The biofuels for sustainable development environmental sciences essay

INTRODUCTION

Background

Natural resources such as coal, petroleum and natural gas cannot be replaced as fast as they are used and it will take them many hundreds or thousands years to form naturally. Ultimately, fossil-based resources become pricey to harvest, forcing humans to shift its reliance to other energy sources. At present, the main energy sourced use is non-renewable fossil fuels. Petroleum and other fossil fuels have been in continual demand ever since the formation of internal combustion engine. And, the continuation at current rate will lead to further global warming and climate change. Global warming and climate change are referred to an increase in average temperature of the earth's oceans and atmosphere and also its projected continued rise. Most climate scientists agree that the main root of all these global warming was initiated by human activities, especially those that increase the concentration of greenhouse gases (particularly carbon dioxide, CO2) in the atmosphere specifically due to deforestation and burning of fossil fuels.

Figure 1.: Global Temperature, 1880 - 2010

During the 20th century, global surface temperature increased by about 0. 74°C. Using computer models of the climate system based on 6 greenhouse gas emission scenarios, the 2007 Fourth Assessment Report by IPCC projected that global surface temperature is likely to rise 1. 1 to 6. 4°C by 2100. The penalty of changing the natural atmospheric greenhouse are hard to predict, but certain effects such as the mother earth becoming warmer, glaciers and ice melting, sea level rising, regular happening of tremendous weathers (droughts, heat waves, hurricane and heavy rainfall) as well as affecting agriculture yields. With the growing concern over the perceived worldwide shortage of oil and increasing cost of oil which affected many sectors of the economy, as well as the increment of global warming and climate change, the concern is to find an alternative source of energy. Renewable resources are natural resources which are able to be reproduced or replenished biologically or through natural processes with time. The use of renewable energy sources such as hydropower, solar, wind, geothermal power, biomass and other natural elements can reduce dependency of oil on one hand, and on the other hand, reducing the emission of sulphur dioxide (SO2) and nitrogen oxide (NO) apart from the reduction of CO2. As such, ethanol production from renewable resources has been receiving great attention. Ethanol produced by starch hydrolysis (liquefaction and saccharification) and sugar fermentation processes from biomass is known as bioethanol, or mainly known as biofuel. It is a renewable resource because it is derived from agricultural crops. Biofuel production is expected to offer a better opportunity to generate income and energy supply, to promote employment in rural areas, to provide long term replacement for fossil fuels as well as to reduce greenhouse gases emissions.

Problem Statement

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9001-Apr-20112. 701. 9005-May-20112. 901. 9016-Jun-20112. 801. 9005-Apr-20122. 901. 90

Table 1.: Prices of petrol from 2009 – 2012 (Tan, 2010)

Figure 1.: Prices of petrol from 2009 – 2012 (Tan, 2010)

The table above clearly shows the petrol prices of RON97 and RON95 in Malaysia starting from May 2009 to May 2012. It shows that the petrol prices were increasing starting from the mid of 2009. This is mainly caused by the dramatic depletion of non-renewable sources worldwide, especially in Malaysia. We are forced to find renewable sources to replace the use of crude oil mainly for the sake of transportation as well as to generation of electricity. The number of cars on the road has been increasing and people have been encouraged to practice car pooling but not many are practicing that. With the frequent increment of petrol prices, it is hard to imagine the living of citizens in the near future. From the environmental point of view, greenhouse gases such as carbon dioxide produced especially from transportation and generation of electricity will absorb and trap the re-radiated energy from the sun. Although there is some uncertainty in the predictions, the general scientific consensus is that the enhanced greenhouse effect is causing a rise in average global temperature which is likely to cause major changes in climate pattern. Consequently, as IPCC predicts, a rise in ocean global temperature of between 1. 1 to 6. 4°C could be expected by the end of 21st century.

Aims and Objectives

To fully understand the current situation of biofuel production in Malaysia. To evaluate the effectiveness and weaknesses of agricultural crops used to produce bioethanol. To compare and conclude the effectiveness of agricultural crops used to produce bioethanol.

LITERATURE REVIEW

Biofuels for Sustainable Development

Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability development is the process of converting natural resources into products and services that are more profitable, productive and useful by involving operational efficiency, minimization of environmental impact and socio-economic considerations, while maintaining or enhancing the quantity, quality, availability and productivity of the remaining natural resource base and the ecological systems on which they depend. It is gradually more apparent that continue reliance on fossil fuel energy resources is unsustainable as it will lead to depletion of world reserves and the increment of greenhouse gas emissions associated with their use. Therefore, vigorous researches have been done aiming at developing alternative renewable and potentially carbon neutral solid, liquid and gaseous biofuels as alternative energy resources. Biofuel is a type of fuel whereby its energy is derived from biological carbon fixation, which is the reduction of inorganic carbon (carbon dioxide, CO_2) to organic compounds by living organisms via photosynthesis as example. Biofuels are gaining increased public attention mainly due to the increased concern over greenhouse gas emissions from fossil fuels and oil price hikes. The production of biofuel can be divided into three generations, namely the first generation, second generation and third generation of biofuel.

First Generation of Biofuel

The first generation of biofuel are those produced from organic matter that can be used for the production of food. They are mainly extracted from food and oil crops. These crops can be further divided into two types: (1) simple sugars: sugarcane, sorghum, sugar beet, whey, and molasses; (2) starches: grains (corn), wheat, and root crops (cassava). Graph showing ethanol production by country in 2005. For more detailed information, see the table below.

Figure 2.: Bioethanol Production by Country, 2005 (From U. S. Department of Energy, 2006)

The production of biofuel from crops was considerably developed as some countries started using this method quite some time ago. Countries such as the United States used corn as the feedstock while Brazil used sugarcane as the feedstock. Based on the Figure 2. 1, both of the countries were still the current largest ethanol producers in the world. In fact, it had been more than 30 years that Brazil produced biofuel on a large scale. Based on the powerhouses such as the United States could be in the forefront in this area, it meant that biofuel was a practical approach and held the key to overcome the shortage of non-renewable fuel (Goldemberg, 2007). Since corn is one of the three principle cereals (i. e., corn, wheat and rice) that supply 50% of the world’s calories, there is increasing apprehension that greater diversion of corn feedstock to meet ethanol demand may contribute to rising food prices and global hunger (Msangi et al., 2007). Increasing reliance on corn as the principle source of bioethanol has also led to additional social and environmental concerns (Food and Agriculture Organization (FAO) United Nations, 2008), suggested the need for additional evaluation for other plant-based bioethanol sources.

Second Generation of Biofuel

Due to the impact of the first generation of biofuel, there are ongoing searches to produce biofuel without using the organic matter which can be converted into food. With current developments, cellulose fibres (found in plant cell walls) may be used to produce ethanol (Inderwildi and King, 2009), which is known as cellulosic ethanol production and it may reduce some of the concerns experienced by first generation of biofuel (Kinver, 2006). According to IEA, cellulosic ethanol could allow bioethanol to participate a much higher role in the future than previously assumed (IEA, 2006). Examples of lignocellulosic materials are sugarcane bagasse, woody materials, straw, grass and etc., and biofuel produced from such materials are known to be second generation biofuel. This generation is considered ideal as the materials would be available in large quantities and their use does not compromise food crops. This method had been given great emphasis in terms of research for the last few decades. The biofuel produced are expected to be superior to many of the first generation of biofuel in terms of energy balances, land use requirement and competition for land, food, fibre and water. The noticeable advantage is the ability to utilize the waste as well but not just a part of it. Unfortunately, the cost of biofuel production from cellulosic materials are relatively high based on current available technologies, about twice as high as that from starchy substrates. Therefore, the main challenges are the low yield and high cost of the hydrolysis materials (Sun and Cheng, 2002) and longer time. Nevertheless, further research and development had to be done before it could be produced on an industrial scale.

Third Generation of Biofuel

The first and second generation of biofuel have their own limitations; hence, the third generation is being introduced to overcome all the limitations experienced. Technically, biofuels can be prepared from just about any plant substance. Algae do not fight with food crops for land as they are grown in either created or natural aquatic environments. They present a yield of roughly 30 times that of conventional feedstock in terms of fuel per acre per year. Algae is an ideal microorganism in recycling carbon from stationary emission sources, especially power plants due to its hunger for CO2, ability to control nitrogen inputs, and its existence in aquatic environment. Algae are proven to be able to absorb 90% of CO2 when gas is piped through algae ponds, very good CO2 fixation ability. Moreover, they can utilize wastewater because they do not need fresh water for growth (Shrank, 2010). To sum up, most of the physical objections towards first and second generation of biofuels – land use, water use, and food security – do not apply to algae. However, further research and investment would be needed in order to bring these fuels into production.

Ethanol

Ethanol, also called ethyl alcohol, pure alcohol, grain alcohol or drinking alcohol is a volatile, flammable and colorless liquid. It is one of the oldest recreational drugs. It was best served as alcoholic beverages in the early years. It is also used in thermometers as solvent and then used as lamp fuel in 1826. It was then used to run automobiles few decades later. There are two different types of ethanol. The first type of ethanol is synthetic ethanol, the petroleum product which is able to be produced by converting ethylene using steam and catalyst. The second type of ethanol is bioethanol, which is produced from the bio-fermentation of sugars. Large incentive is being given to biofuel as to replace the usage of oil at the beginning of this century. Several countries worldwide including countries in Asia such as Japan, India and China are of interest to develop their internal biofuel markets and have established plans to encourage use of these biofuels. Firstly due to the rise of oil prices and recognition that the global oil reserves are draining fast. Secondly, the awareness and concern towards furl emissions. Thirdly, to fulfil the requirements of the Kyoto Protocol and the Bali Action Plan on carbon emissions. Bioethanol is good to replace oil because it is clean as it contains oxygen and it has lower emission of toxic substances especially CO2 buildup in 2 important ways: by displacing the use of fossil fuels and recycling the CO2 that is released when it is combusted as fuel. It is able to reduce carbon emissions by more than 80% in the mean time eliminate the release of acid-rain-causing sulphur dioxide (SO2) entirely (Lashinky and Schwarts, 2006). In 2011, OPEC introduced a bill into Congress that would mandate most cars sold in the US to be warranted to run on ethanol, as well as methanol and gasoline. OPEC is a bipartisan group in the US actively working for passage of H. R. 1687, the " Open Fuel Standard Act of 2011". The OFS Coalition views this legislation as the solution to the current energy crisis by implementing alternative energy sources into our fuel transportation market sector, breaking our dependence on foreign oil. The bill aims to provide enough financial incentive to find better ways to make ethanol fuel so it could compete economically against gasoline. The main reasons for the Open Fuel Standard are as follows (Shackleton, 2011): Save money as it will bring down prices of gasoline at the pump. Healthier as the fumes from burning alcohol and other alternatives are less toxic than the fumes from burning gasoline, considerably less toxic to humans and other living things. Better economy as it will generate jobs in the US. Americans will be building fuel-processing plants, fuel stations, growing raw materials to make alcohol from biomass, growing crops to make ethanol, inventing new kinds of other alternative fuels, and coming up with new ways to make fuel from waste products. Safer as alcohol is less flammable than gasoline (less dangerous). Cooler as alcohol fuels will give out less carbon into the air. Cheap as manufacturing a car with flex-fuel capability adds very little to the price of a car (Woodall, 2010). Cheaper as it does not cost the federal government any money. Environmentally friendly as an alcohol spill would not be a disaster as to oil spill. Alcohol dissolves in water and is readily consumed by bacteria. Within a few days of an Exxon-sized ethanol, the ocean would be back to normal. National security as the fuel competition at the pump will reduce the amount of money going to regimes hostile to America and hostile to their own populations. These regimes are dangerous for the world and their enormous revenues give them power and influence around the world. Democracies would be better off if those regimes did not have their inexhaustible wealth to wield (Korin and Luft, 2011). Freedom as the bill requires 95% of cars to be capable of burning any alternative fuel by 2017, leaving the choice up to the automaker. Cars could be electric, hydrogen, natural gas, bio-diesel or any other non-gasoline alternative and qualify under the Act. Good for everyone as it will have a positive global impact such that when foreign car makers switch to make flex-fuel cars, those same cars will be sold in other parts of the world, spreading fuel choice everywhere (and reducing pollution, reducing environmental damage from oil spills, and reducing carbon in the air everywhere too).

Raw Material for Bioethanol Production

As mentioned previously in section 2. 2, there are three generations of biofuels, leading to three different ways to production of bioethanol.

1st Generation of Bioethanol

Simple sugars (Sugarcane) as Bioethanol Crops

Sugarcane is one the of the world's most important commercial crops as it occupies more than 20 million hectares in which nearly 1, 300 million tonnes were produced in the year 2006 to 2007. C: UsersuserDesktopUntitled. png

Figure 2.: Leading Sugarcane Producing Countries in 2005 (FAO, 2007)

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Figure 2.: Typical Sugarcane Biomass Structure (Seabra, 2008)

Sugarcane is a semi-perennial plant with C4-type photosynthetic cycle, genus Saccharum family Gramineae which consists of perennial tall grass species. The aerial part of the plant is essentially formed by stalks, containing saccharose, and by tips and leaves, which form the sugarcane straw as shown in the figure above. These components altogether sum around 35 tonnes of dry material per hectare. The ideal weather to cultivate sugarcane is one that has two distinct growing seasons, which are the warm and wet season to make possible the sprouting, tilling and vegetative development, followed by a cold and dry season to promote the maturation and the consequent accumulation of saccharose in stems. Therefore, it does not make any sense for the Amazon forest to be used for extensive commercial sugarcane cultivation as sugarcane does not attain good productivity in climates such as those found in wet equatorial regions. For sugarcane, Brazil stands out as the leading producer with a cropland area of around 7 million hectares, representing close to 42% of total production as shown in Figure 2. 2.

1st Generation of Bioethanol

Starches (Corn) as Bioethanol Crops

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Figure 2.: Typical Structure of Corn Biomass (Seabra, 2008)

Similar to sugarcane, corn is a C4 plant from the grass family with annual production cycle. Corn is served as an important food item in several countries as human and animal food. Corn is the main feedstock in US bioethanol production as there are more than 98% of bioethanol produced in the US is from corn. Bioethanol may be produced using corn by means of wet or dry milling. Wet milling was the most common option until the 1990s, although dry milling has become the preferred process nowadays. Wet milling provides a large variety of products. However, improvements have made dry-milling processing the best option considering its lower investment and operation costs that enable substantial cuts in bioethanol final costs (Novozymes, 2002). In temperate zones, corn is planted in the spring because it is a plant that cannot endure cold weather. Corn crops typically involve a crop rotation with some sort of nitrogen-fixing plant (such as alfalfa or soybean). The harvesting is usually performed by a mechanical harvesting machine whereby the ear is separated from the stem and the kernels are extracted from the ear, whereas the straw and corncob are left on the field.

1st Generation of Bioethanol

Starches (Cassava) as Bioethanol Crops

Cassava (Manihot esculenta), sometimes also called manioc, the third-largest source of carbohydrates in the tropics. It is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy, tuberous root (Fauquet and Fargette, 1990). It is largely grown in tropical regions of Africa and Asia. It is a major staple food especially in the developing world, supplying a basic diet for more than 500 million people (FAO, 1995). It provides a large fraction needs for energy-rich materials and generally a significant proportion of the intake of other nutrients as well.

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Figure 2.: Cassava

Cassava has been used as source of starch for decades. Cassava is high in starch content (70-85% dry base or 28-35% wet base) and the starch from cassava is of a high quality compared to other starch sources. Due to the fact of ease of plantation and low input requirement, cassava is mostly cultivated in marginal land by poor farmers and is sometimes named as the crop of the poor. In these planting areas, cassava plays an essential role not only as food security, but also income generation. Being starch-rich roots itself, they are good raw materials for industrial production of commercial tapioca starch with excellent characteristics of high whiteness, odourless and tasteless. It yields high paste viscosity, clarity and stability upon cooking. In short, cassava is very attractive for a broad range of food and non-food application, be it as native or modified form, including paper, textile, pharmaceutical, building materials and adhesives. In each locality where the crop is grown, numerous cassava cultivars exist, with different leaf sizes, plant heights, colours, tuber shape, timing of maturity, overall yields, dry matter contents, starch content, as well as cyanogenic glycoside content of the roots. Roots with irregular shapes are more difficult to harvest and peel leading to greater losses of usable root material. In many countries, significant research has been done to evaluate the use of cassava root as bioethanol feedstock whereby countries such as Thailand, Africa, the People's Republic of China and etc. has been practicing the production of bioethanol using cassava. Under the Development Plan for Renewable Energy in the Eleventh Five-Year Plan in the People's Republic of China, the target is to increase the application of bioethanol by non-grain feedstock to 2 million tonnes by 2010, equivalent to a substitute of 10 million tonnes of petroleum. As a result, cassava has gradually become a major source for bioethanol production. In Thailand, cassava is a cash crop of many farmers and serves as the major raw material for industrialization. Currently, there is a total of 18. 5 million ha of the land devoted for the world cassava production and around 220 million tonnes of fresh roots are annually produced with the average root productivity of 12 tons/ha. By employing the Thai developed practice of yield improvement, the root production can increase by 5 tons/ha for instance, around 90 million tonnes which can be converted cost-effectively to 15, 000 ML of ethanol (Sriroth et al., 2009). With all these regards, cassava is signified as a very important commercial crop that can have the value chain from low-valued farm produces to high-valued, commercialized products.

2nd Generation of Bioethanol

Sugarcane Bagasses as Bioethanol Crops

Sugar Cane Bagasse 01 Crushed-Bagasse

Figure 2.: Sugarcane Bagasse

When producing bioethanol from corn or sugarcane, the raw material constitutes about 40-70% of the production cost (Sendelius, 2005). By using waste products from foresty, agriculture and industry, the costs of the feedstocks may be reduced. Lignocellulosic materials from different crop residues have been used for conversion to bioethanol. One of the major lignocellulosic materials found in great quantities to be considered, especially in tropical countries is sugarcane bagasse (SCB), the fibrous residue obtained after extracting the juice from sugarcane in the sugar production process (Martin et al., 2007). SCB is produced in large quantities by sugar and alcohol industries in Brazil, India, China, Mexico, Indonesia, and Colombia (Cardona et al., 2009). In general, 1 tonne of sugarcane generates

280kg of bagasse and there are 5. 4 x 108 dry tonnes of sugarcane are processed annually throughout the world (Cerqueira et al., 2007). About 50% of this residue is used in distillery plants as a source of energy (Pandey et al., 2000) whereas the remainder is stockpiled. The bioethanol production from SCB include five main steps which are biomass pretreatment, cellulose hydrolysis, fermentation of hexoses, separation and effluent treatment (Cardona et al., 2009). The first main challenge for successful use of SCB as raw material in producing bioethanol is to reduce hydrolysis costs to make SCB a cheaper substrate like molasses and other directly fermentable materials (Cardona et al., 2009). Second challenge is process optimization including detoxification and in situ cellulose enzyme production (Cardona et al., 2009). Third challenge is to maintain a stable performance of the genetically engineered microorganisms in commercial scale fermentation operations (Cardona et al., 2009). The production of genetically modified plant materials with higher carbohydrate content or modified plant structure to facilitate pretreatment in milder conditions are required in future to improve the pretreatment of lignocellulosic feedstocks (Cardona et al., 2009). Therefore, there are still changes needed to be made with all the challenges that need further investigations evethough bioethanol production has been greatly improved by new technologies. A more efficient pretreatment technology for lignocellulosic biomass has to be developed and the optimal component into the economic ethanol production systems needs to be integrated.

3rd Generation of Bioethanol

Microalgae as Bioethanol Crops

Algae fuel is an alternative to fossil fuel that uses algae as its source of natural deposits. Harvested algae, like fossil fuel, release carbon dioxide gas when burnt but unlike fossil fuel, the carbon dioxide gas is taken up by growing algae. Due to the increment of oil prices and competing demands between foods with other biofuel sources as well as rising of world food crisis have ignited people's interest in algaculture (farming algae). 40% lipid fats25% cellulose20% protein/lignin10% starches5% glucose sugars

Figure 2.: Composition of Algae

Algae can be good bioethanol crops mainly because algae have high concentration of lipids which can be converted into biofuel. Commercially, most microalgae are produced in open ponds because it is the least expensive method. Microalgae are microscopic plant that typically grow suspended in water and carry out the same photosynthesis process as higher land plants. It is important to distinguish the differences between micro and macroalgae (which is commonly known as seaweed). Microalgae are tiny, unicellular algae which have many different species with widely varying compositions and live as single cells without any specialization whereas macroalgae are less versatile, multicellular algae which are often seen growing in the ponds. spirulina-under-microscope

Figure 2.: Microalgae

Microalgae are present in all existing earth ecosystem, not just aquatic but also terrestrial, representing a large diversity of species living in a wide range of environmental conditions. It is estimated that more than 50, 000 species exists, but only a limited number have been studied and analyzed (Richmond, 2004). The advantages of using microalgae-derived biofuels are: Microalgae are capable of all year round production; therefore, oil productivity of microalgae cultures exceeds the yield of the best oilseed crops, eg. Biodiesel yield of 12, 000 L/ha for microalgae production (open pond production) compared to 1190 L/ha for rapeseed (Schenk et al., 2008). They grow in aqueous media, but need less water than terrestrial crops therefore reducing the load on freshwater sources (Dismukes et al., 2008). Microalgae can be cultivated in brackish water on non-arable land, and therefore may not incur land-use change, minimising associated environmental impacts (Searchinger et al., 2008), while not compromising the production for food, fodder, and other products derived from crops (Chisti, 2007). Microalgae have a rapid growth potential and many species have oil content in the range of 20-50% dry weight of biomass, the exponential growth rates can double their biomass in periods as short as 2. 5 hour (Chisti, 2007). With respect to air quality maintenance and improvement, microalgae biomass production can affect biofixation of waste CO2 (1 kg of dry algal biomass utilise about 1. 83 kg of CO2) (Chisti, 2007). Nutrients for microalgae cultivation (especially nitrogen and phosphorus) can be obtained from wastewater (Cantrell et al., 2008). Algae cultivation does not require herbicides or pesticides application (Rodolfi et al., 2008). They can also produce valuable co-products such as proteins and residual biomass after oil extraction, which may be used as feed or fertilizer (Spolaore et al., 2006).

Production of Bioethanol

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Figure 2.: Flowchart with the main raw materials and processes used for ethanol production (Mussatto et al., 2006)

The basic steps to production of bioethanol are: Ethanol Fermentation (Alcoholic Fermentation)Ethanol is produced through a biological process whereby sugars such as glucose, fructose and sucrose are converted into cellular energy. This is classified as anaerobic because yeasts perform the conversion in the absence of oxygen. Fermentation of glucose: $C_{12}H_{22}O_{11}$ (sucrose) + H_2O + invertase2($C_6H_{12}O_6$)$C_6H_{12}O_6$ + zymase2(C_2H_5OH) (ethanol) + CO_2Generally, any raw materials that contain sugar are able to produce ethanol. There are two types of microbes which are used to convert the glucose to ethanol, which are Saccharomyces cerevisiae and recombinant bacteria such as Escherichia coli, E. coli, and K. oxytoca. Sacccharomyces cerevisiae are commonly used because it is able to hydrolyze starch to glucose and fructose, whereas recombinant bacteria are able to convert biomass to ethanol, especially cellulosic biomass. Different raw materials will undergo same fermentation process but will have different production method which is shown in the figure above whereby sugar crops need a milling process for the extraction of sugars to fermentation only (not requiring any step of hydrolysis), becoming a relatively simple process of sugar transformation into bioethanol (Mussatto et. al., 2006). In this process, bioethanol can be fermented directly from cane juice or beet juice or from molasses generally obtained as a by-product after the extraction of sugar. Some crops require saccharification before fermentation such as starch from grains like corn. In this step, starch is gelatinized by cooking and submitted to enzymatic hydrolysis to form glucose monomers, which can be fermented by microorganisms. Ethanol production from grains involves milling and hydrolysis of starch that has to be wholly broken down to glucose by combination of two enzymes (α-amylase and amyloglucosidase) before it is fermented by yeast as yeast cannot use starch directly for ethanol production. For lignocellulosic materials, they involve technologies that are more complex and ethanol production costs are higher when compared to cane, beet or corn. However, most of lignocellulosic materials are byproducts of agricultural activities and industrial residues and show great potential for production of fuel ethanol at large scale and a worldwide consumption as a renewable fuel (Solange et. al., 2010). The basic process steps in producing bioethanol from lignocellulosic biomass are: (1) pre-treatment to render cellulose and hemicelluloses more accessible to the subsequent steps. Pre-treatment involves a mechanical step to reduce the particle size and a chemical pre-treatment (diluted acid, alkaline, solvent extraction, steam explosion among others) to make the biomass more digestible; (2) acid or enzymatic hydrolysis to break down polysaccharide to simple sugars; (3) fermentation of the sugars (hexoses and pentoses) to ethanol using microorganisms; (4) separating and concentrating the bio-ethanol produced by distillation-rectification-dehydration as shown above (Cardona and Sánchez, 2007). DistillationIn order for the ethanol to be usable as fuel, distillation will be carried out as to separate the unwanted compound from ethanol whereby most of the water is removed during distillation. The purity is limited to 95-96% due to the formation of a low-boiling water-ethanol azeotrope with maximum 96. 5% v/v ethanol and 3. 5% v/v water, which is known as hydrous ethanol and can be used as a fuel alone, unlike anhydrous ethanol (not miscible in all ratios with gasoline). Therefore, in anhydrous ethanol, water fraction is typically removed in further treatment in order to burn in combination with gasoline in gasoline engines (Filho, 2008).

Dehydration (requirements vary)It is then followed by dehydration to further eliminate water. Many methods have been proposed that avoid distillation altogether for dehydration with increasing attention being paid to saving energy. Of all the methods, one method has emerged and has been adopted by the majority of modern ethanol plants which uses molecular sieves to remove water from bioethanol. In this process, ethanol vapor under pressure passes through a bed of molecular sieve beads. The bead’s pores are sized to allow absorption of water while excluding ethanol. The bed is then regenerated under vacuum or in the flow of inert atmosphere after a period of time to remove the absorbed water. Often, two beds are used so that one is available to absorb water while the other is being regenerated. This latest technology can account for energy saving of 840kJ/L compared to azeotropic distillation which was used in the earlier days (Madson and Monceaux, 2003).

Advantages and Disadvantages of using Bioethanol

The development of bioethanol are actually holding great promise for developing countries like ours, Malaysia where majority of the population often lives in rural areas and subsidies on agriculture. There are two main environmental benefits of replacing fossil fuels with bioethanol. First and main benefit of using bioethanol is that it is mainly renewable. It offers the potential for long term, relatively cheap, secure energy supplies. Secondly, bioethanol mostly contribute to significantly less GHGs emissions in the production and use compared to oil or natural gas, leading to a less carbon-intensive economy, preventing climate change and providing us the potential to maintain the current transport infrastructure well for the future generation. http://soilcarboncenter. k-state. edu/originals/Renewable_Energy_files/image003. jpg

Figure 2.: Carbon Cycle & Solar Energy Conversion

Bioethanol is completely biodegradable. As shown in figure, carbon dioxide (CO_2) will be produced when bioethanol is burnt for transportation; CO_2 will be utilized by the crops for photosynthesis repeating the cycle over and over again unlike petroleum whereby CO_2 will be trapped in the atmosphere, causing global warming. Besides, usage of bioethanol can decrease the dependency on costly fossil fuel, improving the economic in our country. In Pakistan, biofuels are used to control the soil erosion in the fertile plans. Hoogwijk (2003) argues that biomass influences the humus content of the soil and reduces erosion, thus increases the biomass production, improving soil quality of agricultural land. Another advantage that Pakistan can have while developing biofuels industry is that it will create more jobs for people from growing raw materials to their manufacture, reducing the unemployment rate (Javed and Zaman, 2010). The UN report describe it as " As biofuels absorb crop surpluses in developing countries, commodity prices will rise, increasing income for farmers in poor countries", leading to a more economically sustainable agriculture and prices in most developing countries, encouraging local production and allowing farmers to live from production (Europa Bio Fact Sheet, 2008). However, there are several disadvantages in the biofuels industry. Due to the use of agricultural products as bioethanol, the demand of agricultural products will become high and supply will be remaining the same, increasing the price of commodities. In the short term, the main consequence will be increment of food prices whereby leading to food shortages in the long run. In short, growing crops to produce bioethanol will reduce the amount of arable land available for food and feed crops. And as a reminder, bioethanol has 67% of energy content of petrol only. Anyhow, changes are needed by not depending much on fossil fuels as the supply will be run out someday.

METHODOLOGY

Introduction

The purpose of this chapter is to obtain a comprehensive analysis based on the data collected related to the aim and objectives of this research. Research in common parlance refers to a search for knowledge. The Advanced Learner’s Dictionary of Current English (1952) lays down the meaning of research as " a careful investigation or inquiry especially through search for new facts in any branch of knowledge". Redman and Mory (1923) define research as a " systemized effort to gain new knowledge". Research is a process by which researchers extend their knowledge and possibly that of the whole community (Sharp et al., 2002), research is not the presentation of one’s own opinions, but it demands showing facts, data and information (Vyhmeister, 2008). Therefore, research can be concluded as a careful investigation to collecting facts, data and information regarding a particular issue to reach a better understanding for a new branch of knowledge. Research method is defined as the way in which the research objectives can be questioned. It can be classified into two distinct types which are the quantitative research and qualitative research (Richardson et al., 2005). In quantitative research, information obtained from respondents is expressed in numerical pattern. Researchers who are using a quantitative approach rely on structured observation, experiments and survey research because this method usually focuses on a limited number of predefined variables that generate primary data (Krysik and Finn, 2010). In qualitative research, the information obtained from respondents is not expressed in numerical form. The main sources of data for qualitative research are unstructured observation and in-depth interviews, and the questions used in qualitative research do not ask participants to select from a number of predefined responses (Krysik and Finn, 2010).

Data Collection

There are mainly two sources of data, which are primary data and secondary data. Primary data is done through primary research, accomplished through various methods including questionnaires and telephone interviews in market research or experiments and direct observations in the physical sciences, amongst others. The advantages of primary research are that it enables marketer to focus on specific subjects and have a higher control over how the information is collected. Taking this into account, researchers can decide on such requirements as size of project, time frame and goal. However, it may be very expensive in preparing and carrying out the research. It is also time consuming and may be out of date by the time the research is complete. As in the case of secondary data, the data is collected by someone other than the user. Common sources include censuses, organisational records and data collected through qualitative methodologies or qualitative research. Secondary data saves time that would otherwise be spent collecting data and particularly in the case of quantitative data, provides longer and higher quality databases that would be unfeasible for any individual researcher to collect on their own. However, the disadvantage is that the information may not meet specific needs (Joop, 2005). It is advisable for researchers to go for secondary data before investing any primary research because some secondary data itself may be sufficient to provide information and solutions in some cases. In this research study, the main research technique is focused on secondary research by searching relevant information on the topics of interest that has been actively carried out globally throughout United State of America, Brazil and South East Asia regions. These included the study of relevant articles, journals, reference books, internet resources and others for the purpose of exploring the existing information and issues in the case of interest.

Literature Review

A literature review discusses published information in a particular subject area and sometimes information in a particular subject area within a certain period of time. This study provides a review of relevant literature on types of agricultural crops used in different countries to produce bioethanol and their effectiveness. A systematic literature review was conducted to cover textbooks, academic journals, and sources from internet. These reviews are very important because they provide a handy guide to a particular topic, presenting the latest development in that field. Besides, reviews also provide a background to the study being proposed. In the past, the first generation of biofuel is very useful, but more issues have been discovered due to the enormous production. The second generation of biofuel has been produced but not being practised in large scale manner due to the expensive production cost. Therefore, the third generation of biofuel has been developed to solve the existing problems. Technologies developed in the past somehow provide useful information which will be useful in the current situation, upon which the future trend of the field can be predicted. In a broader context, the purposes of a review are (Hart, 1998): To distinguish what has been done from what needs to be doneTo discover important variables relevant to the topicTo synthesis and gain a new perspectiveTo identify relationships between ideas and practiceTo establish the context of the topic or problem

Case Studies

A case study which is also known as a case report is an intensive analysis of an individual unit stressing developmental factors in relation to the context (Flyvbjerg, 2011). Case studies are analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods (Thomas, 2011). One of the reasons why case study is recognized as a research method is that researchers were getting more concerned about the limitations of quantitative methods in providing holistic and in-depth explanations of the social and behavioural problems in question. A researcher is able to go beyond the quantitative statistical results through case study methods and understand the behavioural conditions through the actor’s perspective. It can help to explain the process and outcome of a phenomenon by including both quantitative and qualitative data through complete observation, reconstruction and analysis of the cases under investigation (Tellis, 1997). Case studies are considered useful in research as they enable researchers to examine data at the micro level and to organise a wide range of information about a case and then to analyze the contents by seeking patterns and themes in the data and by further analysis through cross comparison with other cases (Maheshwari, 2011). As an alternative to quantitative or qualitative research, case studies can be a practical solution when a big sample population is difficult to be obtained (Maheshwari, 2011).

Data Analysis and Interpretation

In this research, qualitative research was adopted by using the literature reviews and case study to collect sufficient data due to the consideration of time constrain. And they are all summarised accordingly. The database will consist of texts, scientific articles and documents as previously stated. The core idea of this research is to transform the gathered information into meaningful and useful conclusions. The data are all analysed, the advantages and disadvantages of every agricultural crops to production of bioethanol with the current advancement of technologies are all identified and evaluated. Evaluation is the systematic acquisition and assessment of information to provide useful feedback about some objects, which in turn help in decision making (Babbie, 2007). Recommendations or suggestions are all provided by then.

Approaches

In order to find the most appropriate agricultural crops in Malaysia, it is very important to understand bioethanol production technologies in terms of:

Economic viabilityEconomic viability is the ability to maintain operation on the basis of current and projected revenues in equal or in excess of current and planned expenditures such as an agricultural crop that can support itself financially. Capability of developing and surviving as a relatively independent social, economic or political unit whereby the agricultural crops that increases in output produced by using the least cost method will be used and further evaluated. Agricultural crop that is able to produce a high amount of energy means that there will be a high economical value, hence, will most probably be chosen. Environmental feasibilityIn environmental feasibility, studies will be carried out aiming to objectively and rationally uncover the strengths and weakness of existing agricultural crops to bioethanol production in the environmental aspects such as the crops to bioethanol production with the lowest pollutant most probably would be used. Ability to empower employment opportunitiesAbility to empower employment opportunities are the ability to create employment opportunities to the society, lowering the unemployment rate. It might be a cash crop for farmers or provides people the opportunities to have extra income.

Overall Research Layout

Research Layout

Figure 3.: Overall Research Layout

DISCUSSION

Agricultural Crops in Malaysia

Malaysia is the 67th largest country by total land area, with a land area of 329, 847 km2 whereby the agriculture makes up 12% of the nation’s GDP. 16% of Malaysia’s population is employed through some sort of agriculture.

The climate of Malaysia produces the proper conditions for production of exotic produce. The weather stays hot and humid all year round. Figure below shows the agricultural crops produced in Malaysia from year 2006 to 2010. C: UsersuserDesktopUntitled. png

Figure 4.: Listed Area (Ha) and Productions (MT) of Agricultural Crops in Malaysia from 2006-2010

The figure which is in Bahasa Malaysia is translated into English as shown in the table below. Types of Crops200820092010Area (Ha)Productions (MT)Area (Ha)Productions (MT)Area (Ha)Productions (MT)Corn6, 31532, 9597, 17636, 3968, 60047, 602Cassava2, 31635, 2093, 07568, 5082, 76937, 187Sweet Potatoes1, 30918, 2281, 30913, 4952, 16423, 054Sugarcane98716, 4141, 50239, 2192, 21644, 780

Table 4.: Listed Area (Ha) and Productions (MT) of Agricultural Crops in Malaysia from 2008-2010

It is shown that the production of corn is the highest, followed by sugarcane and cassava and then sweet potatoes. The best choice for production of bioethanol is further discussed in the following sections.

Economic Viability

The ability of agricultural crops that produces the most output with the least cost method will highly be considered and used. Agricultural crops such as corn, sugarcane and cassava will be discussed in details in the following sections to determine the most economic crops for bioethanol productions.

Sugarcane vs. Corn (Maize)

Since that sugarcane-based bioethanol production is the highest productive and needs an easier processing among the agricultural crops that have already been used for bioethanol productions, it therefore provides the lowest production costs (Biofuels Platform, 2010). Bioethanol from corn and other feed stocks requires considerable amount of " external" energy for production, whereby most of it comes from fossil fuels which reduces only marginally GHGs emissions compared to sugarcane. Whereas for bioethanol production from sugarcane, it is of a lower cost and competitive with gasoline through gains in productivity and economies of scale (Goldemberg, 2007); the cost of bioethanol from corn would cost almost twice and from wheat, sugar beets, sorghum four times (Worldwatch Institute, 2006). Besides, IEA estimates that with integrated sugarcane to bioethanol technology, the well-to-wheels CO2 emissions can be 90% lower than conventional gasoline (IEA, 2007). C: UsersuserDesktopUntitled. png

Figure 4.: Simplified Flowsheet of Bioethanol Production from Sugarcane (Quintero et al., 2006)

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Figure 4.: Simplified Flowsheet of Bioethanol Production from Corn (Quintero et al., 2006)

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Figure 4.: Ethanol yields and total capital and operating costs for fuel ethanol production from Corn and Sugarcane (Quintero et al., 2006)

As shown in the table above, the calculated bioethanol yield from corn (in terms of produced bioethanol per tonne of feedstock entering the plant) is greater than that from sugarcane because of the higher amount of fermentable sugars (glucose) that may be released from the original starchy material. However, the annual ethanol yield from each hectare of cultivated corn is 23. 6% lower than that for sugarcane which preliminary shows that the comparative advantage of using sugarcane as feedstock for bioethanol production under high-productivity conditions for cane cropping in Colombia (Quintero et al., 2006). Therefore the advantages of sugarcane-based bioethanol are very apparent especially after comparing to corn-based bioethanol. Comparative advantages of sugarcane over corn for production of bioethanol: Sugarcane is able to produce much more energy compared to corn in terms of pound for pound because it is easier to produce sugarcane-based bioethanol as corn requires additional enzymes for production, adding more steps and costs to the process. It is tough to determine the amount of corn available from year to year, especially for individual corn-based bioethanol plants as corn is often grown over varying conditions. Amount of sugarcane available for bioethanol production is much more predictable as it remains stable year after year, eliminating the needs of producers to worry for not being able to meet the contractual obligations. Sugarcane weathers the storm a little better as compared to corn as pests, droughts, floods or even high winds can all wreak havoc on corn. There is only one harvest per planting cycle for corn as it is planted every year, usually in the spring and then harvested in the fall whereas sugarcane in some cases, up to seven harvests before planting is needed. The summary above simply shows that it is definitely more energy and cost efficient to produce ethanol from sugarcane as compared to corn. But, there is one drawback to usage of sugarcane for bioethanol production, which is that sugarcane is the main source of sugar production in Malaysia. Using sugarcane to produce bioethanol might lead to the price increase of sugar in Malaysia, causing a negative economic feedback.

Cassava vs. Other Traditional Crops:

Cassava can be grown and harvested throughout the year resulting in a constant supply of cassava to the bioethanol production facility in contrast to more seasonal crops (Kuiper et al., 2007). Cassava can be grown on infertile land where cultivation of other crops is difficult (i. e. not enough for the cultivation of sugarcane), still leading to a reasonable yield (Kuiper et al., 2007). Bioethanol yield from cassava is the highest among all main bioethanol crops (up to 6 tonnes/ha) under optimal conditions (Kuiper et al., 2007). Cassava bioethanol production plant requires less complex processing equipment, leading to lower investments (Kuiper et al., 2007). Waste stream of cassava bioethanol production can be used for the production of biogas (Kuiper et al., 2007). Due to its high availability, its large potential to optimize yields as well as its integration in small scale communities, bioethanol can be produced in a viable way using cassava. Besides, cassava's potential in producing bioethanol is further enhanced due to its beneficial export conditions and relatively low production costs. The costs of cassava bioethanol are summarized as below: Cassava cultivation including land preparation, planting, crop maintenance (fertilization and weed control) and harvesting (Kuiper et al., 2007). Cassava processing into dried chips (Kuiper et al., 2007). Ethanol conversion, milling, mixing and liquefaction, saccharification and fermentation, and distillation and dehydration (Kuiper et al., 2007). C: UsersuserDesktopUntitled. png

Figure 4.: Flowchart of Cassava Ethanol Production (Nguyen et al., 2006)

Overall Economic Evaluation of Agricultural Crops

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Figure 4.: Bioethanol Production Costs, both Calculated and Market Reported (Kuiper et al., 2007)

According to the figure above, it clearly shows that the bioethanol production from corn and sugarcane can be produced at lower costs than cassava but it somehow has a favourable pricing position in comparison with wheat and sugar beet. However, there are several options that slightly improve the economics of bioethanol production from cassava: The ethanol conversion from cassava produces a sludge residue, making it a good soil conditioner in principle whereby it could be sold to cassava farmers. However, there implies a small additional costs to the distillery as it is necessary to dewater the sludge before realizing this option (Kuiper et al., 2007). Besides, we could use cheaper rice husk for heat and electricity generation for the distillery instead of fuel oil (Kuiper et al., 2007). With these options, it is possible to reduce the bioethanol production costs of cassava by at least 10%. Beside these, energy conservation and good practices of steam production while producing cassava-based bioethanol including regular monitoring of combustion efficiency, insulation of steam equipments and pipelines, condensate recovery, as well as controling quality of feedwater entering boiler can improve the energy efficiency making it more economic practically. Lastly, technical knowledge about cassava-based bioethanol production such as Simultaneous and Fermentation (SSF) and water-waste-water management need to be encouraged for industrial application (Silalertruksa and Gheewala, 2009).

Environmental Feasibility

Environmental evaluations of traditional agricultural crops for bioethanol productions are very important besides the economic viability. No matter what agricultural crop is being used, the following ecological aspects have to be considered thoroughly to assess the sustainability of bioethanol production. Ecological Criteria: Carbon storage: Carbon losses can be caused by conversion of high carbon storage age land such as forest into bioethanol plantations (Kuiper et al., 2007). Biodiversity: Biodiversity losses can be caused by conversion of high carbon storage land into bioethanol plantations (Kuiper et al., 2007). Soil quality: Soil quality of bioethanol plantations may decrease; in the case that no measures are taken to prevent erosion, an excess application of pesticides and fertilizers and decrease of soil fertility due to an excessive export of nutrients, especially potassium in the case of cassava (Kuiper et al., 2007). Water use: Water quality in the production regions might deteriorate in the case of an overuse of pesticides and fertilizers. A sustainable water use has to take the natural ground water level regeneration rates into account (Kuiper et al., 2007). Air quality: Air quality in the production regions might deteriorate as well in the case of burning of residues or the use of fires to burn forests with the aim of setting up new bioethanol plantations (Kuiper et al., 2007).

Environmental Evaluation of Sugarcane and Corn

The total output rate of environmental impact for processes examined in bioethanol production, which is the potential environmental impact (PEI) is generated within the system for both sugarcane and corn as shown in the figures below: C: UsersuserDesktopUntitled. png

Figure 4.: Total Output Rate of Environmental Impact for the Studied Processes (as PEI leaving the system per mass of product streams) (Quintero et al., 2006)

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Figure 4.: Potential Environmental Impact (PEI) Generated within the Studied Processes (per mass of product streams) (Quintero et al., 2006)

The two figures above have clearly shows that sugarcane-based bioethanol production has lower impact on the environmental as compared to the corn-based bioethanol production as the latter process exhibits a higher PEI per mass of products. The corn-based process has a more negative generated PEI, indicating that the PEI of the substances entering the system is reduced by their transformation into other less dangerous compounds; whereas for the sugarcane-based process, the higher value of generated PEI (although negative) indicates that the conversion of entering substances also occurs, but to a lesser degree, showing that this process requires the input of a greater amount of feedstock (Quintero et al., 2006). The improved environmental performance of the sugarcane-based process can be explained by the operation of the co-generation unit (in terms of the PEI leaving the system per mass of products) whereby one of the process by-products (sugarcane bagasse) is utilized as a renewable fuel in order to generate all thermal and mechanical energy required by the process; whereas for the corn-based process, energy demand would be supplied by fossil fuels whose combustion generates atmospheric emissions, leaving to a direct influence on most of the impact categories, especially on ATP and AP as shown in Figure 4. 6 (Quintero et al., 2006). When sugarcane bagasse is burned, the negative effect of carbon dioxide (CO2) released onto the atmosphere during its combustion is compensated positively bt the CO2 fixed from the atmosphere during sugarcane growth, showing that the utilization of sugarcane bagasse as fuel does not necessarily imply a net increase of CO2 in the atmosphere. The conclusion is, the sugarcane-based process is more likely to exhibit a better environmental evaluation compared to the corn-based process (Quintero et al., 2006).

Environmental Evaluation of Cassava

The production of bioethanol from cassava consists of four main sub-processes, which are milling, mixing and liquefaction, fermentation, distillation and molecular sieve dehydration, whereby the environmental impacts would be related to several aspects such as emissions from combustion of fuel in industrial boilers for steam production and emissions from electric power used in the plant. C: UsersuserDesktopUntitled. png

Figure 4.: Life Cycle Impact Assessment results from Productions of 1000L of Cassava-based Bioethanol (Silalertruksa and Gheewala, 2009)

As shown in the figure above, the conversion stage of cassava contributes to the heaviest environmental burdens in the system. Emissions of CO2, SOx, NOx, CO and particulates from steam boiler using sub-bituminous coal in the ethanol plant contribute to about 52%, 48%, 51% and 43% to global warming, photochemical oxidation, acidification and human toxicity impacts, respectively. Besides these, the indirect emissions due to grid electricity production and coal extraction are also added in this stage making it the crucial source of environmental problems. However, the main stems to environmental impacts are two major sources, the fertilizers use in cassava cultivation and wastewater discharged from the Upflow Anaerobic Sludge Blanket (UASB) system are the eutrophication potentials; they are collected in wastewater ponds inside the plant (Silalertruksa and Gheewala, 2009). In order to use cassava as feedstock for bioethanol production, several options can be done to improve the environmental performance, such as: Improve the soil quality by using organic fertilizers or animal waste to reduce chemical fertilizers consumption for increasing the feedstock productivity without reducing the land use impact for long-term sustainability of bioethanol feedstock. Manure application is valuable for improving soil physical, chemical and biological properties, improving water infiltration, reducing runoff and erosion. Usage of organic fertilizers does not only gives soil quality benefits but also will reduce the eutrophication impact during the feedstock production stage originating mainly from the use of chemical fertilizers.(Wortmann et al., 2008)Reduce emissions of air such as CH4, CO and NOx from agricultural activities, which will be caused for sugarcane-based bioethanol production due to sugarcane trash burning during harvesting, contributing to global warming, photochemical oxidation, acidification, and etc (Silalertruksa and Gheewala, 2009). Enhance waste management efficiency of bioethanol producers and create a value-added to the environment by promoting waste recycling such as biogas recovery, organic fertilizers productions and dry distiller grains (DDG) or dry distiller grains with soluble (DDGS) production (Silalertruksa and Gheewala, 2009). Promote utilization of renewable fuel in ethanol conversion can help to reduce the GHG emissions while improving renewability as ethanol conversion stage is the heaviest energy consumer over the life cycle (Silalertruksa and Gheewala, 2009).

Overall Environmental Evaluation of Agricultural Crops

Sugarcane-based bioethanol production would provide a lower environmental impact as compared to corn-based bioethanol production. Nevertheless, cassava-based bioethanol production would provide an even better environmental concerns despite the fact that sugarcane bagasse would counter-affect the negative impacts of sugarcane trash burning during harvesting. Several economics and environmental friendly options can be done for cassava-based bioethanol productions, making cassava a better choice for bioethanol productions as compared to sugarcane and corn.

Employment Empowerment Ability

Renewable energy production using agricultural crops by cultivation in set aside areas or in even larger available marginal areas worldwide has a large positive impact on rural development such as creation of new jobs and supplementary incomes. However, these kinds of bioethanol productions are essentially produced from food. Especially if corn is used as the agricultural crops for bioethanol production, it has attracted criticism due to increment of food prices and global food shortage. Therefore, the main focus falls on sugarcane and cassava because even though they are food crops, but they hardly affect the food productions. As mentioned in section 4. 1. 1, sugarcane in some cases can be harvested up to seven times before another planting is needed. This is especially good seeing from the economic point of view as it lowers the needs of labour hence lowering production costs. But it does not improve the employment rate at all. In the case of cassava which was mentioned earlier in section 4. 1. 2, it can be grown and harvested throughout the year leading to a constant supply of bioethanol production. The highlight of cassava is that it can be grown on infertile land where cultivation of other crops is difficult, especially for sugarcane. Cassava besides being more economically viable than sugarcane, it can also become a cash crop for many people especially for those working in the farm. And thus, lowering the unemployment rate as well as providing a better positive impact for those living in the rural areas.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Bioethanol production has experienced unseen levels of attention due to its value as a fuel alternative to gasoline, the increase of oil prices, and the climatic changes, besides being a renewable and sustainable energy source, efficient and safe to the environment. It is important to emphasize that, to be a viable alternative, bioethanol must present a high net energy gain, have ecological benefits, be economically competitive and able to be produced in large scales without affecting the food provision. In conclusion, cassava would definitely be the best choice as an agricultural crop for bioethanol production. As discussed in Chapter 4, corn will not be a suitable agricultural crop for bioethanol production. First, it is to prevent the increment of food prices and the shortage of food. Secondly, corn-based bioethanol processes have a greater environmental impact mostly due to the utilization of fossil fuels to produce thermal and electric energy required during grain conversion. Therefore, the focus falls on both sugarcane and cassava for bioethanol production. They have been compared critically from economic, environmental and social point of view. It has clearly shown that cassava provides more advantages after being compared with sugarcane and they are as summarized below: Economically: Cassava can be grown on infertile land where cultivation of sugarcane is not enough. Bioethanol yield form cassava is better than sugarcane under optimal conditions. Cassava, as a starch root requires less complex processing equipment compared to sugarcane. Waste stream of cassava bioethanol production can be used for production of biogas. Cassava is in a more beneficial export conditions compared to sugarcane and has a low production costs. Ethanol conversion from cassava produces a sludge residue which is a good soil conditioner whereby it can be sold to cassava farmers. Environmentally: The only and most important reason why cassava-based bioethanol production can be better than sugarcane-based bioethanol production is that it does not produce as much emissions of air such as CH4, CO and NOx. These emissions will be caused for sugarcane-based bioethanol production due to sugarcane trash burning during harvesting, leading to global warming, photochemical oxidation, acidification, and etc. We can further improve the environmental performance of cassava-based bioethanol production as per discussed in Chapter 4, section 4. 3. 2. Employment Empowerment Ability: Cassava can be grown on infertile land which can become a cash crop for many people especially for those working in a farm, and thus lowering the unemployment rate.

Recommendations

Fostering scientific and technological development is a key element in the bioethanol production chain, critical to ensure the use of environmentally friendly and high efficient raw materials. In order to develop a market and infrastructure for cassava, several aspects need to be further addressed. Firstly, increase stable cassava yields by using high yielding root materials and optimizing harvesting methods to make larger volumes of additional cassava available. Secondly, further explore the possibilities of cassava, especially the waste, conversion into other materials which can be beneficial to both the society and the environment. Improved waste treatment and utilization is significant in order to minimize the overall production cost of cassava-based bioethanol. With those development, the use of cassava as energy crop raises more concerns for food and duel security. With a combination of zero-waste process concept, effective policies and market mechanism, the use of cassava as food crop, industrial crop and energy crop become sustainable and beneficial to mankind.