A DECISION SUPPORT SYSTEM FOR SUSTAINABLE DEVELOPMENT OF BIODIESEL INDUSTRY

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A DECISION SUPPORT SYSTEM FOR SUSTAINABLE DEVELOPMENT OF BIODIESEL INDUSTRY

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Specially dedicated to my beloved family

And my lovely twins, Sofia and Sonia

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ABSTRACT

Energy plays a crucial role in modern life. The recent crises in the world oil market, rapid depletion of crude oil reserves along with growing concerns about emission of greenhouse gas have drawn attention to biofuels sources. Despite the many positive characteristics of biofuels, they cause a variety of environmental, economical, and social challenges that are not known to decision-makers by conventional evaluation tools such as Environmental Impact Assessment. This study designed and developed a specific Decision Support System (DSS) to analyze the sustainability of alternative biodiesel production in Malaysia by integrating and using Eco-indicator 99 method as a damage oriented Life Cycle Assessment (LCA), spatial analysis and Analytic Hierarchy Process (AHP). DSS was carried out to estimate four sustainability damage categories covering human health, ecosystem quality, resources depletion and socio-economic aspects to help decision makers in achieving a holistic insight into the entire system. LCA results show that fossil fuels depletion impact is the highest contributor to the environmental burdens of palm oil and jatropha biodiesel production, by 1.5E3 MJ and 1.99E3 MJ surplus respectively. This is followed by the respiratory inorganics impact with 1.32 E-3 and 3.28 E-4 Disability-Adjusted Life Year (DALY) for palm oil and jatropha biodiesel productions respectively. LCA as environmental analysis tool and Geographical Information System as spatial analysis tool were combined to provide an integrated methodology that is able to determine land use change impacts. Land use change analysis showed that approximately 42.2% of expansion during the period was the result of the conversion of forest, followed by agroforest and plantations (34.8%). The study used AHP to assign criteria weights from a Malaysian perspective. According to AHP analysis, the importance weights of both human health (40.9%) and ecosystem quality (32.2%) damages are higher than both resources depletion (16.5%) and socio-economic (10.4%) damages. Combining the effects on all impact categories as a single score supports the notion that the palm oil biodiesel production with 30.5 Eco-indicator point (Pt) generates 9.7% higher negative impacts on sustainability than jatropha biodiesel production which means jatropha development is more consistent with sustainability criteria and furthermore it could be beneficial in Clean Development Mechanism projects.

ABSTRAK

Tenaga memainkan peranan yang penting dalam kehidupan pada zaman moden. Krisis terkini dalam pasaran minyak dunia, penyusutan yang cepat dalam simpanan minyak mentah disertai dengan bertambahnya kebimbangan mengenai pelepasan gas rumah hijau telah menyebabkan tumpuan diberikan terhadap sumber-sumber biobahan api. Walaupun terdapat banyak ciri-ciri positif biobahan api, namun ianya telah mewujudkan pelbagai cabaran dari segi alam sekitar, ekonomi dan sosial yang tidak diketahui oleh pihak yang bertanggungjawab membuat keputusan dengan menggunakan alat penilaian konvensional seperti Penilaian Impak Alam Sekitar (EIA). Kajian ini adalah untuk mereka bentuk dan membangunkan satu Sistem Sokongan Keputusan (DSS) khusus untuk menganalisis kemampanan pengeluaran biodiesel alternatif di Malaysia dengan mengintegrasi dan menggunakan kaedah Eco-penunjuk 99 sebagai satu kerosakan yang berorientasikan Penilaian Kitaran Hayat (LCA), analisis ruang, dan Proses Analitik Hierarki (AHP). DSS telah dijalankan untuk menganggarkan empat kategori kerosakan kemampanan yang meliputi kesihatan manusia, kualiti ekosistem, penyusutan sumber, dan aspek-aspek sosio-ekonomi untuk membantu pihak pembuat keputusan dalam mencapai fahaman yang holistik ke dalam keseluruhan sistem. Keputusan LCA menunjukkan bahawa kesan pengurangan bahan api adalah penyumbang tertinggi kepada bebanan alam sekitar minyak sawit dan pengeluaran biodiesel jatropha, dengan masing-masing mempunyai lebihan sebanyak 1.5E3 MJ dan 1.99E3 MJ. Ini diikuti oleh kesan respiratori bahan bukan organik dengan masing-masing sebanyak 1.32 E-3 dan 3.28 E-4 Tahun Hayat Pelarasan Tunaupaya (DALY) untuk pengeluaran minyak sawit dan jatropha. LCA sebagai alat menganalisis alam sekitar, dan Sistem Maklumat Geografi sebagai alat menganalisis ruang telah digabungkan untuk menyediakan satu kaedah bersepadu yang dapat menentukan kesan perubahan penggunaan tanah. Analisis perubahan penggunaan tanah telah menunjukkan bahawa lebih kurang 42.2% daripada perkembangan dalam tempoh tersebut adalah disebabkan oleh penukaran hutan, diikuti oleh hutan tani dan perladangan (34.8%). Kajian ini menggunakan AHP untuk menetapkan kriteria pemberat dari perspektif Malaysia. Analisis AHP menunjukkan kerosakan kesihatan manusia (40.9%) dan kualiti ekosistem (32.2%) adalah lebih tinggi berbanding kerosakan pengurangan sumber (16.5%) dan sosio-ekonomi (10.4%). Gabungan kesan terhadap semua kategori impak sebagai satu skor menyokong tanggapan bahawa pengeluaran minyak sawit biodiesel dengan 30.5 Titik Eko-penunjuk (Pt) telah menjana 9.7% kesan negatif yang lebih tinggi terhadap kemampanan berbanding pengeluaran biodiesel jatropha, yang memberi maksud bahawa pembangunan jatropha adalah lebih konsisten dengan kriteria kemampanan, disamping boleh memberi manfaat dalam projek-projek Mekanisme Pembangunan Bersih.

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LIST OF ABBREVIATIONS

AHP	-	Analytic hierarchy process
APEC	-	Asia-Pacific economic cooperation
APERC	-	Asia-Pacific energy research centre
BGS	-	British geological society
BP	-	By product credit
BSB	-	Bionas Sdn. Bhd
CBA	-	Cost-benefit analysis
CC	-	Capital cost
CDM	-	Clean development mechanism
CI	-	Compression ignition
CPM	-	Centre for environmental assessment of product and material systems
CPO	-	Crude palm oil
DALY	-	Disability adjusted life years
DSS	-	Decision support systems
EC	-	European commission
EFB	-	Empty fruit bunch
EFQ	-	Ecosystem functional quality
EIA	-	Environmental impact assessment
EMS	-	Environmental management systems
ERA	-	Environmental risk assessment
ESQ	-	Ecosystem structural quality
ETP	-	Economic transformation program
FAL	-	Franklin associates ltd
FAME	-	Fatty acid methyl esters
FC	-	Feedstock cost

FEB	-	Fresh fruit bunches
FiT	-	Feed-in-tariff
FSC	-	Forest stewardship council
FU	-	Functional unit
GDP	-	Gross domestic product
GHG	-	Greenhouse gas
GIS	-	Geographical information system
GWP	-	Global warming potential
HCV	-	High conservation value
HTU	-	Hydrothermal upgrading
IEA	-	International energy agency
IPCC	-	International panel on climate change
IPP	-	Integrated product policy
ISO	-	International organization for standardization
J. curcas	-	Jatropha curcas
JME	-	Jatropha methyl-ester
LCA	-	Life cycle assessment
LCC	-	Life cycle cost
LCI	-	Life cycle inventory
LCIA	-	Life cycle impact assessment
LUC	-	Land use change
MC	-	Maintenance cost
MCA	-	Multi criteria analysis
MCDM	-	Multiple criteria decision making
MEW	-	Multiplicative exponential weighting
MFA	-	Material flow analysis
mPt	-	Milli- eco-indicator point
MRB	-	Malaysian rubber board
NDVI	-	Normalized difference vegetation index
NKEA	-	National key economic areas
OC	-	Operating cost
OS	-	Ordnance survey
PAF	-	Potentially affected fraction

PDF	-	Potentially disappeared fraction
PME	-	Palm methyl-ester
POME	-	Palm oil mill effluent
Pt	-	Eco-indicator point
PTM	-	Pusat tenaga Malaysia
RE	-	Renewable energy
REPA	-	Resource and energy profile analysis
RIVM	-	National institute of public health and the environment
RPO	-	Refined palm oil
RS	-	Remote sensing
SAW	-	Simple additive weighting
SE	-	Surplus energy
SEA	-	Strategic environmental assessment
SEDA	-	Sustainable energy development authority
SETAC	-	Society for environmental toxicology and chemistry
SV	-	Salvage value
TOPSIS	-	Technique for order of preference by similarity to ideal solution
VROM	-	Dutch ministry of housing, spatial planning and the environment
WHO	-	World health organization
YLD	-	Years lived disabled
YLL	-	Years of life lost

LIST OF SYMBOLS

A^S_i	-	Weight of alternative *i*
B5	-	5 % biodiesel blend in diesel fuel
Bnl	-	Billion liters
$CF_{i,j}$	-	Characterization factor for impact category *i*
CI	-	Consistency index
CR	-	Consistency ratio
D_{refsub}	-	Damage factor for CO_2
EJ	-	Exajoules
E_j	-	Emission *j* or consumption of resource *j* per functional unit
FI	-	Final Index*i* or category indicator*i*
GW	-	Gigawatts
I	-	Unit matrix of size *n*
I_i	-	Indicator for impact category *i*
Ktoe	-	Thousand tonnes of oil equivalent
LHVA	-	Lower heating values of oil
LHVB	-	Lower heating values of seed
M	-	Reciprocal matrix
m_i	-	Size of intervention of type *i*
Mtoe	-	Million tonnes of oil equivalent
MW	-	Megawatts
n	-	Number f elements
NF_i	-	Normalization factor
NIR	-	Normalized indicator result for impact category *i*
ppm	-	Parts per million
q	-	Correct Eigen value
S_j	-	Impact category *j*
TWh	-	Terawatt-hours

W_{Di}	-	Weighting factor for damage of category *i*
WFi	-	Weighting factor for impact category *i*
W_{SDi}	-	Weighting factor for sub damage of category *i*
λ_{max}	-	Maximum eigenvalue of the comparison matrix

Greek Letters

∂	-	Partial derivative
$\sum$	-	Summation

Subscripts

i	-	Substance
l	-	Related location of the receptor
s	-	Location of the emission
t	-	Time period

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CHAPTER 1

INTRODUCTION

1.1 Overview

The recent crises in the world oil market, rapid depletion of crude oil reserves along with growing concerns about emission of greenhouse gas have drawn attention to alternative and renewable energy sources [1-3]. The huge demand for energy in the developed countries and transportation section [4] and spread of pollution caused by fossil fuel consumption signals the necessity to develop renewable energy sources that cause less negative effects on the environment. The candidate fuel must be easy to obtain from technical viewpoint, economic, environment friendly, and practically accessible [5]. In spite of the fact that several alternative energy sources have been found such as biomass, sun, mini-hydro, etc., fossil fuels still constitute the main portion of energy consumption in the world. For instance, fossil fuels constituted 79.3% of total world primary energy production in 2014 as shown in Figure1.1 [6]. The same year experienced 0.9% increase in global primary energy consumption and coal and oil consumption increased by 0.4% and 0.8% in 2014 respectively [7].

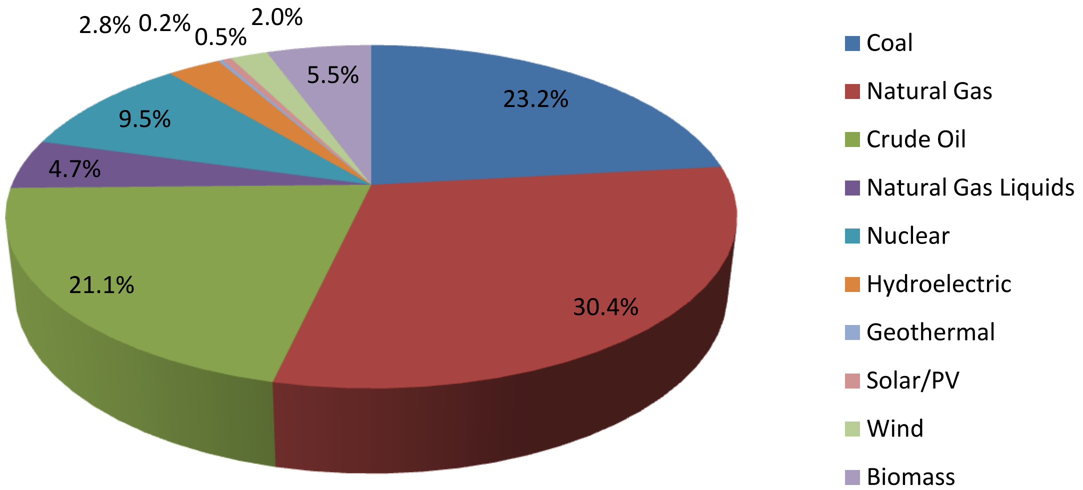

Figure 1.1: World primary energy production in 2014 by source [6].

Resources of all fossil fuel are limited and with this rate of consumption, in near future there will be no fossil energy resource to use [5, 8]. One of the promising options for renewable energy, which has drawn great deal of attention lately, is biodiesel. It is characterized with almost the same properties of petroleum-derived diesel [9]. The main producer of biofuel in the world is North America. Table1.1 illustrates the biofuel production rate on region basis [7].

Table1.1: Biofuels production (Thousand tonnes oil equivalent) [7].

Regions	**2005**	**2010**	**2014**
North America	7612(38.6%)	26322(44.0%)	31252 (44.1%)
Central and South America	8093(41.0%)	18118(30.3%)	20294 (28.7%)
Europe & Eurasia	3160(16.0%)	11322(18. 9%)	11683 (16.5%)
Middle East	–	4 (0.006%)	4 (0.005%)
Africa	6 (0.03%)	32(0.05%)	21 (0.02%)
Asia Pacific	834 (4.2%)	3953(6.6%)	7538 (10.6%)
Total World	19704 (100%)	59752(100%)	70792(100%)

Statistics illustrate that production of biodiesel has shown a steep raising trend in the recent years. Figure 1.2 shows the annual production of ethanol and biodiesel between 2005 and 2012 and expected increase [10].

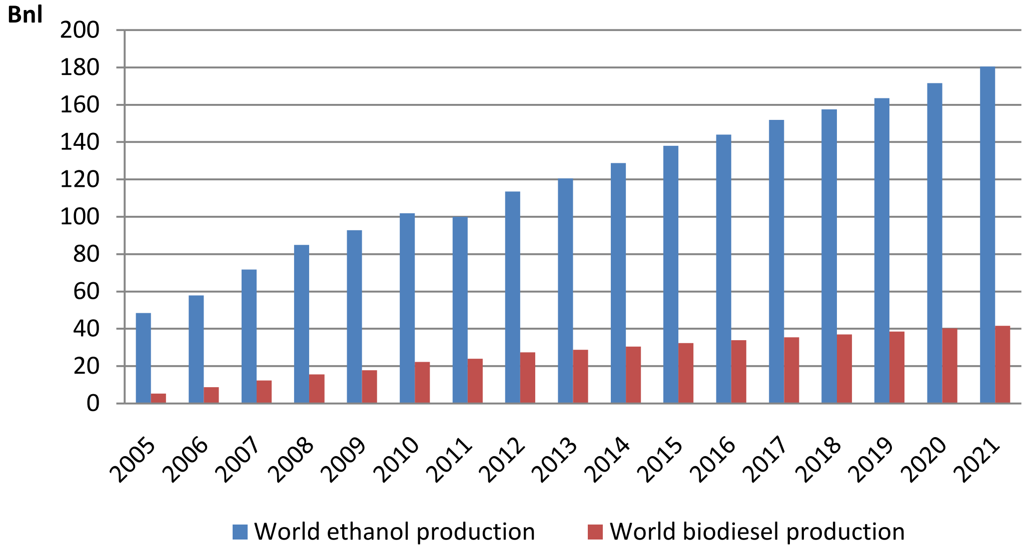

Figure 1.2: World annual biodiesel and ethanol production [10].

There are expectations of a growth up to 42 Billion liters (Bnl) in production of biodiesel by 2021. In recent developments, the two main producers of palm oil (Indonesia and Malaysia) have prepared refining capacities with flexibility for quick shift to biodiesel production in case the world prices justify export of the fuel[10].

Some countries like Canada, the USA, France, Brazil, Indonesia, Malaysia, and Australia are cited as the major biodiesel producers. There are speculations that global vegetable oil production may hit 35 Million tonnes in 2021, which is a 28% increase compared with 2011. About 79% of global vegetable oil production is supplied by Indonesia, Malaysia, China, the EU, The USA, Brazil, and India. Indonesia and Malaysia have plans to emerge as the leading producers of oil production (20% and 14% respectively) by 2021 [10, 11]. It is expected that in the coming 10 years total production of palm oil of the two countries grow by 37% (12 Million tonnes). Consequently, palm oil is expected to constitute about 33% of the world vegetable oil production in 2021. About 2% annual growth of global demand for vegetable oil is forecasted. There are expectations of growth in demand for edible vegetable oil to be used for biodiesel production up to 30 Million tonnes; this figure represents a 76% raise over the base period and increase of the portion of vegetable oil in production of biodiesel from 12% in 2009-11 to 16% in 2021 [10]. There has been extensive planning and preparations to increase share of biodiesel in the fuel supply in many countries as shown in Table 1.2.

Table 1.2: Summary of worldwide biofuel targets [12-15].

Country	Official biofuel targets
Brazil	40% rise in ethanol production, 2005 – 2010; Mandatory blend of 20 –25% anhydrous ethanol with petrol; minimum blending of 5% (B5) biodiesel to diesel by January 2013
Canada	5% renewable fuel standard in all Canadian fuel and 2% biodiesel content in diesel fuel by 2012
European Union	10% in 2020 (biofuels); target set by European Commission (EC) in January, 2008
UK	5% by 2020 (biofuels, by energy content)
Indonesia	20% biodiesel and 15% ethanol blend in fossil fuel by 2025
India	20% biodiesel content in diesel fuel by 2012
Malaysia	15% biodiesel in transport and commercial sectors by 2015
Thailand	10% replacement of diesel in 2012

Biofuels constitutes about 10 to 15% of the global energy supply, which comes to about 45 exajoules (EJ) [16]. The International Energy Agency (IEA) has set a goal to cover more than 25% of world energy needs in transportation sector by biofuels until 2050 [17].

Malaysia National Energy Policy targets an efficient, safe, reliable, and environment-friendly energy supply in the future [18]. In line with its biofuels drive, the government approved 91 licenses with an annual target of 10.2 million tonnes of palm oil biodiesel [2, 19]. By its nature, production of biofuel in the developing countries and the potential of production is not a straight forward matter and this has caused considerable debates in recent years. Still, the heated policy debate uncover that there are several questions to be answered and that there are impacts to be assessed.

The Life Cycle Assessment (LCA) methodology is of the capacity of being a key management tool to help decision makers to achieve a holistic insight into the entire system associated with single product/service to be introduced. Assessing the environmental performance of biofuels is a complex issue. LCA is an internationally renowned methodology for evaluating the global environmental performance of a product, process or pathway along its partial or whole life cycle, considering the impacts generated from "cradle to grave". LCA is considered as the best methodology for holistic assessment of environmental impacts associated with biofuel production but it has its limitations [20, 21].

The environmental impacts caused by land use and socio-economic aspects are often excluded from the calculations and usually, these sources are not effectively dealt with by life cycle assessment (LCA). Consequently, many impact categories are neglected in LCA studies. Therefore, it is crucial to adopt a systematic approach to study the whole upstream/downstream processes in detail. Such analysis helps to ensure benefits of "cleanliness" of what is known as "green energy". The purpose of this study is to develop a systematic framework and specific decision support system for producing environmentally and socio-economically sound biodiesel considering criteria importance weights from a Malaysian perspective.

1.2 Problem Statement

Strategic decision making is the art of managing organizations in maximizing the potential of achieving objectives. It attempts to organize qualitative and quantitative information, allowing effective decisions to be made under different conditions of uncertainty[22, 23]. As interactive tools, Decision Support Systems (DSS) make the users able to take informed decisions regarding unstructured problems. The systems usually consist of database of the information pertinent to the problem, a model that dictates how to examine the functions of the problem, and an interface for the operator [24].

Three fields must be taken into account to make sure of sustainable development of biodiesel production; environmental sustainability, economic sustainability and social acceptance [25]. Some parties see mainly the new chances of improved market for agricultural goods and rural development along with low-carbon development. Some express their worries about competition for land and food while no advantage is expected for the rural communities and the environment. In this regard some has raised concerns about more intense competition for limited land and natural resources, shortage of food, deforestation for farming land, water contamination, land and air quality, loss of biodiversity, and even higher carbon footprint. One result of deforestation for farming purposes is higher rate of greenhouse emission. Lack of effective and proper waste management system in biofuel mills increases the severity of air and water pollution, which is a new environmental challenge for the biodiesel development. More interestingly, carbon footprint of biodiesel production is a function of the production systems and method. There are records of growth in the rate of greenhouse gases (GHG) production due to deforestation and displacement effects [3, 26].

Many believe that it is possible to achieve a win-win solution, though it needs careful assessment and policy making [1, 27, 28]. For instance, along with creating job for one million Brazilian by biofuel industry in the country, 30% of the sugarcane plantations are still controlled by independent and mainly small-scale farmers [29]. There are cases of large areas of deforestation for biofuel production and consequently increase in emission of GHG and attenuation of biodiversity. Some of such cases to name are Malaysia and Indonesia palm oil and Brazil soy production projects [26].

Recent studies [25, 30] have shown that several environmental crises are caused by cumulative, induced and synergistic effects. Such factors cannot be dealt with using common process of environmental assessment such as EIA as assessment tools at project-level. Because such assessments are commonly used upon completion of the design stage and approval of the projects, they are considered as passive approach to planning system and constitute the final part of cycle step in the process of planning. One of the mostly used methods to evaluate environmental advantages and disadvantages of biodiesel industry is the Life Cycle Assessment (LCA), which entails a complete evaluation and analysis of a product throughout its “cradle to grave”. One of the merits to name is its better coverage of the whole range of effects and that is can provide a general view of the upstream impact. Although the merits of LCA as a tool to measure the environmental effect of products/services are undeniable, there are also some dominant disadvantages recognized [31]. At any rate, one of critical demerits of LCA as an input for strategic decision making is its failure to encompass costs and investments issues. In fact, it leaves economic and social sustainability unanswered. Moreover, methodologically and practically speaking, it is not easy to make comparison between the option concerning environmental effects, costs, and social aspects.

LCA fails to cover the effect of systems under study concerning issues such as land usage [32]. About 9% of world CO_2 emission comes from land use changes[33]. Usually, these sources are not effectively dealt with by life cycle assessment. Along with population growth, available land area becomes scarcer. On one hand, forestry, agriculture, community, building and services, and natural ecosystem compete over a limited area of land and on the other hand, different products (food, feed, fiber, fuel, and the like) compete on gaining more land. About 11.7% of available land (the area covered by ice is not included) is used for agricultural purposes and it is proposed that this figure should not be increased to 15%, Otherwise, this trend leads to increase of deforestation, which results in critical impacts on the essential ecosystem services [34]. International policies to increase production of biofuels have led to considerable changes in land use.

However, the impact category “land use” is part of some of most common Life Cycle Impact Assessment (LCIA) methods (e.g. ReCiPe, CML, or EI99), but only one aspect of environmental impacts caused by land use is included. Therefore, these methods are not comprehensive. Although, climate change is recognized as major factor in environmental problem that need the most immediate mitigations, most of LCA studies have only focused on the direct GHG emissions generated by biofuel and bioenergy system [35] while indirect emissions should also be taken into account. At any rate, lack of complete coverage of land used data attenuates the reliability of the results of LCA.

Therefore a new approach is required in order to integrate socio-economic aspects, both the direct and indirect land-use changes impacts and environmental considerations into a single analysis as for the importance of each impact for Malaysia using Analytic Hierarchy Process (AHP) as weighting tool because default weight in LCA software represent European importance of each impact. Thus, this study is significant to fulfil the gaps of covering indirect land-use changes impacts and socio-economic aspects of biodiesel production base on life cycle assessment (LCA) framework given the specific importance of the effects for Malaysia.

This new systematic approach will eventually reveal the true potential of the product evaluated and identify the environmental hot spots in the product chains so that precautionary steps can be suggested to reduce the negative environmental impact. Figure 1.3 shows intention of improvement in sustainability assessment of biodiesel production.

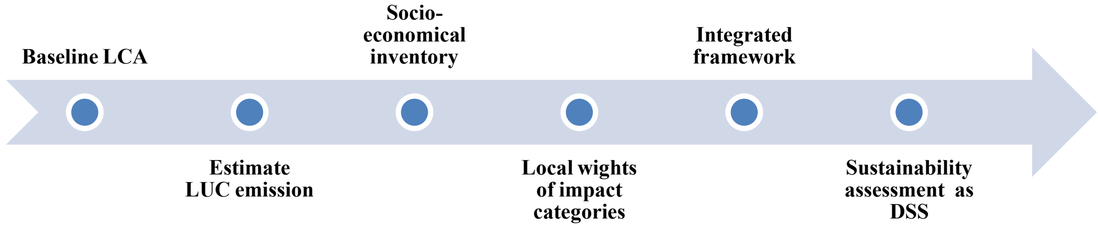

Figure 1.3: Intention of improvement in sustainability assessment of biodiesel production

1.3 Research Contributions

The main contribution of this research is to develop an integrated socio-economic and land use change with LCA based approach on Malaysia case study. The specific research contributions are described as follows:

i. A new method of decision making for evaluating the sustainability of biodiesel industry
ii. New inventory of socio-economic, life cycle cost and job creation
iii. New indicator system to estimate the land use change emission in LCA
iv. Develop a weighting system for sustainability life cycle assessment for jatropha and palm oil biodiesel case study

Case studies implemented in this research works are based on data collected within the region of Malaysia. The results therefore reflect the evaluation of development of the biodiesel industry in Malaysia. These results will be analyzed and evaluated as a mean to help decision making for biodiesel industry in Malaysia.

1.4 Objective of the Study

The aim of this study is to design a new process of decision making that consider land use change impacts and socio-economic aspects along with the environmental aspects regarding development of palm and jatropha as different scenarios of biodiesel production resources by the way of evaluating, applying, optimizing and developing instruments in energy planning. Hence, a comprehensive investigation on the effect of production and utilizing biodiesel on the environment can be carried out scientifically, which is crucial in decision making to develop biodiesel industry.

In order to achieve this purpose, the following objectives have been identified:

Objective-1: to establish the baseline study to compare environmental impacts of palm oil and jatropha as different alternatives of biodiesel production

Objective-2: to assess the indirect land-use changes impacts caused by biodiesel production on the climate change

Objective-3: to assess the socio-economic implication for biodiesel production using jatropha and palm oil

Objective-4: to perform a integrated framework to assess the sustainability life cycle of biodiesel production for Malaysia case study

1.5 Scope of Study

The scope of this study is to evaluate the sustainable performance of biodiesel production from several options in Malaysia. The alternative biodiesel source have been selected based on Malaysia's energy policy, the biodiesel targets of other countries that have the similar status and assessment of thresholds. The analysis covers environmental and socio-economic acceptance of production suitable biodiesel based on Malaysia condition. The scope of study covers all the four objectives.

The analysis is divided into three stages: crop plantation, milling stage (oil extraction) and transesterification into biodiesel (biodiesel plant). The data will be collected from chosen factories in Malaysia to represent Malaysia‘s condition. Therefore the following scopes have been identified to answer objectives:

1) Establishing the baseline study to compare environmental impacts of palm oil and jatropha as different alternatives of biodiesel production:

(i) Palm oil biodiesel and jatropha oil biodiesel as main feedstock for biodiesel production in Malaysia

(ii) Life cycle assessment methodology for assessment of environmental impacts of biodiesel production using eco-indicator 99 method by Simapro 7.1 software

(iii) Eleven categories of environmental impacts were of interest: climate change, carcinogen, respiratory organics and inorganics, ozone layer depletion, ecotoxicity, acidification/ eutrophication, minerals, radiation, land use and fossil fuels

2) Estimating the indirect land-use changes impacts caused by biodiesel production on the climate change:

(i) Spatial assessment methodology for considering land use change impact using Arc GIS 10.2 software

3) Assessing the socio-economic implication for biodiesel production using jatropha and palm oil:

(i) Considering Life Cycle Cost (LCC) and job creation as socio-economic aspects of production of different biodiesel scenario into decision making approach

4) Performing a integrated framework to assess the sustainability life cycle of biodiesel production for Malaysia case study:

(i) Multi-Criteria Decision Making to allocation specific Malaysian weight for environmental and socio-economic impacts as sustainability factors using Analytic Hierarchy Process (AHP) method by Expert Choice 11.1.32 software

(ii) Four broad categories of adverse effects on sustainability of biodiesel production including: effects on human health, ecosystems quality (flora and fauna), resources of the earth and socio-economic

1.6 Thesis Organization

The thesis was arranged into five chapters: Chapter 1 – 3 (Introduction, Literature Review and Methodology); Chapter 4 (Result); Chapter 5 (Conclusion). Figure 1.4 shows the flow chart summarizing the thesis organization. The details are as follows:

Chapter One: Introduction – This chapter gives general background of the study. It also highlights the problems associated with the research area. In addition, the chapter outlines the main aim, scope and significance of the study.

Chapter Two: Literature Review - This chapter focuses on evaluation of relevant researches to the study area and describes the current general framework for biodiesel sources and technology. Important concepts in energy situation in Malaysia and Palm oil and jatropha oil as main alternative sources for biodiesel production were discussed. Overview on life cycle assessment (LCA) methods with more emphasis on endpoint model was presented. Land use impacts and multi-criteria analysis were reviewed; and their assessment tools are presented as well.

Chapter three: Methodology – This chapter consists of detailed research approaches adopted for the study. It explained LCA and AHP and model formulation methodologies. It also gave explanation of assessment and integration of land use impact into LCA model.

Chapter four: Result – This chapter present the achievements of the thesis objectives (Objectives 1- 4).

Chapter five: Conclusions and Recommendations – In this Chapter, important inferences were arrived at, based on the findings in the previous chapters. In addition, recommendations were made for the application of the outcome of the research or for further studies.

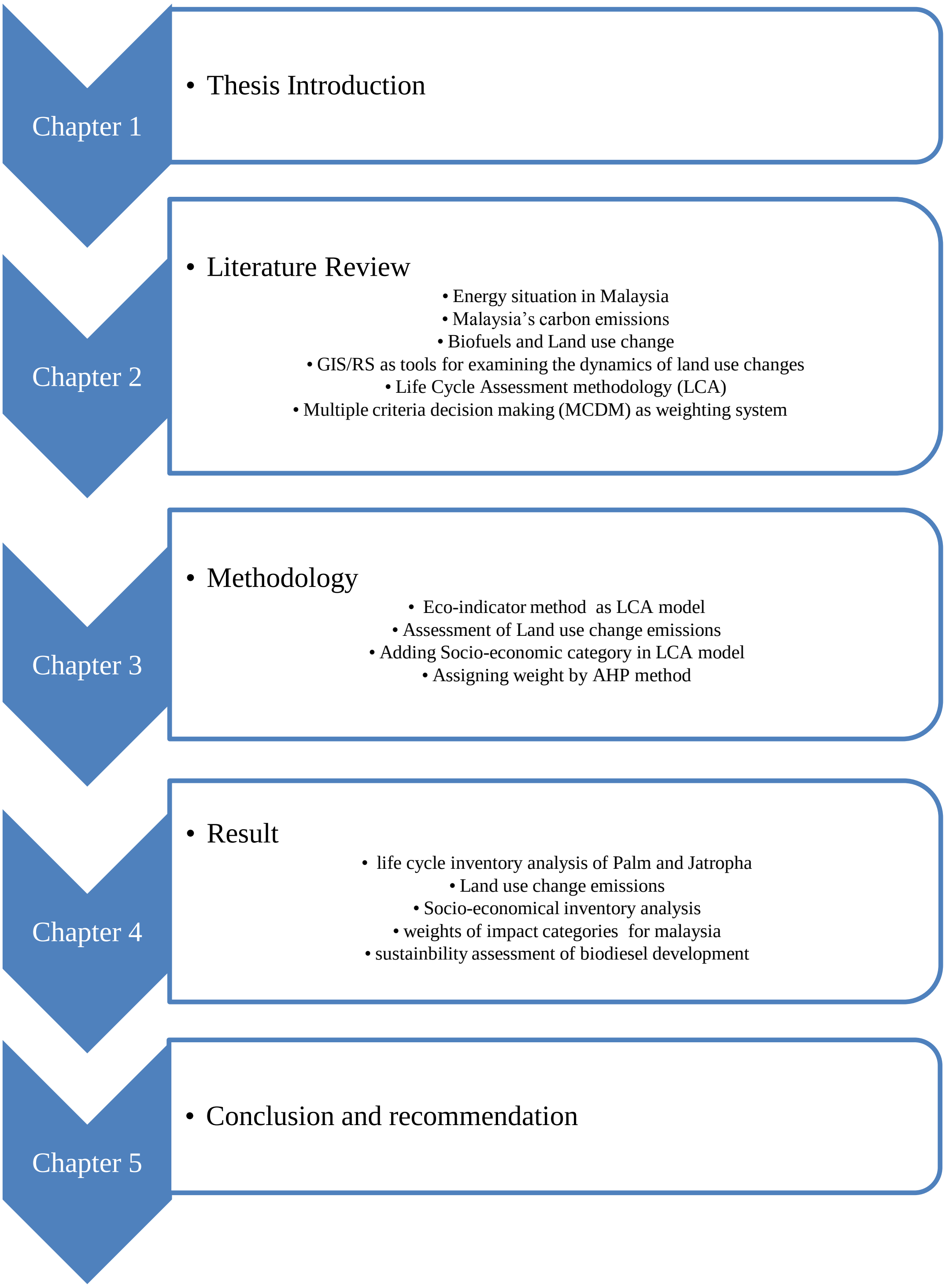

Figure 1.4: Flow chart for thesis organization

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