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Master's Thesis

COMPARING THE ALTERNATIVE UTILIZATION METHOD FOR COCONUT IN NZEMA, GHANA

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ABSTRACT

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Comparing the best utilization method for coconut in Nzema, Ghana

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There are many opportunities to utilise coconut in Nzema to support farmers. Coconut oil that is mainly used for food preparation in Nzema can be utilized as fuel to support overcoming of the energy crisis in the Ghana. Coconut oil in Nzema is not used in both transportation and electricity generation. A few of the waste husk and shell are mainly used as fuel in homes for heating but greater amount is left to rot or burn the coconut plantation. In addition, some portion of the granulated coconut kernel is sometime used as feed for piggery feed and the rest of the granulated kernel are left as waste on the oil processing site.

In this thesis, the author identified alternative utilization of cocoanut, for instance the use of coconut husk and shell for charcoal production, and the use of coconut trunks as construction materials. It is envisaged that exploring these alternatives will not only reduce carbon emission in the country but will also contribute significantly to the sustainability of the local agro-industry.

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Dedication

To my father Mr James Armah and my late mother Mrs Doris Tayi, my wife Regina Armah Nredah and sons: Stephen Armah Nredah and Daniel Armah Nredah

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1 INTRODUCTION

The goal of this thesis is to increase the awareness of the possibilities of utilizing coconut to produce energy in Nzema, Ghana. The native people in this area have been planting this cash crop for hundreds of years. Coconut has been the primary source of livelihood for the natives of Nzema. They grow coconut palm for oil and also transport coconut and its products (e.g. oil) to major cities for sale.

Nowadays, coconut farmers are turning their farmland to rubber plantation and the rubber plantation is taking the fertile lands used for food crops. The drift towards rubber plantation is partly fuelled by the initial bulk sum of money (which superficially appears to be enough), that a rubber company in the region gives to the coconut farmers to motivate them to plant rubber trees. Meanwhile, this assumed huge initial money is given in Ghanaian cedis and later all rubber production tools and equipment are bought in American dollars because the Ghana cedis is not stable. For these above reasons, this thesis is to increase the awareness and review the possible uses of coconut oil and its other biomass to generate energy to increase the profitability of coconut to the farmers.

There are many ways of utilising coconut oil as an energy fuel. The coconut oil can be combined or blended with diesel fuel to be used in automobile engine. (A. M. Liaquat, 2013). In certain conditions, it can be used as a replacement for diesel fuel. Coconut oil in Nzema is mainly used for food (A. Osei-Bonsu et al 2009). For example, the oil is used to fry food and the used oil is disposed of. Husk (the fibrous cover around the shell) and other biomass from the coconut are mainly used as firewood for heating. According to the natives coconut farmers interviewed, different vegetable cooking oils are imported into Nzema. These vegetable oils are competing with the coconut oil because consumer feels it is better than traditionally made coconut oil. This is one of the reasons farmers have lost interest in coconut plantation. With the increasing price of conventional fuel for example diesel and petrol, production of biodiesel from coconut oil could be a good alternative to increase the social, economic and environmental sustainability in the area.

More importantly, rural access to electrification in some part of Nzema is a challenging goal for the ministry of energy and petroleum in Ghana and this can be solved by utilizing coconut oil as a fuel for electrification (A. Demirbas 2001). With technological

advancement nowadays, many power generators have the possibilities to use straight vegetable oil as a fuel. Moreover, the biomass from coconut waste can be gasified to produce synthetic gas (J. Kopyscinski et al 2010) that is itself a fuel. Gasification of coconut biomass such as husk, which is mainly in the farms, can be a feedstock for gasification to produce electricity in some part of Nzema.

1.1 Background

Cocos nucifera is the botanical name of coconut. It is important that coconut provides oil, serve as food, and drink in each community. The oil extracted from the coconut kernel can be used in the manufacture of biodiesel through esterification; as pure vegetable oil for running engines; as a blend with diesel, soap making and for cooking. The husk and the shell are used for fuel and charcoal. The coir (mesocarp) is used for doormat, brushes and ropes. In some region, trunk provides an excellent wood for building trusses and furniture (Arancon R. N. 1997).

According to Global Environment Facility small grants programme conducted on effective management of coconut waste for bio-gas production and organic fertilizer in Nzema, Nzema districts owns about 80% of Ghana´s coconut crop. The people in the area are experts in using the kernel from the nut for oil production. About 114,600 households are involved in coconut plantation and oil production in Ghana as in table 1 below. The total household was generated from three ecological zones that are notable for producing coconut, which are the forest zone, coastal zone and the savannah. The result shows that, the coastal and the forest zones have the highest number of household in coconut production. These two zones are in the western region and Nzema is the largest area notable for coconut production. The annual income for the coconut farmers and oil producer is about 17.7 million Ghana Cedis. However, the major portion of the plantation is along the coastal ecological zone of the Gulf of Guinea. The table 1 below defines the estimated number of households that harvest coconut in all parts of Ghana.

Table 1 Estimated number of households that harvest coconut in all parts of Ghana

GHANA	Coastal Zone	Forest Zone	Savannah Zone
114,600	73,200	40,000	1,400

Source: Ghana Statistical Service: GLSS, 2000.

From the field observations, coconuts are harvested in the dry form though the farmers prefer the fresh coconut because of the high oil content in the dry coconut as compared to the fresh coconut. According to farmers interviewed, the oil extracted from the coconut fruit is sold in the major cities of Ghana for example Accra, Kumasi, Takoradi and Tarkwa (a mining town in the western region). Observations and interviews made in the Nzema have revealed that the oil production in the area is declining partly due to the evasion of Nigerians traders ready to buy the nut at a reasonable price, and transport them to Nigeria; and influx of other edible oil from the nearby countries (e.g. Ivory Coast) to Ghanaian markets.

With the supposed reasonable price offered by the Nigerians, farmers are still complaining about coconut farming because the other product such as husk and shell from the coconut are wasted. It could be seen that there are no alternative ways for farmers to utilised coconut to increase their income in the area.

This paper examines the production of coconut in the area and the alternative possible ways of utilising coconut in Nzema to increase the income of farmers. In addition, the paper presents the benefits of coconut as a renewable source of energy and the fight against environmental impacts and effects. The paper may help readers to understand that coconut trees have more benefits such as producing energy for the country.

1.2 Statement of the problem

The coconut industry is the only major job and source of income for the indigence in Nzema. The industry has created employments for thousands of people (the old and the youth) in the area. The coconut industry comprises of small-scale farmers, milling operators, collectors and oil extractor, marketers, transporters.coconut industry also provide feed for other agro industries example piggery. It is estimated that about 40,000 hectares of coconut plantation are found in two regions in Ghana (Osei-Bonsu and Dery 2009). The Nzema land accounts for about 85% of the total coconut plantation in Ghana. A research made in 1985 shows that the production of coconut is about 219,000 tons (FAO Field Working Paper 1990). However, in 2013, the production has increased to 290,000 tons.

Despite the large number of small-scale production of coconut oil in the area, farmers have limited knowledge of different ways of utilizing the coconut product such as waste husk to produce energy. The only way of utilizing the coconut is production of oil and using small portion of the waste husk with the shell as a fuel to produce heat. The whole part of the coconut tree can be utilized to increase the income of the farmer, from its leaflet, fruit, frond, trunk to the root (Chomchalow N. 2011).

1.3 Justification and Relevance of the study

Coconut also produced in other developing countries like the Philippines, Indonesia, India, Sri Lanka, Thailand and Malaysia. In Philippines, the coconut industry is the highest net foreign exchange earner and it is about 1.5% of the GNP. About 20 million people are direct and indirect employed in the coconut industry and they earn more than US$510m annually (ACLAR 1995). Agriculture commodities such as cocoa, palm oil and coffee have been upgraded to contribute more income and GDP growth for some country (Bedijo 2009).

Researches in agriculture commodities in Ghana are focused primarily on different utilization of cocoa and palm oil. However, little research has been done on different ways of utilizing coconut and on increasing the income of farmers. Therefore, the study will contribute to the existing works on coconut utilization in Ghana. In addition, the results of

the research can give an open opportunity for farmers to consider energy production as an alternative use of coconut oil for economic sustainability.

1.4 Research Objectives and Questions

The objective of the study is to introduce the farmers to alternative utilisation methods of coconut, and how coconut products such as the oil can be used to reduce the energy crises in the region. Analysing the best utilisation methods of coconut in the area requires a closer look at the prevailing methods of using coconut products and the possible method of generating energy from coconut. This needs a vivid understanding of the chemical properties of coconut. For the case in Ghana, this paper will focus on the tradition way of extracting coconut oil, the uses of coconut products, and alternative ways of using coconut fruit to generate energy to overcome the energy crises and reduce the environment impact and effect caused by other forms of fuel.

The main research question for this study is; what are the alternative utilisation methods of coconut in Nzema and how to generate energy from coconut? The stages involved in answering the question are:

- What are utilization options for coconut and its by-products?
- Which of the options is the most relevant from sustainability and economic aspects?
- Can coconut production help Ghana to increase renewable energy production?

1.5 Research Methodology

The research paper is based on both primary and secondary data collection. The study therefore consists of two methods:

- Literature review of similar utilisation of coconut. In this part, many research papers were reviewed to understand different methods of utilisation of coconut. Major coconut producing countries Sri lanka and Fiji were considered and analysis was done on how coconut products has help their economy and society, and how

their geographical location influenced the usage. In addition, a review of research area of biofuel from coconut was done and this provided a good data for the study.

- A fieldwork in Ghana was also done to know the current situation in Nzema. More in-depth interviews with some coconut farmers and rubber farmers were conducted from 5th November to 21st December. The fieldwork was designed to make the farmers aware of alternative ways of using coconut and to obtain the current utilisation of coconut.

1.6 Limitations of the Research

There were challenges during the research. Though the author has substantial knowledge on the current utilization methods, by virtue of being an indigene, further field studies were conducted to gather more information to guide the limitation of the research. The research was based on the following guidelines:

- Majority of the coconut farmers were involved in the interview
- Those interviewed were the farmers, coconut oil producers, coconut revenues collectors and the ministry of energy and petroleum staff in two districts in Nzema.
- Some Nigerian buyers were interview to know the price of the coconut and amount each of them buys.
- The author was able to have discussions with coconut oil buyers in Accra, the capital city of Ghana to know the use of oil and after the oil is used, the next level of utilisation.
- Communicating with the indigenes was not difficult because the author can speak the language. The difficult part of the communication is the translating the English questions to the local language, especially, the technical terms. The outcome of the interview and the group discussion were good because most of the farmers and the coconut oil producers had limited knowledge of biodiesel from coconut oil or waste coconut oil for energy. In addition, the use of coconut husk and shell for bio char or briquette is not known to most of them.

1.7 Structure of the Paper

This research paper consists of eight chapters and organised as follows. The first chapter contains the introduction of the paper, which discussed the background of the study, methodology and the limitation of the research topic. The second chapter contains the estimated quantity of coconut produce in Nzema. A detail method of extraction of oil and the waste associated with the oil production are noted. In addition, it contains a theoretical description of utilisation of coconut biomass such as husk and shell to product bio energy. Lastly, the second chapter describes a possible symbiosis from coconut. The third chapter focuses on the life cycle of coconut oil production, from the nut collection to copra manufacturing while the later part of this chapter describes the oil production methods.

Since the research is mainly about providing energy with the use of coconut, the fourth chapter present the major parts of coconut and its energy related issues. Decentralisation of power and diesel saving by using coconut as a fuel are discussed in this chapter. The composition and properties of coconut are in the fifth chapter. Coconut oil related properties are also in fifth chapter. Chapter Six detailed some of the uses of coconut oil as bio fuel. It describes the theoretical aspect of making biodiesel, biodiesel blend and possible coconut oil for diesel engines. Chapter Seven describes an alternative uses of biomass from coconut to generate energy and its characteristics. The last chapter is the result from the field and analysis of the theoretical study.

1.8 Current Uses of Coconut in Nzema

Currently, in Nzema, coconut is used primarily for oil production and heat generation from coconut husk and shell. Nowadays, with the evasion of Nigerians traders in the business, farmers in the area have started selling the coconut without the husk to the traders. This contributed to the decline in the production of coconut oil in the area. In addition, to the production of oil which was the main activity in the area, pig famers feed their pigs with waste meat from the coconut after oil extraction.

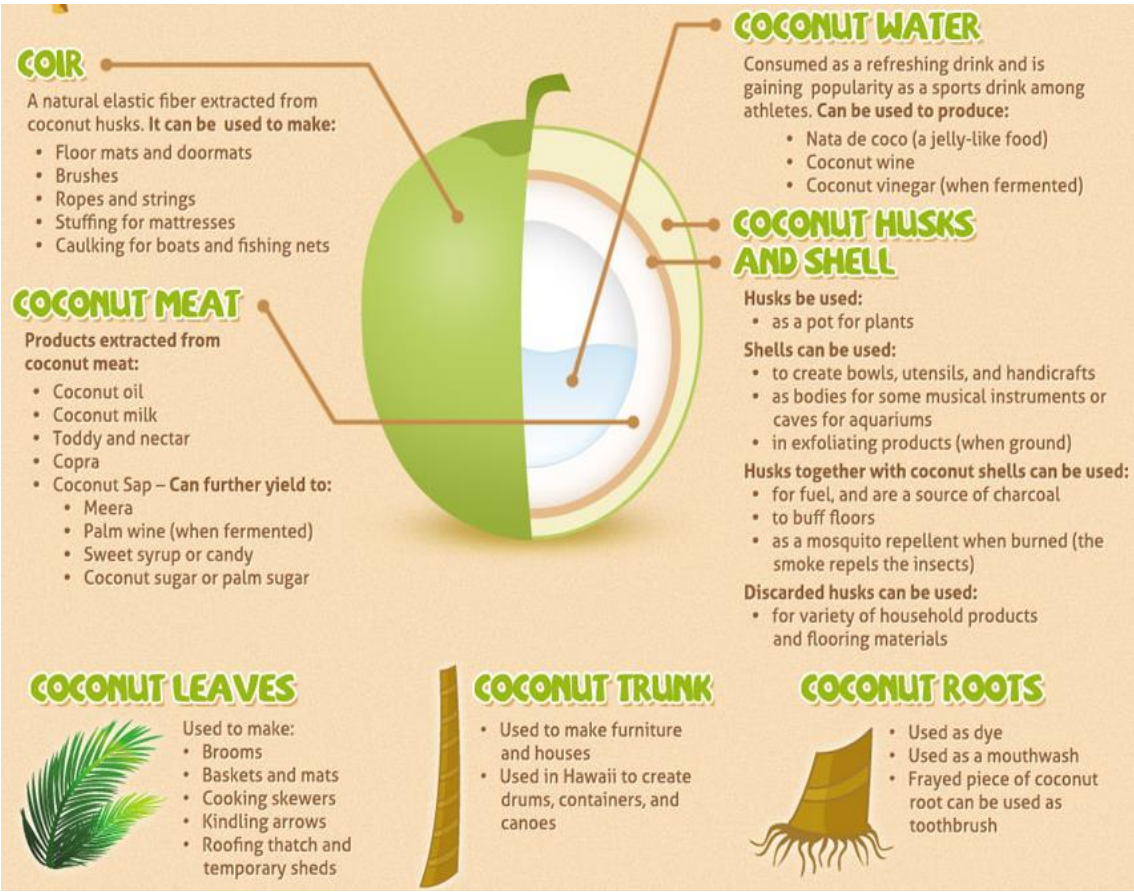

Figure1. A cross-section of a coconut fruit showing the parts of the fruit

Nzema lies in the coast and southwestern part of Ghana. Coconut products exported from the area are seedlings, coconut oil and coconut (without the husk). These are transported to Accra, Kumasi, Takoradi and Tarkwa, all in Ghana, but now most of the coconuts (without husk) are mainly transported to Nigeria. In this research, the author could not establish the estimated quantity of coconut that is exported from Nzema because there was no previous data available. Nevertheless, in 2013, the production quantity of coconut was 290000 tons in Ghana (Fact Fish, 2013). According to the Global Environment Facility Small Grants Programme project done in the Nzema District with the theme ´´Effective Management of Coconut Waste for Bio-Gas Production and Organic Fertilizer in the Nzema`` claims that about 80% of Ghana's coconut production is from the Nzema District. From this, it can be deduced that 232000 tons of coconut as at 2013 are produced from Nzema. According to W. Quaiku 2013, coconut product has declined compared to previous year due to Cape Saint Paul's wilt coconut. The harvested area in hectare has remain constant from 2001 to 2013, 55000 hectare in Ghana (Fact Fish, 2013).

The method of extraction of coconut oil in Nzema is mainly wet processes partly because piggery farmer needs coconut meat to feed pigs and also because it is economical and fast method in the area. A detail explanation wet process is in chapter 2.

The wet method of extraction of coconut oil in the area generates a large amount of husks waste that can be used for heat energy or use as a feedstock to generate power (electricity) in the area. After removing the coconut kernel from the cracked coconut, the husks attached to the shell are left in the farms to rot. Sometime, husks are burnt by the farmers to avoid snake using them as a hiding place.

In addition to the above waste (husk and shell), grinded coconut kernel are left on the ground as waste after the extraction of oil. Since the process is a wet method, much water is used to mash the grinded coconut meat, and then milk is collected. After fermentation, the oil suspends on top of the water and the oil is separated from the water. The waste water is poured on the ground, and as this practice is repeated over time, the ground becomes waterlog.

Figure 2. Waterlog area caused by coconut oil extraction in Nzema

A few of the husk and shell are used as fuel to cook the oil, this helps to separate the oil from water. In addition, few household uses coconut husk for heating during cooking at home.

Figure 3. Coconut husks

2 LIFE CYCLE OF COCONUT OIL

The figure 4 below shows an example of coconut oil life cycle from Nzema. The coconut are harvested from the plantation by means of man power and then transported by a vehicle to the processing site. The vehicle takes in diesel fuel and gives out waste gases. At the processing site cracking and scoping of coconut kernel from the shell is done. After that the kernel is grinded by a grinding machine which uses diesel fuel. Water is added to the grinded kernel and the mixture is squeezed to get more coconut milk. In the processing site waste gases and coconut milk that pours on the ground are notable wastes. The coconut milk left for overnight for the oil to suspend on the water. The oil is collected and refine with heat and then packaged in container when the oil cools.

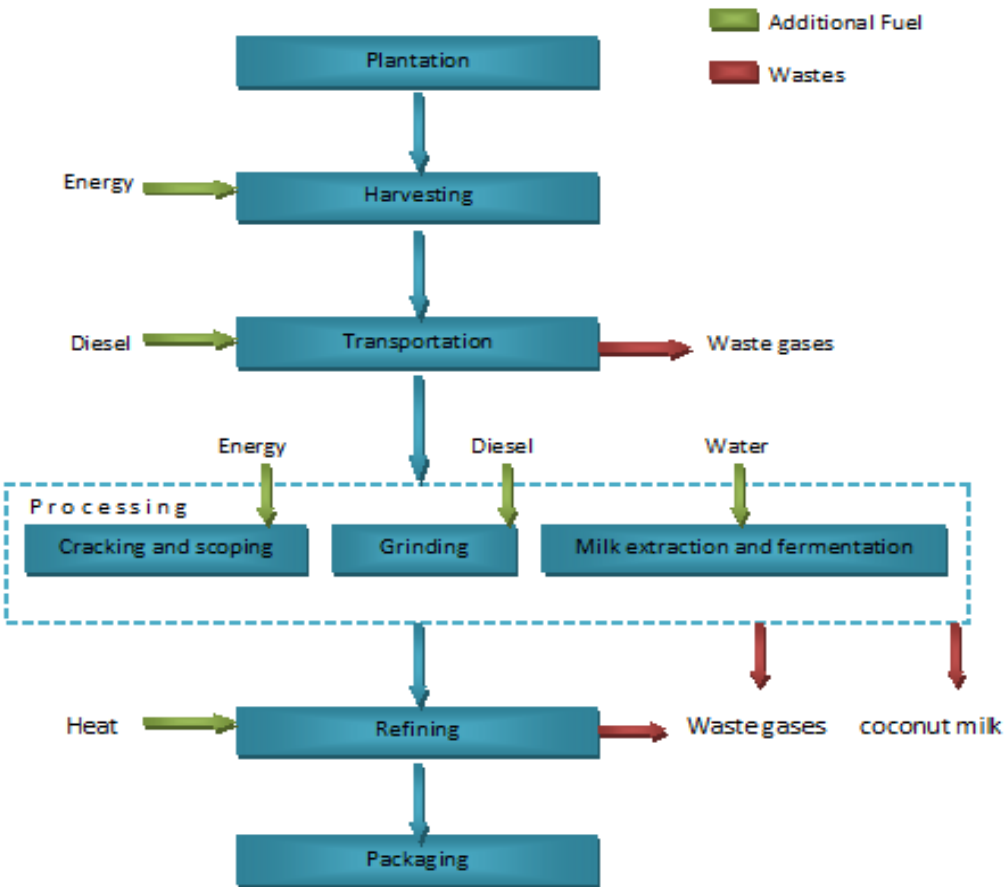

Figure 4. Life cycle of coconut oil

2.1 Nut Collection and handling

The field work revealed that, coconut collection serves as jobs for some young and adult male. Most of these collectors depend on the generated income for livelihood and paying utilities including school fees. The total number of collectors for a given farm depends on the size of the farm and the urgent demand of the coconut product. The nuts are normally gathered at a common place for dehusking or cracking in the same coconut farm. This place serves as a storage place and during periods of peak harvests, not all nuts harvested daily can be cracked the same day.

Farmers interviewed declared that storage of dry coconuts is done primarily in the dry season, or under favourable conditions, but not stored in a warehouse to avoid high cost of production. Keeping it in a warehouse increases the risk of nut theft and rodent attacks. In addition, dry coconuts are mostly cracked immediately to avoid germination at the storage site. The purpose of nuts storage at one particular place is to make dehusking and cracking easier. In addition, scooping and packaging becomes easier when all the nuts are gathered at one particular place.

2.1.1 Dehusking and Cracking

According to interviews and observation dehusking of coconut is now the simplest way for farmer in Nzema land to sell coconut. This is because farmers tend to avoid the process of producing coconut oil. This current trend might be because of several reasons including: number of days and labour involved in producing the coconut oil, competitor edible oil from neighbouring countries, and availability of ready buyers to buy the dehusked nuts. Dehusking is a method of removing the husk from the shell to reduce the weight of the coconut. This is the most popular way of selling coconut to buyer such as Nigerians buyers in the area. Dehusked coconuts are exported to Nigeria in tonnes. The packing area of these trucks is locally made in Ghana to suit the local condition as seen in figure 4.

Figure 5. Truck loaded with coconut to be exported

- The reasons for dehusking coconut in Nzema are as follows:
- Dehusking coconut for sale is easier than processing coconut to produce coconut oil
- There are ready buyers for dehusking coconut products
- It helps to avoid the risk of theft because farmers can dehusked the coconut easily and sell it immediately to buyers. If coconut is intend to be used for oil, it need to go through cracking, transportation to milling site, milling, processing the milled kernel with water to wait for the next day for the oil to settle on the surface of the water. At this stage the floating oil can be stolen.

Dehusking of coconut is now the most efficient way for farmer to sell coconut in Nzema or the above reasons. It is done with a sharp vertical standing metal steel bar, secured in the ground in a slanting position. The sharp edge points upwards to penetrate through the nuts, followed by twisting the nut sideways against the bar to lose the husk from the shell. This is repeated twice or thrice for the total removal of one coconut husk. It is a difficult and a dangerous work so an experience worker is needed for dehusking. The number of dehusked nut per a day depends on factor like, the thickness of the husk, the size of the nut, the skill and the energy of the worker. An average worker in Nzema can dehusk 1000 to 1300 nuts per a day.

Figure 6. Dehusked coconut ready for export

There are no mechanized systems or automated systems implemented in the region, all dehusking are done manually. There are some dehusking machines that have been developed in some countries such as Malaysia, the UK, India and Trinidad and Tobago. For instance, CoCoMaN below is dehusking machine developed by Sdn Bhd in Malaysia

Figure 7. CoCoMaN machine for cracking coconut Source: http://www.coconutmachine.com/

Cracking is a method of dividing the whole nut into parts including the husk. After it cracks the water content is not used and is left with the kernel attached to the shell and the

husk. Cracking is done if the kernel is to be used to produce oil. A sharp cutlass is used for cracking. The kernel is scoop by a sharp edge knife. Scooping is done with experience workers to avoid risk of breaking the kernel into smaller pieces and hurting the hand because it is done manually.

2.1.2 Nut Transportation

Before transporting coconut nut to a milling station, the nuts are packed in a sack or in a basket depending on the most available package methods. However, packing the nuts in a sack is preferred to packing nuts in a basket because a sack holds more nuts than a basket does. The mode of transportation depends on the volume of nuts to be handled and the distance over which the volume has to be transported. Small-scale farmers with low volume of nuts manually carry the sacks of nuts through short or long distances to the milling station. This is practice in especially prevalent in areas with no road networks by which vehicles could reach the farm. Also, heavy rainfall in Nzema makes difficult to reach the farming areas by vehicles. Farmers use vehicles for example motor tricycle, and tractors with carts to transport the sacks of nuts to the milling station. Recently, there has been an improvement in the road networks linking the farms to the milling stations. Sometimes, labours are required to carry the load from deep farms by foot to the side of the linking roads for vehicles to convey them to the milling station.

2.1.3 Copra manufacturing

Oil production from coconut around the world is mostly derived from a dry coconut called Copra. After scooping the kernel from the shell, the fresh kernel is dry under the hot sun to reduce the moisture content from 50% to moisture content to 6%. This process is done carefully to avoid the kernel from deteriorating because the fresh kernel contains protein and sugar that attract bacteria and fungi (Patterson & Perez, 1981)

This method of extracting coconut oil has faded out in the region because of the much time needed for drying the kernel, theft and deterioration of kernel. Meanwhile there are improved or modern methods of drying copra and these methods will be more viable in produce a large quantity of coconut kernel. The improved method is that, the copra can be produced by using heat from the sun (Sun drying and solar drying) or using heat from

burning biomass (kiln drying by smoke and indirect drying by hot air) such as abundant husk in the coconut farm.

2.2 Oil Pressing & Refining

From the field interview and information gathered from field trips, there are two main methods of processing coconut oil in Nzema. These are dry process and wet process. Both individual farmers and the small-scale coconut oil producers use these two methods. The most common and popular method is the wet processing method. The dry processing method is not popular because most of the farmers use the waste coconut meat as pig feeds in their pig farms.

2.2.1 Dry Process and Oil Refining

The dry method of extraction of coconut oil starts from the removal of kernel from the shell. The meats are transported and dried on a platform opened to the sun. The kernel is left under the sun during the day for a number of days to reach the required state. The drying help to reduce the moisture content of the coconut meat. Farmers in this area have no tool to detect the required moisture content. The coconut meat is turned during the day under the sun to make sure that it is evenly dried. The dried coconut meat is called copra.

Dry coconut meat (copra) is grinded in a mechanical machine to have smooth small sizes of coconut meat. The machine for grinding can be a hand-held manual machine or an electrical powered machine. The granulated coconut meat is pressed to extract the oil. The coconut oil is then filtered by a micro-sieve to remove the impurities in the coconut oil. Figure 1 shows a flow chat of extracting oil from dry coconut.

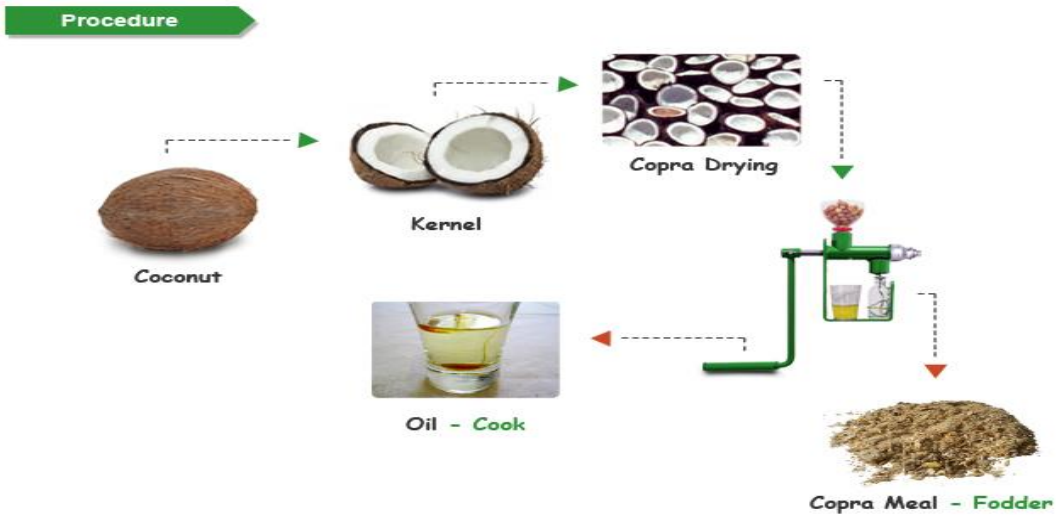

Figure 8a. A flow chart of dry method of extraction of coconut oil

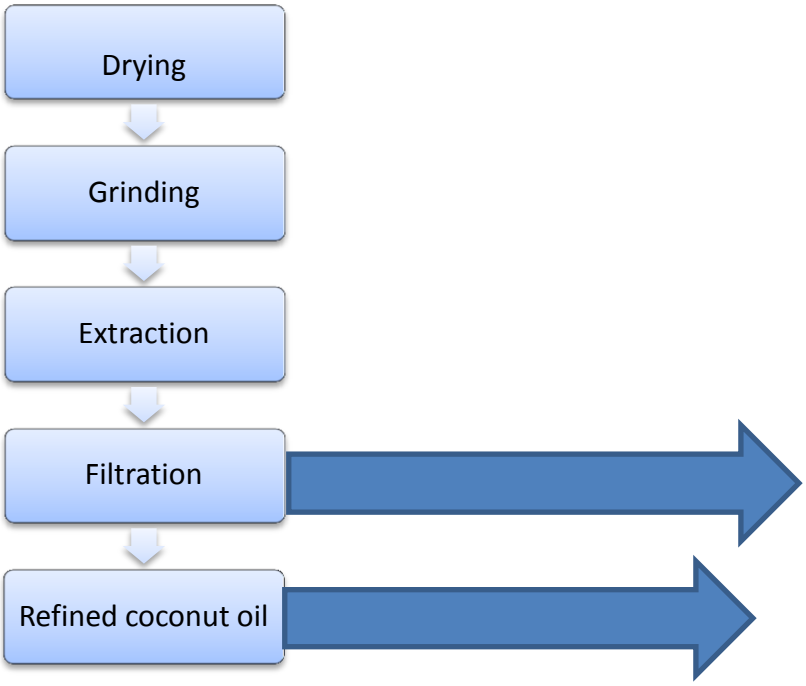

Figure 8b. A flow chart of dry method of extraction of coconut oil

In most, the copra oil is not refined by the farmers. Most of the oil is exported to the nearby cities such as Tarkwa, Takoradi, Cape coast and other cities for sale.

2.2.2 Wet Process and Oil Refining

It was observed during the field trip that, traditionally, for centuries, coconut farmers produce oil in large quantity by using this process. The wet process starts from wet kernel coconuts to obtain a high quality and edible coconut oil. Wet kernel is grated to form a granulated coconut meat. The granulated coconut meat is mixed with much water in a traditionally sieving system to extract most of the milk from the coconut meat (granulated kernel).

The coconut milk and water solution is left to ferment for 24 to 48 hours as shown in figure 8 (a). At this stage, the oil sludge suspends on the water for collection. Since the oil sludge contains much water, it is heated in a big aluminum pan to evaporate the water content as shown in figure 8 (b). In most cases, the coconut husks are used to fuel the fire for heating the oil.

After heating the oil, it is filtered by using a heat resistant micro sieve to retain the cooked sludge from the oil. After filtration, the oil is left in an open space to cool (Tillekeratne H. A. and Ranasinghe A. T., 1997).

Figure 9. (a) Fermented coconut oil (b) Heat the oil to evaporate the water

2.3 Biofuels from Coconuts

2.3.1 Energy and Weight Content of Parts of the Coconut Palm

Traditionally, a mature coconut for oil extraction is ready when it dries and fall from its tree. At this stage, the coconut is crack without dehusking and kernel is removed leaving the husk attach to the shell. The kernel or meat is used for coconut oil and the husk attach to the shell is used for heating. Most of the husk attached the shell are left in the farm, a few is used for heating. Sometimes, firewood producers sell the husk for money. Apart from the coconut oil and the husk, the coconut palm branches and the trunks are used for heat purpose in the area. When the branches are dried and eventually fall of the coconut tree, they are used as firewood.The trunks are used when the palm tree becomes old and cannot produce much fruit.

A study conducted in some countries, especially in the pacific, which also split the coconut without dehusking shows the composition of a mature dried coconut ready for oil extraction. The figure below shows the percentile weight of a coconut (Krishna R 2010).

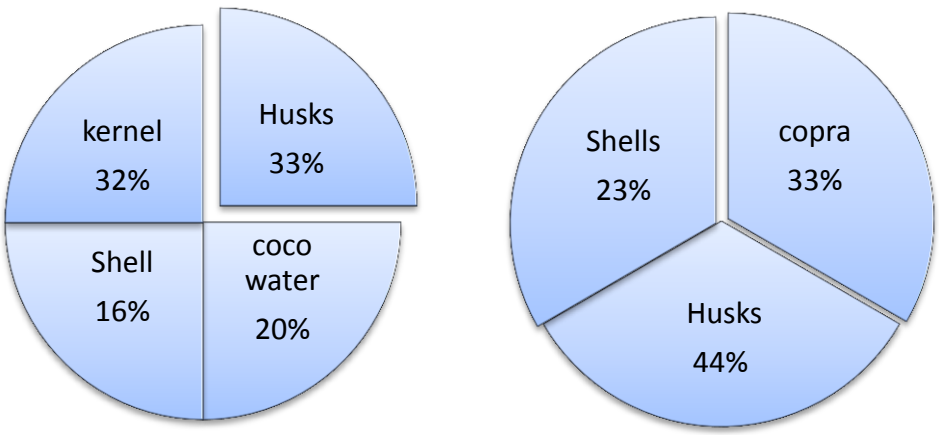

figure10. Compositions of a mature (left) and dry (right) coconut by weight in percentage

The above weight depends on the size of the coconut; however, the average weight for this calculation is 1.2 kg. The table below shows the weight in kilogram of each composition of 1.2 kg of one coconut (Cloin J et al., 2005).

Table 2.Composition of one coconut by weight

	Part	Weight (kg)
1	Husks	0.40
2	shells	0.18
3	Coco water	0.24
4	Copra	0.37

Source Cloin J et al., 2005

Coconut palm is now known in the world as a renewable biomass energy source (Banzon J. A. 1980). According to Banzon (1980), in the mid1970s, when petroleum crude oil prices were raised by petroleum countries, some countries such as Philippines started to substitute coconut oil for diesel oil. Various experiments were conducted and 5 to 10% of coconut oil blend was found to be successful. Several problems developed when high level of coconut oil was used to ignite engines, such as clogging of filters, corrosion caused by the high free fatty acid presence in coconut oil. Banron J. A (1980) claim that the challenges related to these problems have been resolved by blending with kerosene, biodiesel production and modification of engines (Banzon J. A. 1980).

Energy content of the coconut varies depending on the part of the coconut. In this research, the fruit of the coconut is taken into account. The fruit produces the kernel for oil, husk and shell. These three parts of the coconut give a significant amount of energy. The coconut trunk is not considered because it is harvestable once in it lifetime. The table below gives the potential energy for each part of the coconut fruit.

Table 3. Energy from component of coconut

Component	Kg	Kcal/kg	Energy kcal	% of total energy
Coconut oil	0.40	9000	1080	27.7
shell	0.18	5500	990	25.4
Husk	0.40	4000	1600	41.1
	0.70		3670	94.2

Source: Banzon J. A. 1980

In addition, coconut oil has been used as a source of lighting fuel in rural area. The oil is burnt with a wick to make a flame in a lantern. The light produced by the oil in the lantern is bright and white, and differ from that of kerosene that is reddish and soot. Furthermore, if a coconut oil is burnt, it serves as an insect repellant especially in rural areas infested with mosquitoes (Ohler J. G. 1999).

2.3.2 Decentralized Power Generation from Coconut Residues

Decentralized power systems play an important role in rural areas and can provide significant economic opportunities to local residents. Decentralization with off-grid systems helps rural areas. Most of the off-grid systems use renewable energy technologies. The energy obtained for off-grid power generation is from solar systems, biomass combustion and hydro-power (Salire S. M. 2010).

Over the years, the renewable energy generation potential of coconut oil as strategic oil option, has gradually received increased attention. More countries have strived to be

energy self-sufficient due to their geographical locations and biomass resources. The harnessing and utilization of coconut products for the generation of power to rural areas for example Samoa`s Power utility CocoGen or less populated areas comprises a critical component of supply security strategy (Cloin J et al., 2005). An evident in power sector in countries where renewable energy is implemented has lessened the country's dependence on imported and polluting fuels. Currently, biofuel is having a good potential once reliability and availability of feedstock are established. Biomass energy may be a sustainable energy supply in Nzema because the major economic activity of the citizens is agriculture. The area´s rich resources in coconut biomass can offer opportunities for the government to maximize decentralized power systems towards attaining the objective of rural electrification (Salire S. M. 2010).

The merits of using decentralized power generation include the following:

- Reduce the need for costly transmission systems
- Substantially reduce grid power losses over long transmission distances resulting in deferred costs for upgrading transmission and distribution infrastructure capacity to meet a growing load.
- Zero carbon for renewable energy sources such as solar, wind and biomass.

A geographical constraint is a hurdle to fully connect the entire country to the national grid. In this regard, a decentralized power system is a better and more sustainable strategy recognized by many countries to be effective in the distribution of efficient power to marginalized areas. The system leads to mobilization of high-level officials from national down to the village level (Metz B et al, 2007).

The application of plant oils for electricity generation as an experimental and demonstration set-ups in diesel generators has been conducted in many regions and institution in the world (Cloin J et al., 2005). These evidences show that utilization of coconut oil power generation in Nzema can be possible. The following dialogs below show examples of plant oil for electricity generation.

The figure 11 below shows an experiment initiated in Thailand in 1999 when energy consumption in the country increased 4.4% over the previous year. All modern energy products such natural gases and petroleum product increased by 4.3% (Department of energy development and promotion, 1999). Most of the diesel product is used by the farmers and since diesel product is increasing farmer turn to vegetable oil as engine fuel. But most of the farmers reported of engine failure so this lead to a study of refined palm oil as a fuel in the Mechanical Engineering Department of Prince of Songkla University, Thailand (Prateepchaikul G. 2003)

Experiments on using palm oil in diesel engines

Michael Allen, a visiting professor at Prince of Songkla University ,Thailand studied the effect of using different blends of Palm oil/diesel in CI engines.

His main findings:

Engine: Kubota diesel

Blends used: 100% Refined Palm oil, 80% Refined palm oil and 50:50 blends; start and stop on diesel

Refined palm oil: Degummed and FFA removed (FFA ~0.5%)

The engines were tested for 2000 hours

Results: The engines performed well with all blends and refined palm oil.

When similar tests were done using crude palm oil (FFA~2-15%) the engine was catastrophically damaged (bang and smoke) i9n less than 300 hours. The piston rings were worn and lube oil was contaminated leading to polymerization.

Figure 11 Experiments on using palm oil in diesel engines in Thailand Source: Allen M., 2002

The figure12 below shows detail specifications of the demonstration project in Fiji. The Fiji Department of Energy has two communities such as the lomaloma and welagi and has provided clean electricity for the communities. The two projects had challenges implementation lifetime during it change of ownership to the communities. The projects

implementation has given information for good planning, development and management of a bigger project in the future (Fiji Development of Energy 2005).

Fiji: Demonstration project 1: Copra biofuel project

Location: Lomaloma, Island of Vanubalavu and Welagi

Population to be served: 200 consumers in 3 villages, a post office & a hospital

Implementing agencies: CIRAD (France), SPC, DOE(Fiji)

Implemented: April 2000

Equipment: Deutz engine modified for coconut oil use: Twin fuel tanks, heating system, start & stop on diesel: Power output at 1500 rpm- 74 kW

Indirect injection: adjusted

Alternator: 90 kVA, 130 A

Mini grid: 220 V. 50 Hz, 3 phase

CNO production: Taby Mill. 40-60 kg per hour

Power required: 1.5 kWh

Progress report: The generator ran on locally available CNO for a short time and then on oil from Savusavu mill. Now, it is operated using diesel

Figure 12 Demonstration project 1: Copra biofuel project in Fiji Source: Khan I., 2005

In figure13 the climatic conditions in the country made the government focus on increasing the participation in renewable sources of energy. The focus was directed to palm oil as a fuel to produce electricity in the amazon. The amazon has great potential of producing palm oil; this is because the climatic condition, sunlight availability and geographical location in the area support palm oil production (Queiroz A. G et al 2011).

Palm oil based electricity production in Amazon region (Brazil)

Project: PROVEGAM: Implantation and test of an unit demonstration of energetic utilization of vegetable oil (Sic)

Implementing Agencies: FINEP, CENBIO (Brazil)

Objective: To install and test in field a diesel engine adapted to run with

palm oil (natural- straight)

Location: Vila Soledae, city of Moju , Para

Population to be served: 700 people

Implementation date: February 2004

Equipment: Diesel generator Model TD229EC-6 (made in Brazil) 6 cylinders, turbo charged, conversion kit (made by Thermal Engine laboratory, Brazil):Hot water from the engine –cooling system is used to heat the palm oil to 85^{0}C prior to injection. Start and stop with diesel.

Palm oil: produced locally

Progress report: generator operates for 5 hours/day with palm oil, 1 hour/day with diesel. Total operating time (until February 2005):>2500 hours

Main findings: Injector nozzle has to be changed every 800 hours of operation

Lube oil: change every 200 hours

Carbon deposits in the combustion chamber and on piston heads (checked after 800 hours)

Figure 13. Palm oil based electricity production in Amazon region (Brazil) Source: Suani T. C. et al. 2005

A socioeconomic survey conducted in Brazil in 2004 at the community with diesel generator model TD 229EC-6 project showed a significant change. The objective of the survey is to know the changes that have occurred in the population's life condition. The percentage of families that have acquired appliances such as lamps, TV sets, etc. has exceeded 80%. The figures below show the change before and after the project.

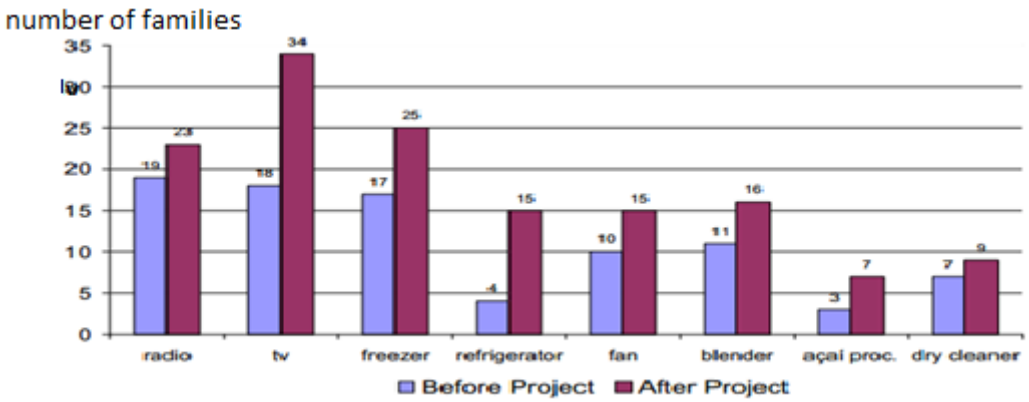

Figure 14 a. Socio-economic chat of TD 229EC-6 project

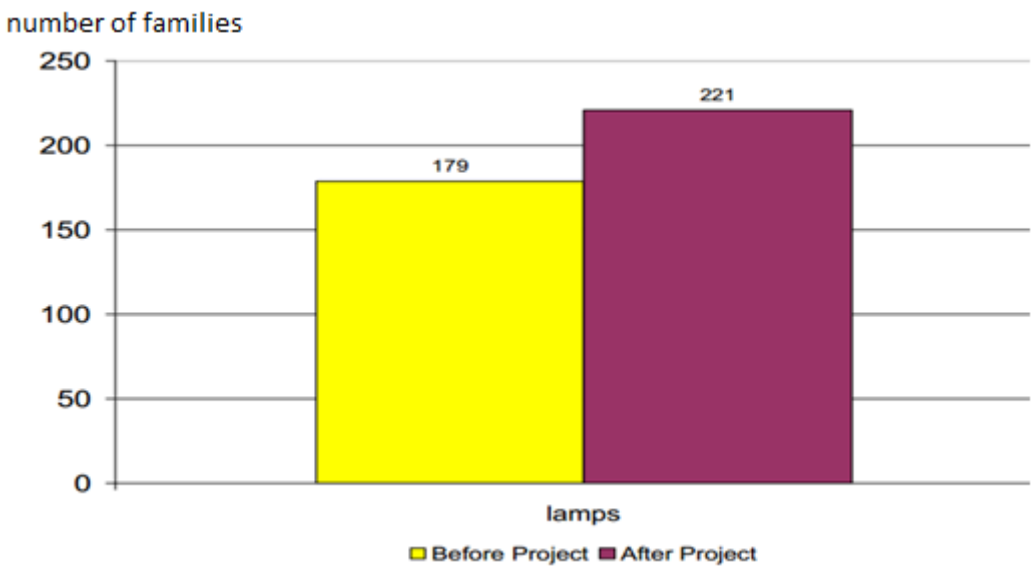

Figure 14 b. Socio-economic chat of TD 229EC-6 project Source: Suani T. C. et al. 2005

2.4 Diesel Savings and Environmental Benefit of coconut oil

Ghana relies mostly on imported petroleum oil products to meet her energy needs in the energy demand sectors. These energy demand sectors are namely residential (household), commercial and services, agriculture and fisheries, industry and transport (Energy Commission of Ghana, 2006). According to the strategic national energy plan (SNEP)

Ghana, 2006, the growing population in Ghana is increasing the economy demand growth in electricity, process heat and transportation services. Processing and combustion of petroleum products or fuel to meet the energy demand sectors has given rise to global warming gases such as methane and nitrous oxide (D. Guggenheim et al, 2006), acid rain pollutants, particulates and other forms of toxic volatile hydrocarbons such as benzene and toluene into the atmosphere (R Chang et al, 2004). An observation made during the field work revealed that many areas such as mechanical shops in the cities are polluted with lubricants, diesel oil etc. on the working floor. The uncontrolled oil drains into water bodies to destroy organisms in the water (Y.-S. Oh, J. Maeng and S.-J. Kim, 2000). Most Ghanaian in the country has little or no knowledge about the effect of petroleum products impact on the environment. Those with the expertise about these impacts on the environment are not well equipped to make the required changes. A relatively examination of vehicles in the capital city indicates that a rise in proportion of catalytic converter-equipped cars are old and not maintained to the required standard , which may increase in particulate emissions in the capital city, Accra (M. E. Kylander et al, 2003). The number of vehicles plying in the capital city has increase exponentially and with use of petroleum fuels, it is causing air pollution in the city.

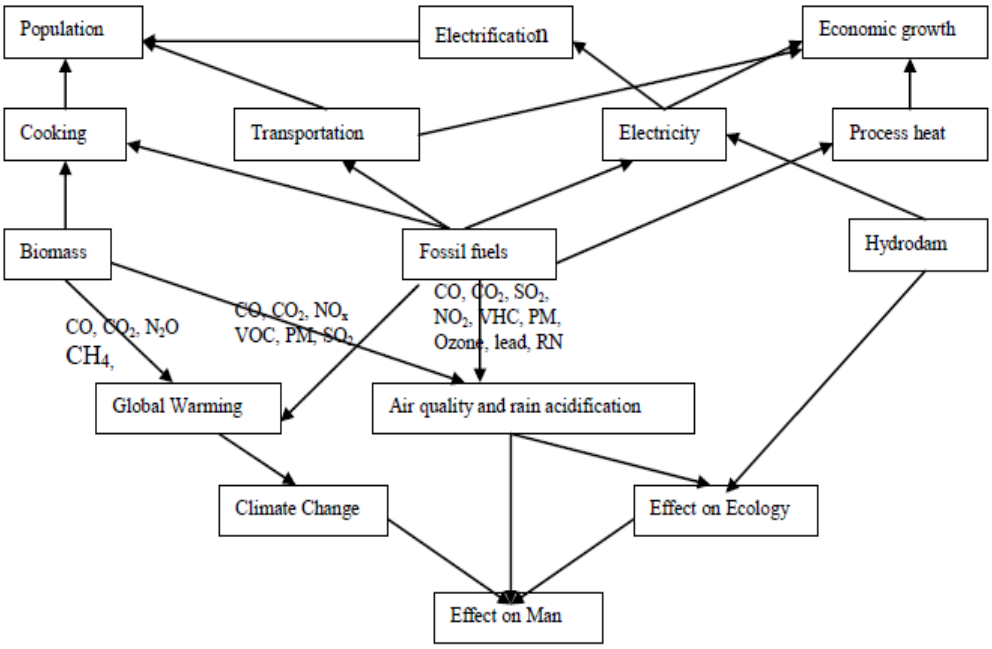

Figure 15 Conceptual models of environmental implications of energy usage in Ghana

The emissions projections from SNEP, July 2006, show that emission from combustion of petroleum fuels may overtake emission from biomass based by 2020. This is due to the rising economic growth in the country that is expected to increase the mean GHG emissions of 10 million tonnes carbon dioxide equivalent in 2000 to around 48 million tonnes of carbon dioxide equivalent by 2020.

Table 4 Projections of emission of pollutions for 2015 and 2020

Gaseous pollutants	2000	2015	2020
	Thousand Tonnes		
Nitrogen oxides	50	193	310
Sulphur oxides	9	13	20
Non-methane VOC	295	440	640
Particulate matter	301	430	580

Source: Strategic national energy plan, 2006

The international energy agency statistical table below in 2012 shows that Ghana imports about 1080000 tonnes of gasoline into the country and 993000 tonnes of this gasoline are used in the transportation sector. Whiles 46000 tonnes is used in the fishing industries. In addition, the liquefied petroleum gases imported in 2012 is 242000 tonnes and 27000 are produced in the country. None is used in transportation but 40000 tonnes is used in the industries, 197000 in residential and 31000 tonnes is used in the commercial and public sectors. In the same year, the natural gas imported into the country was 16345 TJ on gross

calorific value basis. There was no domestic supply and all the imported natural gas was used in electricity plants for power generation in the country (International energy agency 2012).

Table 5. The use of petroleum products in Ghana, 2012, in 1000 tonnes

	Liquefied petroleum gases	Motor gasoline
Import	242	1080
Industry	40	0
Transportation	0	993
Residential	197	0
Commercial and Public service	31	0

Source: International energy agency 2012

International energy agency statistics shows that Ghana produces 212022TJ of primary solid biofuel domestically. Only 122366 TJ are transform to other use not including power generation and heat productions. Only 23042TJ are for industrial use, 63655 TJ are for residential use, 2869 TJ are for commercial and public sector and 90 TJ is for agriculture and forestry.

Table 6 The use of solid biofuel in Ghana, 2012, in TJ

Solid biofuel	212022
Other transformation	122366
Industrial	23042
Residential	63655
Commercial and public sector	2869
Agriculture and forestry	90

The energy demand mix in 2006 done by international energy agency indicates that 19% of crude, NGL and feedstock, 11% of petroleum products, 5% hydro and 65% of combustible renewable and waste are needed in Ghana. The chat above indicate that combustible renewables and waste are in high demand in the country because most of the population are living in the rural areas which depends on fire woods and charcoal mainly for heating(International energy agency 2006).

Meanwhile, most of these combustibles such as coconut husk and shell are left to rot in the coconut plantation. With this result, waste husk and shell can be modified to bio-char to increase the use of renewables to replace petroleum products or crude, NGL and it feedstock. In addition, the conversion of coconut husk with shell and sawdust to bio-char will reduce the use of virgin trees for charcoal production. Currently, most of the coconut

husks with shells are burnt in the farm to prevent snakes using it as hiding place (International energy agency 2006).

The figure 12 below shows that the demand from renewable source is the highest, 65%. It is followed by crude, NGL and feedstock, 19%. Petroleum products are 11% and hydro is 5% in Ghana. This shows that waste husk and shell in coconut farms could be utilised in a form that may be attractive to the people in the area.

The above situation makes the country vulnerable to conventional fuel for transportation. The vulnerability such as security of oil supply has become a major concern in the country. Sometimes, fuel shortages hit parts of the capital cities, forcing private and commercial activities to halt (laary D. 2014). All the fuel filling stations are fueling vehicles with 100% diesel fuel without a blend of vegetable oil or fully 100% vegetable oil. Meanwhile, since 2002, there has been a high purchasing of coconut in southwestern Ghana, Nzema, by Nigerians to their country. These coconuts could be used for oil as biodiesel or the waste husk in the farm can utilized as biomass to generate electricity for rural areas in the region (Ruf F. et al. 2010). This could minimize the power shortage in the country.

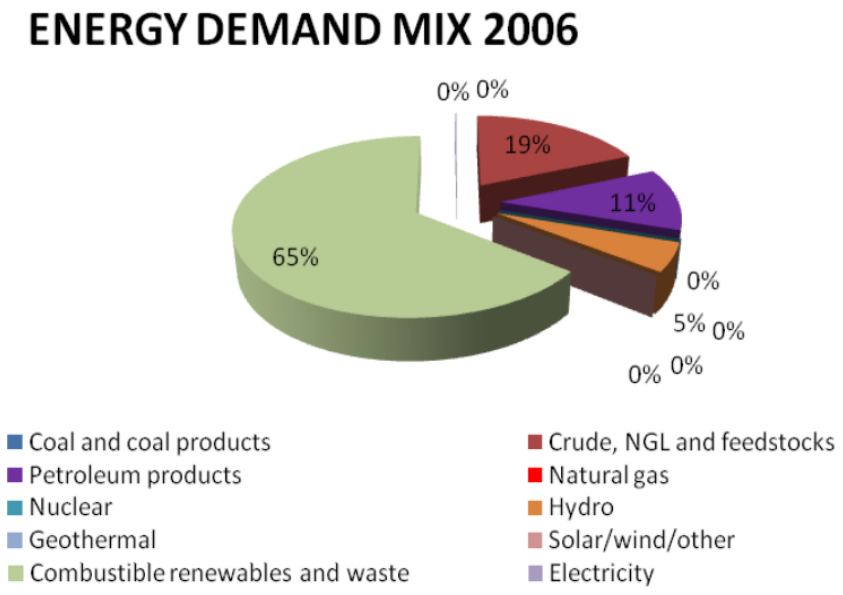

Figure 16. Energy demand mix 2006

Diesel fuel pollutes the atmosphere by releasing greenhouse gases such as carbon dioxide, sulfur dioxide and nitrogen dioxides (Brigdes A et al,. 2014). Replacement of diesel fuel with coconut oil and its blends may reduce the impact of air pollution in the country. The following observations are the environmental benefit that could be gained by using coconut oil and its blends:

- The burning of coconut oil in diesel engine releases gases but does not add to the greenhouse gases because these gases are from a plant source and they are absorb from the atmosphere back to the plant.
- Coconut oil emits less sulfur dioxide compared to diesel fuel that pollutes the environment.
- The particle matter releases by combusting coconut oil is 50% less compared to diesel fuel.
- Spillage during transportation is not harmful to the environment.
- The process involve in production of coconut oil are fuelled by the same coconut waste products therefore no additional greenhouse gases.
- The coconut oil is a biodegradable substance (Deamer et al, 2005).

2.5 Coconut Oil - Composition and Properties

2.5.1 Composition

Various laboratories with several techniques have determined the composition of coconut oil but the main compositions of coconut oil that affect the characteristics of the oil are triacylglycerol, fatty acids phospholipids, tocopherols, trace metal, sterols, volatiles and mono-and di-acylglycerols.

Triacylglycerol is an ester of glycerol with fatty acids and is the major component of coconut oil. It makes up to 95% of the oil. The major triacylglycerol of coconut are trilaurin 36 carbons chains, dilauryldcaprylglycerol 34 carbons chains, dilauryldimyristylglycerol 40 carbons, lauryldcaprylglycerol 34 carbons and lauryldimyristylglycerol 34 carbons (Rossell 1985).

Tocopherols are antioxidants present in most vegetable oils. In coconut oil, it stabilizes the oil against oxidation by air. The percentage of phospholipids in coconut oil is 0.2% and is

lower compared to other vegetable oils. Phospholipids are removed during the refining stage of vegetable oils and the amount of composition differs depending on the type of oil. Phospholipids serve as a good emulsifier in coconut oil (Krishnamurthy 1983).

Trace metal in vegetable has effects on the stability of the oil example copper and iron which are pro-oxidative, reduces the stability of the oil and these metals may come from the natural source or during the processing of the coconut kernel for oil extraction. The source and origin of the coconut may determine the level of trace metal in the oil (Young 1983).

The high content of short and long chain fatty acids characteristic of coconut oil differentiate it from other vegetable oils. Again, coconut oil solidifies below ambient 24 degree Celsius in temperate countries but has a melting point of 24 to 27 degree Celsius. The low melting point of coconut oil is caused by the molecular weight of its glycerides but not the degree of unsaturation. Most of the fatty acids (90%) in coconut oil are saturated. These are mainly of lauric, myristic, caprilic, stearic, linoleic, oleic and palmitic acids. Lauric acid is the dominatfatty acid about 50% and for this reason, coconut oil and palm oil is called Lauric oil (Krishna R 2010).

Table 7.Fatty acids composition of coconut oil

Fatty acids	***Fraction %***	***formula***
Lauric acid	51.0	$CH_3(CH_2)_{10}COOH$
Myristic acid	18.5	$CH_3(CH_2)_{12}COOH$
Palmitic acid	7.5	$CH_3(CH_2)_{14}COOH$

Oleric acid	5.0	$CH_3(CH_2)_7 CH = CH_3(CH_2)_7COOH$
Caprilic acid	18.5	$CH_3(CH_2)_6COOH$
Stearic acid	3.0	$CH_3(CH_2)_{16}COOH$

Source: Rossell J B et al, 1985

Coconut oil has sterol content to be 100 mg/100g, reported by Masson (1981). This value is lower than other vegetable oil. There are different kinds of sterols in coconut oil. These are cholesterol (trace-2.0 %), β -Sitosterol (43-70 %), Stigmasterol (13-20 %), Δ^5-Avenasterol (4.7-25.6), Δ^7 Stigmasterol (trace-6%), Campesterol (7-8.4%) and Brassicasterol (0-trace %). β –Sitosterol is the major sterol present in coconut oil (Rossell J B et al, 1985).

2.5.2 Fuel Related Properties

Coconut oil has relevant properties as diesel fuel. These properties are:

Specific energy is indicative of the amount of energy released by coconut oil when it is burned. The energy content of coconut oil is (38.4 MJ/kg or 34.9 MJ/liter) compare to that of petro-diesel that is (46 MJ/kg or 38.6 MJ/liter).

Cetane Number (CN) shows the willingness of the oil to ignite when it is compressed. Coconut oil has Cetane Number 60 as the highest.

Viscosity shows the ability of the oil to atomize in the injector system. Coconut oil has a higher viscosity than petro-diesel.

Solidification Point gives the temperature at which the oil will start to solidify. Coconut oil has a solidification point of 24°C. This makes it unsuitable during winter and areas with low temperature.

Saponification Value (SV) shows the oil´s ability to vaporize and atomize due to the carbon chains in the oil. The SV value for coconut oil is 268. This value makes coconut oil to ignite more quickly than other vegetable oils. SV is measured by the number of milligrams of potassium hydroxide required to convert 1 gram of fat into glycerin or soap.

Iodine Value (IV) shows the ability of the oil to polymerize due to the degree of bonds in the oil and indicates the degree of unsaturation of fat. The IV for coconut oil is 10.

Each of the properties discussed above has a problem associated with it. These problems inhibit coconut oil as a viable engine fuel.The table below shows each property, effects and it required solution.

Table 8. The effects and solutions of coconut oil as diesel fuel

Properties	Effects	Solutions
Specific energy	High temperatures affect the cylinder head and piston head adversely	Blend CNO with diesel/ kerosene
Cetane number	Difficult ignition	Heating of the as-produced oil, properly dried copra (low moisture content) should be used

Solidification point	Solid fat particles floating in the oil form waxes. If the temperature drops to around 240C ,the oil solidifies and blocks the fuel lines: catastrophic failure	Removal of FFA and solid triglycerides. Dual fuel system
Iodine value	Injection system problems	Start and stop with diesel fuel
Saponification value	Soap is formed in the engine sump	Use coconut oil both as fuel and lube oil
Viscosity	inefficient combustion, Pump and injector failure	Pre-heating , Blending

Source: Raturi A. P. SEFP, World Bank

3 COMPARISONS OF UTILIZATION METHODS OF COCONUT

In the wake of fuel shortage in the world today, coconut needs consideration as an energy source. More energy plant such as sugar cane, forest trees and some oil-bearing plant have been considered leaving coconut because of its oil production per tree and per hectare. However, some countries such as the Philippines and Fuji have started using the oil from coconut as a replacement for diesel vehicles. Compared to a well-known energy crop such as soya beans, coconut has protein content of only 1% while soya bean contains 40% protein. This comparison makes sense to minimize the use of food crops as energy fuel but however the differences in percentages shows that it is better to convert coconut instead of soya beans into oil (Ohler J. G. 1999).

3.1 Utilization as Biodiesel

The amount of Cetane number in coconut oil makes combustion possible in compression-ignition engines (internal combustion engine that uses the heat of compression for ignition and burns the fuel that is in the combustion chamber). The name of the engine is derived from the type of fuel used. The fuel used is a diesel fuel; hence, it is also called Diesel engines (khemani H, 2008). Direct usage of coconut oil in diesel engine has two disadvantages: high viscosity and high melting point. These two drawbacks can be corrected by esterification of the oil to biodiesel. Transesterified coconut oil is called Coconut Methyl Ester (CME). Biodiesel from coconut oil has the same cetane number as the original coconut oil but the melting point is below zero degrees Celsius. Biodiesel from coconut oil has similar physical properties as petroleum diesel. The similarity in property makes it possible to transport, distribute and even mixed with petroleum diesel. Furthermore, there is no need for modification of diesel engines to use coconut biodiesel (Krishna R. 2010).

The following steps explain the figure below, the production processes of esterification of coconut oil by using a catalyst (NaOH or KOH) and Methanol:

- A methoxide is produce by mixing the catalyst with methanol. This is first done because the catalysts are in a solid state and do not dissolve immediately in methanol.
- The methoxide is added to the oil in a stirred reactor then a transesterification reaction will start.
- When the transesterification is completed, two products is form in the reactor. The ester, that is the diesel and a glycerol, which is a denser product than the diesel settles at the bottom of the reactor with some allowed hours.
- The glycerol is separated from the diesel but a soapy products formed during the process contaminates the diesel and there is a need to wash the diesel.

There are two types of washing. These are water washing and dry washing. Water washing is done by using distilled warm water gently added to the diesel. Since the methanol and the glycerol are soluble in water, it removes them from the diesel. This is done till the water settling at the bottom of the reactor becomes clear to show that there is no more soapy substance in the diesel (Demirdas A, and Kara H, 2006 619-626). The dry washing is done by replacing water with ion exchange resin or a magnesium silicate powder to remove impurities. These reduce the glycerol level and also effective for removing the soapy substances in the diesel. Because the process does not involve water it eliminate problem such as long production time (Cooke et al. 2005)

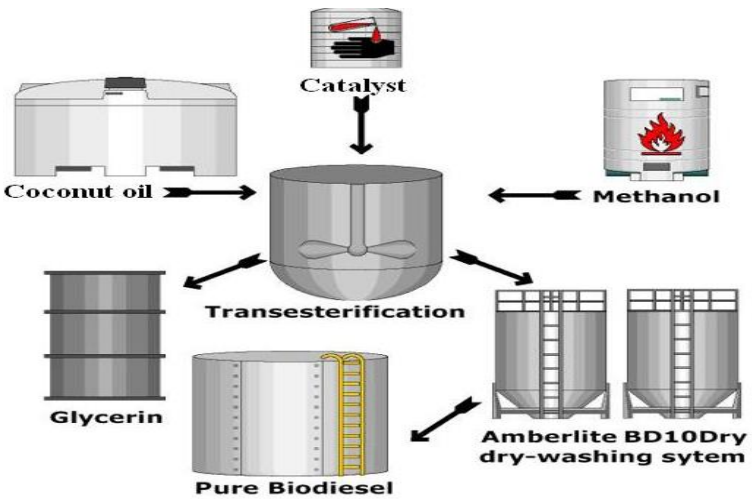

Figure 17. Production process of coconut biodiesel

3.1.1 Factors Affecting Engine Performance Using Biodiesel

- Several factors affect the engine performance by using biodiesel as a fuel.
- Biodiesel as a fuel has less energy per unit volume than petroleum diesel and this reduces the engine power and torque by 3% to 5%.
- The same lower energy content of biodiesel tends to reduce the fuel efficiency of a vehicle than petroleum diesel.
- One advantage in using biodiesel is that it has a long engine wear than petroleum diesel.
- Lower quality of biodiesel tends to deposit and clog the piping line of the engine but if it is of high quality, it is not normally a problem.
- Pollution from engine is less due to the high oxygen content but nitrogen oxide (NOx) emission is high. This can be minimized by proper tuning of the engine.
- Cold weather performance is sometimes a problem, depending on the quality of the biodiesel and the area of operation. Additives such as kerosene to the biodiesel can resolve this problem (Dwivedi G, et al. 2011)

3.1.2 Coconut Oil for Diesel Engines

Vegetable oil as an engine fuel is dated back in the 19th century during the invention of the diesel engine (Demirbas A. 2002). A universal exhibition held in Paris in 1900, a company called OTTO powered a small diesel engine with groundnut oil (Shay EG, 1993). Also, a port in lvory coast which share border with Ghana in the Nzema region had a difficulty in conventional fuels, powered a 50–800 hp engines with filtered palm oil (Vaıtilingom G. 2009). This shows that diesel engines can be powered by a striaght vegetable oil (SVO).

Coconut oil is considered under vegetable oil and it is possible to be used straight in diesel engines. It has been tested in the pacific to be working in diesel engines (Cloin J et al 2005). The use of filtered coconut oil in diesel engines needs a special adaptation on the engine. However, without the adaptation, the engine may have shorter lifetime. The adaptation may be one of the following technical supports:

Fuel heater is installed between the coolant and the fuel to reduce the viscosity of the coconut oil. The heat approximates the viscosity of the coconut to diesel oil. In addition, as

coconut oil solidifies at 25 Degree Celsius, heater in the fuel tanks helps to increase the temperature (Kopial, T. et al 2004)

A start and stop on diesel oil is one of the adaptations needed when using straight coconut oil. The engine is started with diesel oil to heat the engine then the fuel supply switches to coconut oil. When the engine is shutting down the fuel supply switches back to diesel oil (Cloin J., 2005).

Special pumps and extra filters are installed in the fuelling systems to enable the use of straight coconut. For example SPC and CIRAD have implemented a pilot plant in Ouvea using this adaptation (Courty, P. 1998).

3.1.3 Performance of straight coconut oil in diesel engine

There are different performance results when using straight coconut oil in engines. The studies show the following:

- The torque and the power of a diesel engine drops to approximately 10 % with coconut oil (Bari S, Lim TH, Yu CW,. 2002). Meanwhile, with adaptation with injection advance, the engine supercharges (Vaıtilingom G., 2006)
- Compared to diesel oil, coconut oil has higher specific consumption (consumption by unit of power and unit of time). This is due to it higher density and higher viscosity (Vaıtilingom G., 2006)
- The thermal efficiency of coconut oil is lower as compared to diesel oil due to the weak combustion in the engine and can be higher than diesel oil if the engine is adapted (Agarwal D, Agarwal AK., 2007).
- Formation of deposit can be observed on the wall of the combustion chamber, the piston and the injection noses (Vaıtilingom G. 2009)

3.1.4 Biodiesel Blend

Many studies have shown that blending coconut biodiesel with diesel fuel can be possible. The blend depends on the type of studies the researchers needed. Most researchers have test a blend of CB5 (5% coconut biodiesel and 95%) and 15% (15% CB and 85% DF).

However, all these ensuing blends have an effect on the torque and brake power of the vehicle (Liaquat A. M. et al, 2013). The blend of biodiesel and diesel fuel increases the cetane number slightly.

In addition, another type of blend is a purified and filtered coconut oil blended with kerosene, which is popular in Vanuatu in the south Pacific. This is done by blending 85% of coconut oil and 15% of kerosene. No engine modification is needed; however, recommended engine pre-heating is needed. From the studies in Vanuatu, it has been observed that many minibus drivers run their vehicle with coconut oil and kerosene blend prepared by themselves. This blend is known as the Island Fuel (Deamer et al, 2005).

3.2 Utilization of Coconut in Energy Production

Coconut has different types of biomasses that can be used in energy production for example syngas, charcoal and waste heat. The full coconut tree can be characterized into two different biomasses and these are the tree consisting of the leave, trunk and the root) and the fruit consisting of husk and shell. However, for a constant production of energy, the coconut tree are not considered to be the best part for biomass energy production because it is for producing fruit and not economical (Satyanarayana K. G. 1982)

3.2.1 Characteristics of Coconut Biomass (Fruit)

The fruit of a coconut is made up of husks, shell, the meat and water. The most important biomass in the fruit is the shell and the husk. The shell is a dense uniform material covering the meet while the husk is a soft fiber tissue cork usually known as pith. The fibers range from 15 to 35 centimeter in length. The fiber consists of lignin and cellulose and contains 10% pectin, tannins and substances that are soluble and insoluble in water (Raghavan K., 2010). Both the shell and the husk are combusted with different principles to release energy.

3.2.2 Basic Principles of Combustion

Both biomasses (husk and shell) can be combusted by using the following principles of combustion:

Combusting coconut biomass: The shells are burnt with excessive air to produce process heat. Charcoal and tar (a black substance) are discharged if manage properly (Yerizam M., 2014). In the figure below, a furnace filled with coconut shells, and burnt with excess air to use the heat released by the shell. Ashes are collected for other use such as soil enrichment.

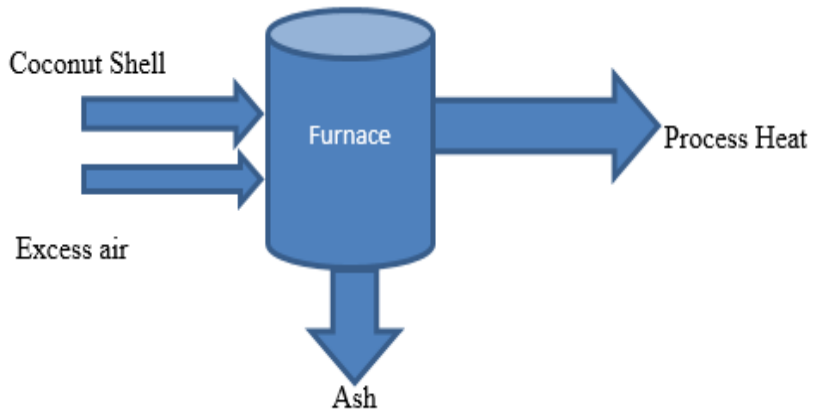

Figure 18. Coconut shell combustionFigure 1

Gasification: In the figure below, a limited air is supply to a gasifier to burn coconut shells to discharge gas that is burnt for process heat. In this process, the tar and char released to the atmosphere is moderate if properly managed (Sivakumar K and Krishna N., 2010).

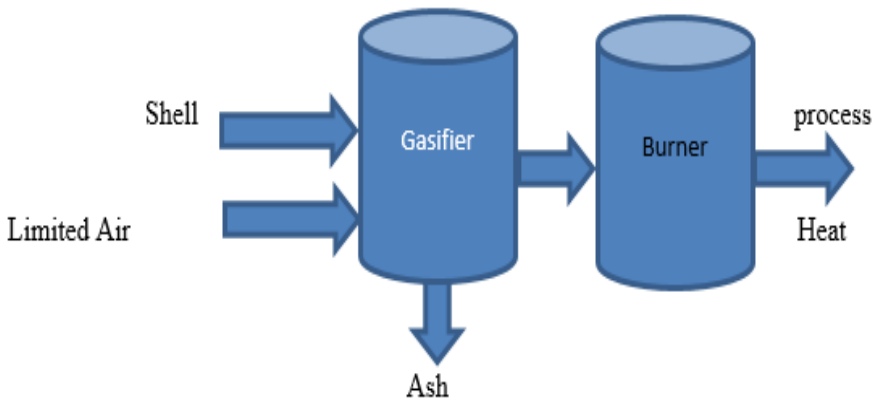

Figure 19. Gasification of coconut biomass

Carbonization: This is a traditional method of burning coconut shells in a pit to produce charcoal with limited air (Strezov V., 2007). In the figure below, a pit is dug in the ground and the coconut biomass is filled. The pit is covered with earth (soil) to allow a limited air for burning. The coconut shell burnt uniformly to produce charcoal. This traditional method releases heat that goes waste. The method has been improved to collect the waste heat.

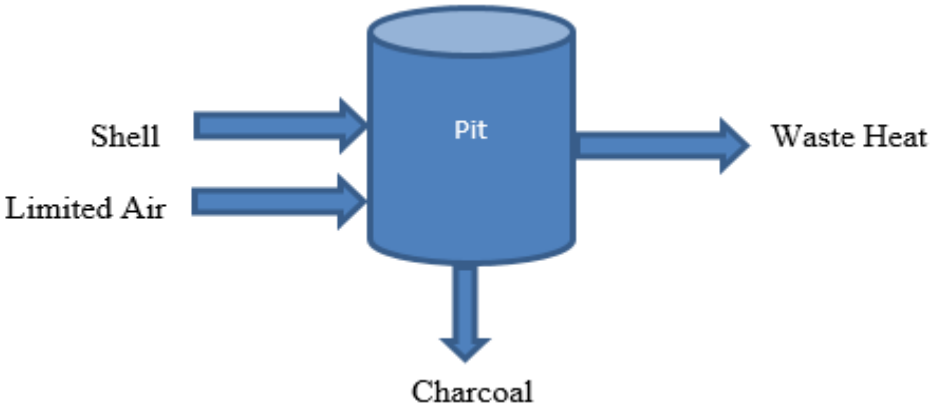

Figure 20. Production of traditional charcoal

Carbonization with Waste Heat Recovery: Charcoal is produced through a carboniser with limited air(Breag G. R. and Joseph P. G., 1989).In the figure below, the methane and other gases release are burnt in the process to produce steam to generate electricity.

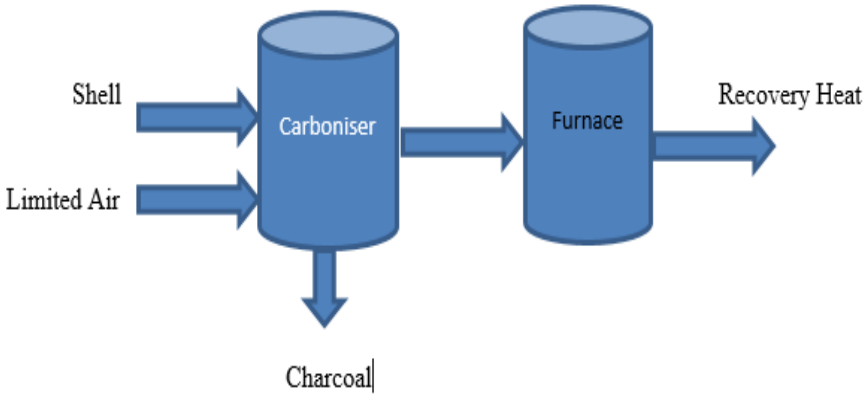

Figure 21. Carbonization with waste heat recovery

Some of the above combustion principles are used in Sri Lanka to produce charcoal. The charcoal is produced in various locations in the north-western part of the country. The biomass is from coconut shell because Sri Lanka is noted for high production of coconut. It is approximated that 185,000 tonne per annum of coconut shell is converted to charcoal. This conversion produces 55,000 tonne per annum of charcoal. The method of production is an open pit charcoal manufacturing (Sugathapaia A. G. T., 2007)

A small-scale project through clean development mechanism has been implemented. The purpose of the project is to generate electricity through activated carbon from coconut shell. The project is using 77,442 tonnes of coconut shell in a year to produce about 26,400 tonnes of charcoal. The project that implemented in five phases generated 5.8 MW of electricity at the end. The process releases methane and vapour, which was combusted to produce steam to generate the electricity (Project design document-CDM-UNFCCC).

3.3 Other Utilization Options

Apart from using coconut for energy purposes, the coconut tree has many uses. The various uses of coconut can be used for domestic and industrial purposes. Coconut tree has many uses because the tree has various parts that can be utilized. The fruit has many useful features that are of importance in medicine and production of cosmetics (Tin Tin B., 2012). Most of the studies in this research concentrated on the energy option from the coconut. In this chapter, more alternative utilization methods of coconut are discussed.

3.3.1 Coconut Tree (Trunk) For Construction

Trunk of the coconut tree is the largest part of the tree. The trunk is use as timber in production of wood. Coconut wood is suitable for construction of trusses, joists, doors, window frames and walls. Because the density varies from the bottom to the top, the low-density part of the wood is used in non-loaded part in construction such as walls and panels while the high-density part are for load-bearing structures such as trusses and joints. The size of the coconut wood board is 25mm in width and 50mm in thickness. This is because of the small diameter of the coconut stem. To resolve the limitation of producing bigger size boards, a glued lamination is required for the desired size (Arancon R. Jr. 1997)

Figure 22. Coconut truck for coco wood

In addition, coconut wood is a good material for manufacturing furniture and handcraft products. The beautiful grain on the surface of the wood and its attractive appearance gives the wood high value when used for handcraft products (Djokoto A. A., 2013)

Figure 23. Coconut wood artefact

Compared to other part of coconut tree, the trunk is useful when the tree starts to give fewer amounts of fruit desired or destroyed by a disease. In addition, the wood is difficult to be nailed because of it hardness. The seasoning process must be checked to avoid cracks developing on the surface; therefore, the moisture content of the coconut wood must be kept at appropriate equilibrium (Arancon R. Jr. 1997).

3.3.3 Coconut as Medicine

Coconut water has a natural electrolyte solution that is good for intravenous therapy. The content of the water is made of higher potassium, calcium, magnesium, phosphate and glucose content than plasma in human (Campbell-Falck D., et al 2008). The roots of the coconut are used in beverage to serve as medicine. The roots are also utilized in dying cloth and producing toothbrush and mouth wash. Health problems such as diarrhea, digestion and dysentery can be treated by coconut root (Tin Tin B., 2012).

More oil has been in the news for being harmful to human health but coconut oil in recent years is useful medicinal oil among others. This is because of its healing agent and good saturated fat (Sayer Ji F., 2012). The following are some of the medicinal properties of coconut oil. Coconut oil has the properties of burning abdomen fat in human. Two studies carried out on both male and female show that taken two tablespoons or 30ml a day can reduce belly fat in a rage of one to three months. In female it reduces the waist circumference and boosted their high-density lipoprotein, which is good cholesterol. In the case of men, two tablespoon of coconut oil ion a day, three times dose, reduces their waist circumference without any change in their blood lipids (Kai Ming L. et al, 2011). Coconut oil contains medium chain triglycerides, which is good in treating mild cognitive impairment (Reger A. M. et al 2004). Coconut oil has the ability to speed re-epithelialization, antioxodant improvement and stimulate collagen cross-linking in tissue (Nevin K. G., and Rajamohan T., 2010)

4 RESULTS AND ANALYSIS

It is possible to determine the amount of energy in coconut and gasoline saving in Ghana if coconut is well utilized in the country. From data gathered, the country produced 290000 tons of coconut in 2013, which is the current data available. In addition, the average weight for a single coconut is 1.2 kg. The heat of combustion of gasoline at 0.733kg per liter is 7795 kcal per liter or 32636.106 KJ per liter (Diaz-Gutierrez L. et al. 2005). From all these data, the amount of energy in coconut and gasoline saving is as follows:

Quantity of coconut in kilogram (kg) $= 290000\ tone = 290000000kg$

Number of coconut fruits $=\frac{290000000\ kg}{1.2\ kg} = 242000000\ approximately$

Therefore, it is possible to calculate the energy in each part of the fruit (shell, husk and coconut oil).

Energy from coconut shell in joules $= 990\frac{kcal}{nut} \times 242 \times 10^6$

$$= 2.396 \times 10^{11} kcal\ = 10.032 \times 10^{11} kj$$

Energy from coconut husk in joules $= 1600\frac{kcal}{nut} \times 242 \times 10^6$

$$= 3.872 \times 10^{11} kcal = 16.211 \times 10^{11} kj$$

Energy from coconut oil in joules $= 1080\frac{kcal}{nut} \times 242 \times 10^6$

$$= 2.614 \times 10^{11} kcal = 10.944 \times 10^{11} kj$$

Comparing to 7795 kcal per liter or 32636.106 kJ per liter of gasoline, each part of the coconut fruit can be converted from kcal to liters.

Amount of energy from coconut shell in liter (l) $= \frac{10.032\times10^{11}kj}{32636.106\text{ kj }/l} = 3.074 \times 10^{7}\ liters$

Amount of energy from coconut husk in liter (l) $= \frac{16.211\times10^{11}kj}{32636.106\text{ kj }/l} = 4.967 \times 10^{7}\ liters$

Amount of energy from coconut oil in liter (l) $= \frac{10.944\times10^{11}kj}{32636.106\text{ kj }/l} = 3.353 \times 10^{7}\ liters$

Total amount of energy in coconut compared to gasoline is $= 11.394 \times 10^{7}\ liters$

Converting $11.394 \times 10^{7}\ liters$ to tonne at the same density of 0.733kg/l gasoline used in vehicles in Ghana, the country could have saved or reduced importation of gasoline by 83998 tons.

Usage of charcoal produced from coconut husk and shell as substitute for some amount of methane gas used for cooking in some Ghanaian homes may also reduce the importation of methane gas into the country. A normal coconut shell that has a weight of 0.18kg may reduce to 0.0504 kg after carbonizing the shell to charcoal for a heating value of 1515.332kjoule. Charcoaling a normal coconut husk at 0.40 kg may reduce in weight to 0.0868kg, given heating value of 548 kcal (Montenegro, H. M. 1976).

Therefore, the total energy from coconut shell charcoal and coconut husk charcoal can be calculated using 2013 data for number of coconuts produced in Ghana.

Energy from coconut shell charcoal kcal = $1515.332\frac{kj}{nut} \times 242 \times 10^{6}$

$$= 3.6676 \times 10^{11} kjoules$$

Energy from coconut husk charcoal kcal = $2293.928\frac{kj}{nut} \times 242 \times 10^{6}$

$$= \mathbf{5.5525 \times 10^{11} kjoules}$$

Total energy from coconut shell and husk charcoal $= 9.2201 \times 10^{11} kjoules$

Comparing the energy gained from non-charcoaling coconut product and charcoaling shell and husk, the energy value obtained in charcoaling shell and husk was less. This means, there were energy losses during charcoaling to gases. These gases can be recovered and used as fuel.

This figure could have increase if most of the coconut farmlands were still being used for coconut plantation. The figure did not include the use of the coconut branches (petiole) that fall under the coconut trees when it is dried. This is because it is difficult to quantify the amount of branches that fall per hectare of coconut plantation. Another factor to increase the energy gained from coconut is to utilized the squeezed kneel or meat in feeding piggery. Piggery dumps may be utilized in biogas production to substitute part of the imported petroleum gas into the country. The pigs may serve as a food source for human.

From the study, it is shown that the coconut plantation is not only source of energy but has some concepts that are more than most quick-growing energy trees. The following could be deduced from coconut plantation:

- The energy from coconut plantation is harvested from the shell, husk and the oil. Sometimes the petioles are also utilized as heating fuel. However, from most of the energy growing trees, the trees are cut down.
- The energy from coconut plantation is harvested periodically and can be uniform. This can be done monthly depending on the energy demand.
- The plantation does not need replanting because the trees are not harvested. This makes coconut plantation more sustainable than other energy producing trees in the sense that less land are used.
- Most of the farmers in the region depend on the same land that has the coconut plantation for growing other food crops such as cassava and others. This reduces competition for land in the area.

Analysis on supply of coconut for the production of biodiesel was done based on the current situation and the result shows that buying coconut from farmers to produce biodiesel can be beneficial because the price of conventional diesel in the market keeps on

rising due to the unstable rising of US dollar rate to the Ghana cedis. The following calculations were obtained.

Table 9. Calculating the cost of 1 liter of coconut oil when coconut are bought

Cost of producing 35 liter of coconut oil		
Number of nut needed	**350**	
Cost of 350 nut in Ghc	**105**	
Cost of labour for 350 nuts in Ghc	**17.5**	
Cost of grating for 350 nut in Ghc	**7.5**	
Cost of transporting 350	**2**	
TOTAL COST	**132 Ghc**	

Therefore, the cost of 1 litre of coconut oil $= \frac{132\ Ghc}{35\ l} = 3.77\ Ghc$

The cost of coconuts in the table above is as of November 2014 and has raised in recent time because of the Nigerians buyers that are in the area for the coconuts. They compete with the local buyers in the buying process and with their high purchasing power; it encourages farmers to sell their coconuts to them. The cost of labour was calculated to include the cost of cracking and the cost of extracting coconut juice. Again, the cost of coconuts collection may be ignored because the farmers did most of the collections. The transportation cost covered delivery from the plantation to grinding machine site. The

transportation cost in the table was an average cost. This is because the distances from the plantation may differ.

If coconut oil is directly used as vehicular fuel then, this price of 1 litre of coconut oil is higher than conventional diesel, which is 3.30 Ghc at the pumping station. The cost of turning coconut oil to biodiesel will increase because there will be addition cost of adding methanol and other chemicals in trans-esterification process. In addition, there will be an extra cost of labour during the process of biodiesel production.

During the calculation, the shell and husk that can be used in charcoal production or for sale were not considered. If we consider the shell and the husk, then production of energy from coconut may be more profitable in this sense. In addition, to increase the profitability of energy from coconut, then the producer must have his or her own coconut plantation. Therefore, the price of coconut may be eliminated from the calculation and all the by-products such as waste squeezed meat must be utilized. In commercial production, whereby labourers are paid monthly could be economical than the current payment arrangement which depends on the number of nuts processed. This is because the leaving expenditure in the region is low so paying a higher salary may be a disadvantage to the production.

In the above situation, the calculation were done, if coconut are bought from farmers but if the coconut plantation is for the oil producer then the price per litre for coconut oil will reduce from 3.77 Ghc to 0.77Ghc The table below shows the data collected from farmers.

Table 10. Calculating the cost of 1 liter of coconut oil when coconut are owned by the oil producer

Cost of producing 35 liter of coconut oil		
Number of nut needed	350	

Cost of 350 nut in Ghc	0	
Cost of labour for 350 nuts in Ghc	17.5	
Cost of grating for 350 nut in Ghc	7.5	
Cost of transporting 350	2	
TOTAL COST	27 Ghc	

Therefore, the cost of 1 litre of coconut oil $= \frac{27\ Ghc}{35\ l} = 0.77\ Ghc$

The result shows that 1 litre of coconut oil may cost 0.77 Ghc. This may help farmer to continue to utilize coconut oil as energy. In addition, waste such as shell and husk from the production may be also utilize by the coconut oil producer for charcoal and it may be more profitable in this sense. The cost of coconut fruit were considered null because the coconut plantation is treated as a wild plantation with little investment and the plantation does not need any extra cost when it grows to a certain height even before and after bearing fruit.

From the above calculations it could be discussed that the price of coconut oil in Nzema lower compared to conventional fuel in the market. Coconut oil as a fuel in vehicular fuel can help the people in the area to reduce the cost of transportation in coconut oil production. Depending on alternatives utilization of coconut in the Nzema will increase the income of coconut farmers than only using the coconut fruit for oil production. Furthermore, with the increase in income social life in each community may improve for the better by taking care of their children in schools and contribute to community development such as healthcare. Moreover, food security may be assured since plantation of coconut provides fruit as food and the oil from the fruit is good as medicinal oil. In addition to the food security, waste produced from coconut oil is suitable for pig

production in a large scale that can decrease unemployment by employing the youth in the area. Utilizing coconut in alternative ways can help develop skills such as artefact.

Again, the result tells that the alternative utilization of coconut can reduce environmentally affected issues caused by coconut oil production and deforestation. Most of the wastes generated during coconut oil production are useful in energy production such as charcoal production noted in the thesis. Most of the people in Nzema communities depend on firewood for heat or cooking. The fell of virgin vegetation has increase the level of deforestation in the area meanwhile, unused husk and shell can be used as charcoal. The husk and shell has significant heat energy as seen in the result calculations. In addition, timber from forest as constructional wood can be also obtained from coconut tree. Moreover, the use of coconut oil in vehicular engine may not only profit farmers but has environmental benefit as compared to conventional diesel. These are some of the benefit that can be discussed:

1. Coconut oil are liquid fuel from renewable source
2. Coconut oil as a fuel do not over burden the environment with emission
3. Coconut oil as a fuel has the potential for making marginal land productive by their property of nitrogen fixation in the soil
4. The production of coconut oil as a fuel requires lesser energy input than conventional diesel.
5. Coconut oil has higher energy content that other energy crop like alcohol.
6. The coconut oil combustion has cleaner emission spectra.

But from thesis it was review that the coconut oil production needs further research and development work for development of on farm processing technology in Nzema.

The economic feasibility of coconut oil as a fuel depends on the price of convention diesel fuel and the transportation cost to the rural areas where coconut plantation are found. The cost of petroleum products in Ghana are increasing due to the rate of Ghana cedis to the US dollar. The dollar always overshadows the cedis and this makes the price of diesel higher that coconut oil since most of the petroleum products in Ghana at the moment are imported into the country.

The answer to effective development of biofuel from coconut oil lies in the availability of resources and the capacity of Ghana to develop these resources. In particular it depends on the motivation of farmers to maximize their income, regulatory frameworks and as well as policy, institutional capacity that facilitate such development. To start this process, however, appropriate data on coconut resources are needed in Nzema. These include the current coconut plantations as well as the suitable land area for future development of coconut plantation. The major issue for implementation of coconut oil as a fuel will be updating the current data on feedstock for production of alternative coconut utilizations. Another stage to consider in the development is land resources in Nzema. The total land area of Nzema is 21941 square kilometres and most of the land is fertile for coconut plantation (Nzema East Municipal Assemble 2006). But not all could be used for coconut plantation because other food crops may be needed as food in the area.

As noted earlier, in the thesis on of the problems facing the alternative utilization of coconut is the lack of human capacity in the area it institutional mechanisms to develop the some of the above alternative methods. The area has already has agriculture institute that research into coconut and other crop but not it alternative utilization especially how to utilize coconut in energy production. This needs expansion and the required human capacity in the field of vegetable oil to energy production. The field of vegetable oil to energy production that is biofuel will call for the establishment of educational institution that will produce human capacity with such knowledge. Again the development of home grown technologies and biofuel industries in the country need to be encouraged.

With the current energy crisis in the country, Ghana needs to develop its policy framework towards finding solution to the energy challenges and one of the first step is its biofuel industries and its tradition heating energy industry. The country which is not generating power from waste can do so by using waste from coconut and other agriculture waste. This can be included in the national energy policy and rural electrification could utilize waste to power generation. Currently, the possibility of using biofuel in Ghana is not encouraging because the country has now discovered oil and gas deposits in the same region where Nzema could found. Most of the attention is on the conventional fuel than biofuel. This calls for the private and individual to pay attention to biofuel production to minimized cost because high percentage of the conventional fuel discovered is not in use in the country

especially the oil, only the gas will be in use but not sufficient to produce power. Government of Ghana need to do more concerning the use of biofuel especially in coconut production that has more alternative utilization methods than other oil producing crop.

5 CONCLUSIONS

Coconut plantation is one of the main sources of income for the people of Nzema, in the western region of Ghana. This research focused on alternative methods of utilizing coconut in Nzema to generate income for farmers through energy productions. The research analysed the life cycle of coconut oil production from the plantation. Utilization of waste products from coconut oil production to maximize energy sources in the region and it benefits were studied. A field study conducted by the author on the current situation revealed that wastes generated from coconut oil production are not fully utilized to the benefit of farmers.

The research investigation has revealed some of the actors in the coconut oil industry and marketing. Some of the actors in the industry and market include the ministry of food and agriculture (MoFA), coconut farmers, the youth in the area that involves in processing of coconut oil, the local and Nigeria buyers, and local processors. Most of these actors involve themselves to satisfy their own economic sustainability, sometimes to the disadvantage of the farmers. It is known that none of these actors are planning to maximise profit through energy production. However, the local buyers export the coconut oil to different regions in the country to be used as cooking oil. The Nigerians export the coconuts to part of Nigeria to be use also as cooking oil. Besides this, the farmers sell some of the coconut fruit to other oil processing intermediates to be used as oil. The research concludes that, no actor is utilizing the coconut husk and shell to produce any form of fuel

such as charcoal, biodiesel and others. However, a few of the husks attached to the sell are used in processing the oil to evaporate the water and purify the oil.

It was revealed that most Ghanaians depend on renewable fuel. This renewable fuel is charcoal that is used by most of the indigenous Ghanaians in the rural areas including Nzema. Utilization of husk and shell from coconut fruit as renewable fuel could be a profitable business in the area and in Ghana as a whole. The study unveiled that people in the Philippines and in the pacific had developed a bio char from coconut shell and its husk. This bio char business has added a value to the coconut production in the region and increased the profit gained by coconut farmers. In addition, the energy gained from coconut oil production has reduced the quantity of convention fuel such as diesel and petrol imported into some regions in the pacific island such as Fiji. Fiji Island has advance in utilizing coconut oil as fuel to produce electricity. In place of diesel fuel, Fiji has demonstrated project by using copra oil in diesel engines to produce power for the people of Lomaloma, Island of Vanubalavu.

Therefore, there is the need to upgrade the coconut production in Nzema. The upgrading could be activities such as plantation, processing and products functional upgrading. Most of the farmers interviewed do not know much about the possibilities of upgrading especially the current traditional processes. This is due to the high level of illiteracy of most of the farmers to conduct research for various improved method of processing. In addition, the scale of production is based on individual farmers, which is small scale. There are no medium and large scale productions of coconuts in the area to help farmers to learn any system of improvement. The only product from coconut know in Nzema is coconut oil for cooking. By upgrading, production to biodiesel and utilizing most parts of the coconut tree may be beneficial to the local farmers.

Apart from the farmers, the government of Ghana must pay important attention to coconut plantations as it has done to cocoa plantations. Undertaking capacity building initiatives such as training farmers and involving government departments such as Ministry of Energy and Ministry of Agriculture can help improve coconut plantation. Financing and funding of projects undertaken by farmers to expand the production. Creation of awareness on applying straight vegetable oil in the energy sector of the country must be promoted. The

government can create biofuel organizations that can collects and collate world and regional information, lessons, experience and knowledge on vegetable biodiesel. In addition, the government can ensure regulations and laws are enacted to permit blending of conventional fuel and vegetable oil. A developed national and regional standard of quality biofuel can be put in place; these standards should be practical and workable but cooperate with manufactures of coconut oil, petroleum companies and vehicular manufactures. As it is in cocoa farming sector, coconut farmers can have exemption in school fee or scholarship for their children in high schools.

However, the environmental and ecological effects of coconut production must be examined in the Nzema. Ensure adequate utilization of waste generated by the production. The waste generated from coconut oil production can add value to coconut production by providing other products. In addition, a supply chain systems and technologies are needed to ensure a constant supply of feedstock for energy production. Most of the shell and husk are hiding in the farms and are not accessible. The government can help by constructing good roads that can help individual farmers to access their produce. Nzema has one of the highest rainfalls in the country and that makes its unpaved roads very bad to access the coconut plantation.

Again, biodiesel has become one of the attractive ways of using vegetable oil on the world because of it environment benefit and the fact that it is from a renewable source. The methods of choice for coconut oil as a fuel in Nzema is transesterification process that bring about a change in molecular structure and start and stop engine with diesel fuel during drying season in Ghana. The viscosity of the coconut oil is reduces after esterification. All test done on coconut oil show that almost the properties that are important for engines are very close to conventional diesel.

Finally, this research paper has adequately contributed to the possibility of utilizing coconut for energy production in Nzema. In addition, the paper has suggested some products that are produced from coconut. These products are produced either from coconut fruit or from other parts of the tree. However, another area that requires a further research in the future of energy from coconut is the supply chain systems and procedures of gathering all coconut waste to produce energy.

6 SUMMARY

The purpose of this thesis is to find out the alternative utilization method of coconut in Nzema, Ghana. The reason for writing this thesis is to help the indigenes in Nzema to have alternative knowledge on coconut utilization than oil production. The methodologies used in this thesis were literature review and field interview in Ghana, where most of the interviewees were coconut farmers.

The thesis is composed of five chapters, each of the chapters has different aspect of coconut utilizations and it benefits. The first chapter is the introductory and has sub parts. The first part of the introductory describes some of the common usage of coconut in the world and the utilization in Nzema. The next part is the statement of the problem of this thesis followed by justification and relevant of the study. In these parts the thesis described the location of the Nzema land in Ghana, the current utilization of coconut in the world and the methods used in production coconut oil in the area. The last three parts of the first chapter were the research objective and question, research methodology and current coconut usage in the area.

The second chapter examined the life cycle of coconut oil in Nzema from collection of the coconut, dehusking or cracking, nut or kernel transportation and copra or oil making. The second chapter has parts. The first part is the oil pressing and refining, it explains the procedure to extract coconut oil from the kernel. The next part describes the possibility of getting many type of biofuel for coconut such as utilization of the husks and the shell for heating. The last part of the second chapter examined the compositions of coconut oil and it possibilities as vehicular engine fuel.

The chapter three researched the different utilization methods of the whole coconut tree. The first utilization is examines the possibility of using coconut oil as biodiesel in Nzema, Ghana. This part highlighted on some countries such as Fiji and Sri Lanka with possible utilization of coconut oil and palm oil as biodiesel. In addition, energy can be generated from coconut oil as a fuel in generators and the husk and shell as charcoal production for heat energy in Nzema. Moreover, there are other optional utilizations describe in chapter

three such as using the coconut roots as medicinal purposes, the trunk as timber for construction and artifacts

The fourth chapter concentrates on the result and the analysis of the research. In this chapter the amount of coconut produce in 2013 was used in calculating the amount of energy it could have given to Nzema, Ghana. The energy from the coconut if utilized could have reduced the importation of conventional diesel fuel into the country and also reduce environment effects. Again, in this chapter, calculation was done to determine the price of coconut oil if coconuts are bought from farmers and compared to the price of coconut oil if an oil producing company has its own coconut plantation. Also, these two prices were compared to the current price of conventional diesel fuel as at November 2014 to know the cheapest fuel at that time.

Conclusions are drawn in chapter five and the chapter concludes the possibility of utilizing coconut for energy and alternative purposes. It also discussed the main idea of the thesis and some effects if coconut is utilize. Most of the countries that utilized coconut for energy and other purposes were mention to support the possibility of utilize coconut for other alternative purposes in the area. The conclusion chapter also discussed the environmental effects that Nzema or Ghana might gain in term of utilizing coconut as vehicular fuel or production of energy for the area. There were suggestions made in the conclusion to the appropriate ministries to support coconut farmers in the area to maximize the social and economic sustainability.

Appendix 1: The map boarded blue is the study area

Appendix 2: Interview Guide

Interview guide for study on selecting the best utilization method for coconut in Nzema, Ghana, November to December, 2014

[The research is part of the study programme for an award of Master of Science in environmental technology studies at the Lappeenranta University of Technology. The purpose of the research is to carry out field assessment of how coconut can be utilized in the energy sector].

The information obtained will be treated confidential and shall only be used for the purpose of this academic research.

Name of Interviewee: …… Age: ……

Sex: ……

Married Status:

Single: ..... Married: …… Divorcee: …… Widow/Widower: …….

Educational level:

None: …… …… Primary: ……

Secondary: ……..... Tertiary: ……

Date: ……

Theme 1: Social and Economic Sustainability of Farmers

1. Are you a farmer Mr. /Madam…..?
2. Do you have coconut farm?
3. Where is your coconut farm?
4. From your estimation how many hectares of coconut farm do you have?
5. Did you cultivate the whole farm yourself or some were bequeathed to you?
6. If **yes** who bequeathed it to you and when?
7. Do you share the proceeds from the inherited farm with other extended family members and at what proportion?
8. How often do you harvest your coconut in a year?
9. Do you harvest the coconuts by yourself or with your family or you hire the services of labourers?
10. If you engage labour services, how much do you pay a labourer per day?
11. Does the labourer do the harvesting and picking at the same time to earn the daily wage?
12. If **no,** who does the picking of the nuts?
13. In what form do you harvest your coconut? Dry or fresh state?
14. Do you sell your coconut?
15. Where and to whom do you sell your coconuts?
16. Let say every three months, how many coconut can you sell?
17. Which buyer or groups of buyers do you normally sell your nuts to?
18. Do you have specific customers/buyers who buy your coconuts?
19. Are you in constant touch with these buyers?
20. Suppose you are in financial difficulty, do you think the buyers would be prepared to advance to you some money and later use the coconut they buy to pay back?
21. If yes, have you ever receive such an offer before from your buyers?
22. How would you describe your relationship with these buyers?

Theme 2: Solid Waste Generated from Coconut Oil Produce and Its Energy Utilization

1. What do you use the coconut fruit for?
2. Where do you process the coconut (cracking or dehusking)?
3. Do you have your own grinding machine?
4. Where do you grind your coconut and oil processing?
5. What do you use the oil for?
6. Do you use the oil as a vehicle fuel? YES OR NO
7. Have you heard that it can be used as vehicle fuel?
8. Do you think using the coconut oil will help your production?
9. Where do you leave these husks and shells?
10. What do you use the husk and shell for and the amount used?
11. In some countries the husk and the shells are used in charcoal production. Will you like to do the same to maximize your profit?
12. Apart from the charcoal production, what do you think the husk and shell can be used for?

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