DISSERTATION

COMPARISON OF EMISSION AND ENERGY FOR BIODIESEL PRODUCTION FROM OIL PALM (*Elaeis guineensis)* AND JATROPHA CURCAS (*Jatropha curcas* L.) BASED ON LIFE CYCLE ASSESSMENT (LCA) IN INDONESIA

(*PERBANDINGAN EMISI DAN ENERGI PRODUKSI BIODIESEL DARI KELAPA SAWIT (Elaeis guineensis) DAN JARAK PAGAR (Jatropha curcas* L.*) BERDASARKAN KAJIAN SIKLUS HIDUP (LCA) DI INDONESIA*)

KIMAN SIREGAR

THE GRADUATE SCHOOL
BOGOR AGRICULTURAL UNIVERSITY (IPB)
BOGOR
2013

STATEMENT OF RESEARCH ORIGINALITY

Hereby, I state that the dissertation entitled “**Comparison of Emission and Energy for Biodiesel Production from Oil Palm (*Elaeis guineensis)* and Jatropha Curcas (*Jatropha curcas* L.) Based on Life Cycle Assessment (LCA) in Indonesia”** is my own work, which has never previously been published in any university. All of incorporated originated from other published as well as unpublished papers are stated clearly in the text as well as in the references.

Bogor, July 2013

Kiman Siregar

SUMMARY

KIMAN SIREGAR. Comparison of Emission and Energy for Biodiesel Production From Oil Palm (*Elaeis guineensis)* and Jatropha Curcas (*Jatropha curcas* L.) Based on Life Cycle Assessment (LCA) in Indonesia. Supervised by ARMANSYAH H. TAMBUNAN, ABDUL KOHAR IRWANTO, SONI SOLISTIA WIRAWAN and TETSUYA ARAKI

Energy sector plays an important role for Indonesia in achieving its economic development goal. Indonesia is still heavily dependent on fossil based energy, which is accounted for more than 90% of its energy mix (including oil, gas and coal). Biodiesel is one of the biofuel being developed and used intensively in Indonesia. Biodiesel can be produced from various oil borne plants, such as palm oil, jatropha curcas, rapeseed, soybean, etc. The USA produced their biodiesel from soybean, Euoropean countries from rapeseed, while Indonesia mainly from palm oil. Currently, environmental consideration becomes the most important issue in biodiesel production. Even though the source of the energy is considered as carbon neutral, the production path can emit various environmentally hazardous gasses.

European and American countries claim that production of biodiesel from palm oil contributes carbon emission to atmosphere along its production path. Furthermore, US EPA-NODA and EU RED stated that palm oil based biodiesel can only reduce emission of GWP by 17% and 19% compared to fossil-fuel based. Considering that the minimum requirement is 20% for US and 35% for EU, CPO from Indonesia experiences difficulties to enter the global market. Scientific approach should be undertaken by Indonesia to address this issue. However nowadays we only still have few numbers of international scientific publications regarding the environmental aspect of biodiesel production. Appropriate method to analyze aforementioned problems is Life Cycle Assessment (LCA) which complies with the International Organization for Standardization (ISO).

This study is aimed to compare life cycle assessment of biodiesel production from oil palm and jatropha produced in Indonesia. The LCA system boundary for this study was from cradle to gate, which consists of eight sub-processes, with functional unit (FU) of 1 ton biodiesel fuel (BDF).

Life cycle inventory (LCI) analysis was performed using the data collected from oil palm plantation and *Jatropha curcas* centre, both located in western part of Jawa island in Indonesia, become primary data. The analysis was also grouped into unstable production stage and stable production stage in order to accommodate the natural growth characteristics of both crops. The LCI results were utilized to perform impact assessment using software MiLCA-JEMAI version 1.1.2.5 for data processing.

The results of this study show that biodiesel production from oil palm give higher value of global warming potential (GWP) than jatropha, it is also shown at a value of oil palm has higher material and energy input utilization than *Jatropha curcas*. The use of agro-chemicala, such as fertilizers, herbicides, insecticides and pesticides, give significant contribution to the total GWP value, which was 68.14% and 37.56% for the respective oil palm and jatropha for scenario 2. Emission characteristics of both crops during unstable productivity period were found to be different from that during the stable productivity. The calculation on stable productivity is lower than unstable productivity. Where as there is 4/5 part or 20 years of 25 years of its life cycle (oil palm and *Jatropha curcas*) lies on this condition. Therefore, appropriate calculation method is needed. In some journals, the calculation is only performed in the first five years. Annual GHG emission value, eutrophication, acidification and energy consumption for producing biodiesel from oil palm was found to be higher than that from jatropha.

For oil palm, the emission and energy consumption due to pre-harvest activity was higher compared to post harvest activity, while for jatropha, the post-harvest activity was higher than the pre-harvest one. The characteristics of GWP emission and energy consumption by biodiesel production from oil palm was higher than that from jatropha, both during unstable and stable productivity period. The emission and energy consumption from oil palm was dominated by pre-harvest activity due to the requirement of more intensive maintenance of the plant compared to that of jatropha.

The use of organic fertilizer is very influential in the reduction of GHG value impact in fertilization sub-process. It could reduce up to 96.2 % for oil palm and 76.8% for *Jatropha curcas* or for all life cycle could reduce up to 37.4 % for oil palm and 61.4% for *Jatropha curcas.* By scenario 5, using jatropha based biodiesel for electricity generation is still better than using other fossil fuel.

The energy input for production biodiesel from CPO is higher than CJCO as show by higher the NEB which is 146,948.08 and 39,334.79 for BDF from CPO and BDF from CJCO, respectively and by lower the RI value which is 0.162 and 0.270 for BDF from CPO and BDF from CJCO, respectively (result of the scenario 3). Scenario 3 is the best scenario which reflects real condition in Indonesia, in which GHG value before stable productivity is 2575.47 kg-CO_2eq./ton-BDF for oil palm and 3057.74 kg-CO_2eq./ton-BDF for *Jatropha curcas*. When the productivity has reached stability, the GHG value is 1511.96 kg-CO_2eq./ton-BDF for oil palm and 380.52 kg-CO_2eq./ton-BDF for *Jatropha curcas*. With if we compared to diesel fuel, CO_2eq. emission is reduced up to 49.27% and 88.45% for BDF-CPO and BDF-CJCO, respectively.

Keywords : Biodiesel, crude palm oil, crude *Jatropha curcas* oil, life cycle assessment

RINGKASAN

KIMAN SIREGAR. *Perbandingan Emisi dan Energi Produksi Biodiesel dari Kelapa Sawit* (*Elaeis guineensis*) *dan Jarak Pagar* (*Jatropha curcas* L.) *Berdasarkan Kajian Siklus Hidup* (LCA) *di Indonesia*. *Dibimbing oleh* ARMANSYAH H. TAMBUNAN, ABDUL KOHAR IRWANTO, SONI SOLISTIA WIRAWAN dan TETSUYA ARAKI

Sektor energi memainkan peranan penting untuk Indonesia dalam mencapai tujuan pembangunan ekonominya. Indonesia masih sangat bergantung pada energi berbasis fosil, yang menyumbang lebih dari 90% campuran energinya (termasuk minyak, gas dan batubara). Biodiesel adalah salah satu dari biofuel yang dikembangkan dan digunakan secara intensif di Indonesia. Biodiesel dapat dihasilkan dari berbagai minyak tanaman, seperti minyak kelapa, jarak pagar, rapeseed, kacang kedelai, dan lain-lain. USA menghasilkan biodiesel dari kacang kedelai, negara-negara Eropa dari rapeseed, sementara Indonesia terutama dari minyak kelapa sawit. Saat ini, pertimbangan lingkungan menjadi isu yang paling penting dalam produksi biodiesel. Meskipun sumber energi ini dianggap sebagai karbon netral, jalur produksinya dapat memancarkan berbagai gas yang berbahaya ke lingkungan.

Negara-negara Eropa mengklaim bahwa produksi biodiesel dari minyak kelapa sawit memberikan kontribusi emisi karbon ke atmosfer sepanjang jalur produksinya. Selain itu, US EPA-NODA dan EU RED menyatakan bahwa biodiesel berbasis minyak kelapa sawit hanya dapat mengurangi emisi GWP 17% dan 19% dibandingkan dengan bahan bakar berbasis fosil. Mengingat bahwa persyaratan minimum US adalah 20% dan EU adalah 35%, maka minyak kelapa sawit dari Indonesia mengalami kesulitan untuk memasuki pasar global. Pendekatan ilmiah harus dilakukan oleh Indonesia untuk mengatasi masalah ini, tetapi saat ini Indonesia hanya memiliki beberapa publikasi ilmiah internasional mengenai permasalahan ini, sehingga perlu untuk menjawab permasalahan emisi pada kelapa sawit ini. Metode yang tepat untuk menganalisis masalah tersebut adalah melalui penilaian siklus hidup (LCA) yang sesuai dengan standar organisai internasional (ISO).

Penelitian ini adalah tentang penilaian komparatif siklus hidup produksi biodiesel dari minyak kelapa sawit dan jarak pagar yang diproduksi di Indonesia. Batasan kajian LCA untuk penelitian ini adalah dari buaian ke pintu gerbang, yang terdiri dari delapan tahapan sub-proses, dengan unit fungsional (FU) 1 ton bahan bakar biodiesel (BDF).

Analisis persediaan siklus hidup (LCI) dilakukan dengan menggunakan data yang dikumpulkan dari perkebunan kelapa sawit dan Pusat Induk Jarak Pagar Pakuwon Sukabumi yang terletak di bagian barat pulau Jawa di Indonesia. Data ini dijadikan sebagai sumber data utama pada kajian ini. Analisis juga dikelompokkan ke dalam tahap produksi tidak stabil dan tahap produksi stabil untuk mengakomodasi karakteristik pertumbuhan alami kedua tanaman tersebut. Hasil LCI digunakan untuk melakukan penilaian dampak dengan menggunakan perangkat lunak MiLCA-JEMAI versi 1.1.2.5 untuk pemrosesan data yang telah menggunakan basis data di Indonesia.

Hasil studi ini menunjukkan bahwa produksi biodiesel dari minyak kelapa sawit memberikan nilai potensi pemanasan global (GWP) yang lebih tinggi dari *jarak pagar, hal ini juga diperlihatkan dengan nilai masukan material dan energi yang lebih besar pada kelapa sawit dibandingkan jarak pagar. Penggunaan agro-kimia, seperti pupuk, herbisida, insektisida dan pestisida, memberikan kontribusi signifikan terhadap nilai total GWP, yaitu sekitar 68,14% dan 37,56% untuk masing-masing minyak kelapa sawit dan jarak pagar. Karakteristik emisi dari kedua tanaman selama periode produksi tidak stabil ditemukan berbeda dengan produksi stabil. Perhitungan pada produksi stabil lebih rendah daripada produksi tidak stabil. Dimana 4/5 bagian atau 20 tahun dari 25 tahun total siklus kehidupan (kelapa sawit dan jarak pagar) terletak pada kondisi ini. Oleh karena itu, metode perhitungan yang tepat sangat diperlukan. Dalam beberapa jurnal, perhitungan hanya dilakukan di lima tahun pertama. Nilai emisi GRK, eutrophication, acidification dan konsumsi energi untuk memproduksi biodiesel dari minyak kelapa sawit ditemukan lebih tinggi dari jarak pagar.*

Untuk kelapa sawit, nilai emisi dan konsumsi energi untuk kegiatan pra-panen lebih tinggi dibandingkan dengan kegiatan pasca panen, sedangkan untuk jarak pagar, kegiatan pasca panen lebih tinggi daripada pra-panen. Karakteristik emisi pemanasan global dan konsumsi energi pada produksi biodiesel dari minyak kelapa sawit lebih tinggi dari jarak pagar, baik selama periode produksi tidak stabil maupun setelah stabil. Emisi dan konsumsi energi pada kelapa sawit yang dominan pada kegiatan pra-panen terjadi karena lebih intensifnya persyaratan pemeliharaan tanaman kelapa sawit dibandingkan tanaman jarak pagar.

Penggunaan pupuk organik ini sangat berpengaruh dalam pengurangan nilai GRK dalam proses tahapan pemupukan. Hal ini dapat mengurangi hingga 96,2% untuk kelapa sawit dan 76,8% untuk jarak pagar atau untuk semua siklus hidup dapat mengurangi hingga 37,4% untuk kelapa sawit dan 61,4% untuk jarak pagar. Dengan skenario 5, menggunakan biodiesel berbasis jarak pagar untuk pembangkit listrik tenaga diesel masih lebih baik daripada menggunakan bahan bakar fosil.

Energi masukan dalam produksi biodiesel dari CPO lebih tinggi daripada CJCO, hal ini ditunjukkan dengan tingginya nilai NEB yaitu 146.948,08 untuk CPO dan 39.334,79 untuk CJCO, serta rendahnya nilai RI yaitu 0,162 untuk CPO dan 0,270 untuk jarak pagar. Skenario 3 lebih mencerminkan kondisi riil Indonesia, dimana nilai GHG sebelum produksi stabil adalah 2575,47 kg-CO_2eq./ton-BDF untuk kelapa sawit dan 3057,74 kg-CO_2eq./ton-BDF untuk jarak pagar, serta pada saat produksi stabil diperoleh nilai GHG sebesar 1511,96 kg-CO_2eq./ton-BDF untuk kelapa sawit dan 380,52 kg-CO_2eq./ton-BDF untuk jarak pagar, dengan penurunan nilai emisi CO_2eq. jika dibandingkan minyak diesel (fosil) sebesar 49,27% untuk BDF-CPO dan 73,06% untuk BDF-CJCO.

Kata kunci*: Bahan bakar nabati, minyak mentah kelapa sawit, minyak mentah jarak pagar, penilaian siklus hidup*

© Copyright 2013 by IPB

All rights reserved

1. No part or all of this dissertation may be exerpted without inclusion or mentioning the sources.
   a. excerption only for research and educating use, writing for scientific papers, reporting, critical writing or reviewing of a problem.
   b. exerption doesn’t inflict a financial loss in the paper interest of IPB
2. No part or all of this dissertation may be transmitted and reproduced in any forms without a written permission from IPB

COMPARISON OF EMISSION AND ENERGY FOR BIODIESEL PRODUCTION FROM OIL PALM (*Elaeis guineensis)* AND JATROPHA CURCAS (*Jatropha curcas L.*) BASED ON LIFE CYCLE ASSESSMENT (LCA) IN INDONESIA

KIMAN SIREGAR

A Dissertation
Submitted in partial fulfillment of the requirements for the
Degree of Doctor in Agricultural Engineering Sciences

THE GRADUATE SCHOOL
BOGOR AGRICULTURAL UNIVERSITY (IPB)
BOGOR
2013

The external assessor for closed examination are :	Dr.Ir.Arief Sabdo Yuwono, M.Sc Dr.Ir.Udin Hasanudin, M.T
The external assessor for open examination are :	Dr.Ir.Prastowo, M.Eng Dr.Ir.Dadan Kusdiana, M.Sc

Dissertation title : Comparison of Emission and Energy for Biodiesel Production from Oil Palm (*Elaeis guineensis)* And Jatropha Curcas (*Jatropha curcas* L.) Based On Life Cycle Assessment (LCA) in Indonesia
Name : Kiman Siregar
Student Number : F164090031

Approved by,
Advisory Committee

Prof. Dr. Ir. Armansyah H. Tambunan
Chairman

Dr. Ir. Abdul Kohar I, M.Sc	Dr. Ir. Soni S.Wirawan, M.Eng	Dr.Tetsuya Araki
Member	Member	Member

Acknowledged by,

Chairman of Agricultural Engineering Graduate Study Program	Dean of Graduate School
Dr. Ir. Wawan Hermawan, MS	Dr. Ir. Dahrul Syah, MSc.Agr

Date of Examination : 25 Juli 2013

Date of Graduation :

Hak Cipta Dilindungi Undang-Undang
1. Dilarang mengutip sebagian atau seluruh karya tulis ini tanpa mencantumkan dan menyebutkan sumber:
a. Pengutipan hanya untuk kepentingan pendidikan, penelitian, penulisan karya ilmiah, penyusunan laporan, penulisan kritik atau tinjauan suatu masalah.
b. Pengutipan tidak merugikan kepentingan yang wajar IPB.
2. Dilarang mengumumkan dan memperbanyak sebagian atau seluruh karya tulis ini dalam bentuk apapun tanpa izin IPB.
© Hak cipta milik IPB (Institut Pertanian Bogor)
Bogor Agricultural University

Dissertation title : Comparison of Emission and Energy for Biodiesel Production from Oil Palm (*Elaeis guineensis)* and Jatropha Curcas (*Jatropha curcas* L.) Based On Life Cycle Assessment (LCA) in Indonesia
Name : Kiman Siregar
Student Number : F164090031

Approved by,
Advisory Committee

Prof. Dr. Ir. Armansyah H. Tambunan, M.Agr
Chairman

Dr. Ir. Abdul Kohar I, M.Sc	Dr. Ir. Soni S.Wirawan, M.Eng	Dr.Tetsuya Araki
Member	Member	Member

Acknowledged by,

Chairman of Agricultural Engineering Science Graduate Study Program	Dean of Graduate School
Dr. Ir. Wawan Hermawan, MS	Dr. Ir. Dahrul Syah, MSc.Agr

Date of Examination : 09 SEP 2013

Date of Graduation : 31 OCT 2013

PREFACE

Gratitude for His glory and greatness, author prays to Allah SWT for His grace and bless that let me to finish this draft dissertation.

For the completion of this draft dissertation I would like to express my most profound gratitude to Prof.Dr.Ir.Armansyah H.Tambunan as the chairman of the advisory committee and all members of advisory committee; Dr.Ir.Abdul Kohar Irwanto,M.Sc, Dr.Ir.Soni Solistia Wirawan,M.Eng, and Dr.Tetsuya Araki for all valuable assistance, support and their tireless and patient counsel. I also say many thanks to Dr.Ir.Arief Sabdo Yuwono,M.Sc and Dr.Ir.Udin Hasanudin,M.T over his willingness as the external assessor for close examination, and Dr.Ir.Prastowo,M.Eng and Dr.Ir.Dadan Kusdiana,M.Sc as the external assessor for open examination. Thanks the author gave to the Rector of Bogor Agricultural University (IPB), the Dean of The Graduate School of IPB, the Chairman of Agricultural Engineering Graduate Study Program, and all the lecturer and staff over all the facilities and assistance in studies and my research. The author also say thanks to the Rector of Syiah Kuala University (UNSYIAH), the Dean of Agricultural Faculty of UNSYIAH, the Chairman of Agricultural Engineering Department of UNSYIAH, and all lecturer of my friends in Agricultural Engineering Department of UNSYIAH.

Then, all of my friends in Heat and Mass Transfer of Laboratory (Mas Bayu R, Rosmeika, Agus Ginting, Christian, Angga, Pak Wahyudin, Mona, Tiara, Aliya, Deni, Tiara, and Ismi), Agricultural Engineering Science Study Program (2009, 2010, 2011, and 2012), and The Graduate School of Bogor Agricultural University (IPB).

Finally, I would like to dedicate this research work to my family, my wife (Sholihati,SP,M.Si), my sons (Farhan Dzaky Siregar, Kaysa Mahira Putri Siregar and Raja Putra Siregar "RPS"), specially for my father (Almarhum H.Nakman Siregar) and my mother (Hj.Mima Harahap), my brothers (Kakak Masnoun, Abang Mukmin, Nurleli, Masleni, Samriana, Herman, Marlina and Sadima) for their love, continuous encouragement and constant support in my life. The end of the authors hope may explain in what has been a writer of dissertations this could be beneficial for writer and in need of them.

Bogor, July 2013

Kiman Siregar

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOMENCLATURE

B_j : The value of the total system load
$b_{j,i}$: The value of variable load j of sub-system i
D : Diameter of steam at 1.3 m height (m)
d_{ijy} : Potential impacts y due to emission compounds i in process j (kg y eq.)
CO : Carbon monoxide
CO_2 : Carbon dioxide
CH_4 : Methane

C : The composition of carbon in the fuel
Es : Emission
E_{bdf} : Energy content of biodiesel fuel
E_{ff} : Energy content of fossil fuel
E_{fo} : Other fossils as a source of energy used during the entire production cycle
GWP^{100} : Global warming potential, 100-year based
e_j : The energy produced from energy source j in process k (kJ)
eq. : Equivalent
f_{ij} : The emission factor of substance i in condition k (kg/kJ)
eq_{iy} : Equivalence value of potential impact y due to compound i (kg y eq./kg i)
H : Height of plant without leaves (m)
Ha : Hectares
H_2 : The composition of hydrogen in the fuel
H_2O : The composition of water vapor in the fuel
H_2 : The composition of hydrogen in the fuel
HVi : HV fatty acid of i
HFC : Hydrofluourocarbons
hv : The heat of vaporization of water
m_{ij} : The mass of compound i (emission) of energy source/fuel j in process k (kg)
N_2O : Dinitrogen oxide
NF_3 : Trifluoride nitrogen
NOx : Nitrous oxide
O_2 : The composition of oxygen in the fuel
PFC : Perfluorocarbons
S : The composition of sulfur in the fuel
SF_6 : Sulfur hexafluoride
SF_5CF_3 : Trifluoromethyl sulfur pentafluoride
T_{FA} : Total percentage of all fatty acid
X_i : Mass fraction of vegetable oil or biodiesel
x, y, z : Molecule number of carbon, hydrogen, and oxygen of chemical formula at each i component
x_i : The mass or energy flow associated with the sub-system i
x : Age of plant (years)
yb : Above-soil biomass (tons / plant)
y_a : Palm roots biomass (tons/plant)
$n_{H2O,out}$: The moles number of evaporated water
$n_{fuel,in}$: The moles number of the combusted fuel

LIST OF ABBREVIATIONS

AD : Activity Data
API : American Petroleum Institute
EF : Emission Factor
BDF : Bio Diesel Fuel
BALITRI : *Balai Tanaman Industri*
BRDST : *Balai Rekayasa Desain dan Sistem Teknologi*

C	: Carbon
CPO	: Crude Palm Oil
CJCO	: Crude Jatropha Curcas Oil
DF	: Diesel Fuel
DESDM	: *Departemen Energi Sumber Daya Mineral*
EFT	: Empty Fruit Bunch
EGR	: Exhaust Gas Recirculation
EU	: European Union
EPA	: Environmental Protect Agency
EMS	: Environmental Management System
FFB	: Fresh Fruit Bunches
FAME	: Fatty Acid Methyl Ester
FFA	: Free Fatty Acids
GWP	: Global Warming Potential
GHG	: Greenhouse Gas
GAPKI	: *Gabungan Pengusaha Kelapa Sawit Indonesia*
GRK	: Gas Rumah Kaca
GPSA	: Gas Processors Suppliers Association
HHV	: Higher Heating Value
HC	: Hydrocarbons
HSD	: Hight Speed Diesel Oil
IV	: Iodine Value
IDO	: Intermediate Diesel Oil
ISO	: International Standard Organization
ISPO	: Indonesia Sustainable Palm Oil
IPPC	: Integrated Pollution Prevention and Control
IPCC	: Intergovernmental Panel on Climate Change
IPOA	: Indonesian Palm Oil Association
IPB	: *Institut Pertanian Bogor*
ITB	: *Institut Teknologi Bandung*
JME	: Jatropha Methyl Ester
JBD	: Jatropha Bio Diesel
JEMAI	: Japan Environmental Management Association for Industry
JO	: Jatropha Oil
KIJP	: *Kebun Induk Jarak Pagar*
kW	: Kilowatt
kWh	: Kilowatt-hour
DJO	: Diesel Jatropha Oil
LHV	: Lower Heating Value
LCA	: Life Cycle Assessment
LCI	: Life Cycle Inventory
LCIA	: Life Cycle Impact Assessment
LCC	: Legume Cover Crops
MW	: Molecular Weight
MFO	: Marine Fuel Oil
MiLCA	: Multiple Interface Life Cycle Assessment
Menristek	: *Menteri Riset dan Teknologi*
Mendiknas	: *Menteri Pendidikan Nasional*

NEB	: Net Energy Balance
NER	: Net Energy Ratio
NGO	: Non Government Organization
NTT	: *Nusa Tenggara Timur*
NTB	: *Nusa Tenggara Barat*
PM	: Particulate Matter
PTPN	: *Perusahaan Terbatas Perkebunan National*
PLN	: *Pembangkit Listrik Nasional*
PLTA	: *Pembangkit Listrik Tenaga Air*
PLTP	: *Pembangkit Listrik Tenaga Panas Bumi*
PLTB	: *Pembangkit Listrik Tenaga Biomassa*
Pertamina	: *Perusahaan Pertambangan Minyak dan Gas Bumu Negara*
PKS	: *Pabrik Kelapa Sawit*
RI	: Renewable Index
RED	: Renewable Energy Directive
RSPO	: Roundtable on Sustainable Palm Oil
SPM	: Solid Particulate Matter
SFC	: Specific Fuel Consumption
SV	: Saponification Value
TSP	: Trisuperphosphate
T	: Transportation
US	: United State
UK	: United Kingdom

LIST OF APPENDICES

CHAPTER I
INTRODUCTION

Research Background

A continuing development of renewable energy is particularly necessary for Indonesia, which is known as an agrarian country with abundance of natural resources. Energy sector plays an important role for Indonesia in achieving its economic development goal. Short (2002) in Ndong (2009) stated that sustainability of modern economy partly depends on the capacity of the countries to guarantee their energy supply (IEA, 2008). Indonesia is still heavily dependent on fossil based energy, which is accounted for more than 90% of its energy mix (including oil, gas and coal). The most reliable alternative for substitution of the fossil fuel is biofuel.

Biodiesel can be produced from various oil borne plants, such as palm oil, *Jatropha curcas*, rapeseed, soybean, etc. Availability of the feedstock is one important consideration for effective production of biodiesel. Thereby, USA produced their biodiesel from soybean, Euoropean countries from rapeseed, while Indonesia mainly from palm oil.

Currently, environmental consideration becomes the most important issue in biodiesel production. Eventhough the source of the energy is considered as carbon neutral, the production path can emit various environmentally hazardous gasses. European countries claim that production of biodiesel from palm oil contributes carbon emission to atmosphere along its production path. Furthermore, EPA-NODA states that palm oil based biodiesel can only reduce GWP emission by 17% compared to fossil-fuel based. The minimum requirement to enter global market is 35%. This condition could make barrier to Indonesia as one of the world's largest CPO producer.

Sheehan et al. (1998) reported that biodiesel B100 from soybean will reduce CO_2 emission by 78.45% compared to oil produced from fossil (fossil-fuel based). In regard to this result, Indonesia should analyze the equilibrium balance between carbon emission produced from biodiesel utilization and its biodiesel production path. This analysis should be conducted for two kinds of oil borne plants i.e. oil palm and *Jatropha curcas*.

Scientific approach through Life Cycle Assessment (LCA) can be used as a tool to assess this issue. LCA has been widely used by America and Europe for other organic materials. Besides for emission analysis, LCA is also designed to analyse all aspects related with energy. LCA is a systematic process which comprises identification, measurement, and assessment of environmental impact caused by a product during its life cycle process or activity. LCA can be used to ensure that all environmental impacts has been considered for deciding action, calculating environmental impact that might occur, comparing process performance and developing data base for further research. In this regard, LCA can be used as a tool to support decision making on environmental improvement conducted by enterprise or government (Cowell, 1999).

Other advantage taken from LCA is that it can be used for in comparing and evaluating products which have similar functions or uses. By using particular criteria, LCA can be a method on deciding whether one certain product has better qualification than others based on particular perspective (Searcy, 2000). The target of LCA is to compare the whole environmental damage caused by product or particular activity and then select one option which have the least damage risk. This step is incorporated in Life Cycle Impact Assessment (LCIA).

LCI is one of four stages of LCA which have important role to conduct the assessment. The result generated from LCA is highly influenced by the validity and sufficiency of data inventory of the object being assessed. In Indonesian case, the data access that can be used in this LCA study is very limited. Collecting data process is the main focus in analyzing the stock and the most time consuming among other process involved in LCA (Searcy, 2000). Number of LCA study on Indonesian biodiesel production come up with different result. This difference could be due to data inconsistency and did not present the actual condition found in the field.

Crude palm oil (CPO) is one kind of biologic resource that has been widely produced for biodiesel fuel, including Indonesia as the world main producer of palm oil. However, CPO is a food resource. This drives Indonesia to find another alternative source for biodiesel production. One promising source is *Jatropha curcas* L. which is considered as non-edible industrial plant used for biodiesel fuel (Silitonga et al., 2011; Tambunan et al., 2012). *Jatropha curcas* could be planted in marginal soil, semi dry climate, and suitable in tropical and subtropic climate. According to Kaushik et al. (2007) in Ndong et al. (2009), *Jatropha curcas* contains 28 and 38% oil that can be changed into jatropha methyl ester (JME).

According to those aforementioned situations, an effort to address this issue should be conducted by identifying and presenting actual condition of Indonesian palm oil and *Jatropha curcas* estate. In this research, LCA is used to analyze the prospect of oil palm and *Jatropha curcas* development.

Problem Formulation

According to those aforementioned situations, scientific approach needs to be taken in order to answer the problem related with global warming emission and others environmental effect along its biodiesel production path from oil palm and *Jatropha curcas*. Reducing emission value generated from oil palm and *Jatropha curcas* for biodiesel production is important to be determined in order to meet the standard of global market. The following questions have been formulated from the previous problem in systematic and structured study to provide good result:

1. What is the emission distribution for planting, harvesting and post-harvesting of palm oil and *Jatropha curcas* oil based biodiesel? Which stage has significant effect? What kind of material input is the most siqnificant increasing the global warming potential emission value?
2. How are the energy consumption, net energy balance, net energy ratio, and renewable index of biodiesel production from palm oil and *Jatropha curcas* oil?
3. How much is the potentialing in reducing greenhouse gas (GHG) emission generated from palm oil and *Jatropha curcas* oil-based biodiesel compared to diesel-fuel one?

It is expected that the research could give solution and describe the net energy balance and net energy ratio for further development of biodiesel processing.

Research Objective

The objective of the research is to analyze and compare life cycle assessment (LCA) of oil palm and *Jatropha curcas* as feedstock for biodiesel in Indonesia with boundary from cradle to gate using data based found in Indonesia.

Research Benefits

The benefits of the research are as follow:

1. Provide information regarding the life cycle assessment of CPO and CJCO to produce biodiesel under catalytic reaction.
2. Provide recommendation to industrialist, government or institute about possible improvement of feedstock for biodiesel production.

Novelty

Novelty of this research are as follows :

1. This is the first comparative study of oil palm and *Jatropha curcas* by assessing their life cycle in two phases, namely unstable productivity (1-5 years) and stable productivity (6-25 years)
2. This research comprehensively study the life cycle energy consumption of biodiesel production in terms of net energy balance (NEB), net energy ratio (NER), and renewable index (RI).

Research Boundaries

LCA is a life cycle assessment of a product from its existence until its extinction. However, in regard with the limitation of data, time and accessibility, and the objective, this research is limited to these conditions :

1. This study is branded with “cradle to gate” life cycle assessment, which is from land preparation up to the biodiesel production.
2. The data used for analysis with in the range of seed preparation to harvesting is secondary data from numerous sources, which presents the typical Indonesian oil palm and *Jatropha curcas* plantation activity.
3. The biodiesel production from palm oil and *Jatropha curcas* oil involve some processing activities from land preparation, seedling, planting, fertilizing, protection, harvesting, extraction crude oil, and biodiesel production. The biodiesel production is processed under catalytic reaction.
4. Emission analysis is performed for air emission, liquid waste and solid waste.
5. Impact analysis is carried out to analyze the global warming potential (GWP), acidification, eutrophication, waste landfill volume and energy consumption.
6. All data used in life cycle inventory (LCI) is based on Indonesia condition.

CHAPTER 2
STATE OF THE ART OF
LIFE CYCLE ASSESSMENT OF BIODIESEL

Introduction

In the late of 1990s, the International Organization for Standardization (ISO) published ISO 14040 as a part of ISO 14000 which describes the procedures of Life Cycle Assessment (LCA) as an environment management standard. In agricultural sector, LCA is not only used to improve the efficiency and reduce environmental effect during cultivation process but also used to analyze the utilization of biomass energy as an alternative energy to substitute fossil energy. The purpose of LCA application in agricultural sector is: (i) as an indicator of efficient and comprehensive energy utilization, (ii) to evaluate the energy availability for production activity, (iii) to calculate the mass equilibrium of released carbon dioxide. Helleret al., 2007 also mentioned that LCA can be used to (i) calculate the environmental emission amount transferred into air, water and soil from agriculture and transportation activities, (ii) calculate the amount of energy used at each stage of agricultural processes, (iii) develop alternative evaluation system model in term of managerial, energy conversion and decision making in agricultural sector policy.

This ISO standard provides guidance for organization on design and use of environment performance evaluation. Environment performance evaluation can be definitely applied by all organization no matter what it kinds, sizes, locations and complexity. This standard is not entitled to determine the level of environment performance or certification purpose. There are five delimitations used by researcher in conducting LCA, i.e.: (1) cradle to grave, (2) cradle to gate, (3) cradle to cradle, (4) well to wheel, and (5) gate to gate.

LCA is carried out in four distinct phases, i.e.: (1) goal and scope, (2) life cycle inventory, (3) life cycle impact assessment, (4) interpretation. Each phase is then described at different ISO standards, i.e.: (1) ISO 14040: Principles and framework, (2) ISO 14041: Goal and scope definition and inventory analysis, (3) ISO 14042: Life cycle impact assessment, (4) ISO 14043: Interpretation.

The objective of this chapter is to assess the development of life cycle assessment research that has been conducted by the world and Indonesia in accordance with the development of biodiesel from CPO and CJCO.

Literature Review

Feedstock of Biodiesel

There are numerous oil borne plants that have been used to produce biodiesel such as rapeseed oil (canola) in Europe, soybean oil in USA, coconut oil in Philippines, and oil palm (Malaysia and Indonesia). In Hawai, used-frying oil has been used by Pasific Biodiesel Inc. with capacity as much as small-production factory (40 ton/month). In Nagano (Japan), 60 fast-food restaurants use their waste for biodiesel feedstock.

A primary natural resource of triglycerides or fatty acid is fat or fatty oil (crude) derived from vegetable. In this research, feedstocks used are Crude Palm

Oil (CPO) and Crude *Jatropha curcas* Oil (CJCO), both of them are easily found in Indonesia.

Crude Palm Oil (CPO)

Biodiesel from palm oil, kernel oil, and coconut oil has satisfied the required cetane number and cloud point based on SNI standard (maximum 18 ^{o}C). However, the oil needs additional treatments if it is going to be used (or exported) to subtropical countries. The additional treatments are: adding additive to reduce cloud point, or mixing palm biodiesel/palm-kernel/coconut with very high iodine-value fatty acid methyl ester in order to produce 70-100-iodine-valued biodiesel or higher, mixing with raw material oil before converting into biodiesel; the example of high iodine-valued oil is rubber seed oil (*Hevea brasiliensis***,** I. V= 132 – 141), candlenut oil (*Aleurites moluccana*, I. V= 136 – 167), and tobacco kernel oil (*Nicotiana Tabacum*, I. V. = 129 – 142) (Eckey, 1954).

Crude *Jatropha curcas* Oil (CJCO)

Jatropha curcas L. fruit is commonly spherical in shape with the average size of its seed is 18 x 11 x 9 mm, 0.62 gram weight, composed by 58.1% fruit kernel and 41.9% fruit shell. The husk can be utilized for fertilizer as it contains potassium and phosphate compound. However, the husk is poisonous due to the existing of *curcin*, therefore it should be processed before applied to animal. Extract ether exists as much as 0.8% in fruit shell and oil content in fruit kernel is 54.2% or around 31.5% of the total fruit weight. Fatty acid found in oil consists of 22.7% saturated fatty acid and 77.3% unsaturated fatty acid. *Jatropha curcas* oil is yellow transparent liquid and able to be stored for a long period of time without experiencing color change. Table 2.1 shows composition of shell, kernel, and husk from *Jatropha curcas* oil extraction. Table 2.2 shows composition of fatty acid and physical characteristic of *Jatropha curcas*.

Biodiesel Production

Transesterification reaction using short-chain alcohol; methanol and ethanol, is the simplest chemical modification process in order to convert raw vegetable oil to fuel oil with lower molar mass. It contains almost similar viscosity with diesel oil, and high cetane number. This high cetane number expresses an indicator for good biodiesel quality. The process produces fatty acids alkyl ester (or biodiesel alkyl ester) as the main product and glycerin as valuable by-product which is easily separated from the main product.

Biodiesel is easily used due to its characteristic i.e. miscible, similar physical characteristics with diesel oil, biodegradable, ten times less toxic compared to common diesel oil, higher cetane number, colorless exhaust gas, and less sulphur or aromatic compound content. The similar physical characterisitic with diesel oil makes biodiesel can be directly applied in existing diesel engines without further modification. Less sulphur content in biodiesel results zero CO_2 emission so it eventually could reduce the effect of global warming.

Therefore, the world biodiesel development, particularly in Indonesia, is really important due to the decreasing number of fossil fuel reserved, global warming, and pollution issue. Biodiesel processing technology is usable for commercial utilization only if the final product meets the requirement standard employed in certain market area. Table 2.3 displays bioodiesel quality standard according to Indonesian government.

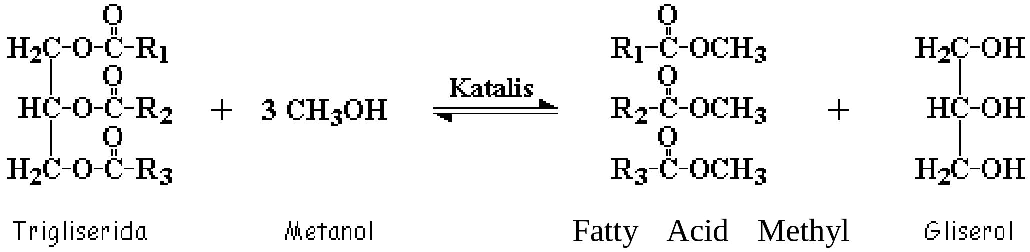
Table 2.1 Composition of shell, kernel, and husk of *Jatropha curcas* oil extraction (Trabi et al.,1999)

Materials	Fruit shell	Fruit kernel	Fruit husk
Dry material (%)	89.8 – 90.4	94.2 – 96.9	100
Component (%-weight dry)			
Crude protein	4.3 – 4.5	22.2 – 27.2	56.4 – 63.8
Lipid	0.5 – 1.4	56.8 – 58.4	1.0 – 1.5
Ash	2.8 – 6.1	3.6 – 4.3	9.6 – 10.4
Neutral detergent fiber	83.9 – 89.4	3.5 – 3.8	8.1 – 9.1
Acid detergent fiber	74.6 – 78.3	2.4 – 3.0	5.7 – 7.0
Lignin acid detergent	45.1 – 47.5	0.0 – 0.2	0.1 – 0.4
High heating value (MJ/kg)	19.3 – 19.5	30.5 – 31.1	18.0 – 18.3

Table 2.2 Composition of fatty acid and physical characteristic of *Jatropha curcas* (Banerji et al., 1985 in Ferry,2009)

Fatty acid	*Jatropha curcas*	Attribute	*Jatropha curcas*
Miristat (14:0)	0 – 0.1	Oil content	48 – 58
Palmitat (16:0)	14.1 – 21.8	Density (25^{o}C)	0.91 – 0.93
Stearat (18:0)	3.7 – 9.8	Bias index (30^{o}C)	1.465
Arakhidat (20:0)	0 – 0.3	Iodium number	97 – 102
Behenat (22:0)	0 – 0.2	Saponification number	195.0
Palmitoleat (16:1)	0 – 1.3	Calor value, MJ/kg	39.6 – 41.8
Oleat (18:1)	34.3 – 49.0	Calor value, MJ/ltr	43.0 – 45.4
Linoleic (18:2)	27.2 – 44.2		
Linolenat (18:3)	0 – 0.3		

Catalyst and non-catalyst are two methods that have been applied in biodiesel production. Stoichiometry equation for triglyceride transesterification with methanol is shown below:



Fatty Acid Methyl Esters (Biodiesel)

Reaction can take place without catalyst but it is time consuming. Catalyst is classified into 3 types, i.e. alkaline, acid and enzyme (Lotero et al., 2005; Liu et al., 2006; Fukuda et al., 2001).

Table 2.3 Biodiesel quality standard according to SNI 7182:2012

Parameters	Units, min/max	Standard	Testing Method
Specific mass at 40 °C	kg/m^3	850 – 890	ASTM D 1298
Kinematic viscosity at 40 °C	mm^2/s (cSt)	2.3 – 6.0	ASTM D 445
Cetane number	Min	51	ASTM D 613
Flash point (closed up)	°C, min	100	ASTM D 93
Cloud point	°C, max	18	ASTM D 2500
Copper strip corrosion (3 hours, at 50 °C)		Number 1	ASTM D 130-10
Carbon residue, in original example, in 10 % distillation residue	%-weight, max	0.05	ASTM D 4530
Water and sediment	%-vol , max	0.05	ASTM D 2709
Distillation temperature 90 %	°C , max.	360	ASTM D 1160
Sulfated ash	%-weight, max	0.02	ASTM D 874
Sulfure	mg/kg, max	100	ASTM D 5453
Phosphorus	mg/kg, max	10	AOCS Ca 12-55
Acid number	mg-KOH/g, max	0.8	AOCS Cd 3d-63
Free glycerol	%-weight, max	0.02	AOCS Ca 14-56
Total glycerol	%-weight , max	0.24	AOCS Ca 14-56
Methyl ester content	%-weight, min	96.5	-
Iodine number	%-weight (g-I_2/100 g), max	115	AOCS Cd 1-25
Oxidation stability, period inductions rancimat method or induction period method petro oxy	Menit	380 27	EN 15751 and ASTM D 7545

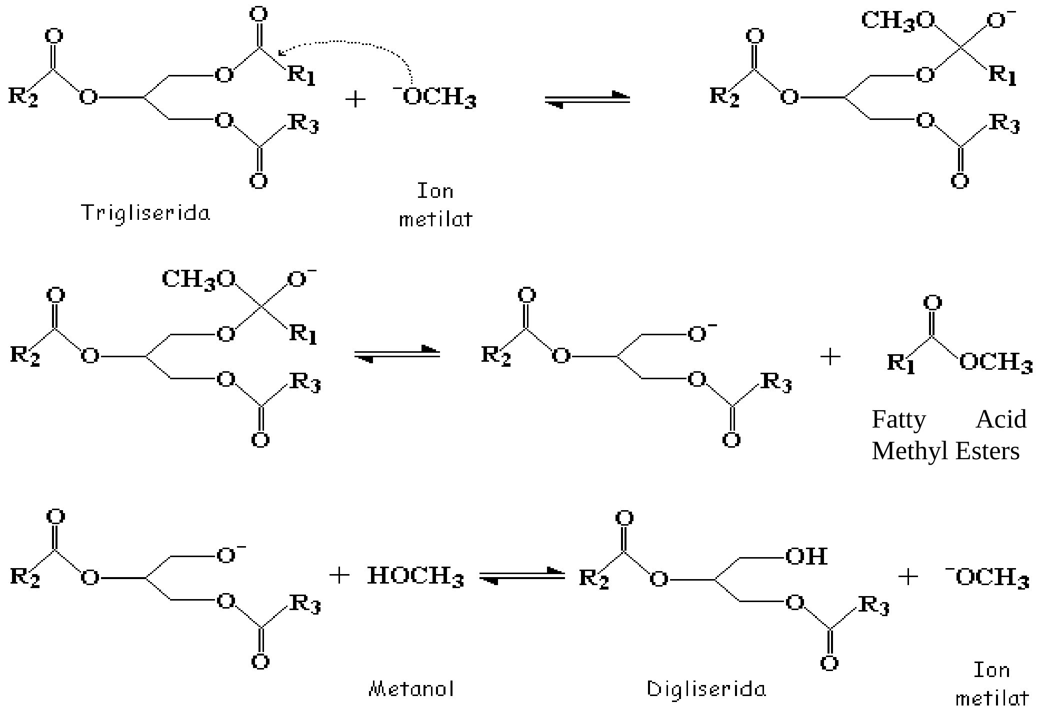
The shortest reaction time occurs when using alkaline catalyst. Therefore, it has been widely used for biodiesel processing. Metanolosis reaction occurs at three phases as follow:

1. Trigliserida (TG) + $CH_3OH \xrightleftharpoons{\text{Katalis}}$ Digliserida (DG) + R_1COOCH_3
2. Digliserida (DG) + $CH_3OH \xrightleftharpoons{\text{Katalis}}$ Monogliserida (MG) + R_2COOCH_3
3. Monogliserida (MG) + $CH_3OH \xrightleftharpoons{\text{Katalis}}$ Gliserol (GL) + R_3COOCH_3

The most commonly used of alkaline catalyst for transesterification process is sodium hydroxide, potassium hydroxide, sodium methylate (metoxide), and potassium methylate. The real catalyst for reaction is methylate ion (methoxide), but when hydroxide is used, the equilibrium reaction is:

$$OH^- + CH_3OH \rightleftharpoons H_2O + CH_3O^-$$

Mechanism reaction from fatty acid methyl ester in each catalyst cycle is defined below (similar mechanism occurs under convertion of diglyceride into monoglyceride and monoglyceride into glycerol):



Using alkaline catalyst, reaction takes place in short time and requires relatively low reaction temperature (methanol boiling point is 65^{o}C) (Formo, 1954 in Tatang, 2006). Therefore, most of industrial/commercial processes operate in the specified temperature range and atmospheric pressure. The amount of catalyst used is about 0.5-1.5 percent of total oil weight.

Free fatty acid content in vegetable oil determines the process that will be usedby vegetable oil with low free fatty acid content (<2%) such as virgin palm oil whether it can be processed directly with transesterification method. However, if free fatty acid is relatively high (>2%) for example crude castor oil, esterification process needs to determine acid number/FFA content (acid value/mgKOH/g-oil). The difference between transesterification and esterification process is in catalyst which involved in reaction. The purpose of esterification process is to reduce free fatty acid content then convert the oil into FAME (Fatty Acid Methyl Ester). Using this process, the failure in biodiesel production during transesterification process can be diminished. High FFA content (without esterification) will deactivate alkaline catalyst that results non-optimum triglyceride conversion to biodiesel.

The properties such as cetane number, iodine value, and cloud point of biodiesel are categorized as ’total netto’ of similar properties in fatty acids methyl ester. Table 2.4 shows some of fuel properties of vegetable oil-based biodiesel. From the table, it can be seen that biodiesel viscosity closes enough with diesel oil’s viscosity. The cetane number of biodiesel is regarded higher than diesel oil.

Biodiesel/fatty acids methyl ester (iodine value = 0), except methyl ester caprilat and caprat, tends to have high cetane number but relatively have high melting point (for virgin fatty acids methyl ester, melting point ≈ pour point), whereas biodiesel cloud point is 3 – 5 ^{o}C higher than its pour point. Commonly, fatty acid methyl ester has specific mass at 40 ^{o}C (except ester arachide) and kinematic velocity value at 40 ^{o}C (except ester caprilat, caprat, and erusat) in required range of biodiesel.

Table 2.4 Properties of biodiesel derived from vegetable oil

Biodiesel/ Ester Metil	Density 15^{o}C, kg/liter	Visk. kinem. 40 ^{o}C, cSt	ΔHc, MJ/liter	Cetane number	CFPP, ^{o}C.	Iodium number, g-I2/(100 g)
Coconut	0.869	2.70	30.80	63	8.0	10
Palm oil	0.874	4.40	32.40	63	16.0	52
Frying oil	0.880	4.20	32.80	49	-5 – +8	60 – 120
Castor	0.879	4.20	32.80	51		95 – 106
Kanola	0.882	4.20	32.80	49	-12	114
Sunflower	0.885	4.00	32.80	47	-4	129
Soybean	0.885	4.05	33.50	46	-4	131
Linseed	0.891	3.70	33.00	53		183
Jatropha curcas*	0.879	4.84	38.50	51	6 - +8	77.81
Diesel No. 2	0.840	2.70	37.08	47.0	-15.0	-33.0

Sources : Mittelbach M, "15 Years of Biodiesel Experience in Europe, "page 132 – 136 in Gübitz GM, Mittelbach M and Trabi, *"*Biofuels and Industrial Products from *Jatropha curcas"*, Dbv-Verlag für die Technische Universität Graz, Graz, Austria, 1997; Mittelbach M and Remschmidt C, *"*Biodiesel : The Comprehensive Handbook*"*, Martin Mittelbach Publisher, Graz, Austria, 2004.* Gubitz et al., 1999; Hanumantha Rao et al.,2009 in Silitonga et al.,2011.

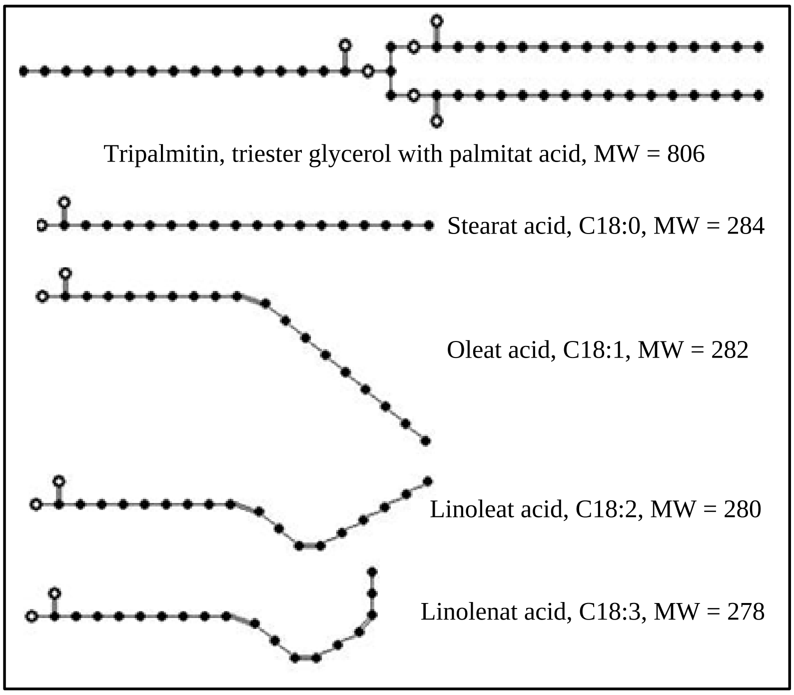


Figure 2.1 Molecule structure of several fatty acid

Fatty oil derived from vegetable or animal is mainly composed of triglyceride, which is trimester glycerol with fatty acids (C8-C24). Triglyceride is a branched-chain molecule and has high molar mass (600 – 900). Hence, less saturated fatty oil, results higher iodine value and lower cetane number. Figure 2.1 shows molecule structure of several fatty acids. The influence of molecule structure towards cetane number is depicted in Figure 2.2. It can be seen from the figure that many branches will result low cetane number.

Oleat acid methyl ester (iodine value = 85.60) has optimal characteristic i.e. kinematic viscosity and specific mass are in the range of biodiesel standard, cetane number is relatively high and melting point is low enough for the use in cold climate areas. Table 2.5 summarizes methyl ester properties of several fatty acids.

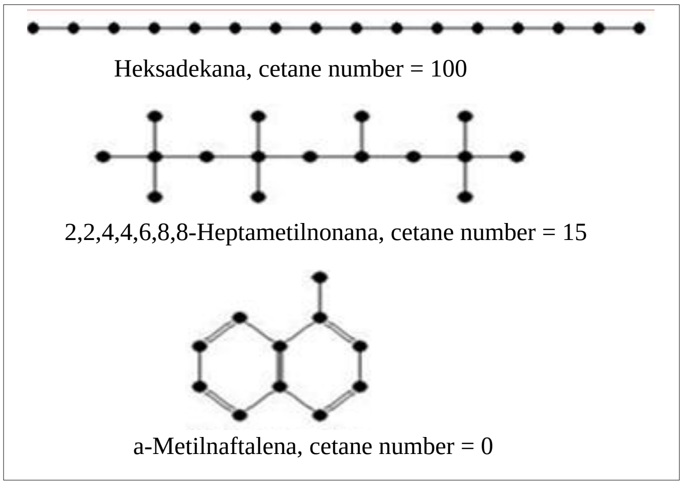


Figure 2.2 The influence of molecule structure towards cetane number

Table 2.5 Methyl ester properties of several fatty acid

Methyl acid ester	Cetane number	Iodium number (g-I_2/100g)	Melting point (^oC)	Kinetic visc. . (cSt), 40 ^oC	Density (g/cc), 40 ^oC
Kaprilat, Me-C8:0	≈ 33.6	0	-34	1.16	0.859
Kaprat,Me-C10:0	47.9	0	-12	1.69	0.856
Laurat, Me-C12:0	60.8	0	5	2.38	0.853
Miristat,Me-C14:0	73.5	0	18.5	3.23	0.867
Palmitat,Me-C16:0	85.9	0	30.5	4.32	0.851
Stearat, Me-C18:0	101	0	39.1	5.61	0.850
Arakhidat, Me-C20:0		0	48	-	0.849
Behenat, Me-C22:0		0	54	-	
Lignoserat, Me-C24:0		0		-	
Palmitoleat, Me-C16:1	51.0	94.55			
Oleat, Me-C18:1	59.3	85.60	-20	4.45	0.860
Linoleat, Me-C18:2	38.0	172.4	-35	3.64	0.872
Linolenat, Me-C18:3	20.0	260.3	-52	3.27	0.883
Gadoleat, Me-C20:1		78.20			
Erusat, Me-C22:1	76.0	71.98	33	7.21	0.856

The composition of fatty acid in vegetable oil depends on the plant. This composition determines cetane number, iodine numer, and cloud point. Cetane number is the benchmark of ‘immediate ignition’ of an engine fuel/diesel motor. Molecule shape/structure of the compound gives effect to cetane number and fuel viscosity. Parafine/alkana that composed diesel fuel is in the range of C13-C17 (molar mass 200-300 kg/mol).

Life Cycle Assessment (LCA)

The objective and scope

Four stages involved in LCA are shown in Figure 2.3. In the comprehensive study of LCA, system delimitation is taken to cover the whole stage of life cycle from raw material extraction until finish (cradle to grave). However, in certain cases, different environmental scope needs different approaches. The objectives are usually concern on the implementation of LCA, the reasons of a research, and what type of the beneficiaries. The scope usually concerns on: function of the system, functional unit and reference flow, definition of a system and delimitation of initial system, description of data category, and criteria for inclusion, and input-output. It includes quality of data requirement, allocation procedure which will be used, impact and assessment methodology, also assumption and analytical constrains.

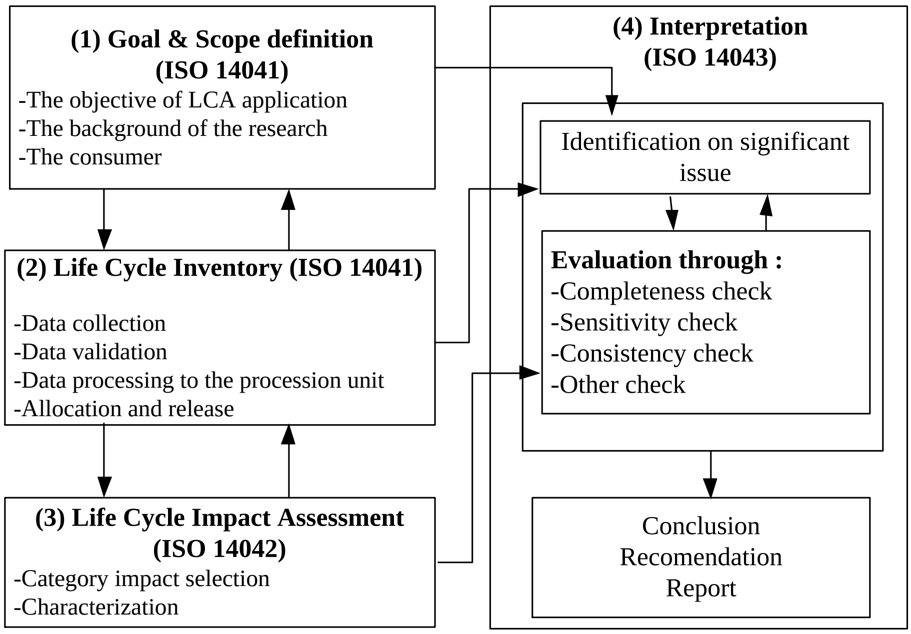


Figure 2.3 Four stages involved in LCA

Life Cycle Inventory (LCI)

LCI involves data collection of environmental burden that is needed to fulfill the objective of the research. Environmental burdenis determined by the raw material and energy used in a system as well as emission released by liquid waste and solid waste into the environment. The system has several stages such as: making flow diagram process, unit process description, data collection, calculating energy utilization process, and data validation. Data is associated with process unit being studied. The data of life cycle is collected and measured in unit function e.g.: material input and product energy; waste; and gas, water, and soil emission (Cowell, 1999). The process of inventory analysis follows the fundamental of knowledge and engineering, focuses on energy and material balance at each element in the system (Curran, 1996 in Searcy, 2000).

Data collection process is the main focus in inventory analysis and the most time-consuming stage of all LCA process (Jensen et al., 1998 in Searcy, 2000). According to Ciambrone (1997), Life Cycle Assessment considers 5 types of output, i.e.: gas emission, liquid waste, solid waste, product, and by-product.

Life Cycle Impact Assessment (LCIA)

LCIA is the third stage of LCA. The main objective of LCIA is to interprete the environmental burden which has been quantified in LCI stages. The stages in LCIA are (U.S. Environmental Protection Agency and Science Application International Corporation, 2001):

1) Selection and definition of impact category: identifying relevant impact category related to the process (for example global warming, acidification, and eutrophication).
2) Classification: input and output data obtained from inventory analysis are classified and assigned to spesific impact category (for example: classifying CO_2 emission in regard to its global warming)
3) Characterization: developing assessment model of environmental impact based on impact category using science-based conversion factors (for example: modeling the potential impact from CO_2 and methane (CH_4) on global warming).
4) Normalization: comparing the result of impact indicator with the defined standard.
5) Grouping: grouping impact indicator result (for example: grouping indicator according to area: local, regional, and global).
6) Scoring: emphasizing the most important potential impact.

The first three steps are mandatory for an LCIA. The other steps are optional. Impact category selection, category indicators, and LCIA models must be consistent with the goal and scope of LCA and must reflect environmental issues of observed system. Classifications involve aggregation of environmental burden to a small number of environmental impact categories which will demonstrate their impacts on human health, ecological health, and resource depletion. In this step, existed environmental burdensare calculated and analyzed. It will be interpreted in the form of potential impacts. This step aims to express the potential impacts in the form of analysis which is useful as the research outputs and is understood by users. Impact analysis types are grouped by considering degradation of abiotic and biotic resource, global warming, acidification, eutrophication, and toxicity level (Cowell, 1999).

Interpretation

The main objective of this stage is to analyze the expected result, to achieve the conclusion of observed system, to explain the system boundaries, and to give recommendation according to the result of LCI or LCIA. Environmental impact quantification is conducted in LCI and LCIA as this analysis could identify the most significant problem. Sensitivity analysis must be carried out before formulating final conclusion and research recommendation. Data availability and reliability are the main issues in LCA because the result and conclusion of LCA study will be determined by the type of data used in research. Sensitivity analysis could help identifying data variability effect, inconsistency and data gap to the final result of the research and displays reliability of final data. The report should provide complete information, transparent and non-bias according to ISO 14040. If the research will be used externally, critical consideration from an independent institution must be provided.

General categories from impact possibility that need consideration are: resource utilization, human health, and ecology consequences. Generally, economic aspect is not reflected in LCA. However, it should be incorporated in LCA study as it becomes one of important factor on decision making process. Therefore, ecology + economy = Eco efficiency is the key to drive wide acceptance of environmental friendly products (Narayan, 2007).

LCA Application and Uses

Haas et al. (2000) used LCA to analyze the negative effect of environmental impact, global warming, and water pollution in 18 agricultural locations in Southern German. This LCA has been widely used and specifically promoted in variable environmental management standards and legislative actions, including European Union Eco-Management and Audit Scheme (EMAS) (EC, 1993), ISO 14000 Environment Management System (EMS) (ISO, 1996) and Integrated Pollution Prevention and Control (IPPC) (EC,1996).

Method

Place and Time

The research was conducted in Laboratory of Thermal and Mass Transfer, Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Engineering and Technology and in Graduate School of Agriculture and Life Science, The University of Tokyo Japan. The research was accomplishedfrom June 2010 up to December 2011.The series of activities research is shown in Appendix 1.

Data Source

The data source was obtained from secondary data of numerous national and international publications from various countries.

Research Stage

The research was carried out in Indonesia and Japan using literature study of national and international publications which relates with LCA of biofuel, palm oil, jathropa curcas, others feedstock of biodiesel and others issues associate with global warming and other environmental issues.

Result and Discussion

World LCA Biofuel and Biodiesel

Sheehan et al. (1998) conducted LCA of soybean-based biodiesel from cradle to grave analysis which involved many parties in America. The result showed that this soybean-based biodiesel will reduce CO_2 emission by 78.45% for B100 and 15.6% for B20 compared to diesel-fuel based.

Several value of biodiesel emission on air, solid and liquid found in numerous publications are as follows: utilizing 100% of biodiesel will reduce the emission of CO_2, SO_2, CO and HC by 100%, 100%, 10-50% and 10-50% oxide, respectively. Even the emission value of SO_2 and particulate matter (PM) is relatively low but it has significant effect to human health. Reducing the emission value of these two matters are important to reduce transportation emission sector. A researcher team led by Timothy Searchinger, the environment and economic expert from Princeton University, found a fact that biofuel production will damage the environmental sector especially tropical forest. Substantially, utilization of biofuel will largely increase the amount of greenhouse gases and endanger the environment. Moreover, Timothy stated that 20% of CO_2 gas was generated by the changes of soil function and forest convertion into plantation area.

According to the National Institute of Space Research, the damage in the region has reached approximately 547,000 square kilometers. The local farmers also contribute on the damage. In fact, according to Fargione, each 10,000 square meters of forest damage produces more than 700,000 kilograms of greenhouse gases.

Life Cycle Assessment of Oil Palm in the World

Lord et al. (2009) stated that the effect of palm oil processing to the environment of water, soil, air and others were 47%, 24%, 8%, and 21%, respectively. Table 2.6 shows a summary of emission contained in air pollution, water, and solid waste. Figure 2.4 shows number of feedstock, emission/waste into air, water and solid based on 1 ton production of fresh fruit bunches (FFB) of palm oil (Chavalparit et al., 2010).

Siangjaeo et al. (2011) mentioned the estimation value of carbon stock changes based on IPCC Guidelines 2006. National Greenhouse Gasses Stock compares the greenhouse gasses emission of palm oil and biodiesel throughout its life cycle production in some areas in Thailand. Krabi produces carbon stock changes at -709 Mg-CO_2eq./day, Chonburi produces -748Mg-CO_2eq./day, and Pathumthani produces -600 Mg-CO_2eq./day. Each number is considered for the production of 1 million liters of biodiesel per day. However, the land use change scenarios selected for this study showed negative greenhouse gas balance which means that biodiesel can help to reduce greenhouse gases in the atmosphere. Siangjaeo et al. (2011) also said that the emission factor for fertilizer production which obtained from LCA diet was 1.46 kg-CO_2eq./kg-urea, TSP 0.54 kg-CO_2eq./kg (Trisuperphosphate), and KCL was 0.67 kg-CO_2eq/kg. Moreover, the application of nitrogen fertilizer was also included in this study as it was the main source of N_2O emissions. In palm oil plantation, there are two nitrogen inputs: synthetic fertilizers and crop residues. For synthetic N fertilizer, three routes of N_2O emissions listed above result in 1.325% of the input nitrogen isconverted into N_2O. In the case of crop residues, N volatilization does not occur which result in 1.225% of the input nitrogen is converted to N_2O (IPCC, 2006).

Table 2.6 Summary of emissions contained in air, liquid, and solid associates with the production of crude palm oil (Chavalparit et al., 2010)

Process	Air Emission	Wastewater (WW)	Solid waste
Loading ramp	-	Oil contaminated WW	-
Sterilisasi	Steam blow down	High organic WW	-
Bunch stripping	-	-	Empty fruit bunch
Oil extraction	-	-	Fiber, shell
Oil clarification	-	High organic WW	Decanter cake
Oil purification	Vapor	High organic WW	-
Steam generation	Particulate matter	-	Ash

Siangjaeo et al. (2011) also showed the detail of green-house emission from the production of 1 million liters biodiesel per day (Table 2.7).

Table 2.7 Total greenhouse gas emission generated from the production of 1 million liters biodiesel per day

Case studies	Greenhouse gas emissions (Mg CO_2-eq/day)				
	Oil palm plantation	Transportation	Palm oil production	Biodiesel transesterification	Biodiesel life cycle
Krabi	718	14	207	113	1052
Chonburi	581	41	207	113	942
Pathumthani	324	106	207	113	750

Based on the Table 2.7, it can be seen that the highest greenhouse gas emission in Krabi is at the planting stage due to higher intensity of fertilization compared to others. In Pathumtani, the highest greenhouse gas emission occurs during transportation stage due to higher FFB. The lowest greenhouse gas emission occurs at planting stage due to lower intensity on fertilization. Table 8 presents the highest greenhouse gas emission occurs at the planting stage due to the use of N fertilizer and its residue.

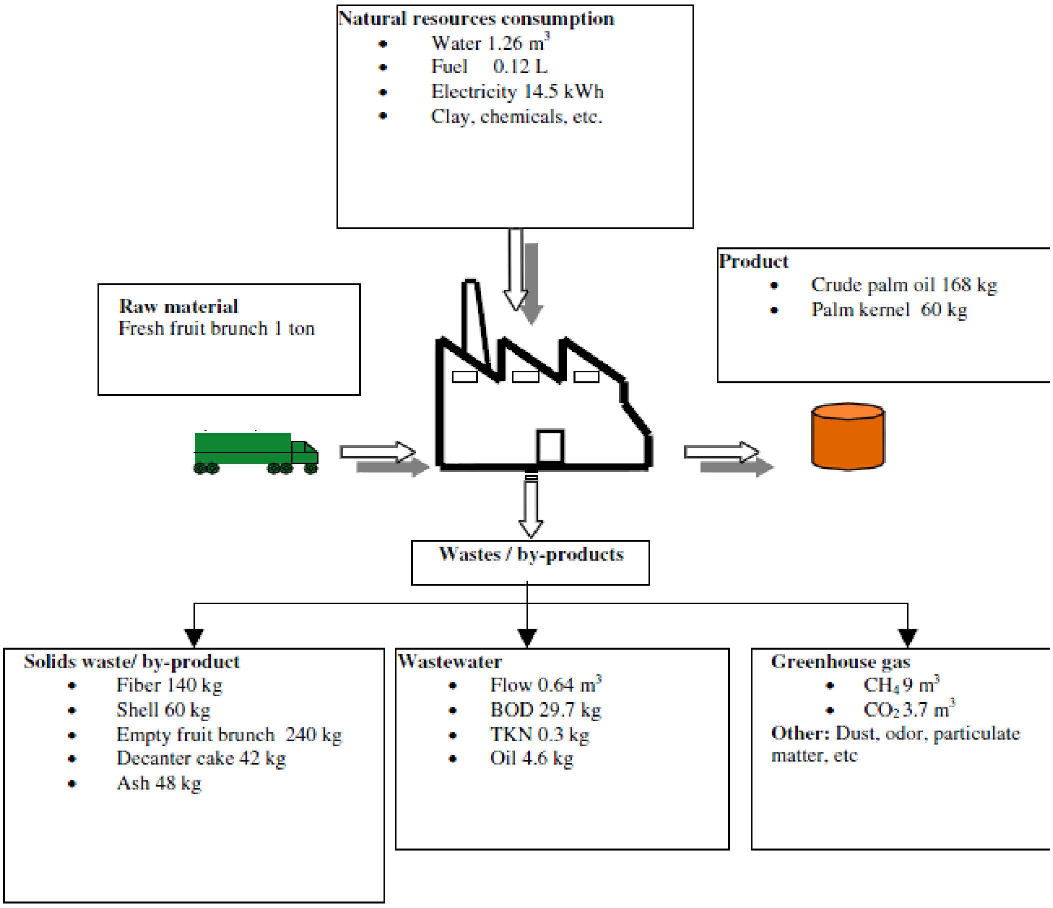


Figure 2.4 Average value and mass distribution of 1 ton FFB production and the amount of waste/emission in solid, liquid and air waste

Figure 2.5 shows mass distribution of 1 ton CPO production and the analysis of greenhouse gas emission using GWAPP model. Lam et al. (2009) conducted a comprehensive study on biodiesel production from *Jatropha curcas* and oil palm which includes crop cultivation, oil extraction and production process. The study found that in order to produce 1 ton biodiesel, *Jatropha curcas* requires land area of 118% higher than that of producing 1 ton biodiesel of oil palm. The ratio of energy output and energy input on palm oil based biodiesel is 2.27, this value is slightly higher than *Jatropha curcas* biodiesel i.e. 1.92. While the CO_2 absorption of *Jatropha curcas* is 20 times lower than the palm oil biodiesel. All researches report the excellence and the sustainability of palm oil as feedstock for biodiesel production. Yee et al. (2009) found that the use of palm oil for biodiesel generated energy ratio amounted to 3.53 (energy output / energy input), it indicated a positive net energy which ensures its sustainability. Energy ratio for palm oil biodiesel was found more than twice of rapeseed biodiesel, which was only 1.44. It shows that palm oil is more sustain as feedstock for biodiesel production compared with rapeseed oil. Yee et al. (2009) also found that the combustion of palm oil biodiesel was found more environmentally friendly than petroleum-diesel. It was indicated by the reduction in CO_2 emissions as much as 38% per liter of fuel.

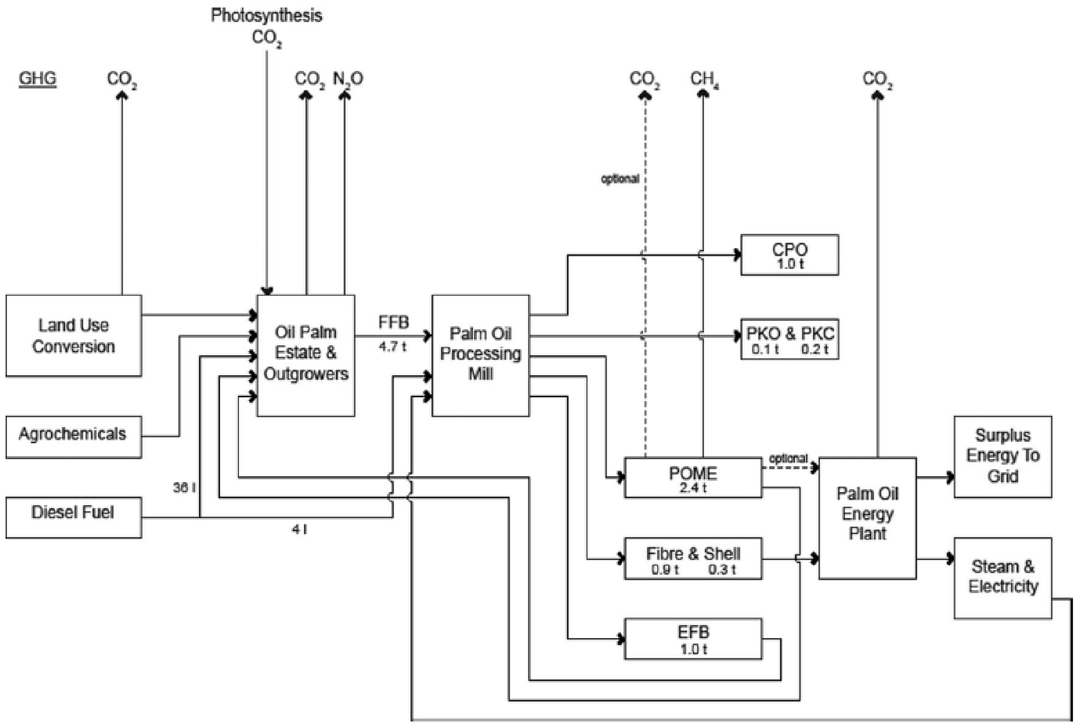


Figure 2.5 Mass distribution analysis of 1 ton CPO production and the analysis of greenhouse gas emission using GWAPP model

Life Cycle Assessment of *Jatropha curcas* in The World

Achten et al. (2010) stated that jatropha consumed higher fossil energy than palm oil. The amount was 82% for jatropha and 45% for oil palm. On the contrary, jatropha had lower global warming potential (GWP) compared with oil palm i.e. 55% and 77%. The research was taken from the milling and plantation in Allahabad India, while the palm oil data was taken in three locations in Cameroon.

Prueksakorn et al. (2006) stated that the GWP was dominantly produced from fertilizers and irrigation activity i.e. 31% and 26%, respectively. However, it had lower greenhouse gas emissions i.e. 77% compared with the production and use of diesel oil. Prueksakorn et al. (2006) also stated that the effect of greenhouse gas emissions occurred from the production and use of fertilizer, diesel consumption for irrigation, and the process of transesterification i.e. 31%, 26%, and 24%, respectively. It also explained that the energy consumption for transesterification was higher than that of fertilization while the highest greenhouse gas emissions occurred at fertilization stage. That's because the N compound of N fertilizer production process and the use of N_2O creates very strong greenhouse gas effect. Moreover, Prueksakorn et al. (2006) described the value of CO_2 emissions released by *Jatropha curcas* oil processing along its path i.e. 4.7% for land preparation, 0.2% for cultivation, 26.1 % for irrigation, 30.3% for fertilization, 3% for cracking, 10.9% for oil pressing, 0.5% for screening, and 24.3% for transesterification.

Reinhardt et al. (2007) stated that *Jatropha curcas* oil produced emission of CO, HC, NO_x, particulate, CO_2 and oil constant value as 0.15, 0.03, 0.37, 0.013, 181, and 15.36, respectively. Ndong et al. (2009) stated that the GWP value of CH_4 and N_2O were 25 and 298. Moreover, Ndong et al. (2009) provided the detail of greenhouse effect in various basic processes, i.e. *Jatropha curcas* cultivation generated 52% of the total emission while the transesterification and final combustion process were 17% and 16%, respectively. The highest emission occurred during cultivation process due to fertilization activity which accounted by 96%.

Gomaa et al. (2011) investigated the effect of exhaust gas recirculation (EGR) emission on indirect injection with jatropha biodiesel (JBD) fuel to reduce the Ox and emission gas. Smoke, NO_x, carbon monoxide (CO) and carbon dioxide (CO_2) and others engine performance parameters were observed and evaluated. The work resulted that 5% EGR in JBD5 could reduce NO_x and smoke by 5%, 27% and 17%, respectively. In JBD20 with 10% EGR could reduce NOx and smoke by 26% and 31%, respectively.

Gomaa et al. (2011) also stated that CO emission generated from JBD was lower than diesel fuel (DF). The increasing of CO_2 emission is in line with the increasing of biodiesel content in JBD. While the increasing of NO_x emission is in line with the increasing of combustion temperature and biodiesel content in JBD. NO_x emission of JBD was higher than DF while the smoke emission of JBD was lower than DF. This could be due to oxygen content in JBD which contributes stable combustion process. *Jatropha curcas* oil saved 66% of greenhouse gas compared to diesel fuel, even when the land conversion from pasture to estate was also taken into account (Gomaa et al., 2011). Brittaine et al. (2010) stated that the energy input to produce 1000 MJ of jatropha curcas oil was 160-216 MJ. Specifically, energy input for cultivation, oil extraction, biodiesel production were 27-81 MJ, 13-17 MJ, 118-120 MJ, respectively or the total was 376 MJ. While the total energy input for rapeseed oil and diesel oil were 437 MJ and1260 MJ, respectively.

LCA of Oil Palm and *Jatropha curcas* in Indonesia

LCA research on Indonesian biodiesel had ever been conducted by Kamahara et al. (2009) using palm oil as the feedstock. Other research was conducted by Widiyanto (2003) which concerns on LCA of electrical power, while Rosmeika (2009) conducted LCA of bagasse in sugar cane milling process. Hidayanto et al. (2011) presented the percentage of impact assessment for cultivation was 19.27%. Wirawan et al. (2009) which used palm oil stated that the utilization of B20 compared to the non-biodiesel may potentially reduce 10.8 thousand ton of SO_2, 2.9 thousand ton of NO_x, 17.2 thousand ton of HC, 2.8 thousand ton of PM and 23.5 thousand ton of CO in 2025. Wirawan et al. (2009) also said that biodiesel content in mix blended fuel had significant contribution in reducing SO_2 emission.

Nasir et al. (2010) showed that biodiesel from palm oil had higher fossil energy consumption compared with *Jatropha curcas*. The highest use of fossil energy occurred during the transesterification process, followed by cultivation and oil extraction process. Nasir et al. (2010) also said that biodiesel from palm oil had higher GHG emissions (greenhouse gas) and environmental impact compared with *Jatropha curcas* oil. Siregar et al. (2012) conducted a life cycle inventory on LCA biodiesel in Indonesia using palm oil and *Jatropha curcas* as feedstock. Rosmeika et al. (2012) conducted exergetic life cycle assessment on the uses of catalytic and non-catalytic method to produce palm oil biodiesel. Pramudita et al.

(2012) conducted life cycle inventory of *Jatropha curcas* in Indonesia. Sekiguzi et al. (2011) conducted life cycle assessment of biodiesel from *Jatropha curcas* using various data obtained from the Center of *Jatropha curcas*, Pakuwon, Sukabumi, Indonesia. Follows are some Indonesian researchers who focus on LCA studies: Dr.Udin Hasanuddin from Lampung University, Dr.Herdata from Faculty of Agriculture, Bogor Agricultural University, Mr.AgungWidianto from BRDST BPPT, etc.

Global Warming and the World Claim against Indonesia (Development of Palm Oil Biodiesel)

Indonesian palm oil biodiesel production process particularly during cultivation stage has gained attention from European countries. Indonesia has set a standard guide line of sustainable palm oil production in Indonesia Sustainable Palm Oil (ISPO) which is compulsory (mandatory) to all various organizations from different sectorswithin the Crude Palm Oil (CPO) industry, while European market only recognizes RSPO (Roundtable on Sustainable Palm Oil). RSPO is a voluntary certification standard which was developed by European Union customers that aims on creating the guideline of the development and implementation of sustainable palm oil within the stake holders. The stakeholders include palm oil producers, palm oil processors or traders, goods manufacturers, retailers, banks and investors, environment and social NGOs. These two certification schemes i.e. RSPO and ISPO become challenges for Indonesia in the future. Indonesia, as the largest producer of palm oil, should be able to convince global market that we can supply good quality of CPO.

Biodiesel is regarded as renewable resource obtained from oil borne plants. It is also regarded as environmentally friendly fuel or widely known as zero CO_2 emission. Produced CO_2 emissions from combustion engines will be reabsorbed by plants through photosynthesis mechanism which entitled to reduce the accumulation of CO_2 in the atmosphere. The accumulation of CO_2 in the atmosphere which is generated by petroleum-fuels or coal produces global climate change or the so-called global warming or global warming potential.

Emission of pollutant such as SPM (solid particulate matter), CO, hydrocarbons (HC), and SO_x from combustion of biodiesel are much smaller than diesel fuel. Biodiesel is considered as neutral in terms of CO_2 emissions and therefore can help reducing greenhouse gas emissions. The impact on the uses of biodiesel on NO_x emissions still requires further study considering that there are no conclusive test results set on this subject. Most researchers concluded biodiesel can reduce NO_x emissions while other researchers claim the other side.

Global Warming Potential describes potential value of global warming caused by emission within 100 years period. GWP^{100} is expressed in kg of CO_2 equivalent unit, which is the main greenhouse gas causing global warming. The equivalent value is published periodically by the Intergovernmental Panel on Climate Change (IPCC). Climate change issues become factors of different kinds of environmental issues in the world.

Climate change or global warming is caused by increasing amount of solar heat trapped in the atmosphere. Naturally, some amount of solar heat that coming into the earth will be absorbed by the earth's surface, while some will be reflected back into the space. The existence of a layer of gases called greenhouse gases in the atmosphere can block the sun's heat to be reflected into space through the atmosphere. The condition that present a trapping solar heat in the earth's surface is known as the greenhouse effect.

Since industrial revolution in the 1870s, the uses of fossil fuels (oil, gas and coal) have marked increasing amount. Activities such as electrical power generation, industrial activities, the use of electronic tools, and the use of motor vehicles will eventually release some greenhouse gas emissions into atmosphere. This climate changes will cause adverse effects to human life, such as sea level rise. This condition brings devastating impact on people, especially for people living in the lowlands, in the densely populated coastal areas in many countries and in river deltas.

It is estimated that number of world's population is threatened by drought and flood in 2020. Poor countries will hardly suffer due to climate changes as it destructs the food and water availability. This condition will increase malaria disease, fever dengue and diarrhea. Because of this situation, we must immediately reduce the activity which release greenhouse gas emission to inhibit the rate of climate changes for human life. CO_2 emission threaten human health which in high concentration (toxicity) could cause fainted and death.

Underlying analysis which causes European countries claim that Indonesian CPO and biodiesel damage the environment or increase carbon emission and global warming is described below.

- Based on the existing conventions and the sources of global warming:
  - Indonesia has ratified convention about global warming through Act No. 6 year 1994 regarding climate change and Act No. 17 Year 2004 on ratification of Protocol Kyoto. As developing country, Indonesian is not obligated to reduce CO_2 emissions. Indonesia is only mandated to report the amount of produced CO_2 emissions. This regulation shows that European claim does not deal with Indonesian condition as Indonesia is not obliged to do so.
  - In this case, Indonesia had reported to UNFCCC regarding with the result of the preparation of First National Communication in 1999 as a proof of its seriousness in addressing climate change, and continued in the second year in 2009. The State Ministry of Environment Living (KLH) is a focal point institution in the implementation of programs relates with climate change.
  - CO_2 emission can be produced from the combustion of fossil fuel, such as: coal, oil and natural gas, emissions from cement industry and land conversion. Carbon Dioxide Information Analysis Center (2000) stated that the use of fossil fuel is considered as the major source of CO_2 emission in the world which reaches 74% of the total emission. Land conversion contributes up to 24% and cement industries is 3%. This data also weaken the claim of European countries about the effect of palm oil plantation on global warming especially in Indonesia.
- However, some organizations reported data and claimed Indonesian activity especially land clearing for palm oil plantation has caused large amount of global warming and has destroyed forest and peat land:
  - CO_2 emission is the largest part of greenhouse gas emissions (GHG) in Indonesia which contributes to nearly 70%. The rest of 30% is generated from other activity.

- Based on the First National Communication report, the main source of GHG emission is energy and forestry sector. The energy sector contributes up to 46% of the total emission of GHG produced from the use of fossil fuel on various activities such as: production, processing and also combustion for power plants or other industrial purposes.
- The history shows that palm oil plantation has resulted deforestation and produced carbon emission. Data shows that 70% of palm oil plantation converted forests and directly produced around 187 PPM during 1982 to 1999. If it is assumed that the 70% of the palm oil plantation was built between 1999 and 2005 (approximately 3 million ha) then the potential emission released into atmosphere is 528 MTC. In fact, palm oil plantation might result higher deforestation number as it often displaces local community, and also found that palm oil plantation is used for access on timber sources.
- Palm oil plantation has been planted on peat land which stores carbon in large quantities. Available data shows that forest land utilization permit reached up to 491,046 ha of peat land in Kalimantan and 97,870 ha in Riau. If all plantation aware on this issues, how many ton of carbon per year released to the atmosphere that cause global warming?
- Conversion of natural forest to palm oil plantation causes loss of biodiversity, extinction of species and various environmental problems such as erosion and water pollution. Such conversion also generates carbon emission. Primary forest in Indonesia is estimated to storing around 230 Mg carbons per hectare, whereas secondary forest store around 176 Mg carbons[1]. Palm oil plantation only stores around 91 Mg[2] carbons per hectare. It means that around 160 Mg carbon lost during conversion of primary forest into palm oil plantation. Higher amount of carbon might be released into the atmosphere if fires are used for clearing the forest and building estate road.
- In 1998, the Department of Forestry addressed temporary moratorium against forest conversion to overcome the international and domestic problem on the impact of palm oil expansion on Indonesian forest. However, before February 1999, the permit was issued to release forest land under agreement written in application i.e. 843,058 ha of forest land. Approximately of 70% of this land was converted into palm oil plantation which consisted of forest land in Riau (417,503 ha), Lampung (74,779 ha), Central Kalimantan (100,100 ha) and East Kalimantan (168,848 ha) (Casson 2000). Another permitof 3.6 million hectare was also issued for estate development. The increasing of palm oil plantation will increase the amount of carbon emission released into the atmosphere.
- During 1999-2001, the government had agreed to use 13.4 million ha of forest area for non-forest purpose area. Most of this land was previously designed as

---

[1]This estimation is considered as stock carbon in primary forest which contain tree which have diameter more than 30cm found in Jambi, Sumatera. Most of stocked carbon in tropical forest can be found in upper soil biomass (ttrunks, branches, leaves, vines epiphytes, under store and ground). This is also stored in death trunk, death standing tree, trash in the form of leaves, trunk, branch, flower, fruits and fire residue (Skutch et al.,2007). Tree in tropical forest contains more than 50% carbon per ha obtained from boreal forest or moderate climate (Streck, 2007)

[2]Ginolga et al.found that palm oil only consist of 27 MG C/ha. This is due to that Ginolga et al.only considers biomass on the upper soil while other research considers biomass from manure and biomass found in soil and under ground.

conversion forest area and limited production forest area. In 2004, the Governor was given the authority for issuing a clearing permit for companies who want to build plantations, such as palm oil plantation. Governor was also given the authority to issue a logging license. However, the Department of Forestry had the right to issue this license before approval of land release by publishing letter of understanding as attributed as Principal of Agreement. This permission allows companies to start the process of the acquisition of land utilization permit from the Department of Agrarian. Under this authority, land clearing for palm oil plantation increases largely and consequently increases huge amount of carbon emission in to the atmosphere.

- Nowadays, anecdotal evidence shows that decentralization on issuing land clearing permit causes large deforestation. Governor has been given an authority to issue land utilization permit to convert the forest without approval from Department of Forestry. Moreover, Head of Seruyan regency in East Kalimantan had been issued to facilitate the permit of 274,188 ha of forest land to be converted into 23 estate companies during 2004-2005 without permission from Department of Forestry. The government of East Kalimantan was also speculated to issue land utilization permit for Surya Dumai Group in Nunukan regency. This company has been issued for timber logging exploitation on the permission area. Moreover, number of NGOs has also proved that this company does not have activity on palm oil plantation.This case had been reported to the commission of Anti-Corruption and has been investigated. The Governor of East Kalimantan (Suwarna Abdul Fattah) was also indicted by the courts of Anti-Corruption in November 2006 as his forest exploitation permit on 1 million ha in Berau, East Kalimantan before obtaining permission from central government (Antara, 2005; Sijabat, 2006). Moreover, information showed that there were land permit about 7.5 million ha was issued in West Kalimantan, Central Kalimantan, East Kalimantan, South Kalimantan, Riau and Papua. This number is equal to land which can be used to produce 41 million ton of CPO in 2020. Sawit Watch estimated that Indonesia needs 13.8 million ha for palm oil plantation to meet the palm oil demand in 2020. Sawit Watch is Indonesian NGO which works to monitor the palm oil development in Indonesia. No other reason to allocate more land for palm oil plantation in these 5-10 years ahead.
- Hooijer et al. (2006) assumed that around1.4 million hectares or 25% of the Indonesian palm oil plantation has been planted in peat land which is considered as one of the largest source closes to terrestrial organic carbon surface. This indicatesthat approximately 17% of the total of land use permit in Kalimantan has converted peat land area for palm oil plantation. Most of the permission locates within West Kalimantan province which covers about 212,670 ha. Another peat land area accounted by 646,324 ha has been also allocated for palm oil plantation planned in Kalimantan. Most of the peat land (79%) locateswithin East Kalimantan and West Kalimantan province. In Riau, approximately 13% of land usepermit is allocated for palm oil plantation which also locates in peat land, however 50% of the locations permission which planned for palm oil plantation (total is 711,815 ha) has been issued for peat land development. This is partly due to the fact that 41% of the main land in Riau is peat land. Palm oil is widely planted in peat land because most of

the soil mineral in low landarea of Sumatera and Kalimantan is suitable for palm oil. Peat land also tends to have a low density of population. Planting palm oil in peat land could cause significant amount of carbon emission. Carbon emission generated from palm oil cultivation in peat land contains average carbon emission of 54-55 ton/ha/year, which means the loss of soil peat is approximately 9 cm/year (based on the carbon content on average 60 KgC/m^3. The impact of palm oil cultivation in peat land might increase higher (ProForest 2003).

- The release of carbon from peat soil is accelerated by the fire as fire immediately releases carbon into the atmosphere. On the other hand, oxidation of peat material generated from compression and drainage of peat soil in palm oil plantation causes gradual loss of peat soil during 10 to 20 years. Expansionof palm oil plantations often associates with fire which generally used for clearing process. Fires can be controlled within the concession territory if it is well managed but it frequently out of control and results destructivesituation, especially in El Nino condition. Peatland also becomes more susceptible to fire (Hooijer et al., 2006).
- Palm oil consumes high nutrient from mineral fertilizer in Southeast Asia (Hardter & Fairhurst, 2003). Fertilizer is used to produce and maintain high productivity. This is usually conducted through applying such amount of fertilizers-based nitrogen-NPK (ammonium nitrate), ammonium sulfate and urea. Table 2.8 shows the need of fertilizer for palm oil in Indonesia.

Tabel 2.8 The need of fertilizer for palm oil in Indonesia

	Year					
	1	2	3	4	5	Total
On mineral soils, kg/ha						
N	58	68	68	81	81	354
P	27	16	19	28	28	118
K	85	125	98	122	122	533
Mg	14	21	18	28	28	109
Ca	-	-	-	-	-	-
On peat soils, kg/ha						
N	45	63	55	81	81	324
P	18	17	20	32	32	118
K	101	139	122	139	139	641
Mg	66	91	94	124	124	70
Ca	144	198	204	270	270	152

Source: IOPRI, these data are relatively similar to those mentioned in Rosenquist (1987), Ho and Chiang (1999) or Ooi et al. (2001) for Malaysian plantations (in Guyon & Simorangkir, 2002)

- Palm Oil Company causes forest fires more than five million hectares in Kalimantan (Siegert, 2004). According to Page et al. (2002) and Santilliet al. (2005), Indonesia fires peat released 0.81 to 2.57 Giga tonnes (Gt) carbon and large number of sulfur oxides into the atmosphere in 1997. This number is equal with 13-40% of the average emissions of fossil fuel on the same year. This number is also higher than annual emission generated from power plant in West Europe (Dauvergne 2001). This number agrees with the fact found in

1997 which experienced highest increase of CO_2 emission (Siegert et al., 2001;. Page et al., 2002.). During 1997-2006, CO_2 emissions generated from fires peatland was accounted by 4300 Mt/y (Hooijer et al., 2006).

- It is difficult to calculate how much carbon that released from peat land cleared with fire to build road for palm oil plantation. If it is assumed that most companies are still using fire for clearing it could be calculated that X tC/ha has been emitted from building 491,046 ha of palm oil plantation in peat land in Kalimantan. So these difficulties have revealed that the palm oil plantation has generated deforestation, peat land degradation and fires. All of these impacts have resulted high carbon emissions.
- Greenpeace said Unilever's palm oil production has environmental costs amounted to € 714 M/y. According to Greenpeace, if Unilever takes into account the consequences of palm oil production, it will add € 714 M/y for operating costs, equivalent to 14% of gross profit in 2007. The company believes that it is not appropriate to put the emission cost resulting from land use. Unilever is the world's largest consumer of palm oil (3% of the total) which uses this material as the ingredient in their various food and soap products. Half of the source of raw materials is obtained from Indonesia. Unilever estimates their own carbon produced from production, distribution, use and waste amounted to 240 M tones/y, of which 50 M tons of supplies occurs during supply chain. Greenpeace said that the palm oil transportation from Indonesia contributes up to the half part. One fact mentions that palm oil plantation has spent the soil after 25 years, so the cost will go up to € 1 billion, equivalent to about 18% of the company's gross profit. Greenpeace also said that palm oil cultivation cause irreparable damage to wildlife. After Greenpeace action in margarine factory in Rotterdam and UK, Unilever supports reforestation and reclamation efforts of peat swamp, and production of palm oil will be terminated immediately. Start from 2015, the company will have all the oil from RSPO certified area.
- GAPKI gives statement according to such conditions, as follows:
  - ✓ Statement of the Indonesian palm Oil Association (IPOA/GAPKI) concerning the temporary suspension of CPO of Unilever business with PT.SMART Tbk:
  - ✓ Based on PT SMART Tbk report submitted to GAPKI on December 15th, 2009 concerning the temporary suspension of future purchase of palm oil from PT SMART Tbk, GAPKI would like to make the following statement:
    - GAPKI deeply concerns over unilateral actions taken and decided by UNILEVER to temporary suspend the purchase contract of CPO from PT SMART Tbk. holding company. GAPKI stated that such suspension will not only affect SMART Tbk. but will also create impact on the perception and attitude of the Indonesian palm oil industry towards UNILEVER.
    - UNILEVER and PT SMART Tbk. are members of Roundtable on Sustainable Palm Oil(RSPO). Both institutions are committed to adopt and implement the principles and criteria of sustainable palm oil. Therefore, it is appropriate for UNILEVER to use RSPO forum for clarifications on the allegations and claims lodged by GREENPEACE, a non-member and highly critical to RSPO. This does not serve

UNILEVER as a good member or as one of pioneers in the establishment of RSPO.

- GAPKI concerns that this incident may influence the perceptions of CPO producers on the credibility of RSPO.
- The unilateral action conducted by UNILEVER reflects distrust on Indonesian laws and regulations which concern on the development and management of palm oil plantation.
- CPO production will steadily grow over time in line with growing demands from domestic and world markets. CPO will remain as one of the most lucrative commodities. Thus, the suspension case of UNILEVER will not impact and influence Indonesian CPO market.

Perhaps, based on claims data and NGOs (such as Greenpeace, Sawit Watch, etc.) mentioned above, the people of Europe points palm oil plantation development in Indonesia as a source of global warming emission.

Some of waste generated by the processing of biodiesel from palm oil and *Jatropha curcas* are as follows:

- Liquid waste: the development of biodiesel can reduce the quality of water. During estate development, there will be water run-off into water bodies with a variety of pollutants that exist in the development site. A pollutant that might occur is fuel and lubricant spills of heavy equipment, sedimentation and domestic waste. Thus, wastewater treatment plants are needed to be processed and neutralized before being discharged to the environment (water bodies). Therefore, biodegradation of the organic components into simple organic compounds in anaerobic atmosphere needs to be taken place. Wastewater (effluent) from the biodiesel plant material contains organic compounds such as carbohydrates, proteins, oils and fatty acids. Figure 2.6 shows the flow diagram of the production process and water treatment in the processing of palm oil.
- Waste to air/emission: during the development process of biodiesel plant, the air quality is predicted to decline due to land leveling activities, mobilization and operation of heavy equipment, and the construction work itself. Disturbance is in the form of an increase of dust in the air and noise. Some of emissions are transferred into the air during biodiesel production from palm oil are as follows:
  - Hydrocarbons (HC): As the name implies, hydrocarbon component consists only hydrogen and carbon element. The release of hydrocarbons from motor vehicles is caused by imperfect combustion of fossil fuels in the engine.
  - Carbon monoxide (CO): Carbon monoxide is a colorless component, taste less and odorless. Carbon monoxide which present in nature is made from one of the following processes:
    1. Incomplete combustion of carbon or carbon-containing components.
    2. Reaction between carbon dioxide and carbon-containing components at high temperatures.
    3. Carbon dioxide changes into carbon monoxide and oxide at high temperature.
  - Greenhouse gas emission is a source of global warming. There are some significant differences in greenhouse gas emission value at the same biodiesel using different modeling approach. Some of these differences are caused by the input study. For example, high emission is generated in the production of

biodiesel in Europe. This is due to the assumption that all of methanol is oxidized during the process. In fact, some fossils replace some of biogenic carbon in biogenic raw material, while carbon presents in the glycerin.

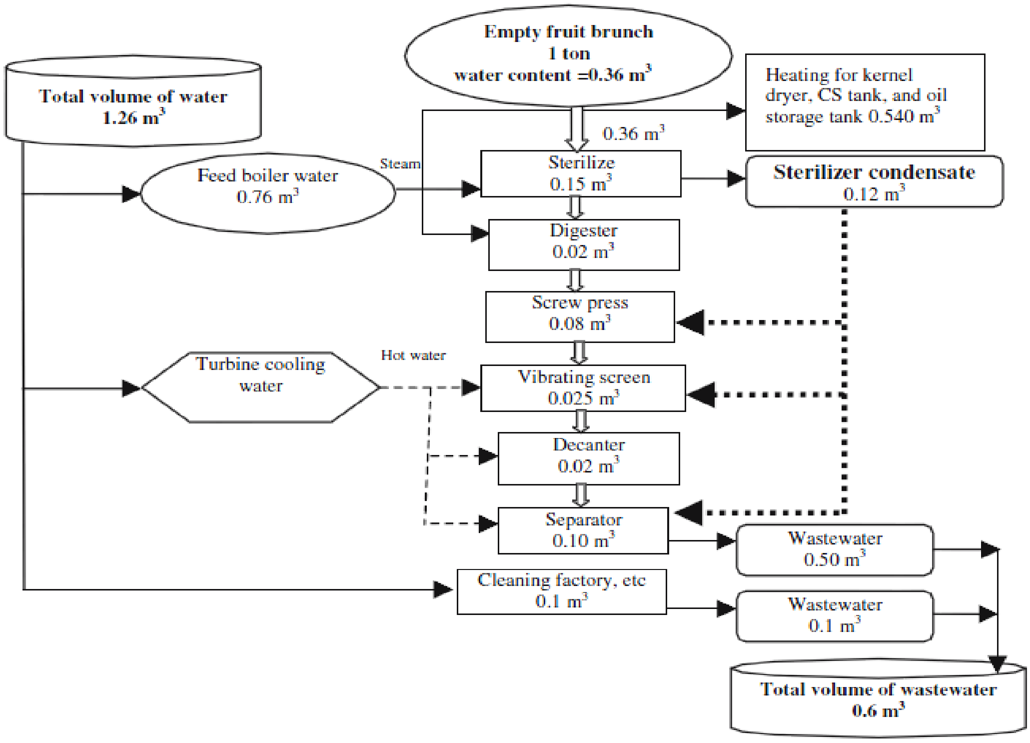


Figure 2.6 Flow diagram of production process and water treatment in the production of palm oil

Figure 2.7 shows the impact/emission (liquid, soil and air) emerges due to palm oil plantation.Jatropha can be cultivated in marginal land or former mined land with low soil fertility of physical, chemical and biological. Existing soil properties depends on the age after mining and the type of mining process. With poor nutrient content in mined land, the growth of the plants is not optimal. Planting jathropa curcas will be an alternative effort to utilize the land with such condition. The following figures (Figure 2.8) are some efforts conducted by SBRC-LPPM IPB in order to utilize the land by planting jathropa curcas in dry land, other marginal lands, former lime stone mined land in Citeureup Bogor, coal in Berau, and tin in Bangka Belitung.

The benefits of large-scale jatropha plantations in the desert areas are as CO_2 neutral fuels stock in remote areas, such as rural areas; stock for high-quality protein concentrate; as land reclamation; reduce air pollution; absorb tradable carbon emissions; and develop socio-economic development activities.

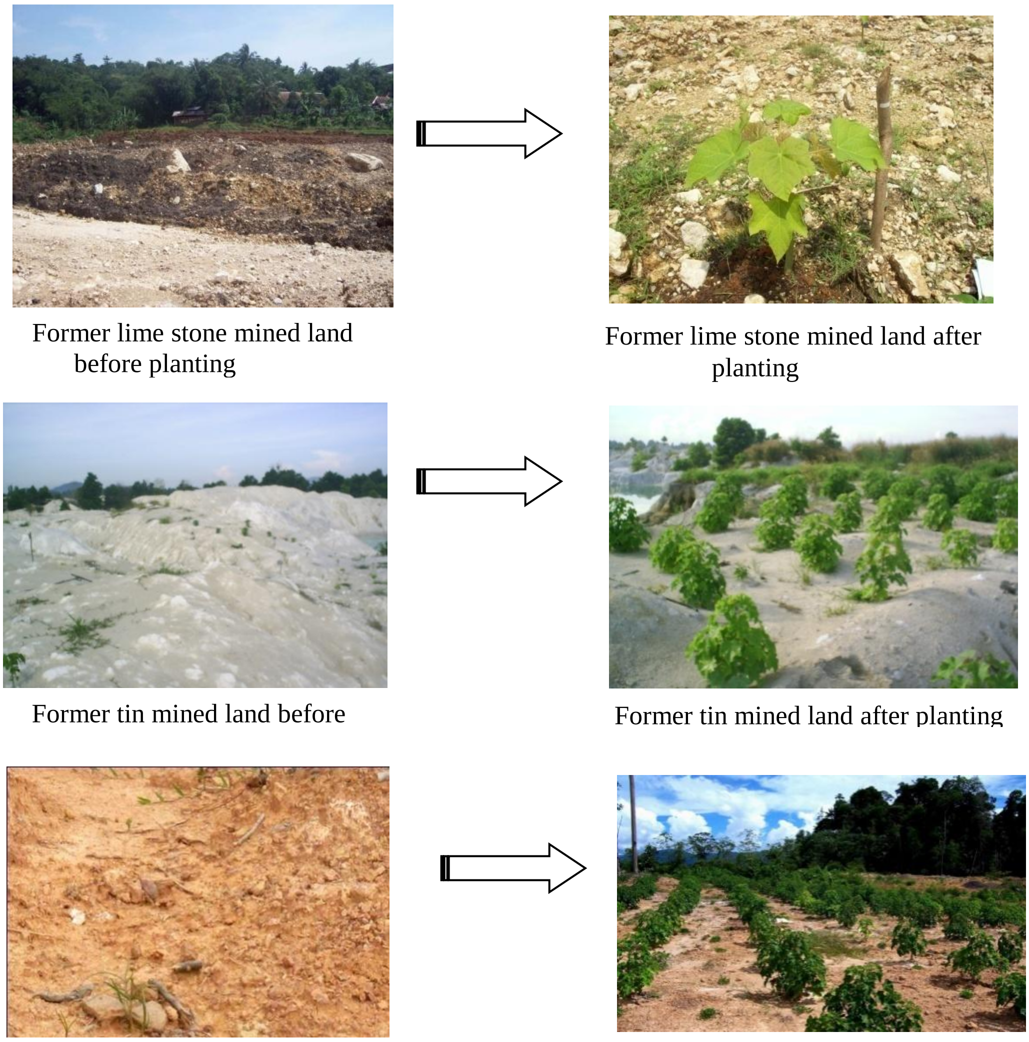
Exhaust emissions from the test results conducted by Biodiesel Team of ITB mentioned that the use of jatropha oil increased HC emissions. Increased HC

Flooded field will cause N_2O and CH_4 emission

Low production and high CO_2 emission due to delayed water retention in peat dome area

Figure 2.7 Field condition of palm oil plantation

is due to the high viscosity of the oil, so that the poor fuel atomization and combustion become imperfect. Based on JO10 and DJO10, HC increases by 29.31% and 28.42%, respectively and HC from JO100 and DJO100 increases by 66.94% and 63.97%, respectively. CO also presents similar condition with HC, CO emission increases due to high viscosity fuels that cause imperfect combustion. Based on the data, CO from JO10 and DJO10 increases by 15.49% and 14.47%, respectively. CO from JO100 and DJO100 increases by 65.78% and 63.42%, respectively compared to petro diesel. Lower combustion temperature and pressure in DJO100 and JO100 decreases NO_x emission. DJO100 and JO100 experiences significant decrease on NO_x emission compared to petro diesel. Under these conditions, $NO_x$from JO10 and DJO10 increases by 9.38% and 0.44%, respectively, while $NO_x$from JO100 and DJO100 decreases by 59.4% and 53.9%, respectively.



Former lime stone mined land before planting

Former lime stone mined land after planting

Former tin mined land before

Former tin mined land after planting

Former coal mined land before

Former coal mined land after planting

Figure 2.8 Marginal land condition before and after *Jathropa curcas* planting

The general conclusion that can be obtained from this study is that the direct use of crude jatropha oil which has low cetane number causes slow ignition process. The high viscosity of crude jatropha oil will increase HC and CO exhaust emission. While decreases NO_x emission is due to imperfect combustion process in cylinder which consequently causes low combustion temperature. NO_x exhaust emission occurs at high combustion temperature.

Utilization of Crude *Jatropha curcas* Oil for Power Generation: direct use of *Jatropha curcas* oil as fuel for power plant generation produces low quality of exhaust emission in the diesel engine. Unsatisfied physical and chemical properties cause slow ignition process due to low cetane number. High oil viscosity increases HC and CO exhaust emission. While decreases NO_x emission is due to imperfect combustion process in cylinder and causes low combustion temperature. NO_x exhaust emission occurs at high combustion temperature. In other cases, the fuel consumption of crude jatropha oil for power plant also give adverse effect on its diesel engine components such as the occurrence of ring sticking, piston erosion, liner erosion and excessive deposit formation in spray nozzles, valves, valve seat and the glow plug. If it occurs continuously for a long time, it can damage the diesel engine.

Conclusion

The conclusions that can be drawn from this chapter are as follows:

1. LCA has been used by European and American countries as the guideline to assess the environmental impact of biodiesel production.
2. In Asia, Japan is the leading country in the development of LCA, followed by Thailand and Malaysia.
3. Indonesia as the world's largest palm oil producer should have developed studies on LCA of biodiesel from palm oil. Present situation shows that Indonesia still haslimited international publications. Thus, it is very difficult to answer the issues released by US EPA-NODA and EU-RED which stated that Indonesia could only reduce global warming by 17% and 19%, respectively.
4. Summary of the literature mentions that the sustainability of biodiesel from palm oil is better than *Jatropha curcas*, even when compared to other sources of raw materials, such as rapeseed.
5. Summary of the literature mentions that the value of carbon that can be absorbed by primary forest is higher than secondary forest and palm oil plantation. This is the reason why world claims Indonesia on global warming issues although research is still needed based on the latest data.

CHAPTER 3
DATA INVENTORY

Introduction

Life cycle inventory (LCI) involves collecting all necessary environmental burden data to meet the objectives of the research. Environmental burden consists of material and energy used in the system, air emission, liquid waste and solid waste that are released into the environment. This stage comprises of several steps as follows: creating flow diagram process, determining unit process, collecting data, calculating energy requirement, and data validation. Data in this study associates with all process units being studied. Determination of all input and output flow often emerges as a very complicated task, so simplification and assumption are often made to facilitate the LCA. The challenge is to ensure that the assumptions and simplifications (a simplified model of the process) maintains the main characteristics of the actual system or process being analyzed.

Data collection process is the main focus in the inventory analysis. At this stage, the input and output of material and energy which associates in the CPO and CJCO production system under catalytic process are identified and measured in units of functionality. Inventory analysis is regarded as a stage where the product system is defined. This stageconsists of: defining system boundaries, defining the flow diagram, determining the format and categories of data, data collection, data validation, elimination and estimation data, and calculation.

In LCA, all economic inputs and outputs in all flow is translated into environmental intervention. Environmental intervention relates to the flow which enters the product system without transformation of human beings. It can also be explained as material flow leaving product system and discharged into the environment. The boundary of economic and environmental must be defined explicitly in order to make clear boundaries of the product system, the environment, the main flow, and other flow. The activity on defining the flow diagram describes the outline of all main process units being modeled including its relationship. This is very helpful in understanding and completing a system to describe the system using a flow diagram. To translate these comparisons consistently, a standard data format must be developed. Collecting data in accordance with the prescribed format can be done to quantify all those flows which associate with the process. This process is followed by checking the validity of the data that has been collected. Various tools such as mass balance, energy balance and comparison of data from other sources can be used.

Principally, LCA must explore all related processes in the life cycle of a given product system, from cradle to grave. But in practice, this seems impossible; however, some flow is usually eliminated and ignored because of lack of accessible available data. In general, industrial processes are multifunctional, where the output generally consists of more than one product, and there is a possibility that one of the input of raw materials consists of discharged products. Therefore it takes a decision to determine the flow of economic and environmental intervention which will be connected to the product system. At the last stage, calculation process is carried out to quantitatively linking the process with each other.

The objective of this chapter is to collect primary and secondary data from palm oil and *Jatropha curcas* plantation until biodiesel production. These data are used in the assessment of impact that might be happened.

Literature Review

Data which associates with life cycle is collected and measured in units of functionality, including: input material and energy product, waste, and emission of air, water, and soil (Cowell, 1999). Inventory analysis process follows the fundamental of science and engineering that focuses on energy and material balance of each element in the system (Curran, 1996 in Searcy, 2000). Data collection process is the main focus in the inventory analysis and is the most time consuming steps in the overall LCA (Jensen et al., 1998 in Searcy, 2000).

Hofstette (1998) in Tambunan et al. (2010) mentions three categories of multidisciplinary character of the LCA study, i.e.:

1. Techno sphere: Dealing with the technical systems, such as production processes, transportation processes, and others. Uncertainty is not greater than two-fold, while almost all measurements areverifiable and repeatable.
2. Eco-sphere: Dealing with the environmental mechanisms. Uncertainty is usually one to three times, and is often difficult or impossible to verify.
3. Value-sphere: Dealing with the subjective choices, including the weight of the impact categories. Value sphere is usually in the field of social sciences. This sphere does not really talk about uncertainty as single truth is never exist.

LCI is a manufacturing process of flow diagrams, unit process description, data collection, energy requirement calculation, and data validation. All data associate with unit being studied. In the life cycle inventory, number of input and output of process unit is described in a single figure. Quantitative description of the process units include the uncertainty due to the average value is uncertain. In fact, there may be differencebetween the values that have been investigated (or measured and reported) and the real value. Various types of uncertainty that present in LCI process are as follows:

- Variability and stochastic errors that describe the input and output due to uncertainties measurement, variations in certain processes, etc.
- Appropriateness of the input or output flow. Sometimes input or output is imperfect according to the actual input or output being observed.
- The uncertainty of the model: the model that is used to describe a process unit may not be appropriate.

Environmental burdenreferred in LCI is material and energy used in the system, emissions in the air, and emission released by liquid and solid waste into the environment. In here, system is defined as a series of operations or sub-processes that the matter and energy are connected and have a clear function. More detailed characterization of the system is done by dividing the system into connected subsystems. This is very important in the quantification process of data variable (Azapagic, 2006).

In general, the quantification of environmental burdenis conducted by calculating the total value of the load variables which are obtained ateach sub-system. This is stated in Equation 3.1.

$$B_j = \sum_{i=i}^{1} b_{j,i}\, x_i \qquad 3.1$$

B_j is the value of the total system load, $b_{j,i}$ is the value of variable load j of sub-system i, and x_i is the mass or energy flow associated with the sub-system i.

If the system produces more than one functional output, the environmental burden of the system should be allocated to the output. For example, CH_4 emission turns out to have impact on several things such as human health, global warming, and water pollution. Many of CH_4 that cause each of these impacts should be quantified into each impact category based on the equivalent value. For example, 1 kg of CH_4 is equivalent to 25 kg of CO_2 emissions in relation to global warming.

Allocation will affect the outcome of the LCA so that the determination of allocation method is crucial (Azapagic, 2006). Sensitivity analysis should also be taken placewhen some allocation methodsare used to determine the effect of allocation method on the result. ISO 14041 recommends three things related to the allocation, i.e.:

- If possible, allocation is avoided by dividing the system into sub-systems or expanding the system.
- If allocation cannot be avoided, the allocation problem should be resolved using a modeling system which based on the physical relationship between each functional unit.
- If the physical relationship cannot be determined, other relations including economic value can be used.

The characteristics of *Jatropha curcas* L. is as follows (Sotolongo et al., 2009):

1. Fruit: diameter of 2 cm, 2-3 seeds, 3500 kg fruits/ha, 400 trees/ha and fruit weight is 3.3 grams.
2. Shell: is used as an organic fertilizer, 30 wt% of the fruit, produced 1000 kg shells/ha, can also be used as fuel, the calor value is 11.1 MJ/kg (15% moisture), shell is also used as a bio-digester to produce biogas
3. Seed: the seed is 70 wt% of the fruit, produces 2500 kg seeds/ha, seed size (length 17.5 mm x wide 11.5 mm, in 1000 seed = 840 gr or 1190 seeds/kg, the composition of the seed: 6.6 wt% water, 18.2 wt% protein, 38 wt% oil, 33.5 wt% carbohydrate, 15.5 wt% (fiber), and 4.5% ash
4. Oil seed contains 38 wt% oil, the extraction mechanism using a screw press gains 27-32% oil, the oil can also be produced for soaps and insecticides, and for pure fuel (B100) and blend (B2, B5, B10, B20, the extraction amount is 29% using sundhara oil expeller containing 3.3 kg of seeds for the production of 1 kg oil (1.086 liters of oil).
5. The cake: the cake contains carbohydrate, fiber and oil. The oil can be used as an organic fertilizer as it contains fairly high nitrogen. The cake can also be used as biogas and animal feed because it contains high protein (> 50%). The cake can also be used as fuel with calorvalue is 11.1 MJ/kg (3% moisture)
6. The fuel wood: produces 20,000 kg of biomass/ha, *Jatropha curcas* (about 20 kg/tree), the wood is produced along cultivation,calorvalue is 15.5 MJ/kg (15% moisture), wood can be used as a living fence, because it is not eaten by animals, can be used to produce charcoal. Each tree produces 6 kg CO_2 and 9

kg O_2 to the environment, *Jatropha curcas* also performs reforestation of marginal soil and preventing erosion of soil, net production from biomass (leaves, wood, fruits, etc.) amounted to 1.2 tons/ha/year on rainfall 200 mm/year. On land with 1500 mm rainfall/year, can produce 11.8 tons/ha/year.
7. Glycerol: 79 ml glycerol is produced under transesterification process along biodiesel production of 1 liter oil, produces 64.5 liters of glycerol per 1 ha of *Jatropha curcas*. Transesterification process produces mix of glycerol, soap, alcohol and unreacted catalyst (potassium or sodium hydroxide). The mixture can be distilled again in order to obtain pure glycerol as feedstock or fuel of biogas production. Thermal conversion of glycerol into energy is an alternative development in the future, the calorvalue of glycerol is 17.28 MJ/kg.

Method

Time and Place

This research was conducted at the Laboratory of Heat and Mass Transfer, Department of Mechanical Engineering and Biosystems, Faculty of Agricultural Engineering and Technology, IPB Bogor started fromJanuary 2011 until September 2012.

Data Sources

Data used in this study consists of primary data and secondary data, i.e.:
Primary data was obtained from:
- Oil palm plantation in PTPN VIII Banten and Palm Oil Mill (PKS) *Unit Kebun Kertajaya* (capacity 30 tons FFB per hour)
- *Jatropha curcas* Estate Center (Balitri), Pakuwon, Sukabumi, West Java for the cultivation, harvesting, extraction of crude oil
- Biodiesel production is processed using BRDST BPPT Puspitek Serpong machine (capacity of 1 ton per day) under catalytic process using CPO / CJCO

Secondary data was obtained from:
- National and international scientific journal
- Research reports from research institution and university, such as Bogor Agricultural University (IPB), *Institut Teknologi Bandung* (ITB), the Agency for Assessment and Application of Technology (BPPT), the Center of Indonesian Palm Oil Plantations, Estate Institution, Department of Agriculture, and others.
- Data from private company engaged in oil palm and *Jatropha curcas*, as well as in CPO / CJCO and biodiesel processing

Research Boundaries and Assumptions

Boundary in this research is cradle to gate (Figure 3.1) which consists of eight sub-process stages. Functional unit of this study is 1 ton of bio-diesel fuel (BDF) for oil palm and *Jatropha curcas*. At this stage, the flow and system boundaries are determined based on the objectives of the study, as well as the identification of the inputs, processes, and outputs associated with Life Cycle Assessment (LCA) in the production of biodiesel from CPO and CJCO under catalytic process. Activities of this inventory data are to identify all systems and sub-systems, sub-sub-system at each station on biodiesel processing. This consists of eight stages of main sub-processes as shown in Figure 3.1 which can be described as follows:

1. The boundary of this study is from cradle to gate, which consists of eight main sub processes i.e. land preparation, seedling, planting, fertilization, protection, harvesting, palm oil mills/extraction of crude oil, and biodiesel production using CPO and CJCO.
2. The study focuses on mass balance (input material and the results of the product (output), the value of energy input and the value of energy output (energy ratio)).
3. The amount of waste and emission produced at each sub-process is analyzed.
4. It is assumed that methane capture has been taken place in palm oil mill and there are no CH_4 or CO_2 which released into the air.

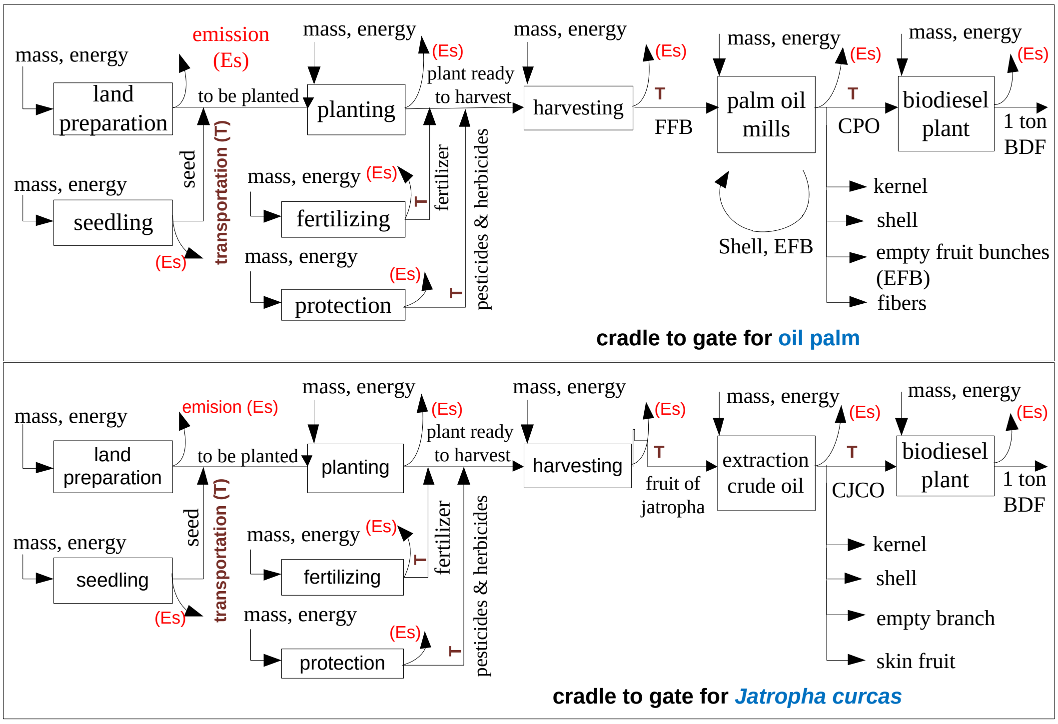


Figure3.1 Boundary used forbiodiesel production from CPO and CJCO under catalytic process

Implementation Stages of LCI

The research is accomplished using the stages shown in Figure 3.2. Each stage is also described.

Objective and scope definition (ISO 14041)

There are three aspects that become the objective of this study, i.e.:

1. The objective of LCA applications is to assess the life cycle from cradle to gate of biodiesel production using CPO and CJCO under catalytic process. Overall, this research is expected to result: global warming potential, acidification, eutrophication, waste landfill volume, energy consumption, and energy ratio, the amount of emissions to air, water and soil.
2. The background of this research is disagreement from researcher about the claim against Indonesian biodiesel development. It is very important to answer

the claim of European and American countries that state Indonesian biodiesel production from CPO cause environmental damage and not comply with the standard. Scientific approach using LCA is applied to assess the life cycle of CPO and CJCO based biodiesel under catalytic process.

3. The results are intended for government (decision maker), entrepreneurs, scientists and academics, as well as national and international organizations especially those related to the environment and global warming.

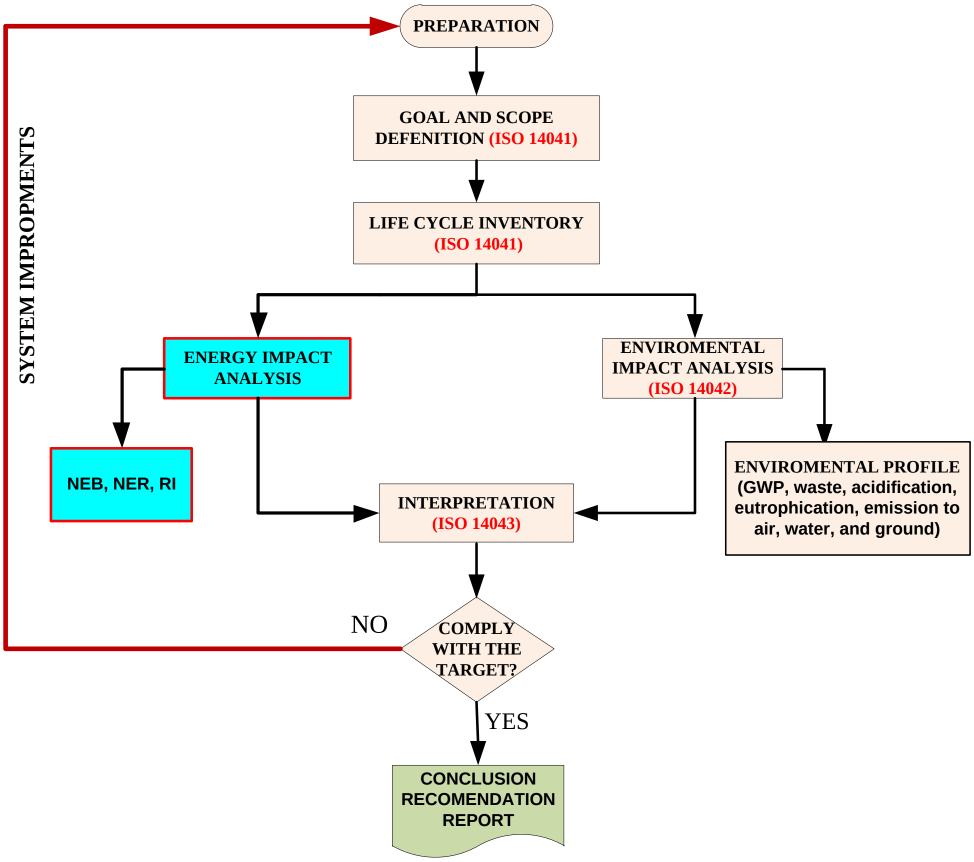


Figure 3.2 Life cycle assessment procedures used in this study

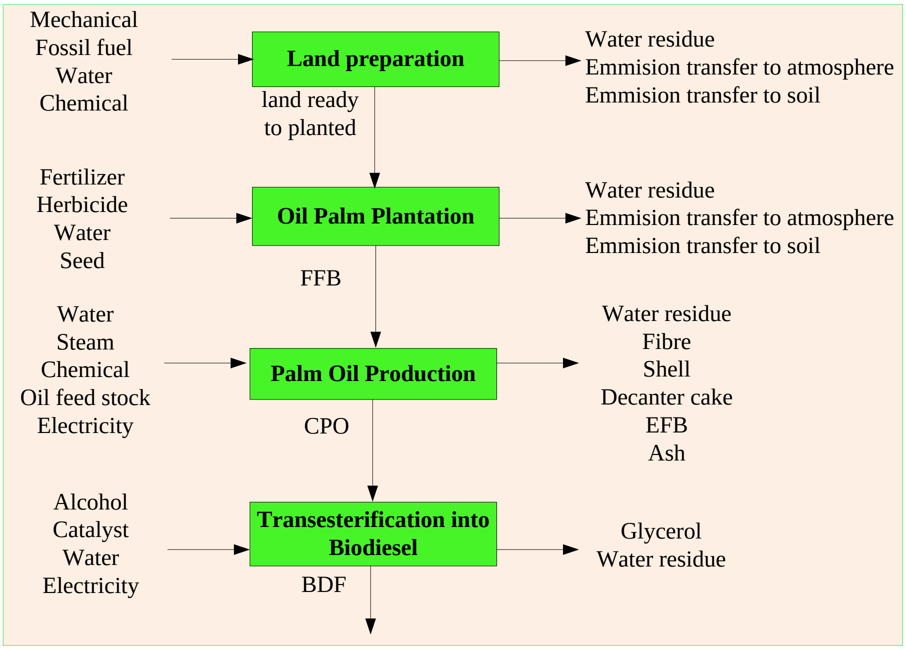


Figure 3.3 Material and energy balance scheme (input and output) of oil palm processing starts from cultivation up to biodiesel production

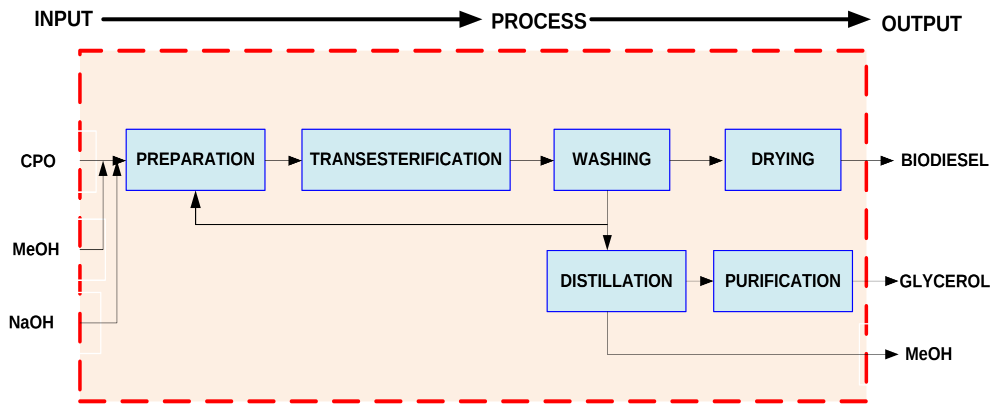


Figure 3.4 Sub-process of biodiesel production using CPO under catalytic process

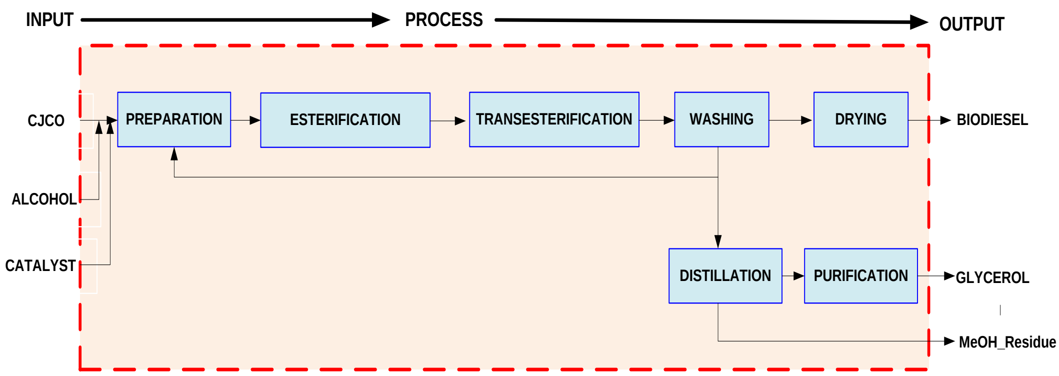


Figure 3.5 Sub-process of biodiesel production using CJCO under catalytic process

Figure 3.3 shows flow chart analysis of biodiesel processing from palm oil cultivation to biodiesel as final product. Figure 3.4 shows sub process of biodiesel production from CPO under catalytic process in order to describe the cradle to gate system boundary. Figure 3.5 shows sub-processes of crude *Jatropha curcas* oil (CJCO) for biodiesel production under catalytic process through esterification and transesterification reactions.

Data Collection

All unit functions are converted into unit of energy and mass. Flow diagram of energy balance, mass balance, and analysis of emissions / waste of biodiesel processing from CPO and CJCO is shown in Figures 3.6 and 3.7.

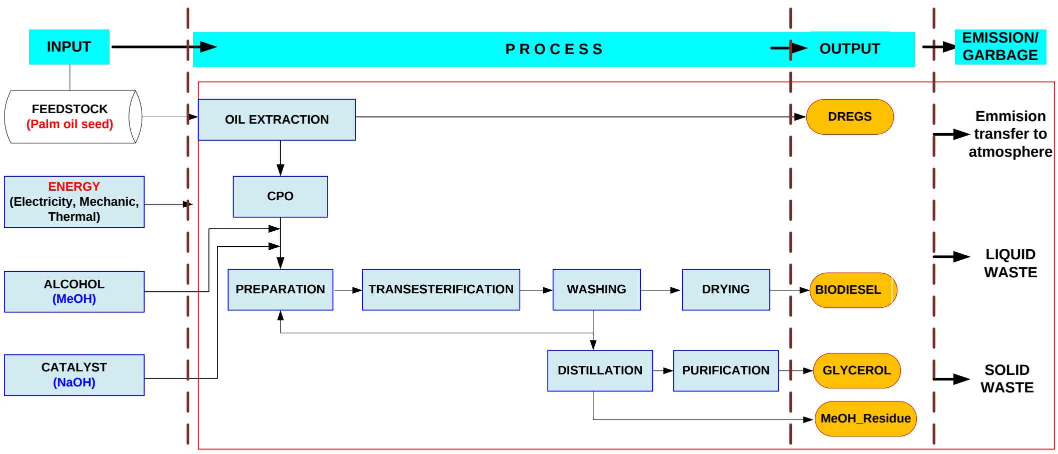


Figure 3.6 Flow diagram of energy, raw material, and emission/waste during biodiesel processing from CPO

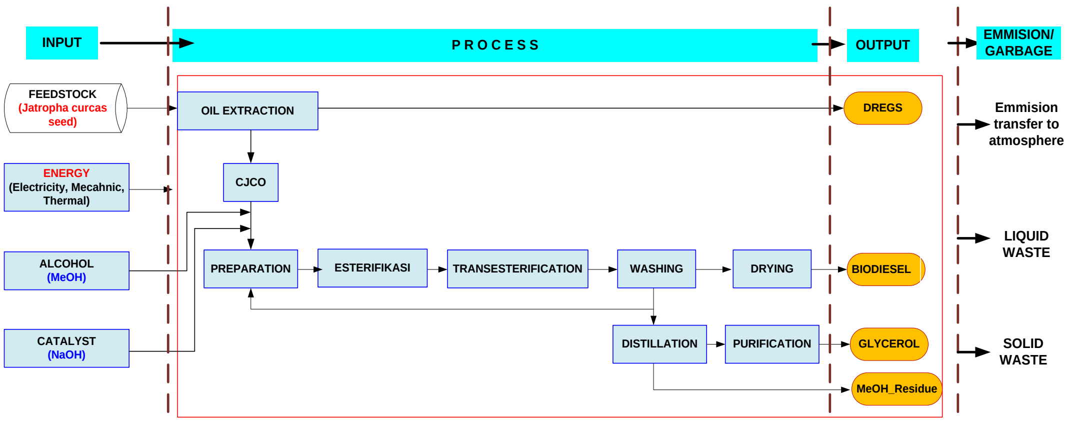


Figure 3.7 Flow diagram of energy, raw material, and emission/waste during biodiesel processing from CJCO

Data used for analysis of energy measurement and utilization of biodiesel production from CPO and CJCO under catalytic process is collected in four methods, i.e. :

1. Survey to obtain related data of the object being studied, relevant sources, used parameter and others associated in the research.

2. Literature study.
3. Consultation and interview from related authorized person including government agencies, private sector and academician.
4. Direct measurement carried out in the laboratory and in the field.

Those four methods are expected to generate valid and accurate data that can be trusted and can be verified through cross-checking among data sources.

Several data are required in this research:

- The composition of CPO and CJCO, methanol and additional material: type, quantity/weight, calor value, consumption, storage time, and others which associates with system being studied. This analysis refers to energy and mass balance.
- Diesel fuel and transport: type, number, and capacity, and others related to the research.
- Production process: processing order, processing time, temperature input and output of each process, the type and amount of fuel, and the number of tools required.
- Waste: types of waste produced per each stage and utilization alternatives, quantity / weight, management, and disposal.

All data is collected from the sources mentioned before and then selected based on the reliability and suitability to the topic and analysis purposes. Similar variable data with different value (from different source) is compared and selected based on certain consideration.

Data Collection and Calculation Procedure

Some of data are converted into energy unit (kJ) and mass (kg) that can be understood by everyone. The database generated from system identification is systematically arranged, edited and updated to obtain perfect results. As the following step, those data is then calculated using MiLCA-JEMAI software from Japan. The software is used due to the similarity between Indonesia and Japan as Asian country.

Life cycle inventory analysis is performed on the input materials and energy, emissions to water, emissions to air, and solid waste that are involved in the production of biodiesel. Stages of analysis and calculation are conducted before stable production until reach stable production.

Results and Discussion

Indonesia consists of many islands, such as Sumatra, Java, Kalimantan, Sulawesi, and Papua which have different characteristics on the soil, climate, and other factors that need different treatment. The data obtained in this study, especially represents the condition of Java and Sumatra. LCI is directly performed based on data collected from palm oil plantation in *PTPN VIII Unit Kebun Kertajaya Lebak Banten* and PT.Adaro Central Kalimantan. Data for cultivation, harvesting, extraction of jatropha oil is collected from *Jatropha curcas* Estate Center (Balitri) Pakuwon Sukabumi West Java and PT.Adaro Central Kalimantan, which serves as primary data. Field survey documentations are shown in Appendix 2. The main key in the inventory phase is data collection. It usually relates the number of secondary data which obtained from national and international journal, student field practice report on palm oil, *Jatropha curcas* and its processing, undergraduate thesis, graduate thesis, relevant research report, and also publication released from national private plantation companies.

Janaun et al. (2010) mentioned that biodiesel has marked an increased acceptance in the global market as an environmentally friendly diesel fuel. However, to develop and continue the penetration of biodiesel in the global market, various aspects must be examined and analyzed. Some of the key issues such as improving efficiency of the production process, using feedstock, technology process, and managing agricultural land, have been reviewed.

LCI was conducted based on input-output analysis of mass and energy at each production line, as shown in Figure 3.1. Detail description of eight sub-processes involved in LCI for palm oil versus *Jatropha curcas* is shown in Table 3.1. Comparison of material and energy used for 1 ton BDF production of oil palm and *Jatropha curcas* based biodiesel with data from PTPN VIII and *Jatropha curcas* Estate Center (Balitri) is shown in Table 3.2**.** Stable productivity of oil palm at PTPN VIII is approximately 21.5 tons per ha per year, while *Jatropha curcas* has stable productivity about 8 tons per ha for IP3-P (Pranowo, 2009; Ferry, 2009).

Overall averaged data (primary and secondary data) is shown in Table 3.3 (Alamsyah, 2006; Pranowo, 2009; Ferry,2009; Wirawan, 2006; Wirawan, 2009; Nasir,2010; Pahan, 2011; Lubiset al., 2011; Wicke, 2011; Pramudita, 2011; Pardamean, 2011; Siregaret al., 2012). Data inventory shows that production of small holder's palm oil plantation is around 12 tons FFB per ha per year. While private estate with better seedling, maintenance and fertilization produces approximately 32.67 tons FFB per ha per year, with average yield about 22.34 tons FFB per ha per year using varieties Lame, Langambi, Simalungun, Dura, Tenera, Pisifera (Pahan, 2011; Lubis, 2011). *Jatropha curcas* produced by farmer is about 2 tons per hectare per year, while using IP3-P is about 8 tons per hectare per year, or the average value is about 5 tons per hectare per year (Pranowo, 2009). The first production of oil palm occurs at 30 months old while *Jatropha curcas* occurs at 4 months old. Inventory of primary and secondary data also obtaines that the oil palm and *Jatropha curcas* will have stable production at the 6th year, it means that the production still increases during the first up to fifth year. The final section of this chapter shows detail result of LCI at each eight stage involved in oil palm and *Jatropha curcas*.

Production amount of biodiesel from oil palm and *Jatropha curcas* oil during its life cycle (25 years) is shown in Figure 3.8. From this figure it can be seen that stable productivity of each crops will be obtained at the 5th years. During stable production, palm oil can produce biodiesel up to 4.16 tons per ha per year while *Jatropha curcas* oil is 1.89 tons per ha per year. Pleanjai et al. (2007) said that 6-7 tons FFB (yield 15.38%) or 1.14 tons of CPO (yield 87.7%) is needed in order to produce 1 ton of biodiesel. Weeds population in oil palm is higher than in *Jatropha curcas* plantation, which needs more effort to control. This fact is the reason for higher herbicide requirement for oil palm plantation than *Jatropha curcas*, as shown in Table 3.2 and Table 3.3. The height of seeds which lives surrounding palm seedlings is approximately 1.5 m while *Jatropha curcas* tree is approx. 0.5 m. Oil palm also consumes higher diesel fuel than *Jatropha curcas* due to the requirement of mechanical tillage. On the other hand, *Jatropha curcas* plantation requires less tillage as the plant is more resistant to critical environmental conditions. At nursery stage, oil palm plantation uses higher amount of pesticides and fertilizer due to longer seedling process (12 months) compared to *Jatropha curcas* plantation (3 months). Oil palm seedling consists of growth stage of seedlings and seedling nursery which need intensive amount of fertilizers and pesticides. However, *Jatropha curcas* needs more application of fertilizer during planting stage, since the number of trees per hectare of *Jatropha curcas* plantation is larger (2500 trees) than oil palm (136 trees) (Ferry 2009; Tjahjana et al. 2010; Lubis at al., 2011).

Table 3.1 The detail description comparison of life cycle on biodiesel production from oil palm and *Jatropha curcas* with boundary cradle to gate

Input activities	Component	Oil palm	*Jatropha curcas*
(1) Land preparation	Early land uses	Primer & skunder forest	Coarse grass forest
	Soil fertility	Fertile	Less fertile
	Tree, diameter > 60 cm	26-100 trees/ha	No trees
	Tree, diameter > 30 cm	Approx. 2500 trees/ha	Approx. 500 trees/ha
	Coarse grass	10-30 groups/m^2	10-30 groups/m^2
	Soil tillage	Effective soil depth 50-150 cm	Effective soil depth 20-30 cm
	Plant above the soil surface	Nuts	No plants, usually
(2) Seedling	Seedling time	12 months	3 months
	Seedling source	Seed	Seed, steck
(3) Planting	Plants width space	9 x 9 x 9 m	2 x 2 x 2 m
	Number of plants	136/ha	2500/ha
	Number of hole	50 x 40 x 40 cm	40 x 40 x 40 cm
(4) Fertilizing	Fertilizer compound	N,P,K,Mg,B, organic fertilizer	N,P,K, organic fertilizer
	Intensity	Very intensive	Scarcely conducted
(5) Protection	Plant pest	Many kinds of pest presents	Almost not present
(6) Harvesting	Start to produce	30 months	4 months
	Production on stable productivity	8 tons seed/ha	21.5 tons FFB/ha
	Edible/non-edible	Edible	Non-edible
(7) Palm oil mills or Extraction oil	Production of crude oil	By milling	By extraction
	Value of FFA	<2	>2
	Ratio of FFB to crude oil	21%	26%
	Produced biomass	Empty bunch, fruit fiber, shell, palm kernel	Kernel pulp, shell, jathropa oil cake
(8) Biodiesel production	Reaction of biodiesel production	Transesterification	Esterification and transesterification
	Ratio of crude oil to BDF	92%	91%
	Biodiesel source	Pulp, kernel	Kernel
	Catalyst	Alkali	Acid and alkali

The table also shows that during the first five years growth, oil palm plantation needs more fertilizer, as well as other agro-chemicals for protection, than the *Jatropha curcas* plantation. Oil palm is more susceptible to plant pests than *Jatropha curcas*. Doses application will change continuously based on the plant’s requirement, which is analyzed and determined by soil and leaves nutrient needs. This analysis will give appropriate amount of fertilizer and agro-chemicals. It can be also seen in Table 3.2 and Table 3.3 that the *Jatropha curcas* uses more organic fertilizer and phosphate fertilizer than oil palm during its growth period. The use of fertilizer in oil palm is higher than *Jatropha curcas*, especially in the use of urea, rock phosphate, muriate of potash, and ammonia. This occurs due to fundamental nature of oil palm which needs high fertilizers, especially fertilizer N, P, and K. Omotto et al. (2009) mentioned that the use of intensive fertilizers would affect the environment. The acidification impact is mostly due to the NO_x emitted by combustion of ethanol as sulfuric acid which is used in industrial process and because of NO_x is emitted by burning during harvesting.

Jatropha curcas grown in Indonesia is known as poisonous plant so it has hight resistance to pest and disease attack. It is probably caused by the planting system that is generally mixed with other plants such as *gamal* (*glyrecidiamaculata*) and *waru*. If planting is conducted in monoculture system with wide space to others plants it might result the occurrence of pests and diseases.

During harvesting sub-process, oil palm consumes higher transportation energy than *Jatropha curcas*. This condition occurs due to the yield of oil palm is higher than *Jatropha curcas*. In order to produce crude oil, *Jatropha curcas* only needs electricity and diesel fuel for its process. On the other hand, palm oil mill process needs more materials and energy. At the stage of biodesel production sub-process, *Jatropha curcas* needs esterification stage before transesterification due to high average value of free fatty acids (FFA). Consequently, *Jatropha curcas* oil needs more materials and energy. Silitonga et al. (2011) also said that the main problem of *Jatropha curcas* oil as a biodiesel is the high content of FFA. Moreover, it still needs filtration and transesterification process to up grade the oil characteristic. Silip et al. (2010) had conducted various methods in order to produce low FFA value such as the methods of seedling, cultivation and harvesting.

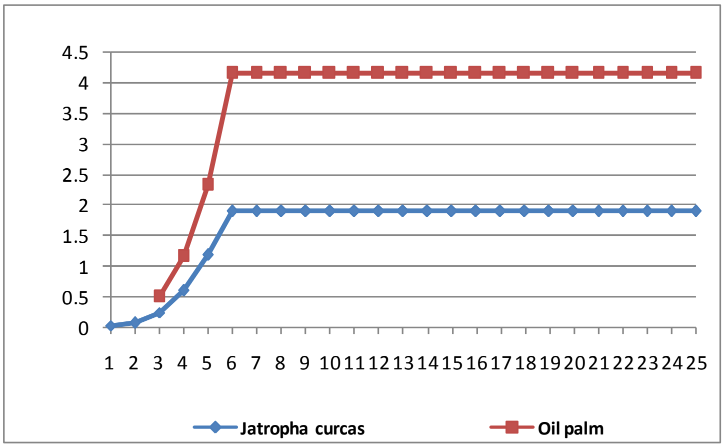


Figure 3.8 Biodiesel production of CPO and CJCO per day during its life cycle

Table 3.2 Mass and energy used for 1 ton BDF from oil palm in *PTPN (Persero) VIII Unit Kebun Kertajaya* and *Jatropha curcas* in PIJP Balitri (primary data)

Process	Mass and Energy	Unit	Oil palm	*Jatropha curcas*
(1) Land preparation	Herbicide	kg	0.861	0.624
	Diesel fuel for toppling & clearing	L	0.703	1.208
(2) Seedling	Fungicides	kg	-	0.852
	Insecticides	kg	0.00018	0.0057
	Fertilizer Meister	kg		-
	Chemical fertilizer Urea 0.2 %	kg	0.00492	-
	Organic fertilizer	kg	8.367	9.377
	Kieserite ($MgSO_4$)	kg	2.008	-
	Urea	kg	0.00007	-
	Herbicide	kg	0.974	-
	Dolomite	kg	2.949	-
	Compound fertilizer	kg	4.686	-
	Electricity for Pump Water	kWh	0.436	-
	Pesticides	kg	0.004	-
Transportation	Diesel fuel for truck 5 tons	L	1.004	1.189
(3) Planting	TSP/SP36	kg	13.387	79.562
	Organic fertilizer	kg	-	994.524
	Rock Phosphate	kg	22.887	-
	KCl		-	15.912
(4) Fertilizing for five years	Compound fertilizer	kg	9.844	-
	Rock Phosphate	kg	252.492	-
	ZA/Urea	kg	279.464	87.518
	HGF Borate	kg	3.347	-
	TSP/SP36	kg	117.140	278.467
	MOP (K)/KCl	kg	245.995	95.474
	Kieserit	kg	184.078	-
	HGF Borate	kg	3.347	-
	Organic fertilizer	kg	-	994.524
(5) Protection for five years	Herbicide	kg	56.317	-
	Insecticides (liquid & powder)	kg	1.323	-
	Pesticides	kg	0.801	2.955
	Diesel for power sprayer & fogging	L	0.554	-
(6) Harvesting	Diesel fuel for truck 10 ton	L	5.027	2.468
(7) Palm oil mills vs Oil extraction	Electricity from grid	kWh	34.392	14.833
	Steam consumption	kg	1325.39	-
	Water consumption	m^3	3.968	-
	PAC	kg	0.125	-
	Flokulon	kg	0.00053	-
	NaOH	kg	0.107	-
	H_2SO_4/HCl	kg	0.109	-
	Tanin Consentrate	kg	0.045	-
	Poly Perse BWT 302	kg	0.045	-
	Alkaly BWT 402	kg	0.043	-
	Shell consumption	kg	133.862	-
Transportation	Diesel fuel for truck 10 tons	L	2.540	1.890
(8) Biodiesel production Esterification	Methanol	ton	-	0.449
	H_2SO_4	ton	-	0.027
	Electricity from grid	kWh	-	1.285
Trans-esterification	Methanol	ton	0.269	-
	Electricity from grid	kWh	15.645	15.645
	NaOH	ton	0.080	0.080
	Water consumption	L	1700.68	1719.180
	Diesel fuel for Boiler	L	14.00	16.00

Table 3.3 Mass and energy for 1 ton BDF from oil palm and *Jatropha curcas* during the first –fifth year (average value of secondary and primary data)

Process	Mass and Energy	Unit	Oil palm	*Jatropha curcas*
(1) Land clearing	Herbicide	Kg	1.216	0.919
	Diesel for toppling & clearing	L	0.675	0.011
(2)Seedling	Fungicide	Kg	0.774	1.277
	Insekticide	Kg	0.053	0.057
	Meister of Fertilizer	Kg	0.081	-
	Chemicalfertilizer/Urea 0.2 %	L	1.123	-
	Organic fertilizer	Kg	3.400	12.503
	TSP/SP36	Kg	0.107	-
	Muriate of Photash (K)	Kg	0.001	-
	Dolomite	Kg	0.002	-
	N-P-K-Mg (mixing)	Kg	0.618	-
	Electricity for water pump	kWh	26.70	-
	Pesticide	Kg	0.183	-
Transportation	Diesel fuel for truck 5 tons	L	4.896	1.560
(3) Planting	TSP/SP36	Kg	9.640	79.562
	Organic fertilizer	Kg	0.162	1591.238
	Rock Phosphate (RP)	Kg	1.217	-
	KCl		-	15.912
(4) Fertilization For five years	Urea	Kg	184.694	140.029
	TSP/SP36	Kg	74.645	445.547
	Rock Phosphate (RP)	Kg	153.685	-
	SulphateAmonia (ZA)	Kg	45.633	-
	Muriate of Potash (K)	Kg	202.001	152.759
	Kieserite ($MgSO_4$)	Kg	119.020	-
	HGF-B (HGF-Borate)	Kg	7.676	-
	$CuSO_4$	Kg	3.651	-
	$ZnSO_4$	Kg	1.582	-
	LSD	Kg	54.759	-
	Organic fertilizer	Kg	-	1291.228
(5)Protection For five years	Insekticide	Kg	2.658	2.278
	Pesticide	Kg	3.155	1.816
	Diesel for sprayer & fogging	L	0.554	-
(6) Harvesting	Diesel fuel for truck 10 tons	L	5.027	2.468
(7) Palm oil mill/oil extraction	Electricity from grid	kWh	44.070	14.833
	Steam consumption	Kg	59.770	-
	Water consumption	m^3	0.852	-
	PAC	Kg	0.027	-
	Flokulon	Kg	0.0001	-
	NaOH	Kg	0.023	-
	H_2SO_4/HCl	Kg	0.023	-
	Tanin consentrate	Kg	0.010	-
	Poly Perse BWT 302	Kg	0.010	-
	Alkaly BWT 402	Kg	0.009	-
	Fiber/shell	kg	28.746	-
Transportation	Diesel fossil fuel	L	4.720	1.890
(8) Biodiesel Prod.	Methanol	Ton	-	0.449
Esterification	H_2SO_4	Ton	-	0.027
Trans esterification	Methanol	Ton	0.269	-
	Electricity from grid	kWh	15.645	16.925
	NaOH	Ton	0.080	0.080
	Crude glycerol	Ton	0.082	0.082
	Water consumption	L	1700.680	1719.180
	Diesel fossil fuel for boiler	L	14.000	16.000

Table 3.4 Some characteristics of CPO (Crude Palm Oil) versus CJCO (Crude *Jatropha curcas* Oil)

No	Description of parameter	Characteristic of feedstocks		Reference
		CPO	CJCO	
1	Content of FFA (%)	< 5	> 5	1
2	Content of FFA (%)	< 2	> 2	2
3	Main reaction	Trans-esterification	Esterification - Transesterification	
4	Catalyst	Alkali	Acid and Alkali	
5	Operational temperature (^oC)	60	60	Catalyst of alkali
		-	100	Catalyst of acid
6	Operational pressure (MPa)	0.1	0.1	Catalyst of alkali
		-	0.5	Catalyst of acid
7	Time of reaction (hour)	1	1	Catalyst of alkali
		-	> 1	Catalyst of acid
8	Convertion of metil ester (%)	87-94	97-92	Catalyst of alkali
		-	95	Catalyst of acid
10	System	Batch	Batch	
11	Stirring	Required	Required	
12	Polluter	Catalyst, soap, water, glycerol, glyceride	Catalyst, water, glycerol, glyceride	
14	Source of biodiesel	Pulp, kernel	Kernel	1
15	Dry oil (%)	45 - 75	40 – 60	1
16	Edible/Non-Edible	Edible	Non-Edible	1
17	Long carbon chains	C12 - C20	-	2
18	Kinematic viscosity (20 ^oC, cSt)	60	77	3
19	Kinematic viscosity (400 ^oC, cSt)	-	40.4	c
20	Density (20 ^oC, kg/liter)	0.915	0.92	3
21	DHC (MJ/kg)	36.9	38	3
22	Cetane number	38 - 50	23 – 41	3
23	The point of cloud (^oC)	31	2	3
24	Point decant (^oC)	23 - 40	-3	3
25	Flash point (^oC)	-	236	4
26	Viskosity at 30^oC (Mm^2/s)	-	0.9177	4
27	Density pada 15^oC (g/cm^3)	-	49.15	4
28	Residue of carbon (% (m/m))	-	0.34	4
29	Content of ash sulphate (% (m/m))	-	0.007	4
30	Water content (ppm)	-	935	4
31	Sulphur content (ppm)	-	< 1	4
32	Acid number (Mg KOH/g)	-	4.75	4
33	Iod number (g iod/100 g minyak)	50.6 - 55.1	96.5	5 &4
34	Saponification num. (kg KOH/g.oil)	190.1 - 201.7	-	5
35	Melting point (^oC)	31.1 - 37.6	-	5
36	Refraction Index (50 ^oC)	1.455 - 1.456	-	5
37	Miristat Acid (C14)	0.7	0	6 & 7
38	Palmitat Acid(C16)	39.2	11.9	6 & 7
39	Stearat Acid (C18)	4.6	5.2	6 & 7
40	Oleat Acid (C18 :1)	41.4	29.9	6 & 7
41	Linoleat Acid (C18 :2)	46.1	26.33	6 & 7

Sources :

1 : Raw material aspect of biodiesel production in Indonesia 2006
2 : Hambali, 2007
3 : Vaitilingom et al, 1997
4 : Hambali, 2006
5 : Hui, 1996
6 : Haas and Mittelbach, 2000
7 : Darnoko, 2005

Currently, there are several large scales of biodiesel production based palm oil as a feedstock's in Indonesia such as : PT.Indo Bio Fuels (150,000 tons/year), PT.Bio Energi Nusantara (150,000 tons/year), PT.Anugerah Inti Gemanusa (80,000 ton/year), PT.Sumi Asih (36,000 tons/year) dan PT. RAP (500 ton/year) (Appendix 3). Recent development shows that PT.EterindoWahanatama produces 2 x 60 tons/day of biodiesel in Tangerang and Gresik, where most of the production is exported and used to supply Pertamina; PT.Sumi Asih in Tambun – Bekasi produces 60 tons/day of biodiesel; PT.Ganesha Energi 77 produces 20 tons/day of biodiesel in Perbaungan North Sumatra. Different characteristics of CPO versus CJCO are shown in Table 3.4.

Next section describes the results of LCI in palm oil and *Jatropha curcas* on their life cycle (cradle to gate), which consists of eight stages of sub-processes that serve as primary data. The complete summary for *Jatropha curcas* and oil palm is shown in Appendix 4.

a. Life cycle inventory in the production of biodiesel from palm oil

So far, there is no standard procedure how to document and analyze various types of uncertainties in LCI. It should be noted that impact assessment could introduce further uncertainty which more importantly needs to be analyzed rather than uncertainty. LCI results life cycle inventory analysis. It covers all the basic aspects of the entire product system being studied.

LCI stages are carried out in accordance with Figure 3.1. Inventory data is carried out in accordance with the data obtained in *PTPN VIII (Persero) Unit Kebun Kertajaya Banten* and refers to the manager (*Mandor Besar*) handbook of *Unit Kebun Kertajaya*, and PT Adaro-Central Kalimantan as primary data. The description of each stage is as follows:

1. Land Clearing

Tillage

Oil palm plantation is usually grown on a variety of conditions within the available land area that would be opened for palm oil area. Methods on land clearing for oil palm area are as follows:

1. New planting in primary forest, secondary forest, shrubs or areas with weeds.
2. Conversion i.e. planting on area which previously planted with plantation crops such as rubber, coconut or other plantation crops.
3. Replanting i.e. planting on area which previously planted with palm oil.

Mechanical land clearing

Land clearing is carried out mechanically on forest area and conversion area with large trees. This mechanical clearing comprises of some works, i.e.:

- Toppling: cutting big and small trees by dislodging the root from the soil
- Pilling: collecting and pilling the toppled trees
- Burning: cutting branches and trunks for dense pilling, drying the pilling and burning. Burning is repeated until it turns out into ashes.
- Mechanical land clearing is ready to be done.

2. Seedling Stage

Plant propagation technology

Plant propagation technology that could be carried out in palm trees is tissue culture and conventional method.

- Breeding in tissue culture: In tissue culture breeding, palm oil materials can be obtained in the form of seed or clone as the result in tissue culture propagation (tissue culture). Palm oil development usingtissue culture system is intended to address the weaknesses found in plant material derived from palm oil seeds which generally have diversity in production, oil quality, vegetative growth, and resistance to pests and diseases. Palm oil seed obtained by tissue culture system is called the palm clones.
- Breeding under conventional method: palm oil seed that will be used in this method should be produced and germinated by official agency appointed by the government. Germination process is generally carried out continuously as follows:
  - Stalk bunchis released from the spikelet.
  - Fruit bunch is ripened for 3 days and occasionally splashed with water
  - Enter the fruit into mixing machine to separate the pulp from the seed. Wash the seed with water, then soaked in water for 6-7 days and then soaking the seed in 0.2% Dithane M-45 for 2 minutes, then dry.
  - Storethe seed into the palm seed germination and keep in can at room temperature (39^{o}C) with 60-70% humidity for 60 days. Every 7 days, the seed is dried for 3 minutes.
  - After 60 days, the seed is soaked in water until the water content reaches up to 20-30% and dry again. Then put the seeds in a solution of 0.2% Dithane M-45 for 1-2 minutes. Store the seed at room temperature 27^{o} C.

Seedling Growth Stage

Seedling growth using germinated seed can be conducted in two methods: two-stage method (prenursery and nursery), and one stage (directly to the nursery). Either using the first or second method, new seedling is ready to be transferred to the field (garden) if the age is 11-12 months. Nursery land should be leveled and cleared from weeds, equipped with watering installation (irrigation sprinkle), and facilitated with roads and drainage ditches.

Prenursery:

- Germinated seed is located in small polybag for prenursery stage then laid on the beds with 120 cm wide and enough length.
- Polybag is filled with 1.5 to 2.0 kg of sifted upper soil. A hole is placed on each polybag for drainage.
- The shoot is grown ± 2 cm depth from the soil surface and each shoot is located with 2 cm wide among others.
- When the prenursery seed reaches 3-4 months and has 4-5 leaves, prenursery seed is ready to be transferred into nursery seedlings.

Nursery seedlings:

- Bigger polybag is needed to plant the seed which transferred from prenursery seedling, 40 cm x 50 cm or 45 cm x 60 cm, and give hole at the bottom side for drainage

- Polybag is filled with sifted top soil as much as 15-30 kg per polybag which adjusted to the length period of seed which will be maintained in nursery site.
- Prenursery seed is planted in such a way that the root collar is at the soil surface of big polybag and soil around the seed is compacted for upright stand.

Maintenance (in the nursery)

Seed that had been planted in the prenurseryor nursery needs to be maintained properly in order to grow healthy and fertile, so that the seed can be moved to the field in proper age and planting time. Maintenance of seeds includes: watering, weeding, monitoring and selection, and fertilization.

- Watering: Seed watering should be conducted twice a day, except when the rain falls. Each polybag needs spray water ± 2 liters / day.
- Weeding: Weeds growing in the polybags and on the ground between the polybag must be cleaned manually or using herbicide. Weeding should be done 2-3 times a month.
- Monitoring and Selection: Monitoring is objected to monitor seed growing and monitor development of pest and disease attack. Seed which dwarf, abnormal, diseased and have genetic abnormalities should be discarded. Thinning out is performed at the time during transfer to the main nursery i.e. when the seed is 4 and 9 months, and at the time of transplanting to the field.
- Fertilization: Fertilization is essential to obtain the healthy seed, grow fast and fertile. Urea fertilizer is given in the form of a solution and compound fertilizer. Dose and type of fertilizer is given in Table 3.5.

Table 3.5 Dose and type of seed fertilizer

Seed age, week-	Type of fertilizer	Dose	Rotation
4 – 5	Urea solution 0.2 %	3-4 L solution/100 seeds	1 week
6 – 7	Urea solution 0.2 %	4-5 L solution /100 seeds	1 week
8 – 16	Rustica 15. 15. 6. 4	1 gram/seed	1 week
17 – 20	Rustica 12.12.17.2	5 gram/seed	2 week
21 – 28	Rustica 12.12.17.2	8 gram/seed	2 week
29 – 40	Rustica 12.12.17.2	15gram/ seed	2 week
41 – 48	Rustica 12.12.17.2	17gram / seed	2 week

3. Planting Stage

Palm oil plant requires environment with rainfall rate 1500 – 4000 mm per year while the optimal rainfall is 2000 – 3000 mm per year with the number of rainy days is not more than 180 days per year. In Java, palm trees grow in the area of South Banten which relatively has wet climate. Palm plant requires large amount of nutrients for vegetative and generative growth. Therefore, high nutrient amount is required to obtain high production. In addition, the pH soil is acid which ranges between 4.0 to 6.0, the optimum is 5.0 to 5.5.

Planting and replanting

The procedure to plant seed living in polybag is as follows:

- Prepare seed which derived from the main nursery at each planting hole.
- Watering the seed which live in polybag a day before planting to provide sufficient soil moisture and water supply.

- Before planting, basic fertilizer is given in the planting hole by evenly put phosphate fertilizer such as Agrophosand Rock Phosphate 250 gram at each hole.
- Hoarding the seed with top soil by gradually inserting soil around the seed and compact by hand.

The main activity during planting process is: creating plant row, planting legume as cover crops and cultivating palm oil. The descriptions are as follow:

- **Creating plant row**: In the first stage, create plant array (row) and a marker point of planting, in which palm oil seed will be planted. Location of marker (stake) should preciseto form a straight row marker that can be seen from all directions. Thus, each individual plant will has straight row and similar area to grow. System that is commonly used is equilateral triangle with a distance of 9 m x 9 m x 9 m. With this equilateral triangle system, the North-South Distance plant is 7.82 m and the distance between each plant is 9 m. The population (density) plant per hectare is 136-143 trees.
- **Making planting holes**: planting hole should be made several weeks before planting so that the soil and planting hole experience physical and chemical changes due to climate influence and can be examined both in size and number of holes per hectare. Making a hole that made at the time of planting or just 1-2 days before planting is not recommended. The planting hole is usually made with a size of 60 cm x 60 cm x 60 cm, but there is also 50 cm x 40 cm x 40 cm. At the time of digging, the upper soil is placed beside the hole and the lower soil is placed on the south side of the hole. Marker is plugged beside the hole and after the hole has been completed, the marker is plugged back in the middle of the hole. If the plants will be planted according to the contour line or made terraces encircling hills, the hole is placed minimum 1.5 m from the side of the slope. For palm oil that will be planted encircling the hill, individual or collective terraces is usually made before planting.
- **Cover crops**: Cover crop is usually planted in palm oil plantation. Plant cover crops are legumes (Legume cover crops, LCC) which planted to cover the open ground between the palm oil as it has not formed canopy that can cover the soil surface. Planting LCC is objected to improve the physical, chemical and biological soil properties, prevent erosion, retain soil moisture and suppress plant pests (weeds). LCC planting should be implemented as soon as the clearance is completed.
- **Pruning**: Pruning is disposal activity of old or unproductive leaves in palm oil plantations. Pruning should not be conducted in young plants except for reducing evaporation released by the leaves when the plant is moved from the nursery to the plantation. The objectives of pruning are as follows:
  - Improve air circulation around the plant so it can help the process of natural pollination
  - Reducing blockage of fruit enlargement and loss a group of fruits that trapped in the midrib of the palm.
  - Assist and facilitate harvesting time
  - Support the plant metabolism for smooth process, especially photosynthesis and respiration process.
- **Plant Stitching**: Plant stitching is conducted to replace dead plant or plant with have poor growth. A good time for plant stitching is during rainy season. Seed

should have similar age around 10-14 months. Plant stitching takes usually around 3-5% per hectare.

Existing data related with palm oil plantation in PT.Adaro, Indonesia is as follows: Location: HW 1, planting year: 2008, plant space: 9 mx 9 mx 9 m, plant type: Palm Oil, number of plants: 1511 trees, total area: 12 Ha. Figure 3.9 shows some palm oil pictures in PT.Adaro, Indonesia.

Figure 3.9 Pictures of existing palm oil plantation

Other plant that is pretty much planted in reclamation area of PT.Adaro Indonesia is palm oil, besides of economic consideration, this plant will also be used as feedstock for biodiesel. Based on interviews with PT.Adaro staff, maintenance data is not recorded properly, so it cannot be described whether the plant is well maintained or not, but the physical appearance shows that FFB (fresh fruit bunches) is less preserved. It can be seen from the weight of FFB which only reaches 10 kg per FFB. For comparison, the weight of FFB found in PTPN VIII is 40 kg.

4. Fertilization Stage

Fertilization aims to provide nutrients for generative growth to obtain optimal production. To determine the proper dose of fertilizer, soil and leave analysis should be carried out first. Using soil and leave analysis, it can be seen the availability of nutrients in the soil at the time being and the last state of nutrient of the plant. Based on the analysis, it can be determined appropriate nutrient based on their need which in turn the dose of fertilizer is also can be determined as shown in Table 3.6.

Example of fertilizer dose on producing plant is as follows :
Urea : 2.0 to 2.5 kg/tree/year → given 2 x applications
KCl : 2.5 to 3.0 kg/tree/year→ given 2 x applications
Kieserit: 1.0 – 1.5 kg/tree/year→ given 2 x applications
TSP : 0.75 to 1.0 kg/tree/year→ given 1 x application
Borax : 0.05 to 0.1 kg/tree/year→ given 2 x applications

Table 3.6 The oil palm fertilization dose based on the plant nutrient

Fertilizer type	Dose (kg/tree/year)*		
Plant age	5 – 5	6 – 12	>12
Sulphate of Amonia (ZA)	1.0 – 2.0	2.0 – 3.0	1.5 – 3.0
Rock Phosphate (RP)	0.5 – 1.0	1.0 – 2.0	0.5 – 1.0
Muriate of Potash (KCl)	0.4 – 1.0	1.5 – 3.0	1.5 – 2.0
Kieserite ($MgSO_4$)	0.5 – 1.0	1.0 – 2.0	0.5 – 1.5

*) Note: N, K and Mg fertilizer is given twice, P is given once, and B (if needed) is given twice per year(example for B fertilizer is 0.05-0.1 kg per tree per year)

For un-producing plant, aged 0-3 years, a dose of fertilizer per tree per year is as follows:
Urea : 0.40 to 0.60 kg
TSP : 0.25 to 0.30 kg
KCl : 0.20 to 0.50 kg
Kiserit : 0.10 to 0.20 kg
Borax : 0.02 to 0.05 kg

Fertilizer application should be carefully managed for efficient implementation. For that reason, fertilizer application on producing plant should be conducted in the following manner:

- N fertilizer is evenly sown at a distance of 50 cm to the outer edge of the disc.
- P, K, and Mg fertilizer is sown evenly from radius 1.0 m to 3.0 m from the base (0.75 to 1.0 m outside the disc)
- B fertilizer is evenly sown at a distance of 30-50 cm from the staple crop, and fertilizer in oil palm is conducted twice a year. The first fertilizer application is carried out at the end of rainy season and the second fertilizer application is carried outat the beginning of rainy season.
- On un-producing plants, N, P, K, Mg, B fertilizer is evenly sown in 20 cm dishes ranges from the basic to the end of the leaf canopy.

5. Protection Stage

Weeding (weed control)

Weed control is conducted by planting legume cover crops and made a disk around each individual plant. Weed control can be done in several ways, such as:

- Manual weed control using equipment and conventional control, for example uprooting, using a hoe, fork-like tool and so on.
- Chemical weed control, using herbicides, either contact or systemic.
- Technical culture, using legume cover crop.

6. Harvesting Stages

Oil palm plant starts flowering and forming fruit after 2-3 years. The fruit ripening process can be observed from the change of its skin color. The fruit will turn red orange when ripe. The oil content reaches maximum amount at the time the fruit reaches its optimum ripeness. If too ripe, the fruit will be detached and fall from the bunch stalk.

The process of palm oil harvesting consists of cutting the ripen bunch, picking the fruits and transport the harvested bunch to the collection point and to the mill. Harvesting criteria which should be consideredis the harvesting criterion, harvesting tool, rotation, harvesting system and crop quality.

- Harvesting criterion: harvesting criterion is an appropriate indication that can help harvesters to cut the fruit at the optimum ripeness. Ripening index is when the fruit reach maximum oil content and minimum free fatty acids (FFA). At this time, the general criteria that are widely used are based on the number fruit group, i.e.(a) plants with age less than 10 years haveless than 10 fruits per fruits group, and (b) plants with age more than 10 years old have 15-20 fruits per fruits group. However, in practice, people commonly use criteria with two fruits groups per 1 kg FFB. One key factor to maintain the yieldvalue is to keep the value of FFA of CPO or CJCO under 5%. Under this condition, the biodiesel process can be carried out using transesterification reaction. If the FFA value is higher than 5%, esterification process should be conducted first before transesterification. The shorter the process will turn to higher yield.
- Harvesting method: Based on the plant height, there are three common methods to harvest palm oil in Indonesia. Squat with *dodos* is used to harvest palm oil with 2-5 m height, standing using axe tool is used to harvest palm oil with 5-10 m height, and sickle with long handle (*egrek*) is used to harvest palm oil with more than 10 m height. For ease of harvesting, the stem should be cut first and orderly arranged in the middle of *gawangan*.
- Harvesting preparation: To deal with harvesting season and in order to make the process run smoothly, collection results (TPH) should be prepared and the transportation road should be improved.

7. Milling Stage

Crude palm oil as known as CPO is produced from the extraction of fruit mesocarp. As oil or fat, palm oil is a triglyceride, which is a compound of glycerol with fatty acids. In accordance with the form of the fatty acid chain, palm oil includes an oleic-linoleat acid oil.

Harvested fresh fruit bunches (FFB) should be immediately processed. The process to obtain palm oil involves sterilization, threshing, cutting, and pressing. Pressing process will produce a liquid phase (oil) and solid phase in the form of waste. Liquid phase still contains a lot of impurities such as sand and fibers that need filtration and clarification to separate these impurities. FFB processing flow chart to produce CPO at palm oil milling plant in *PTPN Kebun Unit Kertajaya VIII* is shown in Appendix 5, and the mass and energy balance is shown in Appendix 6.

8. Biodiesel Production Stage

Simple biodiesel production process is shown in Figure 3.10. Biodiesel is made by reacting CPO with methanol through transesterification reaction and under catalytic process to form ester compound with glycerin as byproduct. In every unit of biodiesel production, 3.2 unit of energy is produced. This means, the absorption of solar energy into chemical energy in the biodiesel is very efficient.

Treatment at harvest greatly affects the content of free fatty acids (FFA) on the oil produced. Harvesting in over-mature produces oil with contain high percentage of FFA (> 5%). Conversely, if harvesting is done in an immature fruit, besides of low FFA levels, the process under this condition produces low oil yield. In general, if the harvesting and processing are conducted properly, the FFA value from CPO will be under 5% so that the biodiesel processing does not need transesterification process.

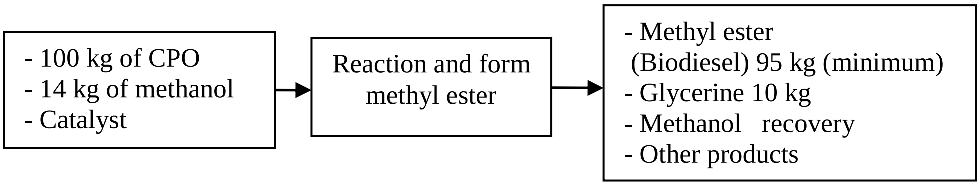


Figure 3.10 Block diagram of biodiesel production

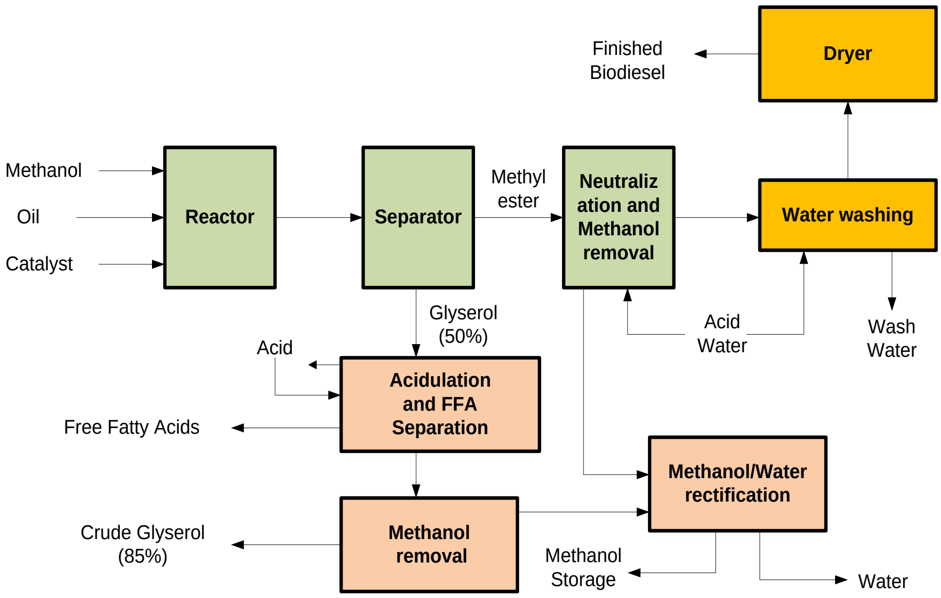


Figure 3.11 Common biodiesel production flow diagrame using vegetable material

Figure 3.11 shows common processing method to produce biodiesel using vegetable material. Figures 3.12 and 3.13 show biodiesel production process using CPO as the feedstock without esterification reaction due to FFA value is lower than 5%. Figure 3.18 shows 3D layout on biodiesel milling plant with capacity 500 liter/batch or about 1 ton per day in BRDST BPPT *Puspitek Serpong*. Figure 3.19 shows mass balance flow under catalytic process, while Figure 3.20 shows biodiesel production with capacity of 1 ton per day performed in BRDST BPPT *Puspitek Serpong*.

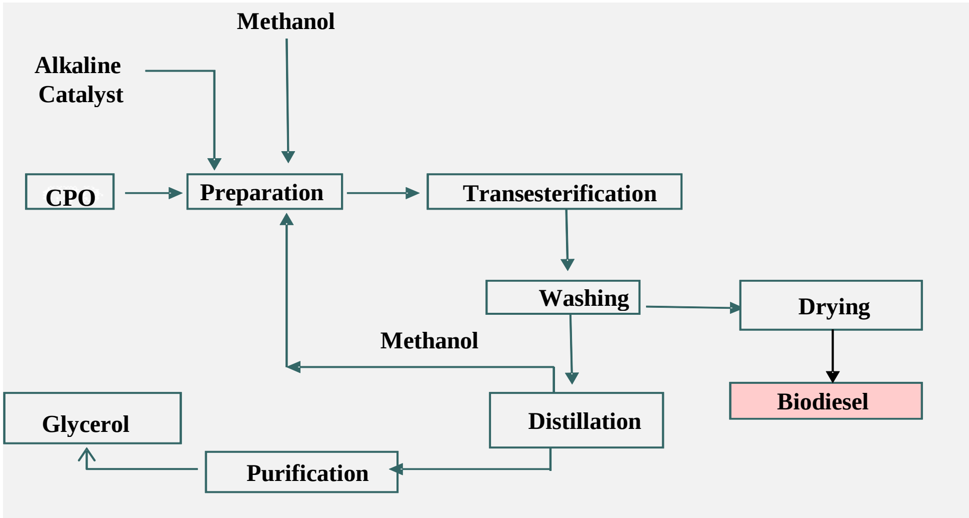


Figure 3.12 CPObased biodiesel processing process under transesterification reaction

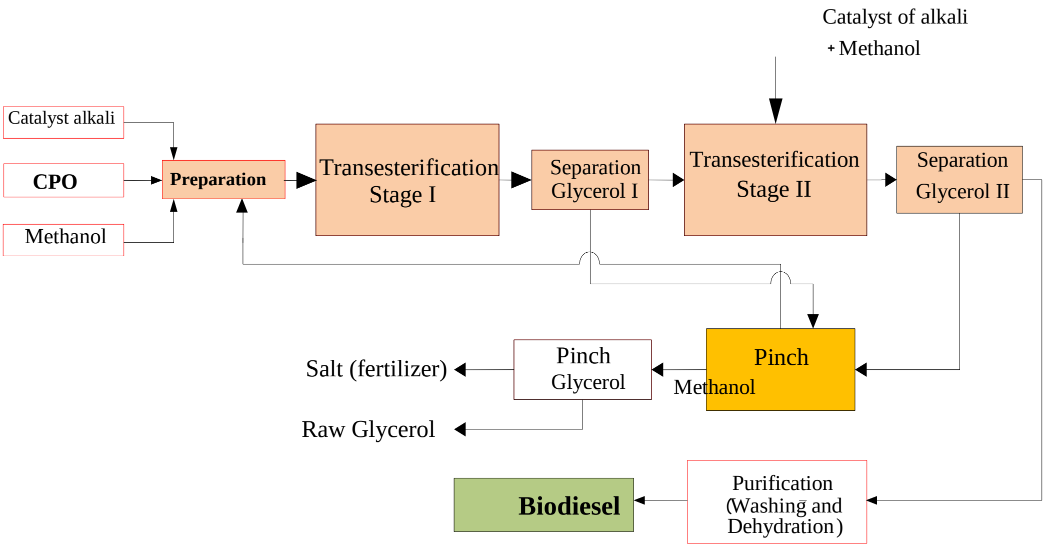


Figure 3.13 Common CPO based biodiesel processing under two stages transesterification reaction in PT Adaro, Central Kalimantan

Detail description of production process in Figure 3.20 and 3.21 and the common method implemented in biodiesel industry, and also to analyze the flow of mass, energy/heat, and waste into the air, liquid waste and solid waste per sub unit process production under catalytic method using CPO is as follow:

1. Sub Unit of Immersed Coil Heater

This sub unit is used to heat CPO before entering centrifuge (Figure 3.14).

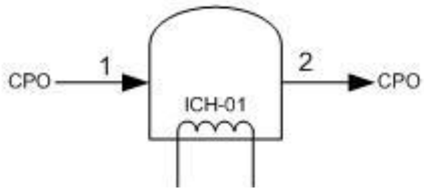


Figure 3.14 Sub unit of immersed coil heater

The input on line number 1 is CPO, water and dirt, and the output on line number 2 is FFA, triglyceride, water and dirt.

2. Sub Unit of Centrifuge 1

This sub unit is used to separate CPO that will be reacted from water and dirt (Figure 3.15).

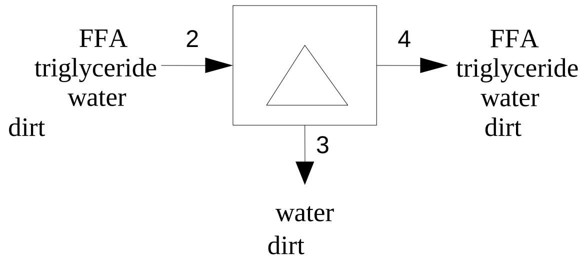


Figure 3.15 Sub unit of centrifuge 1

The input on line number 2 is FFA, triglyceride, water and dirt; while the output in line number 4 is: FFA, triglyceride, water and dirt; and the output in line number 3 is: water and dirt.

3. Sub Unit of Mixer 1

This sub unit is used to blend methanol solution with KOH alkali as the catalyst (Figure 3.16).

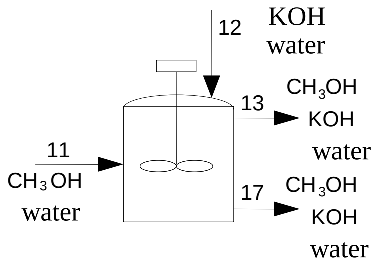


Figure 3.16 Sub unit of mixer 1

The input on line number 11 is: methanol and water, the input on line number 12 is : KOH, and water; the output in line number 13 is : methanol, KOH catalyst, and water; while the output in line number 17 is : methanol, KOH catalyst and water.

4. Sub Unit of Transesterification 1

This sub unit is used to react triglyceride with methanol to produce methyl ester (biodiesel) using KOH catalyst (Figure 3.17).

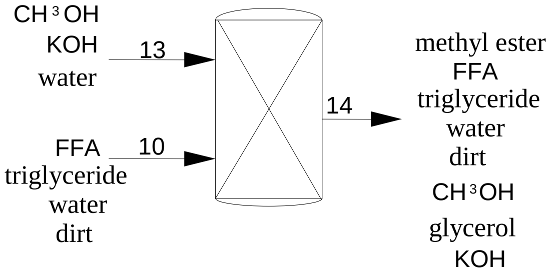


Figure 3.17 Sub unitof transesterification 1

The input on line number 10 is : FFA, triglyceride, methanol and water; the input on line number 13 is: methanol, KOH catalyst and water. The output on line number 14 is : methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water and dirt.

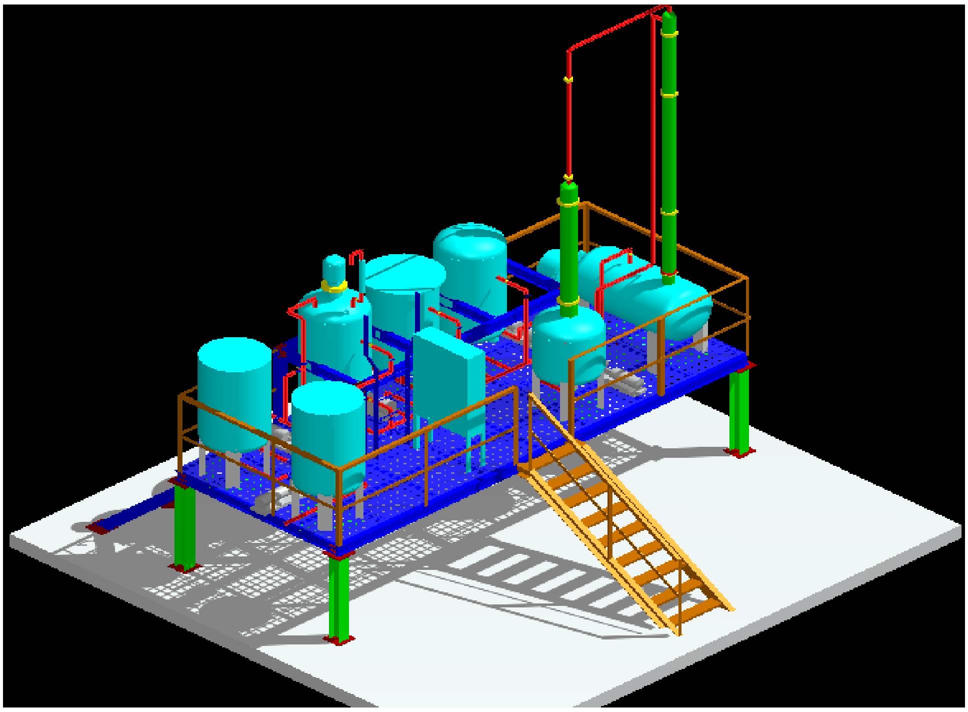


Figure 3.18 3D layout biodiesel milling plant with capacity of 500 liter/batch or about 1 ton per day in BRDST BPPT Puspitek Serpong

5. Sub Unit of Centrifuge 2

This sub unit is used to separate methyl ester from glycerol, water, dirt and catalyst (Figure 3.19).

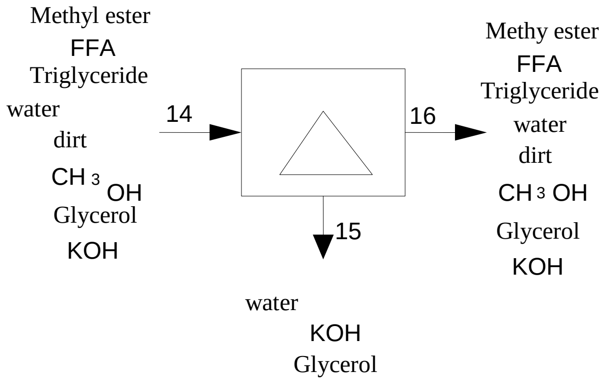


Figure 3.19 Sub unit of centrifuge 2

The input on line number 14 is: methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water and dirt. The output on line number 15 is : glycerol, KOH catalyst, and water. While the output on line number 16 is : methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water and dirt.

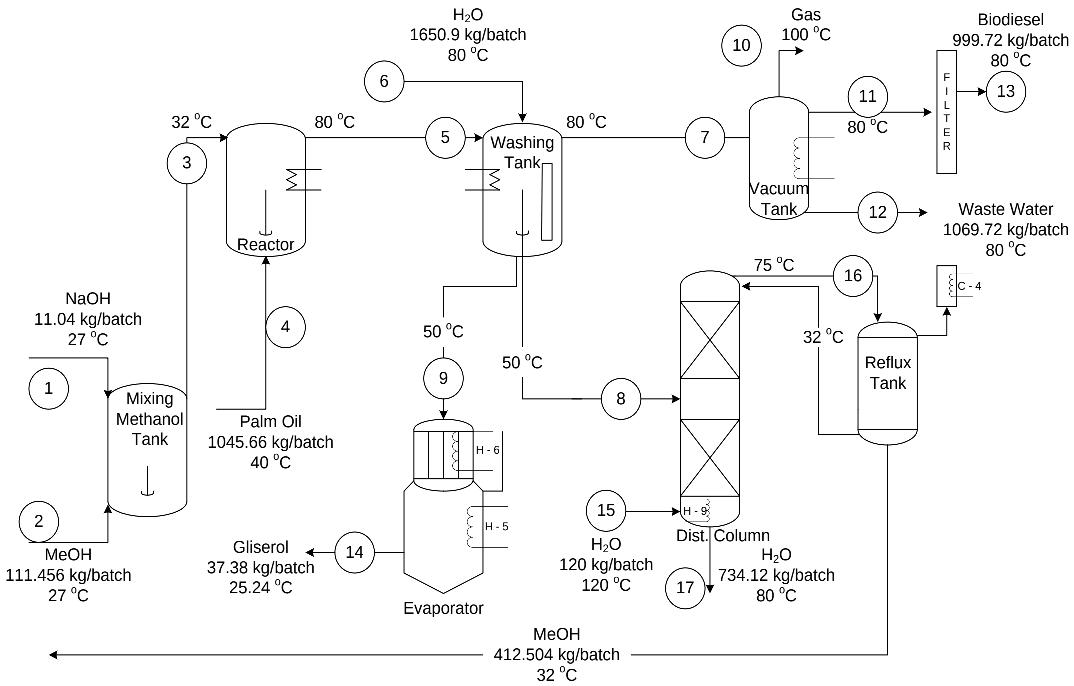


Figure 3.20 Mass balance flow under catalytic production process

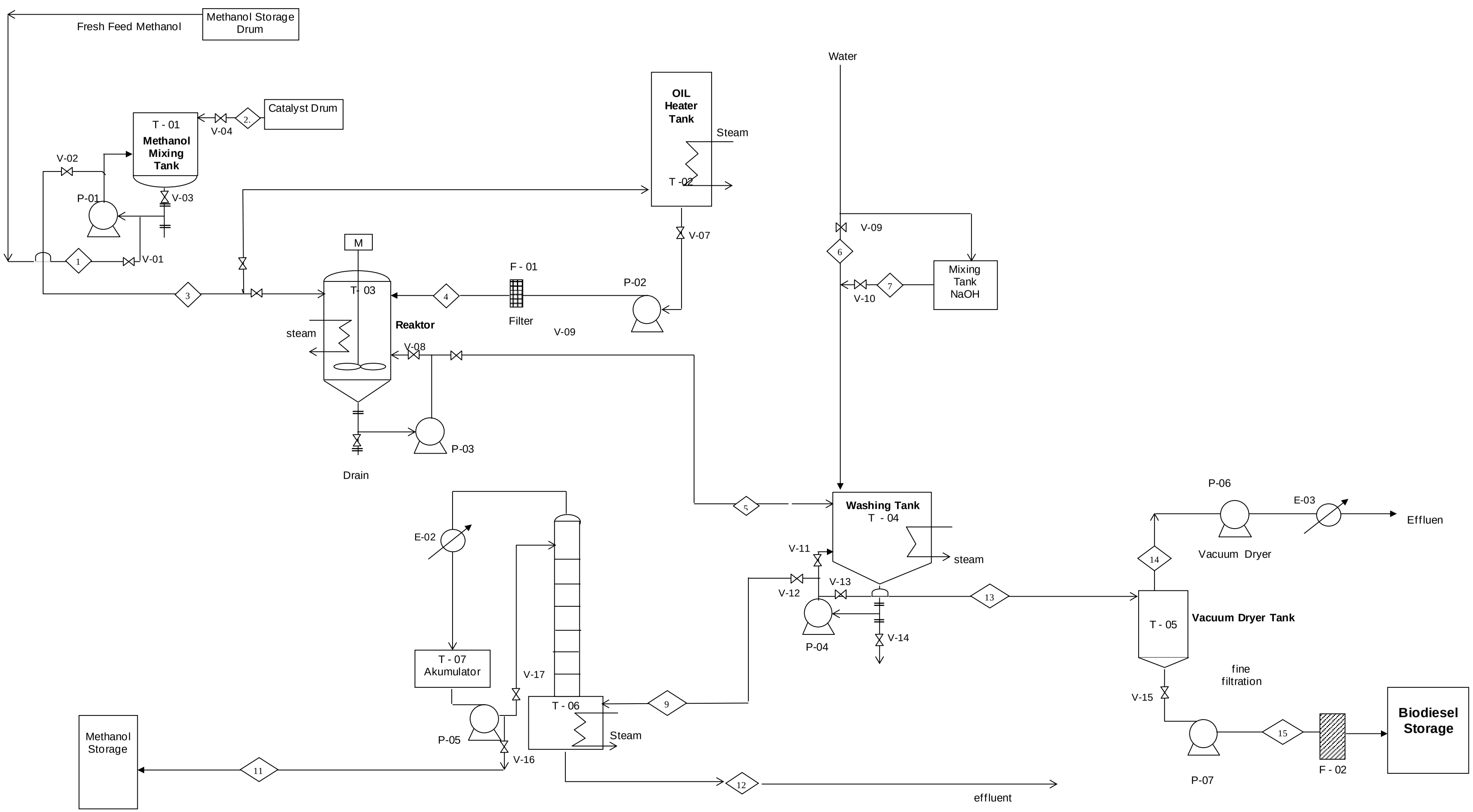


Figure 3.21 Flow diagram of biodiesel process production in BRDST BPPT Puspitek Serpong

6. Sub Unit of Transesterification 2

This sub unit is used to react triglyceride with methanol to produce methyl ester (biodiesel) using KOH catalyst (Figure 3.22).

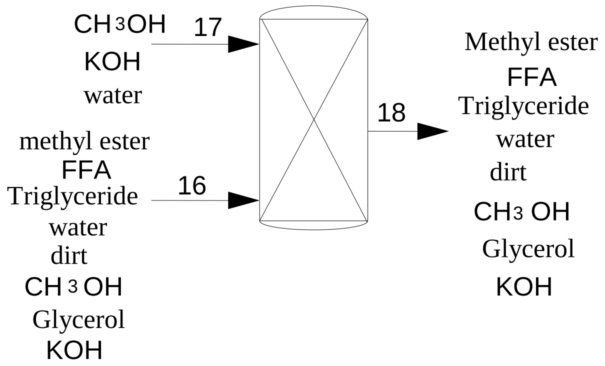


Figure 3.22 Sub unit of transesterification 2

The input on line number 16 is: methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water and dirt. The input on line number 17 is: methanol, KOH catalyst, and water. While the output on line number 18 is: methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water and dirt.

7. Sub Unit of Centrifuge 3

This sub unit is used to separate methyl ester from glycerol, water, dirt and catalyst (Figure 3.23).

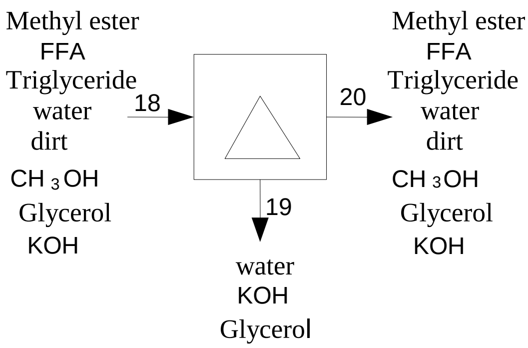


Figure 3.23 Sub unit of centrifuge 3

The input on line number 18 is: methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water, and dirt. While the output on line number 19 is: methanol, KOH catalyst, and water; the output on line number 20 is: methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water and dirt.

8. Sub Unit of Washing Tank

This sub unit is used to remove residual methanol and catalyst dissolved in methyl ester (Figure 3.24). The input on line number 20 is: methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water, and dirt, the input on line number 21 is: water. While the output on line number 22 is: methyl esters, FFA, triglyceride, methanol, KOH catalyst, glycerol, water, and dirt.

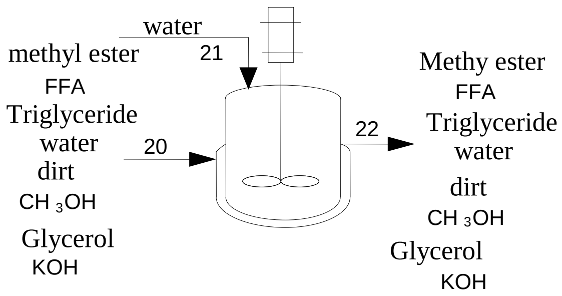


Figure 3.24 Sub unit of washing tank

9. Sub Unit of Dekanter

This sub unit is used to separate methyl ester from water, the remaining methanol, catalyst, and glycerol (Figure 3.25). The input on line number 22 is : methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water, and dirt. While the output on line number 23 is : Water, Methanol, KOH catalyst, glycerol, and dirt. The output on line number 24 is: methyl esters, FFA, triglycerides, methanol, KOH catalyst, glycerol, and water.

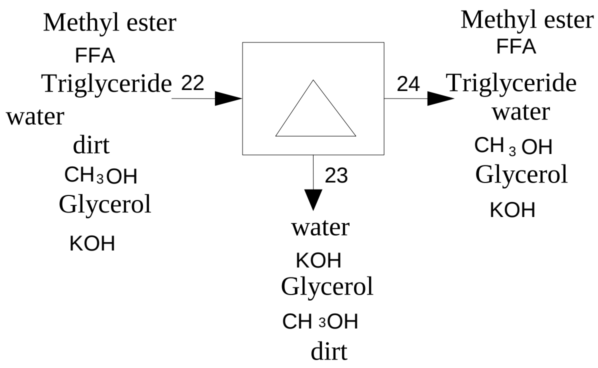


Figure 3.25 Sub unit of decanter

10. Sub Unit of Evaporator

This subunit is used to eliminate water content and remaining methanol in methyl ester (Figure 3.26).

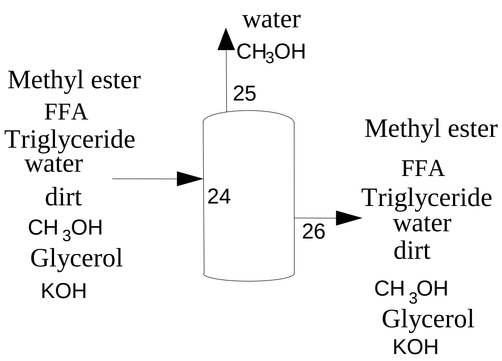


Figure 3.26 Sub unit of evaporator

The input on line number 24 is: methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water, and dirt. While the output on line number 25 is:water, and methanol, and output on line number 26 is: methyl ester, FFA, triglyceride, methanol, KOH catalyst, glycerol, water, and dirt.

11. Sub Unit of Cooler

This subunit is used to lower the temperature of biodiesel from the to enter the storage tank (Figure 3.27).

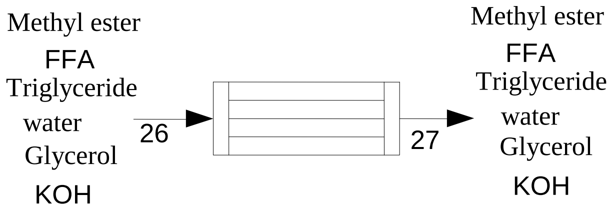


Figure 3.27 Sub unit of cooler

The input on line number 26 is: methyl ester, FFA, triglyceride, KOH catalyst, glycerol, and water. While the output on line number 27 is: methyl ester, FFA, triglyceride, KOH catalyst, glycerol, and water.

12. Sub Unit of Heater

This sub unit is used to raise the temperature of the feed which will enter to distillation sub uit (Figure 3.28).

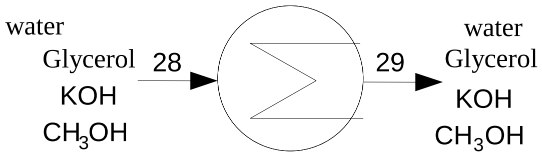


Figure 3.28 Sub unit of heater

The input on line number 28 is: methanol, KOH catalyst, glycerol, and water. While the output on line number 29 is: methanol, KOH catalyst, glycerol, and water.

13. Sub Unit of Distillation Tray

This sub unit is used to recover residual methanol. Incoming feed consists of methanol, water, glycerol, and KOH. The input on line number 29 is: water, methanol, glycerol, and KOH catalyst; the input in line number 35 and 32 is: water, and methanol. While the output on line number 34 is: water, methanol, glycerol, and KOH catalyst; the output on line number 30 is : methanol, and water (Figure 3.29).

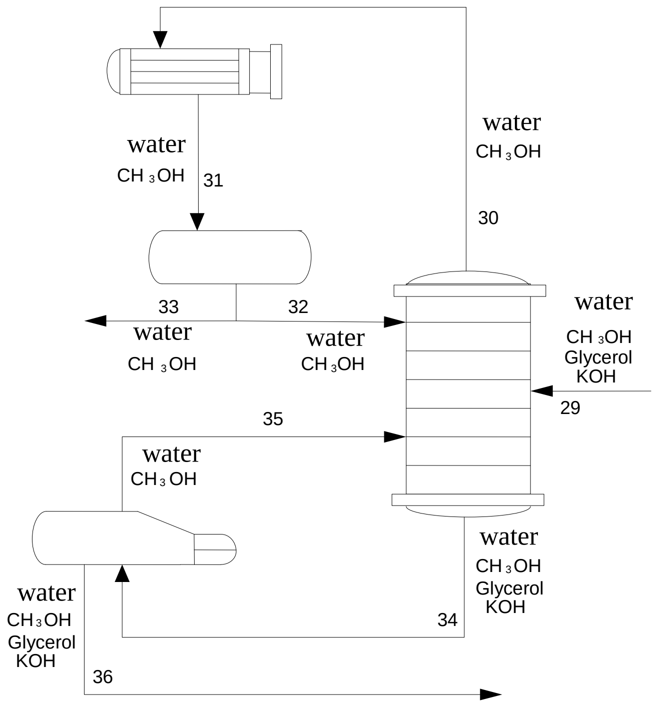


Figure 3.29 Sub unit of distillation tray

13.1. Sub Unit of Condensor

This subunit is used to lower the methanol vapor temperature on distillation unit (Figure 3.30). The input on line number 30 is: methanol, and water. While the output on line number 31 is: methanol, and water.

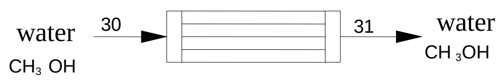


Figure 3.30 Sub unit of condensor

13.2. Sub Unit of Reflux Drum

This subunit is used to divide the resulting distillate from the condenser with a specific composition, where some will be a part of distillate and remain will be fed again into distillation unit (Figure 3.31).

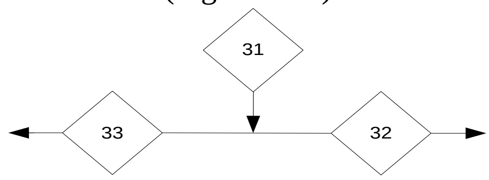


Figure 3.31 Sub unit of reflux drum

The input on line number 31 is: methanol, and water. While the output on line number 32 and 33 is: methanol, and water.

13.3. Sub Unit of Reboiler

This subunit is used to vaporize methanol and flows this material into distillation sub unit (Figure 3.32).

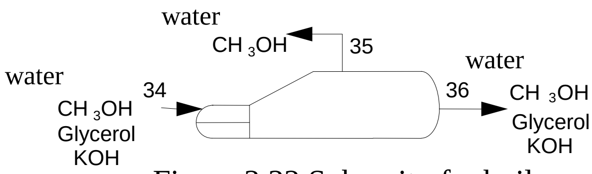


Figure 3.32 Sub unit of reboiler

The input on line number 34 is: KOH catalyst, glycerol, methanol, and water. While the output on line number 36 is: KOH catalyst, glycerol, methanol, and water, and the output on line number 35 is: methanol, and water.

b. Life Cycle Inventory (LCI) on *Jatropha curcas*

LCI stage on *Jatropha curcas* is also similar with Figure 3.1. The next step is to conduct data inventory based on data found in *Jatropha curcas* Estate Center (KIJP) – BALITRI *Parung kuda Sukabumi* and PT.Adaro-Centre Kalimantan which serve as primary data. Eight sub processes conducted in this research are described below:

1. Land Opening Stages

KIJP had ever planted *Jatropha curcas* as much as 50 ha. The area of PT Adaro which located in Tanjung Banjarmasin has also been planted by *Jatropha curcas* as much as 30 ha, but unfortunately the land was then used for coal mining land due to lack availability of land fill. *Jatropha curcas* is able to adapt Indonesian land and agro-climate, even in dry conditions and on marginal land/critical. Problems which occur on its development is that there are no improved varieties and appropriate cultivation technique. Hence, necessary technique and research development need to be studied. There are some requirements needed to build a location for *Jatropha curcas* plantation as shown in Table 3.7 (Ferry, 2009). Land clearing is carried out by using human power and mechanical power (tractor), with land clearing requirements by KIJP-BALITRI as shown in Table 3.8 (Ferry, 2009).

Table 3.7 Location requirements for *Jatropha curcas* plantation

No	Componen	Condition
1	Area	5 ha
2	Land	Not considered as an area of major outbreaks of jatropha pest and disease
3	Topography	Flat to swell
4	Height	< 700 above sea level
5	Soil pH	5 – 7
6	Rainfall rate	1500 – 2500 mm/year
7	Sun exposure	Minimal 2000 hour/year

Land preparation involves land clearing, creating plant row, and creating planting hole. The land should be cleared from shrubee specially around potential planting site. Creating plant row is carried out by driving stakes (bamboo or wooden sticks) with spacing adjusted to the expected plan of plant populations. Planting is at 2.0 m x 3.0 m (population 1600 trees/ha), 2.0 m x 2.0 m (population 2500 trees/ha) or 1.5 m x 2.0 m (population 3300 trees/ha). On slopes land, contour system with 1.5 m spacing in the row should be used. Planting hole is made with a size of 40 cm x 40 cm x 40 cm. The distance and the size of the planting hole are determined by the slope of the land, water availability, and soil fertility. Generally, the space for planting hole is 200 x 200 cm. Creating planting holes in poor soils can be made in narrow distance. *Jatropha curcas* planting can also be carried out with inter cropping systems, such ascorn, pepper, *wijen* and others. Inter cropping system has been applied by farmers in Bayan, West Lombok.

Jatropha can grow on all types of soil. This plant grows well in lights soil or land with good drainage and soil aeration. Fertile land with un-stagnant wateris the proper place for this plant to grow and produce optimally. Tillage is carried out mechanically (tractor) or manual as deep as 20-30 cm in order to obtain the appropriate soil for plant growing. Besides, land tillage can also be carried out in minimum tillage i.e. land clearing by digging the soil only on the planted row.

Table 3.8 Land clearing requirements for *Jatropha curcas* plantation

No	Component	Requirement
1	Land clearing	All vegetations and stumps in the plan area is cleared and plowed 2-3 times and then levelled off
2	Land tillage	Tillage 2-3 times and then levelled off
3	Drainage	Drainage ditch is made every 5 ha to prevent water puddle and erotion
4	Farm road	Farm road is built for ease transportation and farm monitoring

2. Seedling stages

Indonesia has several jatropha varieties such askepyar (*Ricinus communis*), jarak bali (*Jatropha podagrica*), jarak ulung (*Jatropha gossypifolia*) dan jarak pagar (*Jatropha curcas*). Only *Jatropha curcas* has potential value as feedstock for biodiesel. Jatropha includes in *Euphorbiaceae* family, one family with rubber and cassava. The tree is shrub with plant height 1-7 m with irregularly branched. It has woody cylindrical stalks and releases sap when injured. The seed is oval with dark brown color and contains oil as much as 30-40%.

Seedling method is considered to have higher production oil than stem cutting method as it generates longer living plants. The seed requirements to build parent plantation are shown in Table 3.9 (Ferry, 2009).

Table 3.9 Seed requirement in KIJP

No	Component	Requirement
1	Variety	Released IP
2	Origin	From certified seedling center
3	Genuineness level	90%
4	Fruit age when harvesting	80-90 days, yellow skin color
5	Fruit weight	8 g/seed or 1300 – 1400 seed/kg
6	Fruit skin appearance	Clean, shiny and no wrinkles
7	Seed healthy	No pest and disease attack
8	Germination	90% after seedling

Nursery stage in KIJP-Pakuwon is as follows (Pranowo, 2009) :

- Preparation of media : (fine soil : manure : sand (1: 1: 1))
- Filling polybag : polybag size 15 cm x 25 cm, black color

- Arranging polybag : minimum 18 holes per polybag
- Stem cutting : mixed media is put into polybag and then arranged 10 lines laid length wise

Seedling can be carried out in polybag plastic, beds, nursery, or planted directly in the field. Planted directly in the soil is more practical and cheaper cost. A tissue culture technique is also possible. If stem cutting method is used, select woody branch or stem. For seed technique, use enough ripe seed which usually has black color. The length period in nursery is 2 to 3 months. Activities conducted during seedling include watering (every day : 2 times i.e. morning and afternoon), weeding, and selection. Nursery in an area of 1 ha can accommodate 112,500 seeds, assuming that the percentage of seedlings growing is about 88 percent, it will produce 100,000 seedlings that are ready to be distributed at the age of 6 months. Number of those seeds is enough to meet the needs of approximately 40 ha with a population of 2,500 trees/ha. The steps in the preparation of the seed are as follows (Ferry, 2009):

-The used seed must be produced from certified seed
- Seed is soaked first for 24 hours, then sowing in polybags with immersing the embryo as deep as 2 cm and then covered with fine soil
- After seedling, the seed should be watering immediately
- When using stem cuttings, select the cuttings with a diameter of 1.5 - 22.5 cm, and length 40 cm, with grayish skin color
- Before the stem cuttings are planted, the plant medium in polybag is watered first
- The stem cutting is planted as deep as 15 cm in the middle of polybag.
- Plant material: The plant material or seed parent should come from the parent garden. If no parent gardens, seeds and stem cuttings can be obtained by selecting the available crop populations, with the following requirements: (1) the age is more than 5 years with a uniform growth, (2) plant population is free from pests and disease (3) From these selected populations, choose plants that have bunches of flowers, young fruit bunch, ripe fruit bunches and dried fruit bunches on one branch, and (4) the productivity is higher than 2 kg of dry seeds per plant per year or equivalent to higher than 5 tons of dried seed per hectare per year.
- Seed: In the optimal environment conditions, jathropacan produce fruit throughout the year, with a peak harvest period 3 times a year. In such conditions it can be found 4 level generative stadia on the branches i.e. flowers, young fruit, old fruit, and dried fruit. For seedling purpose, seed should be obtained from yellow fruit at harvest, dried and then temperate in shaded place. The fruit from this seed will have shiny black color and has 1500 seed per kg. Seed germination is carried out by immersing selected seeds for 1 night. After that, the seeds are put into sand medium that will be germinated in 1-7 days. The seed can be moved into polybag after 1-2 weeks germination by drowning the seed as deep as 10-15 cm inside the polybag. The seed can also be directly germinated in the polybag or in the field.
- Stem cutting: Plant material should be selected from the woody branches or stem (1 year old) which is characterized by grayish green color, length 40-50 cm and diameter 1.5 – 2.5 cm. Put the cutting as deep as 15 cm inside the polybag.
- Nursery location: Nurseries should be located in the open area so that the sun is not obstructed in and close to the planting area to save time and cost. To ensure

the availability of water for watering purpose, the location should also near to water sources. Once the area is cleared from shrubs or tree logging, the nursery area is leveled and makes ditches to avoid puddles. Bamboo fences needs to be made to avoid disruption of livestock, such as goats or chickens.

- Media preparation: nursery media is filled with soil mixed with manure and husk rice (1:1:1). The polybag size is 25 cm x 15 cm and provided with 18 holes. Soil should be sifted before mixed with manure and husk rice.

Seed Preservation

Seed preservation includes: watering, weed control and pest control. This activity is carried out until the seeds 1.5 up to 2.0 months. Watering should be done every day, unless it rains. Removing of pests and diseases is carried out as needed. Pests that are commonly found in nurseries are snails, grass hoppers and termites. Weaning seedlings from stem cutting is conducted after 4 weeks by grouping plants by height (large plants), while the seed weaning is conducted after 6 weeks. Seeds from stem cutting or seed can be transferred to the field after ± 2 months.

3. Planting Stage

Planting and replanting

Planting *Jatropha curcas* is carried out at the beginning or during rainy season to provide sufficient water availability. Planted seed should be health and strong enough and the height is about 50 cm or more. *Jatropha curcas* plant has root system that is able to with stand with water and soil, so it is a drought resistant crop plants and serve as plant barriers to erosion. Besides, jatropha can also be adapted to soils that are less fertile or saline soil, have good drainage, not flooded, and soil pH from 5.0 to 6.5.

Plant material can be in the form of seeding, stem cutting or seed. If planting is made using seed, the planting space is 2 x 2 m and needs seed about 5-6 kg/ha in which 2 seeds per hole. Planting is conducted at the beginning or during rainy season to provide sufficient water availability for plants. The seeds should be health and strong enough with 50 cm height.

Wide space of plants can give higher fruit production at least for 2 years. Thinning should be conducted in area with dense population. Replanting activitiesis intended to replant the dead plants and ungrowing plants. Replanting should be done at 3-6 months using the same seed.

Planting is conducted after creating planting hole for 2-3 weeks at the beginning of rainy season to avoid rood seeding.Upper soil which locates at the north side is mixed with manure (1-2 kg per hole) and chemical fertilizers (20 g of Urea, 50 g of SP-36 and 10 g of KCl). From a total urea of 20 g, ½ portions (10 g) of urea is applied at the time of planting, while the other 10 g is given 1 month later. The seedling is placed into the hole after polybag is cut at the bottom and made an incision at the polybag until the tip point. Direct planting on the field is conducted by putting stem cutting into the planting hole in 10-20 cm deep and recommended to use at least 50 cm long stem cutting which have 1-2.5 cm diameter. At the end of the planting, the hole should be filled with remain soil on the surface and compacted. For planting in dry climate, the soil surface on planting hole should be concaveto hold much water in the rainy season. In wet climate, the surface of the planting hole should be elevated or form *gulud* shaped to avoid the puddles that can cause drainage and poor soil aeration. Back up seedling as much as 20% (500 seedings) should be prepared for replanting.

Pruning

Jatropha curcas is planted as a fence cropor estate crop which should be pruned periodically for maximal branching. Pruning is carried out to increase the number of productive branches. More branches on jatropha will produce more seeds. In order to increase the number of branches, pruning can be conducted in 25 days. Pruning is done by cutting the plant shoots as high as 20-30 cm from the ground, leaving at least 2 leaves on the rest of the trunk. Pruning is done on the woody trunk (grayish brown). On the cut trunk, new branches will grow and should be maintained. The quantity and quality of bunches that will appear in each branch is influenced by the level of soil fertility. Thinning also needs to be done to reduce the occurrence of competition among plants that can essentially be used as a source of seeds or stem cuttings. Pruning and thinning should be carried out periodically. Data planting of *Jatropha curcas* in 6 ha in PT. Adaro-Tanjung Banjarmasin is as follows:

- Location : S2
- Planting Year : 2010
- Planting distance : 2 m x 2 m
- Variety : IP - 1P
- Number of plants : 3,438 trees
- Fertilizer dose i.e. : 10 g of NPK/tree during planting, and ½ kg of manure/tree

In the process of plant preservation, in order to provide fertile land for good *Jatropha curcas* growth, some weeds should be planted also during hydro seeding as shown in Figure 3.33. Figure 3.34 shows some pictures of *Jatropha curcas* plants aged about 1.5 years in PT Adaro.

4. Fertilization Stage

Fertilizeris principally applied to increase the availability of nutrients for plants. The type and dosage of fertilizer are adapted to the required soil fertility. Dose of fertilizer for plants per ha: 80 kg of N, 18 kg of P_2O_5, 32 kg of K_2O, 12 kg of CaO and 10 kg of MgO. N fertilizeris applied at the time of planting and 28 days after planting (DAP), while P, K, Ca and Mg fertilizer are given at the time of planting. Organic fertilizer application is recommended to improve soil structure. Other material that can be used as a substitute and companion of compost fertilizer is residual yield of jatropha extraction. The use of this material aims to reduce the cost of fertilizer. Fertilizer dose is shown in Table 3.10. Fertilization can be done as many as two times a year at the beginning of rainy season and the end of rainy season. Plants need organic fertilizer/compost, N, P and K in order to obtain maximum result. Mikoryza bacterial can help the growth of plants on land with limited content of phosphate. If oil experiences nitrogen deficiency, flower will fall and the seed production will be disrupted.

Table 3.10 Jatropha fertilizer dosage (gr/tree/year)

Year-	Urea	SP-36	KCl
1	2 x 20	2 x 20	2 x 20
2	2 x 40	2 x 30	2 x 30
3	2 x 60	2 x 50	2 x 40
4	2 x 100	2 x 75	2 x 60
>=5	2 x 150	2 x 100	2 x 80

Figure 3.33 Weeds planted in *Jatropha curcas* area

Figure 3.34 Existing *Jatropha curcas* plantation in PT Adaro

Fertilizer application is carried out as follows:

- Make a small trench around the plant as far as ¾ crown with a depth of about 3-5 cm.
- Prepared fertilizers are sown or inserted into the ditch. Ditch is then covered with soil and compacted.

5. Protection Stages

Weeding

New planted *Jatropha curcas* is very sensitive to weed (others disturbing crops). Therefore, weeds must be controlled periodically until the plant reaches four months old. Intensive control should be done around the plant with a distance of one meter from the plant stem. Control of weeds can be done by using a hoe to remove or clean it. Hoeing should be done carefully to avoid disturbing the roots. Weeds can also be treated with chemicals.

Pest control

Jatropha curcas planted by farmers in Indonesia is known as a toxic plant that has insecticidal properties due to the absence of pest and diseases attack. This is presumably due to the planting system that is generally mixed with other plants such as Gliricidia (*Glyrecidiamaculata*) and hibiscus. Pest and disease attack will emerge if planting is done extensively especially with monoculture systems. Insects attack *Jatropha curcas* plant at the inflorecent flower and fruit, while termite attacks the base of stem. Control can be performed technically and chemically even it is recommended to use biological material. It is also important to maintain the condition of plant and soil from various pesticide contaminations.

6. Harvesting Stages

Harvest and productivity

Jatropha curcas plant starts flowering after 3-4 months, while the fruit formation began at 4-5 months. Harvesting is done when the fruit is ripe, yellow fruit skin and began to dry up. Ripe fruit is reached after 5-6 months. Jatropha is a perennial plant that can live more than 25 or 50 years if maintained properly.

At the first harvest, the productivity of *Jatropha curcas* is only 0.5 to 1 ton of dry beans per ha per year. Furthermore, yields can be increased gradually up to 5 tons in the fifth year after planting. Harvesting can be performed by picking the fruit using hand or scissors. The productivity of *Jatropha curcas* ranges from 3.5 to 4.5 kg seeds/tree/year. Population is between 2500 - 3300 trees/ha, the productivity is between 8-15 tons of beans/ha. If the oil yield is 35%, each hectare can produce 2.5 to 5 tons of oil/ha/year. Production unit is determined in weight unit by kg or ton. Good quality of dry grain is expressed in 1300-1500 grains per kilogram, while the poor one only reaches up to 2000-2500 grains.

7. Extraction stages (beans to CJCO)

Several methods that can be used to obtain the oil or fatty substance are rendering, mechanical pressing technique and solvent extraction.Mechanical pressing is a method of separating the oil from the material in the form of grains and most suitable to separate the oil from the high oil content (30-70 percent). *Jatropha curcas* oil is contained in the material in the form of seeds (approximately 48-58 percent) (Banerji et al., 1985 in Ferry, 2009). Based on these conditions, the most appropriate method for extraction of *Jatropha curcas* is mechanical pressing technique.

Crude *Jatropha curcas*Oil (CJCO)

The bean of *Jatropha curcas* consists of 60 percent of weight kernels (fruit pulp) and 40 percent of the skin weight. Nucleus seed (kernel) of jatropha oil contains about 40-45 percent oil that can be extracted by mechanical or solvent extraction such as hexane. Jatropha oil is a type of oil that has triglyceride composition similar to peanut oil. Unlike Jatropha Kaliki (*ricinus communis*), the essential fatty acids in jatropha oil is high enough so that jatropha oil can be directly consumed as long as the poison content such as phorbol ester and curcinishad been removed. *Jatropha curcas* oil is denser than other vegetable oil. Two methods that are commonly used in mechanical pressing are hydraulic pressing and expeller pressing. Hydraulic press is pressed by pressure around 140.6 kg/cm. The amount of used pressure will affect the yield of *Jatropha curcas* oil. In hydraulic pressing, prior to pressing, jatropha needs pretreatment such as cooking to coagulate protein. Protein clumping is needed for efficient extraction. Hydraulic press is generally produced oil yield up to 30 percent. Figure 3.35 shows the flow diagram of *Jatropha curcas* oil extraction method using hydraulic presses. The complete diagram along with the equipment is shown in Appendix 7.

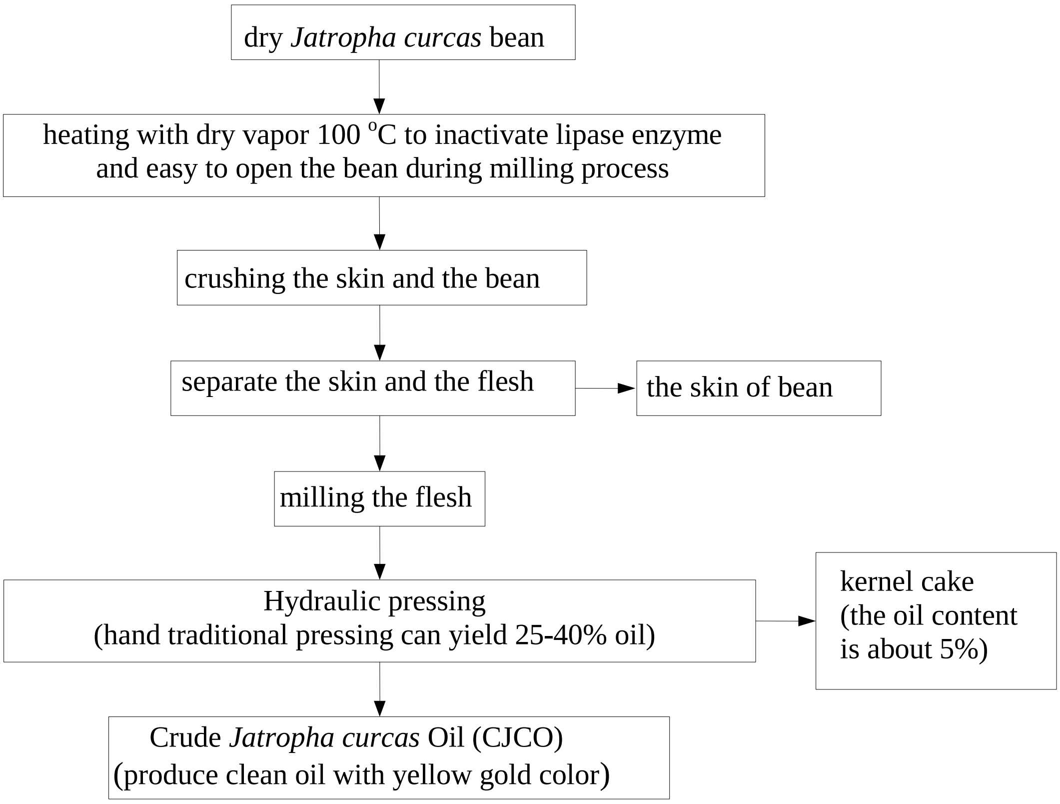


Figure 3.35 *Jatropha curcas* oil extraction using hydraulic pressing

Oil pressing technique using screw is a more advanced technology and widely used in the oil processing industry today. In this method, the beans are pressed using screw press that runs continuously. This extraction technique does not require pre-treatment. Dry jatropha beans can be directly inserted into screw press. The screw press can be a single screw pressor twin screw press. Yield of jatropha oil produced by single screw pressing techniques is approximately 25-35 percent, while the technique of twin screw press produces approximately 40-45 percent. Figure 3.36 shows the pressing process flow diagram using screw pressing method. The complete diagram along with the equipment is shown in Appendix 8.

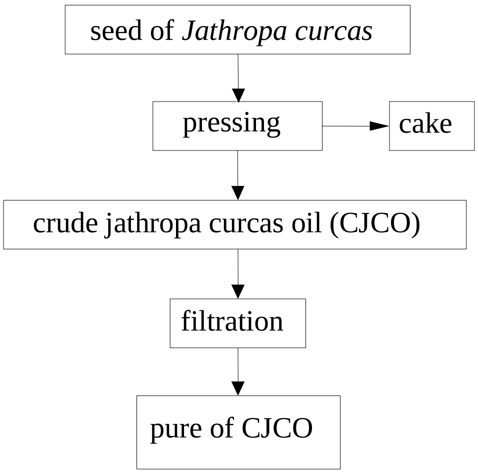


Figure 3.36 *Jatropha curcas* oil extraction using screw pressing

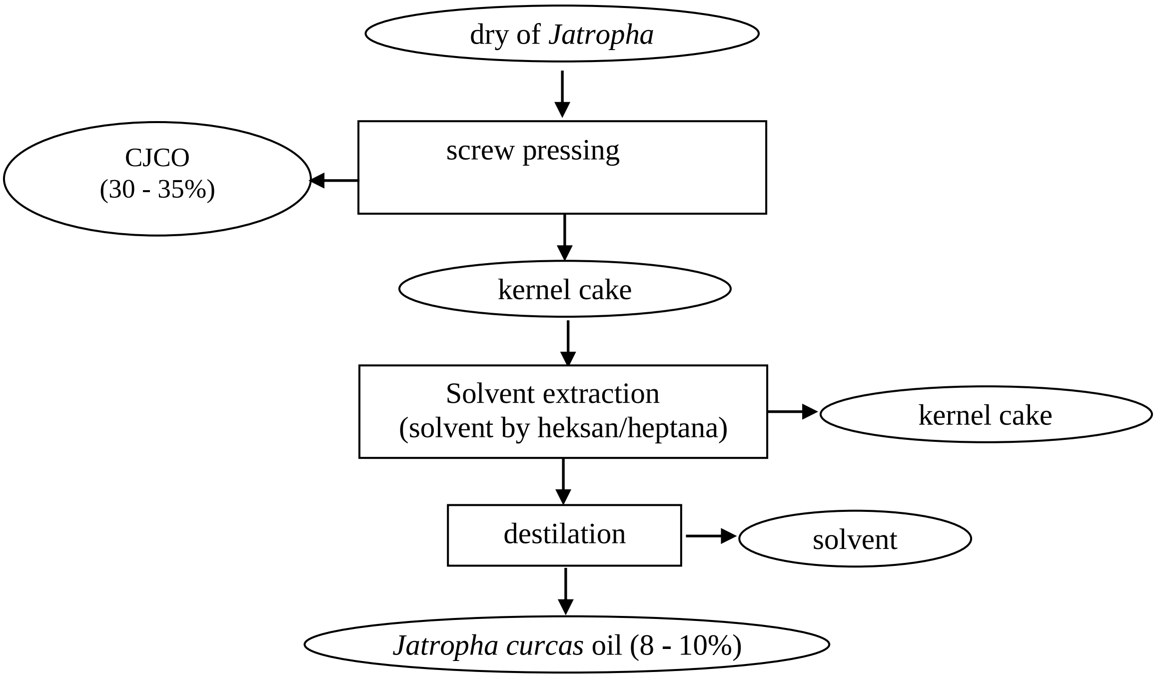


Figure 3.37 Oil extraction flow chart from *Jatropha curcas* beans under combination method of twin screw press and solvent extraction

Mechanical pressing technique can also be combined with solvent extraction technique. Although it results good quality, especially when using solvent extraction method, the production cost is very expensive. So the combination method of pressing and solvent extraction is not suitable for small and medium industries. This combination of techniques is more appropriate for large industries. Figure 3.37 presents oil extraction flow chart from jatropha beans under combination methods.

The advantages on using screw pressing are as follows :

- Production capacity increases due to continue pressing process.
- Saves time because the production process does not require pretreatment, i.e.size reduction and cooking/heating.
- Increase yield

8. Biodiesel Production Stage

Methyl ester (biodiesel) from jatropha oil can be produced through a process of transesterification. In the production of biodiesel, the common used catalyst is sodium ethylate, NaOH or KOH. To drive the reaction to move right to produce methyl ester (biodiesel) it is necessary to use alcohol in excess amount or one of the resulting products must be separated. The main factors affecting the ester yield under transesterification reaction are molar ratio between triglycerides and alcohol, the type of used catalyst, the reaction temperature, reaction time, water content, and free fatty acid content in the raw material (which may inhibit the expected reaction). Others factors affecting the ester content of biodiesel are the content of glycerol, the type of alcohol used in the transesterification reaction, the amount of residual catalyst and soap content.

Figure 3.38 shows the production process stages of biodiesel using CJCO. This scheme shows common production process which is generally carried out by milling industry i.e. esterification process followed by transesterification stage 1 and stage 2. Esterification reaction with acidic catalysts is performed due to FFA value of CJCO is greater than 5%.

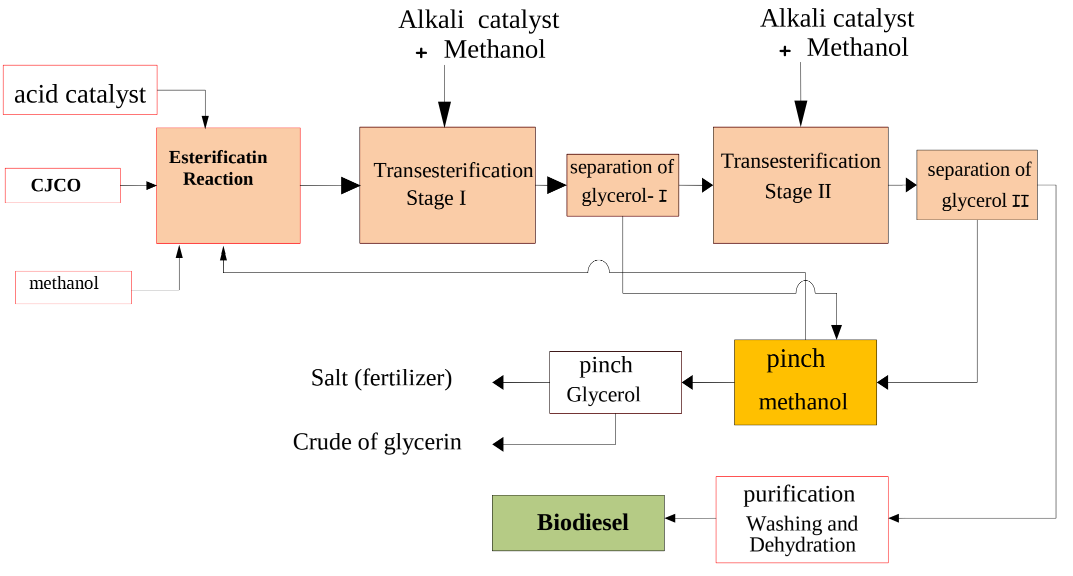


Figure 3.38 CJCO process under catalytic method in PT Adaro (esterification and 2 stages transesterification)

Detail process of biodiesel production from CJCO is similar with crude palm oil (CPO). The difference is that esterification process should be performed in CJCO process. Flow chart of mass and energy balance at each sub process of esterification is as follows:

Sub Unit of Esterification Reactor

This sub unit is used to react free fatty acid and methanol in the presence of sulfuric acid catalyst (Figure 3.39).

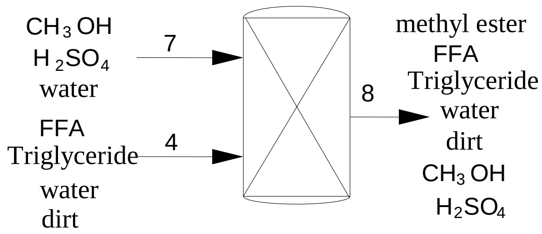


Figure 3.39 Sub unit of esterification reactor

The input on line number 7 is: methanol, sulfuric acid, and water. The input on line number 4 is: FFA, triglycerides, water, and dirt. While the output on line number 8 is: methyl esters, FFA, triglycerides, methanol, sulfuric acid, water, and dirt.

The results of biodiesel milling plant survey which implemented in PT.Adaro are as follows:

- Biodiesel plant capacity is 1.1 tons per day
- Raw material used in the process is still obtained from the outer city. Based on the results found in the field, CJCO is purchased from Jakarta and West Nusa Tenggara.
- FFA value of CJCO is higher than 5% i.e. 7% to 11%. Thus, esterification process should be followed by transesterification.
- FFA value of CPO is less than 5%. Thus it only needs transesterification process.
- Biodiesel plant in PT.Adaro is developed by BPPT Serpong, Indonesia. In general, the existing system of machine equipment consists of : crude oil tank, degumming tank, degummed oil tank, FFA tank, FFA separator, FFA recovery tank, vacuum evaporator (FFA) tank, FFA free oil tank, vacuum (oil) evaporator tank, salt water tank, alkaline tank, mixing alkaline catalyst tank, mixing acid catalyst tank, washing tank, reactor tank 4 units, vacuum evaporator biodiesel, esterification reactor 1 unit, transesterification reactor 3 units, QC tank, biodiesel tank 4 units, and pump equipment at each stage.

Conclusion

The conclusions that can be drawn in this chapter are as follows:

1. Palm oil consumes higher input material and energy than *Jatropha curcas*.
2. *Jatropha curcas* starts to produce at 4 months (the first year), while palm oil starts to produce at 30 months (the third year).
3. Intensive application of agro-chemical input (fertilizers, herbicides, pesticides, etc.) on oil palm and *Jatropha curcas* occurs during the 1-5 years (unstable production). Stable application occurs when the plants have reached 6-25 years (stable production).
4. The life cycle of oil palm is 25 years, while *Jatropha curcas* can reach up to 50 years, but the effective life cycle is only up to 25 years.

5. The productivity of oil palm is higher than *Jathropa curcas*. It can be seen that oil palm productivityis around 21.5tons of FFB per hectare per year (around 4.3 tons biodiesel per ha per year), while the productivity of *Jatropha curcas* is about 5 tons per ha per year (around 1.09 biodiesel tons per ha per year).
6. *Jatropha curcas* consumes higher organic fertilizer than oil palm. On the contrary, oil palm consumes higher NPK fertilizer than *Jatropha curcas*.
7. Biodiesel production from CPO only needs transesterification process due to the FFA value is lower than 5% (other references mention that FFA value is lower that 2%). Biodiesel production from CJCO needs esterification and transesterification process due to the FFA value is higher than 5%.

CHAPTER 4
IMPACT ASSESSMENT

Introduction

Life cycle impact assessment (LCIA) is the third phase of LCA. The main goal of this stage is to interprete the quantified environmental burden in LCI stage. Impact selection, category indicators, and LCIA model used in this research reflect the environmental issues of the observed system. Classifications involve aggregation of environmental burdens to a small number of environmental impact categories which will demonstrate their impacts on existed resource depletion. In this stage, the existed environmental burden is calculated and analyzed as well as interpreted as the potential impacts. The purpose is to present the potential impacts in the form of analysis which is useful as the research outputs and can be understood by users.

LCA model focuses on physical characteristics of industrial activities and other economic processes; it does not include market mechanisms or secondary effects on technology development. In general, LCA regards all processes as linear, both in the economy and in the environment. LCA is a supporting tool based on linear modeling. Furthermore, LCA focuses on environmental aspects of products and disregard the economic, social, and other characteristics. The environmental impacts are often defined as "potential impacts", as they are not specified in time and space and are related to an arbitrarily defined functional unit.

Although LCA aims to be science-based, it involves a number of technical assumption and value choices. An important role is played by ISO standardization process, which helps to avoid the arbitrariness. Another important aim is to make these assumptions and choices as transparent as possible. Finally, fundamental characteristic considers that LCA is an analytical tool as it provides information for decision support. However, LCA can not replace the decision making process it self.

The objective of this chapter is to carry out impact assessment on data collected in Chapter 3 and assess some option scenario to obtain optimum result which reflects the real condition of Indonesia.

Literature Review

In the impact assessment phase, the result of inventory analysis is interpreted on the contribution to a relevant impact category such as the depletion of abiotic natural resource, climate change, acidification, and many more. There are three different groups of impact category that can be chosen based on the interest of environment in relation to LCA and available characterization method. Intervension conducted on inventory analysis results is quantified in general indicator. In impact category, a characterization method consists of category indicators, model characterization, and factor characterization. According to Ciambrone (1997), Life Cycle Assessment considers 5 output types, i.e.: atmospheric emissions, water borne wastes, solid wastes, products, and by-products. These are some points of basic characterization methods developed by

Guinee et al. (2001) which is used on baseline impact categories. The first group, basic impact category, consists of 11 impacts, i.e.:

- Resource depletion
- Land use impact (land competition)
- Climate change
- Stratospheric ozone depletion
- Human toxicity
- Ecotoxicity, consists of 3 impacts: fresh water aquatic ecotoxicity, marine aquatic ecotoxicity, and terrestrial ecotoxicity.
- Photo-oxidant creation
- Acidification, and eutrophication

On the second group, study specific impact categories consist of 9 impacts:

- Impacts of land use (losses on life support functions, losses on flora and fauna diversity)
- Ecotoxicity, consists of two types: toxicity impacts on sediment in fresh water and marine ecosystem
- Impacts of ion radiation
- Noise, heat energy waste
- Causal relationship

On the third group, another group category consists of three impacts which can be added when needed:

- Abiotic resource depletion
- Dry preservation
- Maladourous water

In the classification stage, the results of inventory analysis are classified into appropriate impact categories. In the characterization stage, the results are calculated to be combined with appropriate characterization factors, and the calculations are processed to obtain indicator scores. A complete collection of category results produces an environment profile. The primary goal is to obtain a better under standing about relative interests and the amount of interests on each product system used in the study. The last two stages in this phase i.e. grouping and weighting are considered as optional stages. Grouping assigns impact categories into one or more sets to provide better facilitation on the interpretation of the results into specific areas of concern. Weighting determines numerical factors of each evaluated impact category according to relative interests.

Key steps of a Life Cycle Impact Assessment

Steps of LCIA conducted in the research are:

1) Selection and definition of impact categories: identifying relevant environmental impact categories. Five points related to the research are: global warming potential, acidification, eutrophication, waste landfill volume, and energy consumption.
2) Classification: classifying data inputs and outputs of inventory analysis into impact categories (e.g: classifying CO_2 emission to global warming potential).
3) Characterization: modeling environmental impact within impact categories using science-based conversion factors (e.g., modeling the potential impact of CO_2 and methane (CH_4) on global warming)

4) Normalization: comparing impact indicator (emission factor data based) results with standardized value. Due to the absence of normalization standard in Indonesia, MiLCA-JEMAI software refers to IPCC data and other common standards according to LCA-ISO 14040.
5) Grouping: sorting or ranking the impact indicators (e.g: sorting the indicators by location: local, regional, and global).
6) Weighting: emphasizing the most potential impacts.

The first three steps are mandatory to build an LCIA model while the other steps are optional. Impact category selection, category indicators, and LCIA model must be consistent with the goal and scope of LCA and must reflect environmental issues of the observed system. Classifications involve aggregation of environmental burden to a small number of environmental impact categories which will demonstrate their impacts on human health, ecological health, and resource depletion rate. In this step, existed environmental burdens are calculated and analyzed. It will be interpreted in the form of potential impacts. This step aims to express the potential impacts in the form of analysis which is useful as the research outputs and is understood by users. Impact analysis types are grouped by considering degredation of abiotic and biotic resource, global warming, acidification, eutrophication, and toxicity level (Cowell, 1999).

In general, LCIA focuses on the relationship between LCI and LCIA steps, for example on how environmental burdens will contribute to potentially arise environmental impacts, before eventually giving effects to ecosystem survival (midpoint damage). The example of problem-oriented method is CML Baseline. The next method is damage-oriented method. It focuses on the endpoint damage which caused by environmental burdens and impacts. Commonly used damage-oriented methods are EPS 2000 (Steen, 1999) and Eco-Indicator 99 (Goedkoop and Spriensm, 2001 and Doka, 2007).

LCA depends on data availability and reliability. Therfore, it requires sensitivity analysis to indentify the effect of data variability, uncertainty, and the deficiencies in final results which leads to determination of reliability. General approaches to compile the information about the extent human activities take place (activity data or AD) with coefficient of emission-measurement or absorption per unit activity. It is called emission factor (EF). Basic equation of EF is displayed in Equation 4.1.

$$\text{Emission} = AD * EF \qquad (4.1)$$

Where :AD : Activity data; EF : Emission factor

Method

Time and Place

The research was conducted in Heat and Mass Transfer Laboratory, Department of Mechanical Engineering and Biosystem, Faculty of Agricultural Technology, started from July 2012 to January 2013.

Measurement Tools and Impact Analysis

Impact assessment (life cycle impact assessment/LCIA) was conducted using MiLCA-JEMAI software (Multiple interface Life Cycle Assessment-Japan

Environmental Management Association for Industry) version 1.1.2.5 (regular license) using data inventory collected in LCI stage in Chapter 3. Calculation process scheme in this research is displayed in Figure 4.1. The software refers to ISO 14040 as international standard of LCA study. However, the researcher using the available data in Indonesia in life cycle inventory stage.

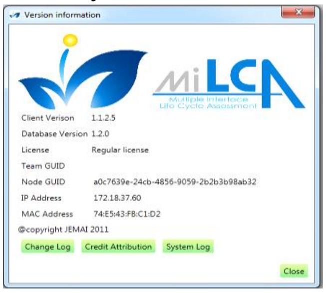
INPUT	PROCESS Calculation by Software MiLCA-JEMAI	OUTPUT
MATERIAL & ENERGY: • Electricity, • Fertilizerr, • Incecticide • Methanol • Etc		• Global warming potential • Acidification • Eutrophication • Waste，landfill volume • Energy consumption

Figure 4.1 Calculation procedure by MiLCA-JEMAI

Stages of work that needs to be done using MiLCA-JEMAI software are: Project information, Product system, Inventory analysis, Impact assessment, Interpretation, Reporting, and Expert review, which is displayed in Figure 4.2. Standard operational procedure to operate MiLCA-JEMAI software is shown in Appendix 9.

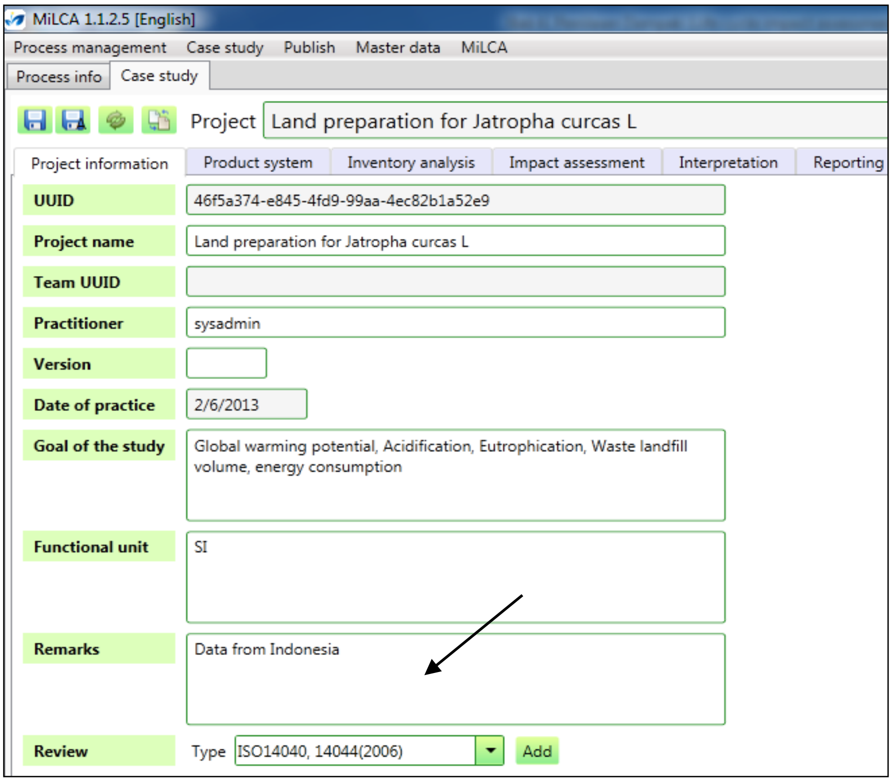


Figure 4.2 Display of MiLCA-JEMAI software version 1.1.2.5

In the stage of impact analysis, two impacts were analyzed. It consisted of environmental impacts and energy consumption. The descriptions are listed below:

1. Environmental Impact Analysis

Environmental burdens which includes in biodiesel processing are: atmospheric potential of atmospheric emission to global warming (greenhouse effect), acidification, and eutrophication, as well as waste landfill volume.

Characterization factor used to predict global warming potential of impact categories was emission data conversion to estimate the possible impacts in the future. For the potential impacts of greenhouse effect, all atmospheric emission data were converted into CO_2 equivalent (eq.). While for acidification, all atmospheric data were converted into SO_2 equivalent. The laststage in eutrophication, all data were converted into PO_4 equivalent. Characterization factors of atmospheric emission impacts are displayed in Table 4.1.

Table 4.1 Characterization factors of atmospheric emission impacts

Variabel	Greenhouse effect[a] (CO_2 equivalent)	Acidification[b] (SO_2 equivalent)	Eutrophication[c] (PO_4 equivalent)
CO_2	1	-	-
CH_4	21	-	-
N_2O	310	-	-
N	-	-	0.42
SO_x	-	1	-
NO_x	-	0.7	0.13

Sources : IPCC, 2007[a]; Guinée et al., 2002[b]; Heijungs et al., 1992 in Haas et al., 2000[c]

To perform manual calculation, it can be done using equivalence value of compiled environmental impacts in CML-IA Database version 3.9. From the emission value, the value of environmental impacts can be calculated.

The next step was to identify the emission reduction or addition caused by the use of biodiesel i.e.:

- **Exhaust emission reduction by the use of biodiesel** : exhaust emission caused by the use of biodiesel will increase local air quality due to emission reduction of CO_2 (0.025 kg CO_2/MJ energy of biodiesel) and hazardous emission such as CO, O_3, NOx, SO_2, and other reactive hydrocarbon emission, as well as smog and small particles.
- **Development Stage**:

- **Physics-Chemistry**: disturbance of physics-chemistry components especially occurs to: (1)air quality, during biodiesel development process, it is estimated that air quality will be decreased due to land leveling activities, mobilization, and heavy machines operation, and the construction itself. The disturbance it self can be seen as the increasing smog occurs and noise; (2)water quality reduction, where the construction workings damage water quality because it is estimated there will be certain amount of run-off seep into water body bringing pollutants from the construction location. Pollutants might be in the form of fuel and lubricants spills, sedimentation, and domestic waste.
- **Biology**: if the proposed land is as the part of feedstock estate for biodiesel industry, the real disruption to sub-components of terrestrial biota is estimated

not going to occur. The possible disruption is on sub-components of aquatic biota (derivative impacts of water quality reduction)

- **Operational Stage**

- **Physics-Chemistry**: the operational of biodiesel industry will generate waste which leads to environmental contamination, especially caused by liquid wastes from the factory operational activities. It must be processed and neutralized before discharging into receiving water bodies. Therefore, biodegradation is proposed to break the complex organic compound into simple organic compound in anaerobic conditions, so that the limitation standard can be adjusted to environment carrying capacity, especially to water. Liquid wastes from biodiesel plant contain complex organic compound such as carbohydrate, protein, and fatty acid.
- **Biology**: as implemented in the construction of biodiesel plant, estimated impacts occur in the operation phase of biodiesel plant to biological components is not great. Liquid wastes will be treated in Liquid Waste Treatment Installation which also treat liquid wastes from another activities, for example when the biodiesel plant is integrated with feedstock plant (palm oil plant is integrated to biodiesel plant)

2.Energy Impact Analysis

Energy consumption analysis and the discussion of Net Energy Balance (NER), Net Energy Ratio (NER), and Renewable Index (RI) will be explained in Chapter 5.

Assumptions and Impact Assessment Limitation

A few assumptions used in this study are:

- Seed transportation, fresh fruit bunch/physic nut, and CPO or CJCO are included in calculation using this scheme, from seeding location to estate, from estate to palm oil plant, from palm oil plant to biodiesel plant. The distance to be included in calculation is estimated for one-way trip with central point in palm oil plant *Unit Kebun Kertajaya Lebak Banten* and *Pusat Induk Jarak Pagar* Pakuwon Sukabumi (Jatropha Curcas Estate Center Pakuwon Sukabumi). The distance from seeding location to planting location is 30 km, truck capacity 5 ton, fuel ratio 1:5 (1 liter for 5 km); the distance from harvesting area for transporting fresh fruit bunch (FFB) to palm oil plant is 150 km, truck capacity is 10 ton with fuel ratio 1:7, and the distance from palm oil plant to biodiesel plant (in Bekasi) is 200 km, truck capacity is 10 ton.
- Material transportation such as fertilizer from the stores to location is calculated.
- Palm oil plant is assumed to have performed methane capture.

Impact Evaluation Scenario

Impact evaluation was made and analyzed in 5 scenarios, i.e.:

1. Scenario 1 : Using primary data from PTPN VIII *Unit Kebun Kertajaya Lebak Banten* and *Jatropha curcas* Estate Center *Pakuwon Sukabumi*
2. Scenario 2 : The calculation was conducted before stable production (1-5 years), and did not calculate the transportation to transport material used from the store to the location of the material used.
3. Scenario 3 : The calculation was conducted annually, from year 1 to year 5 (before stable production) and from year 6 to year 25 (stable production). The

calculation used Indonesian electrical data and calculated the transportation to transport material used from the store to the location.

4. Scenario 4 : Using organic fertilizers for fertilization stages, other aspects were similar with scenario 2.
5. Scenario 5 : Using 20% of biodiesel to substitute diesel fuel for Indonesian power plant, as stated in government target in 2025.

Results and Discussion

Scenario 1

Greenhouse gas (GHG) emission on this research is the source of global warming potential (GWP). Thus, the next analysis uses the term of greenhouse gases as global warming potential value. Five categories of environmental impacts are greenhouse gas (GHG), acidification, waste for landfill volume, eutrophication, and energy consumption (Table 4.2). Table 4.2shows that total environmental impact beforestable production for biodiesel production from palm oil is higher than that of *Jatropha curcas* oil. GHG is the most significant environmental impact caused by biodiesel production either from palm oil or *Jatropha curcas* oil.

Most of GHG emission produced from utilization of agro-chemical is in the form of fertilizer and plant protection which is accounted by 50.46% and 33.51% of the total emission released from palm oil and *Jatropha curcas*, respectively.Other works conducted by Pramudita (2011) and Sekiguchi (2012) showed that the value of GHG emission of crude *Jatropha curcas* oil (CJCO) extraction process was estimated to be 1.34 kg-CO_2eq./kg-CJCO and 0.08 kg-CO_2eq./kg-BDF. In this research, the GHG value was 18.65 kg-CO_2eq./ton-BDF with the assumption that drying was carried out naturally (sun drying). Siangjaeo et al. (2011) mentioned that carbon stock changed by 709, -748, and -600 Mg-CO_2eq. per day at 1 million liters biodiesel production in Krabi, Chonburi, and Pathumthani, respectively.

Life cycle of oil palm is about 25 years, while *Jatropha curcas* can reach up to 50 years (Pranowo, 2009; Ferry, 2009; Tjahjana et al., 2010), even the production of *Jatropha curcas* is stable until the 25th year. According to Figure 4.3 and Figure 4.4, it can be seen that the GHG value for oil palm is higher than *Jatropha curcas* in every stage except in planting and producing biodiesel.The most significant environmental impact based on GHG value is due to fertilizing and biodiesel production stages both at oil palm and *Jatropha curcas*. The total value of GHG emission before-stable production is 2568.82 and 1733.67 kg-CO_2eq./ton-BDF for oil palm and *Jatropha curcas*, respectively. Figure4.3 shows that oil palm's GHG value of eight sub-processes which consist of land preparation, seedling, planting, fertilizing, protection, harvesting, palm oil plants, and biodiesel production is0.44 %, 0.61 %, 0.91 %, 35.15 %, 15.31 %, 1.23 %, 22.90 %, and 23.44 %, respectively. While for *Jatropha curcas* as shown in Figure4.4 is 0.63 %, 0.74 %, 11.79 %, 29.49 %, 4.02 %, 0.48 %, 1.08 %, and 51.78 %, respectively. Table 4.3 shows the proportion of each stage including pre-harvest, harvest and post-harvest.

Table 4.2 Environmental impacts to produce 1 ton BDF from Oil palm and *Jatropha curcas* (1-5years)

Input activities	Input names	Unit	Oil palm	*Jatropha curcas*
(1) Land Preparation	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	11.21	10.88
	Acidification, DAF(LIME,2006)	kg-SO_2eq	0.020	0.017
	Waste,landfill volume(LIME,2006)	m^3	4.92E-06	5.7E-06
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	1.02E-06	1.18E-06
	Energy consumption,(fossil fuel)	MJ	163.41	161.66
(2) Seedling	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	15.73	12.81
	Acidification, DAF(LIME,2006)	kg-SO_2eq	0.026	0.021
	Waste,landfill volume(LIME,2006)	m^3	9.57E-05	1.62E-04
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	1.93E-06	1.34E-06
	Energy consumption,(fossil fuel)	MJ	242.94	186.28
(3) Planting	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	23.46	204.38
	Acidification, DAF(LIME,2006)	kg-SO_2eq	0.04	0.40
	Waste,landfill volume(LIME,2006)	m^3	0.00038	0.0044
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	2.85E-06	4.17E-05
	Energy consumption,(fossil fuel)	MJ	387.40	3394.34
(4) Fertilizing	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	902.90	511.27
	Acidification, DAF(LIME,2006)	kg-SO_2eq	1.02	0.81
	Waste,landfill volume(LIME,2006)	m^3	0.0071	0.0088
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	0.000058	0.000074
	Energy consumption,(fossil fuel)	MJ	18240.00	10841.11
(5) Protection	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	393.38	69.64
	Acidification, DAF(LIME,2006)	kg-SO_2eq	0.69	0.21
	Waste,landfill volume(LIME,2006)	m^3	0.00067	0.0011
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	0.000069	8.93E-06
	Energy consumption,(fossil fuel)	MJ	6211.61	1178.64
(6) Harvesting	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	31.67	8.27
	Acidification, DAF(LIME,2006)	kg-SO_2eq	0.058	0.015
	Waste,landfill volume(LIME,2006)	m^3	1.1E-08	2.86E-09
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	9.47E-11	2.47E-11
	Energy consumption,(fossil fuel)	MJ	422.55	110.38
(7) Palm oil mills or Extraction oil	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	588.34	18.65
	Acidification, DAF(LIME,2006)	kg-SO_2eq	0.98	0.053
	Waste,landfill volume(LIME,2006)	m^3	0.00082	5.24E-06
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	0.000064	7.49E-06
	Energy consumption,(fossil fuel)	MJ	7994.14	234.18
(8) Biodiesel production	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	602.12	897.77
	Acidification, DAF(LIME,2006)	kg-SO_2eq	0.72	0.98
	Waste,landfill volume(LIME,2006)	m^3	0.00031	0.00052
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	0.000047	0.000059
	Energy consumption,(fossil fuel)	MJ	16169.11	25623.45
Total	GHG, 100-year GHG (IPCC, 2007)	kg-CO_2eq	2568.82	1733.67
	Acidification, DAF(LIME,2006)	kg-SO_2eq	3.55	2.50
	Waste,landfill volume(LIME,2006)	m^3	0.0094	0.015
	Eutrophication, EPMC(LIME,2006)	kg-PO_4eq	0.00024	0.00019
	Energy consumption,(fossil fuel)	MJ	49831.17	41730.03

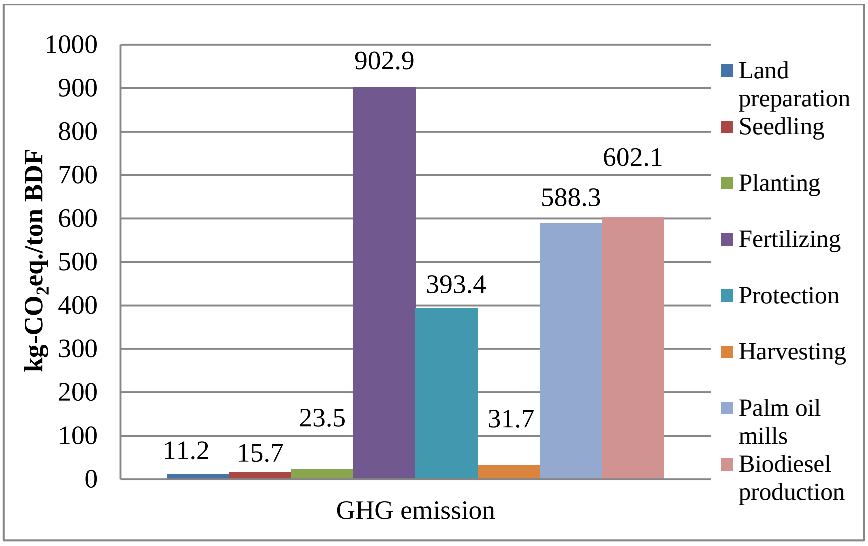


Figure 4.3 The value of GHG emission of oil palm before stable production (1-5years)

Table 4.3 Percentage of GHG-100 years for LCA with cradle to gate boundary of oil palm and *Jatropha curcas*

Input activity	Percentage (%)	
	Oil palm	*Jatropha curcas*
Pre-harvest	52.42	46.66
Harvest	1.23	0.48
Post-harvest	46.34	52.86

Lord et al. (2009) stated that environmental impact towards aquatic, land, air and others of palm oil processing from operation to processing stage was 47 %, 24 %, 8 %, and 21 %, respectively. Prueksakorn et al. (2006) said that the major contribution of greenhouse gas (GHG) effect during biodiesel production from jatropha came from the production and use of fertilizers, diesel oil consumption for irrigation, and transesterification process which is accounted for 31 %, 26 %, and 24 %, respectively. Prueksakorn et al. (2006) also explained that CO_2 emissions for producing biodiesel from crude jatropha oil with transesterification method was generated from land preparation, cultivation, irrigation, fertilizing, cracking, extraction oil, filtering, and transesterification process which was accounted by 4.7%, 0.2%, 26.1%, 30.3%, 3%, 10.9%, 0.5%, and 24.3%, respectively. Ndong et al. (2009) gave the details of GHG emissions in the various processes involving the cultivation of jatropha, transesterification and combustion which were accounted by 52%, 17% and 16%of the total emissions, respectively. Large emission occured in fertilizer application i.e. 93%.

The calculation analysis for stable production is shown in Figure 4.5. It represents GHG value at stable production which is 1658.50 and 740.90 kg-CO_2eq./ton-BDF for oil palm and *Jatropha curcas*, respectively. The GHG value of oil palm and *Jatropha curcas* decreases until the 5^{th} year and becomes stable until the 25^{th} year.

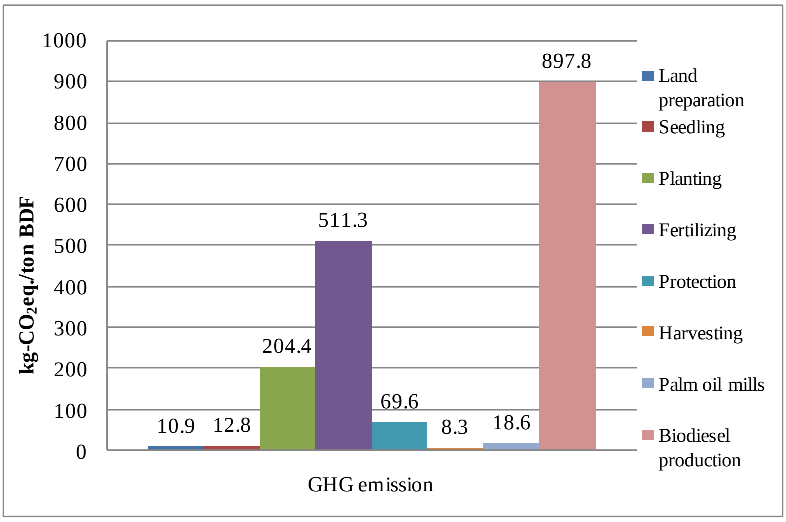


Figure 4.4 The value of GHG emission of *Jatropha curcas* before stable production (1-5 year)

Similar trend occurs in impact assessment including acidification, eutrophication, and landfill waste as shown in Figure 4.6, Figure 4.7, and Figure 4.8. Assessment conducted by Sekiguchi (2012) showed that total CO_2 emission was 0.46 CO_2eq./kg-BDF for SMV method, 0.79 CO_2eq./kg-BDF for alkali-catalyzed method and 3.4 CO_2eq./kg-diesel for diesel oil. The different result might be due to the differences in methods and assumptions used in the study.

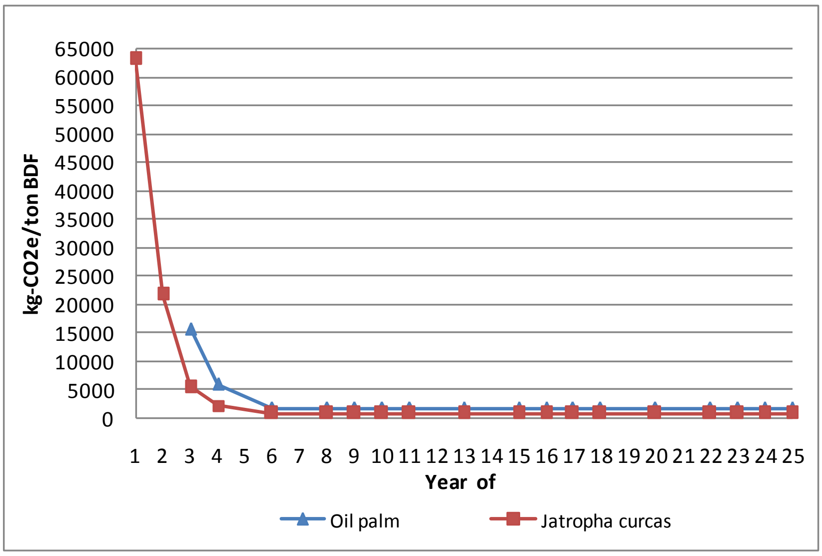


Figure 4.5 The value of GHG emission of oil palm and *Jatropha curcas* before and after stable production (1-25 years)

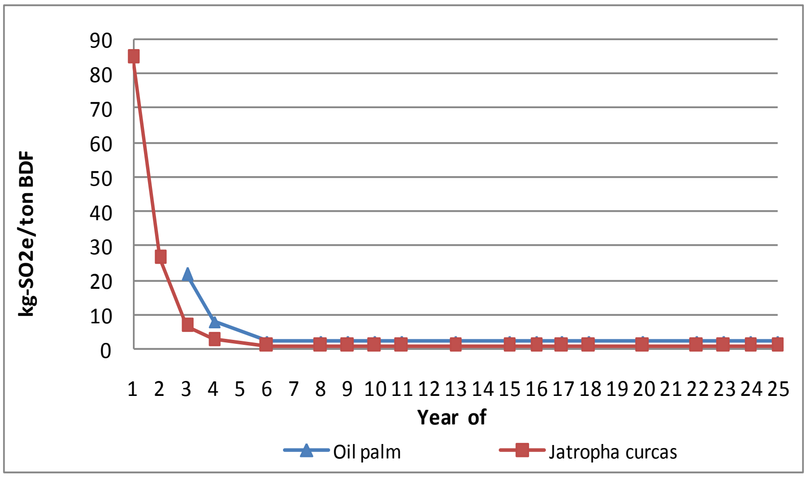


Figure 4.6 The acidification value of oil palm and *Jatropha curcas* before and after stable production (1-25 years)

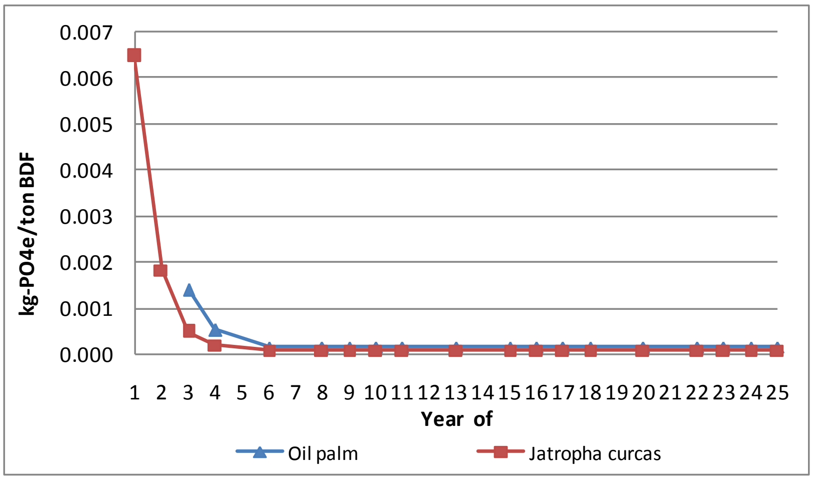


Figure 4.**7** The eutrophication value of oil palm and *Jatropha curcas* before and after stable production (1-25 years)

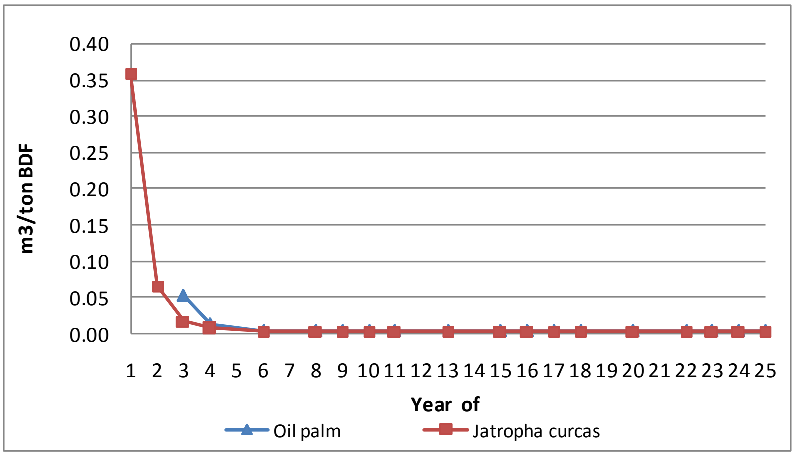


Figure 4.8 The waste landfill volume value of oil palm and *Jatropha curcas* before and after stable production (1-25 years)

Table 4.4 Impact evaluation to produce 1 ton BDF from Oil palm and *Jatropha curcas* (1-5 years)

Input Activity	Input Names	Unit	Oil palm	*Jatropha curcas*
1. Land preparation	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	15.52	8.25
	Acidification, DAF-LIME,2006	kg-SO_2eq	0.043	0.02315
	Waste,landfill volume-LIME,2006	m^3	0.000009	5.01E-06
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	6.60E-08	5.94E-10
	Energy consumption,fossil fuel	MJ	269.70	129.70
2.Seedling	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	29.14	24.93
	Acidification, DAF-LIME,2006	kg-SO_2eq	0.18	0.13
	Waste,landfill volume-LIME,2006	m^3	0.00014	0.00048
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	1.06E-08	4.22E-08
	Energy consumption,fossil fuel	MJ	590.50	481. 50
3.Planting	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	11.71	302.10
	Acidification, DAF-LIME,2006	kg-SO_2eq	0.03	5.39
	Waste,landfill volume-LIME,2006	m^3	0.00028	0.0042
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	1.67E-08	7.96E-07
	Energy consumption,fossil fuel	MJ	251.10	4813.00
4.Fertilizing	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	1408.00	661.40
	Acidification, DAF-LIME,2006	kg-SO_2eq	4.45	6.97
	Waste,landfill volume-LIME,2006	m^3	0.014	0.012
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	0.000032	1.09E-06
	Energy consumption,fossil fuel	MJ	24330.00	11220.00
5.Protection	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	159.35	70.15
	Acidification, DAF-LIME,2006	kg-SO_2eq	0.62	0.26
	Waste,landfill volume-LIME,2006	m^3	0.0029	0.0011
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	2.31E-08	8.72E-08
	Energy consumption,fossil fuel	MJ	2704.50	1179.50
6.Harvesting	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	1.73	0.85
	Acidification, DAF-LIME,2006	kg-SO_2eq	0.0023	0.0012
	Waste,landfill volume-LIME,2006	m^3	5.36E-09	2.63E-09
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	1.81E-13	8.84E-14
	Energy consumption,fossil fuel	MJ	224.80	110.40
7.Palm oil mill or oil extraction	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	94.39	11.15
	Acidification, DAF-LIME,2006	kg-SO_2eq	0.32	0.08
	Waste,landfill volume-LIME,2006	m^3	0.000102	3.38E-09
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	0.000005	1.14E-13
	Energy consumption,fossil fuel	MJ	1447.00	209.80
8.Biodiesel production	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	580.40	868.80
	Acidification, DAF-LIME,2006	kg-SO_2eq	0.97	1.26
	Waste,landfill volume-LIME,2006	m^3	0.00023	0.00026
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	1.85E-08	1.98E-08
	Energy consumption,fossil fuel	MJ	16490.00	25950.00
Total	GHG, 100-year GHG-IPCC, 2007	kg-CO_2eq	2300.24	1947.63
	Acidification, DAF-LIME,2006	kg-SO_2eq	6.61	14.11
	Waste,landfill volume-LIME,2006	m^3	0.018	0.013
	Eutrophication, EPMC-LIME,2006	kg-PO_4eq	3.72E-05	2.03E-06
	Energy consumption,fossil fuel	MJ	46307.60	44093.90

Scenario 2

Table 4.4 displayes the result of total environmental impact from overall average primary and secondary data before-stable production. The similar result with scenario 1 is also gained using this scenario, in which the total environmental impact before-stable production in 5 categories for biodiesel production from palm oil is higher than that of *Jatropha curcas* oil. The greatest portion of GHG value percentage also emerges from utilization of agro-chemical in fertilizer and plant protection, i.e 68.14% for palm oil and 37.56% for *Jatropha curcas* oil. The GHG value for extraction stage in *Jatropha curcas* is 11.15 kg-CO_2eq./ton-BDF-CJCO using assumption that the drying process is carried out naturally (sun drying). The most significant GHG value is also caused by the fertilization phase and biodiesel production, both for palm oil and *Jatropha curcas*.

The total value of GHG emission before-stable production is 2300.24 kg-CO_2eq./ton-BDF and 1947.63 kg-CO_2eq./ton-BDF forCPO and CJCO, respectively. Due to the existence of data input differences, it caused the differences in impact evaluations. Figure 4.9 and Figure 4.10 show that GHG value from palm oil is higher than *Jatropha curcas oil* in every stage except in planting and producing biodiesel. According to Figure 4.9, the percentage value of eight sub-process consisting of land preparation, seedling, planting, fertilizing, protection, harvesting, constructing palm oil plant, and biodiesel production is 0.67%; 1.27%; 0.51%; 61.21%; 6.93%; 0.08%, 4.1%; and 25.23%, respectively. While for *Jatropha curcas* as shown in Figure 4.10 the value is 0.42%; 1.28%; 15.51%; 33.96%; 3.60%; 0.04%; 0.57%; and 44.61%, respectively. Table 4.5 diplays the proportion of each stage including pre-harvest, harvest, and post-harvest.

The calculation analysis for stable production is shown in Figure 4.11. It represents GHG at stable production i.e. 1109.42 and 662.85 kg-CO_2eq./ton-BDF for oil palm and *Jatropha curcas*, respectively. The GHG value of oil palm and *Jatropha curcas* decreases until the 5^{th} year and becomes stable until the 25^{th} year.

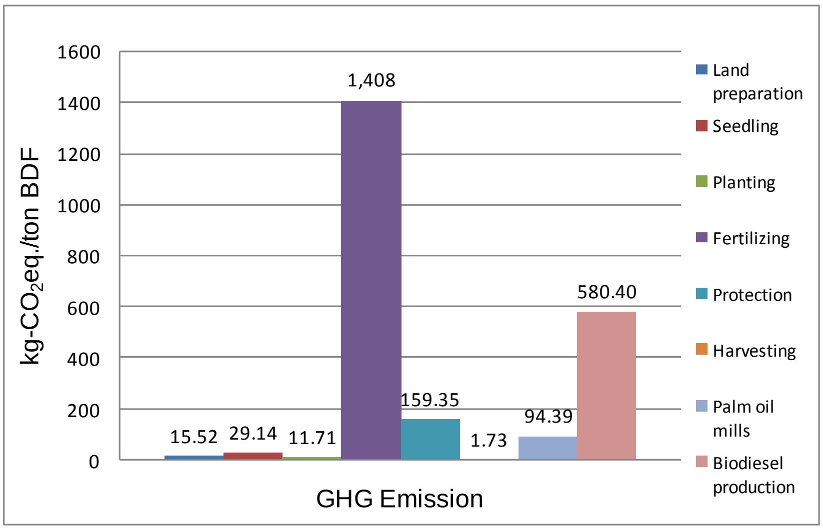


Figure 4.9 The total value of GHGemission of BDF-CPO before stable production (1-5years)

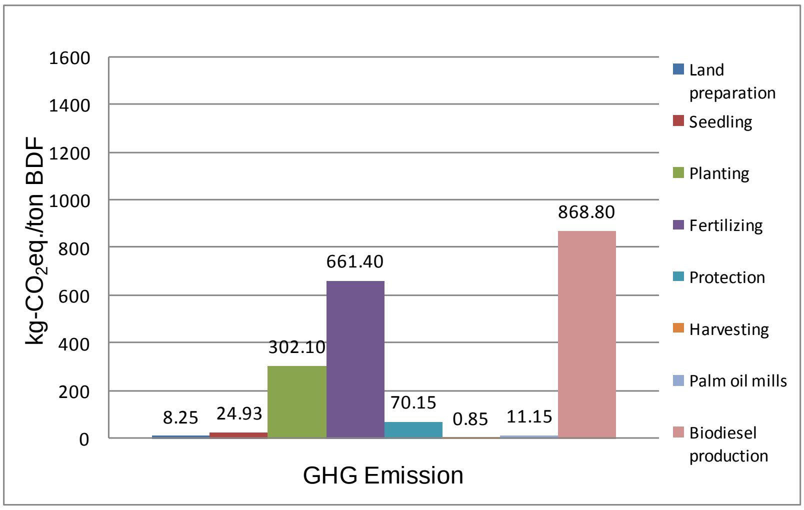


Figure 4.10 The total value of GHG emissionof BDF-CJCO before stable production (1-5 years)

Table 4.5 Percentage of GHG value for LCA with cradle to gate boundary of BDF-CPO and BDF-CJC

Input activity	Percentage (%)	
	Palm oil	*Jatropha curcas*
Pre-harvest	70.59	54.78
Harvest	0.08	0.04
Post-harvest	29.34	45.18

Similar trend occurs in impact assessment including acidification, eutrophication, and landfill waste is shown in Figure 4.12, Figure 4.13, and Figure 4.14.

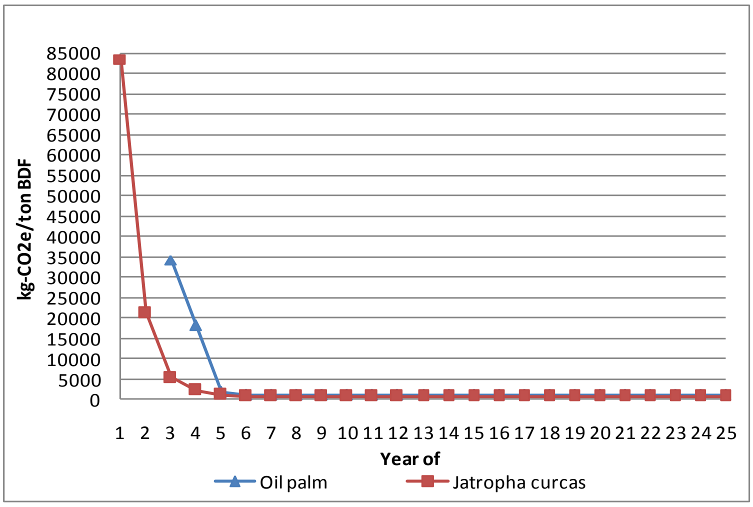


Figure 4.11 The value of GHG emission of oil palm and *Jatropha curcas* before and after stable production (1-25 years)

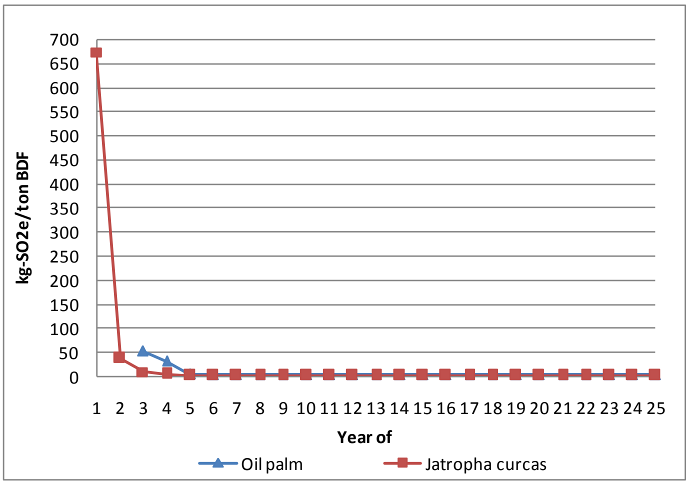


Figure 4.12 The acidification value of oil palm and *Jatropha curcas* before and after stable production (1-25 years)

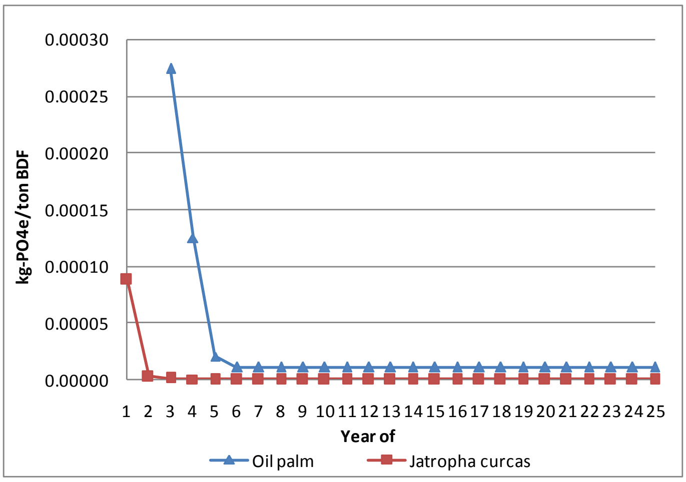


Figure 4.13 The eutrophication value of oil palm and *Jatropha curcas* before and after stable production (1-25 years)

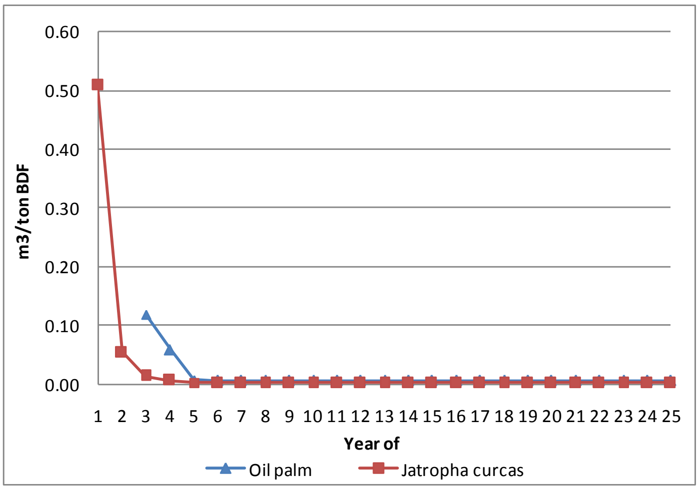


Figure 4.14 The waste landfill volume value of oil palm and *Jatropha curcas* before and after stable production (1-25 years)

Scenario 3

Scenario 3 uses similar data with scenario 2. The difference is on the calculation and treatment in a way closer to real conditions in the field. In this scenario, the calculation is performed annually by distributing material inputs and energy for biodiesel production in a year, material transportation from the market to location is also calculated. The average of GHG value before-stable production (1-5 years) is 2575.47 kg-CO_2eq./ton-BDF for palm oil and 3057.74 kg-CO_2eq./ton-BDF for *Jatropha curcas*. While GHG value in stable production is 1511.96 kg-CO_2eq./ton-BDF for palm oil and 380.52 kg-CO_2eq./ton-BDF for *Jatropha curcas*. The difference showed that calculation method should be included to explain the results. LCA highly depends on data input and calculation method. However, in real condition, impact evaluation results in scenario 2 is the most appropriate to represent field condition. The assumptions are made that material and energy inputs for stable production remain constant from year-6 to year-25. According to field survey and literatures, it can be summarized that material and energy input are almost similar from year-6 to year-25. If unexpected thing occurs such as plant disease, the leaves will be taken to the laboratory and analyzed. Thus, nutrients needed for plant growth will be revealed.

Greater difference in greenhouse gas emission is known as regional factor and usually beyond producers' control. Nitrogen fertilizer production is different in different places. Different producers will affect the difference of products and technology. In Europe, the most common fertilizer used is nitrate fertilizer (based on ammonium nitrate and calcium nitrate, etc). While in North America, people are more familiar with ammonium and urea. Various types of fertilizer give significant impact on biodiesel emission life cycle. Emission amount also associates with the local condition of environment and soil types. It might occur in Indonesia which has thousands of islands, each has different conditions, land texture and climate. Eventually, it generates different material and energy input. This study more reflects the condition of Sumatera and Java. Moreover, LCA standard is not available for Indonesia, thus normalization and emission factor value could not be performed.

Due to the lack of data basis, this research should consider the appropriate calculation software. Japan, as the reference of MiLCA-JEMAI software, is assumed to have close relation with Indonesia. Based on the description from JEMAI, it was known that the data were taken from some locations in Asia. For example, the LCA study on palm oil fresh fruit bunch (FFB) was conducted in Thailand. There will be greater differences if we choose to use SimaPro or GaBi software from Europe and US, despite the international standard ISO 14040-14044. In order to use MiLCA-JEMAI software, data inputs corresponding to real condition in Indonesia are included, such as the use of power plant composition. Japan relies on nuclear energy (34%) as the source of electrical energy while Indonesia uses coal for about 38.5% of total energy source and the calculation includes electricity in Indonesia based on statistic data from PT.PLN in December 2011. The complete electricity composition used in Indonesia and Japan are shown in Table 4.6 and Table 4.7. From the impact assesements of GHG emission, coal power plant releases more emission than nuclear. The complete impact assessment results for GHG, acidification, eutrophication, waste landfill volume and energy consumption is shown in Table 4.8.

Figure 4.15 shows decreasing GHG value from year-1 to year-5, and become stable from year-6 to year-25. It was due to the assumption that energy input, materials, and productionis constant. Similar trends also occur in acidification, eutrophication, and waste landfill volume (Figure 4.16, Figure 4.17, and Figure 4.18). Because palm oil starts to produce in year-3, those values are calculated in year-3. At first, the value is incredibly high because production value per ton BDF is still very small. When divided by biodiesel, the material and energy value are relatively high (first year) which resulted high impact assessment. Besides, during the first year of *Jatropha curcas* and the third year of palm oil, 8 stages of sub-process are included in calculation. Remaining years only considers 5 stages, since land preparation, seedling, and planting are no longer included.

The system used in the making of impact assessment using MiLCA-JEMAI software for the first, second, and third year is shown in Figure 4.19. Figure 4.20 shows the condition of year-6 (stable production). The first year of *Jatropha curcas* is shown in Figure 4.21. Stable production at year-6 is shown in Figure 4.22. Complete results can be found in Appendix 10.

Table 4.6 National electrical fuel composition (based on statistic data from PT.PLN (Persero), 2011)

A kind of a power plant and a source of fuel	Percentage (%)
Hydropower (PLTA)	7.23
Fossil fuel-HSD	22.46
Fossil fuel-IDO	0.03
Fossil fuel-MFO	6.83
Geothermal (PLTP)	2.44
Coal	38.50
Natural Gas	22.52
Solar power plant	0.0005

Table 4.7 Japan electrical fuel composition (Widiyanto et al.,2003)

A kind of a power plant and a source of fuel	Percentage (%)
Hydropower (PLTA)	9.60
Fossil fuel	9.20
Nuclear	34.30
Coal	18.40
Natural Gas	26.40
Others	2.1

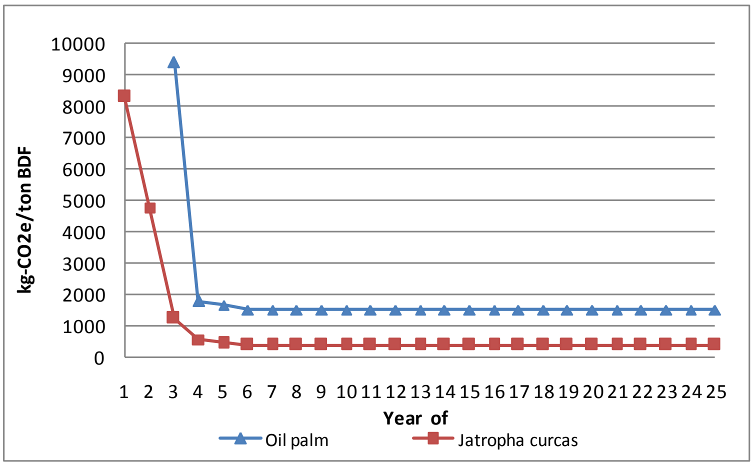


Figure 4.15 The GHG emission value of oil palm and *Jatropha curcas* throughout its life cycle (1- 25 years)

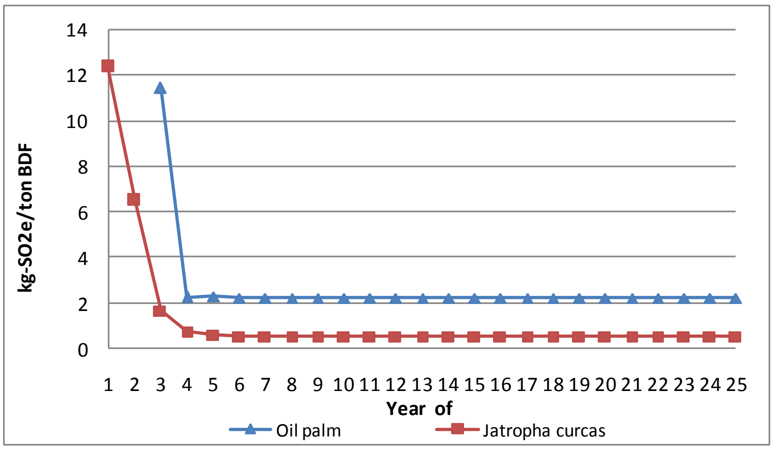


Figure 4.16 The acidification value of oil palm and *Jatropha curcas* throughout its life cycle (1- 25 years)

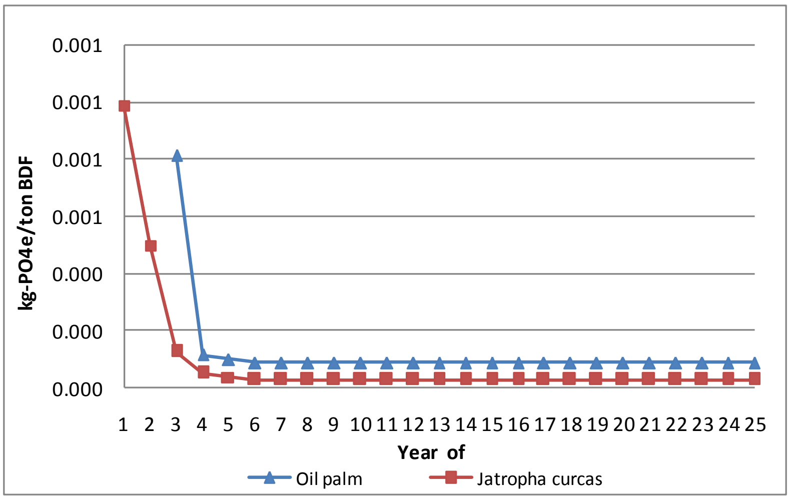


Figure 4.17 The eutrophication value of oil palm and *Jatropha curcas* throughout its life cycle (1- 25 years)

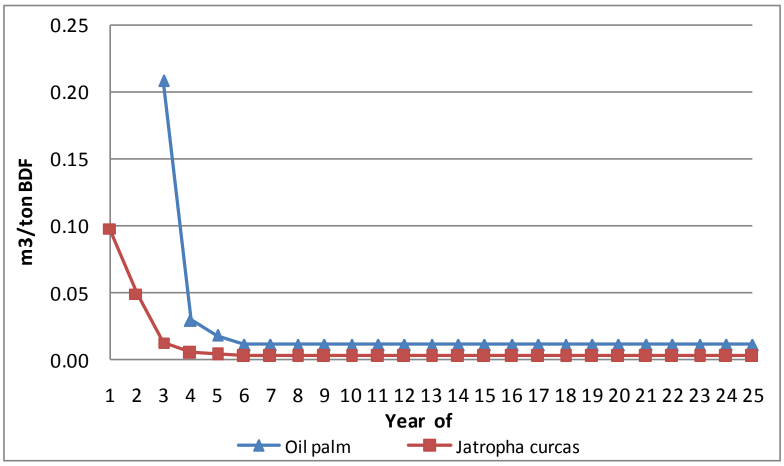


Figure 4.18 The waste landfill volume value of oil palm and *Jatropha curcas* throughout its life cycle (1- 25 years)

Scenario 4

According to the explanation above, it can be seen that the impacts caused by the utilization of chemical fertilizer is very dominant. Therefore, if organic fertilizer is applied,the analysis of organic fertilizer effect to impact assessment results is needed. It is shown by GHG emission value of stable productionwhich decreased from 1511.96 kg-CO_2eq./ton-BDF to 1211.97 kg-CO_2eq./ton-BDF for oil palm and from 380.52 kg-CO_2eq./ton-BDF to 341.02 kg-CO_2eq./ton-BDF for *Jatropha curcas*. The uses of organic fertilizer reduces the GHG value on fertilizing sub-process from 307.28 kg-CO_2eq./ton-BDF to 11.66 kg-CO_2eq./ton-BDF for oil palm and from 219.36 kg-CO_2eq./ton-BDF to 46.72 kg-CO_2eq./ton-BDF for *Jatropha curcas*. Impact assessment value of commonly used fertilizers is shown in Table 4.9. From the table, it can be seen that organic fertilizer generates the lowest impact value in all chosen categories: GHG emission, acidification, eutrophication, waste landfill volume, and energy consumption.

Scenario 5

The government has targeted *Jatrhopha curcas* based biodiesel utilization by 20% of the total energy source in 2025. If the portion (20%) will substitute fossil fuel-HSD, power plant composition will be changed (see Table 4.10). By entering GHGemission value used in scenario 2, GHG emission value of BDF-CJCO throughout its life cycle is 0.689 kg-CO_2eq./kg-BDF-CJCO or 0.614 kg-CO_2eq./liter-BDF-CJCO. The GHG emission value to produce 1 kWh electricity is 0.165 kg-CO_2eq. by assuming that SFC (specific fuel consumption) per 1 kWh electricity is 0.27 (normal Diesel Power Plant). This value is lower than fossil fuel, coal, and natural gas, but higher than nuclear, hydropower, and geothermal. The complete results can be seen in Table 4.11.

Table 4.8 Impact assessment of power plant system (GHG emission, acidification, eutrophication, waste landfill volume and energy consumption)

GHG (per kWh)			Acidification (per kWh)			Waste (per kWh)			Eutrophication (per kWh)			Energy consumption (per kWh)		
No	A kind of power plant	GHG kg-CO_2eq	No	A kind of power plant	Acidification kg-SO_2eq	No	A kind of power plant	Waste m^3	No	A kind of power plant	Eutrophication kg-PO_4eq	No	A kind of power plant	Energy Consm.(MJ)
1	Coal	0.337	1	Fossil fuel-IDO	0.003	1	Hydropower	2.8E-06	1	Nuclear	3.9E-07	1	Geothermal	10.062
2	Fossil fuel-IDO	0.308	2	Natural gas	0.0004	2	Nuclear	2.2E-06	2	Geothermal	2.4E-07	2	Nuclear	7.535
3	Fossil fuel-HSD	0.287	3	Coal	0.0002	3	Geothermal	5.2E-08	3	Hydropower	5.40E-08	3	Hydropower	4.355
4	Fossil fuel-MFO	0.278	4	Fossil fuel-HSD	0.00016	4	Coal	1.2E-09	4	Coal	1.3E-10	4	Fossil fuel-IDO	3.993
5	Natural gas	0.186	5	Fossil fuel-MFO	0.00014	5	Fossil fuel-MFO	1.4E-10	5	Fossil fuel-MFO	1.21E-12	5	Fossil fuel-MFO	3.842
6	Nuclear	0.039	6	Nuclear	0.00013	6	Fossil fuel-IDO	1.3E-10	6	Fossil fuel-IDO	1.10E-12	6	Fossil fuel-HSD	3.743
7	Hydropower	0.007	7	Hydropower	0.00006	7	Fossil fuel-HSD	1.2E-10	7	Fossil fuel-HSD	1.03E-12	7	Coal	3.616
8	Geothermal	0.003	8	Geothermal	0.000005	8	Natural gas	0.0E+00	8	Natural gas	0.0E+00	8	Natural gas	3.545

Table 4.9 Impact assessment of various types of fertilizers (GHG emission, acidification, eutrophication, waste landfill volume and energy consumption)

GHG emission (per kg)			Acidification (per kg)			Waste (per kg)			Eutrophication (per kg)			Energy consumption (per kg)		
No	A kind of fertilizer	GHG kg-CO_2eq	No	A kind of fertilizer	Acidific. kg-SO_2eq	No	A kind of fertilizer	Waste m^3	No	A kind of fertilizer	Eutrophic. kg-PO_4eq	No	A kind of fertilizer	Energy Cnsm.(MJ)
1	Chemical-N15%, P_2O_5 15%, K	2.626	1	Chemical-N15%, P_2O_5 15%, K	0.0036	1	Miscellaneous phosphatic acid	1.5E+01	1	Fused phosphate	5.4E-07	1	Nitrogenous & phosphatic	45.585
2	Nitrogenous & phosphatic	2.382	2	Miscellaneous ammonia	0.0034	2	Fused phosphate	2.0E-05	2	Miscellaneous phosphatic acid	3.2E-07	2	Chemical-N15%, P_2O_5 15%, K	43.621
3	Nitrogen fertilizer	2.181	3	Miscellaneous phosphatic acid	0.0033	3	Phosphate fertilizer	1.6E-05	3	Chemical-N15%, P_2O_5 15%, K	2.38E-07	3	Nitrogen fertilizer	42.593
4	Miscellaneous phosphatic acid	2.020	4	Fused phosphate	0.00305	4	Chemical fertilizer	1.531E-05	4	Chemical-N 19%, P_2O_5 42%	1.68E-07	4	Miscellaneous phosphatic acid	30.658
5	Miscellaneous ammonia	1.891	5	Nitrogen fertilizer	0.00203	5	Compound fertilizer	1.526E-05	5	Miscellaneous ammonia	1.50E-07	5	Miscellaneous ammonia	29.111
6	Phosphate fertilizer	1.222	6	Nitrogenous & phosphatic	0.00195	6	Mixed fertilizer	1.52E-05	6	Phosphate fertilizer	1.37E-07	6	Phosphate fertilizer	20.481
7	Chemical fertilizer	1.008	7	Phosphate fertilizer	0.00177	7	Miscellaneous chemical	1.4E-05	7	Miscellaneous chemical	1.02E-07	7	Chemical-N 19%, P_2O_5 42%	18.112
8	Chemical-N 19%, P_2O_5 42%	1.005	8	Chemical fertilizer	0.00141	8	Miscellaneous ammonia	1.1E-05	8	Chemical fertilizer	9.3E-08	8	Chemical fertilizer	17.189
9	Miscellaneous chemical	0.987	9	Chemical-N 19%, P_2O_5 42%	0.00139	9	Nitrogen fertilizer	1.07E-05	9	Compound fertilizer	8.57E-08	9	Compound fertilizer	16.587
10	Fused phosphate	0.984	10	Compound fertilizer	0.00133	10	Nitrogenous & phosphatic	9.05E-06	10	Nitrogenous & phosphatic	8.02E-08	10	Miscellaneous chemical	16.580
11	Compound fertilizer	0.961	11	Miscellaneous chemical	0.00127	11	Chemical-N15%, P_2O_5 15%, K	7.67E-06	11	Mixed fertilizer	7.56E-08	11	Mixed fertilizer	15.692
12	Mixed fertilizer	0.890	12	Mixed fertilizer	0.00121	12	Potassic fertilizer	7.48E-06	12	Nitrogen fertilizer	6.87E-08	12	Fused phosphate	11.692
13	Potassic fertilizer	0.310	13	Potassic fertilizer	0.00072	13	Chemical-N 19%, P_2O_5 42%	3.66E-06	13	Potassic fertilizer	4.44E-08	13	Potassic fertilizer	4.947
14	Organic fertilizer	0.080	14	Organic fertilizer	0.00016	14	Organic fertilizer	1.52E-06	14	Organic fertilizer	1.71E-08	14	Organic fertilizer	1.049

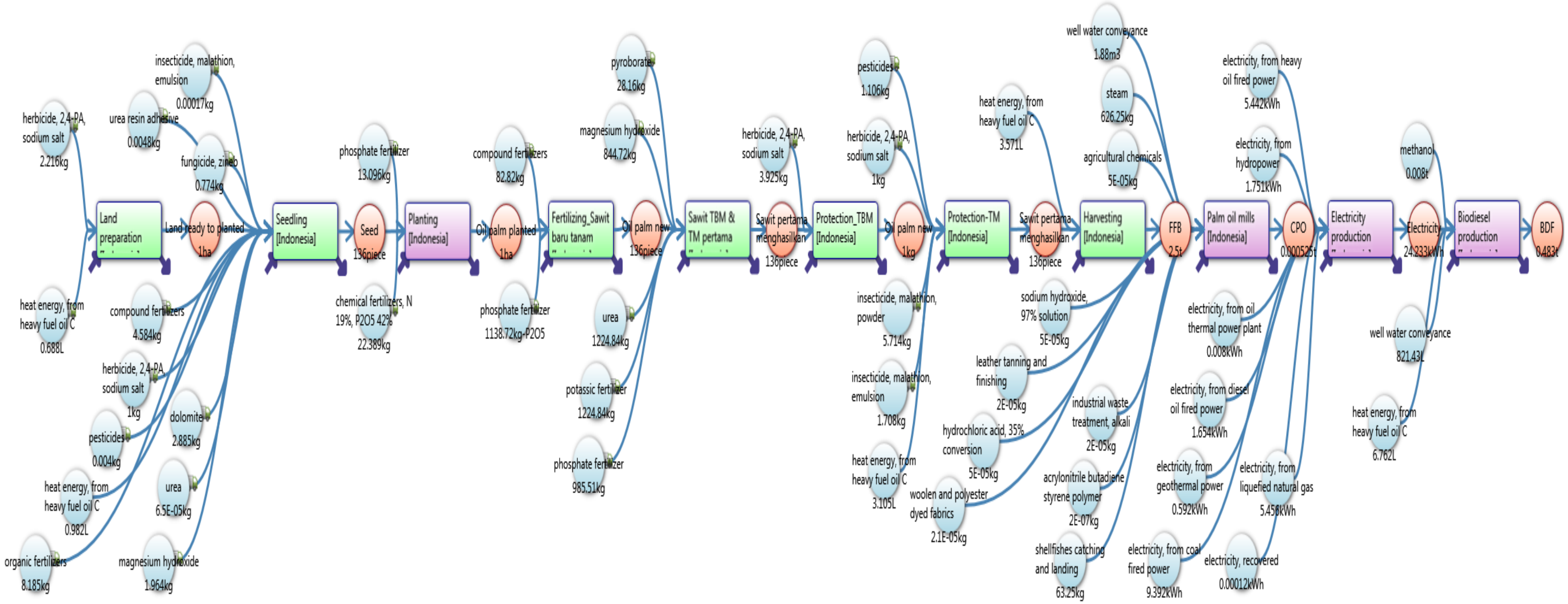


Figure 4.19 Product system of oil palm with MiLCA-JEMAI software at the first, second, and third year

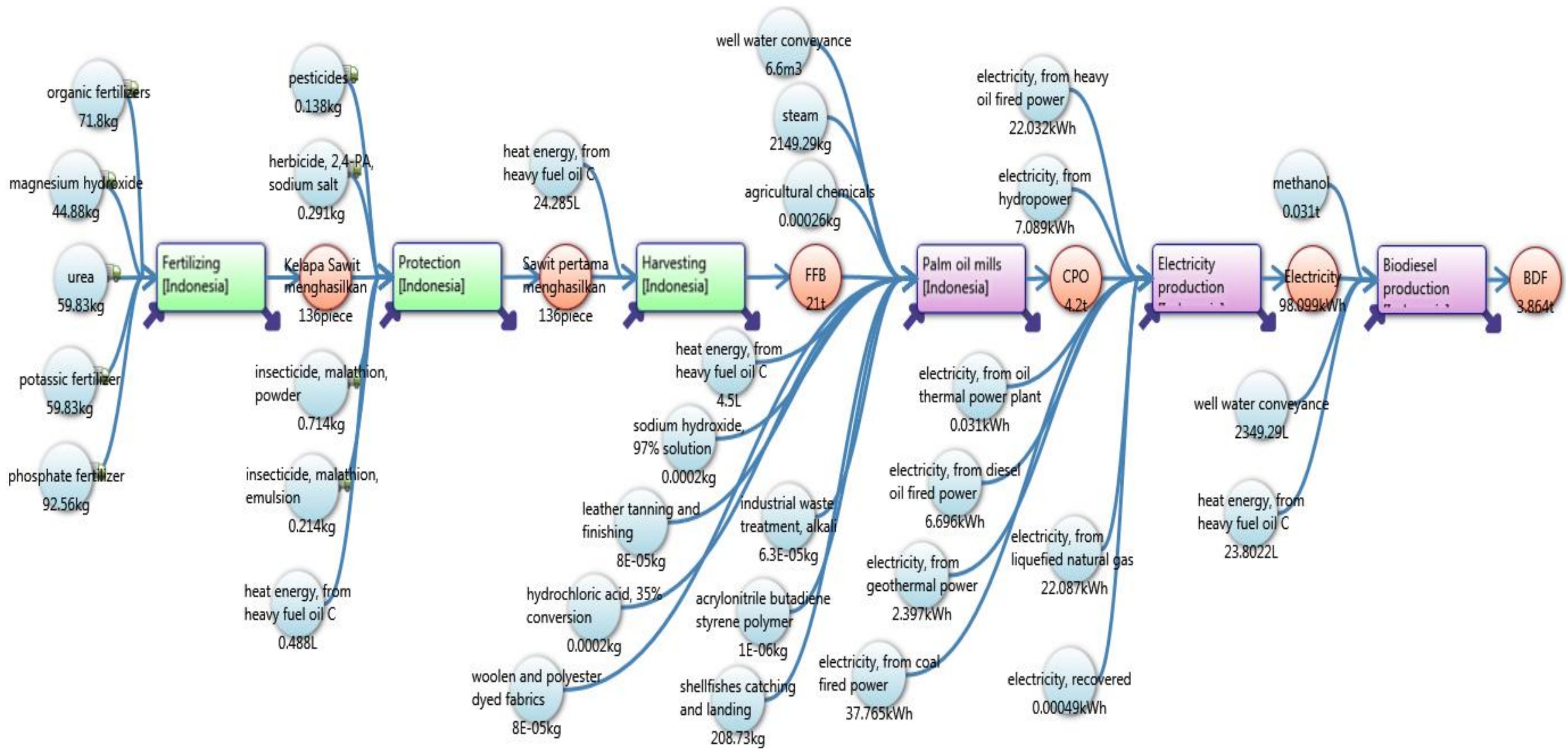


Figure 4.20 Product system of oil palm with MiLCA-JEMAI software in the sixth year (stable production)

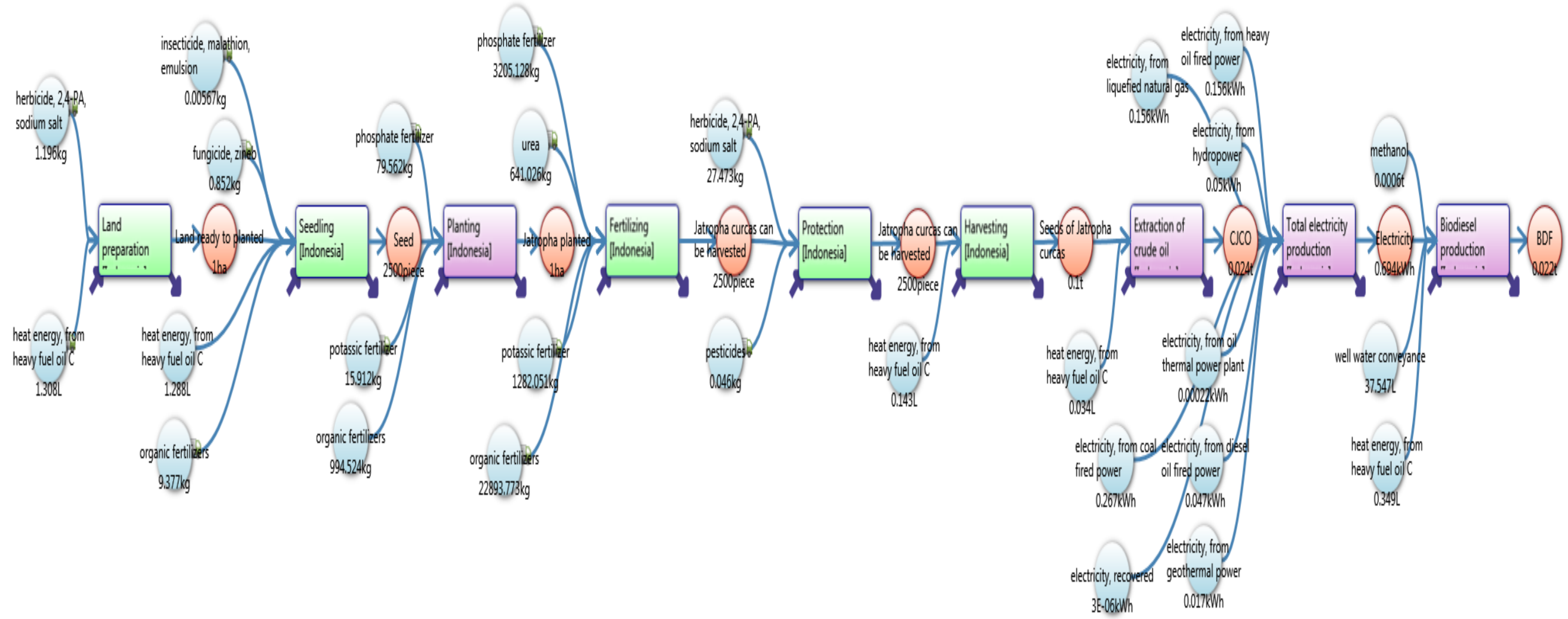


Figure 4.21 Product system of *Jatropha curcas* with MiLCA-JEMAI software in the first year

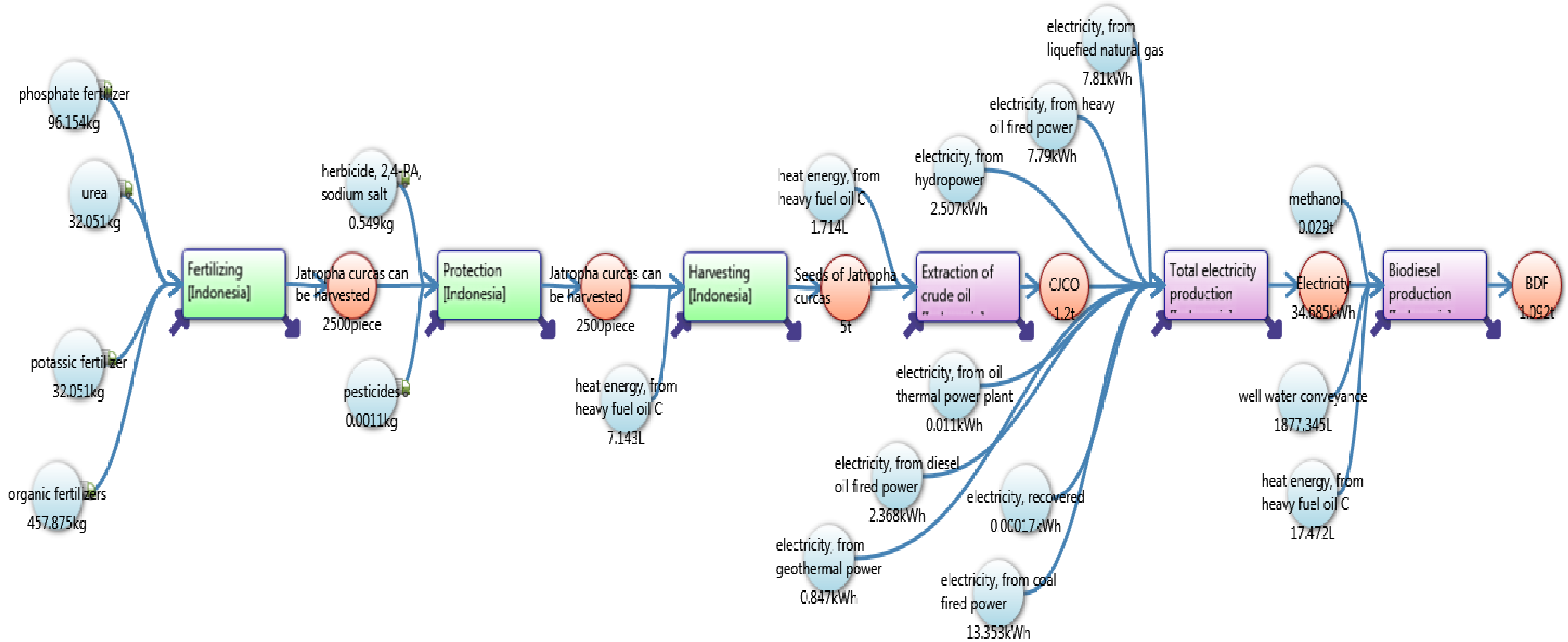


Figure 4.22 Product system of *Jatropha curcas* with MiLCA-JEMAI software in the sixth year

Tabel 4.10 The electrical composition in Indonesia (scenario 5)

A kind of a power plant and a source of fuel	Percentage (%)
Hydropower (PLTA)	7.23
Fossil fuel-HSD	2.46
Fossil fuel-IDO	0.03
Fossil fuel-MFO	6.83
Geothermal (PLTP)	2.44
Coal	38.50
Natural Gas	22.52
Solar power plant	0.0005
Bio Diesel from CJCO	20.00

Tabel 4.11 Impact assessment of GHG emission value of power plant system (scenario 5)

No	A kind of power plant	GHG kg-CO_2eq.
1	Coal	0.337
2	Fossil fuel-IDO	0.308
3	Fossil fuel-HSD	0.287
4	Fossil fuel-MFO	0.278
5	Natural gas	0.186
6	Bio Diesel-CJCO	0.165
7	Nuclear	0.039
8	Hydropower	0.007
9	Geothermal	0.003

Conclusion

The conclusions of this chapter are:

1. Life cycle assessment shows that GHG emission value of oil palm is higher than *Jatropha curcas*.
2. Scenario 3 is the best scenario to be applied as it reflects real condition in Indonesia. The GHG emission value before stable production is 2575.47 kg-CO_2eq./ton-BDF for oil palm and 3057.74 kg-CO_2eq./ton-BDF for *Jatropha curcas*. When the production has reached its stable point, the GWP value is 1511.96 kg-CO_2eq./ton-BDF for oil palm and 380.52 kg-CO_2eq./ton-BDF for *Jatropha curcas*.
3. According to all developed scenarios, it is found that the impact assessment calculation on stable production is lower than before-stable production. By considering that 4/5 or 20 years of 25 years of its life cycle lie on stable production, appropriate calculation method is needed. In some journals, the calculation is only performed in the first five years.

4. The total environmental impact of biodiesel production from CPO which involves GHG emission value, acidification, eutrophication, and energy consumption is higher than CJCO.
5. Agro-chemical utilization such as fertilizer, insecticides, pesticides, and fungicides produces significant contribution to environmental impact in biodiesel production. It is accounted by 50.46% for oil palm and 33.51% for *Jatropha curcas* for scenario 1, and 68.14% for oil palm dan 37.56% for *Jatropha curcas* for scenario 2.
6. The use of organic fertilizer very influences the reduction of GHG emission value in fertilization sub-process. It could reduce up to 96.2 % for oil palm and 76.8% for *Jatropha curcas*.
7. In term of electricity generation, scenario 5 shows that *Jatropha curcas* oil based biodiesel is better than fossil fuel.

CHAPTER 5
CONSUMPTION OF ENERGY PRODUCTION, NET ENERGY BALANCE (NEB), NET ENERGY RATIO (NER), AND RENEWABLE INDEX (RI)

Introduction

The main characteristic of LCA is entitled on the major strength and the limitation. The major strength of LCA is the analysis which conducted on the whole aspects. The limitation lies on the analysis which conducted at the same time. Implementing a broad range of comprehensive LCA of a product can only be achieved by simplifying the other aspects. LCA can not measure local impact and does not provide a frame work for a local study assessment that identifies the impacts generated by functions of a specific place. In terms of time range aspect, LCA presents steady state condition not dynamic. It means that LCA is used to study a period of time, all conditions including the technology is assumed as fixed condition. The condition and energy analysis used in this study are expected to provide more comprehensive assessment on biodiesel development.

The objective of this chapter is to calculate and analyze the consumption of renewable energy, non-renewable energy, fossil energy and see the relationship of net energy balance (NEB), net energy ratio (NER), and renewable index (RI) at each scenario to obtain optimum result which reflects the condition of Indonesia.

Literature Review

Direct Energy

Direct energy is energy which directly used in the production process. The direct energy is in the form of fossil fuel. Direct energy used on this study consists of fossil fuel, methanol, electricity and steam. Fossil fuel that is widely used in agricultural production is gasoline and diesel. Calor value of some types of fossil fuel is presented in Table 5.1.

Table 5.1 Calor value of some types of fuel

No	Source of energy	Unit	Calor value MJ/Unit	Product input MJ/Unit	Total of calor value MJ/Unit
1	Gasoline	kg	32.24	8.08	40.32
2	Diesel	kg	38.66	9.12	47.78
3	Diesel Fuel	kg	38.66	9.12	47.78
4	LPG	kg	26.1	6.16	32.36
5	Natural Gas	m^3	41.38	8.07	49.45
6	Hard coal	kg	30.23	2.36	32.59
7	Soft coal	kg	32.39	2.37	32.76
8	Hard coal	kg	19.26	1.44	20.7
9	Soft coal	kg	17.58	1.32	18.9
10	Electricity	kWh	3.6	8.39	11.99

Source : Cervinka (1980)

Indirect Energy

Indirect energy is energy used to produce a product besides of fuel energy. The amount of direct and indirect energy used to produce a product is called embodied energy. According to Doering (1980), embodied energy is the energy used indirectly on agricultural production such as energy for machinery, equipment, building and other supporting material. Indirect energy comprises of:

- Agricultural inputs (such as fertilizers, pesticides, and herbicides),
- Agricultural equipment
- Agricultural machinery
- Buildings and other materials

Indirect energy from manure

Chemical fertilizer used in palm oil and *Jatropha curcas* cultivation is considered as energy intensive as it consumes high number of fossil fuel along its production. Energy consumption for fertilizer production mostly occurs during chemical processes. The amount of energy input to produce fertilizer is shown in Table 5.2, Table 5.3 and Table 5.4.

Table 5.2 Energy input for phosphate and potassium fertilizer

No	A kind of fertilizer	Product (MJ/kg)	Transportation (MJ/kg)	Distribution (MJ/kg)	Total (MJ/kg)
1	Phospate Rock	1.67	-	3.77	5.44
2	Normal superphospate (0-20-0)	2.51	0.84	6.28	9.63
3	Triple Superphospate ((0-46-0)/TSP)	9.21	0.84	2.51	12.56
4	Muriate of Potash (0-0-60)	4.6	-	2.09	6.69

Source : Stout (1990)

Table 5.3 Energy input for some types of fertilizers

No	A kind of fertilizer	MJ/kg
1	Ammonia	57.20
2	Urea prilled	79.50
3	Ammonium nitrate prilled	73.40
4	Ammonium sulfate	60.00
5	Single superphosphate	8.50
6	Pottasium chloride, Nort America	4.30
7	Pottasium chloride, Europe	7.70

Source : Stout (1990)

Table 5.4 Energy input for nitrogen fertilizer

No	A kind of fertilizer	Product (MJ/kg)	Transportation (MJ/kg)	Storage (MJ/kg)	Total (MJ/kg)
1	Anhydrous ammonia	48.97	0.84	0.42	50.23
2	Urea	56.93	1.67	1.26	59.86
3	Ammonium nitrate	58.18	2.09	1.26	61.53

Source : Pimentel (1980) in Nuryanto (1998)

Indirect energy from pesticides

Pesticide production requires direct energy such as electricity and heat, and also indirect energy such as fuel (Pimental, 1980 in Nuryanto 1998). Additional energy input is required to formulate pesticide, packaging and transport.

Net Energy Balance (NEB) and Net Energy Ratio (NER)

By products generated from biodiesel processing should be maximally used for energy source during biodiesel process. James (2006) said that the amount of energy required for the production of biodiesel is relative to the energy content. This hypothesis can be evaluated with the net energy balance (NEB) as shown in Equation 5.1:

$$NEB: E_{bdf} - (E_{ff} + E_{fo}) \quad (5.1)$$

Where :

E_{bdf} : energy content of biodiesel fuel

E_{ff} : energy content of fossil fuel

E_{fo} : other fossils as a source of energy used during the entire production cycle

Fossil fuel has negative NEB, the second law of thermodynamic says that if energy does not enter or leave the system then the potential energy will always be lower than the initial state. In the conversion of crude oil into gasoline, Net Energy Ratio (NER) is determined as the energy output divided by the energy input of gasoline. The NER value is less than one (= <1). NEB and NER are two methods for evaluating the sustainability of biofuels since energy crisis in 1970's (U.S. Department of Energy, 1980). Stout (1990) in James (2006) states that NEB value of biofuel is positive due to renewable energy inherent in the raw materials, the waste can still be used as an energy source in the treatment process, and because most of agricultural energy analysts realize that the sun energy is freely captured by biomass. It is believed that the fuel with higher NEB is said to have more efficient energy. If the NEB has low value, the biofuel will have low production efficiency or equal to higher load environment and higher resource consumption for fuel production.

Thus, NEB can be used as the first approach in measuring environmental sustainability of biofuel. Besides of emission and environmental impact, the other focus relies on energy consumption process. Besides of that energy, biomass used in boiler is also considered as renewable. Renewable energy percentage of all required energy is called renewability. If waste is also used as fuel for production process, the net energy production can be calculated.

If the required value of the energy input per unit mass is higher than the heating value of produced fuel or has low efficiency, it appears that the technology is not appropriate to produce related fuel. It means that new technology should be developed or modificated. This might occur also in energy input using fossil fuel or non-fossil fuel because if everything is converted into the energy per unit mass or MJ/kg it will have similar analysis. However, if non-fossil fuel is derived from processing material, the efficiency calculation will use available energy input. For example, this condition occurs when palm oil bunch is used for broiler.

Renewable Index (RI)

Renewable index (RI) presents the value of renewable energy in the biodiesel production process path. If compared to energy from fossil, higher RI means that the development process on this biodiesel is getting better or more sustain.

Biomass derived from the development of oil palm and *Jatropha curcas* has a considerable amount. The produced biomass can be used as fuel in boiler, power plants and others. The calculation of oil palm biomass is outlined below:

- Biomass in the form of canopy is computed under non-destructive method using allometric equation developed by Yulianti (2010) which derived from the equation of Chave et al. (2005) (Equation 5.2):

$$y_b = 2.69 \exp^{-4} D^{2.31} H^{0.57} \tag{5.2}$$

Where:
yb : above-soil biomass (tons / plant)
D : diameter of stem at 1.3 m height (m)
H : height of plant without leaves (m)

- Palm root biomass using allometric equation developed by Syahrinudin (2005) (Equation 5.3):

$$y_a = 0.08\,x + 0.56 \tag{5.3}$$

Where:
y_a : palm roots biomass (tons/plant)
x : plant age (years)

Higher Heating Value (HHV) and Lower Heating Value (LHV)

One important parameter in fuel is the heating value. HV (heating value) or CV (calor value) is the amount of heat energy that released by fuel during its chemical oxidation. Heating value or calor value of a substance, usually a fuel or food (such as food energy) is the amount of heat released during combustion process. Calor value is a characteristic of each substance. It is measured in unit of energy per unit of substance, usually mass, such as: kcal/kg, kJ/kg, MJ/kg, J/mol, Btu/m³. Calor value is generally determined using bomb calorimeter. The heat from fuel combustion is expressed as HHV (higher heating value) or GHV (gross heating value) and LHV (lower heating value) or NHV (net heating value).

Higher heating value (HHV) and lower heating value (LHV) are described as follows:

a. Higher Heating Value (HHV)

HHV (higher heating value) is the calor value obtained from the combustion of 1 kg of fuel by considering the vapor condensation heat (liquid water resulting from the combustion). HHV value can be calculated using the Dulong and Petit formula (Power Plant Engineering, 2002) as shown in Equation 5.4.

$$HHV = 33.950C + 144.200\left[H_2 - \frac{O_2}{8}\right] + 9.400S \quad kJ/kg \tag{5.4}$$

Where:

C : the composition of carbon in the fuel
H_2 : the composition of hydrogen in the fuel
O_2 : the composition of oxygen in the fuel
S : the composition of sulfur in the fuel

HHV is an important property that characterizes the energy content of the fuel either in solid, liquid or gas form. HHV estimation of vegetable oil and biodiesel using fatty acid composition is needed in the study of biodiesel. Comparison between HHV derived from prediction and experiment method causes the average bias error -0.84% and the average absolute error of 1.71%. These values indicate the utility, validity and application of methods for vegetable oil and its derivatives (Fassinou et al., 2010). This method is based on the fact that vegetable oil and biodiesel is primarily a mixture of fatty acids. This fatty acid has hydrocarbon component with the chemical formula $C_xH_yO_z$. The proposed method uses these assumptions to estimate the HHV of renewable energy. Equation 5.5 is the equation used to calculate the HHV by considering a fatty acid content of biodiesel (Fassinou et al., 2010).

$$HHV = 100(THV)/T_{FA} \tag{5.5}$$

THV value is calculated using Equation 5.6.

$$THV = \sum(HV_i) \tag{5.6}$$

Where :HVi : HV fatty acid of i

HVi (in MJ/kg) is calculated using Equation 5.7 which suited with the chemical formula of fatty acid $C_xH_yO_z$ and mass fraction (X_i) of vegetable oil or biodiesel.

$$HV_{(C_xH_yO_z)} = 34.03x + 121.64y - 12.54z \tag{5.7}$$

And

$$HV_i = (Xi)HV_{(C_xH_yO_z)i} \tag{5.8}$$

Where x, y, and z are molecule number of carbon, hydrogen, and oxygen of chemical formula at each i component. Total percentage (T_{FA}) of all fatty acid is detected and calculated using Equation 5.9. Equation 5.10 is used to evaluate HV of hydrocarbon product with the chemical formula is C_xH_y.

$$T_{FA} = \sum Xi \tag{5.9}$$

$$HV_{(C_xH_y)} = (393x + 241y/2)/(12x + y) \tag{5.10}$$

Factor 100 in Equation 5.5 shows that it has already account HVS components which cannot be detected by GC or HPLC device. The error made using Equation 5.7 and Equation 5.10 ranges between 3 and 4%. HV value of some products has been calculated with Equation 5.7 and 5.10, and the result shows that the relative error between the two values derived by the equation is approximately 3%. This suggests that this formula gives almost the same value for HV.

The other common method used to calculate HHV is shown in Equation 5.11.

$$HHV = LHV + h_v \times (n_{H2O,out} / n_{fuel,in}) \quad (5.11)$$

Where hv is the heat of vaporization of water, $n_{H2O,out}$ is the moles number of evaporated water; $n_{fuel,in}$is the moles number of the combusted fuel. In fact, there is much fuel combustion which the resulted water vapor is not reutilized during the process. In such condition, the lower heating value is applied. This is particularly relevant for natural gas in which the hydrogen produces much water. Gross calor value is relevant for gas burnt in boiler and power plant where the water vapor is then condensed with water vapor which produced from combustion process to recover heat that would be wasted. The use of this term is considered as historical reason, the efficiency of power plant, combined heat and power plant in Europe is generally calculated based on LHV, while HHV is usually used in the U.S.. The difference between HHV and LHV sometimes causes confusion to the user, because there is a difference of about 10% for power generation on natural gas (Wikipedia, 2010). Moisture calculation for both HHV and LHV can be expressed in terms of AR (all moisture is counted), MF and MAF (only water from combustion of hydrogen). AR, MF, and MAF are usually used to indicate the heating value of coal:

- AR (as received) indicates that the fuel heating value has been measured with all moisture and ash which present to form the mineral.
- MF (moisture free) or dry indicates that the fuel heating value has been measured after the fuel drained from all inherent moisture but still maintain ash which forms mineral.
- MAF (moisture and ash free) or DAF (dry and ash free) indicates that the fuel heating value has been measured in the absence of water and mineral which forms ash.

Another equation is developed to calculate the HHV value of vegetable oil and biodiesel based on viscosity value (VS) and density (DN). HHV equation for vegetable oil is shown in Equation 5.12 and biodiesel is shown in Equation 5.13.

$$HHV = 0.0467*VS + 38.052 \quad (5.12)$$
$$HHV = 0.6154 + 38.998*VS \quad (5.13)$$

The regression coefficients (r) are 0.9858 and 0.9809, respectively. This correlation can also be used to estimate the HHV biodiesel derived from vegetable oil mixture. Demirbas (2007) had studied the relationship of physical properties of vegetable oil and biodiesel i.e. HHV and viscosity, density and flash point. The higher heating value (HHV) of vegetable oil and biodiesel is measured and correlated using linear least square regression analysis. Result showed that there is a relationship between viscosity and HHV for vegetable oil and biodiesel. Increasing biodiesel density from 848 to 885 g/L will be followed by the increasing of viscosity from 2.8 to 5.1 cSt. There is also a relationship between density and viscosity values of methyl ester vegetable oil, whereas the relationship between viscosity and flash point of methyl ester vegetable oil tends to be stable.

HHV can also be calculated based on the saponification and iodine values, as shown in Equation 5.14 (Eevera et al., 2009).

$$HHV = 49.43 - (0.041*SV + 0.015*IV) \quad (5.14)$$

Where:
SV : saponification value
IV : iodine value

b. Lower Heating Value (LHV)

LHV (lower heating value) is the calor value obtained from the combustion of 1 kg of fuel without calculating vapor condensation heat (the water produced from combustion is a gas/steam-form). LHV value can be calculated using Dulong and Petit formula (Power Plant Engineering, 2002) as shown in Equation 5.15.

$$LHV = HHV - 2.400(H_2O + 9H_2) \ \ kJ/kg \quad (5.15)$$

Where:
H_2 : the composition of hydrogen in the fuel
H_2O : the composition of water vapor in the fuel

Lower heating value (LHV) is also called net calor value. LHV is determined by subtracting the vaporization heat of water vapor from higher heating value. The value is lower than LCV. It assumes that H_2O is at vapor state. LHV calculation assumes that the water component produced from combustion process is in the vapor state at the final stage of combustion, while HHV assumes that all water produced from combustion is in the liquid state after combustion process. LHV assumes that the latent heat of vaporization of water in the fuel and the reaction products have not recovered yet. This is useful in comparing fuels where condensation of combustion products is impractical, or heat temperature below 150 ° C cannot be used (adopted from the definition of the American Petroleum Institute (API) using a reference temperature of 60°F (15.56°C). Other definition of LHV (used by GPSA - Gas Processors Suppliers Association and is initially used by API) is enthalpy from all combustion products subtracted with reference enthalpy of the fuel (in the research project API 44 uses 25 ° C, GPSA uses 60 ° F), minus with enthalpy of stoichiometric oxygen (O_2) at the reference temperature, and then reduced by evaporation heat content of the combustion product.

The difference between the two definitions is that the second definition assumes that all combustion products return to the reference temperature. In this condition, the heat content of steam condensation is not considered. This is more easily calculated using HHV than using the previous definition which in fact it gives a slightly different answer. This value is important for fuel like wood or coal, which usually contains some amount of water before combustion. Measurement of higher heating value is carried out in a bomb calorimeter by concealing a stoichiometric mixture of fuel and oxidizer (eg, two moles of hydrogen and one oxygen) in a steel container at 25°C (Wikipedia, 2010). When hydrogen and oxygen react during combustion, water vapor appears. HHV is calculated by the product water in liquid form, while the lower heating value (LHV) is calculated by the water product in the form of water vapor. The relationship between heating values and the difference between two heating values depend on the chemical composition of the fuel. In the case of pure carbon or carbon monoxide, both heating values are almost similar.

Method

Time and Place

This research was conducted at the Laboratory of Heat and Mass Transfer, Department of Mechanical Engineering and Biosystems, Faculty of Agricultural Engineering and Technology, IPB Bogor from July 2012 to March 2013.

Energy Calculation and Analysis Tool

Life cycle impact assessment for energy used MiLCA-JEMAI software version 1.1.2.5 (regular license) using Indonesian data. This software refers to the ISO 14040 as an international standard in LCA studies. The different is on the life cycle inventory data that uses Indonesian data and some of calculation were carried out manually through entering calor value (MJ/kg) and calculating the amount of the product (kg) used at each sub process of life cycle into developed mathematical equation. Required energy of energy sources used at each sub process is calculated based on specific and inventory data that has been done. From this value, the emission value can be calculated based on the emission factor published by Intergovernmental Panel on Climate Change (IPCC).

Analysis of energy consumption in this study consisted of: the consumption amount of non-renewable energy, the consumption amount of fossil energy, the consumption amount of renewable energy, the consumption amount of total energy, Net Energy Balance (NER), Net Energy Ratio (NER), and Renewable Index (RI).

Specifically for energy balance, related energy units should be in the same unit (kJ). It occurs by adding all energy process sources i.e. energy from fossil fuel and energy from renewable material. In renewable index analysis, the research also conducted differences study on energy sources of fossil fuel and renewable material such as by product produced during palm oil and *Jathropa curcas* processing that can still be used as an energy sources.

At each stage of sub-process, the first step is to calculate the required energy at each process. Required energy can be obtained by defining the fuel consumption. For diesel used during transportation, the mass of used diesel fuel is calculated using Equation 5.16.

$$mass\,of\,diesel = \frac{load(kg) * distance(km) * diesel\,consumption\,(litre.truck/km) * density(kg/litre)}{capacity\,of\,truck\,(kg/truck)} \quad (5.16)$$

Energy requirement of fuel and electrical energy is calculated using Equation 5.17 and Equation 5.18.

$$\text{energy of fuel} = \text{mass of fuel (kg)} \times \text{calor value } \left(\frac{\text{kJ}}{\text{kg}}\right) \quad (5.17)$$

$$\text{energy of electricity} = \text{set up of power (watt)} \times \text{time (hour)} \times \frac{1 \text{ hour}}{3600 \text{ detik}} \quad (5.18)$$

By using the value of energy consumption, the amount of emission compound can be calculated using Equation 5.19.

$$m_i = f_{ij} \times e_i \quad (5.19)$$

Where:

m_{ij} : the mass of compound i (emission) of energy source j in process k (kg)
f_{ij} : the emission factor of substance i in condition k (kg/kJ)
e_j : the energy produced from energy source j in process k (kJ)

Based on the amount of emission compound, the value of the environment potential impact can be calculated using Equation 5.20.

$$d_{ijy} = eq_{iy} \times m_{ij} \quad (5.20)$$

Where:

d_{ijy} : potential impact y due to emission compound i in process j (kg y eq.)
eq_{iy} : equivalence value of potential impact y due to compound i (kg y eq./kg i)
m_{ij} : the mass of compound i (emission) of fuel j in process k (kg i)

The potential impact value and energy required by each process (energy produced by fuel) is summed to obtain the total value of the entire process, from the handling of pre-harvest, harvest and post-harvest, and until the biodiesel is produced. In this research, the concept of energy balance is that the incoming energy is equal to the amount of stored energy and energy leaving the system, i.e.:

$$Energy_{input} = Energy_{stored} + Energy_{output} \quad (5.21)$$

Assuming steady condition so that no energy is absorbed by the system, the above equation can be simplified into:

$$Energy_{input} = Energy_{output} \quad (5.22)$$

In the context of biodiesel processing which is being studied, the energy balance is as follow:

$$Energy_{input} = Energy_{process} + Energy_{output} \quad (5.23)$$

If input energy is described into sub system as shown in Figure 3.6 and Figure 3.7 on Chapter 3, the equation is as follow:

$$\underbrace{Energy_{input}}_{E_{in}} = \underbrace{Energy_{CPO}}_{E_1} + \underbrace{Energy_{MeOH} + Energy_{NaOH}}_{E_2} \tag{5.24}$$

The energy process is performed from preparation-transesterification-washing and so on to form biodiesel (E_{pr}).

$$E_{pr} = Energy_{fossil} + Energy_{non-fossil} + Energy_{electricity} + Energy_{mechanical} + Energy_{thermal} \tag{5.25}$$

The energy output consists of:

$$\underbrace{Energy_{output}}_{E_{out}} = \underbrace{Energy_{biodiesel}}_{E_{out\_target}} + \underbrace{Energy_{glyerol} + Energy_{MeOH\_residual}}_{E_{out\_residual}} \tag{5.26}$$

If catalyst (NaOH) can be recycled 100% and calculated methanol is used so there is no residual methanol, the equation is as follow:

$$Energy_{input} = Energy_{CPO} \tag{5.27}$$

The energy output is:

$$Energy_{output} = Energy_{biodiesel} + Energy_{glycerol} \tag{5.28}$$

Based on the above mentioned equations, it can be described three energy parameters for biodiesel production and feasibility, i.e.:

$$Net\ Energy\ Ratio(NER) = \frac{Energy_{output}}{Energy_{input}} \tag{5.29}$$

$$Net\ Energy\ Balance(NEB) = Energy_{output} - Energy_{process} \tag{5.30}$$

$$Renewable\ Index(RI) = \frac{Energy_{renewable}}{Energy_{process}} \leq 1 \tag{5.31}$$

Assumptions and Limitations on Energy Calculation Analysis

Some of the assumptions used in this study are as follows:

- Transportation on seeds, FFB or jatropha seeds, as well as CPO or CJCO are calculated in this study i.e. from the nursery to the plantation area, from plantation to palm oil mill, as well as from the palm oil mill to the biodiesel plant. Transportation distance is assumed as one-way direction with a central point in the palm oil mill of *Unit Kebun Kertajaya Lebak Banten* and *Jatropha curcas* Estate Center Pakuwon Sukabumi. The distance from the nursery area to the planting area is 30 km with a capacity of 5 ton trucks, with diesel fuel ratio 1:5 (1 liter for 5 km); from harvesting area to palm oil mill is 150 km with capacity of 10 ton per truck with diesel fuel ratio 1:7; and from the palm oil mill to the biodiesel plant (in Bekasi) is 200 km with a capacity of 10 ton per truck.
- Material transportation such as fertilizer from stores to the plantation area is also taken into account.
- Palm oil mill is assumed has conduct methane capture
- Fuel used in the transportation is diesel fossil

Impact Assessment Scenario

Impact assessment was made and analyzed in 5 scenarios, i.e.:

1. Scenario 1: Using primary data from PTPN VIII *Unit Kebun Kertajaya Lebak Banten* and *Jatropha curcas* Estate Center *Pakuwon Sukabumi*
2. Scenario 2: The calculation was conducted before stable production (1-5 years), and did not calculate the transportation to transport material used from the store to the location of the material used.
3. Scenario 3: The calculation was conducted annually, from year 1 to year 5 (before stable production) and from year 6 to year 25 (stable production). The calculation used Indonesian electrical data and calculated the transportation to transport material used from the store to the location.
4. Scenario 4: Using organic fertilizers for fertilization stages, other aspects were similar with scenario 2.
5. Scenario 5: Using 20% of biodiesel to substitute diesel fuel for Indonesian power plant, as stated in government target in 2025.

Result and Discussion

Energy plays an important role in the analysis of LCA. All sub-processes involved in a process obviously require energy to take place. In addition, emission of each sub-process is calculated based on the consumed energy. Most importantly, energy is the main aspects in LCA. The background is clear i.e. the issue of energy crisis which caused by the decreasing of reserved fossil fuel which have been the main energy source of human activity. How much energy is required in the process and how much the utility of renewable energy is the important aspect to be determined. A good process is a process with high efficiency and low negative effects.

The energy, in this analysis, consists of energy used during the process and energy that can be produced from waste utilization. Energy for this process includes conventional energy and renewable energy. Comparison between the amounts of renewable energy to total energy process is called renewability. Energy utilization of waste needs to be calculated in order to be used in the biodiesel production process. Waste will give a big contribution for input energy during production process.

Scenario 1

Figure 5.1 and Figure 5.2 show that energy consumption for oil palm is higher than *Jatropha curcas* in every stage except planting and biodiesel production. The largest energy consumption for *Jatropha curcas* occurs in biodiesel production sub-process i.e. 25,623.45 MJ/ton-BDF. While the largest energy consumption for oil palm is fertilization sub-process i.e. 18,240.0 MJ/ton-BDF. However, energy consumption in biodiesel production sub-process of *Jatropha curcas* oil is higher than that of palm oil due to higher free fatty acid (FFA) content which needs esterification process prior to the transesterification process.The total value of energy consumption before stable production for oil palm and *Jatropha curcas* is 49,831.17 and 41,730.03 MJ/ton-BDF, respectively.

Figure 5.1 shows that oil palm energy consumption during land preparation, seedling, planting, fertilizing, protection, harvesting, palm oil mills, and biodiesel production is 0.33%, 0.49%, 0.78%, 36.60%, 12.47%, 0.85%, 16.04%, and 32.45%, respectively. While for *Jatropha curcas*, the value of each sub process is 0.39%, 0.45%, 8.13%, 25.98%, 2.82%, 0.26%, 0.56%, and 61.4% (Figure 5.2), respectively. Table 5.5 shows the proportion of each stage which comprises pre-harvest, harvesting and post-harvest. Prueksakorn et al. (2006) also explained that energy consumption needed for transesterification is higher than fertilization. On the contrary, greenhouse gas emissionis higher during fertilization sub-process. It occurs because of the N compound and the use of N_2O has strong effects on GHG. James et al. (2006) explained that the amount of energy required to produce biodiesel is relative to the energy content. This is due to renewable energy characteristic on the feedstock itself, such as *Jatropha curcas* and palm oil, where the waste still can be used as a source of energy during processing and it also because most agriculture energy analyst believes that solar energy is freely provided.

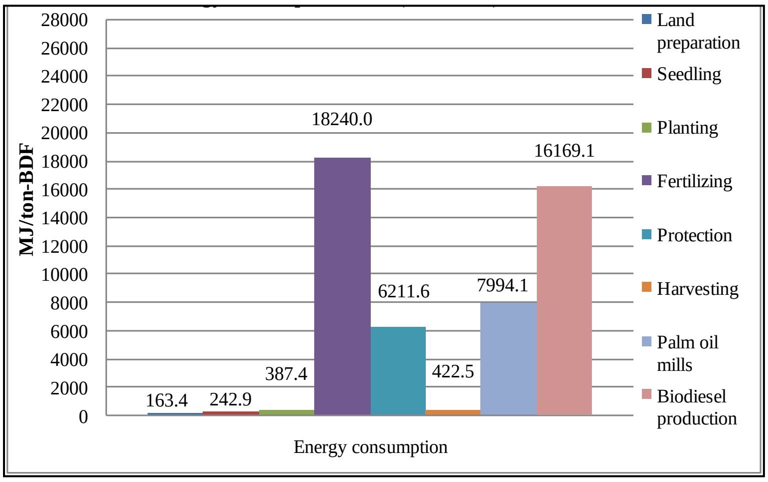


Figure 5.1 The energy consumption value of oil palm before stable production (1-5 year)

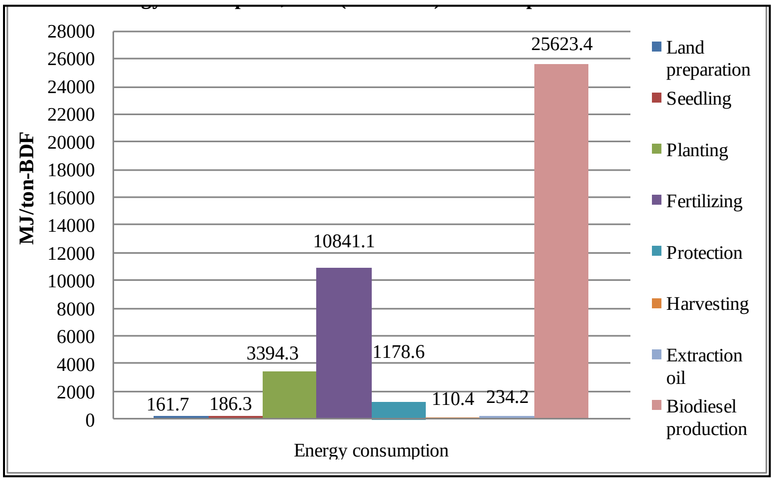


Figure 5.2 The energy consumption value of *Jatropha curcas* before stable production (1-5 year)

Table 5.5 Energy consumption percentage for LCA of palm oil and *Jatropha curcas* from cradle to gate

Input activities	Percentage (%)	
	Palm oil	*Jatropha curcas*
Pre-harvest	50.66	37.77
Harvesting	0.85	0.26
Post-harvest	48.49	61.96

Figure 5.3 shows that the energy consumption of non-renewable fuel for stable production is 33,190.05 and 19,395.89 MJ/ton-BDF for oil palm and *Jatropha curcas*, respectively. The GHG emission value and energy consumption of oil palm and *Jatropha curcas* decreases until the 5th year and becomes stable until the 25th year.

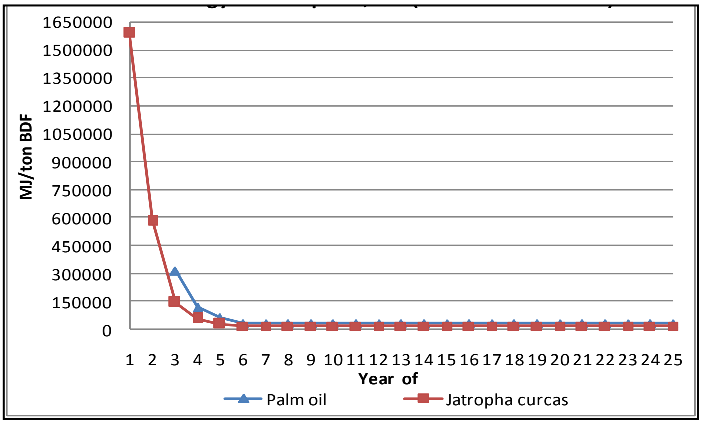


Figure 5.3 The value of non-renewable energy consumption of oil palm and *Jatropha curcas* before and after stable production (1-25 year)

Scenario 2

The second scenario as shown in Figure 5.4 and Figure 5.5 also obtaines that the value of energy consumption for oil palm is higher than *Jatropha curcas* in every stage of the process except at planting and biodiesel production stage. The highest energy consumption for *Jatropha curcas* occurs at biodiesel production i.e. 25,950.00 MJ/ton-BDF. While the largest energy consumption of oil palm occurs at fertilization stage i.e. 24,330.00 MJ/ton-BDF. The total value of energy consumption of oil palm and *Jatropha curcas* before stable production is 46,307.6 MJ/ton-BDF from CPO and 44,093.90 MJ/ton-BDF from CJCO.

According to Figure 5.4, it can also be described the percentage distribution of energy consumption of oil palm from land preparation, seedling, planting, fertilization, protection, harvesting, palm oil mills, and the production of biodiesel, i.e. 0.58%, 1.28%; 0.54%, 52.54%, 5.84%, 0.49%, 3.12% and 35.61%, respectively. While the value for *Jatropha curcas* (Figure 5.5) is 0.29%, 1.09%, 10.92%, 25.45%, 2.67%, 0.25%, 0.48%, and 58.85%, respectively. Table 5.6 shows the proportion at each stage of pre-harvest, harvest and post-harvest. Energy for fossil fuel during stable production is 25,468.13 MJ/ton-BDF for oil palm and 18,957.63 MJ/ton-BDF for *Jatropha curcas* as shown in Figure 5.6.

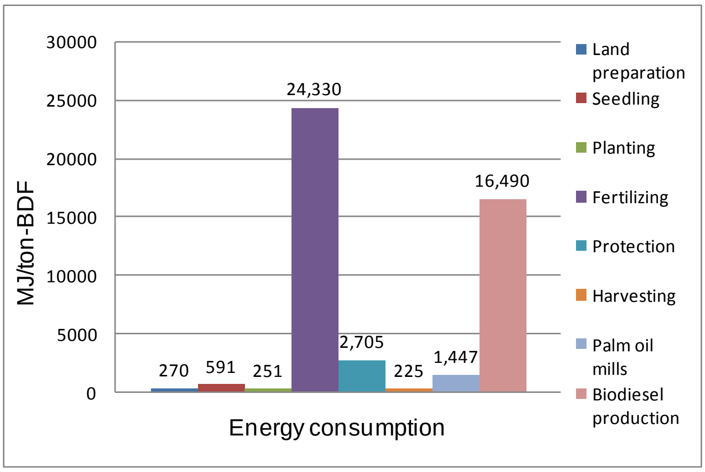


Figure 5.4 The energy consumption value of BDF-CPO before stable production (1-5years)

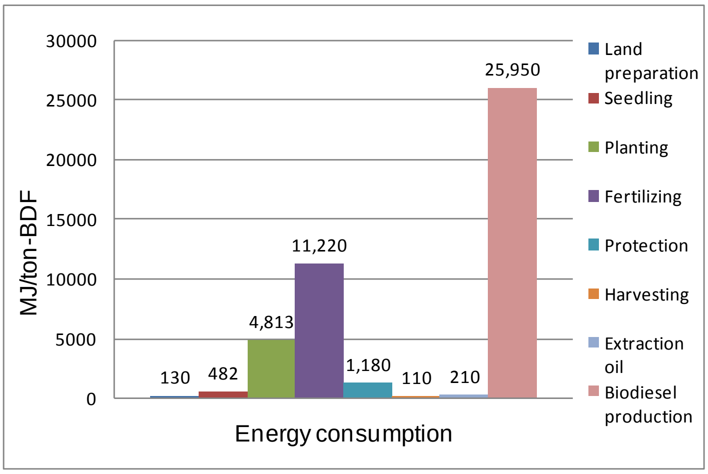


Figure 5.5 The energy consumption value of BDF-CJCO before stable production (1-5 years)

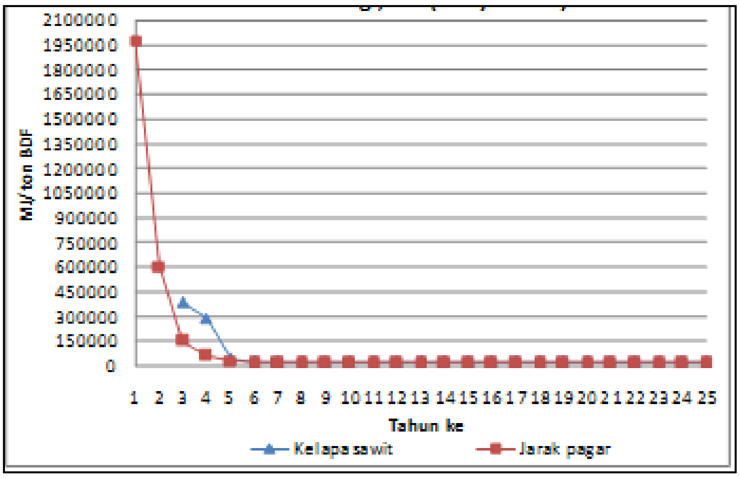


Figure 5.6 The energy consumption value before and after stable production for palm oil and *Jatropha curcas*

Table 5.6 Percentage value of energy consumption in LCA of oil palm and *Jatropha curcas* from cradle to gate

Sub process	Percentage (%)	
	Oil palm	*Jatropha curcas*
Pre-harvest	60.78	40.42
Harvesting	0.49	0.25
Post-harvest	38.73	59.33

Scenario 3

Energy consumption of fossil fuel at stable production is 25,468.13 MJ/ton-BDF-CPO for oil palm and 18,957.63 MJ/ton-BDF-CJCO for *Jatropha curcas*. Figure 5.7 shows the fossil energy consumption value for oil palm and *Jatropha* throughout its life cycle (1-25 years). Figure 5.8 shows the value of non-renewable energy consumption; Figure 5.9 shows the value of renewable energy consumption, Figure 5.10 shows the value of the total energy consumption.

Table 5.7 shows the running results of MiLCA-JEMAI software for fossil energy consumption value in year 6th (stable production) for oil palm and *Jatropha curcas* (Table 5.8). From this table it can be seen that equivalent value is a multiplication result between LCI results with characterization factor. Characterization factor is usually issued by the IPCC or the authority of a particular region or country. Table 5.9 and Table 5.10 present the running result of non-renewable energy consumption value in year 6th for oil palm and *Jatropha curcas*. Table 5.11 and Table 5.12 show the running result of renewable energy consumption value (renewable fuel) in year 6th for palm oil and *Jatropha*. Table 5.13 and Table 5.14 show the running result of all energy consumption value in year 6th for palm oil and *Jatropha* and more is shown in Appendix 11.

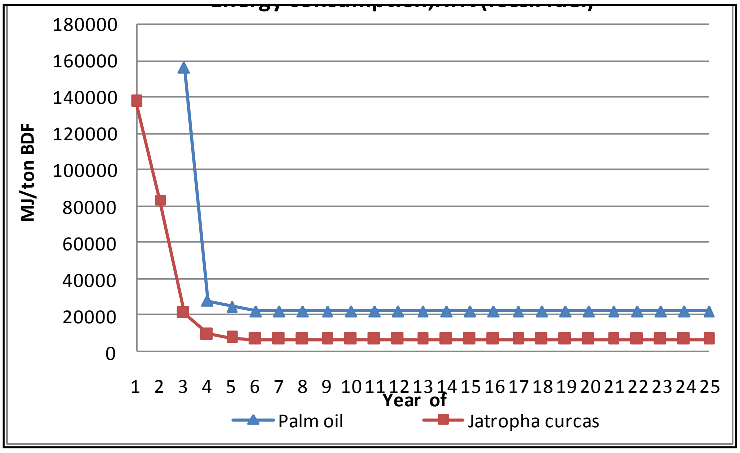


Figure 5.7 Fossil energy consumption value before and after stable production of oil palm and *Jathropa curcas*

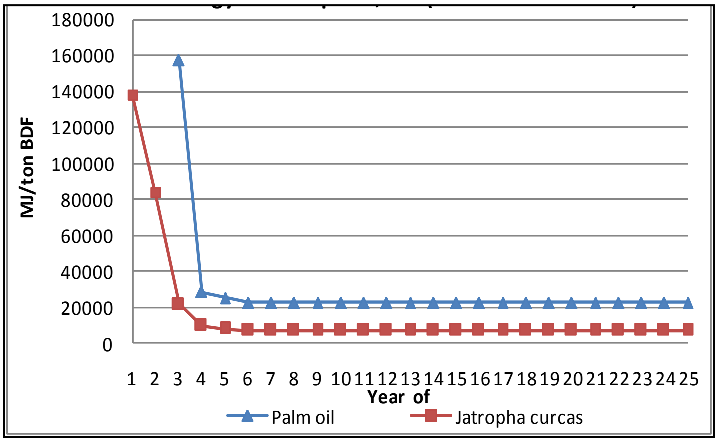


Figure 5.8 Non-renewable energy consumption before and after stable production of oil palm and *Jatropha curcas*

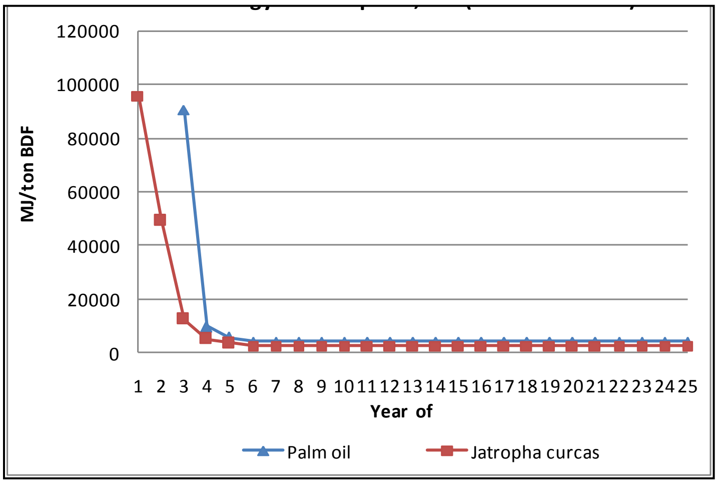


Figure 5.9 Total renewable energy consumption value before and after stable production of palm oil and *Jatropha curcas*

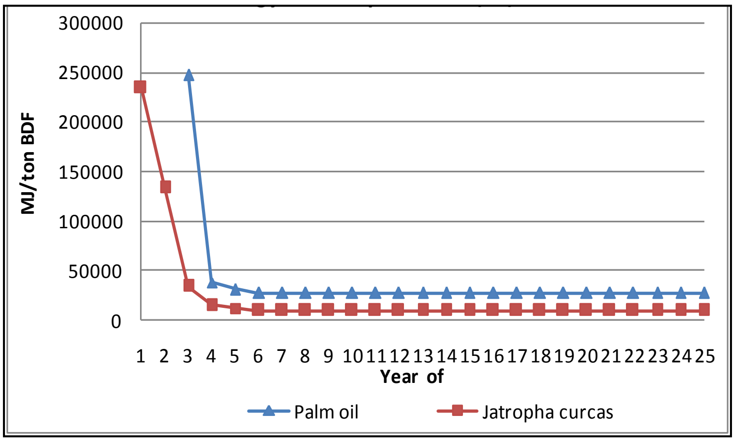


Figure 5.10 Total energy consumption value before and after stable production of palm oil and *Jatropha curcas*

Figure 5.11 shows the NEB value of BDF-CPO and BDF-CJCO throughout its life cycle. NEB value is the result of output energy values substracted by energy processes. The output energy consists of BDF-CPO energy added with glycerol energy, while the energy process consists of fossil energy added with renewable energy which is calculated from the beginning of the process until the biodiesel is produced in accordance with the limits in this experiment. According to the NEB value, it can be seen that the value during initial production is still negative, because the production is not as high as the energy process used. The NEB value will become positive as the production increases due to the production energy in the form of produced biodiesel has become higher than the energy process during biodiesel production. The positive value of NEB means that there is energy surplus during the production process which presents good sustainability. In this case, based on NEB value, the sustainability of CPO based biodiesel is better than CJCO based biodiesel.

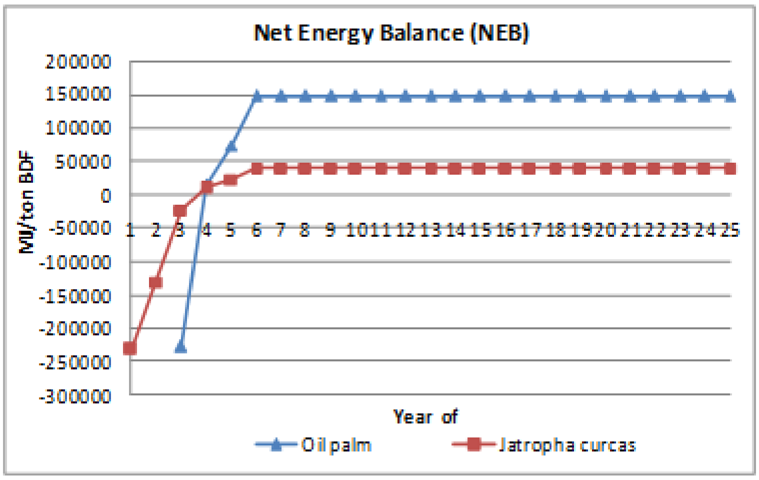


Figure 5.11 The NEB value of BDF-CPO and BDF-CJCO throughout its life cycle (1-25years)

Figure 5.12 shows NER value for oil palm and *Jatropha curcas* i.e. 1.041 and 1.042, respectively. NER value is derived from the value of energy output that consists of energy BDF-CPO added with glycerol energy and divided with energy input that consists of CPO energy. It turns that NER value appears to be constant value due to increased output value will increase the input value, although the NER value can reach higher value if the produced biomass energy is calculated as output energy. The NER value of oil palm and *Jathropa curcas* is 2.93 and 2.11, respectively. NER value of oil palm is higher than *Jathropa curcas* as palm oil produces higher biomass.

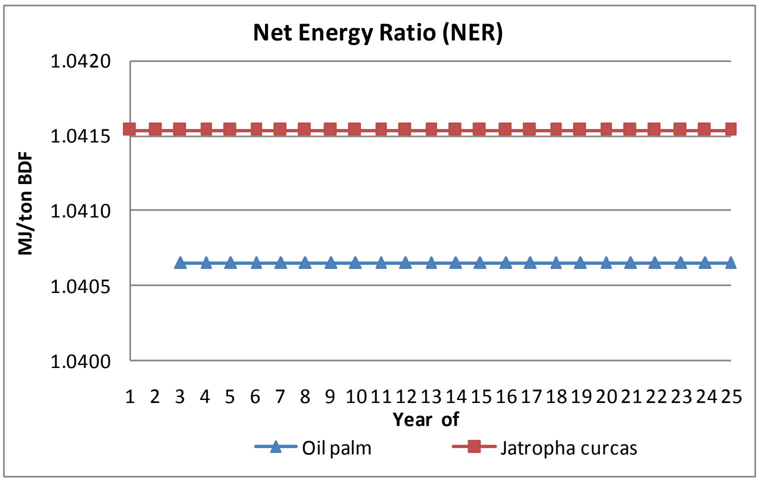


Figure 5.12 The NER value of BDF-CPO and BDF-CJCO throughout its life cycle (1-25 years)

Figure 5.13 shows RI value of palm oil and *Jatropha curcas*. RI is an indicator of renewable energy amount used in the biodiesel production. If RI increases or closes to one mean that more of renewable energy used in this process. In other words, if more fossil energy used in the process means that RI value should be increased to perform environmental friendly of biodiesel production. Figure 5.13 shows that RI value of *Jatropha curcas* is higher than the palm oil. This could be caused by lower fossil energy used by *Jatropha curcas* during its life cycle than the palm oil. Both in palm oil and *Jatropha curcas* shows that RI value from the first year till the sixth year tends to have lower value. The increasing number of oil palm and *Jatropha curcas* will increase fossil fuel consumption including the diesel fuel consumption in boiler. This condition can be anticipated by using biomass produced by biodiesel during its production in boiler.

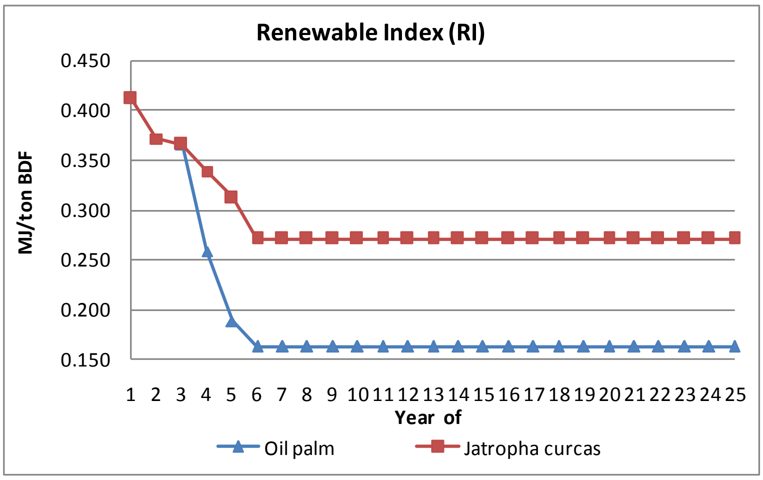


Figure 5.13 The RI value of BDF-CPO and BDF-CJCO throughout its life cycle (1-25 years)

Table 5.7 LCIA result of fossil fuel consumption of BDF-CPO in year 6th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	361.62	kg	44.7	16164.64
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	40.29	kg	25.7	1035.35
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	4.86	kg	29	140.90
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	0.00001	kg	46.5	0.00039
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	92.74	kg	54.6	5063.34
						Total	22404.22

Table 5.8 LCIA result of fossil fuel consumption of BDF-CJCO in year 6th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	64.38	Kg	44.70	2877.74
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	23.77	Kg	25.70	610.96
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	1.042	Kg	29	30.21
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	5.37E-08	Kg	46.50	0.000002
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	63.017	Kg	54.60	3440.72
						Total	6959.63

Table 5.9 LCIA result of non-renewable fuel consumption of BDF-CPO in year 6^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. Factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	361.62	Kg	44.7	16164.64
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	40.29	Kg	25.7	1035.35
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	4.86	Kg	29	140.90
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	0.00001	Kg	46.5	0.00039
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	92.74	Kg	54.6	5063.34
Resources	Ground	Non-renewable energy	uranium,U_3O_8	0.00007	Kg	454662.0	32.52
						Total	22436.75

Table 5.10 LCIA result of non-renewable fuel consumption of BDF-CJCO in year 6^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. Factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	64.379	kg	44.70	2877.74
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	23.773	kg	25.70	610.96
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	1.042	kg	29.00	30.21
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	5.37E-08	kg	46.50	0.000002
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	63.017	kg	54.60	3440.72
Resources	Ground	Non-renewable energy	uranium,U_3O_8	4.60E-05	kg	454662.00	20.91
						Total	6980.54

Table 5.11 LCIA result of renewable fuel consumption of BDF-CPO in year 6th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. Factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	1961.46	MJ	1	1961.46
Resources	Water	Renewable energy	primary energy from hydro power	81.06	MJ	1	81.06
Resources	Air	Renewable energy	primary energy from solar energy	2298.17	MJ	1	2298.17
						Total	4340.68

Table 5.12 LCIA result of renewable fuel consumption of BDF-CJCO in year 6th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. Factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	1065.49	MJ	1	1065.487
Resources	Water	Renewable energy	primary energy from hydro power	40.433	MJ	1	40.433
Resources	Air	Renewable energy	primary energy from solar energy	1468.41	MJ	1	1468.407
						Total	2574.326

Table 5.13 LCIA result of all energy consumption of BDF-CPO in year 6th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	361.62	Kg	44.7	16164.64
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	40.29	Kg	25.7	1035.35
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	4.86	Kg	29	140.90
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	0.00001	Kg	46.5	0.00
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	92.74	Kg	54.6	5063.34
Resources	Ground	Renewable energy	primary energy from geothermics	1961.46	MJ	1	1961.46
Resources	Water	Renewable energy	primary energy from hydro power	81.06	MJ	1	81.06
Resources	Air	Renewable energy	primary energy from solar energy	2298.17	MJ	1	2298.17
Resources	Ground	Non-renewable energy	uranium,U_3O_8	0.00007	Kg	454662.0	32.52
						Total	26777.43

Table 5.14 LCIA result of all energy consumption of BDF-CJCO in year 6th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	64.38	Kg	44.7	2877.75
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	23.77	Kg	25.7	610.96
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	1.042	Kg	29	30.21
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	5.37E-08	Kg	46.5	2.50E-06
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	63.0168	Kg	54.6	3440.72
Resources	Ground	Renewable energy	primary energy from geothermics	1065.49	MJ	1	1065.49
Resources	Water	Renewable energy	primary energy from hydro power	40.43	MJ	1	40.43
Resources	Air	Renewable energy	primary energy from solar energy	1468.41	MJ	1	1468.41
Resources	Ground	Non-renewable energy	uranium,U_3O_8	4.60E-05	Kg	454662	20.91
						Total	9554.87

Scenario 4

The summary value of NEB, NER, and RI for scenario 2, 3 and 4 during stable production is shown in Table 5.15. This value is still in the viable category for biodiesel development, one of which can be seen from the NEB value which shows positive value. James et al. (2006) stated that NEB value of biofuel is positive due to renewable energy inherent in the raw materials, the waste can still be used as an energy source in the treatment process, and because most of agricultural energy analysts realize that the sun energy is freely captured by biomass. NEB and NER parameter are regarded as the method for evaluating the sustainability of biofuels since the energy crisis of the 1970s in the United States. In the second scenario, it can be seen that NER value is considerably high both in palm oil and *Jatropha curcas* as the produced biomass energy is assumed as energy output during its life cycle. The NER value of palm oil is higher than *Jatropha curcas* due to higher produced biomass. The RI value on the second scenario is higher than the third and fourth scenario. It occurs due to added biomass energy as a renewable energy generated in the life cycle of biodiesel production from oil palm and *Jatropha curcas*.

Table 5.15 The average value of NEB, NER and RI

Item	Scenario 2		Scenario 3		Scenario 4	
	Oil palm	*Jatropha curcas*	Oil palm	*Jatropha curcas*	Oil palm	*Jatropha curcas*
NEB	408,750.58	365,350.47	146,948.08	39,334.79	155,041.89	42,649.83
NER	2.97	1.98	1.041	1.042	1.041	1.042
RI	0.80	0.41	0.162	0.270	0.06	0.116

Table 5.16 presents the HHV and LHV value from literature study for CPO, CJCO, CPO based biodiesel, CJCO based biodiesel and diesel fuel. Heating value (HV) in Table 5 presents that diesel fuel still has the highest value. Ndayishimiye et al. (2011) stated that heating value of diesel fuel is 45.0 MJ/kg, while biodiesel from pure CPO is 39.8 MJ/kg, and B5 diesel (biodiesel using CPO 5%) is 44.8 MJ/kg, B10 diesel (biodiesel using CPO 10%) is 44.5 MJ/kg, B20 diesel (biodiesel using 20% CPO) is 43.4 MJ/kg, and B30 diesel (biodiesel using 30% CPO) is 41.5 MJ/kg.

Heating value of vegetable oil is considerable more accurate than biodiesel. But for all the selected fuel, the absolute error is lower than 5% which shows good accuracy. Average absolute error is 1.71% while the average bias error is 0.84% (Fassinou et al., 2010). Fassinou et al. (2010) also mentioned that HHV value of any oil can be calculated using fatty acid composition as there is always a relationship between HHV and LHV. If the HHV has been found, then the value of LHV also can be calculated.

This calor value is used as input for calculating each energy. Heating values for some input material, such as tree biomass, herbicides, and others are shown in Table 5.17. The complete calculation of NEB, NER, and RI is shown in Appendix 12.

Table 5.16 HHV and LHV value of CPO, CJCO, CPO based biodiesel, CJCO based biodiesel and diesel fuelbased on the literature

Name of feedstocks	Value of calor heating (HV)		Reference	Remarks
	HHV	LHV		
CPO	39.74 MJ/kg	33.5 MJ/kg	Demirbas, 2008	
	39.19 MJ/kg (HHV_C) 39.11 MJ/kg (HHV_M)		Fassinou etal., 2010	C = calculation, M = measurement (ASTM D240)
	39.4 MJ/kg (CV)		Yusup et al., 2010	Calorific value
	39.2 MJ/kg (HC)		Ndayishimiyeetal., 2011	Heat of combustion
	39.9 MJ/kg (HV)		Ndayishimiyeetal., 2011	Preheated at 50, 60, 70 ^oC
CJCO	33 MJ/kg		Singh &Padhli, 2009 in Marchetti, 2011	
	39.10 MJ/kg (HHV_C) 39.00 MJ/kg (HHV_M)		Fassinou etal., 2010	C = calculation, M = (ASTM D240)
	35.58 MJ/kg (HV)		Trubus, 2005 in Purba, 2007	HV = Heating value
	39.23 MJ/kg (CV)		Gui etal, 2008 in Marchetti, 2011	
Biodiesel from CPO	39.837 MJ/kg 40.334 MJ/kg	37.1 MJ/kg	Benjumea etal.,2008	ASTM-D240
	41.24 MJ/kg		Demirbas, 2008	
	39.8 MJ/kg (HV)		Ndayishimiyeetal., 2011	Biodiesel from pure CPO, ASTM-D240
Biodiesel from 5%-CPO		41.7 MJ/kg	Benjumea etal.,2008	Plot at grafic (correlation HHV & LHV)
	44.8 MJ/kg (HV)		Ndayishimiyeetal, 2011	95%-Diesel, ASTM-D240
Biodiesel from 10%-CPO	44.5 MJ/kg (HV)		Ndayishimiyeetal., 2011	90%-Diesel, ASTM-D240
Biodiesel from 20%-CPO		41.0 MJ/kg	Benjumea etal.,2008	Plot at grafic (correlation HHV & LHV)
	43.4 MJ/kg (HV)		Ndayishimiyeetal., 2011	80%-Diesel, ASTM-D240
Biodiesel from 30%-CPO		40.5 MJ/kg	Benjumea etal.,2008	Plot at grafic (correlation HHV & LHV)
	41.5 MJ/kg (HV)		Ndayishimiyeetal., 2011	70%-Diesel, ASTM-D240
Biodiesel from CJCO	9423 kCal/ltr (Gross HV)		Suhartana etal., 2008	Calculation
Biodiesel from 5 %- CJCO	9271 kCal/ltr (Gross HV)		Suhartana etal., 2008	95%-Diesel, calculation
Biodiesel from 10%-CJCO	9275 kCal/ltr (Gross HV)		Suhartana etal., 2008	calculation, 90%-Diesel
Diesel	44.8 MJ/kg		Wikepedia, 2010	
	9256 kCal/ltr (Gross HV)		Suhartana etal., 2008	
	45.0 MJ/kg (HV)		Ndayishimiyeetal., 2011	ASTM D-240

Table 5.17 Heating value for some input materials in CPO and CJCO production process

Input names	Calor Value (MJ/kg)	Remarks	Reference
Herbicide	139.39	Liquid	Pimentel, 1980 in Nuryanto, 1998
Diesel fuel	43.33		Calor value (IPCC 1996, 1-23)
Soft wood	17.58		Cervinka,1980 in Nuryanto, 1998
Fungicide	139.39	Liquid	Pimentel, 1980 in Nuryanto, 1998
Insecticide	139.39	Liquid	Pimentel, 1980 inNuryanto, 1998
Fertilizer meister	58.18	Ammonium nitrate	Pimentel 1980 inNuryanto, 1998
Urea	56.93		Pimentel 1980 inNuryanto, 1998
Organic Fertilizer	8.50	Single Superphosphate	Stout, 1990 inNuryanto, 1998
TSP	9.21		Stout, 1990 inNuryanto, 1998
Muriate of Photash (K)	4.60		Stout, 1990 inNuryanto, 1998
Dolomite	61.53		Nuryanto, 1998
N-P-K-Mg (mixing)	48.97	Fertilizer of nitrogen	Stout, 1990 inNuryanto, 1998
Electricity per kWH	3.60		Stout, 1990 inNuryanto, 1998
Pesticide	139.39	Liquid	Pimentel, 1980 inNuryanto, 1998
Calor value of weeds	0.01		Houston 1972 in https://docs.google.com/:digilib.its.ac.id
Rock of Phosphate(RP)	1.67		Stout, 1990 inNuryanto, 1998
KCl	6.69		Nuryanto, 1998
Sulphate of Ammonia (ZA)	60.00		Nuryanto, 1998
Kieserite ($MgSO_4$)	6.00		Nuryanto, 1998
HGF-B (HGF-Borate)	2.51	Normal Superphosphate	Stout, 1990 inNuryanto, 1998
$CuSO_4$	0.02	Ammonium nitrate	http.google.com/digilib.its.ac.id/.../ITS
$ZnSO_4$	0.08	Ammonium nitrate	http.google.com/digilib.its.ac.id/.../ITS
LSD	2.51	Normal superphosphate	Stout, 1990 inNuryanto, 1998
Calor value of steam	2.76	at 8.6 Bar	http.google.com/hematbahanbakarindustri.blogspot.com
Calor value of water	0.0042		http.google.com/digilib.its.ac.id/.../ITS
NaOH	17.94		http.google.com/digilib.its.ac.id/.../ITS
Shell of oil palm	15.24		Nuryanto, 1998
EFB	18.80		http://www.google.com//co-product of oil palm
The midrib of oil palm	15.72		Enreach, 2011
Fibre of oil palm	10.12		Nuryanto, 1998
Calor value of seed *Jatropha curcas*	21.20		www.engineringtoolbox.com (2011) (accessed August 12,2012)
Calor value of dry seed *Jatropha curcas*	25.50		www.engineringtoolbox.com (2011) (accessed August 12,2012)
Calor value of hard wood	29.60		www.engineringtoolbox.com (2011) (accessed August 12,2012)

Conclusion

The conclusions that can be drawn in this chapter are as follows:

1. Scenario 3 shows that the energy input in oil palm is higher than *Jatropha curcas* which reflected by higher NEB and lower RI value. The NEB value of oil palm and *Jatropha curcas* is 146,948.08 and 39,334.79, repectively. The RI value of oil palm and *Jatropha curcas* is 0.162 and 0.270, respectively.
2. NER value of BDF-CPO and BDF-CJCO is higher than 1.
3. The improvement of Indonesian power plant should consider the utilization of low GHG emission fuel, such as natural gas and biodiesel fuel.

CHAPTER 6
GENERAL DISCUSSION

Interpretation (ISO-14043)

LCA can determine the key steps process, the most significant impact, major contributor, and the most appropriate science method to compare various alternative products or processes that is the most environmentally friendly. LCA is usually used to analyze several categories which bring effect to environment, such as greenhouse gas emission and its contribution to global warming. The greenhouse gas emission values, i.e. CO_2, CH_4 and N_2O, are converted to CO_2 emission value according to global warming potentials (GWP) value in the assessment report released by Intergovernmental Panel on Climate Change (Forster et al., 2007; Ndong et al., 2009). The main purpose of this phase is to: analyze desired results, obtain conclusion from observed system, explain encountered boundaries, and give recommendation according to LCI and/or LCIA evaluations. Environmental impact quantification which conducted using LCI and LCIA enables to identify the most significant problems. Sensitivity analysis should be performed before formulating final conclusions and research recommendations. Data availability and reliability are the main concern in using LCA due to this effect to the results and conclusions. Sensitivity analysis supports to identify the influence of data variability, data uncertainty, and data gaps which occur in the final result. It also helps to indicate the final reliability of the research it self. The report should provide complete and transparent information, according to ISO 14040 series.

General category of potential impacts requires several considerations, such as: resource utilization, human health, and ecological health. In general, economic aspects are not reflected in LCA. Whereas, it should be the part of LCA study because financing is an important decision-making factor. It will influence the decision shifting so that more environmentally friendly option will be chosen or to define two options. Therefore, ecology + economy = ecoefficiency, is the key to obtain widespread acceptance of environmentally friendly products (Narayan, 2007).

In this stage, the result of measurement analysis which made in previous stages are evaluated and summarized. Thus, a recommendation which acts as a reference in the decision-making process to reduce potential impacts can be achieved, to improve and increase energy efficiency/added value of biodiesel production by catalytic process from CPO and CJCO. LCA is an appropriate method to study life cycle assessment of a process. However, if the input data or approaches are in appropriate or even manipulative, the output will not be used by users.

Global Warming Potential (GWP)

Global warming potential, 100-year based (GWP^{100}) is an indicator of global warming potency caused by emission in a period of 100 years. Greenhouse gas (GHG) emission on this research is the source of global warming potential (GWP). Thus, the value of greenhouse gases is considered as global warming potential in the next analysis. GHG is expressed in the unit of kg-CO_2 equivalent (eq.), which is the main greenhouse gas causing global warming. This value is issued periodically by Intergovernmental Panel on Climate Change (IPCC). GHG^{100} as it stated in the units (kg-CO_2) is mainly composed by CO_2 gas. Other gases also have a potentially large amount of GHG equivalent value; CH_4 and CO_2 value are 25 kg-CO_2 and 298 kg-$CO_{2,}$ respectively. However, CO_2 remains as the main component which causes global warming as it is the main product of hydrocarbon-oxygen reaction.

According to IPCC 2006, the components of greenhouse gases (GHG) emission are carbon dioxide (CO_2), methane (CH_4), dinitrogen oxide (N_2O), hydrofluourocarbons (HFC), perfluorocarbons (PFC), sulfur hexafluoride (SF_6), trifluoride nitrogen (NF_3), trifluoromethyl sulfur pentafluoride (SF_5CF_3), halogenated ether (i.e. $C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$) and CF_3I, $CH_2Br_2CHCl_3$, CH_3Cl, CH_2C_{l2}. The gases mentioned above are global warming potential (GWP) identified by IPCC before the finalization of 2006 Guidelines. The guide line also provides the method to assess GWP value of other gases which are unavailable in the previuos guideline i.e. C_3F_7C (O) C_2F_5, C_7F_{16}, C_4F_6, C_5F_8 dan c-C_4F_8O. These gases are sometimes used as the substitute for the gases in the list and each country are encouraged to create the estimation its elf.

Table 6.1 and Table 6.2 display the MiLCA-JEMAI software result of global warming potential in year-6 (stable productivity) for oil palm and *Jatropha curcas*, respectively. Of all 10 gases which are the part of GWP, according to IPCC 2006 mentioned above, those gases in Table 6.1 and Table 6.2 are definitely greenhouse gases. And if the gases in Table 6.1 for oil palm are sorted, the percentage for unspecified CO_2 (fossil), unspecified methane (CH_4), unspecified nitrous oxide (NOx), carbon air close to ground CO_2 (fossil), NOx by carbon air close to ground, unspecified PFC-14, CH_4 (fossil) by carbon air close to ground, sulfur hexafluoride, CO_2 (fossil) by troposphere, and unspecified CO_2 (biogenic) is 95.14%, 2.33%, 2.06%, 0.47%, 0.0011%, 0.0010%, 0.0002%, 0.0001%, 0%, and 0%, respectively. For *Jatropha curcas*, as shown in Table 5.2, the list is different, the percentage for unspecified CO_2 (fossil), unspecified nitrous oxide (NOx), carbon air close to ground CO_2 (fossil), unspecified methane (CH_4), NOx by carbon air close to ground, CH_4 (fossil) by carbon air close to ground, unspecified PFC-14, sulfur hexafluoride, CO_2 (fossil) by troposphere, unspecified CO_2 (biogenic) is 89.82%, 4.64%, 3.46%, 2.06%, 0.0084%, 0.0013%, 0.00065%, 0.00005%, 0%, and 0%, respectively. And if the greenhouse gases which taken into account are unspecified CO_2 (fossil) and CH_4, the percentage has reached 97.37% of global warming potential (kg-CO_2 eq.) for palm oil and 91.88% for *Jatropha curcas*. Table 6.1 and Table 6.2 also present the characterization factor for sulfur hexafluoride, PFC-14, NO_x, and methane (CH_4) is 22800, 7390, 298, and 25, respectively. While the characterization factor of CO_2 is only 1. It implies that in production process, the formation of the gases with high characterization factor must be avoided or converted to CO_2as much as possible. Therefore, a methane capture is developed in Palm Oil Mill. Methane released in the air affects 25 times stronger than CO_2 at the same amount.

Emission Reduction of CO_2eq. Biodiesel vs Diesel Fossil

Scenario 1

Figure 6.1, Figure 6.2, and Figure 6.3 show the comparison of CO_2eq. emission reduction value produced in biodiesel from oil palm and *Jatropha curcas*. Figure 6.1 and Figure 6.2 show that reduction in CO_2eq. emissions is higher at stable productivity due to lower input energy and mass which only used for maintenance, fertilizing and harvesting. The sub-processes of land preparation, seedling, and planting are not carried out in this phase. Figure 6.3 shows combination values of CO_2eq.emission before and after stable production. It can be seen that reduction value of CO_2eq.emission for biodiesel fuel from crude palm oil (BDF-CPO) and biodiesel fuel from crude *Jatropha curcas* oil (BDF-CJCO) is 37.83% and 63.61%, respectively. Research conducted by Gomma et al. (2011) mentioned that jatropha biodiesel can save greenhouse gas emission by 66 % compared to diesel fuel even it accounts pasture land use. Prueksakorn et al. (2006) stated that greenhouse gas emission jatropha is 77% lower than disel fuel's production and consumption. Pehnelt et al. (2013) concluded the more accurate GHG emission saving value of palm oil feedstock for electricity generation and biodiesel by 52% and between 38.5 - 41 %, respectively, depending on the fossil fuel comparator. Gmunder et al. (2009) stated that rural electrification based on extensive jatropha cultivation is more environmentally friendly compared to the usage of fossil diesel.

Scenario 2

Figure 6.4, Figure 6.5, and Figure 6.6 show the comparison of CO_2eq. emission reduction value produced in biodiesel from palm oil and *Jatropha curcas*. Figure 6.4 and Figure 6.5 also display higher reduction of CO_2eq. emission in stable productivity state due to decreasing of energy input and mass which only used in maintenance, fertilizing, and harvesting. The sub-process of land preparation, seedling, and planting are not carried out in this phase. Figure 6.6 displays combination values of CO_2eq. emission before and after stable production for crude palm oil (BDF-CPO) and biodiesel fuel from crude *Jatropha curcas* oil (BDF-CJCO) i.e. 49.96% and 61.61%, respectively.

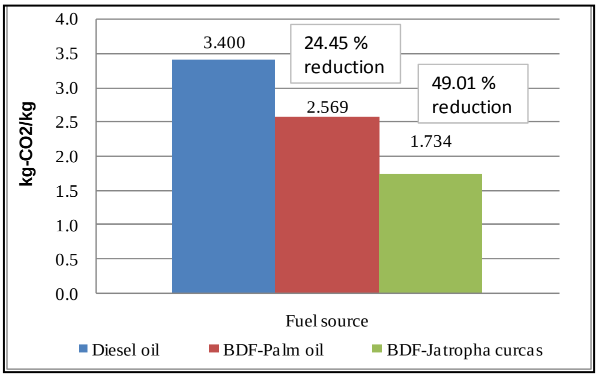


Figure 6.1 The reduction percentage of CO_2eq.emission before stable productivity (1-5 years) for scenario 1

Table 6.1 Result of LCIA for global warming potential (GWP-100) by BDF-CPO in year 6th

No	Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent
1	Emissions	Air	Unspecified	carbon dioxide (biogenic)	1.67	kg	0	0
2	Emissions	Air	Urban air close to ground	carbon dioxide (fossil)	7.09	kg	1	7.09
3	Emissions	Air	Unspecified	carbon dioxide (fossil)	1438.43	kg	1	1438.43
4	Emissions	Air	Troposphere	carbon dioxide (fossil)	0.000	kg	1	0
5	Emissions	Air	Unspecified	methane	1.41	kg	25	35.22
6	Emissions	Air	Urban air close to ground	methane (fossil)	0.00011	kg	25	0.0027
7	Emissions	Air	Urban air close to ground	nitrous oxide	0.00006	kg	298	0.017
8	Emissions	Air	Unspecified	nitrous oxide	0.10	kg	298	31.18
9	Emissions	Air	Unspecified	PFC-14	0.000002	kg	7390	0.016
10	Emissions	Air	Unspecified	sulfur hexafluoride	0.0000001	kg	22800	0.0013
							Total	1511.96

Table 6.2 Result of LCIA for global warming potential (GWP) by BDF-CJCO in year 6th

No	Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent
1	Emissions	Air	Unspecified	carbon dioxide (biogenic)	1.25	kg	0	0.000
2	Emissions	Air	Unspecified	carbon dioxide (fossil)	341.78	kg	1	341.78
3	Emissions	Air	Urban air close to ground	carbon dioxide (fossil)	13.18	kg	1	13.18
4	Emissions	Air	Troposphere	carbon dioxide (fossil)	0.000	kg	1	0.000
5	Emissions	Air	Unspecified	Methane	0.31	kg	25	7.85
6	Emissions	Air	Urban air close to ground	methane (fossil)	0.0002	kg	25	0.005
7	Emissions	Air	Unspecified	nitrous oxide	0.059	kg	298	17.67
8	Emissions	Air	Urban air close to ground	nitrous oxide	0.00011	kg	298	0.032
9	Emissions	Air	Unspecified	PFC-14	0.0000003	kg	7390	0.002
10	Emissions	Air	Unspecified	sulfur hexafluoride	0.00000001	kg	22800	0.00018
							Total	380.52

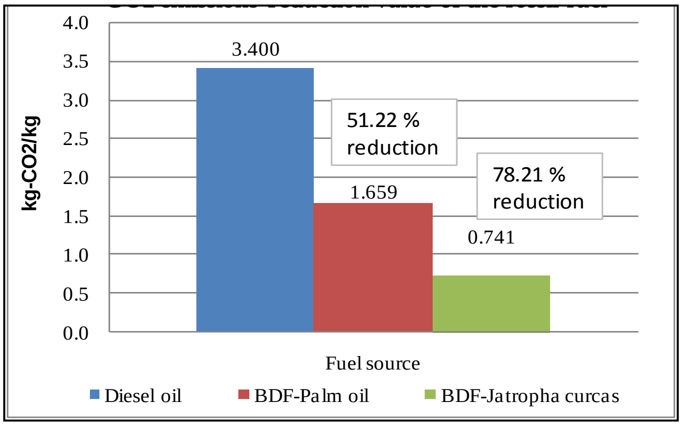


Figure 6.2 The reduction value of CO_2eq.emission after stable productivity (6-25 years) for scenario 1

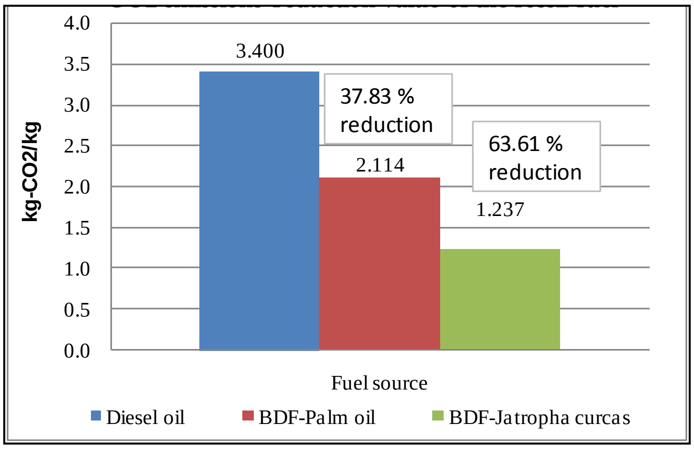


Figure 6.3 The total value of CO_2eq.emission during its life cycle (1-25 years) for scenario 1

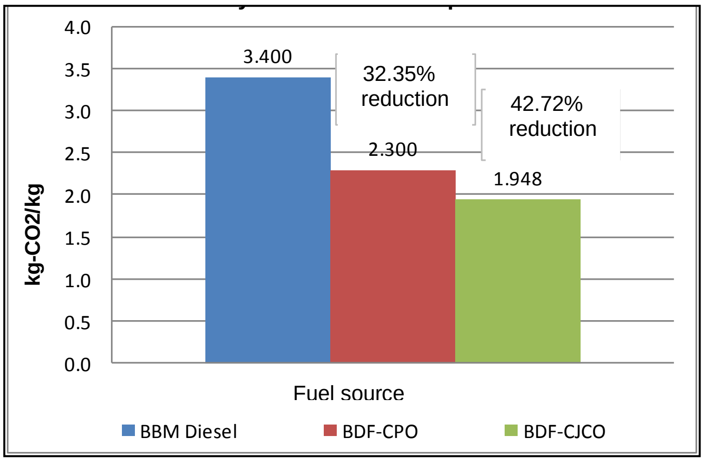


Figure 6.4 The reduction percentage of CO_2eq.emission before stable productivity (1-5 years) for scenario 2

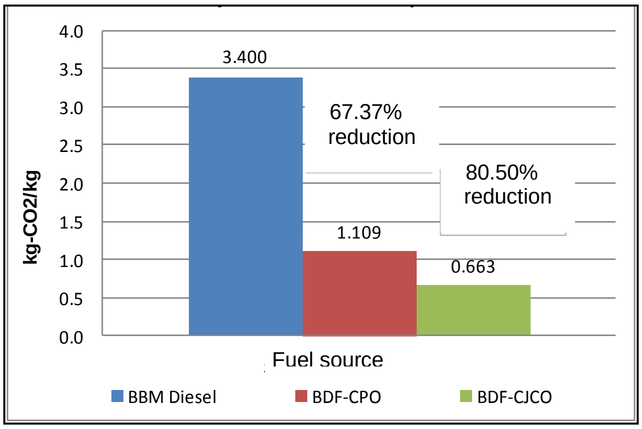


Figure 6.5 The reduction percentage of CO_2eq.emission after stable productivity (6-25 years) for scenario 2

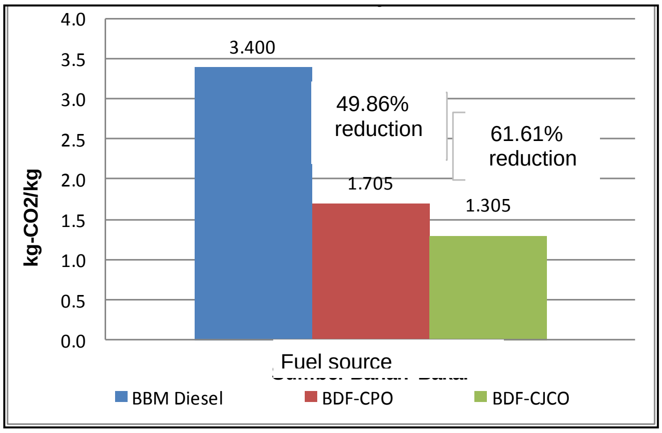


Figure 6.6 Total reduction percentage of CO_2eq.emission before and after stable productivity (1-25 years) for scenario 2

Scenario 3

Figure 6.7, Figure 6.8, and Figure 6.9 show the comparison of CO_2eq.emission reduction value produced in biodiesel production from palm oil and *Jatropha curcas*. Figure 6.7 and Figure 6.8 also display higher reduction of CO_2eq.emission in stable productivity state due to decreasing of energy input and mass which only used in maintenance, fertilizing, and harvesting. The sub-process of land preparation, seedling, and planting are not carried out in this phase.

Figure 6.9 displays combination values of CO_2eq. emission before and after stable production for crude palm oil (BDF-CPO) and biodiesel fuel from crude *Jatropha curcas* oil (BDF-CJCO) i.e. 49.27% and 73.06%, respectively.

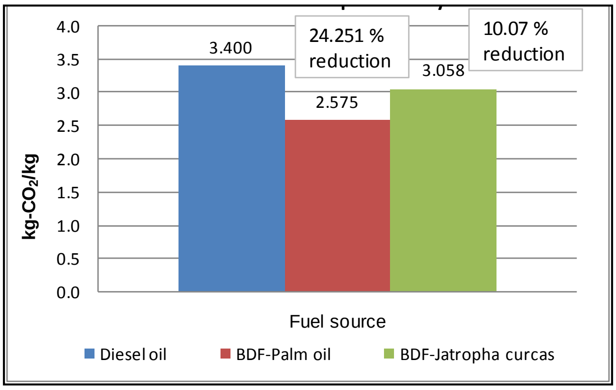


Figure 6.7 The reduction percentage of CO_2eq. before stable productivity (1-5 years) for scenario 3

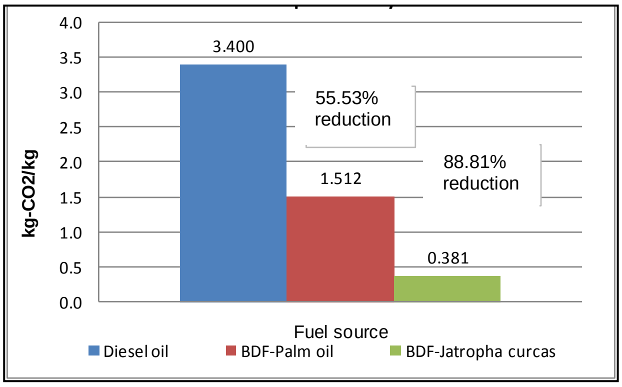


Figure 6.8 The reduction percentage of CO_2eq.emission after stable productivity (6-25 years) for scenario 3

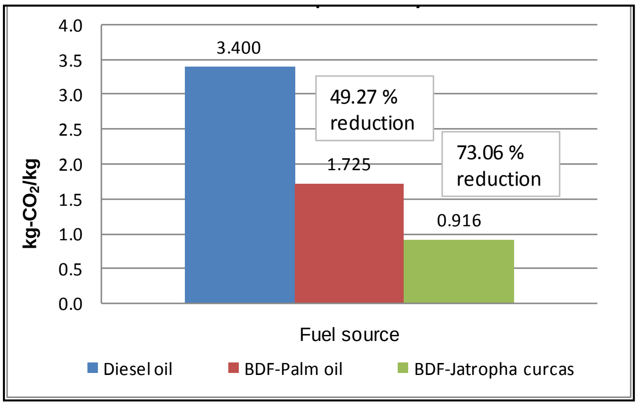


Figure 6.9 Total reduction percentage of CO_2eq.emission before and after stable productivity (1-25 years) for scenario 3

Scenario 4

Figure 6.10, Figure 6.11, and Figure 6.12 show the comparison of CO_2eq.emission reduction value produced in biodiesel from palm oil and *Jatropha curcas*. Figure 6.10 and Figure 6.11 also display higher reduction of CO_2eq.emission in stable productivity state due to decreasing of energy input and mass which only used in maintenance, fertilizing, and harvesting. The sub-process of land preparation, seedling, and planting are not carried out in this phase.

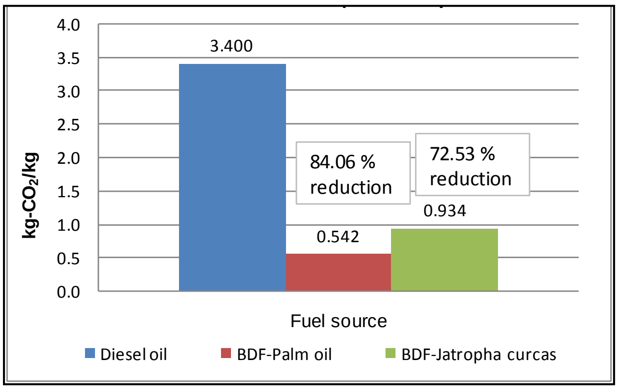


Figure 6.10 The reduction percentage of CO_2eq.emission before stable productivity (1-5 years) for scenario 4

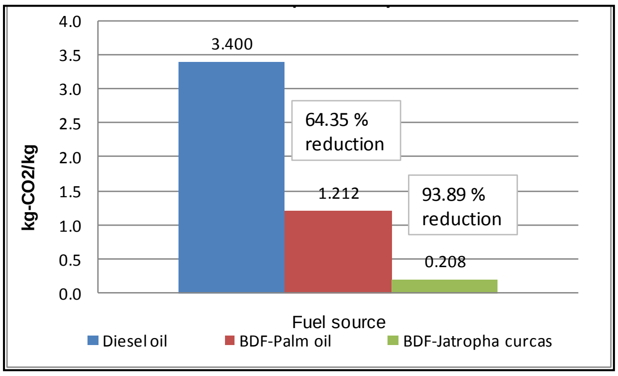


Figure 6.11 The reduction percentage of CO_2eq.emission after stable productivity (6-25 years) for scenario 4

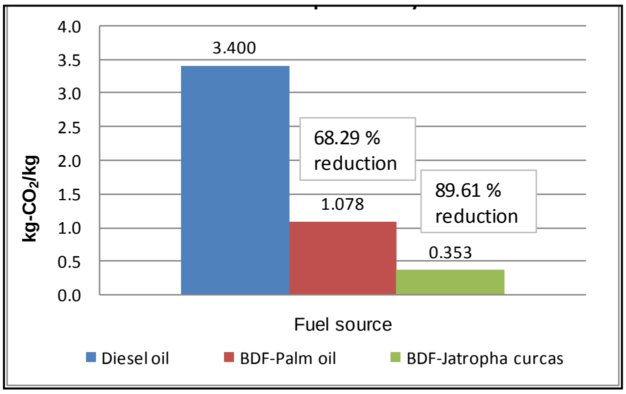


Figure 6.12 Total reduction percentage of CO_2eq.emission before and after stable productivity (1-25 years) for scenario 4

Figure 6.12 displays the combination values of CO_2eq. emission before and after stable production for crude palm oil (BDF-CPO) and biodiesel fuel from crude *Jatropha curcas* oil (BDF-CJCO) i.e. 49.96% and 61.61%, respectively.

Acidification

SO_2 and NO_2 are two kinds of emission which have effect on acidification. Air emission is influenced by SO_2 and SO_2 equivalent compounds. Acidification is the reduction of pH value of soil and water due to the formation of H^+ion (Wikipedia, 2011a dan 2011b). The formation of hydrogen cation is caused by some reactions of alluminum sulfate, nitrogen compounds in fertilizer, the leaching of ions (calcium, magnesium, potassium, and ammonium ion) into the soil. Acidification potential is expressed in the unit of kg-SO_2 equivalent. This is the approach in impact category (j) for midpoint-oriented approach. Table 6.3 and Table 6.4 present the acidification results based on MiLCA-JEMAI software in year-6 (stable productivity) for oil palm and *Jatropha curcas*. Of all 10 gases, sulfur oxide (SO_2) results the highest acidification value. The three largest values for palm oil are SO_2, nitrogen oxide (NO_x), and sulfur oxide (SO_x) i.e. 66.36%, 27.0%, and 6.16%, respectively (Table 6.3). And the three largest values for *Jatropha curcas* are SO_2, nitrogen oxide (NO_x), and sulfur oxide (SO_x) i.e. 56.84%, 33.16%, and 6.86%, respectively (Table 6.4).

Waste landfill volume

Waste landfill volume is the total area to be provided in order to accommodate the waste from evaluated LCA study. Table 6.5 and Table 6.6 show waste landfill volume resulted from MiLCA-JEMAI software in year-6 (stable productivity) for palm oil and *Jatropha curcas*. Of all 3 wastes which are the part of waste landfill volume, the highest percentage is from sludge (landfill). If the list is sorted from the highest, the results are sludge (landfill), metal waste (landfill), and slag (landfill) i.e. 76.19%, 23.81%, and 0.0016% (Table 6.5) for palm oil, respectively and 76.19%, 23.81%, and 0.0033% (Table 6.6) for *Jatropha curcas*, respectively.

Eutrophication

Eutrophication is a condition to explain the great increasing of a certain species followed by declining of another species due to the increasing amount of nitrate and phosphate compounds. Eutrophication in water body induces reductions in specific water species and other animal populations because the amount of phytoplankton is increasing. It triggers increased competition for nutrients and difficulty in obtaining oxygen (hypoxia). It could also occur in terrestrial ecosystem, showed by the increasing of tall grasses followed by the decreasing of other species (Wikipedia, 2011c). Eutrophication potential caused by emission is expressed in the unit of kg PO_4^{3-} equivalent. Table 6.7 and Table 6.8 display the eutrophication resulted from MiLCA-JEMAI software in year-6 (stable productivity) for palm oil and *Jatropha curcas*. Of all 6 emission categories which are parts of eutrophication, the three largestpercentage for palm oil is total N, nitrogen dioxide, and chemical oxygen demand i.e. 68.18%, 30.97%, and 0.67%, respectively. Total P value is only 0.0079% or the fifth rank (Table 6.7). The three largest percentage for *Jatropha curcas* is total N, nitrogen dioxide, and chemical oxygen demand i.e. 98.76%, 0.67%, and 0.43%, respectively. Total P value is only 0.0024% or the fifth rank (Table 6.8). Thus, many literatures state that eutrophication value is called nitrate equivalent, because the most dominant composition is nitrate percentage.

Table 6.3 Result of LCIA for acidification of BDF-CPO in year 6th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. Factor	Equivalent	Percent. (%)	Rangk
Emissions	Air	Unspecified	Ammonia	0.0000009	kg	5.99	0.0000057	0.00025	7
Emissions	Air	Unspecified	hydrogen chloride	0.0000002	kg	2.61	0.0000005	0.000024	8
Emissions	Air	Urban air close to ground	nitrogen dioxide	0.0025	kg	0.717	0.0018	0.08	5
Emissions	Air	Urban air close to ground	nitrogen oxides	0.013	kg	0.717	0.0091	0.41	4
Emissions	Air	Unspecified	nitrogen oxides	0.84	kg	0.717	0.6007	27.00	2
Emissions	Air	Troposphere	nitrogen oxides	0.0000000	kg	0.717	0.00	0.00	9
Emissions	Air	Urban air close to ground	sulfur dioxide	0.000045	kg	1	0.000045	0.00202	6
Emissions	Air	Unspecified	sulfur dioxide	1.48	kg	1	1.48	66.36	1
Emissions	Air	Troposphere	sulfur dioxide	0.0000000	kg	1	0.00	0.00	10
Emissions	Air	Unspecified	sulfur oxides	0.14	kg	1	0.14	6.16	3
						Total	2.23	100	

Table 6.4 Result of LCIA for acidification of BDF-CJCO in year 6th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent	Percent. (%)	Rangk
Emissions	Air	Unspecified	Ammonia	0.00000043	kg	5.989	0.000003	0.00048	7
Emissions	Air	Unspecified	hydrogen chloride	0.00000009	kg	2.613	0.0000002	0.000045	8
Emissions	Air	Urban air close to ground	nitrogen dioxide	0.000017	kg	0.717	0.000012	0.0022	6
Emissions	Air	Unspecified	nitrogen oxides	0.25	kg	0.717	0.176	33.16	2
Emissions	Air	Urban air close to ground	nitrogen oxides	0.023	kg	0.717	0.0166	3.12	4
Emissions	Air	Troposphere	nitrogen oxides	0.00000000	kg	0.717	0.00	0.000	9
Emissions	Air	Unspecified	sulfur dioxide	0.302	kg	1	0.302	56.84	1
Emissions	Air	Urban air close to ground	sulfur dioxide	0.000084	kg	1	0.000084	0.016	5
Emissions	Air	Troposphere	sulfur dioxide	0.00000000	kg	1	0.00	0.00	10
Emissions	Air	Unspecified	sulfur oxides	0.036	kg	1	0.0364	6.86	3
						Total	0.531	100.00	

Table 6.5 Result of LCIA for waste landfill volume of BDF-CPO in year 6^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent	Percent. (%)	Rangk
Emissions	Ground	Soil managed	metal wastes (landfill)	5.21	kg	0.0005	0.0026	23.81	2
Emissions	Ground	Soil managed	slag (landfill)	0.00035	kg	0.00052	0.0000002	0.0016	3
Emissions	Ground	Soil managed	sludge (landfill)	8.33	kg	0.001	0.0083	76.19	1
						Total	0.011	100	

Table 6.6 Result of LCIA for waste landfill volume of BDF-CJCO in year 6^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent	Percent.(%)	Rangk
Emissions	Ground	Soil managed	metal wastes (landfill)	1.172	kg	0.0005	0.00059	23.81	2
Emissions	Ground	Soil managed	slag (landfill)	0.0002	kg	0.00052	0.0000001	0.0033	3
Emissions	Ground	Soil managed	sludge (landfill)	1.875	kg	0.001	0.0019	76.19	1
						Total	0.0025	100.00	

Table 6.7 Result of LCIA for eutrophication volume of BDF-CPO in year 6^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent	Percentage (%)	Rangk
Emissions	Air	Unspecified	Ammonia	9.45E-07	kg	0.092	8.69E-08	0.099	4
Emissions	Water	Unspecified	Ammonium	1.46E-09	kg	0.202	2.95E-10	0.00034	6
Emissions	Water	Unspecified	chemical oxygen demand	0.000592	kg	0.001	5.92E-07	0.67	3
Emissions	Water	Unspecified	N total	0.00023	kg	0.26	5.98E-05	68.18	1
Emissions	Air	Urban air close to ground	nitrogen dioxide	0.0025	kg	0.011	2.72E-05	30.97	2
Emissions	Water	Unspecified	P total	6.90E-08	kg	1	6.90E-08	0.079	5
						Total	8.78E-05	100.00	

Table 6.8 Result of LCIA for eutrophication volume of BDF-CJCO in year 6^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent	Percentage (%)	Rangk
Emissions	Air	Unspecified	Ammonia	4.29E-07	kg	0.092	3.95E-08	0.14	4
Emissions	Water	Unspecified	Ammonium	2.98E-11	kg	0.202	6.03E-12	0.000022	6
Emissions	Water	Unspecified	chemical oxygen demand	0.000118	kg	0.001	1.18E-07	0.43	3
Emissions	Water	Unspecified	N total	0.000104	kg	0.26	2.70E-05	98.76	1
Emissions	Air	Urban air close to ground	nitrogen dioxide	1.66E-05	kg	0.011	1.82E-07	0.67	2
Emissions	Water	Unspecified	P total	6.69E-10	kg	1	6.69E-10	0.0024	5
						Total	2.73E-05	100.00	

Biodiesel Development and the Efforts to Reduce GWP

To encourage the development of alternative energy, the government has issued National Energy Policy targeting biodiesel production in 2025 reaches 5% of total fuel national energy and assigns Ministry of Forestry to contribute and play an active role in the development of biofuel feedstock, include releasing Planted Forest Management Permit especially in unproductive areas as well as Natural Forest Management Forest (MoF, 2009). To trigger biofuel development and implementation, several policies are released which are listed below:

1. Presidential Regulation No. 5/2006 on National Energy Policy
2. Presidential Decree No. 10/2006 on the Establishment of National Team for Biofuel Development to Accelerate Reduction of Poverty and Unemployment.
3. Presidential Instruction No. 1/2006 on Supply and Utilization of Biofuel as Alternative Fuel
4. ESDM Ministry Regulation No. 0048/2005 on Standard and Quality (Specification) and Control of Oil Fuel, Gas Fuel, Other Fuel, LPG, LNG, and Other Refined Products for Domestic Market.
5. Directoral General for Oil and Gas Decree No. 3674K/24/DJM/2006 on Gasoline Specification for Domestic Market.
6. Law No.30/2007 on Energy, which regulates the authorities held by national and local government on supply and utilization of new and renewable energy and to achieve society welfare and prosperity by increasing access to energy for the poor and people in remote area.

To achieve the targets; the availability of feedstock, oil processing technology and utilization, and also supporting activities must be prepared. Once the policy is issued, the implementation in real condition with the help of various authorized institutions and agencies are needed. It also requires control and evaluation to observe the program. If the implemented program gives satisfactory results, it still needs optimization. Otherwise, the next step is to find applicable solutions. By implementing process flow mentioned above, the process and utilization of biofuel (both biodiesel and bioethanol) will be well-applied.

Another effort to optimize is to utilize palm oil bunches as boiler fuel or organic fertilizer. For *Jatropha curcas*, the fruit shells can also be utilized as boiler fuel. Several considerations in the utilization of feedstocks from palm oil and *Jatropha curcas* are:

- In biodiesel production process, the process should optimize co-products of *Jatropha curcas* or palm oil as the feedstock, so that the excessive waste of CPO or CJCO processing can be reduced.
- Glycerol processing as the co-product of biodiesel. Glycerol or glycerine is a liqiud chemical substance in room temperature and colorless and known as co-product of fatty-oil transesterification. Glycerol has many uses, from cosmetics ingredients to explosive material component. It provides good selling price. The integration of refining unit in a biodiesel plant is feasible but the economic aspect of glycerol refining process should be carefully calculated. For medium to very large-size plantation, the glycerine processing unit can be integrated. For small to medium-size used glycerin is directly utilized as boiler fuel by mixing with the fuel. Therefore, the production cost is optimized or saved.

- Minimalization of waste, especially feed water. Water is used as extraction medium of methanol residue, glycerol, catalyst in leaching (washing) process after reactions take place. It has high COD level and direct discharge will be harmful for the environment. Thus, water is purified by means of: 1) Membrane filtration, 2) Evaporation and recondensation, 3) multi-stage refinery similar to drinking water refinery. Minimizing the cost helps reducing the cost. .
- Catalyst recycling, if possible. Biodiesel production processes using recycled catalyst will greatly reduce production cost. Conventional biodiesel process usually omits catalyst recycling. One of the catalyst recyling alternatives is by using solid acidic catalyst for esterification unit as well as solid base acidic catalyst for transesterification. Solid catalyst will not dissolve during the reactions. Thus, the cost for buying catalyst will be reduced. Of course, catalyst willslowdown the deactivation process which cannot be avoided and after a certain time-span, catalyst should be replaced.
- Energy efficiency by reusing energy residue from production process.
- Dry washing method using cleaning agent can adsorb dirts contained in crude biodiesel. The success of biodiesel purification technology by utilizing cleaning agent is possible to be applied in the industry. Development of dry washing method has more advantages compared to water washing method. It reduces the use of water, shortens biodiesel refining process, reduces large amount of liquid waste, and requires lower operational cost than water washing method. It also helps reducing investment cost due to decreasing needs of cleaning reactor, drying tank, and liquid waste storage tank. Another advantage is less energy required for heating the washing water in washing process and energy used in drying biodiesel.

Several suggestions for transportation, construction, and physical plant establishment sector are:

- Plant layout should be designed as close as possible to the estate. It will help reducing transportation cost and minimizing the fuel cost. Eventually, the emissions caused by transportation activities are also greatly reduced.
- Consuming local material in plant construction to reduce the material and transportation cost.
- Plant construction should involve local labors. Moreover, the plant capacity should be carefully adjusted to the feedstock availability in order to minimize excessive energy consumption.
- *Jatropha curcas* have more co-product, i.e. : organic fertilizer, medicines, animal feed, biomass for boiler, cake, etc. If all of the co-products can be utilized or sold, it could reduce the biodiesel production cost.

Moreover, Table 6.9 and Table 6.10 provide more detailed explanations about the suggestions for the policies regarding potencies, prospects, and problems, as well as supporting and inhibiting factors, and solutions.

Table 6.9 Suggestions for government policies for future development regarding biodiesel production (general suggestions) and biodiesel production based on feedstock utilization of CPO and CJCO in the study (specific suggestions), in terms of potency, prospect, and problem

No	Description	Suggestion for government policies for future development		
		Potency	Prospect	Problem
1	General biodiesel production in Indonesia	Feedstock continuity is secured; government policy should include the development of specific estate for biodiesel.	Planting area and labors are guaranteed.	Most people are still not familiar with *Jatropha curcas* and oil palm for biodiesel utilization. Palm oil is usually processed for cooking oil (personal consumption)
		Supportive environmental policies are available, especially to reduce global warming (air pollution), water and soil pollution.	Biodiesel is a renewable resource, biodegradable, and helps eliminating greenhouse gas effect. Thus, it is more environmentally friendly than diesel fuel.	Infrastructure support and environment supervisory control are relatively weak.
		According to the projected demand for biofuel, government has targeted the use of biofuel (bioethanol and biodiesel) approximately by 2% of total national fuel consumption by 2010. Furthermore, increased to 5% in 2025 (ESDM, 2006). Biofuel consumption in Indonesia is estimated to reach 47 million kilo liter in 2025	Fuel consumption is still rising. In some provinces, fuel shortage is a common phenomenon in Bangka, Jambi, Kalimantan, and many other provinces. Biofuel utilization will be beneficial for many people.	Biofuel is unavailable in fuel stations and government policies are not working properly
		Skeer (2007) stated if international crude oil price is above $ 50 per barrel, biodiesel development from various types of plants will be able to complete. He also stated if international crude oil price is in the range of	Demand for biofuel will continue to increase as a result of increasing international crude oil price and technological development. .	Infrastructure and technology are still not affordable and biofuel feedstock diversification from various types of plants is not well

No	Description	Suggestion for government policies for future development		
		Potency	Prospect	Problem
		US$ 80 – US$ 100 per barrel, biofuel from high-cellulose plants will provide attractions to be studied.		developed despite the existence of prospective plants (*nyamplung*)
		Energy consumption in Indonesia increases considerably due to economic and population growth. Indonesia highly depends on fossil fuel as the energy source.	Due to various reasons, biodiesel development should be implemented in Indonesia as soon as possible. It has large amount of feedstock, renewable fuel alternatives to help strengthen energy security and as a solution to reduce air pollution in big cities	Control, reward, and punishment for the rule-breakers.
		Energy has important roles in social, economy, and environment sector.	The opportunity for biodiesel development is widely open for public and private. Government fully supports the biodiesel development.	It is still quite expensive and unattractive for private sector to join in the development. However, the number of private company invest in this sector is increasing.
		Government policy has led to the development of machinery and equipment by related institutions and departments, such as (in Wahyudi, 2006): providing incentives through the revision of Government Regulation (PP) 148 on tax incentive for new investors in various fields	Processing technology and equipment for biodiesel creation is relatively simple. Gradual development of technology and equipment through cooperation with research and development institutions is needed as well as with the industry	There are still very few private companies in this sector. As a result, the machine availability is limited and production cost is relatively high.
		New investors are really interested in the field of biofuel industry.	Area for estate and factory are guaranteed.	Lack of disseminations and promotions held by government

No	Description	Suggestion for government policies for future development		
		Potency	Prospect	Problem
2	Biodiesel production from CPO	Suarna et al. (1998) stated that according to feedstock availability, biodiesel made from palm oil has a greater potency than others (*Jatropha curcas* and soybean) because of the planted area is already available and enough to ensure CPO (crude palm oil) production as the biodiesel feedstock. CPO production has long been known to be used for making cooking oil and soap composition. Biodiesel can be produced from CPO waste which only 1% of the total CPO production	The development of estate and factory expansion for CPO and biodiesel is still possible in Indonesia, especially in Papua, Kalimantan, and Sulawesi.	Poor infrastructures such as bumpy roads, electricity availability, complicated regulations which will not attract new investors.
3	Biodiesel production from CJCO	The policies regarding the use of marginal lands have been regulated by the government and Land Use Permit for investors and private has been given. It is really suitable for *Jatropha curcas* development because it can grow in marginal areas, even in the former mining areas (for land reclamation program)	Marginal areas are available, especially in eastern Indonesia, such as NTT province and NTB province.	The investors are insecure and hesitate to invest in marginal areas because of lack guarantee from local community and government.
		Jatropha curcas kernel is a good fertilizer containing potassium and phosphate. It will be very good for fertilizer if government policy is available as well as the facilities and infrastructures. Government can help to provide the kernel processing technology due to high demand of fertilizer.	Fertilizer stock is limited in certain provinces. Mass production of *Jatropha curcas* fertilizer made from kernels will help solving problems of fertilizer shortage.	Investors are not interested in investing due to relatively high production cost and unsupportive infrastructures.

Table 6.10 Suggested actions to support and inhibit factors and solutions for the biodiesel development (general suggestion) and biodiesel production from CPO and CJCO in Indonesia in the future (specific suggestion)

No	Description	Suggestion for government policies for future development		
		Supporting factor	Inhibiting factor	Solution
1	General biodiesel production in Indonesia	Government regulations have stated the targets and instructions clearly.	The regulations are not firm and sound regarding the biodiesel development in Indonesia.	Control, reward, and punishment are highly needed for the rule breakers.
		Huge amount of biodiesel source in Indonesia	Unclear and implicit government policy control towards PERTAMINA as biodiesel distributor and buyer, such as SPBU is obliged to sell biodiesel.	Special officers to conduct inspections in the field are required to ensure the law enforcement. Rewards and punishments are needed. For example, rewards and discount for fuel stations selling biofuel. On the contrary, punishment for the breakers. The punishments are varied from the lightest to the heaviest such as license withdrawal.
		Consumers (community, employers, government) are easily found.	Central and local government regulations on purchasing feedstock produced by farmers or employers are not clear.	Government has the obligation to buy feedstock produced by farmers or employers with standard price set by the government.For example: BULOG or related authorities buy rice from farmers to help maintaining good price of rice
		Indonesia is able to master catalytic biodiesel production technology through BPPT, Biodiesel Group from ITB, IPB, and many more.	Technological cost or manufacturing is still unaffordable and the production cost is expensive.	Government, through MENRISTEK or MENDIKNAS, should invite and cooperate with the academic and research institutions (scientists and lecturers) to conduct researches and machine optimization for biodiesel production.
		Areas available for biodiesel feedstock planting are available in many provinces in Indonesia.	Consumers prefer fossil fuel to biodiesel because of fuel subsidy.	Fuel subsidy must be removed. For the alternative, subsidy is given to biodiesel production and both fossil fuel and biodiesel receive same treatment.

No	Description	Suggestion for government policies for future development		
		Supporting factor	Inhibiting factor	Solution
		Labors are available and affordable	Car or engine manufacturer cannot guarantee the consumer's safety if one is about to use biodiesel as the fuel	Manual guidelines is compulsory and guarantee the consumer's safety
		Human resources are highly educated from public or private universities.	Poor infrastructures for storing crude oil from biodiesel feedstock	The construction of infrastructures for biodiesel production, storage, and distribution to users are highly required
		Biodiesel is a renewable resource, environmentally friendly, CO_2 emission from machines will be absorbed by the plants through photosynthesis mechanism. It will reduce the CO_2 accumulation in the atmosphere or known as CO_2 emission. Pollutant emission such as SPM (solid particulate matter), CO, hydrocarbon (HC), and SO_x from biodiesel combustion is much lower than diesel fuel. The source of biodiesel is biomass, thus CO_2 emission is considered neutral and it helps reducing greenhouse gas emission.	Overall life cycle assessment has not been performed	Life cycle assessment of each biodiesel feedstock is required to ensure its utilization effect to the environment. The assessment includes seedling, land preparation, planting, harvesting, crude oil production, biodiesel production, consumers (cradle to grave principal)
2	Biodiesel production from CPO	Biodiesel production from CPO	Indonesia is the largest CPO producer in the world	Government regulation on the CPO percentage for biodiesel utilization proceeded by feasibility study is needed.
		Palm oil estate productivity shows satisfying results.	CPO is the raw material for edible oil, so it would be contradictory if used for	Researches, studies, and optimizations of machine components

No	Description	Suggestion for government policies for future development		
		Supporting factor	Inhibiting factor	Solution
			biodiesel raw materials	
		Biodiesel from palm oil satisties the cetane number and its cloud point fulfills SNI standard (maximum 18 ^{o}C)	FFA of CPO is relatively high for biodiesel	Adjustment is needed if the fuel is about to be exported to subtropical countries/regions, an additive treatment might be needed to lower the cloud point or by mixing palm oil/palm kernel/coconut biodiesel with acid methyl ester or fatty acid contained high iodine number to produce biodiesel with iodine number in the range 70-100.
		Estates and plants for producing CPO are already available.	CPO is still more profitable as cooking oil than biodiesel and the biodiesel production process is a lot more complex compare to cooking oil production process.	The observation regarding biodiesel production technology should be improved in order to produce the simplest machine through researches and studies in academic institutions or government agencies.
3	Biodiesel production from CJCO	It is not categorized as edible oil	Its kernel is highly toxic because of toxic substance (curcin). Despite the high protein content, for animal feed, it must be processed to remove the toxin.	Further study for development is still needed, for example, the addition of additives to remove toxic substance in its shells.
		Able to adapt in arid zone, *Jatropha curcas* is able to live in various soil and climate conditions	Biodiesel production from CJCO cannot compete with fossil fuel as the energy source due to its expensive production cost.	Market expansion, CPO is not only sold inexisted non-energy market but also to biodiesel plants for energy source.

CHAPTER 7
CONCLUSION AND SUGGESTION

Conclusion

1. Biodiesel production from oil palm has higher total environmental impact than *Jatropha curcas* including the GHG emission value, acidification, eutrophication, and energy consumption.
2. Utilization of agro-chemical in form of fertilizer and plant protection generates significant contribution to environmental impact during biodiesel production i.e. 50.46% and 33.51% for palm oil and *Jatropha curcas* oil, respectively for scenario 1 and 68.14% and 37.56% for palm oil and *Jatropha curcas* oil, respectively for scenario 2.
3. Pre-harvest activity of oil palm production has higher GHG emission value and energy consumption than post-harvest activity. This condition is caused by higher consumption of on farm agro-chemicals to maintain crops productivity. On the contrary, *Jatropha curcas* shows lower value during pre-harvest activity.
4. In scenario 2, the GHG emission value at stable production (year 6^{th} up to 25^{th}) is 1109.42 kg-CO_2eq./ton-BDF and 662.85 kg-CO_2eq./ton-BDF for palm oil and *Jatropha curcas*, respectively. At this condition, compared to diesel fuel, CO_2 emission is reduced up to 67.37% and 80.50% for BDF-CPO and BDF-CJCO, respectively.
5. Compared to diesel fuel, CO_2eq. emission is reduced up to 49.27% and 88.45% for BDF-CPO and BDF-CJCO, respectively for scenario 2.
6. The third scenario provides the best representation for Indonesian condition, where the GHG emission value during stable production is 1511.96 kg-CO_2eq./ton-BDF-CPO and 380.52 kg-CO_2eq./ton-BDF-CJCO
7. Compared to diesel fuel, CO_2eq. emission in the third scenario is reduced up to 49.27% and 73.06% for BDF-CPO and BDF-CJCO, respectively.

Suggestion

Inclusion of the share land use change to the total emission will put this study to a higher level of comprehensive.

Recommendation

1. Based on GHG emission value, Indonesian biodiesel development using *Jatropha curcas* is more recommended rather than oil palm.
2. Utilization of organic fertilizer during cultivation period should be increased.

Acknowledgement

This research was supported by Directorate General of Higher Education, Ministry of Education and Culture of Indonesia under competitive grant and JSPS-DGHE Bilateral Join Research Project.

REFERENCES

Azam MM, Waris A, Nahar NM. 2005. Prospect and potential of fatty acid methyl esters of some non traditional seed oils for use as biodiesel in India, New Delhi : Biomass and Bioenergy.

Azapagic A. 2006. Carbon calculation over the life cycle of industrial activities (CcaLe),EPSRC/NERC/Carbon Trust. The University of Manchester. www.manchester.ac.uk. Accessed July 10, 2011.

Achten WMJ, Verchot L, Franken YZ, Mathijs E, Singh VP, Aerts R, Muy SB. 2008. Jatropha biodiesel production and use. Biomass and Bioenergy, Vol.32,pp.1063-1084.www.rjest-ng.com. (Accessed August 16, 2012).

Ardiansyah F. 2008. Realising Sustainable Oil Palm Development in Indonesia – Challenges and Opportunities. WWF– World Wide Fund For Nature (also known as World Wildlife Fund). Jakarta. Indonesia.

Achten WMJ, Almeida J, Vandenbempt P, Bolle E, Fobelets V, Verchot LV, Singh VP, Mathijs E, Muys B. 2010. Life Cycle Assessments of Biodiesel : Jatropha versus Palm Oil. Proceeding of LCA food 2010.2 : 113-118, Bari-Italy. September 22-24.

Alamsyah R. 2010. *Studi Proses Mekanisme Pengadukan Dengan Metode Static-Mixer Untuk Meningkatkan Efisiensi Transesterifikasi Minyak Sawit Menjadi Biodiesel*, Disertasi. Pascasarjana. IPB. Bogor.

BSN. 2012. *Indonesian National Standard on Biodiesel*SNI 7182 : 2012. Indonesia.

Bejan A, Tsatsaronis G, Moran M. 1996. Thermal Design and Optimization. New York : John Wiley & Sons, Inc.

Banerji R, Chowdhury AR, Misra G, Sudarsanam G, Verma SC, Srivastava GS. 1985. Jatropha Seed Oil For Energy. Biomass, Vol.8, Issue 4, p. 277-282.

Benjumea P, Agudelo J, Agudelo A. 2008. Basic properties of palm oil biodiesel-diesel blend. Elsevier : 87 : 2069-2075.

Brittaine R, Lutaladio N. 2010. Jatropha : A smallholder bioenergy crop-The potential for pro-poor development integrated crop management, Vol.8. Food and Agricultural Organisation of The United Nation, Rome.Italy.

Cervinka,V. 1980. Fuel and Energy Efficiency.In Handbook of Energy Utilization in Agricultural. Pimentel,D.CRC Press,Inc. Boca Raton, Florida,USA.

Curran MA. 1996. Environmental Life-Cycle Assessment.McGraw-Hill. New York, N.Y.

Ciambrone DF.1997. Environmental Life Cycle Analysis, Florida: CRC Press LLC.

Cowell SJ. 1999. Use of Environmental Life Cycle Assessment to Evaluate Alternatif Agricultural Production Systems, Proceeding 52nd Plant Protection Conference: 40-44. New Zealand. http://www.hortnet.co.nz. (Accessed July 30, 2011).

Cengel YA, Boles MA. 2002. Thermodynamics, An Engineering Approach. Second Edition. New York: Mc Graw Hill.

Cornelissen R, Hirsh G. (2002). The value of the exergetic life cycle assessment besides the LCA.Energy Conversion and Management, Vol.43, No. 9-12, p. 1417-1424.

Cengel YA. 2003. Heat Transfer, A Practical Approach. Second Edition. New York: Mc Graw Hill.

Canakci M. 2007. Combustion characteristics of a turbocharged DI compression ignition engine fueled with petroleum diesel fuels and biodiesel. Bioresource Technology, pp. 1167-1175, Elsevier :www.sciencedirect.com. (Accessed August 8, 2011)

Chang YF, Lin CJ, Chyan JM, Chen IM, Chang JE. 2007. Multiple regression models for the lower heating value of municipal solid waste in Taiwan. Journal of Environmental Management 85, pp. 891-899. Elsevier :www.elsevier.com/locate/jenvman. (Accessed July 20, 2011)

Casson A, Tacconi L, Deddy K. 2007. Strategies to reduce carbon emissions from the oil palm sector in Indonesia. WWF-Indonesia, 22 Ocyober 2007.

Chavalparit O, Rulkens WH, Mol APJ, Khaodhai S. 2010. Options for environmental sustainability of the crude palmoil industry in Thailand through enhancement of industrial ecosystems. Bangkok, Thailand.

Costa RED, Lora EES. 2009. The Energy Balance in The Production of Palm Oil Biodiesel-Two Case Studies : Brazil and Colombia.

Demirbas A. 2000. A direct route to the calculation of heating values of liquid fuels by using their density and viscosity measurements.Energy conversion & Management 41, pp.1609-1614.Elsevier :www.elsevier.com/locate/enconman. (Accessed August 18, 2011)

DincerI, Cengel YA. 2001. Energy, Entropy, and Exergy Concepts and Their Roles in Thermal Engineering. Entropy 3:116-149. www.mdpi.org/entropy/. (Accessed July 25, 2011)

Department of Energy and Mineral Resources (DESDM). 2005. Blue Print *Pengelolaan Energi Nasional*, Workshop *Sosialisasi* Blue Print *Pengelolaan Energi Nasional* 28-29 June 2005.

DESDM. 2006. Kebijakan Energi Nasional Dalam Konteks Pengembangan Biofuel di Indonesia, Simposium Biodiesel Indonesia, 5 – 6 September 2006. Jakarta.Indonesia.

DESDM. 2006. Pemanfaatan Biodiesel Sebagai Bahan Bakar Pembangkit Listrik. Laporan Penelitian Direktorat Energi Baru Terbarukan dan Konservasi Energi, Departemen Energi dan Sumberdaya Mineral pada November 2006. Jakarta. Indonesia.

Direktorat Jenderal Listrik dan Pemanfaatan Energi. 2006. *Pokok – Pokok Pikiran dan Permasalahan Pemanfaatan Biofuel*. Makalah : Disajikan pada Seminar Nasional Biofuel “Implementasi Biofuel Sebagai Energi Alternatif”, Departemen Energi Dan Sumber Daya Mineral, 5 Mei 2006.

De Meester B, Dewulf J, Janssens A, and Van Langenhove H. 2006.An improved calculation of the exergy of natural resources for exergetic life cycle assessment (ELCA). Environ.Sci.Technology, 2006, 40, 6844-6851.

Dincer I, Rosen MA. 2007. Exergy : Energy, environment, and suistanable development, Canada

Demirbas A. 2008. Relationships derived from physical properties of vegetable oil and biodiesel fuels. Fuel 87, pp.1743-1748.Elsevier :www.fuelfirst.com. (Accessed October 29, 2011)

De Meester B, Dewulf J, Verbeke S, Janssens A, and VanLangenhove H. 2008. Exergetic life cycle assessment (ELCA) for resource consumption evaluation in the built environment, Belgium, Available online 19 January 2008.

Dehue B, Hettinga W. 2008. GHG Performance Jatropha Biodiesel, ECOFYS, 2 June 2008, Netherland

Eckey EW. 1954. Book Riviews Vegetable Fats and Oils, Science 19 November 1954 : Vol.120, No.3125, p.832, DOI: 10.1126/science. www.sciencemag.org. (Accessed November 6, 2011)

Eevera T, Rajendran K, Saradha S. 2009. Biodiesel production process optimization and characterization to assess the suitability of the product for varied enviromental conditions. Renewable energy, pp. 762-765, Elsevier :www.elsevier.com/locate/renene. (Accessed July 19, 2011)

Fukuda H, Kondo A, Node H. 2001. Biodiesel Fuel Production by Transesterification of Oils. J.Biosci Bioeng, Vol.92, No.5, p. 405-4016.

Flaschi D, Lombardi L. 2002. Integrated gasifier combined cycle plant with integrated CO2-H2S Removal : Performance analysis, life cycle assessment and exergetic life cycle assessment. International Journal of Applied Thermodynamics, Vol.5, No.1, p.13-24, March-2002

Ferry Y. 2009. *Budidaya Jarak Pagar* (*Jatropha curcas* L.). Balitri-Pakuwon.Sukabumi.Indonesia.

Fassinou WF, Sako A, Fofana A, Koua KB, Toure S. 2010. Fatty acids composition as a means to estimate the high heating value (HHV) of vegetable oils and biodiesel fuels 87, pp.4949-4954.Elsevier :www.elsevier.com/locate/energy. (Accessed August 9, 2011)

Fassinou WF, Steene LVD, Toure S, Martin E. 2011. What correlation is appropriate to evaluate biodiesels and vegetable oils higher heating value (HHV). Fuel 90, pp. 3398-3403. Elsevier :www.elsevier.com/locate/fuel. (Accessed August 9, 2011)

Ginoga K, Cacho O, Erwidodo, Lugina M, and Djaenudin D, Economic performance of common agroforestry systems in southern Sumatra: implications for carbon sequestration services, Working paper.

Greenpeace. 2002. Company News : Unilever eyes bids for palm oil estates, November, 2002.

Greenpeace. 2003. Oleochemicals : Indonesia's palm oil body revises forecasts, October, 2003.

Greenpeace. 2008. Environment : Greenpeace says Unilever's palm oil production has enviromental cost of €714 M/y, July 2008.

Greenpeace. 2009. Environment : Palm oil producers misled over green claims, November, 2009.

Greenpeace. 2011. Endless grouses over Rountable on Suistanable Palm Oil trademark, August, 2011.

Gomaa M, Alimin AJ, Kamarudin KA. 2011. The Effect of EGR Rates on NO_x and Smoke Emmisions of an IDI Diesel Engine Fuelled with Jatropha Biodiesel Blends. International Journal of Energy and Enviroment, Vol.2, Issue 3, 2011, pp.477-490.

Holman JP. 1995. Perpindahan Kalor. Edisi keenam. Jasjfi E, penerjemah; Jakarta: Penerbit Erlangga. Terjemahan dari: *Heat Transfer*. Hal.480-522.

Haas G, Wetterich F, Köpke U. 2000. "Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment", Institute of Organic Agriculture, University of Bonn, Katzenburgweg 3, D-53115 Bonn, Germany.

Hadi A, Haridi M, Inubushi K, Purnomo E, Razie F and Tsuruta H. 2001. Effects of Land-Use Change on Tropical Peat Soil on The Microbial Population and Emission of Greenhouse gases. Microbes and Environments, Vol.16, p. 79-86.

Hadi A, Inubushi K, Furukawa Y, Purnomo E, Rasmadi M and Tsuruta H. 2005. Greenhouse Gas Emissions from Tropical Peatlands of Kalimantan, Indonesia. Nutrient Cycling in Agroecosystems, Vol.71, p. 73-80.

Hambali E. 2006. *Jarak Pagar : Tanaman Penghasil Biodiesel*. Jakarta: Penebar Swadaya. Indonesia.

Hooijer A, Silvius M, Wösten H and Page S. 2006. PEAT-CO_2 : Assessment of CO_2 emissions from drained peatlands in SE Asia. Delft Hydraulics report Q3943. Rotterdamseweg 185.The Netherlands.

ISO 14040. 1997. Environmental Management–Life Cycle Assessment–Principles and Framework, International Organisation for Standardisation, Geneva.

ISO 14041. 1998. Environmental Management–Life Cycle Assessment–Goal and Scope Definition and Inventory Analysis, International Organisation for Standardisation, Geneva.

ISO 14042. 2000a. Environmental Management–Life Cycle Assessment–Life Cycle Impact Assessment, International Organisation for Standardisation, Geneva.

ISO 14043. 2000b. Environmental Management–Life Cycle Assessment–Life Cycle Interpretation, International Organisation for Standardisation, Geneva.

Inpres No.1 .2006. *Penyediaan dan Pemanfaatan Bahan Bakar Nabati* (Biofuel) *sebagai Bahan Bakar Lain*. Jakarta. Indonesia.

IPCC. 2006. IPCC Guidelines for national greenhouse gas inventories, Vol.4 ; Agriculture, forest and land use. IPCC,2006.

James AD, Shapouri H, Wang M. 2006. Assessment of Biofuels. Renewables-Based Technology: Sustainability Assessment. John Wiley & Sons, Ltd. ISBN: 0-470-02241-8.

Kalogeras K, BezergianniS, Kazantzi V, Pilavachi PA. 2010. On the prediction of properties for diesel/biodiesel mixtures featuring new environmental consederations. 20th European Sysmposium on Computer Aided Process Engineering-ESCAPE20.

Kamahara H, Widiyanto A, Tachibana R, Atsuta Y, Goto N, Dainen H, Fujie K. 2010. Improvement Potential for Net Energy Balance of Biodiesel Derived from Palm Oil : A Case Study from Indonesia Practice and Carbon Footprint and Life Cycle Assessment: Current Status, Action Needed, and Future Prospect. J.Biomass and Bioenergy.Vol.34, p.1818-1824.

Kusumadewi D. 2011. How RSPO Sees National Initiatives on Sustainable Palm Oil, Jakarta Convention Center-Indonesia, 13th May 2011.

Lotero E, Liu Y, Suwannakarn K, Lopez DE, Goodwin Jr JG, Bruce DA. 2005. Synthesis of Biodiesel Via Acid Catalysis. Industrial and Engineering Chemistry Research, Vol.44, p. 5353-5363.

Liu Y, Lotero E, Goodwin Jr JG. 2006. A Comparison of The Esterification of Acetic Acid With Methanol Using Heterogeneous vs Homogeneous Acid Catalysis. Journal of Catalysis, Vol.242, p. 278-286.

Lam MK, Lee TK, Mohamed AR. 2009. Life Cycle Assessment for The Production of Biodiesel: A Case Study in Malaysia for Palm Oil versus Jatropha Oil.Society of Chemical Industry and John Wiley & Sons, Ltd, 5 October 2009.

Lord S, Clay J. 2009. Environmental Impacts of Oil palm-Practical Considerations in Defining Sustainability for Impacts on the Air, Land and Water, USA.

Lubis RE, Widanarko A. 2011. *Buku Pintar Kelapa Sawit*.Agromedia. Jakarta.Indonesia.

Moore DF. 1981. Thermodynamic Principle of Energy Degrading. Department of Mechanical Engineering, University College, Dublin.

Mittelbach M and Remschmidt C. 2004.Biodiesel: The comprehensive Handbook, 1st Ed.Boersedruck Ges.m.b.H, Vienna.

Macor A, Pavanello P. 2009. Performance and Emissions of Biodiesel in a Boiler for Residential Heating.Energy 34, pp.2025-2032.Elsevier :www.elsevier.com/locate/energy.(Accessed June 20, 2012)

Marchetti JM. 2011. A Summary of The Available Technologies for Biodiesel Production Based on AComparison of Different Feedstock's Properties. Process Safety and Enviromental Protection, Elsevier :www.elsevier.com/locate/psep.(Accessed Jule 21, 2012)

Marpaung DA. 2010. *Mempelajari Aspek Keteknikan Pertanian Pada Proses Pengolahan Kelapa Sawit Menjadi CPO di PT.Cakung Permata Nusa*, TEP FATETA.IPB.Bogor.

Napitupulu FH. 2006. *Pengaruh Nilai Kalor* (Heating Value) *Suatu Bahan Bakar Terhadap Perencanaan Volume Ruang Bakar Ketel Uap Berdasarkan Metode Penentuan Nilai Kalor Bahan Bakar Yang Dipergunakan*.Jurnal Sistem Teknik Industri, Vol.7 No.1, pp.60-65, Januari 2006.

Napitupulu FH. 2006. *Analisis Nilai Kalor Bahan Bakar Serabut dan Cangkang Sebagai Bahan Bakar Ketel Uap Di Pabrik Kelapa Sawit*. Jurnal Sistem Teknik Industri, ISSN : 0854-4468,Vol.23 No.1,pp.44-48, Edisi Januari-Juni 2006.

Narayan R. 2007. Environmental Footprint/Profile of Biobased, Biodegradable Products, Department of Chemical Engineering & Materials Science. Michigan State University East Lansing MI 48824.

Ndong R, Vignoles MM, Girons OS, Gabrielles B, Pirot R, Domergue M, Sablayrolles C. 2009. Life cycle assessment of biofuels from Jatropha curcas in West Africa : a field study, GCB Bioenergy (2009) 1, pp. 197-210, doi:10.1111/j.1757-1707.2009.01014.x

Nasir N and Setyaningsih D. 2010.Life Cycle Assessment of Biodiesel Production from Palm Oil and Jatropha Oil in Indonesia.7th Biomass Asia Workshop, November 29-Desember, 2010, Jakarta.Indonesia.

Ndayishimiye P and Tazerout M. 2011. Use of palm oil-based biofuel in the internal combustion engines : Performance and emissions characteristics, Energy, pp. 1790-1796, Elsevier: www.elsevier.com/locate/energy. (Accessed July 12, 2011)

O'Connor D. 2011. Biodiesel GHG Emissions, Past, Present, and Future : a Report to IEA Bioenegy Task 39, Commercializing 1st-and 2nd-Generation liquid biofuels from biomass, Canada.

Petit and Dulong. 2002. Power Plant Engineering. Website. http://www. thermal value hhv and lhv. Com [16 Oktober 2010].

Page S, Siegert F, Rieley J, Dieter V Boehm H, Jaya A, Limin S. 2002. The Amount of Carbon Released from Peat and Forest Fires in Indonesia during 1997.Nature. Vol. 420, November 2002.

Prueksakorn K and Gheewala SH. 2006. Energy and Greenhouse gas Implications of Biodiesel Production from Jatropha curcas L., The 2nd Joint International Conference on Sustainable Energy and Environment (SEE 2006), Bangkok-Thailand, 21-23 November 2006

Pleanjai S, Gheewala SH, and Garivait S. 2007.Environmental Evaluation of Biodiesel Production from Palm Oil in a Life Cycle Perspective.Asian J. EnergyEnvironmental, Vol. 8, Issue 1 and 2, p.15-32.

Purba J. 2007. *Pembuatan dan Karakterisasi Metil ester Asama Lemak Minyak Jarak Pagar Yang Digunakan Sebagai Biodiesel*.Skripsi. Departemen Kimia-Fakultas Matematika dan Ilmu Pengetahuan Alam.USU.Medan

Pranowo D. 2009.Jatropha Cultivation Technology (*Jatropha curcas* L.). Balitri-Pakuwon.Sukabumi.Indonesia.

Pahan I. 2011.*Panduan Lengkap Kelapa Sawit-Manajemen Agribisnis dari Hulu Hingga Hilir*, Penebar Swadaya.Depok. Indonesia.

Pramudita D. 2011.Life Cycle Inventory Analysis of Postharvest Handling and Extraction of Jatropha Curcas Oil.Skripsi.IPB Bogor.

Pardamean M. 2011. *Sukses Membuka Kebun dan Pabrik Kelapa Sawit*. Penebar Swadaya. Depok, Jakarta.Indonesia.

Reklaitis GV. 1983. Introduction to Material and Energy Balances. New York: John Wiley & Sons.

PT. PLN (Persero) Reports.2011. Statistik PLN Indonesia 2011.Jakarta.

PT.PN VIII (Persero) unit Kebun Kertajaya. 2011. *Laporan Kebun dan Pabrik Kelapa Sawit (PKS) Unit Kebun Kertajaya, Banten*. Indonesia.

Cornelissen RL and Hirs GG. 2002. The value of the exergetic life cycle assessment besides the LCA, Netherlands, available online 22 January 2002.

Reinhardt G, GartnerS, Rettenmaier GN, Munch GJ, Falkenstein EV. 2007. Screening Life Cycle Assessment of Jatropha Biodiesel, IFEU, 11 December 2007, Heidelberg.

Rosmeika. 2009. Assessment of BagasseLife CycleatMadukismo SugarMill, YogyakartausingLifeCycleAssessment (LCA) Method. Jurnal Enjinering Pertanian, Indonesia.

Sheehan J, Camobrecco V, Duffield J, Graboski M, Shapouri H. 1998. Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus.NERL/SR-580-24089. Colorado: National Renewable Laboratory, USA.

Suarna E. 1998. Analisis pemanfaatan biodiesel terhadap sistem penyediaan energi.Strategi Penyediaan Listrik Nasional Dalam Rangka Mengantisipasi Pemanfaatan PLTU Batubara Skala Kecil, PLTN, Dan Energi Terbarukan.

Sambodo MT. 1999. Energy sector in Indonesia and enviromental impact : from fossil fuel to biofuel. Ecomic Reserach Center indonesian Institute of Sciences-Jakarta.

Searcy C. 2000. An Introduction to Life Cycle Assessment.http://www.i-clps.com/lca/.(Accessed 30 July 2011).

Simarmata H. 2001. *Aspek Keteknikan Pertanian Pada Proses Pengolahan Kelapa Sawit di PT.Incasi Raya, Pangian Padang (Kap. 50 ton TBS/jam), Laporan Praktek Lapang*, TEP, Fateta. IPB. Bogor.

Sargeant HJ. 2001. Oil Palm Agriculture in The Wetlands of Sumatra: Destruction or development? Report, Forest fire prevention and control project; Government of Indonesia Ministry of Forestry & European Union.

Siegert F, Ruecker G, Hinrichs A, Hoffmann AA. 2001. Increased Damage from Fires in Logged Forests During Droughts Caused by El Nino. Nature.Vol.414.

Sijabat R. 2006. Governor on logging graft trial. Jakarta Post, November 2006, Jakarta.

Skutsch M, Bird N, Trines E, Dutschke M, Frumhoff P, De Jong B, Laake P, Masera O, Murdiyarso D. 2007. Clearing the way for reducing emissions from tropical deforestation.in*Environmental Science and Policy*.Vol.10, p. 322-334, Elsevier.

Sigalingging R. 2008. *Analisis Energi dan Eksergi pada Produksi Biodiesel Berbahan Baku* CPO (Crude Palm Oil) [Tesis]. Bogor: Sekolah Pascasarjana. Institut Pertanian Bogor.

Suhartana, Arifin Z. 2008. *Pemanfaatan Minyak Jarak Pagar Sebagai Bahan Bakar Alternatif Mesin Diesel*. Jurnal Penelitian Saintek, Vol. 13, No. 1, April 2008: 19-46

Sahirman.2008. *Penelitian Pembuatan Biodisel dari Biji Nyamplung dengan Proses Esterifikasi dan Transesterifikasi*.Disertasi. Fakultas Teknologi Industri. Sekolah Pascasarjana Institut Pertanian Bogor, Bogor.

Sotolongo JA, Beaton P, Diaz A, de OCA SM, del Valle Y, Paron SG, Zanzi R. 2009. *Jatropha curcas* L. As a source for the production of biodiesel : A carbon experience, download http://hm.tyristorg.com/zanzi/paper/w2257.pdf. Accessed July 30, 2011.

Sahoo PK and Das LM. 2009. Combustion analysis of Jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine, Fuel 88 : 994–999.

Silitonga AS, Atabania AE, Mahlia TMI, Masjuki HH, Badruddina IA, Mekhilefe S. 2011. A Review on Prospect of Jatropha curcas for Biodiesel in Indonesia.Renewable and Sustainable Energy Reviews, Vol.15, p. : 3733–3756.

Siangjaeo S, Gheewala SH, Unnanon K, Chidthaisong A. 2011. Implications of land use change on the life cycle greenhouse gas emissions from palm biodiesel production in Thailand. Energy for Sustainable Develop-Scient Direct-Elsevier,Inc.

Siregar K, Tambunan AH, Irwanto AK, Wirawan SS, Araki T. 2012. A Comparison of Life Cycle Inventory of Pre-harvest, Production of Crude

Oil, and Biodiesel Production on Jatropha curcas and Palm Oil as A Feedstock for Biodiesel in Indonesia. Proceeding of Ecobalance 2012 conference,Yokohama 21 – 24 November 2012, Japan.

Sekiguchi T. 2012. Life Cycle Assessment of Bio Diesel Fuel Production by SMV method. Workshop of Life Cycle Assessment of Biodiesel Production Using Non-Catalytic Super-heated Methanol Vapor Method, Bogor, 28 Oct 2011, The Universuty of Tokyo and IPB.

Situmorang JP. 2008. *Aspek Keteknikan Pertanian Pada Pengolahan Kelapa Sawit Menjadi CPO di PTP Nusantara IV, PKS Adolina Parbaungan-Sumatera Utara (kap. 30 ton TBS/jam), Laporan Praktek Lapang*, TEP IPB. Bogor.

Situmorang JP. 2009. *Mempelajari Alat dan Metode Ekstraksi Minyak Biji Jarak Pagar* (*Jatropha curcas* L.), Skripsi TEP- Fateta. IPB.Bogor.

Trabi M, Gubitz GM, Mittelbach M. 1999. Exploitation of The Tropical Oil Seed Plant *Jatropha curcas* L. Bioresource Technology, Vol.67, Issue 1, p. 73-82.Elsevier :www.sciencediret.com. (Accessed August 28, 2012)

Tatang HS. 2006. *Fondasi-Fondasi Ilmiah dan Keteknikan dari Teknologi Pembuatan Biodiesel*, Seminar Nasional Biodiesel Sebagai Energi Alternatif Masa Depan, UGM Yogyakarta, 15 April 2006.

Tatang HS. 2006. *Bahan-Bahan Bakar Berbasis Minyak-Lemak untuk Mesin/Motor Diesel : Basis Teoretik dan Survey Literatur*, Kelompok Riset Biodiesel, Institut Teknologi Bandung, 2006.

Tatang HS.2006. *Bahan bakar terbarukan pensubstitusi minyak diesel fosil :Minyak-lemak atau biodiesel ester metil*, Pusat Penelitian Pendayagunaan Sumber Daya Alam dan Pelestarian Lingkungan, Institut Teknologi Bandung, 2006.

Tatang HS. 2008. *Laporan Penelitian-Pemanfaatan Biodiesel Sebagai Bahan Bakar Pembangkit Listrik" pada Direktorat Energi Baru Terbarukan dan Konservasi Energi, Departemen Energi dan Sumberdaya Mineral*, Jakarta.Indonesia.

Tarigan AS. 1998. *Aspek Keteknikan Pertanian di PT.Perkebunan Nusantara I Langsa, Aceh Timur (Komoditi Kelapa Sawit). Laporan Praktek Lapang*, TEP, Fateta.IPB.Bogor.

Tambunan AH. 2010. *Disain* Pilot Plant Biodisel *dengan Reaktor* Bubble Methanol : Lokakarya Pengembangan dan Perekayasaan Teknologi Biodiesel. Jakarta : Badan Pengkajian dan Penerapan Teknologi, 21 Oktober 2010.

Tambunan AH,Situmorang JP, Silip JJ, Joelianingsih A, Araki T. 2012.Yield and Physicochemical Properties of Mechanically Extracted Crude Jatropha Curcas L Oil, Journal of Biomass and Bioenergy, 43, 2012, pp.12-17.

Tjahjana BE, Pranowo D. 2010. Cultivation and Processing of Primary Jatropha curcas primary.Publishing and publication unit.Balitri-Pakuwon. Indonesia.

Yee KF, Tan KT, Abdullah AZ, Lee KT. 2009. Life Cycle Assessment of Palm Biodiesel : Revealing facts and benefits for sustainability. 22 Mei 2009, Malaysia.

Yusup S, Khan M.2010. Basic properties of crude rubber seed oil and crude palm oil blend as a potential feedstock for biodiesel production with enhanced

cold flow characteristics,Biomass and Bioenergy, pp. 1523-1526, Elsevier :www.elsevier.com/locate/biombioe. (Accessed July 10, 2011)
Yang Yin C. 2011.Prediction of higher heating values of biomass from proximate and ultimate analyses. Fuel 90, pp. 1128-1132, Elsevier :www.elsevier.com/locate/fuel.(Accessed July 22, 2012)
Wall G. 1995. Exergy And Sustainable Development. International Exergy Institute, Mölndal, Sweden, gw@exergy.se, http://www.exergy.se.(Accessed December 28, 2010)
Widiyanto A, Kato S, Maruyama N, Nishimura A, Sampattagul S. 2003. Environmental Impacts Evaluation of Electricity Grid Mix System in Four Selected Countries Using A Life Cycle Assessment Point of View. Proceeding of EcoDesign2003 : Third International Sysmposium on Environmental Conscious Design and Inverse Manufacturing, Tokyo, Japan, December 9-11, 2003, EcoDesign2003/1A-I.
Wirawan SS. and Tambunan A. 2006.The Current Status and Prospects of Biodiesel Development in Indonesia : a review. Presented on the Third Asia Biomass Workshop, November 16, 2006, Tsukuba, Japan.
Wirawan SS. 2009. Potential of Jatropha curcas L. Joint Task 40/ERIA Workshop, Tsukuba Japan, 28 October 2009.
Wikepedia. 2010. Heat of Combustion. http://www. thermal value hhv and lhv. Com [11 Desember 2010].
Wicke B, Sikkema R, Dornburg V, Faaij A. 2011. Exploring land use changes and the role of palm oil production in Indonesia and Malaysia, Elsevier : Land Use Policy, 1 June, 2010.
Zah R, Faist M, Reinhard J, Bircmeier D. 2009. Standarized and Simplified life-cycle assessment (LCA) as driver for more suistainable biofuels, Elsevier, 9 May, 2009.

Appendix 1.Research Activities (January 2011 to September 2012)

No	Activities	2010					2011												2012												2013										
		Month of					Month of																																		
		8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
1.	State of The Art of LCA	■	■	■	■	■	■	■	■	■	■	■	■	■	■																										
2.	Colloquium							■																																	
3.	Prelim															■																									
4.	Proposal Research																	■																							
5.	LCI of scundary in Japan													■	■			■																							
6.	LCI of oil palm and jatropha in Indonesia	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■														
6.	LCI Analysis																											■	■												
7.	International Seminar on Ecobalance 2012, Yokohama Jepang																													■											
8.	Analysis of Life Cycle Impact Assessment of LCI for mass and energy balance																						■	■	■	■	■	■	■	■	■										
9.	Analysis of GHG, eutrophication, acidification for palm and jatropha																							■	■	■	■	■	■	■	■	■									
10.	Analysis of NER, NEB, and RI																												■	■	■	■	■								
11.	National publication																													■	■	■	■								
12.	International publication																												■	■	■	■	■	■	■						
13.	Seminar on IPB																																		■						
14.	Draft dissertation																																			■					
15.	Close examination																																				■				
16.	Draft dissertation																																					■			
17.	Open examination																																						■		
18.	Final dissertation																																							■	■

Appendix 2. Field survey documentations

Ex of land the oil palm ready to be planted again at*PTPN VIII Unit Kebun Kertajaya Lebak Banten*

Seedling area of oil palm at*PTPN VIII Unit Kebun Kertajaya Lebak Banten*

Oil palm plantation of *PTPN VIII Unit Kebun Kertajaya Lebak Banten*

Jatropha curcas plantation at*PT.Adaro-Kalimantan Tengah*

Appendix 2.Field survey documentations (advanced)

Oil palm plantation at *PT.Adaro-Kalimantan Tengah*

Palm oil mills at*PTPN VIII Unit Kebun Kertajaya Lebak Banten*

Empty fruit bunch at *PTPN VIII Unit Kebun Kertajaya Lebak Banten*

Production of biodiesel at*BRDST BPPT Puspitek Serpong* with capacity 1 ton BDF per day

Appendix 3. Data of several large scales of palm oil mills based biodiesel in Indonesia

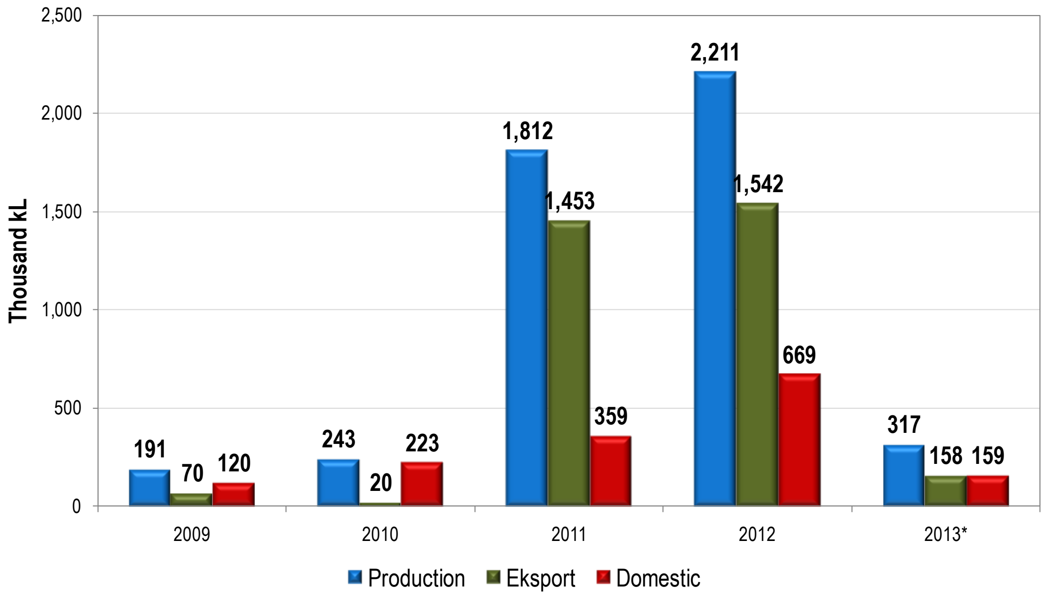
No	Name of Company	Installed Capacity**		Location
		MT/Year	kL/Year	
1	PT. Indo Biofuels Energy *)	60,000	68,966	Cilegon, Banten
2	PT. Anugrah Inti Gemanusa *)	40,000	45,977	Gresik, East Java
3	PT. Eterindo Nusa Graha *)	40,000	45,977	Gresik, East Java
4	PT. Wilmar Bio Energi Indonesia *)	1,050,000	1,206,897	Dumai, Riau
5	PT. Darmex Biofuels *)	150,000	172,414	Bekasi, West Java
6	PT. Pelita Agung Agrindustri *)	200,000	229,885	Bengkalis, Riau
7	PT. Musim Mas *)	850,000	977,011	North Sumatera and Batam
8	PT. Sintong Abadi *)	30,450	35,000	Asahan, North Sumatera
9	PT. Multi Energi Nabati *)	20,000	22,989	Bekasi, West Java
10	PT. Cemerlang Energi Perkasa *)	400,000	459,770	Dumai, Riau
11	PT. Bioenergi Pratama Jaya *)	66,000	75,862	East Kutai, East Kalimantan
12	PT. Ciliandra Perkasa *)	250,000	287,356	Dumai, Riau
13	PT. Wilmar Nabati Indonesia *)	690,000	793,103	Gresik, East Java
14	PT. Sinar Alam Permai *)	41,400	47,586	Kumai, Central Kalimantan
15	PT. Petro Andalan Nusantara	130,500	150,000	Dumai, Riau
16	PT. Primanusa Palma Energi	20,880	24,000	Pluit, North Jakarta
17	PT. Sumi Asih OleoChemical	100,000	114,943	Bekasi, West Java
18	PT. Eternal Buana Chemical Industries	40,000	45,977	Tangerang, Banten
19	PT. Pasadena Biofuels Mandiri	8,909	10,240	Bekasi, West Java
20	PT. Wahana Abdi Tritatehnika Sejati	11,484	13,200	North Jakarta
21	PT. Alia Mada Perkasa	9,570	11,000	Kosambi, Tangerang
22	PT. Damai Sentosa Cooking	120,000	137,931	Surabaya
23	PT. Oil Tanking Merak	504,000	579,310	Cilegon, Banten
24	PT. Tjengkareng Djaya	72,000	82,759	Daan Mogot, Jakarta
25	PT. Energi Alternatif	7,000	8,046	Tanjung Priok, North Jakarta
	Total installed capacity	4,912,193	5,646,199	
	Total active production	3,887,850	4,468,793	

Source : Directorate Of New, Renewable Energy And Energy Conservation- Ministry Of Energy And Mineral Resources Republic Of Indonesia, 2013

Note : * Producing active; ** : Based on the business license Niaga Biofuel

Appendix 3. Data of several large scales of palm oil mills based biodiesel in Indonesia (advanced)

INDONESIA BIODIESEL PRODUCTION 2009 - 2013



Source : Directorate Of New, Renewable Energy And Energy Conservation-Ministry Of Energy And Mineral Resources Republic Of Indonesia, 2013

Appendix 4. The complete summary for oil palm and *Jatropha curcas*

Life cycle inventory of oil palm :

No	Stage of eight sub-process	Input of material and energy	Unit	Value	Reference
1	Land preparation	Natrium Arsenit	cc/tree	20	Anonim, 2006
		Diesel fuel	ltr/ha.year		
		Tracktor	MJ/kg	69.83	Costa, 2009
	Provision	Stubled land	m^2/kg BDF	0.0676	Nazir et al.,2010
2	Seedling	The amount received sprouts	Grain	200	Pahan,2011
a	Growing seedlings	Dithane M-45 0.2%	%/menit	2	Anonim, 2006
		Fungicide	L	0.5	In Tatang, 2008
		Antibiotik	L	0.5	In Tatang, 2008
		Water	ltr/polybag.day	2	Anonim, 2006
			ltr/polybag.day	1	Pardamean, 2011
	Planted in a seedbed sprouts	Selection in seedbed (7.5%)	Trees	185	Pahan, 2011
	0 to 3 month	Fertilizer Mesiter	gr/seedling	5	Pahan, 2011
	Week of :				
	4 to 6	A solution of urea 0.2 %	gr/seed	2.1	In Tatang, 2008
	6 to 7	A solution of urea 0.2 %	gr/seed	2.7	In Tatang, 2008
	8 to16	A solution of urea 0.2 %	gr/seed	1	In Tatang, 2008
	17 to20	A solution of urea 0.2 %	gr/seed	5	In Tatang, 2008
	21 to 28	A solution of urea 0.2 %	gr/seed	8	In Tatang, 2008
	29 to 40	A solution of urea 0.2 %	gr/seed	15	In Tatang, 2008
	41 to 48	A solution of urea 0.2 %	gr/seed	17	In Tatang, 2008
	1 to 3 month (weeks 1 and 3)	A solution of urea 0.2 %	cc /seed	0.1	Pahan,2011
	1-3 bulan (weeks 2 and 4)	A solution of urea 0.2 %	cc /seed	0.1	Pahan,2011
	When charging the land on polybag	TSP	gr/polybag	0.2	Lubis et al.,2011
	Week to 4	Urea	gr/polybag	0.06	Lubis et al.,2011
		Air	L/polybag	0.03	Lubis et al.,2011
	5	Urea	gr/polybag	0.06	Lubis et al.,2011
		Air	L/polybag	0.03	Lubis et al.,2011
	6	Urea	gr/polybag	0.06	Lubis et al.,2011
		Air	L/polybag	0.03	Lubis et al.,2011
	7	Urea	gr/polybag	0.06	Lubis et al.,2011
		Air	L/polybag	0.03	Lubis et al.,2011
	8	Urea	gr/polybag	0.06	Lubis et al.,2011
		Air	L/polybag	0.03	Lubis et al.,2011
	9	Urea	gr/polybag	0.06	Lubis et al.,2011
		Air	L/polybag	0.03	Lubis et al.,2011
	10	Urea	gr/polybag	0.06	Lubis et al.,2011
		Air	L/polybag	0.03	Lubis et al.,2011
		MOP	gr/polybag	0.03	Lubis et al.,2011
	11	Urea	gr/polybag	0.06	Lubis et al.,2011
		Air	L/polybag	0.03	Lubis et al.,2011
		MOP	gr/polybag	0.03	Lubis et al.,2011
b	Main nursery				
	Control stadium beetles in seedlings	Insekticide 10E	gr/polybag/month	4	Lubis et al.,2011
	Selection in seedbed (10%)	Big polybag	tree	170	Pardamean, 2011
		Content of soil	kg/polybag	20	Pardamean, 2011

For 100 kg of soil	SP36	Kg SP36/soil	300	Pardamean., 2011
	SP36 per polybag	gr/polybag	5	Pardamean, 2011
Week to 12	SP36 per polybag	gr/polybag	0.06	Lubis et al.,2011
	Lime-dolomite	gr/polybag	0.1	Lubis et al.,2011
13	N-P-K-Mg (mix)	gr/polybag	0.008	Lubis et al.,2011
15	N-P-K-Mg (mix)	gr/polybag	0.008	Lubis et al.,2011
17	N-P-K-Mg (mix)	gr/polybag	0.01	Lubis et al.,2011
19	N-P-K-Mg (mix)	gr/polybag	0.01	Lubis et al.,2011
21	N-P-K-Mg (mix)	gr/polybag	0.014	Lubis et al.,2011
23	N-P-K-Mg (mix)	gr/polybag	0.014	Lubis et al.,2011
25	N-P-K-Mg (mix)	gr/polybag	0.014	Lubis et al.,2011
27	N-P-K-Mg (mix)	gr/polybag	0.014	Lubis et al.,2011
29	N-P-K-Mg (mix)	gr/polybag	0.02	Lubis et al.,2011
31	N-P-K-Mg (mix)	gr/polybag	0.02	Lubis et al.,2011
33	N-P-K-Mg (mix)	gr/polybag	0.03	Lubis et al.,2011
35	N-P-K-Mg (mix)	gr/polybag	0.03	Lubis et al.,2011
37	N-P-K-Mg (mix)	gr/polybag	0.03	Lubis et al.,2011
39	N-P-K-Mg (mix)	gr/polybag	0.03	Lubis et al.,2011
41	N-P-K-Mg (mix)	gr/polybag	0.036	Lubis et al.,2011
43	N-P-K-Mg (mix)	gr/polybag	0.036	Lubis et al.,2011
45	N-P-K-Mg (mix)	gr/polybag	0.036	Lubis et al.,2011
47	N-P-K-Mg (mix)	gr/polybag	0.036	Lubis et al.,2011
49	N-P-K-Mg (mix)	gr/polybag	0.036	Lubis et al.,2011
51	N-P-K-Mg (mix)	gr/polybag	0.036	Lubis et al.,2011
	Nursery time	Month	9	Pardamean, 2011
	Total of nursery time	month	10-12	Pardamean, 2011
3 month	CRF Meister MX 20-6-14+3	gr/seed	50	Pahan,2011
9 month	NPK 15-15-6,4	gr/seed	30	Pahan,2011
0 - 3 month	Water	L	12240	Pahan,2011
3 - 6 month	water	L	24480	Pahan,2011
		L/polybag/day	2	Pardamean., 2011
6 - 12 month	water	L	73440	Pahan,2011
		L/polybag/day	3	Pardamean, 2011
Seed ready to plant	Include 10% for inset	tree	150	Pahan,2011
Total of seed/ha		tree/ha	136	Anonim, 2006
		tree/ha	136	Pahan,2011
		tree/ha	136	Pardamean, 2011
Pump	5 hours/day, 60 HP	kWh	223.8	Pahan,2011
pest apoginia (Pesticide)	Aldicarb (Temik)	gr/seed	4	In Tatang, 2008
Killed of jangkrik (Pesticide)	Carbamyl+BHC (Sevidol 4/4 G)	gr/seed	5	In Tatang, 2008
	Seed	seeds	200	Pahan, 2011
Pre-nursery	Seed for pre-nursery	seeds	185	Pahan, 2011
per week in 3 month	N15P15K6Mg4	g/1000 seeds	22.5	
	Meister	g/seed	5	Pahan, 2011
	SP36	g/100 kg soil	325	Pahan, 2011
	TSP	g/seed	100	Lubis et al., 2011
	MOP	g/500 seeds	30	Lubis et al., 2011
per week in 3 month	Urea	g/400 seeds	56	Fauzi et al., 2012
		g/500 seeds	320	Lubis et al., 2011
		g/seed	3.2	BB Pengkajian, 2008

	Main nursery	Seed for main nursery	trees	170	Pahan, 2011
	week 4 - 15	N15P15K6Mg4	g/polybag	2.5	Pardamean, 2011; Sunarko, 2009
	week 16 - 17	N15P15K6Mg4	g/polybag	5	Pardamean, 2011; Sunarko, 2009
	week 18 - 20	N15P15K6Mg4	g/polybag	7.5	Pardamean, 2011; Sunarko, 2009
	week 22 - 24	N15P15K6Mg4	g/polybag	10	Pardamean, 2011; Sunarko, 2009
	week 26, 28, 30, 32	N12P12K17Mg2	g/polybag	10	Pardamean, 2011; Sunarko, 2009
	week 34, 36, 38, 40	N12P12K17Mg2	g/polybag	15	Pardamean, 2011; Sunarko, 2009
	week 42, 44, 46, 48	N12P12K17Mg2	g/polybag	20	Pardamean, 2011; Sunarko, 2009
	week 50, 52	N12P12K17Mg2	g/polybag	25	Pardamean, 2011; Sunarko, 2009
		Kieserit	g/polybag	55	Pardamean, 2011; Sunarko, 2009
			g/seed	30	BB Pengkajian, 2008
	week 17	N15P15K6Mg4	g/seed	1	Sastrosayono, 2003; BB Pengkajian, 2008
	week 18, 20	N12P12K17Mg2	g/seed	5	Sastrosayono, 2003; BB Pengkajian, 2008
	week 22, 24, 26, 28, 30, 32	N12P12K17Mg2	g/seed	8	Sastrosayono, 2003; BB Pengkajian, 2008
	week 30 - 40	N12P12K17Mg2	g/seed	15	Sastrosayono, 2003; BB Pengkajian, 2008
	week 42 - 48	N12P12K17Mg2	g/seed	17	Sastrosayono, 2003; BB Pengkajian, 2008
	total	N15P15K6Mg4	g/seed	8	Lubis et al., 2011
	total	N12P12K17Mg2	g/seed	226	Lubis et al., 2011
	total	N15P15K6Mg5	g/seed	44	Allorerung et al., 2010
	total	N12P12K17Mg2	g/seed	200	Allorerung et al., 2010
	3 month	CRF Meister MX 20-6-14+3	g/seed	50	Pahan, 2011
	9 month	NPK 15-15-6,4	g/seed	30	Pahan, 2011
		ZA	g/seed	22	Fauzi et al., 2012
		TSP	g/seed	30	Lubis et al., 2011
		SP36	g/seed	30	Allorerung et al., 2010
		Dolomite	g/seed	50	Lubis et al., 2012
	total 12 month	Water	liter/seed	720	Pahan, 2011
	total 12 month		liter/seed	756.44	Fauzi et al., 2012
	total 12 month		liter/seed	730	Sunarko, 2009
	total 12 month		liter/seed	742.66	Lubis et al., 2011
	total 12 month		liter/seed	730.00	BB Pengkajian, 2008
3	Planting				
	fertilization in the planting hole	TSP for mineral soil	gr/hole	250	Lubis et al.,2011
		TSP for peatland		300	Lubis et al.,2011
		planting distance	m^3	9 x 9x 9	Anonim, 2006
	average	Total seed	tree/ha	136	Anonim, 2006
				143	Lubis et al.,2011
	Fertilizer of	Agrophos & Rock Phosphate	gr/hole	250	Anonim, 2006
		Rhizobium compost	gr/hole	10	Pahan,2011
	Manuring nuts : Before transplanting	Lime- agriculture	kg/ha	400	Lubis et al.,2011

	The cropping	TSP	kg/ha	6	Lubis et al.,2011
		Rock Phosphate	kg/ha	10.2	Lubis et al.,2011
	Cultivation: Fertilizer (total (seedling to plantation)	Urea	kg/kg BDF	0.265797	Nazir et al., 2010
		KCl	kg/kg BDF	0.399267	Nazir et al., 2010
		DAP	kg/kg BDF	0.072647	Nazir et al., 2010
		Boron	kg/kg BDF	0.074327	Nazir et al., 2010
	Total seedling to plantation	Chemical Herbicide	kg/kg BDF	1.57E-07	Nazir et al., 2010
	Total seedling to plantation	Pesticide	kg/kg BDF	4.82E-07	Nazir et al., 2010
	Total seedling to plantation	Fertilising Broadcaster	Ha/kg BDF	0.00014	Nazir et al., 2010
	Cover Crops Planting	Rock Phosphate	kg/ha	281.25	Pardamean, 2011
		Rock Phosphate	g/hole	500	Pardamean, 2011
			g/hole	1000	Sastrosayono, 2003
			g/hole	500	Sunarko, 2009
			g/hole	250	BB Pengkajian, 2008
			g/hole	500	Allorerung et al., 2010
		TSP	g/hole	125	Pahan, 2011
			g/hole	100	Fauzi et al., 2012
			g/hole	250	Lubis et al., 2011
		Meister	g/hole	300	Pahan, 2011
		Cupri sulfat	g/hole	15	Fauzi et al., 2012
			kg/ha	190	Sastrosayono, 2003
			Kg/ha	30	Pahan, 2011
			kg/ha	200	Fauzi et al., 2012
			kg/ha	150	Lubis et al., 2011
			kg/ha	40	Allorerung et al., 2010
		N15P15K6Mg4	kg/ha	63	Pardamean, 2011
			kg/ha	40	Fauzi et al., 2012
		Dolomit	kg/ha	400	Pahan, 2011
			kg/ha	400	Lubis et al., 2011
		Urea	kg/ha	15	Pahan, 2011
			kg/ha	15	Lubis et al, 2011
		TSP	kg/ha	330	Pahan, 2011
			kg/ha	215	Lubis et al., 2011
		Glyfosate	l/ha	0.753	Pahan, 2011
4	Fertilizing				
	1 month	Urea	kg/ha	15	Lubis et al.,2011
		TSP	kg/ha	30	Lubis et al.,2011
		Rock Phosphate	kg/ha	51	Lubis et al.,2011
	3 month	TSP	kg/ha	60	Lubis et al.,2011
		Rock Phosphate	kg/ha	102	Lubis et al.,2011
	6 month	TSP	kg/ha	120	Lubis et al.,2011
		Rock Phosphate	kg/ha	204	Lubis et al.,2011
	12 month	Rock Phosphate	kg/ha	150	Lubis et al.,2011
	Age of plant :				
	1 to 5 years				
		Sulphate of Amonia (ZA)	kg/tree/year	1.5	In Tatang, 2008
		Rock Phosphate (RP)	kg/tree/year	0.75	InTatang, 2008
		Muriate of Potash (KCl)	kg/tree/year	0.7	In Tatang, 2008
		Kieserite (MgSO4)	kg/tree/year	0.75	In Tatang, 2008
	6 to 12 yeasr				In Tatang, 2008
		Sulphate of Amonia (ZA)	kg/tree/year	2.5	In Tatang, 2008
		Rock Phosphate (RP)	kg/tree/year	1.5	In Tatang, 2008
		Muriate of Potash (KCl)	kg/tree/year	1.75	In Tatang, 2008

	Kieserite (MgSO4)	kg/tree/year	1.5	In Tatang, 2008
> 12 years	Sulphate of Amonia (ZA)	kg/tree/year	2.25	In Tatang, 2008
	Rock Phosphate (RP)	kg/tree/year	0.75	In Tatang, 2008
	Muriate of Potash (KCl)	kg/tree/year	1.75	In Tatang, 2008
	Kieserite (MgSO4)	kg/tree/year	1	In Tatang, 2008
The plant yielding :				InTatang, 2008
2x aplications	Urea	kg/tree/year	2.25	In Tatang, 2008
2x aplications		kg/tree/year	2	Pahan,I.,2011
2x aplications	KCl	kg/tree/year	2.75	InTatang, 2008
2x aplications	Kiserit	kg/tree/year	1.25	In Tatang, 2008
		kg/tree/year	1	Pahan,I.,2011
	TSP	kg/tree/year	0.875	In Tatang, 2008
			1.5	Pahan,2011
2x aplications	Borax	kg/tree/year	0.75	In Tatang, 2008
2x aplications	MOP	kg/tree/year	1.25	Pahan,2011
Not producing plants (year to 1, 2 and 3) :				
	Urea	kg/tree/year	0.5	In Tatang, 2008
	KCl	kg/tree/year	0.7	In Tatang, 2008
	Kiserit	kg/tree/year	0.15	In Tatang, 2008
	TSP	kg/tree/year	0.475	In Tatang, 2008
	Borax	kg/tree/year	0.035	In Tatang, 2008
Plantation :	Urea	kg N/ha.year	79	Wicke et al.,2008
	Urea	MJ/kg	2	Costa, 2009
	Nitrogen (N)	MJ/kg	49	Costa, 2009
	Ammonium sulphate	kg N/ha.year	70	Wicke et al.,2008
			70	In Tatang, 2008
	Triplesuperphospate (P_2O_5)	MJ/kg	0.014	Kamahara et al.,2010
	Phosphorus (P_2O_5)	MJ/kg	17.430	Costa, 2009
	Rock Phosphate (RP)	MJ/kg	0.069	Kamahara et al.,2010
	Muriate of Potash (KCl)	MJ/kg	0.246	Kamahara et al.,2010
	Kieserite ($MgSO_4$)	MJ/kg	0.038	Kamahara et al.,2010
	Dolomite	MJ/kg	0.022	Kamahara et al.,2010
	Herbiside	MJ/kg	0.014	Kamahara et al.,2010
	Potassium (K_2O)	MJ/kg	10.38	Kamahara et al.,2010
	Calcium (CaO)	MJ/kg	2.32	Kamahara et al.,2010
	Organic fertilizer (fronds & EFB)	kg N/ha.thn	31	Wicke et al.,2008
Year to 1 (month of 2, 6 dan 8) :	Urea (3x aplications)	kg/tree	0.7	Pahan,2011
2x applications		kg/tree	1.2	Pahan,2011
5x applications		kg/tree	1.35	Suyatno, 1994
3x applications	Muriate of Photash (K)	kg/tree	0.5	Pahan,2011
2x applications		kg/tree	2	Pahan,2011
4x applications		kg/tree	1	Suyatno, 1994
3x applications	Rock Phospate (P)	kg/tree	0.45	Pahan,2011
2x applications		kg/tree	3	Pahan,2011
3x applications		kg/tree	1.75	Suyatno, 1994
3x applications	CuSO4	kg/tree	0.1	Pahan,2011
2x applications	ZnSO4	kg/tree	0.015	Pahan,2011
2x applications	LSD	kg/tree	1.75	Pahan,2011
2x applications	Kieserite (Mg)	kg/tree	0.25	Pahan,2011
2x applications		kg/tree	1.1	Pahan,2011
4x applications		kg/tree	0.7	Suyatno, 1994
3x applications	HGF-Borate	kg/tree	0.03	Pahan,2011
2x applications		kg/tree	0.050	Pahan,2011
Months to 8 :		kg/tree	0.02	Suyatno, 1994
3x applications	RP	kg/tree	0.15	Pahan,2011
Years to 2 :	Urea	kg/tree	1	Pahan,2011

2x applications		kg/tree	1.55	Pahan,2011
3x applications		kg/tree	1.5	Suyatno, 1994
	MOP	kg/tree	1.2	Pahan,2011
2x applications		kg/tree	2.75	Pahan,2011
3x applications		kg/tree	1.75	Suyatno, 1994
	Rock Phospate	kg/tree	0.9	Pahan,2011
2x applications		kg/tree	1.5	Pahan,2011
Months to 20 :		kg/tree	1	Suyatno, 1994
	CuSO4	kg/tree	0.075	Pahan,2011
	ZnSO4	kg/tree	0.05	Pahan,2011
	LSD	kg/tree	0.5	Pahan,2011
	Kieserite	kg/tree	0.5	Pahan,2011
2x applications		kg/tree	1.7	Pahan,2011
3x applications		kg/tree	1.5	Suyatno, 1994
	HGFB	kg/tree	0.06	Pahan,2011
2x applications		kg/tree	0.06	Pahan,2011
2x applications		kg/tree	0.08	Suyatno, 1994
Years to 3:	Urea	kg/tree	2	Pahan,2011
2x applications		kg/tree	2.15	Pahan,2011
2x applications		kg/tree	1.5	Suyatno, 1994
	MOP	kg/tree	2	Pahan,2011
2x applications		kg/tree	3.45	Pahan,2011
2x applications		kg/tree	1.75	Suyatno, 1994
	Rock Phospate	kg/tree	2	Pahan,2011
2x applications		kg/tree	1.75	Pahan,2011
Months to 28 :		kg/tree	1	Suyatno, 1994
	$CuSO_4$	kg/tree	not doing	Pahan,2011
	$ZnSO_4$	kg/tree	not doing	Pahan,2011
	LSD	kg/tree	not doing	Pahan,2011
	Kieserite	kg/tree	1	Pahan,2011
2x applications		kg/tree	2.15	Pahan,2011
2x applications		kg/tree	1.5	Suyatno, 1994
	HGFB	kg/tree	0.06	Pahan,2011
2x applications		kg/tree	0.1	Pahan,2011
Years to 4 (12, 16, 18, 20,25)	Urea	kg/tree	2.4	Pahan,2011
	MOP	kg/tree	2.5	Pahan,2011
	Rock Phospate	kg/tree	1.1	Pahan,2011
	CuSO4	kg/tree	not doing	Pahan,2011
	ZnSO4	kg/tree	not doing	Pahan,2011
	LSD	kg/tree	not doing	Pahan,2011
	Kieserite	kg/tree	1	Pahan,2011
	HGFB	kg/tree	0.06	Pahan,2011
Age of 3 - 5 years	Urea (2x applications)	kg/tree	1.325	Pahan,2011
2x applications		kg/tree	1.325	Lubis et al.,2011
2x applications	ZA	kg/tree	2	Pahan,2011
2x applications		kg/tree	2	Lubis et al.,2011
2x applications	Rock Phosphate (RP)	kg/tree	1.125	Pahan,2011
2x applications		kg/tree	1.125	Lubis et al.,2011
2x applications	TSP	kg/tree	0.9	Pahan,2011
2x applications		kg/tree	0.9	Lubis et al.,2011
2x applications	MOP	kg/tree	1.85	Pahan,2011
2x applications	Kieserite ($MgSO_4$)	kg/tree	0.95	Pahan,2011
2x applications		kg/tree	0.95	Lubis et al.,2011
2x applications	*janjang* ash	kg/tree	-	Pahan,2011
2x applications	HGFB	kg/tree	0.075	Pahan,2011
Year of 6 to 15 :	Urea (2x applications)	kg/tree	2	Pahan,2011

2x applications	ZA	kg/tree	-	
	Rock Phosphate (RP)	kg/tree	2.375	Pahan,2011
2x applications		kg/tree	2.375	Lubis et al.,2011
	TSP	kg/tree	2	Pahan,2011
2x applications		kg/tree	2.125	Lubis et al.,2011
2x applications	MOP	kg/tree	2.5	Pahan,2011
	Kieserite ($MgSO_4$)	kg/tree	1.5	Pahan,2011
2x applications		kg/tree	1.5	Lubis et al.,2011
2x applications	*janjang* ash	kg/tree	3	Pahan,2011
2x applications		kg/tree	3	Lubis et al.,2011
Age> 15 years :	Urea (2x applications)	kg/tree	2	Pahan,2011
2x applications		kg/tree	2	Lubis et al.,2011
2x applications	Rock Phosphate (RP)	kg/tree	2.125	Pahan,2011
2x applications		kg/tree	2.125	Lubis et al.,2011
2x applications	TSP	kg/tree	1.5	Pahan,2011
2x applications		kg/tree	1.5	Lubis et al.,2011
	MOP	kg/tree	1.875	Pahan,2011
	Kieserite (MgSO4)	kg/tree	1.75	Pahan,2011
2x applications		kg/tree	1.75	Lubis et al.,2011
	janjang ash	kg/tree	2.5	Pahan,2011
2x applications		kg/tree	2.5	Lubis et al.,2011
Cultivation : fertilizer	Urea	kg/kg BDF	0.266	Nazir et al.,2010
	KCl	kg/kg BDF	0.399	Nazir et.al.,2010
	DAP	kg/kg BDF	0.073	Nazir et.al.,2010
	Boron	kg/kg BDF	0.074	Nazir et al.,2010
Fertilising	Broadcaster	Ha/kg BDF	0.000142	Nazir et al.,2010
Total fertilizing :	N	kg/ton FFB	50	`
	P	kg/ton FFB	14	Hidayatno et al., 2011
	K	kg/ton FFB	35	Hidayatno et al., 2011
	Mg	kg/ton FFB	9	Hidayatno et al., 2011
	B	kg/ton FFB	1	Hidayatno et al., 2011
Not producing plants	ZA (total)	kg/tree	4.35	Pardamean, 2011
total	Urea	kg/tree	2.45	Pahan, 2011
total		kg/tree	4.25	Fauzi et al., 2012
total		kg/tree	4.35	Lubis et al., 2011
total		kg/tree	1.5	BB Pengkajian, 2008
total		kg/tree	4.35	Allorerung et al., 2010
total	TSP	kg/tree	1.8	Pardamean, 2011
total		kg/tree	3.125	Pahan, 2011
total		kg/tree	2.5	Fauzi et al., 2012
total		kg/tree	1.8	Allorerung et al., 2010
total	RP	kg/tree	0.5	Pardamean, 2011
total		kg/tree	3.75	Lubis et al., 2011
total	SP36	kg/tree	0.825	BB Pengkajian, 2008
total	MOP	kg/tree	4.25	Pardamean, 2011
total		kg/tree	4.1	Pahan, 2011
total		kg/tree	4.5	Lubis et al., 2011
total		kg/tree	4.75	Allorerung et al., 2010
total	KCL	kg/tree	3.8	Fauzi et al., 2012
total		kg/tree	1.05	BB Pengkajian, 2008
total	Kieserit	kg/tree	3.7	Pardamean, 2011
total		kg/tree	2.475	Pahan, 2011
total		kg/tree	1.85	Fauzi et al., 2012
total		kg/tree	3.7	Lubis et al., 2011
total		kg/tree	0.45	BB Pengkajian, 2008

total		kg/tree	3.7	Allorerung et al., 2010
total	HGF-B	kg/tree	0.1	Pardamean, 2011
total		kg/tree	0.105	Pahan, 2011
total		kg/tree	0.1	Fauzi et al., 2012
total		kg/tree	0.1	Lubis et al., 2011
total		kg/tree	0.1	Allorerung et al., 2010
average	N	kg/ha/year	108	Sunarko, 2009
average	P	kg/ha/year	150.4	Sunarko, 2009
average	K	kg/ha/year	74.4	Sunarko, 2009
average	Mg	kg/ha/year	36	Sunarko, 2009
total	Borax	kg/tree	0.105	BB Pengkajian, 2008
The plant yielding	Urea (year 3 – 8)	kg/tree/year	2	Pardamean, 2011
year 9 - 13		kg/tree/year	2.75	Pardamean, 2011
year 14 - 20		kg/tree/year	2.5	Pardamean, 2011
year 21 - 25		kg/tree/year	1.75	Pardamean, 2011
average		kg/tree/year	1.56	Sastrosayono, 2003
average		kg/tree/year	1.91	Pahan, 2011
average		kg/tree/year	2.26	Fauzi et al., 2012
average		kg/tree/year	1.91	Lubis et al., 2011
average		kg/tree/year	2.25	BB Pengkajian, 2008
average		kg/tree/year	2.08	Allorerung et al., 2010
year 3 - 8	SP-36	kg/tree/year	1.5	Pardamean, 2011
year 9 - 13		kg/tree/year	2.25	Pardamean, 2011
year 14 - 20		kg/tree/year	2	Pardamean, 2011
year 21 - 25		kg/tree/year	1.25	Pardamean, 2011
average		kg/tree/year	0.875	BB Pengkajian, 2008
average		kg/tree/year	1.62	Allorerung et al., 2010
average	RP	kg/tree/year	2.10	Lubis et al., 2011
average		kg/tree/year	1.29	Sastrosayono, 2003
average	TSP	kg/tree/year	2.10	Pahan, 2011
average		kg/tree/year	1.41	Fauzi et al., 2012
year 3 - 8	MOP	kg/tree/year	1.5	Pardamean, 2011
year 9 - 13		kg/tree/year	2.25	Pardamean, 2011
year 14 - 20		kg/tree/year	2	Pardamean, 2011
year 21 - 25		kg/tree/year	1.25	Pardamean, 2011
average		kg/tree/year	2.08	Pahan, 2011
average		kg/tree/year	2	Fauzi et al., 2012
average		kg/tree/year	1.90	Sastrosayono, 2003
average		kg/tree/year	1.62	Allorerung et al., 2010
average	KCL	kg/tree/year	2.75	BB Pengkajian, 2008
year 3 - 8	Kieserit	kg/tree/year	1	Pardamean, 2011
year 9 - 13		kg/tree/year	1.5	Pardamean, 2011
year 14 - 20		kg/tree/year	1.5	Pardamean, 2011
year 21 - 25		kg/tree/year	1	Pardamean, 2011
average		kg/tree/year	1.54	Pahan, 2011
average		kg/tree/year	1.25	Fauzi et al., 2012
average		kg/tree/year	1.10	Sastrosayono, 2003
average		kg/tree/year	1.41	Lubis et al., 2011
average		kg/tree/year	1.25	BB Pengkajian, 2008
average		kg/tree/year	1.16	Allorerung et al., 2010
average	HGF-B	kg/tree/year	0.0102	Pahan, 2011
average	N	kg/ha/year	134.95	Sunarko, 2009
average	P	kg/ha/year	139.45	Sunarko, 2009
average	K	kg/ha/year	323.65	Sunarko, 2009
average	Mg	kg/ha/year	139.45	Sunarko, 2009
average	Bo	kg/ha/year	5.07	Sunarko, 2009
average	Borax	g/tree/year	0.050	Sastrosayono, 2003
average		kg/tree/year	0.075	BB Pengkajian, 2008

5	Protection	Herbisida	kg	2.227796	Costa, 2009
		Insecticides	kg	1.606174	Costa, 2009
	Pest of oryctes on tree of palm	Insekticide Curater 3G	gr/year	7.5	Lubis et al.,2011
		Fungicide	Kg/ha	0.849038	Costa, 2009
		Dipterek 95 sp	kg/ha	1	Tarigan,1998
	Control of reeds :	Herbicide Glifosat Amofosat 480 AS	L/ha	6.5	Pahan,2011
		Herbisida Imazapir Assault 250 AS	L/ha	2.5	Pahan,2011
		Handsprayer Solo/CP-15	pcs	1	Pahan,2011
	Control weed ferns :	Herbicide Ally	gr/ha	75	Pahan,2011
		Herbisida Herbatop	L/ha	1.5	Pahan,2011
		Handsprayer Solo/RB-15	buah	1	Pahan,2011
	Chemical	Herbicide	kg/kg BDF	1.57E-07	Nazir et al.,2010
		Pesticide	kg/kg BDF	4.82E-07	Nazir et al.,2010
	Plant protection	Field sprayer	Ha/kg BDF	0.000142	Nazir et al.,2010
	Herbicide	Glyfosate	g/l water	8.75	Pardamean, 2011
			l/ha	6.5	Pahan, 2011
			ml/ha/rotation	8	Sunarko, 2009
		Imazapir Assault	l/ha	2.5	Pahan, 2011
		Ally	gr/ha	75	Pahan, 2011
		Herbatop	l/ha	1.5	Pahan, 2011
	Herbicide total	Paraquat	kg/ton FFB	0.2	Hidayatno et al. 2011
	total	Glyposate	kg/ton FFB	0.4	Hidayatno et al. 2011
	total	Diesel	liter/ton FFB	0.33	Hidayatno et al. 2011
	total	Water	m3/ton FFB	1400	Hidayatno et al. 2011
6	Harvesting	Diesel fuel/Truk	MJ/kg	62.8	Costa, 2009
		Harvesting activity	MJ/kg	15	Costa, 2009
		Dump Truck, Kap. 5 ton FFB	pcs/ha	1	Pahan,2011
				1	Lubis et al.,2011
		Whell tractor 20-30 ton FFB/day	pcs/ha	1	Pahan,2011
				1	Lubis et al.,2011
	Wood Chopping	Mobile chopper	kg/kg BDF	4.533	Nazir et al.,2010
	Transportation	Tractor/trailer	t.km/kg BDF	0.0533	Nazir et al.,2010
		Lorry > 16 ft	t.km/kg BDF	0.032	Nazir et al.,2010
		Freight	t.km/kg BDF	0.111197	Nazir et al.,2010
		Labour	MJ/kg BDF	0.004	Nazir et al.,2010
	Productivity	Minimum	ton FFB/ha/year	12	Pahan,2011
		Maximum	ton FFB/ha/year	32.67	Pahan,2011
7	Palm oil mills	Tractor/Trailer	t.km/kg BDF	0.00196	Nazir et al.,2010
		Lorry > 16ft	t.km/kg BDF	0.377	Nazir et al.,2010
		Freight	t.km/kg BDF	0.00327	Nazir et al.,2010
		Diesel fuel on FFB	kg/ton	1.4	Kamahara et al.,2010
	Cap. 30 ton FFB/hour	Electricity consumption	kWh/ton FFB	13.00	PT.PN VIII, 2011
		Electricity	MJ/k BDF	0.07	Nazir et al.,2010
		Diesel fuel	MJ/kg	0.28	Kamahara et al.,2010
		Diesel fuel	MJ/kg BDF	0.089	Nazir et al.,2010
		Power and steam	MJ/kg BDF	4.967	Nazir et al.,2010
		Steam consumption	kg	501	PT.PN VIII, 2011
		Water consumption	m^3/ton FFB	1.5	PT.PN VIII, 2011

		PAC	gr/ton FFB	47.32	PT.PN VIII, 2011
		Flokulon	gr/ton FFB	0.2	PT.PN VIII, 2011
		Na OH	gr/ton FFB	40.41	PT.PN VIII, 2011
		H_2SO_4/HCl	gr/ton FFB	41.25	PT.PN VIII, 2011
		Tanin Consentrate	gr/ton FFB	16.89	PT.PN VIII, 2011
		Poly Perse BWT 302	gr/ton FFB	16.89	PT.PN VIII, 2011
		Alkaly BWT 402	gr/ton FFB	16.16	PT.PN VIII, 2011
		Shell consumption	kg/ton FFB	50.6	PT.PN VIII, 2011
	Cap. 45 ton FFB/hour :				
	Station acceptance fruit **:**	Capasity	ton	0.4 - 40	Marpaung, 2010
	Weightbridge	Capasity	ton	125	Marpaung, 2010
	Loading ramp	Elictricity consumption	kWh/ton FFB	4.48	Marpaung, 2010
			kWh/ton FFB	0.133	Situmorang, 2008
	Boiling station	Elictricity consumption	kWh/ton FFB	2.617	Situmorang, 2008
	Thresher Station	Elictricity consumption	kWh/ton FFB	2.83	Marpaung, 2010
			kWh/ton FFB	0.033	Simarmata,2001
			kWh/ton FFB	0.93	Situmorang, 2008
	Pressing station	Elictricity consumption	kWh/ton FFB	5.47	Marpaung, 2010
	Compression Statiun	Elictricity consumption	kWh/ton FFB	8.54	Situmorang, 2008
	Clarification tank	Elictricity consumption	kWh/ton FFB	2.35	Marpaung, 2010
	Oil station	Elictricity consumption	kWh/ton FFB	5.982	Situmorang, 2008
	Station hoarding oil	Elictricity consumption	kWh/ton FFB	0.073	Situmorang, 2008
	Excerpts of oil station	Elictricity consumption	kWh/ton FFB	0.683	Situmorang, 2008
	Station depericarper	Elictricity consumption	kWh/ton FFB	1.157	Situmorang, 2008
	Kernel station	Elictricity consumption	kWh/ton FFB	7.54	Marpaung, 2010
		Elictricity consumption	kWh/ton FFB	0.073	Situmorang, 2008
	Boiler	Elictricity consumption	kWh/ton FFB	8.86	Marpaung, 2010
	Steam turbin Station	Elictricity consumption	kWh/ton FFB	6.67	Marpaung, 2010
		Elictricity consumption	kWh/ton FFB	15.80	Simarmata,2001
		Elictricity consumption	kWh/ton FFB	8.30	Situmorang, 2008
	Station a steam boiler	Elictricity consumption	kWh/ton FFB	9.89	Situmorang, 2008
	Station of generator	Elictricity consumption	kWh/ton FFB	11.11	Marpaung, 2010
		Elictricity consumption	kWh/ton FFB	17.0	Simarmata2001
	Demint Plant	Elictricity consumption	kWh/ton FFB	1.815	Situmorang, 2008
	Stasiun of Water Treatment Plant	Elictricity consumption	kWh/ton FFB	4.383	Situmorang, 2008
	Stasiun hopper of EFB	Elictricity consumption	kWh/ton FFB	15.395	Situmorang, 2008
	Palm oil mills to fabrication biodiesel	Energy transportation	MJ/kg	0.214	Kamahara et al.,2010
8	Biodiesel production				
	Minimum	Biodiesel production	ton	2.252	
	Maximum			6.13	
		Raw material	kg/kg	1.05	Kamahara et al.,2010
		Glycerin	kg/kg	0.167	Kamahara et al.,2010
		Methanol	kg/kg	0.135	Kamahara et al.,2010
		Caustic potash	kg/kg	9.15	Kamahara et al.,2010
		Electricity	kWh/ton BDF	307	Kamahara et al.,2010
			MJ/kg	3.211	Kamahara et al.,2010
			kWh/ton BDF	36.82	Nazir et al.,2010
		Methanol production	MJ/kg	0.378	Kamahara et al.,2010

	Methanol	MJ/kg	19.7	Kamahara et al.,2010
		kg/kg BDF	0.0989	Nazir et al.,2010
	NaOH	kg/kg BDF	0.01	Nazir et al.,2010
	Feedstock of methanol	MJ/kg	4.521	Kamahara et al.,2010
	Glycerin	MJ/kg	18.05	Kamahara et al.,2010
	Steam	MJ/ton BDF	1360	Kamahara et al.,2010
	Steam	kg/kg BDF	0.18	Nazir et al.,2010
Laboratorium scale	Optimum alkali basa	%	0.5 – 1.0	Alamsyah,2010
	Input TG	ton	0.01001	Alamsyah,2010
		ton	1.04566	Sigalingging, 2008
	Input Methanol	kg	4.35	Alamsyah,2010
		kg	523.96	Sigalingging, 2008
	Input catalys (KOH/NaOH)	kg	0.1	Alamsyah,2010
			11.04	Sigalingging, 2008
	Output of Product biodiesel	ton	0.00924	Alamsyah,2010
		ton	1.0073	Sigalingging, 2008
	Output on bottom layer (crude glycerol)	kg	3.81	Alamsyah,2010
		kg	110.49	Sigalingging, 2008
	Loss	ton	0.00141	Alamsyah,2010
	Avarage temperature reaction	^oC	60	Alamsyah,2010
	Average of intial heating	menit	11	Alamsyah,2010
	Average of Metil Ester percentage	%	96.73	Alamsyah,2010
		%	96.33	Sigalingging, 2008
	Average of water flow on condensor	mL/det	150	Alamsyah,2010
	Average of total water for washing	L	30	Alamsyah,2010
	Pump static-mixer	kWh/ton BDF	23.674	Alamsyah,2010
	Motor blade agitator	kWh/ton BDF	23.674	Alamsyah,2010
	Heater	kWh/ton BDF	293.561	Alamsyah,2010
		MJ/ton BDF	1056.820	Alamsyah,2010
Scale 1 ton BDF (Scale up)	Mixed Methanol Pump	kWh/ton BDF	0.185	Sigalingging,2008
	Reaktor 1 Circulation Pump	kWh/ton BDF	1.1	Sigalingging,2008
	Reaktor 2 Circulation Pump	kWh/ton BDF	1.1	Sigalingging,2008
	Drying Circulation Pump	kWh/ton BDF	2.2	Sigalingging,2008
	Vacuum Pump	kWh/ton BDF	2.2	Sigalingging,2008
	Evaporator Pump	kWh/ton BDF	0.666	Sigalingging,2008
	Distilation Feed Pump	kWh/ton BDF	0.666	Sigalingging,2008
	Reflux Pump	kWh/ton BDF	1.232	Sigalingging,2008
	Cooling Tower Pump	kWh/ton BDF	2.498	Sigalingging,2008
	Hot Water Pump	kWh/ton BDF	0.248	Sigalingging,2008
	Mixing Catalyst	kWh/ton BDF	0.55	Sigalingging,2008
	Mixer 3 Reactor 1	kWh/ton BDF	1.5	Sigalingging,2008
	Mixer 4 Reactor 2	kWh/ton BDF	1.5	Sigalingging,2008
	Total listrik	MJ/ton BDF	56.32	Sigalingging,2008
	Heat	MJ/ton BDF	1129.77	Sigalingging,2008

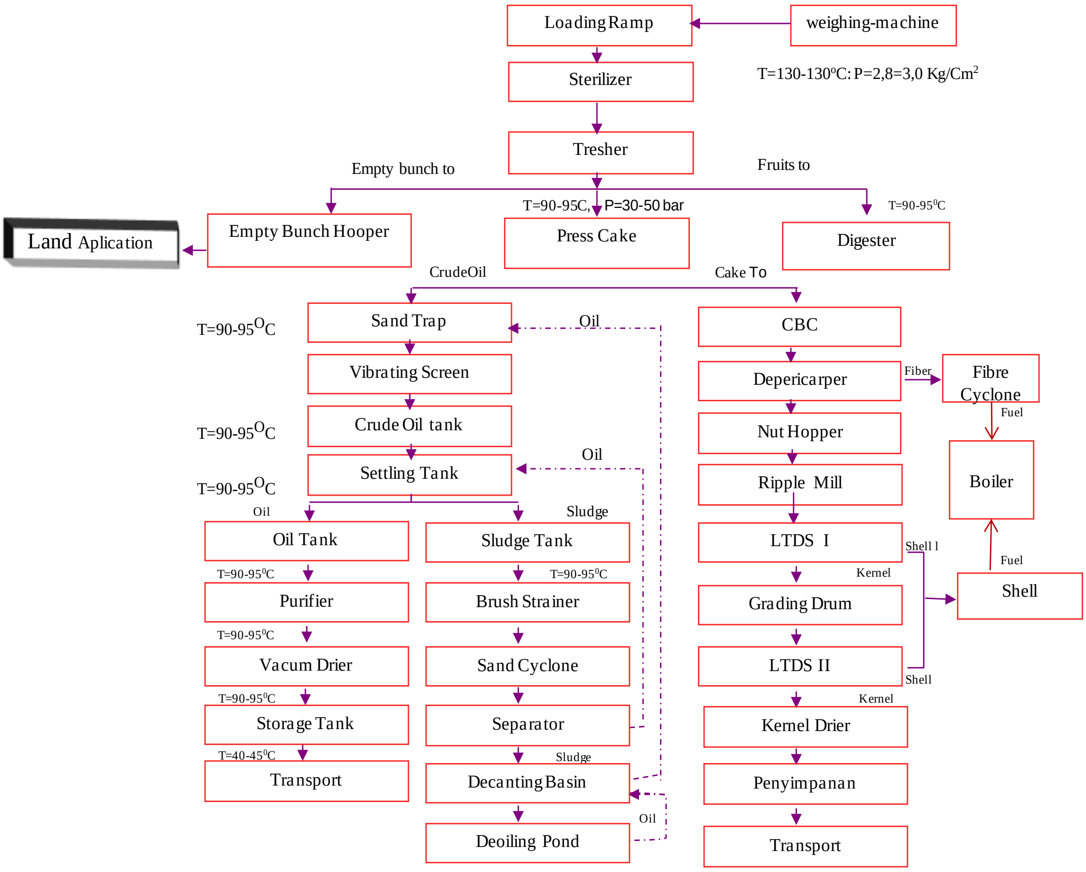
Life cycle inventory of *Jatropha curcas* :

No	Stage of eight sub-process	Input of material and energy	Unit	Value	Reference
1	Land preparation				
		Diesel fuel	kg/kg BDF	0.0105	Nazir et al.,2010
2	Seedling	Input of seed	kg/ha	5 - 6	Priyatno,2007
		Amount of seed per kg	seedi/kg	1500	Priyatno,2007
		To soak water for selected seeds	hours	12	Priyatno,2007
		Aldrin Insecticide	cc/ha	2	Priyatno,2007
		Agrep Insecticide	gr/ha	2	Priyatno,2007
		To soak water for selected seeds	hours	12 - 24	BPPP-PPPP, 2008
		Mite/Samite	cc/liter	1	BPPP-PPPP, 2008
		Dursban	cc/liter	2	BPPP-PPPP, 2008
		Fungicide Dithane M-45	gr/L	2	BPPP-PPPP, 2008
		Fungicide Dithane M-45	gr/ha	1	Priyatno,2007
	The composition of soil : compost : sand (1:1:1)	Manure	gr/polybag	1	Nazir et al.,2010
		Boletus organic fertilizer (mikoriza arbuskula)	gr/polybag	10	Nazir et al.,2010
		Jumlah biji/bibit	biji/polybag	1-2	Nazir et al.,2010
	Transportation	Freight	t.km/kg.BDF	0.0671	Nazir et al.,2010
3	Planting	Direct data collecting on site plantation			
	Distance planting	2 m x 2 m x 2 m	tree/ha	2500	Balitri, 2012
	Fertilizing the planting hole :				
		Manure	kg/hole	1.5	In Tatang, 2008
			kg/hole	1	Balitri, 2012
			kg/hole	0.4	BPPP-PPPP, 2006
	The cropping	Urea	kg/hole	10	In Tatang, 2008
		SP-36	kg/hole	50	In Tatang, 2008
			kg/hole	50	Balitri, 2012
			kg/hole	20	BPPP-PPPP, 2006
		KCl	kg/hole	10	In Tatang, 2008
			kg/hole	10	Balitri, 2012
			kg/hole	4	BPPP-PPPP, 2006
	1 month later	Urea	kg/hole	10	In Tatang, 2008
4	Fertilizing (Suggested using manure)				
		N	kg/ha	80	In Tatang, 2008
			kg/ha	80	Priyatno,2007
			kg/ha	14 -34.3	Jongschaap et al.,2007
	Assumed if equals Jatropha kepyar	P_2O_5	kg/ha	32	In Tatang, 2008
			kg/ha	18	Priyatno,2007
		CaO	kg/ha	12	In Tatang, 2008
			kg/ha	12	Priyatno,2007
		MgO	kg/ha	10	In Tatang, 2008
			kg/ha	10	Priyatno,2007
		P	kg/ha	0,7-7	Jongschaap et al.,2007
		K/K_2O	kg/ha	14-31.6	Jongschaap et al.,2007
			kg/ha	32	Priyatno,2007
	Plant year to:				
	1	Urea	kg/ha	14	Pranowo,2009
			kg/ha	50	Sudaryono et al.,2009
			kg/ha	50	In Tatang, 2008
			kg/ha	16.67	Sudradjat,2008
		SP-36	kg/ha	70	Pranowo , 2009
			kg/ha	150	Sudaryono et al.,2009

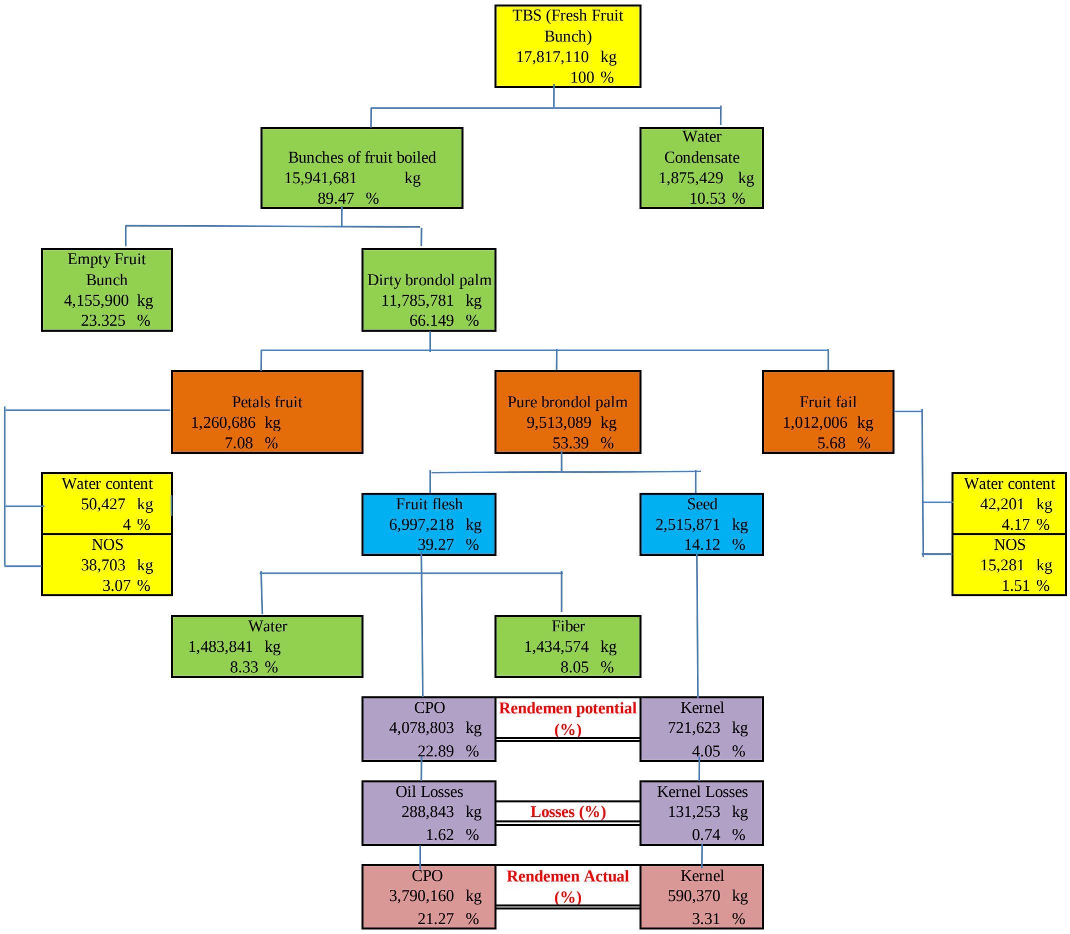
			kg/ha	50	In Tatang, 2008
			kg/ha	50	Sudradjat,2008
		KCl	kg/ha	28	Pranowo,2009
			kg/ha	30	Sudaryono et al.,2009
			kg/ha	50	In Tatang, 2008
			kg/ha	16.67	Sudradjat,2008
	2	Urea	kg/ha	35	Pranowo,2009
			kg/ha	100	In Tatang, 2008
			kg/ha	50	BPPP-PPPP,2006
			kg/ha	50	Sudradjat,2008
		SP-36	kg/ha	105	Pranowo,2009
			kg/ha	75	In Tatang, 2008
			kg/ha	150	BPPP-PPPP, 2006
			kg/ha	150	Sudradjat,2008
		KCl	kg/ha	35	Pranowo, 2009
			kg/ha	75	In Tatang, 2008
			kg/ha	30	BPPP-PPPP, 2006
			kg/ha	50	Sudradjat,2008
	3	Urea	kg/ha	35	Pranowo,2009
			kg/ha	150	In Tatang, 2008
			kg/ha	50	Sudradjat,2008
		SP-36	kg/ha	105	Pranowo, 2009
			kg/ha	125	In Tatang, 2008
			kg/ha	150	Sudradjat,2008
		KCl	kg/ha	35	Pranowo, 2009
			kg/ha	100	In Tatang, 2008
			kg/ha	50	Sudradjat,2008
	4	Urea	kg/ha	35	Pranowo, 2009
			kg/ha	250	In Tatang, 2008
			kg/ha	50	Sudradjat,2008
		SP-36	kg/ha	105	Pranowo, 2009
			kg/ha	187.5	In Tatang, 2008
			kg/ha	150	Sudradjat,2008
		KCl	kg/ha	35	Pranowo, 2009
			kg/ha	150	In Tatang, 2008
			kg/ha	50	Sudradjat,2008
	5	Urea	kg/ha	35	Pranowo, 2009
			kg/ha	375	In Tatang, 2008
			kg/ha	50	Sudradjat,2008
		SP-36	kg/ha	105	Pranowo, 2009
			kg/ha	250	In Tatang, 2008
			kg/ha	150	Sudradjat,2008
		KCl	kg/ha	35	Pranowo, 2009
			kg/ha	200	InTatang, 2008
			kg/ha	50	Sudradjat,2008
	Manure		ton/ha	2.5 -5	BPPP-PPPP, 2006
			ton/ha	2.5 -5	Sudradjat,2008
	Fertilizer on cultivation :	Urea	kg/kg BDF	0.135	Nazir et al.,2010
		KCl	kg/kg BDF	0.0675	Nazir et al.,2010
		DAP	kg/kg BDF	0.0336	Nazir et al.,2010
	Fertilizing	Broadcaster	Ha/kg BDF	3.59E-06	Nazir et al.,2010
5	Protection				
	Herbicida/Fungicide	Diazenon 60 EC or Thiodan 35 EC or Sevin 855 or Nogos	L/ha	1	Elma et al.,2006 in Sudradjat,2008
	Pest leaf (Thrips)	Curacron	L/ha	1	Elma et al.,2006 in Sudradjat,2008
	Pest leaf (mite)	Regent	L/ha	1	Elma et al.,2006 in Sudradjat,2008

	Pest leaf (aphids, grasshopper)	Regent/Mipcindo	L/ha	1	Elma et al.,2006 in Sudradjat, 2008
	Pest fruit (Ladybugs javelin)	Klopindo/Micpindo	L/ha	1	Elma et al.,2006 in Sudradjat,2008
	Pest roots (larva)	Faster 15BC/Furadan	L/ha	1	Elma et al.,2006 in Sudradjat,2008
	Ladybugs javelin	Mipcindo 50 WP	gr/Liter	1	Priyatno,2007
6	Harvesting				
		Labour	MJ/kg BDF	0.007	Nazir et al.,2010
		Scissor harvester	pcs/ha	2	Priyatno,2007
7	Extraction	Freight	t.km/kg BDF	0.0022	Nazir et al.,2010
		Heater	W	600	Situmorang,2009
		Electricity	MJ/kg BDF	0.0814	Nazir et al.,2010
		Diesel	L	2.018	BPPP-PPPP,2006
		Mesin Expeller, kap.	ton/hari	10	Prihandana et al.,2008
		Elictricity consumption	kWh/ton CJCO	0.2	Prihandana et al.,2008
8	Biodiesel production				
	Minimum	Biodiesel production	ton	0.347	
	Maksimum			1.852	
		Rendemen average	%	24	Situmorang,2009
		Average production	ton dry seed	4.75	Situmorang,2009
		Average CJCO	ton CJCO	1.14	Situmorang,2009
		Average Biodiesel	ton BDF	1.026	Situmorang,2009
		Glycerol	kg/kg BDF	0.111	Kaewcharoensombat et al.,2011
		NaOH	kg/kg BDF	0.012	Kaewcharoensombat et al.,2011
		Methanol	kg/kg BDF	0.207	Kaewcharoensombat et al.,2011
		H_2SO_4	kg/kg BDF	0.015	Kaewcharoensombat et al.,2011
		Electricity	W/kg BDF	0.710	Kaewcharoensombat et al.,2011
			kWh/kg BDF	0.085	Nazir et al.,2010
		Water	kg/kg BDF	0.010	Kaewcharoensombat et al.,2011
		Heat	Mcal/kg BDF	0.512	Kaewcharoensombat et al.,2011
		Salts	kg/kg BDF	0.021	Kaewcharoensombat et al.,2011
		Liquid waste	kg/kg BDF	0.028	Kaewcharoensombat et al.,2011
		Sulfuric acid	kg/kg BDF	0.0217	Nazir et al.,2010
		Methanol	kg/kg BDF	0.14	Nazir et al.,2010
		NaOH	kg/kg BDF	0.0088	Nazir et al.,2010
		Catalys	%	1	Prihandana et al.,2008
		Methanol	%	20	Prihandana et al.,2008
		Steam	kg/kg BDF	0.294	Nazir et al.,2010

Appendix 5. FFB processing flow chart to produce CPO at palm oil milling plant in PTPN Kebun Unit Kertajaya VIII



Appendix 6. The mass and energy balance to produce CPO at palm oil milling plant in PTPN Kebun Unit Kertajaya VIII



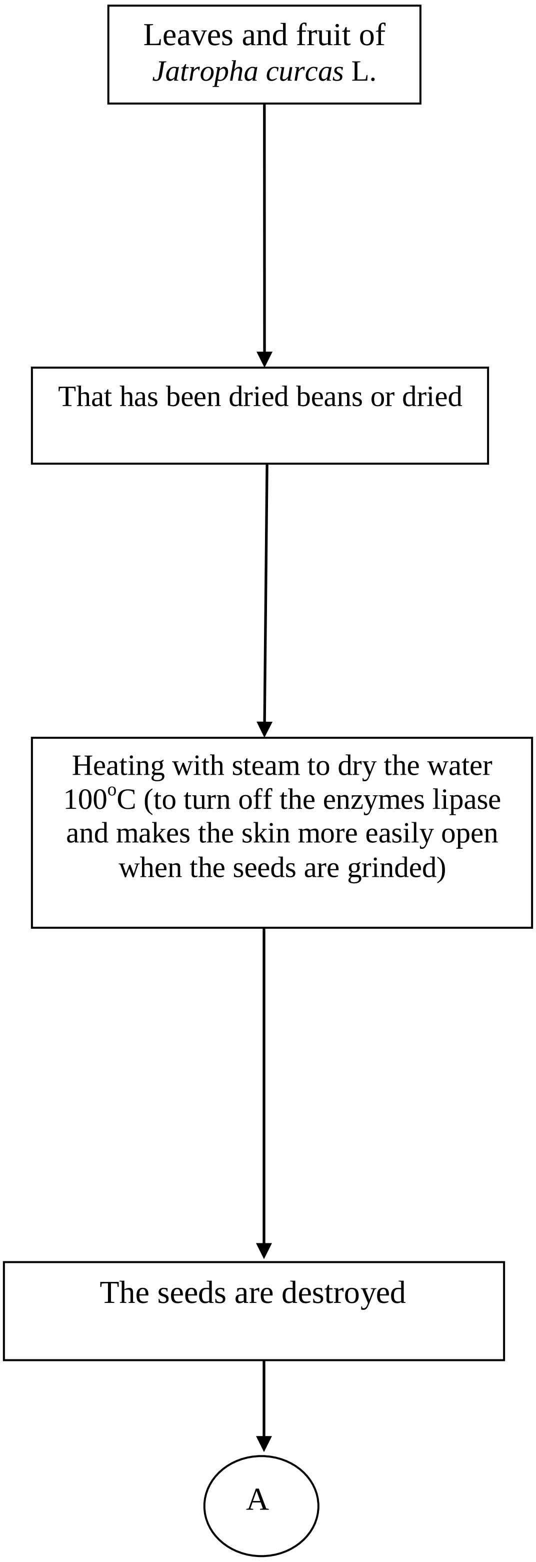
Appendix 7. The complete diagram flow of *Jatropha curcas* oil extraction method using hydraulic presses.

Leaves and fruit of *Jatropha curcas* L.

Dry seed of *Jatropha*

Heater seeds

Skin brutalizers seeds (tool double-milled)



A

After pulverizing the skin tool through the skin and the seeds are ready to be separated

Kernel (white) and Shell

Seeds and meat separator skin

The separation of flesh and seed seed skin done by blowing with air on its alloy tool

Meat seeds and rind seeds will be separate well and meat seeds ready to facilitate pengempaan to be destroyed

Meat seeds

Skin seeds

Destruction of seeds to start the bark separates the seeds and seed flesh

Mincer

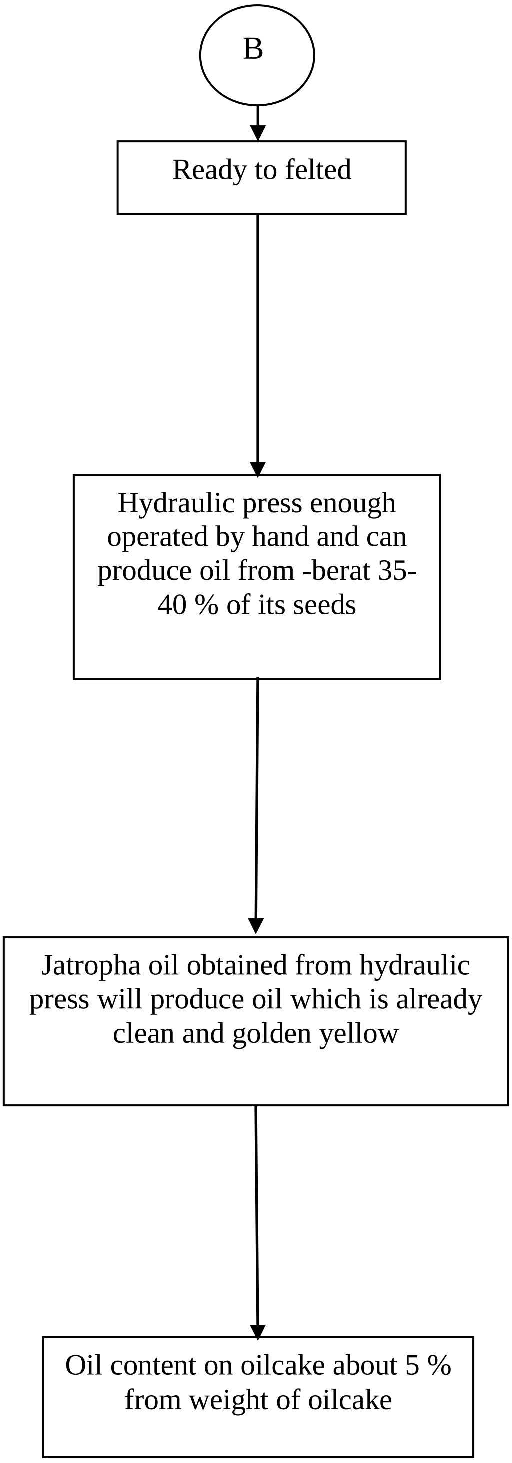
B

Meat that has been ground seeds

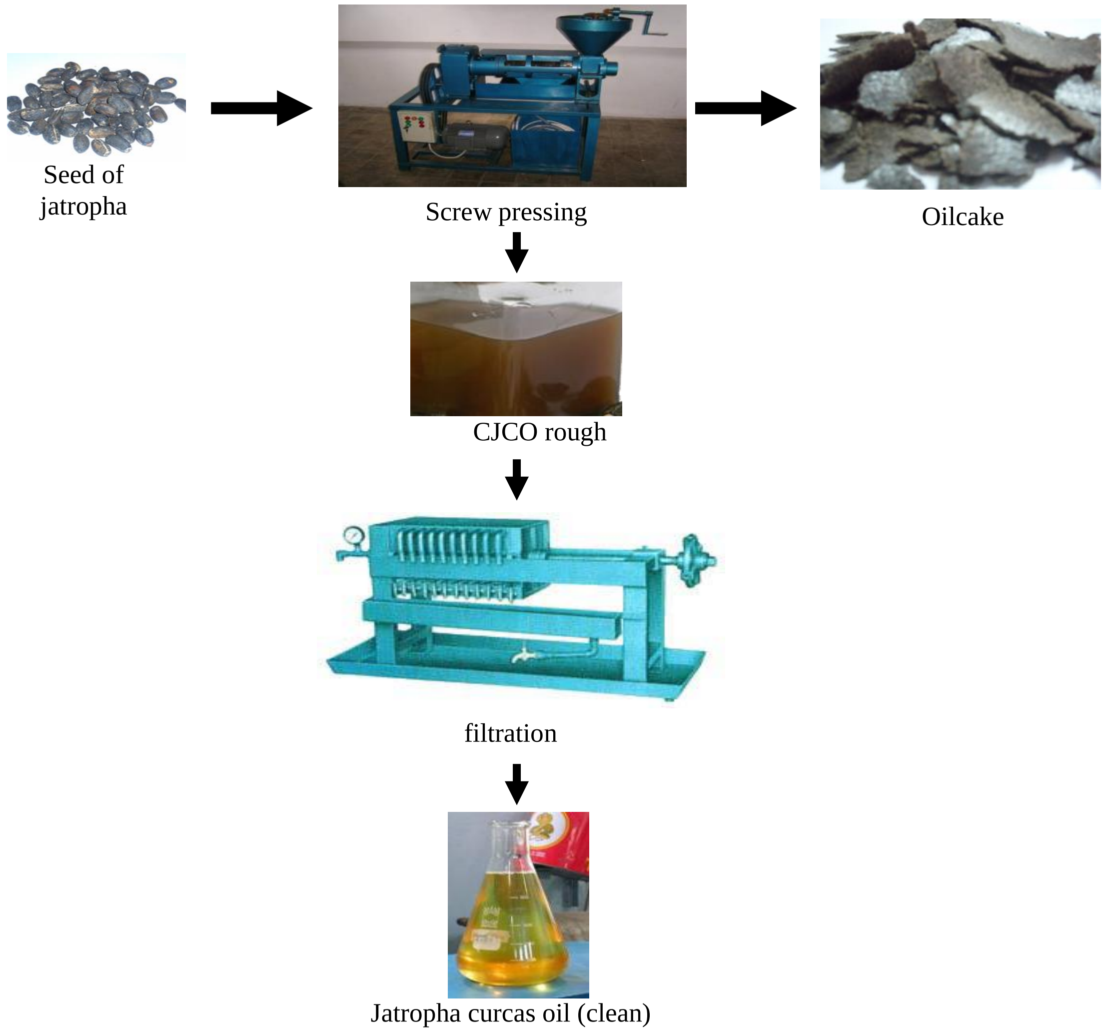
Hydraulic press

Jatropha curcas oil (clean)

Oilcake

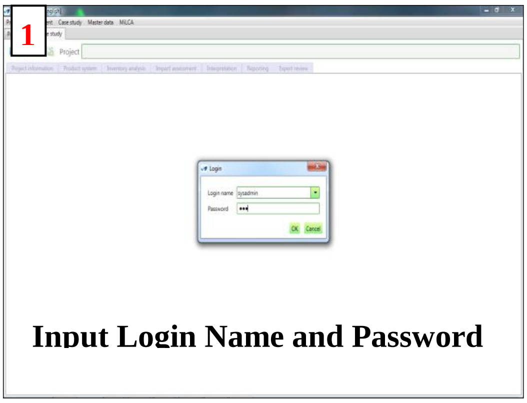


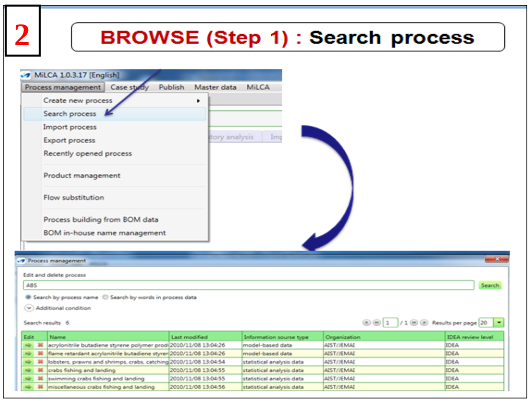
Appendix 8.The complete diagram flow of the pressing process using screw pressing method

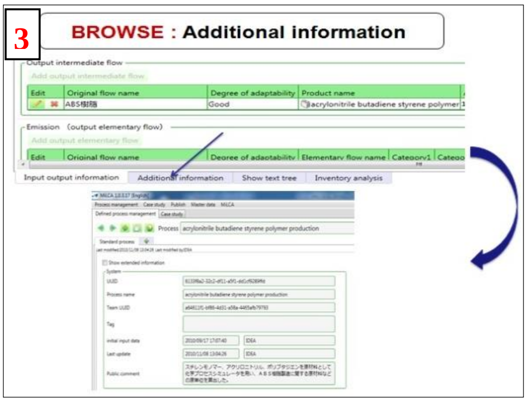


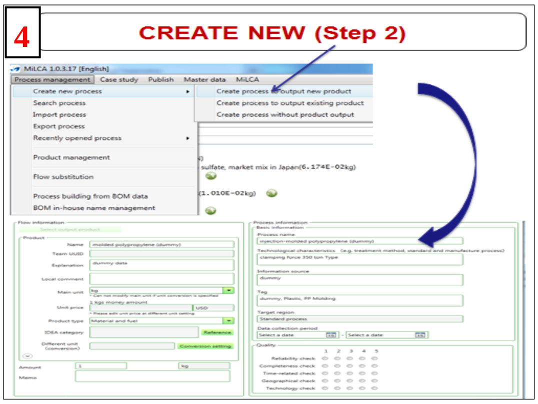
Appendix 9. How to operate of MiLCA-JEMAI software

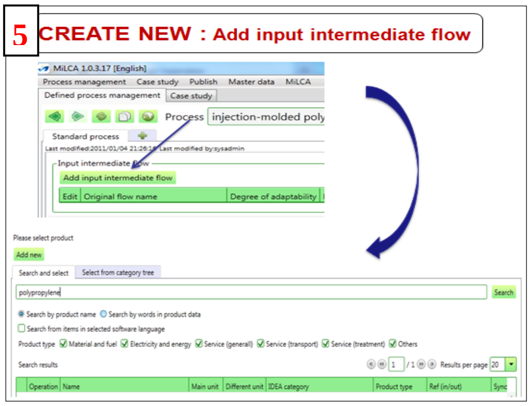
Stage for operating software MiLCA-JEMAI :

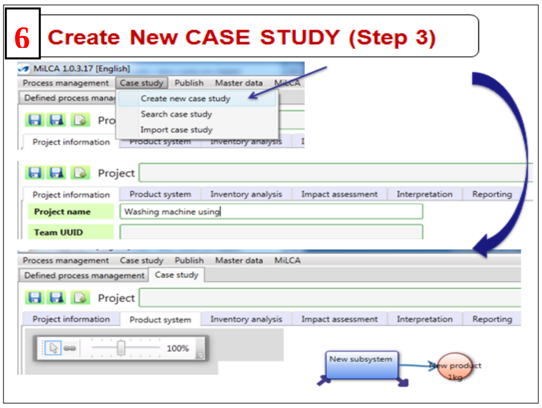




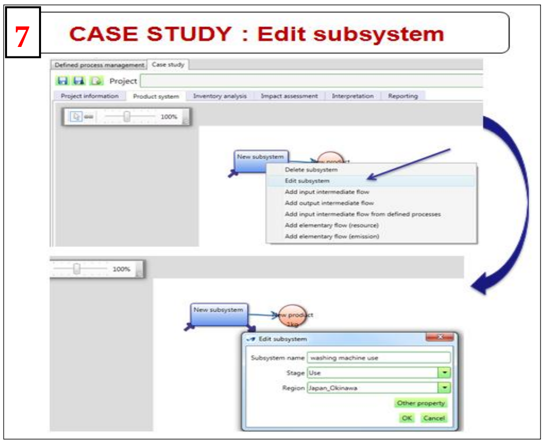


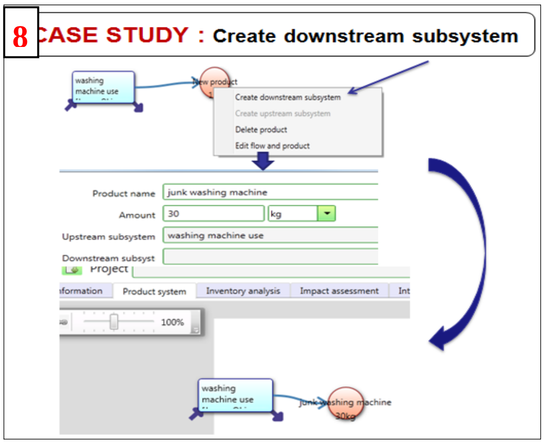


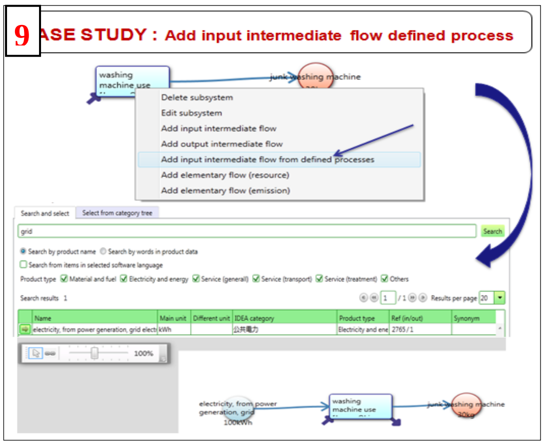


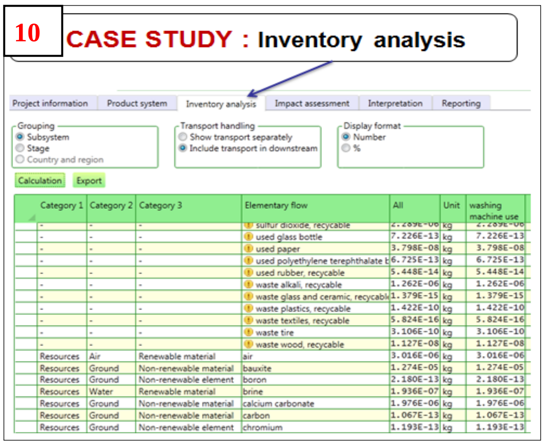


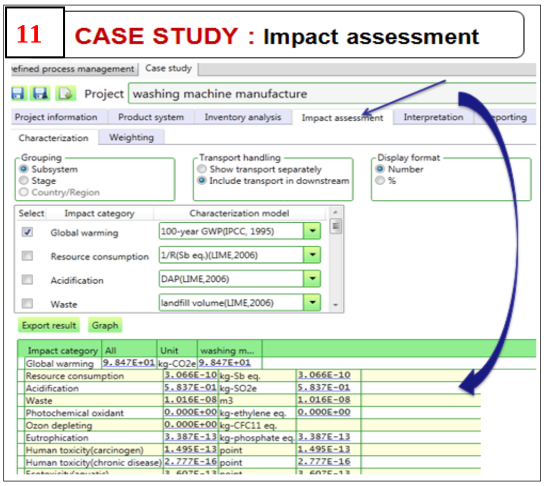
Appendix 9. How to operate of MiLCA-JEMAI software (advanced)

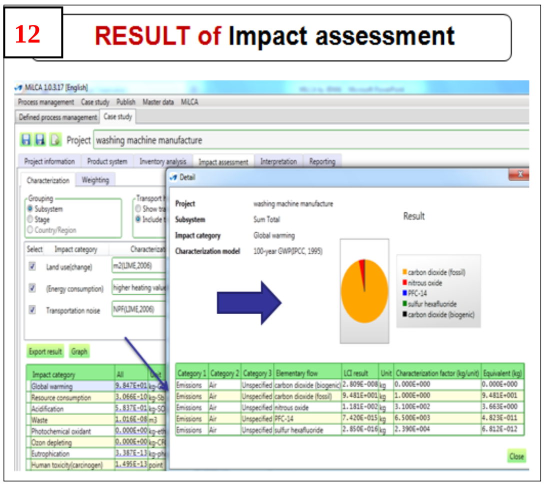












Appendix 10. Complete results for scenario 3 of assessment using MiLCA-JEMAI software for oil palm and *Jatropha curcas*

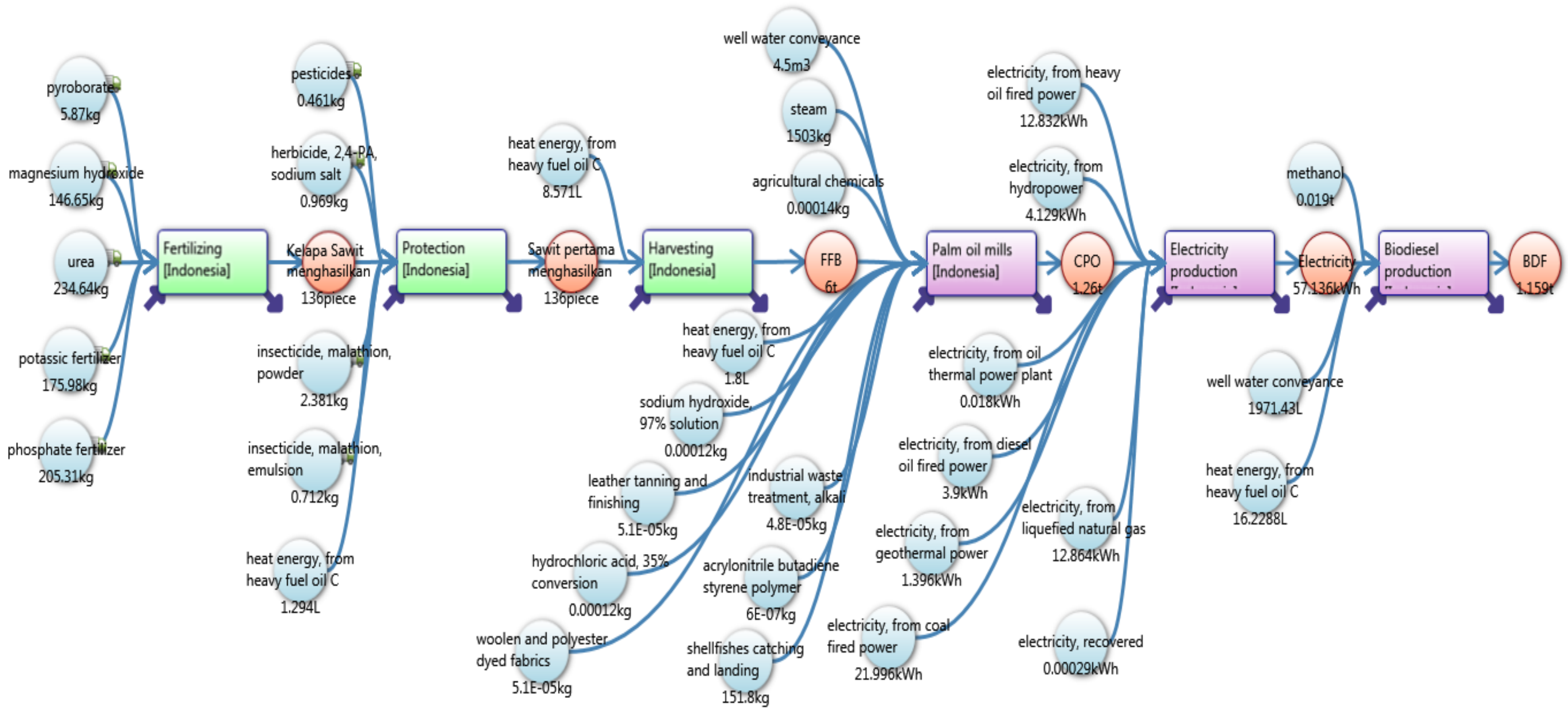


Figure 10.1 Product system on oil palm with MiLCA-JEMAI software for the fourth year

Appendix 10. Complete results for scenario 3 of assessment using MiLCA-JEMAI software for oil palm and Jatropha curcas (advanced)

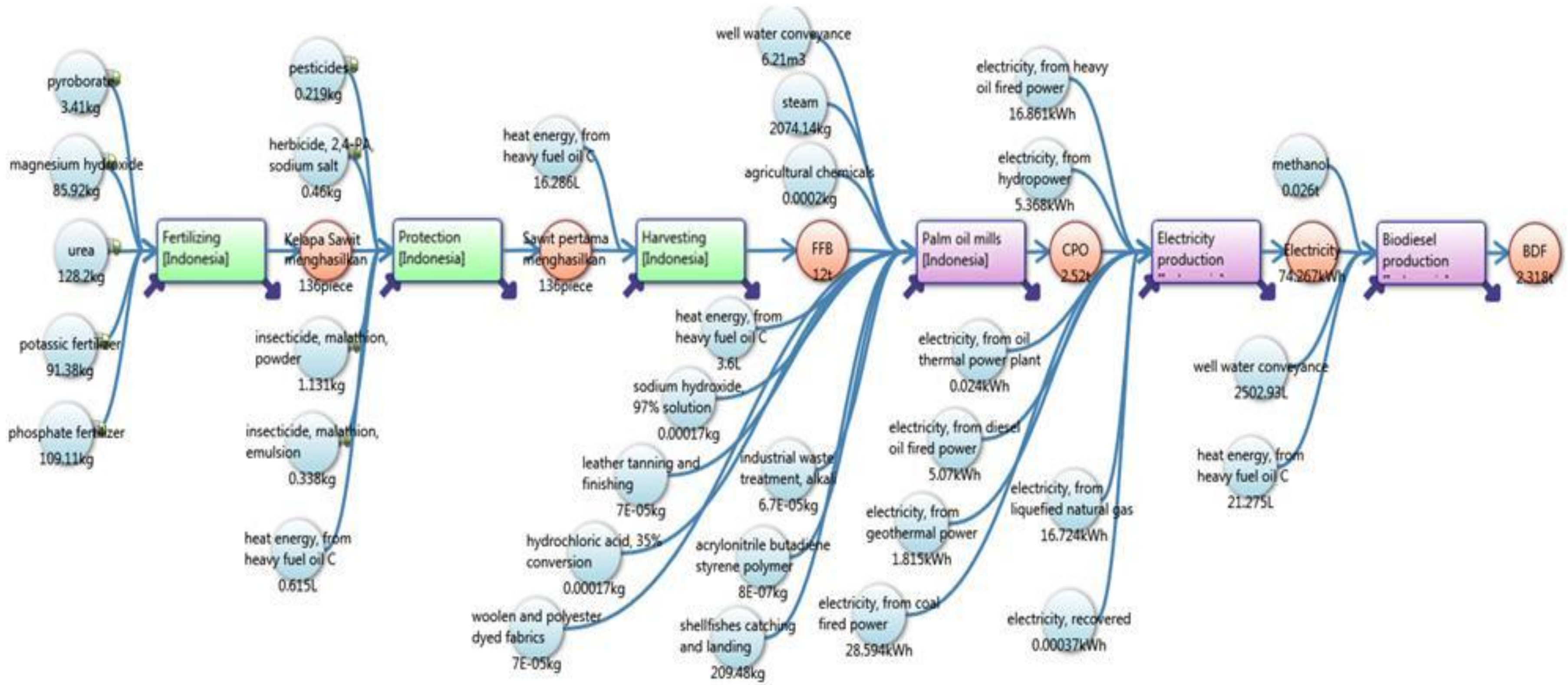


Figure 10.2 Product system on oil palm with MiLCA-JEMAI software forthe fifth year

Appendix 10. Complete results for scenario 3 of assessment using MiLCA-JEMAI software for oil palm and Jatropha curcas (advanced)

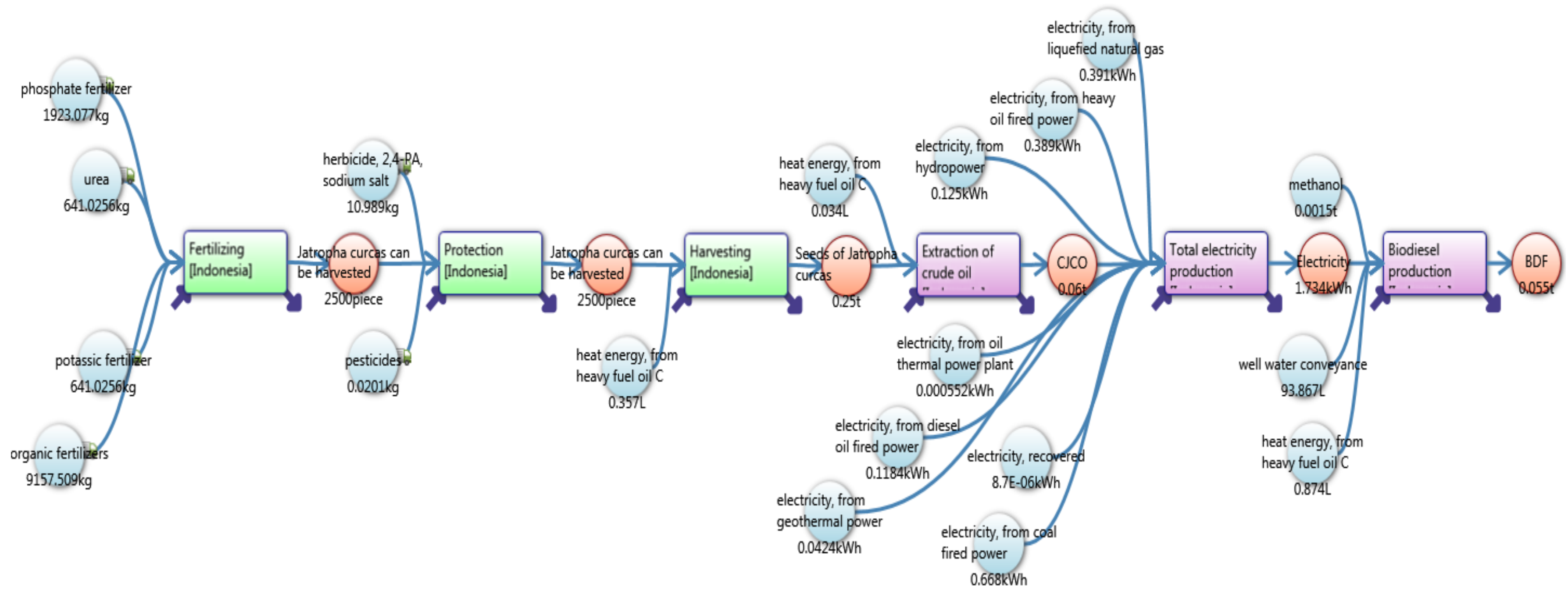


Figure 10.3 Product system on *Jatropha curcas* with MiLCA-JEMAI software for the second year

Appendix 10. Complete results for scenario 3 of assessment using MiLCA-JEMAI software for oil palm and Jatropha curcas (advanced)

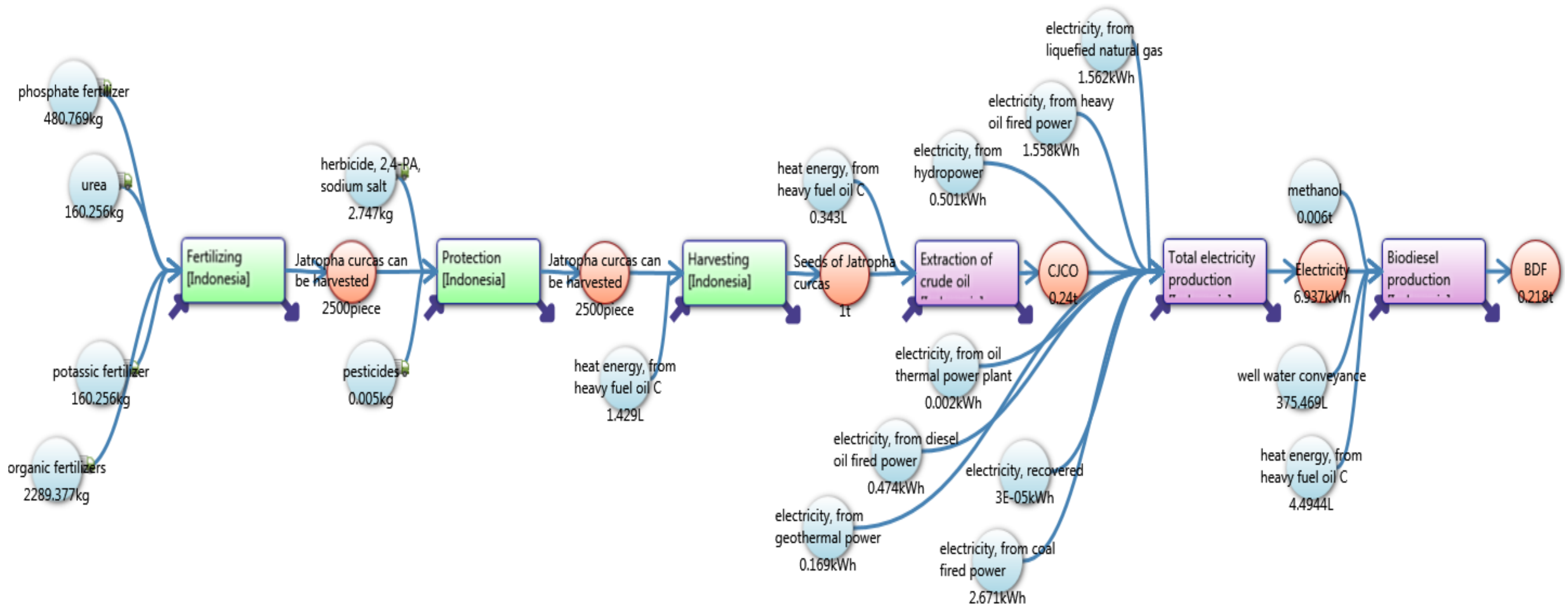


Figure 10.4 Product system on *Jatropha curcas* with MiLCA-JEMAI software for the third year

Appendix 10. Complete results for scenario 3 of assessment using MiLCA-JEMAI software for oil palm and *Jatropha curcas* (advanced)

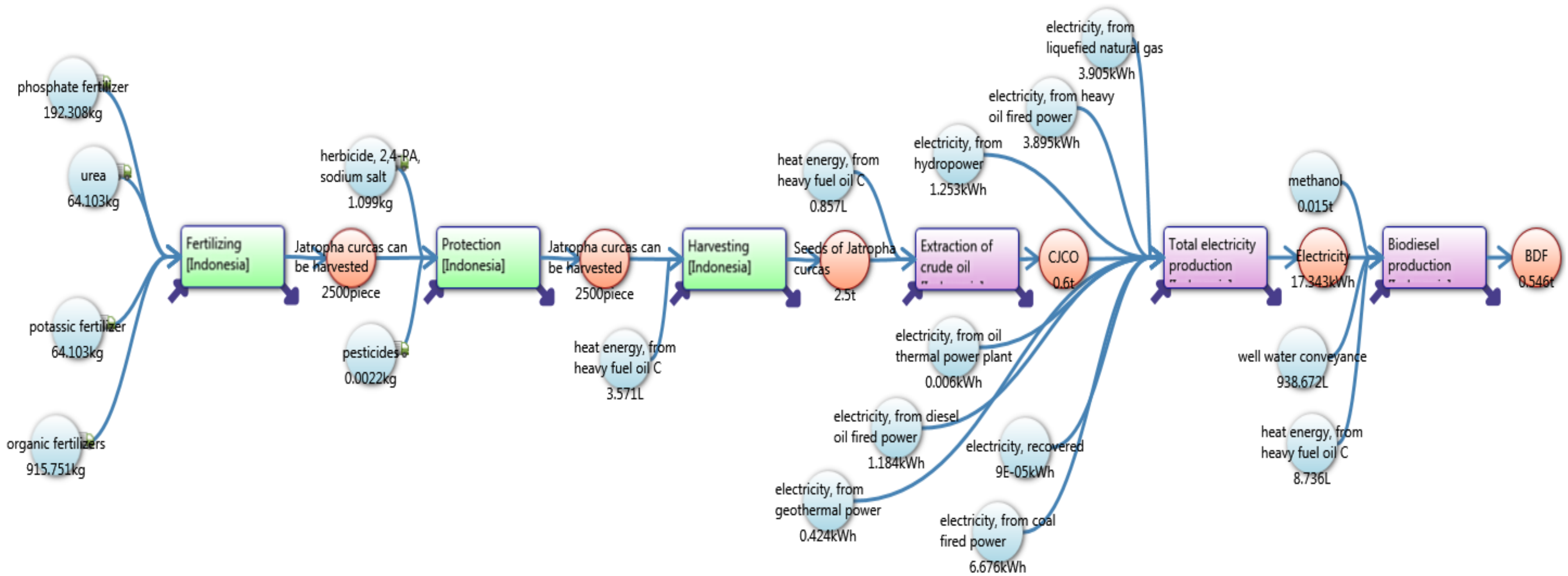


Figure 10.5 Product system on *Jatropha curcas* with MiLCA-JEMAI software for the fourth year

Appendix 10. Complete results for scenario 3 of assessment using MiLCA-JEMAI software for oil palm and Jatropha curcas (advanced)

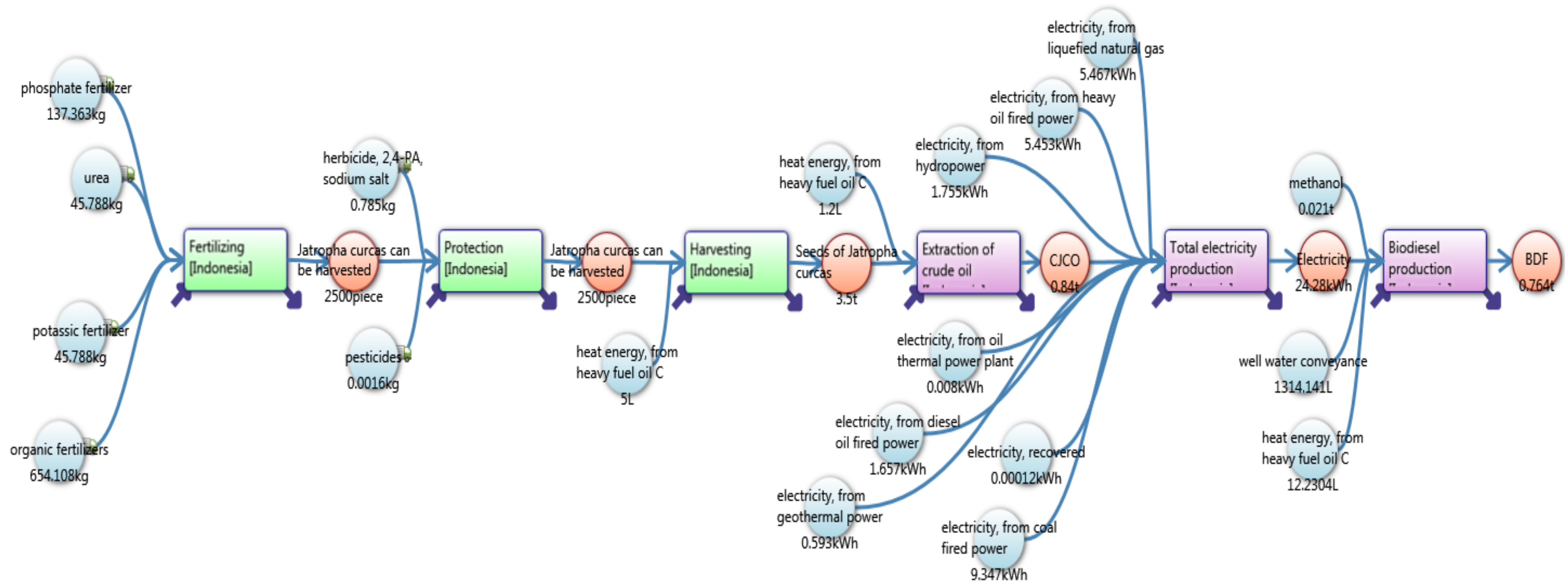


Figure 10.6 Product system on *Jatropha curcas* with MiLCA-JEMAI software for the fifth year

Appendix 11. The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas*

Result of LCIA for fossil fuel by BDF-CPO in year to 1, 2, and 3

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	1214.21	kg	44.7	54275.27
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	724.90	kg	25.7	18629.99
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	86.76	kg	29	2515.99
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	0.000003	kg	46.5	0.000121
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	1497.81	kg	54.6	81780.59
						Total	157201.8

Result of LCIA for non-renewable fuel by BDF-CPO in year to 1, 2, and 3

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	1214.21	kg	44.7	54275.27
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	724.90	kg	25.7	18629.99
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	86.76	kg	29	2515.99
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	2.61E-06	kg	46.5	0.000121
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	1497.81	kg	54.6	81780.59
Resources	Ground	Non-renewable energy	uranium,U3O8	0.00191	kg	454662	869.79
						Total	158071.63

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for renewable fuel by BDF-CPO in year to 1, 2, and 3

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	31061.32	MJ	1	31061.32
Resources	Water	Renewable energy	primary energy from hydro power	1021.42	MJ	1	1021.42
Resources	Air	Renewable energy	primary energy from solar energy	58620.15	MJ	1	58620.15
						Total	90702.89

Result of LCIA for all energy consumption by BDF-CPO in year to 1, 2, and 3

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	1214.21	kg	44.7	54275.27
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	724.90	kg	25.7	18629.99
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	86.76	kg	29	2515.99
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	2.61E-06	kg	46.5	0.00012
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	1497.81	kg	54.6	81780.59
Resources	Ground	Renewable energy	primary energy from geothermics	31061.32	MJ	1	31061.32
Resources	Water	Renewable energy	primary energy from hydro power	1021.421	MJ	1	1021.42
Resources	Air	Renewable energy	primary energy from solar energy	58620.15	MJ	1	58620.15
Resources	Ground	Non-renewable energy	uranium,U3O8	0.00191	kg	454662	869.79
						Total	248774.52

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for fossil fuel by BDF-CPO in year 4th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	312.56	kg	44.7	13971.27
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	68.34	kg	25.7	1756.41
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	12.58	kg	29	364.80
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	6.14E-06	kg	46.5	0.00029
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	220.66	kg	54.6	12048.003
						Total	28140.48

Result of LCIA for non-renewable fuel by BDF-CPO in year 4th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	312.56	kg	44.7	13971.27
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	68.34	kg	25.7	1756.41
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	12.58	kg	29	364.80
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	6.14E-06	kg	46.5	0.00029
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	220.66	kg	54.6	12048.003
Resources	Ground	Non-renewable energy	uranium,U3O8	0.00015	kg	454662	66.73
						Total	28207.21

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6^{th} for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for renewable fuel by BDF-CPO in year 4^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	3407.28	MJ	1	3407.28
Resources	Water	Renewable energy	primary energy from hydro power	117.71	MJ	1	117.71
Resources	Air	Renewable energy	primary energy from solar energy	6276.03	MJ	1	6276.03
						Total	9801.02

Result of LCIA for all energy consumption by BDF-CPO in year 4^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	312.56	kg	44.7	13971.27
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	68.34	kg	25.7	1756.41
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	12.58	kg	29	364.80
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	6.14E-06	kg	46.5	0.00029
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	220.66	kg	54.6	12048.00
Resources	Ground	Renewable energy	primary energy from geothermics	3407.28	MJ	1	3407.28
Resources	Water	Renewable energy	primary energy from hydro power	117.71	MJ	1	117.71
Resources	Air	Renewable energy	primary energy from solar energy	6276.03	MJ	1	6276.03
Resources	Ground	Non-renewable energy	uranium,U3O8	0.00015	kg	454662	66.73
						Total	38008.23

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for fossil fuel by BDF-CPO in year 5th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	358.72	kg	44.70	16034.86
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	47.33	kg	25.70	1216.29
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	7.83	kg	29.00	227.11
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	8.47E-06	kg	46.50	0.00039
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	138.58	kg	54.60	7566.38
						Total	25044.65

Result of LCIA for non-renewable fuel by BDF-CPO in year 5th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	358.72	kg	44.70	16034.86
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	47.33	kg	25.70	1216.29
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	7.83	kg	29.00	227.11
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	8.47E-06	kg	46.50	0.00039
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	138.58	kg	54.60	7566.38
Resources	Ground	Non-renewable energy	uranium,U3O8	9.05E-05	kg	454662.00	41.15
						Total	25085.79

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for renewable fuel by BDF-CPO in year 5th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	2400.27	MJ	1.00	2400.27
Resources	Water	Renewable energy	primary energy from hydro power	88.50	MJ	1.00	88.50
Resources	Air	Renewable energy	primary energy from solar energy	3302.13	MJ	1.00	3302.13
						Total	5790.90

Result of LCIA for all energy consumption by BDF-CPO in year to 5th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	358.72	kg	44.70	16034.86
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	47.33	kg	25.70	1216.29
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	7.83	kg	29.00	227.11
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	8.47E-06	kg	46.50	0.00039
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	138.58	kg	54.60	7566.38
Resources	Ground	Renewable energy	primary energy from geothermics	2400.27	MJ	1.00	2400.27
Resources	Water	Renewable energy	primary energy from hydro power	88.50	MJ	1.00	88.50
Resources	Air	Renewable energy	primary energy from solar energy	3302.13	MJ	1.00	3302.13
Resources	Ground	Non-renewable energy	uranium,U3O8	9.05E-05	kg	454662.0	41.15
						Total	30876.70

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for fossil fuel by BDF-CJCO in year 1th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	1399.75	kg	44.7	62568.95
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	727.65	kg	25.7	18700.51
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	43.05	kg	29	1248.54
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	2.84E-06	kg	46.5	0.000132
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	1003.58	kg	54.6	54795.70
						Total	137313.70

Result of LCIA for non-renewable fuel by BDF-CJCO in year 1th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	1399.75	kg	44.7	62568.95
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	727.65	kg	25.7	18700.51
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	43.05	kg	29	1248.54
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	2.84E-06	kg	46.5	0.000132
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	1003.58	kg	54.6	54795.70
Resources	Ground	Non-renewable energy	uranium,U3O8	0.001565	kg	454662	711.48
						Total	138025.18

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6^{th} for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for renewable fuel by BDF-CJCO in year 1^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	38727.18	MJ	1	38727.18
Resources	Water	Renewable energy	primary energy from hydro power	1053.05	MJ	1	1053.05
Resources	Air	Renewable energy	primary energy from solar energy	56080.22	MJ	1	56080.22
						Total	95860.46

Result of LCIA for all energy consumption by BDF-CJCO in year to 1^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	1399.75	kg	44.70	62568.95
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	727.65	kg	25.70	18700.51
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	43.05	kg	29.00	1248.54
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	2.84E-06	kg	46.50	0.00013
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	1003.58	kg	54.60	54795.70
Resources	Ground	Renewable energy	primary energy from geothermics	38727.18	MJ	1.00	38727.18
Resources	Water	Renewable energy	primary energy from hydro power	1053.05	MJ	1.00	1053.05
Resources	Air	Renewable energy	primary energy from solar energy	56080.22	MJ	1.00	56080.22
Resources	Ground	Non-renewable energy	uranium,U3O8	0.00156	kg	454662.00	711.4789
						Total	233885.63

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6^{th} for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for fossil fuel by BDF-CJCO in year 2^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	709.4685	kg	44.70	31713.24
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	390.3081	kg	25.70	10030.92
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	20.71742	kg	29.00	600.81
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	1.07E-06	kg	46.50	4.99E-05
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	754.6331	kg	54.60	41202.97
						Total	83547.93

Result of LCIA for non-renewable fuel by BDF-CJCO in year 2^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	709.4685	kg	44.70	31713.24
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	390.3081	kg	25.70	10030.92
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	20.71742	kg	29.00	600.81
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	1.07E-06	kg	46.50	4.99E-05
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	754.6331	kg	54.60	41202.97
Resources	Ground	Non-renewable energy	uranium,U3O8	0.000917	kg	454662.00	416.74
						Total	83964.67

Appendix 11.The running result for scenario 3 of overall energy consumption value in year 6^{th} for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for renewable fuel by BDF-CJCO in year 2^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	19391.71	MJ	1	19391.71
Resources	Water	Renewable energy	primary energy from hydro power	568.54	MJ	1	568.54
Resources	Air	Renewable energy	primary energy from solar energy	29368.14	MJ	1	29368.14
						Total	49328.40

Result of LCIA for all energy consumption by BDF-CJCO in year to 2^{th}

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	709.47	kg	44.70	31713.24
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	390.31	kg	25.70	10030.92
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	20.72	kg	29.00	600.81
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	1.07E-06	kg	46.50	4.99E-05
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	754.63	kg	54.60	41202.966
Resources	Ground	Renewable energy	primary energy from geothermics	19391.71	MJ	1.00	19391.71
Resources	Water	Renewable energy	primary energy from hydro power	568.54	MJ	1.00	568.54
Resources	Air	Renewable energy	primary energy from solar energy	29368.14	MJ	1.00	29368.14
Resources	Ground	Non-renewable energy	uranium,U3O8	0.00092	kg	454662.00	416.74
						Total	133293.06

Appendix 11. The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for fossil fuel by BDF-CJCO in year 3th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	183.81	kg	44.70	8216.29
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	98.39	kg	25.70	2528.69
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	5.18	kg	29.00	150.23
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	2.6E-07	kg	46.50	1.25E-05
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	193.58	kg	54.60	10569.71
						Total	21464.92

Result of LCIA for non-renewable fuel by BDF-CJCO in year 3th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	183.8095	kg	44.70	8216.29
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	98.39268	kg	25.70	2528.69
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	5.180444	kg	29.00	150.23
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	2.68E-07	kg	46.50	1.25E-05
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	193.5844	kg	54.60	10569.71
Resources	Ground	Non-renewable energy	uranium,U3O8	0.000229	kg	454662.00	104.20
						Total	21569.11

Appendix 11. The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for renewable fuel by BDF-CJCO in year 3th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	4866.35	MJ	1	4866.35
Resources	Water	Renewable energy	primary energy from hydro power	144.3995	MJ	1	144.40
Resources	Air	Renewable energy	primary energy from solar energy	7342.022	MJ	1	7342.02
						Total	12352.77

Result of LCIA for all energy consumption by BDF-CJCO in year to 3th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	183.8095	kg	44.70	8216.29
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	98.39268	kg	25.70	2528.69
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	5.180444	kg	29.00	150.23
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	2.68E-07	kg	46.50	1.25E-05
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	193.5844	kg	54.60	10569.71
Resources	Ground	Renewable energy	primary energy from geothermics	4866.35	MJ	1.00	4866.35
Resources	Water	Renewable energy	primary energy from hydro power	144.3995	MJ	1.00	144.40
Resources	Air	Renewable energy	primary energy from solar energy	7342.022	MJ	1.00	7342.02
Resources	Ground	Non-renewable energy	uranium,U3O8	0.000229	kg	454662.00	104.20
						Total	33921.89

Appendix 11. The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for fossil fuel by BDF-CJCO in year 4th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	85.33	kg	44.70	3814.45
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	41.19	kg	25.70	1058.46
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	2.07	kg	29.00	60.17
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	1.1E-07	kg	46.50	4.99E-06
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	88.43	kg	54.60	4828.25
						Total	9761.33

Result of LCIA for non-renewable fuel by BDF-CJCO in year 4th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	85.33	kg	44.70	3814.45
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	41.19	kg	25.70	1058.46
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	2.07	kg	29.00	60.17
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	1.1E-07	kg	46.50	4.99E-06
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	88.43	kg	54.60	4828.25
Resources	Ground	Non-renewable energy	uranium,U3O8	9.2E-05	kg	454662.0	41.71
						Total	9803.04

Appendix 11. The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for renewable fuel by BDF-CJCO in year 4th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact. factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	1987.93	MJ	1	1987.93
Resources	Water	Renewable energy	primary energy from hydro power	62.83	MJ	1	62.83
Resources	Air	Renewable energy	primary energy from solar energy	2936.84	MJ	1	2936.84
						Total	4987.60

Result of LCIA for all energy consumption by BDF-CJCO in year to 4th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	85.33	kg	44.70	3814.45
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	41.19	kg	25.70	1058.46
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	2.07	kg	29.00	60.17
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	1.1E-07	kg	46.50	4.99E-06
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	88.43	kg	54.60	4828.25
Resources	Ground	Renewable energy	primary energy from geothermics	1987.93	MJ	1.00	1987.93
Resources	Water	Renewable energy	primary energy from hydro power	62.83	MJ	1.00	62.83
Resources	Air	Renewable energy	primary energy from solar energy	2936.84	MJ	1.00	2936.84
Resources	Ground	Non-renewable energy	uranium,U3O8	9.2E-05	kg	454662.00	41.71
						Total	14790.64

Appendix 11. The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for fossil fuel by BDF-CJCO in year 5th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	70.92	kg	44.70	3169.91
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	30.91	kg	25.70	794.39
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	1.48	kg	29.00	43.03
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	7.7E-08	kg	46.50	3.6E-06
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	72.14	kg	54.60	3939.10
						Total	7946.43

Result of LCIA for non-renewable fuel by BDF-CJCO in year 5th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	70.92	kg	44.70	3169.91
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	30.91	kg	25.70	794.39
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	1.48	kg	29.00	43.03
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	7.7E-08	kg	46.50	3.6E-06
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	72.14	kg	54.60	3939.10
Resources	Ground	Non-renewable energy	uranium,U3O8	6.6E-05	kg	454662.00	29.82
						Total	7976.25

Appendix 11. The running result for scenario 3 of overall energy consumption value in year 6th for oil palm and *Jatropha curcas* (advanced)

Result of LCIA for renewable fuel by BDF-CJCO in year 5th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Renewable energy	primary energy from geothermics	1453.69	MJ	1.00	1453.69
Resources	Water	Renewable energy	primary energy from hydro power	49.03	MJ	1.00	49.03
Resources	Air	Renewable energy	primary energy from solar energy	2097.75	MJ	1.00	2097.75
						Total	3600.47

Result of LCIA for all energy consumption by BDF-CJCO in year to 5th

Category 1	Category 2	Category 3	Elementary flow	LCI result	Unit	Charact.factor	Equivalent
Resources	Ground	Non-renewable energy	crude oil, 44.7MJ/kg	70.92	kg	44.70	3169.91
Resources	Ground	Non-renewable energy	hard coal, 25.7MJ/kg	30.91	kg	25.70	794.39
Resources	Ground	Non-renewable energy	metallurgical coal, 29.0MJ/kg	1.48	kg	29.00	43.03
Resources	Ground	Non-renewable energy	Natural Gas Liquids, 46.5MJ/kg	7.7E-08	kg	46.50	3.6E-06
Resources	Ground	Non-renewable energy	natural gas, 54.6MJ/kg	72.14	kg	54.60	3939.10
Resources	Ground	Renewable energy	primary energy from geothermics	1453.69	MJ	1.00	1453.69
Resources	Water	Renewable energy	primary energy from hydro power	49.03	MJ	1.00	49.03
Resources	Air	Renewable energy	primary energy from solar energy	2097.75	MJ	1.00	2097.75
Resources	Ground	Non-renewable energy	uranium,U3O8	6.6E-05	kg	454,662.0	29.82
						Total	11576.72

Appendix 12.The complete calculation of NEB, NER and RI

For Scenario 3 :

	Oil palm			Jatropha curcas		
Year to	NEB	NER	RI	NEB	NER	RI
1	-	-	-	(232,196.78)	1.0415	0.4111
2	-	-	-	(130,432.89)	1.0415	0.3712
3	(226,193.11)	1.0407	0.3659	(24,043.94)	1.0415	0.3653
4	14,166.39	1.0407	0.2583	9,685.44	1.0415	0.3382
5	73,380.24	1.0407	0.1878	22,661.23	1.0415	0.3118
6	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
7	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
8	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
9	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
10	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
11	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
12	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
13	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
14	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
15	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
16	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
17	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
18	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
19	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
20	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
21	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
22	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
23	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
24	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700
25	146,948.08	1.0407	0.1623	39,334.79	1.0415	0.2700

BIOGRAPHY

Kiman Siregar, S.TP, M.Si. (author) was born in Janjimauli-Padangsidimpuan Nort Sumatra on May 01th, 1978. In 1997, he was graduated from SMU N. 1 Padangsidimpuan-Tapanuli Selatan North Sumatra and continued his under graduate study in Agricultural Enegineering Faculty of Technology of Bogor Agricultural University and graduated in 2001. He continued his study in Master Degree Program in Agricultural Engineering Science of Bogor Agricultural University and was graduated in 2004.

In 2009 He got scholarship from the Directorate General of Higher Education, Ministry of National Education. Author has been working as a lecturer in Agricultural Engineering Department of Agricultural Faculty in Syiah Kuala University and now He is joint with ASR-Group as a member of Heat Transfer Research Inc. (HTRI) to design, calculation and manufacturing of heat exchanger, radiator of cooling engine for PT.PLN (Persero) in Indonesia, and Power Plant Biomass (small capacity/50 kW).

Some scientific work that is part of a dissertation writer who were published, among them :

- A Comparison of Life Cycle Inventory of Pre-harvest, Production of Crude Oil, and Biodiesel Production on *Jatropha curcas* and Oil Palm as A Feedstock for Biodiesel in Indonesia, presented with oral and published in the Proceeding of The 10th International Conference on EcoBalance 2012, B2-01 in Yokohama, Japan, November, 20-232012.@Copyright The Institute of Life Cycle Assessment, Japan.
- *Perbandingan Penilaian Siklus Hidup Produksi Biodiesel Secara Katalis dari* Crude Palm Oil (CPO) dan Crude Jatropha curcas Oil (CJCO), published in Journal of *Teknologi Industri Pertanian* (Accredited by DIKTI), Vol.23, 2013.
- A Comparison of Life Cycle Assessment on Oil Palm and Jatropha Curcas as Feedstock for Biodiesel Production in Indonesia, processing publications on The International Journal of Life Cycle Assessment-Springer with index factor 2.4.
- Comparison Between Life Cycle Assessment of Biodiesel Production Using Catalyst From Crude Palm Oil and Crude Jatropha curcas Oil, presented with oral and published in Regional Conference and Workshop of Life Cycle Thinking on Energy, Food and Agriculture in Asia LCA Agrifood Asia 2013, Jakarta, June, 24-26 2013.
- Life Cycle GHG Emission and Energy Consumption for Production of Biodiesel Using Catalyst from Crude Palm Oil and Curde Jatropha Curcas Oil in Indonesia,presented with poster and published in International Conference on Sustainable Rural Development (ICRSD) **“**Sustainable Rural Development–Towards a Better World”, Purwokerto, Central Java, Indonesia, August 25-26, 2013.