A FEASIBILITY STUDY OF JATROPHA CURCAS OIL AS ALTERNATIVE ENERGY RESOURCE

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I would like to dedicate this thesis to my parents
for their endless love and guidance which always helps me
to choose the right path

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ABSTRACT

Energy is fundamental to the quality of our lives. Substantial economic growth and industrialization are expected around the world during the 21st century. As a result, average living standards will rise, leading to a strong increase in energy demand; therefore, meeting the growing demand for energy sustainably is one of the major challenges of the current century. Indonesia is one of the developing countries and energy supply is an important factor for all-around development Total annual energy consumption grew by 50 percent between 2001 and 2010. The energy consumption of the country still depends on non-renewable energy such as crude oil, coal and natural gas as sources of energy. Indonesia has planned by the declaration of Energy Law 2006 to shift its dependence on fossil fuels towards more environmentally friendly and sustainable energy sources. The energy mixes plan in Indonesia depends on crude oil, natural gas, coal and renewable energy. Biodiesel is an alternative fuel similar to fossil diesel. Jatropha curcas is one of biodiesel resources that offer immediate and sustained greenhouse gas advantages over other biodiesel resources. Jatropha curcas has created an interest for researchers because it is non-edible oil and can be used to produce biodiesel with similar performance results when testing in diesel engines. This study is concerned with a feasibility of Jatropha curcas oil as renewable energy resource. Currently over one million households in the Province of Riau in Indonesia, mainly in rural villages, do not have access to electricity A decentralized power generation plant can be a solution for providing rural communities in developing countries with electricity. Substituting diesel with locally produced Jatropha oil can improve economic and environmental sustainability of rural electrification. A full Life Cycle Assessment (LCA) was conducted on Jatropha-based rural electrification and then compared with electrification approaches diesel-fuelled power generator.

ABSTRAK

Tenaga adalah sangat penting untuk kehidupan kita yang berkualiti. Perkembangan ekonomi dan industri yang tinggi dijangka berlaku diseluruh dunia semasa abad ke-21. Hal ini menyebabkan purata aras kehidupan meningkat, seterusnya permintaan tenaga meningkat dengan tinggi; oleh itu, memenuhi permintaan yang meningkat untuk tenaga yang berterusan adalah satu daripada cabaran utama di abad ini. Indonesia adalah salah satu Negara yang sedang membangun dan bekalan tenaga adalah salah satu faktor utama untuk keseluruhan pembangunan. Jumlah penggunaan tenaga tahunan telah meningkat sebanyak 50 peratus antara 2001 dan 2010. Indonesia telah merancang dengan pengishtiharan oleh Undang-undang Tenaga 2006 untuk ubah kebergantungan mereka pada bahan api fosil kepada sumber tenaga yang lebih menjaga alam sekitar dan berterusan. Pelan pelbagai tenaga di Indonesia bergantung kepada minyak mentah, gas asli, arang batu dan tenaga yang boleh diperbaharui. Biodiesel adalah bahan api alternative yang sama dengan fosil diesel. Jatrophacurcas adalah salah satu sumber biodiesel yang menawarkan cepat dan berterusan kelebihan gas rumah hijau berbanding sumber biodiesel yang lain. Jatrophacurcas telah menarik minat penyelidik kerana ia adalah minyak yang tidak boleh dimakan dan boleh digunakan untuk menghasilkan biodiesel dengan prestasi yang sama apabila diuji dengan enjin diesel. Sekarang, lebih satu juta penduduk di wilayah Riau, Indonesia, kebanyakannya kawasan-kawasan kampung, tidak ada kemudahan elektrik. Satu tempat menghasilkan tenaga berpusat boleh menjadi penyelesaian untuk menyediakan orang-orang di pedalaman di negara yang membangun dengan elektrik. Menggantikan diesel dengan minyak Jatropha yang dihasilkan dalam negara, boleh memperbaiki ekonomi dan kemudahan elektrik yang berterusan di kawasan pedalaman. Penilaian Kitar Hayat (LCA) yang lengkap telah dibuat pada sistem elektrik menggunakan minyak Jatropha dan dibandingkan dengan sistem elektrik menggunakan penjana elektrik diesel.

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LIST OF SYMBOLS AND ABBREVIATIONS

F	-	Total annual generator fuel consumption.
F_O	-	Generator fuel curve intercept coefficient.
F_1	-	Generator fuel curve slope.
Y_{gen}	-	Rated capacity of the generator.
P_{gen}	-	Output of the generator in this hour.
F_{spec}	-	Total annual generator specific fuel consumption.
E_{gen}	-	Total annual electrical production of the generator.
Q_{fuel}	-	Fuel energy input.
ρ_{fuel}	-	Fuel density in kg/m^3.
LHV_{fuel}	-	Lower heating value (a measure of energy content) of the fuel.
P_{gen}	-	The electrical output.
m_{fuel}	-	The mass flow rate of the fuel.
η_{gen}	-	mean electrical efficiency of the generator
ATMI	-	Akademi Tehnik Mesin Industri.
BizDEC	-	Business Development and Ethics Center
BHC	-	British High Commission
SHGW	-	Stichting Het Groene Woudt
CH4	-	Methane
CH3NaO	-	Sodium Methylate
C3H5(OH)3	-	Glycerol
CH3OH	-	Methanol
CHP	-	Combined Heat And Power
CO2	-	Carbon dioxide
EPA	-	United States Environmental Protection Agency
ESSV	-	Energy Self-Sufficient Village
FACT	-	Fuels from Agriculture for Communal Technology

FAME	-	Fatty Acid Methyl Esters
HC	-	Unburned Hydrocarbons
KOH	-	Potassium Hydroxide
MFC	-	Mali Folkecenter
Mha•m	-	Millions of hectare meters
NaOH	-	Sodium Hydroxide
NOx	-	Nitrogen Oxide
O&M	-	Operation and Maintenance
PM	-	Particulate Matter
PSO	-	Public Service Obligation
RCOOH	-	Fatty acids
SDC	-	Swiss Agency for Development and Cooperation
SO2	-	Sulfur Dioxide
SOE	-	State-Owned Enterprises
VOG	-	Vegetable Oil Generator

CHAPTER 1

INTRODUCTION

1.1 Background

In order to reduce the use of depleting primary energy sources, renewable energy technologies have been developed. There are several issues that are related to renewable energies such as environment and sustainable development of alternative technologies. That is why environmental friendly techniques of renewable energy need to be explored, promoted and encouraged for the real implementation.

The renewable energy sources depend on natural energy sources such as solar energy, wind energy, hydropower exist in flowing water , biological decay processes for methanation and $CO_{2,}$ and geothermal energy resources near volcanic areas. It is readily understood that there are many alternatives for renewable energy that needs cost effective technique to use them. Yet there is no ultimate technique that can solve the energy problems of the next generation fuel. However, several techniques have been tried in some countries in conjunction to each other to distinguish the characteristics that can ascertain some techniques more appropriate than others. All these natural energy resources are not available in every country; for instance

Denmark is very windy that can benefit by focusing on wind energy. Some other countries like Tanzania and India, solar power is most convenient and suitable energy source, these countries can also benefit from derivative of solar energy using biomass as primary energy source. [1]

Nowadays, all branches of modern economics depend on energy which is the primary input source of economy. In recent decades, the global energy consumption is increasing faster than the population. As a consequence the global consumption of primary fuel has grown from 6630 million tons of oil equivalent (Mtoe) in 1980 to almost double 12,002.4 Mtoe in 2010. According to estimate of International Energy Agency, 53% increase in global energy consumption has been predicted for the year 2030 [1]. The consumption of energy is related to 87% fossil fuels which have 33.57% crude oil, 29.62% of coal and 23.81% of natural gas.

In the perspective of energy estimation the share of Renewable energy is 1.32%, Nuclear Energy is 5.22%, and Hydropower is 6.46% which is too small of total energy usage [2]. Nowadays, energy security is an increasingly critical issue because of the depleting of fossil fuel and increasing of demand for energy. Therefore, there is increasing interest in the renewable and new energy resources that could prove key energy sources for the next generation fuel of the world [3].

Biomass differs from the other renewable energy sources in that it can be converted directly into liquid fuels, called “biofuels” to meet the needs of the fuels. There are two common types of biofuels in use today called ethanol and biodiesel. The achievement of biofuels are at the top of agendas in both developing and industrialized countries while the production of world biofuels is expected to rise quadruple in the year 2020. Biodiesel has emerged one of the mutual types of biofuels in the world reports. Biodiesel is biodegradable, renewable and non-toxic that has huge potential to be a part of a sustainable energy [4]. It is the better choice as an alternative fuel because of its capability of reduction of greenhouse gas emissions. In the years 2000 to 2009 the global annual production of biodiesel has

increased from 15,800 barrel per day to 291,000 barrel per day while its consumption has increased from 8.40 thousand barrel per day to 281.63 thousand barrel [5].

1.1.1 Potential of Renewable Energy for Electricity Generation

Electrical energy is an essential component in the developing process of any given location of the globe. Therefore, rural electrification remains an important issue in many countries. More often rural areas, which can also be seen as developing areas, are prone to several electrification problems and a common alternative to this has been for decade the use of diesel power supplies. However, diesel supplies are environmentally not friendly, less reliable and less efficient. A better alternative could be the use of renewable energy sources (such as Biomass and wind) in order to achieve optimum system design in terms of efficient load demand satisfaction [6]. There is continuously rising trend in energy and commodity prices, which motivates that the use of decentralized renewable energies would be even more attractive and competitive solution for the future. All these factors are very relevant specially in Sub-Saharan Africa where 14.3% of the population have access to electricity in rural areas [7]. In particular cases, the use of bioenergy would be extra value addition in rural areas that can stimulate additional income generation if local agricultural products are processed within the region before exporting them. In current situation, agricultural products are mostly processed outside the villages where processing costs are high due to transport, high energy costs and a labor economic scale. The bioenergy resources can boost the local income generation that can further be stimulated by substituting energy that would have been imported from outside the region. The renewable energy resources not only provide electricity but also play significant role in ecological benefits. Although supply of electricity to rural areas in developing countries can substitutes only a comparable small amount of fossil fuels. Considering the future uses of energy the expansion of fossil-based energy seems to be unavailable and also deforestation through over-exploitation of wood and charcoal resources might be reduced considerably. Thus, the electrification of rural areas needs alternate solution and renewable energy resources have got importance which

has compatibility with nature, more friendly to the environment and free from significant pollution effects upon climate protection [6]. Within the fold of the expected changes, renewable system distributed generation have a very significant role to play as shown in Figure 1.1.

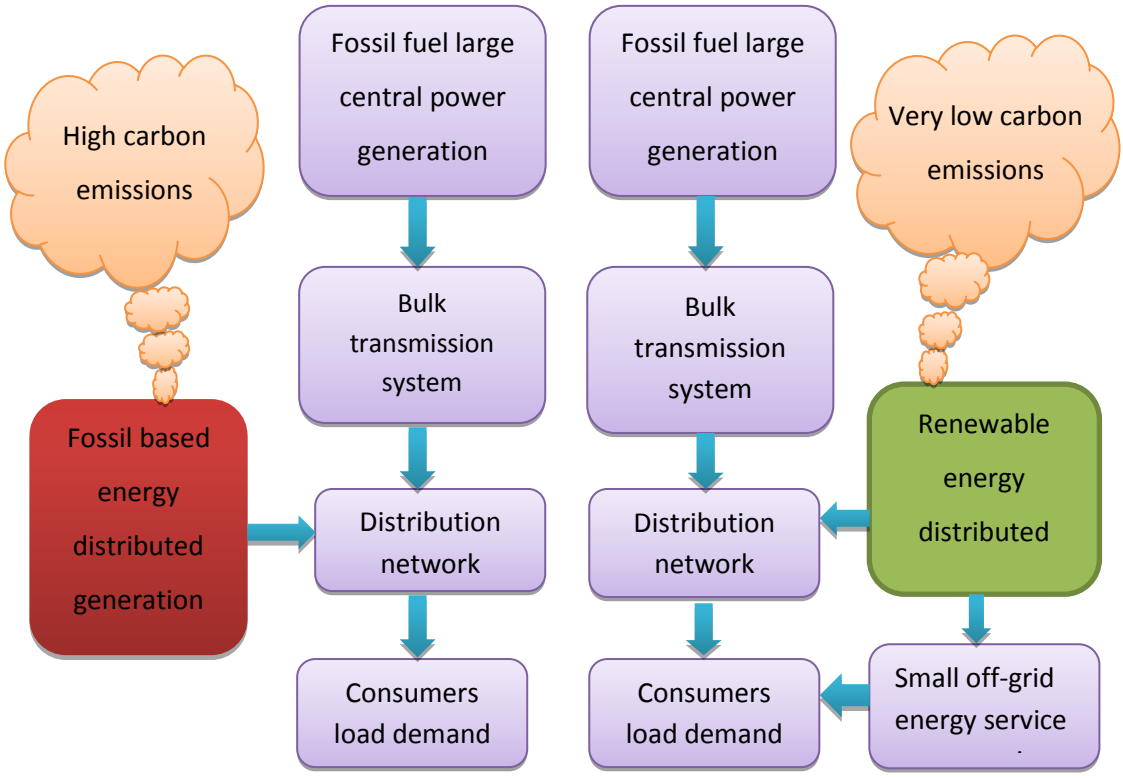

Figure 1.1: Comparison between the present and future electricity supply structure.

1.1.2 Biodiesel as a Potential Renewable Energy Resource

In the recent past decades, the trend for the search of environmental friendly alternative energy resources instead of petrol and its derivatives has been increased. Among these alternative energy resources biodiesel could be produced from different vegetable oils (soybean, rapeseed and sunflower, Jatropha curcas). It has promising scope for several reasons which can replace diesel oil in boilers and internal

combustion engines without major changes. When its whole life-cycle is considered including cultivation, production of oil and conversion to biodiesel, it has small decrease in performances, almost zero emissions of sulfates, a small net contribution of CO2 emission as pollutants as compare to diesel oil.

Considering these facts, many countries have planned to introduce and promote use of biodiesel as alternative energy source. However, there are many uncertainties for real potentialities of biodiesel as a substitute of diesel oil and literature presents its restricted use for specific applications and analysis. Biodiesel is free from any petroleum products but it is adaptable with ordinary diesel. It can make a stable blend with diesel in any ratio in a compression ignition engine. In current scenario biodiesel is one of the mutual types of biofuels in the world [8].

1.2 Statement of the Problem

The increased consumption of energy has emerged a rapid cause of depletion of non-renewable energy source. The global rising trend of price of fossil-based fuels and awareness about the potential shortage in the future has led to major concern about the energy security. Also the increase of fossil fuel energy, has contributed to the greenhouse effect which has produced unbalance in some important gas cycles such as carbon dioxide (CO2) and CH4 level in the air. The exhaust gases from vehicle engines and turbines have caused global warming that has led to increase the temperature of the surface of the Earth. The problem of the electricity generation seems to be severed and should not be underestimated. As per global estimation, nearly 1.5 billion people are still without access to electricity because of insufficient population density and low number of potential customers in rural areas. In economic perspective, lack of public funds and private disposable income, the long distance separating the rural areas from a main electrical grid and the cost necessary to solve such problems. In future, the extension of the central electricity grid would be not cost effective approach and electrification at affordable prices would not be available [7].

The decentralization approach using renewable energy resources and technologies has emerged the most economical option for electrification of remote areas.

1.3 Research Objectives

The general aim of this study is to contribute to the knowledge on the potential sustainability of Jatropha biodiesel as renewable energy source. This study will focus on the following objectives:

i- To review the production process and the applications of Jatropha biodiesel.

ii- To simulate the applications of Jatropha biodiesel in electricity power generation.

iii- To analyze the simulation results of electricity power generation using Jatropha biodiesel and compare them with the results of electricity generation using fossil diesel.

1.4 Scope of the Work

i- A diesel generator will be used to generate power and supply an electrical load for 24 hours a day. HOMER simulation program has been chosen as a tool for the system design.

ii- Three different sources will be used with the diesel generator,

the first source is fossil diesel, the second source is Jatropha biodiesel and the third source is a blend of 10 % of Jatropha biodiesel with 90 % of fossil diesel.

iii- The output results such as the efficiency, the fuel consumption, the capital cost and the emissions characteristics of the three cases will be presented, and compared with each other.

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