regression model is used to find change in GER due to rise in Per Capita Income (PCI).

Table 4.9: State-wise Gross Enrolment Ratio and Per Capita Income

State/UT	Population		
		Gross Enrolment Ratio	**Per Capita Income (Rs.)**
Andhra Pradesh	75730000	53.09	16373
Assam	26640000	49.41	10467
Bihar	82890000	22.47	5108
Gujarat	50600000	55.3	19228
Haryana	21080000	52.94	23742
Karnataka	52740000	59.03	18041
Kerala	31890000	93.19	19463
Madhya Pradesh	60380000	45.66	10803

Maharashtra	96750000	68.91	23726
Orissa	36710000	53.73	8547
Punjab	24290000	51.47	25048
Rajasthan	56470000	43.91	11986
Tamil Nadu	62110000	80.66	19889
Uttar Pradesh	166060000	48.92	9721
West Bengal	80220000	41.46	16072

Source: ://www.indiastat.com

Based on the data available for GER at the state-level, we can calculate the rise in GER due to rise in PCI as follows.

GER = 53.09* (PCI at State Level+ Rise in PCI)/ PCI at State Level

Where,

GER = Gross Enrolment Ratio and

PCI = Per Capita Income

5. RESULTS AND DISCUSSIONS

Following the methodology described in the previous section and based upon the available data and information, through field survey and from other sources, the estimations of economic, environmental and social impacts have been obtained for Jatropha Cultivation stage (TOIL) and Oil Extraction & Biodiesel Production stages (SBTL). Estimation of economic, environmental and social impacts used primary data from the field survey of these companies and secondary data for literature. Some assumptions have also been made where no data is available. Details of calculations are given in Appendix 1.

Consolidated results of estimations are being described stage wise during the biodiesel production chain, as follows.

5.1 Jatropha Cultivation Stage

The data of TOIL have been used for various estimations during the cultivation stage. The Jatropha plantation farm is well managed with all the waste being recycled and utilized at the farm. The biomass generated at the farm is composted by vermicomposting and natural composting. Vermiculture is also one of the activities at the farm and the output is utilized for earthworm multiplication and Vermicomposting. The animal excreta is utilized by the biogas digester to generate gas which is used for cooking by the workers' families staying at the farm.

The major sources of power used at the farm are diesel and electricity. The farm has a diesel run generator, which is a necessity because of irregular power supply due to frequent power cuts in the area. Also, there is tractor which is used for farm work and also transportation of workers and their families. The company reported that both tractors and electric generators are run by the oil extracted at the farm itself using its own raw material i.e. oil seeds.

The company does not get any incentive, support or encouragement from the government but it reported that there was no interference too.

a) Economic Impact

The study shows that for cultivation of Jatropha and Pongamia, there is a gestation period of about three and six years, respectively, before the plantation starts giving economically viable yields of seeds. Profitability starts from third year, rises till fifth year and may stabilize thereafter. Thus, if only oil tree yield (in this case, Jatropha and Pongamia), is considered, unless there's an increase in the yield of seeds or increase in the price of seeds, the present revenue generated is not enough to meet the cost incurred at the farm. It is reported that the most of the ancillary activities at farm start generating revenue from the second year onwards and some of them from the first year itself. Presently the ancillary activities at the farm generate almost same revenue as sale of seeds and from fifth year onwards this revenue (from ancillary activities) may even surpass the revenue generated by sale of seeds.

It is to be noted that while estimating economic returns the capital cost has not been taken into account. The capital cost for purchase of land was Rs.24,00,000 @ Rs. 20,000/- per acre. However, the real estate prices have gone up drastically in last decade and as per information of the company, the price of purchased land presently stands about ten times @ Rs.2,00,000/- per acre. Considering this appreciation in land cost, the project for the company is definitely a highly profitable venture in economic terms.

The results of the economic analysis in terms of revenue generation (GVA) and profit at TOIL are given in Table 5.1. Thus, after the fifth year gross profit from the farm may be stabilized at about Rs.1.6 million per year, which is quite attractive return on investment of the company.

Employment generation at TOIL is shown in Table 5.2. The job creation by the company per unit of yield of seeds is 0.112. Additional employment is generated through ancillary activities, which is reported to be about half of the regular employment in person days per hectare per year.

Although this is not very efficient for the company but keeping in view that agriculture activities are labour intensive and social angle of generating rural employment, job creation by the company is quite impressive.

Table 5.1: Economic Analysis (GVA) of TOIL

SN	Items	Year of Jatropha Plantation				
		1	2	3	4	5
1	Total Operating cost (in Million Rupees)	1.2	1.2	1.2	1.2	1.2
2	Yield of Seeds in kg per ha (seeds @ 2 kg per plant yr with 1110 plants/ha from 3rd yr onwards)	0	0	2220	2220	2220
3	Total income per ha per yr (sale of seeds @ Rs.14 per kg)	0	0	31,080	31,080	31,080
4	GVA (in Million Rupees)					
	Va (from main products)	0	0	1.509	1.509	1.509
	Vb (from by-products)	0	0.5	0.6	1.200	1.300
5	GVA (Va+Vb) (in Million Rs.)	0.00	0.5	2.109	2.709	2.809
6	Profit (Revenue-Total Cost) (in Million Rs.)	-1.20	- 0.70	0.909	1.509	1.609

Table 5.2: Job Creation Per unit of Seed Output at TOIL

SN	Item	Values
1	Total Production (seeds in kg per year)	107803.2
2	Person days per year	12045
3	Employment (person days per unit of seeds per year)	0.112

The potential for the biodiesel produced by the company shows that there would be a positive impact on foreign trade with a forex savings of about US Dollar 27122 per year (Table 5.3). This forex saving may not be a benefit for the company itself but will add to the economy of the country.

Table 5.3: Impact on Foreign Trade by TOIL

SN	Item	Values
1	Potential biodiesel that could be extracted (@34% of seeds weight in lt)	43121.28
2	Above in terms of barrels	361.63
3	Foreign exchange saved @US $75/barrel (in US Dollars)	27122.58

Note: 1barrel (US liquid)= 119.24 lt

b) Environmental Impacts

The diesel requirement for operating the generator and tractor at TOIL farms is 400 litres per month or 4800 litres per year. The electricity is supplied at a subsidized rate (@ Rs.6 per unit) and about Rs.5000 per month is spent on electricity for lifting ground water for irrigation of plants. Apart from electricity and diesel, another source of GHG emissions is fertilizer used during cultivation which adds 1942 kg of nitrogen, 2913 of phosphorous and 1214 for potassium per year. These three items could be considered as main sources of GHG emissions at the plantation stage (Table 5.4).

The net CO_2 balance of the plantation stage at TOIL is shown in Table 5.4. Thus, per year carbon emission are 36.7 tons per year and 0.589 tons per year per hectare. The conversion factor used in Table 5.4 is taken form Woods et al. (2005).

c) Social Impacts

i) Income and Expenditure

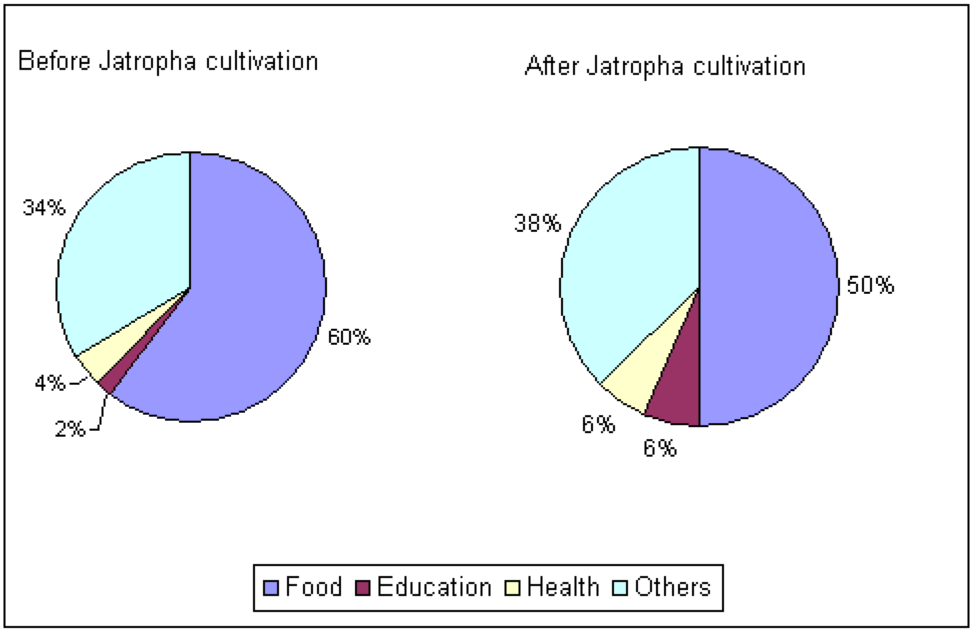
During the field survey of TOIL's farms, it was observed that ten families of workers were staying at the farm permanently. The families reported that they were earning an average monthly income of Rs.4000 per month after their employment in this venture. They also reported a substantial increase (a 60% jump) in their monthly income after their employment at TOIL.

Table 5.4: CO_2 Emissions during Cultivation Stage

SN	Item	Quantity/yr	Quantity/ha/yr	Conversion factor	CO_2 Emissions (in tons/yr)	CO_2 Emissions (in tons/ha)
1	Diesel (lt)	4800	98.85	2.7	12.96	0.267
2	Electricity (Mwh)	10	0.21	0.81	8.1	0.000
3	Fertilizer N (kg)	1942	39.99	6.69	12.99198	0.268
4	Fertilizer P (kg)	2913	59.99	0.71	2.06823	0.043
5	Fertilizer K (kg)	1214	25	0.46	0.55844	0.012
6	Total emissions				36.67865	0.589

Figure 5.1 shows the monthly income and expenditure pattern of families employed at TOIL. The increase in income also resulted in higher monthly expenditure on various items such as food, education and health. For example, monthly spending on food, education and health was 34%, 2% and 4%, respectively, before their employment in Jatropha cultivation, which went up as 38%, 6% and 6%, respectively, after their employment in this venture. Although the percentage under the head "others, that includes savings", declined from 60% to 50% but in absolute terms the savings of each family also increased (Figure 5.1).

Figure 5.1: Monthly Spending Pattern and Income of Families affetced by TOIL



Income

Rs.2500

Income

Rs.4000

ii) Employment Generation

Apart from the regular full time employees, on an average, about 10 daily wage workers are hired for additional/miscellaneous works. The social benefits, in terms of employment generation, through Jatropha Cultivation at TOIL, has been estimated as follows (Table 5.6). Thus, in total, 12045 person days per year are created at TOIL, which comes to a figure of 248 persons per hectare of Jatropha cultivation.

Table 5.6: Employment Generation at TOIL

SN	Item	Values
1	Area of Jatropha Cultivation (acres/ ha)	120 / 48.56
2	Employment (person days per day)	33
3	Employment (person days per year)	12045
4	Employment in person days per hectare per year	248

iii) Change in HDI

As per the latest HDI ranking (2007), India is placed at 134th rank, (with an HDI of 0.612), among 182 countries included in HDR (2009). Other rankings of the country are reported as 128th in terms of life expectancy (LE=63.4 years), 120th in terms of adult literacy rate (ALR=66.0%), 134th in terms of combined gross enrolment ratio (GER=61.0%) and 128th in terms of GDP per capita on PPP basis (2,753 US$).

The modified values of various sub-indices of HDI (LE, ALR, GER and Per Capita Income) were calculated from obtaining these values for Andhra Pradesh (Tables 4.7, 4.8 and 4.9). These values were adjusted for the rise in income of the population affected by TOIL's activities. The new HDI value for the region affected by the TOIL is 0.615, and thus, there is an increase in the HDI, which is = 0.615-0.612 = 0.003 (Table 5.12).

iv) Gender-related Development Index

The values of GDI were calculated in the similar manner as HDI but using goal post of UNDP for females. Local data were also included for females. The value for GDI was estimated as 0.603 which is about 98.2% of HDI value shown above (Table 5.12)

Other SDIs

i) Standard of living

The families who are staying at the farm were earlier living in a nearby village in joint families. They had agricultural land ranging between 1 and 3 acres, which was either cultivated by the family or was given on contract to other farmers with yield sharing arrangement. In the case of contract arrangement, the family members would work on other farms on daily wages. However, the work was not regular i.e. was seasonal and required travel, at times, far away form their homes. The house of these families in the village was owned but made of mud (called kachcha house, locally) and had no toilet facilities. For cooking, firewood was used and household members, particularly women and young children, were exposed to smoke, carbon monoxide and other emissions released from biomass burning, resulting in various health hazards in the family.

The living standard of families at the farm has increased substantially. The biogas plant at the farm generates biogas, which is utilized by the families for cooking and other household activities, thus, providing them with cleaner and better alternative fuel. They also have latrine within there premises and electricity is supplied either through normal grid or generated by the biodiesel generator. Thus, as per definition of NSS, as all of these families are having all the three amenities, viz., water supply, latrine and electricity within their premises, the living standards of these families is higher than others.

In quantitative terms, as given in Table 4.6 of section 4 of this report, the rise in income has contributed to overall social development in the locality. While only 8 families were having a higher living standards before TOIL plantation, the number of families having a higher standard of living increased to 27 after TOIL plantation. Thus, a rise in living standard of 19 families per 100 households is quite impressive.

ii) Education

Due to rise in the income, the spending of families on education increased by 4% (Figure 5.1). Also, the company has made transport arrangements for carrying school going children to their schools. Due to both rise in income and transport support of the company, the families have started sending the children to the school. Families reported that they are also sending girl children to school, which was not done before they were employed in this venture, and thus, there is some improvement in the female literacy.

In quantitative terms, as given in Tables 4.3 and 4.5 in section 4, the number of illiterate persons per 1000 households were 271 before TOIL plantation, which decreased to 186 after the plantation that is the change in literacy by 85 persons per 1000 households. Also, there is a remarkable change in female literacy and this number among female decreased by 158 (543 before and 385 after plantation) persons per 1000 households. Further, education index is captured in HDI, which shows an increase due to TOIL plantation.

iii) Health

Due to rise in income, the spending on health has increased by 2% (Figure 5.1). Families staying at farm also reported that the company bears the cost of any major medical expenses, and therefore, they are looked after in a better manner as compared to their earlier status when staying in the village. Further, although, the health is not directly captured by the HDI but, to some extent, it is reflected by increased expenditure on food and health services, which may have some positive impact on life expectancy, which is shown by a marginal increase in HDI.

iv) Change in Dwelling Units

The rise in income also affects the type of dwelling units and it is expected that families would like to have Pucca houses, when their disposable income rises. In quantitative terms, as given in Table 4.5, per 100 dwelling units, there is an increase of 15 units from Kachcha house to a Pucca houses (from 38 to 53) due to rise in income from TOIL plantation.

5.2 Biodiesel Production Stage

Southern Online Biotechnologies Limited is the company is involved in both Oil Extraction and Biodiesel Production Stages. Due to shortage of supply of oil seeds, the company is using various feed stocks in the production process. Assuming use of Jatropha and other oil seed as only feed stock and plant efficiency as 100%, the results of production of biodiesel stage (SBTL) are analysed in Table 5.7. The company reported an investment of Rs.33 crores, and hence, per year GVA of Rs.51.97 crores and a profit of 27.87 crores is quite impressive.

Table 5.7: Economic Analysis (GVA) of SBTL

SN	Items	Values
1	Biodiesel Production capacity/day (lt)	40000
2	Annual Production Capacity (lt)	14600000
3	Raw Material (RM) Requirement/year (kg)	12556000
4	Cost of RM @ Rs. 16/kg	200896000
5	Production Cost without RM (@ Rs. 2.75/ lt)	40150000
6	Va (Value added from main product) – @ 33/lt Selling Price	481800000
7	Vb (Revenue from by-products (glycerine & Rs. 26/kg)	37960000
8	GVA (VAa+VAb) in Rs.	519760000
9	Profit (Gross Revenue-Total Cost) in Rs.	278714000

Comparing the biodiesel production stage with the plantation stage indicates that productivity is much higher in the biodiesel production stage. This is true for all agricultural activities when compared with manufacturing sector. The employment generated per litre of biodiesel produced at SBTL is 0.002 person day per litre of biodiesel produced (Table 5.8).

Table 5.8 Job Creation Per Unit of Biodiesel Prodcution at SBTL

SN	Items	Values
1	Total Production (lt)	14600000
2	Person days (110x365)	40150
3	Employment per unit yield (in person days)	0.00275

The impact on foreign trade (Forex savings) by the SBTL is as shown in Table 5.9. It indicates a positive impact on foreign trade as the savings in terms US Dollar 9.18 million per year, which is quite significant.

Table 5.9: Impact on Foreign Trade by SBTL

SN	Items	Values
1	Bio-diesel production per year	14600000
2	Above in terms of barrels	122442.13
3	Foreign exchange saved @US $ 75/barrel (US$)	9183160.01

1barrel (US liquid)= 119.24 lt

b) Environmental Impacts

Electricity supply at the location of SBTL plant is quite irregular and there is a power cut for 48 hours or more per week. As the plant is operated round the clock on all 365 days of the year, to run the plant during the power cut, a diesel generator has been installed. The diesel used in the generator is blended with 20% biodiesel produced by the company. For generating heat and steam, rice husk is the main fuel used in the boilers. Although the availability of rice husk is not a problem and the plant gets regular supply of the same, in case of non-availability of rice husk, which is very rare, coal or firewood is used, which is negligible in terms of quantity.

Thus, for estimation of GHG emissions during the production process, diesel, electricity and rice husk have been considered and estimations are shown in Table 5.10. Accordingly, per year carbon saving at SBTL is 2763609 tons. This carbon saving may earn carbon credits through which company would be able to generate extra revenue.

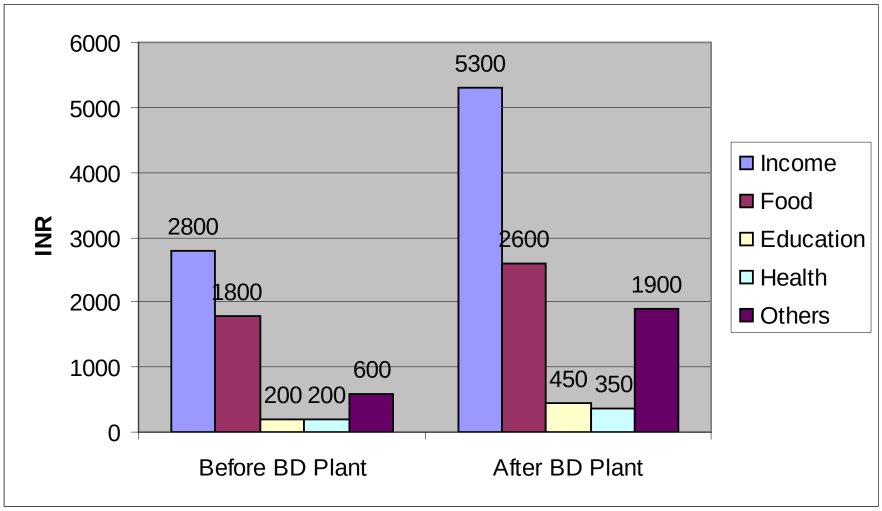
c) Social Impact

Monthly income and expenditure pattern of the persons employed in the SBTL is given in Figure 5.2. The average salary per person reported before and after the employment in biodiesel plant was Rs.2800 and 5300, respectively, which indicates a rise of about 53% in salary after the employment at SBTL plant. Although total spending increased in all items but interestingly the percentage rise of spending did not increase, except for education which is increased marginally by 1%. The contribution towards the head "others, that includes savings," increased substantially, which indicates that families are more concerned about their financial security in the future and probably use this money for better housing and similar other factors of raising living standard.

Table 5.10: CO2 Emissions during Bio-diesel Production Stage

SN	**Item**	**Quantity/yr**	**Conversion factor**	**CO_2 Emissions (in tons)**
1	Diesel (lt)	119808	2.7	323.48
2	Electricity (MWh)	1277.5	0.81	1034.78
3	Rice Husk (Kg)	9125	29.9	272.83
4	Total Emissions per year			1631.09
5	Carbon Saving per liter of Biodiesel			0.189
6	Carbon Saving per year with BD use			2765240.00
7	Net Carbon Saving per year (Consumption Stage)			2763608.91

Figure 5.2: Monthly Income and Expenditure of Workers at SBTL



The social benefits, in terms of employment generation from Bio-diesel production stage, at SBTL has been estimated as given in Table 5.11. Thus, in total, 40150 person days per year are created at SBTL. In addition, employment is also created by some other activities such as disposal of flyash from boilers, use of this flyash for bricks and other building material production, etc. However, these activities are carried out by outside contractors and not by the company directly, and hence, note counted.

Table 5.11: Employment Generation at SBTL

SN	Item	Values
1	Production of Biodiesel (lt)	40000
2	Employment (person days per day)	110
3	Employment in Person days per year	40150
4	Biodiesel Production per year	14600000
5	Oil Requirement (kg) per year	12556000
6	Seed Requirement (kg) per year	36929411.76
7	Land area required for above oil (ha)	10463.33333
8	Labour requirement (person days per hectare per year)	42.19086022

i) Change in HDI

The HDI value for the region affected by the SBTL is 0.616 (Table 5.12), and thus, there is an increase in the HDI, which is = 0.616-0.612 = 0.004.

ii) Gender-related Development Index

The values of GDI were calculated in the similar manner as HDI but using goal post of UNDP for females. Local data were also included for females. The value for GDI was estimated as 0.604 which is about 98.3% of HDI value shown above (Table 5.12).

Other SDIs

i) Standard of living

The living standard of families of employees of SBTL is expected to rise due to increased income. The company provides free food and shelter to the employees. In quantitative terms, as given in Table 4.6 (please refer to section 4 of the report), the living standards of 28 families per 100 families is expected to increase due to SBTL plant employment.

ii) Education

Due to rise in income, the spending on education increased only marginally by 1% (Figure 5.2). In quantitative terms, as given in Tables 4.3 and 4.5 in section 4, the overall illiteracy decreased by 92 persons per 1000 households and female illiteracy decreases by 192 persons per 1000 households. Further, education index is captured in HDI, which shows an increase due to SBTL plantation.

iii) Health

There was no change in spending on health in percentage terms but total expenses towards health increased (Figure 5.2). Further, although, the health is not directly captured by the HDI but, to some extent, it is reflected by increased expenditure on food and health services, which may have some positive impact on life expectancy, which is shown by a marginal increase in HDI.

iv) Change in Dwelling Units

The rise in income also affects the type of dwelling units and it is expected that families would like to have Pucca houses, when their disposable income rises. In quantitative terms, as given in Table 4.5, per 100 dwelling units, an increase of 22 units is expected from Kachcha house to a Pucca house due to rise in income from SBTL plant.

5.3 Overall Impact Assessment

Table 5.12 summarizes the overall impact during the life cycle of biodiesel production, which is based upon two companies, viz, of TOIL and SBTL. The analysis is based upon Jatropha cultivation stage of TOIL and Oil Extraction and Biodiesel Production stages of SBTL. The emissions from transportation of raw material and finished products or by-products have not been considered for estimation in this study. The emissions from land use change have also not been considered as waste land has been converted into plantation land where there was no vegetation earlier. Consumption stage is captured only for environmental analysis in terms of GHG savings through use of biodiesel produced at SBTL.

Economic benefits during biodiesel production are much higher than those from cultivation stage of Jatropha and other Oil Trees. Same is the case with the GHG saving potential and social benefits. However, it is to be noted that in this case both cultivation as well production stages are performed in rural areas. Overall assessment indicates a positive impact on economic, environmental and social aspects in the locality where the biodiesel facilities are situated.

Table 5.12: Overall Impact of Biodiesel Production

STAGE / IMPACT	Jatropha Cultivation (TOIL)	Biodiesel Production (SBTL)	TOTAL / AVERAGE
Economic			
GVA (Rs.)	2809245	519760000	522569245
Net Profit Per Year (Rs.)	1609245	278714000	280323245
Net Profit Per Hectare Per Year (Rs.)	33139	6392	39531
Job Creation (per unit output)	0.112	0.003	0.057
Forex Savings (US$)	27123	9183160	9210283
Environmental			
GHG Emissions (Tons CO2 per yr)	37	1631	1668

GHG Emissions per hectare (Tons CO2 per yr)	0.589	0.041	0.630
GHG Savings during Consumption (Tons/ Yr)	8072	2763609	2771681
Social			
Employment (PDs per yr)	12045	40150	52195
Employment (PDs per ha per yr	248	42.19	290
Change in PCI (Rs. Per Year)	1980	1999	1989
HDI (Actual)	0.615	0.616	0.616
HDI (UNDP for 2006)	0.612	0.612	0.612
Change in HDI	0.003	0.004	0.004
GDI	0.603	0.604	0.604
Other SDIs			
Living Standard (Rise per 100 HH)	19	28	24
Change in Literacy (No. per 1000 HH)	87	92	90
Change in female Literacy (No. Per 1000 HH)	158	192	175
Change in Pucca Dwellings (No. per 100 HH)	15	22	19

Note: Please refer to Appendix 1 for detailed calculations; PD- person days; HH- Household.

6. CONCLUTIONS AND RECOMMENDATIONS

This study aims at assessment of sustainability of biodiesel production in India and focuses on estimation of economic, environmental and social impacts during various stages of biodiesel production. Three companies, viz., TOIL, NBL and SBTL were selected for capturing various stages of life cycle of biodiesel production. Although long term plans of all theses companies are to get involved in all stages but at present they were focusing on only one or two aspects of biodiesel production chain. For example, the TOIL was involved in plantation of Jatropha, Pongamia, and other oil trees, the NBL was involved in R and D on Jatropha and other oil trees and SBTL was producing bio-diesel with oil tree seeds and other feed stocks.

As there is no single company which has an integrated facility to exhibit all the stages of life cycle of biodiesel production, estimations were made based upon the best possible data available for any particular stage of the company. For example, data of TOIL was used for impact in

Jatropha cultivation stage and data of SBTL was used for oil extraction and biodiesel production stage. The methodology adopted for estimation of the above impacts was developed by the WG experts of ERIA.

Based upon the results of the pilot study following conclusions could be drawn.

6.1 Conclusions

The GoI policies are encouraging production of biodiesel in the country. For biodiesel development various tasks have been initiated, which include development of high oil-yielding varieties of Jatropha; plantation of Jatropha by government-sponsored agencies; setting up of pilot plants for transesterification; successful trial runs on locomotives and road vehicles using 5 per cent biodiesel blend and organizing seminars to expand awareness of the biodiesel program.

Indian biodiesel industry, in comparison to ethanol industry, is still in its early stages. However, the demand for diesel is about five times higher than the demand for petrol, and thus, more attention is needed on biodiesel production. Since the demand for edible vegetable oil exceeds the supply, to meet the ambitious targets of 20% blending by 2011-2012, the decision of GoI to use non-edible oil from Jatropha Curcas and other oil seeds for biodiesel production is justified. Formation of National Biodiesel Mission and bringing substantial area under Jatropha cultivation are the steps in right direction.

There is a visible increase in employment and income of individuals employed in Jatropha and Tree Oil plantations. This marginal increase in income has improved the living standard and life style of people, as they are able to spend more on their basic needs such as food, education and health. Income increase of poor masses in rural areas also has some positive impact on female literacy and upliftment of women.

The economic indicators estimated were, Gross Value Added (GVA), Employment Generated Per Unit of Yield (Output) and Foreign Trade Impact (Forex Saving). The study shows that GVA is highest at the 5th year of the Jatropha plantation and may tend to stabilize thereafter. Also, the GVA during the biodiesel production stage is much higher as compared with GVA of plantation stage.

Economic benefits in terms of Profit and Forex saving are better in bio-diesel production stage as compared to the plantation stage.

Employment generated per unit of yield at plantation stage is 0.112 and 0.0028 per unit of biodiesel production. Thus, Jatropha cultivation, being an agricultural activity, is labor intensive and hence, beneficial for employment and development of rural areas.

The cumulative savings in foreign exchange comes to around US$9.2 million per annum, of which over ninety percent of the saving comes from biodiesel production stage. Hence, GoI should encourage setting up of more biodiesel production plants.

The GHG savings in at the plantation stage is about 397 tons per year and at the biodiesel production stage is quite high at 2763609 tones per year.

The company involved in biodiesel production reported shortage of supply of oil tree seeds and for sustained production the company is using various other feed stocks such as animal fats, waste oils, etc. This is not good as it defeats the basic purpose of the company i.e. biodiesel production using Jatropha and other tree oils.

The case studies taken on Jatropha cultivation indicate that geographical situation and field conditions have tremendous effect on survival rates of Jatropha plants. Under adverse conditions, survival rate of Jatropha plant is very low and yield per plant is also low. The average yield is 1-2 kg per plant depending on various conditions. In the R and D centre of one of the companies studied, (NBL) it was observed that frequency of irrigation, fertilizer application and other care of Jatropha plants can increase the yield substantially.

Thus, the myth that oil trees like Jatropha can grow without any care and attention should be dispelled. In fact for better yield Jatropha and other oil trees require irrigation, fertilizers, pesticides, etc., similar to other crops. However, the amount of these inputs is much lesser than other crops and depends upon the location of plantation. For example, in arid and semi-arid regions, frequency of irrigation may be higher, particularly in first few years of plantation.

6.2 Recommendations

The first and foremost task for sustainability of biodiesel production is to encourage farmers to undertake Jatropha and other oils seeds plantation. This requires that suitable activities should be identified for the non-yielding years (first 2-3 years) to sustain the income and interest of farmers in cultivation. These may be poultry farming, intercrops, raring milk producing animal, etc.

All arrangements of bio-fuel plantation including contract farming, should be allowed for CERs and these Carbon credits should be given to farmers for additional revenue. Thus, atleast from plantation stage biodiesel companies should renounce their claim of CERs. This is justified as the companies would have sufficient margins from the sale of bio-diesel. Also, companies may claim these carbon credits from the potential of biodiesel in reduction of GHGs at consumption stage.

For sustainability of biodiesel production from Jatropha and other Tree Oils, research on increasing the yield of seeds and oil content in seeds should be undertaken at war footing. These factors will increase the economic returns per hectare of cultivation and are important in attracting farmers and other stakeholders to get involved in biodiesel production chain.

The government should provide tax incentives for the research activity in this area. It is necessary to increase the yield of seeds from Jatropha so that its cultivation gives better returns for the farmer. For instance, in India, sugarcane plantations yield 70 ton per hectare and fetch the farmer Rs.70,000 per hectare at a sugarcane price of Rs.1,000 per ton. In comparison, with Jatropha plantation farmer gets only Rs.5,000-10,000 per hectare at present seed purchase price.

Region-specific business models should be developed by taking into account government and public support. Regular power supply to the farms and biodiesel production plants may be provided to limit the reliance on diesel. Even use of B100 may be promoted for use in generators by suitable modifications.

The reported cost of biodiesel production is higher (Rs.32-33 per liter) than the purchase price fixed by the GoI (Rs.26.5 per liter). It is necessary that both price of oil seeds and biodiesel are kept at such as level which can sustain the biodiesel industry. It is recommended that tree oil seed price should be above Rs.10 per kg and biodiesel purchase price should be above Rs.35 per liter.

Small and marginal farmers, possessing small land holdings, will be interested in cultivating the biofuel crops only if they are assured of improvement in their economic returns. This necessitates introduction of mass awareness and capacity building programs in rural areas. In addition, financial and technical supports such as interest free loans or soft loans, easy availability of quality seeds and other inputs, crop insurance, etc., may be introduced.

6.3 Future Scope of the work

The results of the pilot study indicate some success on assessment of socio-economic and environmental impacts but both the scale of study and duration of the project were small, which were not enough for a comprehensive assessment of sustainability of biodiesel production. Although all the three companies selected in the pilot study have ambitious future plans, their current status on sustainability aspect is yet to be ascertained. Companies blame a long gestation period for less seed production, and hence, lack of seed availability from Jatropha and other oil trees and lack of clarity on biofuel pricing policy of the GoI. Further, the results of a small scale project are not enough for making some meaningful projections at national or even regional (state) level.

Future work on the project may be undertaken on the similar lines as this pilot study but extended to a larger scale such as state, regional (involving few states) or at national level. The duration of the project could be anywhere between 3-5 years. As India is a vast country, having diverse agro-climatic conditions, it is necessary to identify few large scale case studies, which could represent the area in question. For example, if a national level study is to be conducted, it is necessary to select at least one or two case studies in each part of the country, say northern, southern, eastern, western and central parts of India. Once some large scale case studies are selected, they would be able to represent the country / region/ state, as the case may be, and give required data and information for assessment of sustainability of biodiesel production at an appropriate level.

APPENDIX 1: Details of Data Analysis

As mentioned earlier in section 5, the data of TOIL and SBTL have been used for the estimations of impact during Jatropha cultivation and biodiesel production stages, respectively.

Following tables show detailed calculations and various sources for secondary data and assumptions made in estimations of impacts.

CULTIVATION STAGE (TOIL)

ECONOMIC IMPACTS

Table 5.1: Economic Analysis (GVA) at TOIL

SN	Items	Yr1	Yr2	Yr3	Yr4	Yr5	Total
1	Total Operating cost	1,200,000.00	1,200,000.00	1,200,000.00	1,200,000.00	1,200,000.00	6000000
2	Yield per hectare	0	0	2220	2220	2220	2220
3	Total income/ha/yr (sale of seeds @ Rs.14 per kg)	0.00	0.00	31,080.00	31,080.00	31,080.00	31,080.00
4	GVA						
	Va (from Jatropha Seeds)	0.00	0.00	1,509,244.80	1,509,244.80	1,509,244.80	3642000
	Vb (from other sources)	0.00	500,000.00	600,000.00	1,200,000.00	1,300,000.00	3600000
5	GVA (Va+Vb)	0.00	500,000.00	2,109,244.80	2,709,244.80	2,809,244.80	8,127,734.40
6	Profit= Gross revenue-Total Cost	-1,200,000.00	-700,000.00	909,244.80	1,509,244.80	1,609,244.80	2,127,734.40

Table 5.1a: Profit from Cultivation Stage Per Hectare (Jatropha/ Oil Tree Seeds)

Item	Quantity	Cost (in INR)	Cost / ha (INR)
Farm Operating Cost	48.56	1200000	24712
(incudes salaries)	(hectare)	(Total)	
Jatropha/ Tree Oil Seeds	2220	14	31080
(include pongamia)	(kg/ha)	(per kg)	
Ancillary Activities	48.56	1300000	26771
(Milk, Poultry, vegetable	(hectare)		
manure, etc.)			
Net Profit (only seeds)			6368
Net Profit (overall)			**33139**

Note: *As per Committee on Biofuels, GoI; Area is calculated on the basis of plantation density of 2500 per hectare, seed production of 1.5 kg per tree or of 3.75 T of seed per hectare corresponding to 1.2 T of oil per hectare of plantation. But at TOIL yield of seeds 2 kg per plant with oil content of 34% and 1110 plants per hectare are planted As the yield is reported to be stabilized after 5th year of plantation, above calculation are for 5th year.*

Table 5.1b: Profit from Biodiesel Production Stage

Item	Quantity	Unit Price (Rs.)	Cost (in INR)	Cost / Litre (in INR)
Raw Material (Tree Oil)	0.86	12	30.35	30.4
	(kg)	(Per kg of seed)		
Production Cost (includes Salaries, Taxes, etc.)	1	2.75	2.75	2.75
	(liter)	(per liter)	(per kg)	

Sale of Biodiesel	1	33.5	33.5	33.5
		(per liter)		
Sale of Glycerin	0.1	26	2.6	2.6
	kg	per kg		
Other Income	1	2.5	2.5	2.5
(Flyash, Seed cake, etc.)	kg			
Net Profit (only BD)				0
Net Profit (overall)				5
Net Profit (per hectare)				**6391.9**

Note: SBTL being an integrated factory, no separate data is available for oil extraction stage

Table 5.1 c: Summary of Net Profit Per Hectare

Stage	**INR/ Hectare**
Cultivation Stage	33139
BD Production Stage	6392
Total Profit	**39531**

Table 5.1d: Annual Labor Requirement and Wages Per Hectare

Stage	**Person Days/ Ha**	**Wages Rate (INR/day)**	**Total Wages Paid (INR)**
Cultivation Stage	248	133	32984
BD Production Stage	42	180	7560
Total	**290**	**313**	**40544**

Table 5.1e: Tax Revenue Generated Per Hectare

Stage	Total Profit (INR)	Tax Revenue (INR)
Cultivation Stage	33139	Exempted
BD Production Stage	6392	255.68
Total	**39531**	**255.68**

Table 5.1f: Total value added per year by product form per hectare of biomass utilization

PRODUCT FORM	TOTAL PROFIT (INR)	WAGES PAID (INR)	TAX REVENUE (INR)	TOTAL VALUE ADDED (INR)
Oil Seeds	33139	32,984.00	exempted	66,123.31
Biodiesel	6392	7560	255.6771546	14,207.61
TOTAL	39,531.24	40,544.00	255.68	80,330.91

Table 5.2: Job Creation Per Unit of Output

SN	Item	Values
1	Total Production (seeds in kg per year)	107803.2
2	Person days per year	12045
3	Employment (person days per kg of seeds per year)	0.112

Table 5.3: Impact on Foreign Trade

Item	Values
Potential biodiesel that could be extracted	43121.28
Above in terms of barrels	361.63
Foreign exchange saved @US $ 75/barrel	27122.58

Note: 1barrel (US liquid)= 119.24 lt

ENVIRONMENTAL IMPACT

Table 5.4: CO2 Emissions during Cultivation Stage

SN	Item	Quantity/yr	Quantity/ha/yr/	Conversion factor	CO2 Emissions (in tons/yr)	CO2 Emissions (in tons/ha)
1	Diesel (lt)	4800	98.85	2.7	12.96	0.267
2	Electricity (Mwh)	10	0.21	0.81	8.1	0.000
3	Fertilizer N (kg)	1942	39.99	6.69	12.99198	0.268
4	Fertilizer P (kg)	2913	59.99	0.71	2.06823	0.043
5	Fertilizer K (kg)	1214	25	0.46	0.55844	0.012
6	Total emissions				36.67865	0.589

Source: For Conversion Factors- Bioethanol Greenhouse Gas Calculator User Guide, Woods et al, 2005, pg 17, Imperial College, London
For Carbon Sequestration by Plants: After 7 yrs Ref: The Jatropha System,
Reinhard K. Henning : http://www.bagani.de/, www.jatropha.de
Savings in emissions using BD Derived from Prueksakorn, K.; Gheewala, S.H. (2006)
carbonrationing.org.uk/wiki/footprinting
Grid Electricity Emission, Factor, CEA Database, version 4.0, INDIA
Revised 1996 IPCC Guidelines for National GHG inventories:Reference Manual, Chap1, pg 1.13
Note: Carbon Sequestration by Jatropha Plants is not considered as per suggestions from the WG members

SOCIAL IMPACT

Table 5.6: Employment Generation at TOIL

SN	**Item**	**Values**
1	Area of Jatropha Cultivation (120 Acres)	48.56
2	Employment (person days per day)	33
3	Employment (person days per year)	12045
4	Employment in person days per hectare per year	248

BIODIESEL PRODUCTION STAGE (SBTL)

ECONOMIC IMPACT

Table 5.7: Economic Analysis (GVA) of SBTL

SN	Items	Values
1	Biodiesel Production capacity/day (lt)	40000
2	Annual Production Capacity (lt)	14600000
3	RM Requirement/year (kg)	12556000
4	Cost of RM @ Rs. 16/kg	200896000
5	Production Cost without RM (@ Rs. 2.75/ lt)	40150000
6	Va (Value added from main product) – @ 33/lt Selling Price	481800000
7	Vb (Revenue from by-products (glycerin & Rs. 26/kg)	37960000
8	GVA (VAa+VAb)	519760000
9	Profit (Gross Revenue-Total Cost)	278714000

Note: RM requirement is 860 gm for one litre of biodiesel Glycerin production @10% of BD produced

Table 5.8 Employment per unit of Biodiesel Production at SBTL

SN	Items	Values
1	Total Production (lt)	14600000
2	Person days (110x365)	40150
3	Employment per unit yield (person days per lt)	0.00275

Table 5.9: Impact on Foreign Trade by SBTL

SN	Items	Values
1	Bio-diesel production	14600000
2	Above in terms of barrels	122442.1335
3	Foreign exchange saved @US $ 75/barrel (US$)	9183160.013

ENVIRONMENTAL IMPACT

Table 5.10: CO_2 Emissions during Bio-diesel Production Stage

SN	Item	Quantity/yr	Quantity / lt of BD Produced	Conversion Factor	CO_2 Emissions (in tons/ yr)	CO_2 Emissions (in kg/ lt BD production / yr)
1	Diesel (lt)	119808	0.008206	2.7	323.48	0.022156274
2	Electricity (MWh)	1277.5	0.0000875	0.81	1034.78	0.000070875
3	Rice Husk (Tons)	9125	0.000625	29.9	272.84	0.0186875
	Total Emissions				1631.09	0.04

Note:

Net Carbon Balance (emission / Saving)

Total Emissions per year (KgCO2)	*1631094.10*
Savings per litre of biodiesel (KgCO2)	*189.40*
Carbon Saving Per Year from BD use	*2765240000.00*
Net savings in GHG emissions (in KgCO2 per year)	*2763608905.90*
GHG Emission in tons	*2763609*

SOCIAL IMPACT

Table 5.11: Employment Generation at SBTL

SN	Item	Values
1	Production of Biodiesel (lt)	40000
2	Employment (person days per day)	110
3	Employment in Person days per year	40150
4	Biodiesel Production per year	14600000
5	Oil Requirement (kg) per year	12556000
6	Seed Requirement (kg) per year	36929411.76
7	Land area required for above oil (ha)	10463.33333
8	Labour requirement (person days per hectare per year)	42.19086022

Note: Oil requirement is 860 gm per litre of BD produced; Person days per year per hectare is taken as 248 from TOIL; Oil Content of Seeds is 34%

Table 5.11a: HDI (Human Development Index) Calculations

Index/sub-index	Cultivations Stage (TOIL)	BD Production Stage (SBTL)
LE (Life Expectancy)	70.3945	70.4673
ALR (Adult Literacy Rate)	50.2962	50.3482
GER (Gross Enrolment Ratio)	59.5102	59.5718
ALI (Adult Literacy Index)	0.5030	0.5035
GEI (Gross Enrolment Index)	0.5951	0.5957
EI (Education Index)	0.5337	0.5342
LEI (Life Expectancy Index)	0.7566	0.7578
GI (GDP Index)	0.55586791	0.55589205
HDI	0.615372434	0.61596951

Note:
i) For calculating various sub-indices of HDI (LEI, EI and GI), it is necessary to take LE, ALR and GER at Local Level corresponding to the Per Capita Income (PCI) at the same level.
ii) In the above table, e.g. LE (62.8) for Andhra Pradesh corresponds to the PCI of 16373 for and similar are the values of ALR (44.87) and GER (53.09)
iii) All these values of sub-indices are modified using higher PCI added to the Local level For example, an increase of PCI by INR 1980 for TOIL site
iv) Increase in PCI at TOIL is the GDP(GVA) to wages and affected population with this income
v) For GDP Index the value of GDP Per Capita for India is US$2753 as per HDR 2009 (for 2007)

Table 5.11b: GDI (Gender-related Development Index) Calculations

Index/sub-index	Cultivation Stage (TOIL)		BD Production Stage (SBTL)	
	Female	Male	Female	Male
LEI	0.62500	0.63500	0.62500	0.63500
Equally Distributed LEI	0.63001		0.63001	
EI	0.56250	0.7073	0.5625	0.7073
Equally Distributed EI	0.62743		0.62743	
Income Index	0.55439	0.55482	0.55440	0.55483
Equally Distributed Income Index	0.55455		0.55460	
GDI	0.603998		0.604015	

Note:
i) All sub-indices of HDI are calculated for male and female population, separately
ii) Equally Distributed Indices (EDIs) are calculated for all sub-indices with formula shown in the cell
ii) GDI is the average of all three EDIs and may be expressed as percentage of HDI
iv) GDI is 98% of HDI showing inequality between men and women

Table 5.12: Overall Impact of Biodiesel Production

STAGE / IMPACT	Jatropha Cultivation (TOIL)	Biodiesel Production (SBTL)	TOTAL / AVERAGE
Economic			
GVA (Rs.)	2809245	519760000	522569245
Net Profit Per Year (Rs.)	1609245	278714000	280323245
Net Profit Per Hectare Per Year (Rs.)	33139	6392	39531
Job Creation (per unit output)	0.112	0.003	0.057
Forex Savings (US$)	27123	9183160	9210283

Environmental			
GHG Emissions (Tons CO2 per yr)	37	1631	1668
GHG Emissions per hectare (Tons CO2 per yr)	0.589	0.041	0.630
GHG Savings during Consumption (Tons/ Yr)	8072	2763609	2771681
Social			
Employment (PDs per yr)	12045	40150	52195
Employment (PDs per ha per yr	248	42.19	290
Change in PCI (Rs. Per Year)	1980	1999	1989
HDI (Actual)	0.615	0.616	0.616
HDI (UNDP for 2006)	0.612	0.612	0.612
Change in HDI	0.003	0.004	0.004
GDI	0.603	0.604	0.604
Other SDIs			
Living Standard (Rise per 100 HH)	19	28	24
Change in Literacy (No. per 1000 HH)	87	92	90
Change in female Literacy (No. Per 1000 HH)	158	192	175
Change in Pucca Dwellings (No. per 100 HH)	15	22	19

Note: Please refer to Appendix 1 for detailed calculations; PD- person days; HH- Household.

APPENDIX 2: Questionnaire for Indian Pilot Study

GENERAL INFORMATION

1.1. Name of the Respondent (individual/ firm)	
1.2. Address	
Phone	
FAX	
E-mail	
1.3. Age /Date of incorporation	
1.4. Qualification (Self/ Head)	
1.5. Occupation (Self/ Head)	
1.6. If individual, total number of family members Infants ___________________	

1.7. In case of individual, Income per month (in Rs) ____________
1.8. For Individual, how much do you spend your income (in percent) Other items(specify
1.9. In case of Firm, Type of ________________________________ No. of Annual
1.10. Location of Biofuel crops farm
1.11. Location of Oil Extraction unit
1.12 Location of Biodiesel production unit
1.13 Distance between farm and Oil Extraction Plant
1.14 Distance between farm and Biodeisel plant
1.15 Approximate Yield from the farm (Jatropha Seeds / ha)
1.16 Approximate Yield from the Seeds (Oil / per Ton of seeds)
1.17 Approximate Yield from the Oil (Biodeesel / Per Ton of Oil)
1.18 Approximate Yield of other products (cake, glycerol, etc.)

DATA ON ENVIRONMENTAL ASPECTS

I. PLANTATION STAGE (I a. Jatropha / Tree Oil Seedling Stage)

2.1. Name of nursery	
2.2. Location	
2.3. Type of nursery	
2.4. No. of cycles/ year (single / two / more stages)	
2.5. Information on Nursery Management and Practices (Please provide figures or information for three consecutive years if available, otherwise approximate current figures are also acceptable)	

No. of bags/ per hectare	
2007	
2008	
2009	
General average	
Number of seedling / hectare	
2007	
2008	
2009	
General average	
Average success rate (seedlings to plant)	

Consumables consumption / year

Consumable	2007	2008	2009	General average
Water (litre)				
Electricity (kWh)				
Diesel (litre)				

2.6. Data to Estimate Electricity Consumption (Use of electric-powered equipment and systems)

No. of sprinklers/hectare	
Motor power of sprinkler, kW	

2.7. Data to Estimate Diesel/Fuel Consumption in Transportation

Distance, km		
Truck capacity, ton		
Actual load, ton		
Empty return	☐Yes	☐No
No. of trips/day		

2.8. Agrochemicals consumption / year

Consumable	2007	2008	2009	General average

Fertiliser • Muriate of potash • ammonium nitrate • phosphate • Others (specify) • _______________				
Pesticides • Methyl metsulfuron, isopropylamine, • Others (specify) • ________________				
• Any Others (Specify) • ________________				

*Note: *Please fill in according to use*

I b. Jatropha / Tree Oil Plantation Stage (Information on Plantation Management and Practices

Company Information (If different from Section IIa)	
3.1. Name	
3.2. Address	
Phone	
FAX	
3.3. Name/position of contact person	
E-mail	
3.4. Name of plantation	
3.5. Location	
3.6. Plantation Size (hectare)	

Additional information (if applicable)	
3.7. Success rate (%)	
3.8. Capacity of palm tree/hectare	
3.9. Duration from seedling to harvest	
3.10. Annual crop/ perennial crop	
3.11. Life span of perennial crop (years)	
3.12. Land-Use prior to current crop (at time of data collection)	(Please tick ✓)
- Forest land to cropland	☐
- Grassland to cropland	☐
- Cropland to cropland (same crop)	☐
- Cropland to cropland (different crop, please specify)	☐
- Peatland to cropland	☐
- Wasteland to Cropland	☐
- Others (specify)	☐

(Please provide figures or information for 3 years if available, otherwise approx current figures are fine)

3.13.	Plantation yield as average metric tons of biomass resource material for bioenergy e.g. (fresh fruit bunches per hectare/per year or per month for oil palms)	
	2007	

	2008	
	2009	
	General average	
3.14.	Weight of Tree Fell / Replaced per hectare / per year	
	2007	
	2008	
	2009	
	General average	

3.15.	Consumables consumption / year				
	Consumable	2007	2008	2009	General average
	Water (litre)				
	Electricity (kWh)				
	Diesel (litre)				

Data to Estimate Electricity Consumption		
3.16.	Use of electric-powered equipment and systems	
	No. of sprinklers/hectare	
	Motor power of sprinkler, kW	
	Others (Specify)	

Data to Estimate Diesel/Fuel Consumption		
3.17	Transportation from plantation to feedstock processing/ mill	
	Distance, km	
	Truck capacity, ton	
	Actual load, ton	
	Empty return (yes/no)	
	No. of trips/day	

3.18.	Agrochemicals consumption / year				
	Consumable	2007	2008	2009	Average
	Fertiliser (• ______________ • ______________				
	Pesticides • _______________ • _______________ • _______________				
	Others • _______________ • _______________				

3.19. Waste Use or Produce

Biomass Waste • Weight of Tree /hectare/year • Agriculture waste/hectare/year • Wastewater/year	
Hazardous waste produce/year	

II. PROCESSING OF FEEDSTOCK MATERIAL (Oil Extraction Stage/ Milling Stage/ Processing Stage (to convert biomass stock to first bioenergy feedstock)

Company Information (If different from preceding sections)	
4.1. Name	
4.2. Address	
Phone	
FAX	
4.3. Name/position of contact person	
E-mail	

4.4. Production Data

Please provide information for three years if available, otherwise approximate current values are acceptable

Production volume (metric tons/year)				
Types of Products	2007	2008	2009	Average
E.g. Jatropha / Tree Oil				
E.g. Seed Cake				
Others (specify)				

4.5. Consumption Data

Raw material consumption (metric tons/year)				
Types of Raw Materials	2007	2008	2009	Average
E.g. Jatropha Seeds				
Utilities & fuel consumption on yearly basis				
Utilities	2007	2008	2009	Average
Electricity (kWh/year) • Grid • Self generated				
Water (m^3/year) • Piped water • Recycling				

Fuel (litre/year) • Medium Fuel Oil • Diesel				

4.6. Environmental Data

Air Emission Flue gas volume/production day (m^3/day) =

(Please sum up all volumes if more than one stack):

Parameters	Concentration
• Carbon dioxide CO_2 • Carbon monoxide CO • Methane CH_4 • Nitrogen monoxide N_2O • Nitrogen dioxide NO_2 • Particulate Matter • SO2 • Other (specify) Compliance to local regulations (state name of regulations)____________________________________ ____	

4.7. Waste Generation

Types of Waste	
Waste produce (metric ton/year)	
Wastewater treatment sludge - organic (metric ton/year) - inorganic (*Please state type of mineral sludges e.g. hydroxide or carbonate etc.*(metric ton/year)	
Fiber (metric ton/year)	
Seed Shell (metric ton/year)	
Boiler ash (metric ton/year)	
Hazardous waste:	

4.8. Wastewater Discharge

Wastewater discharge after treatment (m^3/year) =

Parameter	**Concentration (mg/l)**
• BOD • COD • Other (Spcify)	

III. BIODEISEL PRODUCTION STAGE

Company Information (If different from preceding sections)	
5.1. Name	
5.2. Address	
Phone	
FAX	
5.3. Name/position of contact person	

5.4. Production Data

Production volume (metric tons/year)				
Types of Products	2007	2008	2009	Average

5.5. Consumption Data

Raw material consumption (metric tons/year)				
Types of Raw Materials	2007	2008	2009	Average
5.6. Utilities & fuel consumption on yearly basis				
Utilities	2007	2008	2009	Average
Electricity (kWh/year) • Grid • Self-generated				
Water (m^3/year) • Piped water • Other source_____________				
Fuel • Medium Fuel Oil (litre/year) • Diesel (litre/year) • Natural Gas (vol/year)				

• Coal (ton/year • Biomass (ton/year)				

5.7. Environmental Data

Air Emission

Flue gas volume/production day (m^3/day) =

(Please sum up all volumes if more than one stack):

Parameters	Concentration
• Carbon dioxide CO_2 • Carbon monoxide CO • Methane CH_4 • Nitrogen monoxide N_2O • Nitrogen dioxide NO_2 • Particulate Matter • SO2 • Other (specify) Compliance to local regulations (state name of regulations)___________________________________ _______________________________________	

5.8. Waste Generation

Types of Waste	
Waste produce (ton/year)	
Wastewater treatment sludge - organic (metric ton/year) - inorganic (*Please state type of mineral sludges e.g. hydroxide or carbonate etc.*(metric ton/year)	
Hazardous waste (ton/year)	

5.9. Wastewater Discharge

Wastewater discharge after treatment (m^3/year) =

Parameter	Concentration (mg/l)
• BOD • COD Others (Specify)	

Transformation to Biofuel

Company Information
6.1. Name
6.2. Contact Person 6.3 Contact Details (Address/ Person/ Tel/ Fax./ Email/ Mobile)

6.4. Production Data

Production volume (metric tons/year)				
Types of Products	2007	2008	2009	Average
Biodiesel				

6.5. Consumption Data

Raw material consumption (metric tons/year)				
Raw Materials	2007	2008	2009	Average

6.6. Utilities & fuel consumption on yearly basis				
Utilities	2007	2008	2009	Average
Electricity (kWh/year) • Grid • Self-generated				
Water (m^3/year) • Sources				
Fuel • Medium Fuel Oil (litre/year) • Diesel (litre/year) • Natural gas (vol/year) • Coal (ton/year) • Biomass (ton/year) • Others (specify)				

6.7. Environmental Data

Air Emission

Flue gas volume/production day (m^3/day) =

(Please sum up all volumes if more than one stack):

Parameters	Concentration
• Carbon dioxide CO_2 • Carbon monoxide CO • Methane CH_4 • Nitrogen monoxide N_2O • Nitrogen dioxide NO_2 • Others (specify)	
Compliance to local regulations? ___________________________________	☐Yes ☐No

6.8. Waste Generation

Types of Waste	
Waste produce (metric ton/year)	
Wastewater treatment sludge - organic (metric ton/year) - inorganic (*Please state type of mineral sludges e.g. hydroxide or carbonate etc.*(metric ton/year)	

Hazardous waste	

6.9. Wastewater Discharge

Wastewater discharge after treatment (m^3/year) =

Parameter	Concentration (mg/l)
• BOD • COD	

DATA ON ECONOMIC ASPECTS

(Producers / Traders / Processors)

I. Plant/Firm Inputs

2.1. Plant size		2.2. Acquisition Cost	
2.3. Total number of employees		2.4. Plant capacity	
2.5. Raw material(s) processed		2.6 Products produced	

2.7. Initial Investment Cost				
Inventory of Fixed Assets	**Quantity**	**Year acquired**	**Life span**	**Acquisition cost**
Land				
Building				
Tools and Equipment				
Work Animals				
Others				
Sub-total				

2.8. Operating Cost			
Cost Item	**Quantity**	**Salary/month**	**Total Cost**
Permanent Labor			
Manager			
Supervisor			
Bookkeeper/Accountant			
Secretary			
Others			
Hired/Contract Labor *(in man days)*	**Mandays/month**	**Wage/day**	**Total Cost**
Purchase of raw material			
Processing			
Sub-total			
Material Cost	**Quantity/month**	**Cost/Unit**	**Total Cost**
Raw materials			
Other inputs (Specify)			
Marketing Cost			
Hauling/transportation			
Fees and others			
Sub-total			
Taxes paid			
Other costs			
TOTAL			

2.9 Procurement of raw materials				
Sources/Location	Product kind/form	Qty. / proc.	Frequency/month	Price/unit

IV. Disposal				
Mode Of Disposal	**Quantity**	**Price**	**Buyer**	**Mode Of Disposal**
	Per cycle	**Lean Months**	**Peak Months**	
Form of processed				
a.				
b.				
Other sales such as by-products				
Given Away				
Outlets Name/Location	Type of outlet/buyer	Quantity (unit)& type	Price/unit	Frequency /vol. of sale
TOTAL				

1.7. Did you encounter problems in plantation? ☐Yes ☐No		
Problem	**Check if Yes (✓)**	**Solution Adopted**
Planting Materials		
High rate of mortality	☐	
High cost of planting materials	☐	
Non-availability of planting materials	☐	
Technology		
Difficult to adopt	☐	
Financial		
Lack of financial support	☐	
Higher interest rate on loans	☐	
Market		

Lesser access to market	☐	
Pest and Diseases		
Harvest/Post-Harvest		
Processing		

II. Farm Inputs

2.1. When did you first completed plantation? No. of pieces planted: ______ Source:
2.2. After your 1st purchase did you buy more? How many? Comment on Price
2.3. When was the last purchase?_______ Qty_______ Amount paid:
2.3.1. If price is lower, how many would you buy?
2.4. Farm size:_____________ 2.4.1. Acquisition Cost: ______________________ 2.4.2. Total number of plants:______ 2.4.3. Number of bearing plants: ________________ System of planting: ☐Monocrop ☐Backyard planting ☐Intercrop with other crops (specify)________________________ ☐Intercrop with coconut (specify number of macapuno relative to coconut

2.5. Investment Cost			
Cost Item	**Quantity**	**Price/Unit**	**Total Cost**
Labor			
Land preparation (man day)			
Planting (man day)			
Fertilization (man day)			
Weeding (man day)			
Material Cost			
Seedlings or any planting material			
Fertilizer (bag)			
Pesticides (bag)			
Other chemicals			
Other Establishment Costs			
Ex. Fencing, licensing etc.			
Sub-total			

Inventory of Fixed Assets	**Quantity**	**Year acquired**	**Life span**	**Acquisition cost**
Land				
Building				
Tools and Equipment				
Work Animals				
Others				
Sub-total				

2.6. Operating Cost			
Cost Item	**Quantity/month**	**Cost/Unit**	**Total Cost**
Hired Labor *(in man days)*			
Farm overseer (man day)			
Grass cutting (man day)			

Watering (man day)			
Ringweeding			
Fertilization			
Prunning			
Pesticide spraying			
Harvesting			
Collecting/piling			
Sub-total			
Material Cost	**Quantity/month**	**Cost/Unit**	**Total Cost**
Water (liters)			
Fertilizer (bag)			
Pesticides (bag)			
Other inputs (Specify)			
Marketing Cost			
Sub-total			
TOTAL			

Ⅲ. Production

Area planted by parcel	Type		Number of trees		Average yield/ / harvest		Number of harvests/yr		Total produce / year	

3.1. Months of low yield ___________________ 3.1.1 harvest/mo______________

3.2. Months of high yield___________________ 3.2.1 harvest/mo______________

3.3. Contribution of produce to household income (%) ___________________

Ⅳ. Disposal

Mode Of Disposal	Quantity	Price		Buyer
	Per harvest	Lean Months	Peak Months	

Sold as fresh				
Sold as mature nuts				
Sold as copra				
Planting material				
Payment in kind				
Home Consumption				
Given Away				
Used as planting materials				
Total				

V. SOCIO –ECONOMIC CONDITION

5.1. Please check if the following items are available in the household	
a. Residential lot	☐Owned ☐Rented ☐Others, pls pecify__________
b. House ownership	☐Owned ☐Rented ☐Others, pls pecify__________
c. Housing materials	☐Concrete ☐Wood ☐Wood and cement ☐Nipa ☐Others, pls specify______________
d. Source of water	☐Artesian well ☐Pump ☐Others, specify________
e. Toilet Facility	☐Flush ☐Manual flush ☐Others, specify ________
f. Lighting Facilities	☐Electric ☐Lamp/gas ☐Others, specify ________
g. Cooking facilities	☐Wood ☐Kerosene ☐Charcoal ☐LPG ☐Electricity ☐Others, specify________
5.2. Household items bought because of biomass planting?	
5.3. How would you describe your level of living before planting biomass?	
5.4. How would you describe your level of living after planting biomass? ☐Better than before Reason	

☐Same as before Reason ☐Worse than before Reason
5.5. What is/are your aspiration(s) for your family?
5.6. Do you think the planting of biomass will help you with the attainment of your aspirations? ☐Yes ☐No If yes, in what way If no, why not?

VI. **CHANGES IN THE ENVIRONMENTAL CONDITIONS / ELEMENTS**

Please check based on your perception and state reasons for the choice/response

5.7. Are there changes in the following properties of the soil in your farm after you planted biomass?

BA = Before Adoption *AA = After Adoption*

Soil properties		Rating *(please check)* (5-very dark, 4-dark, 3-slightly dark, 2-light, 1-very light)					Reason for the Rating
		1	2	3	4	5	
1.1. Color	BA						
	AA						
Soil properties		Rating *(please check)* (5-very fast infiltration, 4-fast infiltration, 3-slightly fast, 2-slow, 1-very slow)					Reason for the Rating
		1	2	3	4	5	
1.2. Porosity or ease of	BA						

infiltration of water	AA						
Soil properties		Rating *(please check)* (5-very abundant,4-more abundant, 3-abundant,2-less, 1-least)					Reason for the Rating
		1	2	3	4	5	
1.3. Abundance of humus or organic matter	BA						
	AA						
Soil properties		Rating *(please check)* (5-least acidic,4-less acidic, 3-acidic,2-more acidic,1-very acidic)					Reason for the Rating
		1	2	3	4	5	
1.4. Acidity	BA						
	AA						
Soil properties		Rating *(please check)* (5-very low,4-low,3-high, 2-moer high,1-very high)					Reason for the Rating
		1	2	3	4	5	
1.5. Occurrence and extent of soil erosion	BA						
	AA						
Soil properties		Rating *(please check)* (5-very deep,4-moredeep,3-deep, 2-shallow,1-very shallow)					Reason for the Rating
		1	2	3	4	5	
1.6. Depth of litter/gradient of decomposition	BA						
	AA						
Soil properties		Rating *(please check)* (5-very fertile, 4-more fertile, 3-fertile, 2-less, 1-least)					Reason for the Rating

		1	2	3	4	5	
1.7.General fertility	BA						
	AA						

5.8. Are there changes in water properties in nearby streams or creeks after the adoption of biomass technology?

BA = Before Adoption *AA = After Adoption*

Water properties		Rating *(please check)* (5-very clear,4-more clear,3-clear, 2-dark,1-very dark)					Reason for the Rating
		1	2	3	4	5	
1.1. Color of Water	BA						
	AA						
Water properties		Rating *(please check)* (5-very abundant,4-more abundant, 3-abundant,2-less abundant, 1-least abundant)					Reason for the Rating
		1	2	3	4	5	
1.2. Quantity	BA						
	AA						
Water properties		Rating *(please check)* (5-very abundant,4-more abundant, 3-abundant,2-less abundant, 1-least abundant)					Reason for the Rating
		1	2	3	4	5	
1.3. Abundance of organic matter	BA						
	AA						

Water properties		Rating *(please check)* (5-least acidic,4-more less acidic, 3-acidic,2-more acidic, 1-very acidic)					Reason for the Rating
		1	2	3	4	5	
1.4. Acidity	BA						
	AA						

5.9. Changes in abundance and variety of plants and animals

BA = Before Adoption *AA = After Adoption*

Properties		Rating *(please check)* (5-very many, 4-many, 3-just enough, 2-few, 1-very few)					Reason for the Rating
		1	2	3	4	5	
1.1. Number of animals							
1.1.a Beneficial *(e.g. butterflies, bees, dragonflies, etc.)*	BA						
	AA						
1.1.b Harmful ***(e.g. snakes, rodents, mosquitoes)***	BA						
	AA						
Properties		Rating *(please check)* (5-very many, 4-many, 3-just enough, 2-few, 1-very few)					Reason for the Rating
		1	2	3	4	5	
1.2. Number of plants							
1.2.a Vegetation	BA						
	AA						
1.2.b Undergrowth	BA						
	AA						

5.10. Other changes in the environment

Properties	Before adoption ✓ ( )	Reason	After adoption (✓)	Reason
Presence of chemicals not properly disposed				
Presence of waste not properly disposed				
Littered plastics and other non-biodegradable materials like plastics				
Presence of impermeable structures *(e.g. pathways, buildings, cemented structures)*				

DATA ON SOCIAL ASPECTS

I. CULTIVATION AND SEED COLLECTION STAGE

1.1. Are you a Farmer or Worker at Biofuel Crops Farm?	
1.1.1. If farmer, how did you hear about Jatropha/ Oil-Tree cultivation?	
1.2. Do you own biofuel crop farms?	☐Yes ☐No________________
1.2.1. If yes, what is the type of crop Jatropha/ Pongamia/ others__________________________________	
1.3. Is your farm rainfed or irrigated?	
1.4. What are other input? (water/ fertilizers/ pesticides etc.)	
1.5. Is it on a waste land or cultivable land or both?	
1.6. What is the size of your farm?	Waste Land ____________cultivable land ____________
1.7. When did you start cultivation?	
1.8. Wherefrom do you obtain seedlings, seed and planting material? LIMITATION / ECONOMIC (tick where appropriate) ☐Own nurseries ☐Govt nurseries (district or regional authorities)-NGO nurseries	
1.9. Are the seeds/seedlings sold/given free?	☐Yes ☐No

1.9.1. If No, prices range from_______________ to ______________________________	
1.10. How many persons are involved in Jatropha Cultivation at your farm? Total_______________ Your own family members_______________ others (hired) ______	
1.10.1. If hired, how much do you pay them per day?	
1.11. If you have used all of your land for biofuel crops, what is the alternate source of income during gestation period of 2-4 years? _________________________________ _________________	
1.12. If diverted cultivable land, how do you meet your daily needs of food grain, vegetables, etc. that you were gaining form your farms earlier_____________________________________	
1.13. What is the amount of Seed Collection per day?	
1.14. Where are the seeds consumed?	
1.15. How much do you pay/ are you paid for seed collection?	
1.16. If you are involved in oil extraction how much are you paid per day?	
1.17. How much is your income per day / month/ year from biofuel crop cultivation? Expenditure on wages__________ other Expenses_________ Net earnings________	
1.18. If you are a worker, what is your income from working in the farm for cultivation / seed collection Personal____________________ Family____________________	
1.19. How do you spend the increased income? Cloth___________ Housing______________ Education__________ Health__________ Food___________ Other items(specify)	
1.20. Do you face any problem after starting cultivation of biofuel crops/ working in the farm? (Specify)_____________________________________	
1.21. What measures do you suggest to tackle above problems	

II. OIL EXTRACTION AND BIODIESEL PRODUCTION STAGE

2.1. Status of Company (Govt., Pvt., Partnership, etc.)	
2.2. Production Capacity (TPD)	Installed________________ Actual______________

2.3. Technology available for biodiesel conversion (indigenous/ imported)	
2.3.1. If imported, wherefrom?	
2.4. What is the electricity consumption of the biodiesel plant, MWh/year	
2.5. What is the fossil fuel consumption of the biodiesel plant, if any, tones/year? And what kind of fuel(s) (gas, coal, diesel, biodiesel, other:)?	
2.6. What is the mass of methanol consumed in the biodiesel plant, tones/year?	
2.7. Quality of Biodiesel produced (as per standards of)	
2.8. Quality of by-products produced (as per standards of)	

2.9. Raw Material Requirement per day__________ seed_________ oil____________

2.10. Type of Raw Material required Jatropha__________ Pongamia______________

Others (specify share of each)____

2.11. Source of Raw Material (oil /seeds) (Owned/ Contract Farming/other)

2.11.1. If Owned / contract farming, areas under cultivation _______________________

2.12. Cost incurred per hectare / ton on raw material, if owned ___________________

2.13. Cost of Raw material per ton if purchased from market ______________________

2.14. Raw material available is just enough/ insufficient/ over supplied______________

2.15. No. of workers employed in Cultivation _______________wage per day________

2.16. No. of workers employed for Seed Collection__________ wage per day ________

2.17. No. of workers Employed in Oil Extraction_____________ wage per day _______

2.18. No. of workers Employed in Biodiesel Production______ wage per day _______

2.19. No. of workers Employed in Other Activities______ wage per day ___________

2.20. List the output (quantity and name like biodiesel & main by-products)

____

____

2.21. Producing biodiesel for local market or exports____________________________

2.21.1. If exports, to which country (ies)____

2.22. If for local market, how do you reach consumers (self/ through distribution chain, specify details)____

2.23. Net savings from per ton of products and by products ____ ____
2.24. Existing support by the govt/ any other agency__________________________

2.25. If you feel some barriers, what are those?	
2.26. What solutions you suggest to remove these barriers?	

2.27. Any initiative for the farmers / workers / community as a part of your CSR?

(Please name the activity and indicate expenses towards it and direct and indirect and indirect benefits achieved by you/ community). Some of the examples are as follows.

Does your company/ activity -

i) Help in promoting sustainable livelihoods and achieve self sufficiency in energy in the local region (how?)____________________________

ii) Creates employment (how much?)_____________________________

iii) Promotes contract farming by marginal, small, medium and large farmers in the area ____

iv) Initiates Ancillary Activities such as Vermicompost and Apiculture. Or Set up Tiny Industries such as Distillation, Drying, Soap making and Rope making. ____

v) Creates additional income through Certified Emission Reductions (Carbon Credits). ____

Any other (please specify) ____

3.1. Does your facility use Biodiesel?	☐Yes ☐No
3.2. Reasons for your facility using Biodiesel *(Check all that apply)* ☐Satisfy Mandate ☐Environment ☐Energy Policy ☐Safety Issues ☐Energy Bill	
3.3. Types of Biodiesel being used. *(Check all that apply)* ☐B100 ☐B50 ☐B20 ☐B10 ☐B5 ☐Other (specify) __________________	
3.4. Estimated Monthly Volume of each type. B100 B50 B20 B5 Other Total	
3.5. What applications are you using Biodiesel for? (vehicles/ generators/ others)	
3.6. Number of vehicles that use biodiesel.	
3.7. Where do you purchase your biodiesel from?	
3.8. How much cost do you pay for biodiesel? *(Per Litre)*	

3.9. Have you encountered problems from biodiesel usage? *(If yes, please explain)* ☐Yes ☐No
3.10. Do you have a biodiesel success story you would like to share? (*If yes, please explain)* ☐Yes ☐No

III. SURVEY OF CONSUMPTION STAGE

IV. OTHER INFORMATION (THESE ARE MEANT FOR OTHER BENETIFS OF BIODIESEL)

4.1. Do you know about merits and demerits of biodiesel over petro-diesel? ☐Yes ☐No	
4.1.1. If yes, what are those?	
4.2. Is biodiesel available locally/ nearby easily?	
4.3. Price of biofuel that you are paying____	
4.4. Is government providing any help in Biodiesel promotion? ☐Yes ☐No	
4.4.1. If yes, what are those?	
4.4.2. If not, what do you expect?	
4.5. Do you feel there is any change in Eco restoration and land degradation(preventing) due to use of biofuel crops cultivation____	
4.6. Is any extra effort necessary for biofuel crop in comparison to other crop?	
4.7. Do you see any change in rural electrification and energy security due to use of biofuel in your areas____	
4.8. Any additional information that you may want to provide here, ____	