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Bio-Energy Carriers in Agriculture in the Republic of Zambia

Master's Thesis

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Assignment Form

Declaration

I hereby declare and confirm that this thesis entitled “Bio-Energy Carriers in Agriculture in the Republic of Zambia” is entirely the result of my own work and all the sources have been quoted and acknowledged by means of complete references. This project is in partial fulfilment of the requirements of the award of Master degree of Sustainable Rural Development in TS at Czech University of Life Sciences.

Place and date:…….. Signature:……..

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Authorization to lend the thesis

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Acronyms/Abbreviations

AEO – African economic Outlook

AU – African Union

BAZ – Biofuels Association of Zambia

BPC – Botswana Power Corpration

CO_2 – Carbon Dioxide

COMESA – Common Market for Eastern and Southern Africa

CSO – Central Statistics Office of Zambia

DRC – Democratic Republic of Congo

ECOWAS – Economic Community of West African States

EDM – Electricidade de Moçambique

ENE – Empresa nacional de Eectricidade

ERB – Energy Regulation Board

ESCOM – Electricity Supply Corporation of Malawi Limited

ESKOM – Electricity Supply Commission

EU – European Union

FAO – Food and Agricultural Organization of the United Nations

GDP – Gross Domestic Product

GHG – Greenhouse gasses

HDI – Human Development Index

IMF – International Monetary Fund

IRENA – International Renewable Energy Agency

KM^2 – Square Kilometer

LDCs – Least Developed Countries

LEC – Lesotho Electricity Company

MDGs – Millennium Development Goals

MoF – Ministry of Finance and National Planning

Mtoe – Million Tons of Oil Equivalent

NDP – National Development Plan

NGOs – Non-governmental Organizations

REA – Rural Electrification Authority

SACREE – SADC Center for Renewable Energy and Energy Efficiency

SADC – Southern African Development Community

SAPP – Southern African Power Pool

SEB – Swaziland Electricity Board

SNEL – Société Nationale d'Électricité

TANESCO – Tanzania Electric Supply Company Limited

TWh – TerraWatt Hour

UN – United Nations

UNDP – United Nations Development Programme

UNIDO – United Nations Industrial Development Organization

USA – United States of America

USD – United States dollar

ZESA – Zimbabwe Electricity Supply Authority

ZESCO – Zambia Electricity Supply Cooperation

Abstract

Bio-Energy Carriers in Agriculture in the Republic of Zambia thesis was carried with some of the main objectives as: analyze the importance of moving from fossil fuel dependence to renewable and sustainable energy; identify which plants can be used as bioenergy carriers in Zambia; justify why energy crops should be considered and used as biomass feedstock for bioenergy carriers in Zambia; analyze what energy and how the energy is produced from these carriers; identify some of the constraints in bioenergy development in Zambia and how to improve the bioenergy sector. The primary data was collected with the help of a questionnaire and 7 energy crops were realized to be grown by the respondents in Eastern Province where the research was done, namely, Cassava, Sweet Potatoes, Sugar Cane, Sorghum, Elephant Grass, Cashew Nuts and *Jatropha*.

The results shows that Zambia indeed has the potential to be among the major powers of bioenergy production in Africa with its massive unused and deforested land. The energy crops grown as biomass feedstock and bioenergy carriers in Zambia have a higher chance of development because they will not affect the prices of the food commodities as these plants are not staple food compared to maize. With the country's climate, landscape and some inputs, all these energy plants are capable of producing high yields and harvests which would be used to produce bioenergy not only for Zambia, but the country would also export to other countries who lack the abundance of land Zambia has.

The growth of these bioenergy carriers and biomass feedstock contributed to the bioenergy sector which is slowly contributing to lowering the current high unemployment rates especially among the rural areas. For Zambia to fully reap the benefits of bioenergy sector should address main constraints in this sector among others lack or low level of technology and know-how in this field. Zambia has recently been cooperating with Brazil and China in bioenergy which is a good sign since both countries are major powers in bioenergy production. Zambia through the relevant ministries still has a lot to do.

Keywords: bioenergy, biofuels, biodiesel, Jatropha, biomass, renewable energy, Zambia

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1. Introduction

$19^{th} – 20^{th}$ century saw a lot of research in the development and enhancement of coal, crude oil (petroleum) to find ways to make use of the available fossil feedstock. The fossil feedstock end products include fuel, chemicals, plastics, fertilizers, lubricants, coke, and asphalt among others to satisfy the increasing demand from the increasing population (Bender, 2000; Demirbas, 2006). According to Shell[1], the need for renewable energy resources is increasing due to the fact the fossil fuels are not sustainable and their reserve levels are also decreasing. It has also been proved that the burning of fossil fuels greatly contributes to the high levels of CO_2 in the atmosphere and these effects of Greenhouse Gas (GHG) are main causes for Global warming (Mabee, et al., 2005).

With all these reasons, the research and investments in renewable energies is becoming more urgent than ever. The world is turning its eyes to the Bio-mass as a source of this renewable and sustainable energy. It has become clear that biofuels from such sources would help tackle the problem of high CO_2 levels damaging the environment from usage of fossil fuels. Biomass end products can also greatly help reduce the current levels of dependence on unsustainable fossil fuels. Biofuels from Biomass such as plants or organic waste need CO_2 to grow and will consume the CO_2 in the atmosphere and in return there will be no increase of CO_2 levels (Osamu and Carl, 1989).

The increase in demand of biofuels and bio-products would in the long run also help alleviate poverty levels in rural areas by providing new income to farmers and employment. It would also help expand the agriculture sector and its contribution to Zambia's GDP, this would in turn help the vision of the government to diversify the economy from being too much dependent on Copper production with its prices unpredictable. This all makes the 21^{st} century's challenge is to move from the dependence on fossil fuels to biomass energy resources (Stevens, 2004; Mongoyana, 2009). A good example of Bio-Energy sector creating

[1] Shell is one of the biggest Petroleum Companies in the world

so many jobs is Brazil where it has generated almost 1.5 million direct jobs in the country (Zanin et al., 2000).

Arguments are that although biofuels produced from these renewable resources help fight global warming and ensure national energy security, but one of the biggest challenges in its production is that it might become a competition between growing crops for food and biofuels. Since the need for energy is growing with the growing population and technologies so the same land would have to be used for energy crops and food crops, and sometimes the food crops such as corn (maize)[2] is also used to produce this renewable energy. This has been categorized as one of the causes for rising food prices due to growing numbers of using such biomass crops for fuel production (Laursen, 2006).

According to Ohimain (2010), five main crops have so far been tested and are in use as biomass to produce Ethanol in five different countries and regions, namely: Sugarcane (Brazil), Corn (USA), Cassava (China, Thailand and Nigeria), Sorghum (Philippines and India) and Sugar beets (European countries). The problem with these crops is that in many countries and regions they are significant food crops, for instance Corn and Cassava are staple food for most of African population (Mongoyan, 2009). This is where the need for non-food crops as biomass become a much more challenging factor and that is where crops such as *Jatropha* and Elephant grass become the most suitable and reliable renewable energy resource.

For countries like Zambia with abundant of unused land, growing biomass energy crops should not be a problem or cause competition between food and fuel production/usage. There are a lot of advantages of using these bio-energy plants to produce sustainable energy for Zambia and its growing energy demand as the population adapts to new technologies. According to United Nations, Zambia has high levels of urbanization[3] whereby almost half of its population in 2014 was living in urban areas, this leaves a lot of land in rural areas

[2] Corn is a staple food for most of the countries in Africa
[3] Urbanization refers to the increasing number of people that live in urban areas

unused. Most of this land is deforested and bare land as the trees were cut down for firewood and charcoal.

Zambia's main source of its electricity power is water with about 95% of electricity being hydro-power generated. Currently most of the electricity used in Zambia is generated from the Kariba Dam which when the water levels are normal it produces about 1,600 MW for both Zambia and Zimbabwe. The last years the water levels have been greatly decreasing in the Kariba Dam causing the reduction of power generation. By end of 2015 the water levels were below 20 % of the normal levels due to severe droughts experienced by the entire Southern African region and this has caused the power generation to be reduced to great extremes like never before. And because of the low power generation Zambia has been going through severe load shedding and on several occasions the country experienced a near total blackout.

These load shedding are experienced by the entire country including sensitive parts of the already struggling economy such as mining industry and hospitals. Most of the private business sector now are having diesel-powered generators readily available in order to minimize loss of business and refrigerated goods to get destroyed. But then the country is also often faced with fossil fuel shortages making even the diesel-powered generated not efficient enough. It is for these very reasons other sources of renewable energy must be sought and utilized such as biomass and possibly solar and wind energy.

The Zambian government has set goals to electrify rural areas by 2030 whose vision is "Electricity for all rural areas by the year 2030" and it is a draft Renewable Energy Strategy which outlines major goals and objectives for the renewable energy resources. The Zambia's rural are off-grid the national power grid and will not be easy and cheap putting these places on national grid line. This the reason the Minister of Energy is encouraging standalone power plants with electricity generated from biofuels or biodiesel powered generators.

2. Literature Review

2.1. Country Background

Zambia is considered as the heart of the Southern Africa because of its location in the region. It is a land locked country surrounded by seven countries which are: to the north it is bordered by the Democratic Republic of Congo (DRC) and Tanzania, to the west is Angola, Namibia to the south-west, to the east are Malawi and Mozambique, and to the south it is bordered by Zimbabwe and Botswana. According to SADC[4], Zambia covers an area of about 752,612 km^2 and is subdivided into 10 provinces. According to the latest census carried out and reported by Zambia Central Statistics office, the country's population is around 13.8 million with an average growth rate of about 3.06 % and about 48 % of the population living in few urban areas. Most of the population is around Lusaka – the capital city and Copperbelt province because of the mining activities.

Figure 1: Map of Zambia

[4] SADC – Southern African Development Community

In the last 15 years Zambia has enjoyed strong economic growth with an average of 6 % Gross Domestic Product (GDP) and in 2013 the growth reached 7.5 % (Word Bank, 2014). According to the African Economic Outlook (2013), Zambia's main contributor to GDP is the service sector accounting for about 70 % of the total GDP followed by the agriculture sector contributing 20 % and 10 % coming from the mining and manufacturing sector. The strong economic growth has been attributed to improved macro-economic management, privatization, economic liberation and a boom in resources. Despite the fact that figures of the growth are positive, the country still has a lot of challenges. For example, the 2014 Doing Business Report ranked Zambia 83rd out of 185 countries, although this is seven places better than it was ranked by World Bank in 2013. This can also be considered as an improvement.

Regardless of the mentioned economic growth, generally there is slow progress in improving human development and social conditions. This is shown in the 2011 Human Development report (UNDP, 2013), Zambia is placed on 163rd from 187 countries with a Human Development Index (HDI) of 0.45 against the 0.48 for the Sub-Saharan Africa average. Zambia is also expected to miss most of the Millennium Development Goals (MDGs) with an exception of education where it has made tremendous improvements. Rates of income, social services and asset inequalities are rising as well accompanied by high levels of unemployment which SADC estimates it to be around 30 % (2010). SADC and Zambian Central Statistics Office (CSO) has attributed this to the fact that about 90 % of employed workers are either in the category of temporary/vulnerable worker or involved only in informal sector. This was also confirmed by the African Economic Outlook report (2013). The government is working on addressing these challenges which play a bigger role in the country's high poverty levels.

2.2. Energy and development

The Zambian government has placed energy sector as a main force the socio-economic development the country needs. The government has proved this with vision called: Zambia Vision 2030 which is a long term plan for Zambia to be middle-income country by 2030. This

vision clearly states that one of its main objectives is to have "universal access to clean, sustainable and affordable energy at the lowest economic, financial, social and environmental cost, consistent with national development goals, by 2030". To show its commitment in achieving this goal, the Government of the Republic of Zambia (GRZ) has developed the so-called five-year National Development Plans (NDPs) making energy as one of the main goals. In the 6th NDP (2011 – 2015) the focus is on securing reliable/sustainable and affordable energy supplies to boost expansion of Zambia's growth sectors, which includes mining, agriculture, tourism and manufacturing (Zambia's Ministry of Finance and National Planning (MoF, 2011).

In 2011, Zambia's electrification rate was around 22 % with only about 3 % in the rural areas and 45 % in urban areas. It is with this regard that the 6th NDP also put focus to have at least 40 % of the population to have access to electricity by 2015 and about 15 % of the rural areas to be able to have access to electricity as well. The 6th NDP also recognizes mining sector as the sector that greatly contributes to the country's economy accounting for about 78 % of total Zambia's exports in 2010 and also the sector that consumes the biggest percentage of energy in the country. Hence the need to finding and improvement of sustainable energy resources would help the mining sector to be less dependent of the electricity as a major energy source produced by the Zambia Electricity Supply Cooperation (ZESCO). ZESCO is "overloaded" and this is seen by the high frequency of power cuts the country experiences. This would also help the mining sector have adequate energy it needs to fully maintain its important role to the economy and its development.

Zambia has formed and put in place several energy related boards to help achieving the Vision 2030 such as: Ministry of Mines, Energy and Water Development (MMEWD) which is responsible for policy framework and guidance through Department of Energy; Energy Sector Advisory Group: this is a committee formed under MMEWD with members from other ministries and authorities, development agencies and business partners. Its aim is to make sure there is cooperation among all sectors of the economy regarding energy policies and provide guidance on energy to policy makers; Energy Regulation Board (ERB): is an

independent energy sector regulator in charge of electricity, petroleum and other forms of energy which includes renewable energy; Rural Electrification Authority (REA): main mandate is to oversee the implementation of bringing electricity access to rural and remote areas; Biofuels Association of Zambia (BAZ) is an association of firms, companies and individuals who are producers or service providers in the biofuel industry in the country. It is also involved in the promotion of production of biofuel and making sure it meets the required quality and social standards.

Zambia being a member state of SADC is also part of the energy strategies SADC is undertaking within its 15 member states[5]. According to SADC statistics, in 2013 the grouping had a total population of around 280 million with a combined GDP of about US$ 575.5 billion and a growth rate of 5.15 %. In 2011 coal was the main source of energy accounting for about 45 %, renewable energy had a share of 39 %, while oil and gas having share of 14 % and 2 % respectively and nuclear energy having the least – 1 %. (SADC and Ibid, 2012). It has to be noted that the 39 % of renewable energy consisted of: 36% traditional biomass used for cooking and heating, 2% hydro-energy and only 0.4% was modern renewable energy. And other renewable energy resources like geothermal, wind, solar and biofuels was negligible.

Table 1 shows some of the key socio-economic/power indicators for the entire SADC region. From the table it can be observed that there is a vast difference not only in population and GDP Per Capita, but also in the levels of access to electricity. The table shows that the island countries – Seychelles and Mauritius have the highest percentage of inhabitants with access to electricity while Zambia is among the moderate-lowest countries. Table 1 also shows that the region still has a milestone to reach its goals on energy access to its population and this can also be attributed to the economic difference of individual member states of the bloc. The bloc confirmed it's slowly but surely making progress towards reaching its energy goals

[5] SADC members: Angola, Botswana, DRC, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Republic of South Africa, Swaziland, Seychelles, Tanzania, Zambia and Zimbabwe.

Table 1: Overview of SADC energy indicators

Country	Population mil. (2011)	GDP PPP*	Energy production**	Electricity consumption***	% access to electricity		
					Urban	Rural	Total
Angola	17.99	5,430	98.92	4.73	63	8	40
Botswana	1.85	8,605	1.10	3.18	71	42	58
DRC	75.26	214	24.08	6.28	37	4	15
Lesotho	1.90	1,259	0.20	0.31	65	3	19
Madagascar	20.69	484	1.10	1.13	43	7	19
Malawi	14.39	404	1.70	1.84	70	4	17
Mauritius	1.29	8,390	2.40	2.40	99	99	99
Mozambique	23.05	532	12.49	10.38	19	3	14
Namibia	2.11	6,036	0.32	3.38	0*	18	40
Seychelles	0.09	12,118	0.00	0.31	99	99	99
S. Africa	50.59	8,079	162.41	240.09	90	64	80
Swaziland	1.07	3,830	1.07	1.53	65	45	51
Tanzania	44.49	536	18.68	3.49	46	4	15
Zambia	13.46	1,429	7.48	8.06	45	3	22
Zimbabwe	12.75	695	8.60	12.85	80	24	44
Total/average	280.98	3,627.56	340.55	299.96	70.83	28.47	42.13

*GDP Per Capita (2011); ** Mtoe/year (2011); *** in TWh

Source: SADC

SADC states that its goal on reliable and adequate energy access for the entire bloc will help it achieve growth rate of about 7 % and also alleviate poverty levels, sustainably. To reach this goal, SADC and its members including Zambia have agreed to reduce the number of inhabitants with no access to energy services by half by 2020 then halve the remaining number every five years until the goal to have every inhabitant have access to energy in the bloc is achieved. One of the bodies that have been formed by SADC in conjunction with UNIDO to address the issues of renewable energy among its member states is called: Regional Renewable Energy and Energy Efficiency Agency (SACREEE). This body will put its efforts on renewable energy and energy efficiency through energy planning and policies and financing projects related to renewable energy in its member states.

2.3. SADC/SAPP Region power demand

According to SADC (2010), electricity power consumption in the Southern African Power Pool (SAPP) was about 50,000 MW per year. SAPP members are: Angola, Botswana, Democratic Republic of Congo, Lesotho, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. The aim of SAPP is to promote cooperation among member states fostering to creating a common electricity market which should provide reliable and affordable electricity to the citizens of the member states. The table below shows the figures more closely per country.

Table 2: SAPP electricity supply and demand

Country	Main Utility	Installed Capacity (MW)	Estimated Annual demand (MW)	Demand Growth (%)
Angola	ENE	1,793	1,480	11
Botswana	BPC	352	604	6
DRC	SNEL	2,442	1398	3
Lesotho	LEC	72	138	3
Malawi	ESCOM	287	412	4
Mozambique	EDM	2,308	636	7
Namibia	Nampower	393	635	5
South Africa	ESKOM	44,170	42,416	3
Swaziland	SEC	70	255	5
Tanzania	TANESCO	1,380	1,444	8
Zambia	ZESCO	1,870	2,287	6
Zimbabwe	ZESA	2,045	2,267	2
Total		57,182	53,702	Average 5

Source: Calculations based on SADC and MEWD 2013

Table 2 shows that South Africa is the highest electricity consumer in the entire region with an estimated demand of about 42,000 MW. ESKOM is also the largest electricity power generator and supplier in Africa and rated among the top 10 in the world in terms of power generation and supply. While Angola has the most rapid growth since the end of the civil war due to many activities taking place to rebuild the country and booming economy as a result of oil production. Other leading consumers are Zambia, DRC and Zimbabwe. SAPP electricity demand and growth is around an average of 5 % per annum. According to SADC, the demand is expected to exceed 80,000 MW per annum by 2020.

2.4. Electricity consumption by economic sector in Zambia

Table 3: Electricity consumption by sector in GWh

Sectors	2013 (GWh)	2014 (GWh)	2013 Proportion	2014 Proportion
Mining	5,921	5,871	54.7 %	54.8 %
Domestic	3,360	3,251	31.0 %	30.3 %
Finance & Property	500	487	4.6 %	4.5 %
Manufacturing	397	479	3.7 %	4.5 %
Agriculture	270	241	2.5 %	2.3 %
Others	121	100	1.1 %	0.9 %
Trade	116	107	1.1 %	1.0 %
Energy & Water	71	73	0.7 %	0.7 %
Quarrying	35	62	0.3 %	0.6 %
Transport	28	31	0.3 %	0.3 %
Construction	16	17	0.2 %	0.2 %
Total	10,835	10,719	100 %	100 %

Source: calculations based on ZESCO data

Table 3 shows Zambia's electricity consumption by sector for the year 2013 and 2014 and can be seen that the mining sector consumed the largest share of electricity accounting for more than 50 % of the total electricity in the country. With domestic consumption accounting for around 30 % for both 2013 and 214 while the agriculture sector consumed less than 3 % despite the fact the sector provides highest form employment in Zambia. This is because most the agricultural activities are in the rural areas where electrification rate is still very low. In 2014 the total consumption reduced by 1.2 % from 10,835 GWh in 2013 to 10,719 GWh in 2014, this can be attributed to the slowdown in mining activities and outages for non-mining consumers which worsened in 2015.

2.5. Zambia's renewable energy potential

Zambia as a country indeed has abundant renewable energy resources and has to be noted that the biggest renewable energy resource potential lies in hydropower. This is because Zambia alone holds about 40 % of water resources in the entire SADC bloc in form of rivers, lakes and dams (SADC, 2012). This is mainly due to the Zambezi River and its Zambezi basin where even one of the world's biggest dams – Kariba Dam is located. The other various renewable resources have also great to be used for production of electricity, biofuel production and in many other sectors. The biggest problem is that the data on most of the renewable energy resources are not readily available.

Table 4: Zambia's renewable energy resources potential and their use

Renewable Energy	Opportunities/use	Resource Availability	Potential Energy Output
Wind	Electricity, mechanical – water pumping	Average 3 m/s at 10 m height	Modest potential – can be used for irrigation
Geothermal	Electricity	Hot springs	Required elaboration and quantification
Mini-hydro	Small grids for electricity supply	Reasonably extensive	6,000 MW+
Solar	Electricity (water pumps. Refrigeration, lighting), thermal (water heating)	6 – 9 hours sunshine	5.5KWh/m^2/day

Source: calculations based on MEWD

2.5.1. Wind energy

The data for wind energy potential are not adequately available as the government of Zambia in partnership with SADC and UNIDO are still carrying out more tests. So far the current available information at the Ministry of energy is that the country averages 3 m/s

at 10 m above the ground. This speed is mainly is mainly suitable to be used a source of mechanical energy to power water pumping/irrigation. There has been some progress made from some of SADC studies that at heights between 70 m – 100 m winds speeds are available in some parts of Zambia which can be used to generate electricity but still need further elaboration before investments can be made (SADC, 2012).

2.5.2. Geothermal energy

The Zambian government thorough the Ministry of Energy confirmed that the country has over about 80 hot and mineralized springs. The confirmation was as a result of the study carried out by the government's expert in cooperation with Italian governments which took place in 1980s. They resolved that several of these hot springs have potential to generate energy. Currently a private and self-funded company called Kalahari GeoEnergy with the agreement of the Zambian government is carrying out geothermal research in the country on the targeted hot springs. The aim is for the company to identify commercially viable geothermal sites around the country which can provide mainly off-grid power production and in the end potentially benefiting rural areas as part of the Rural Electrification scheme and programmes. It is thought that by using modular binary power plants, the targets would be brought into productions at lower capital costs than large direct steam-fed turbines.

2.5.3. Hydro energy

According to data readily available from UN, SADC and Zambian government, Zambia's hydro energy potential is estimated to be more than 6,000 MW with only about a third of that currently exploited. The actual small hydro energy potential is still unknown. The Zambezi River/Basin is the biggest hydro energy resource in the SADC region with Zambia having about 40 % of the total river basin as Figure 2 shows. In November, 2014 installed hydro power energy was estimated at 2.2 GW. The government is working hard to encourage and build smaller hydropower stations which can be either added to the national electricity grid or off-grid to distribute.

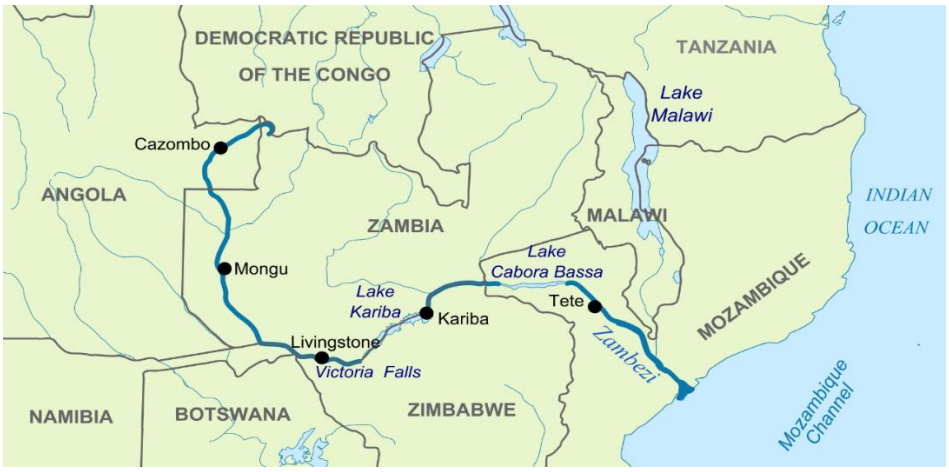

Figure 2: Zambezi River basin

Zambia's main source of hydro power is Kariba Dam which is shared between Zambia and Zimbabwe as it is on the border of the 2 countries. Kariba Dam generates supplies 1,626 MW to both countries amounting to 6,400 Gigawatt-hours (23,000 TJ) per year. Zambia gets 960 MW while Zimbabwe gets the rest. The second biggest hydro power plant for Zambia is Kafue Gorge on the Kafue River supplying about 900 MW to the national grid line. Although for the last years Zambia has been facing droughts reducing the levels of water in the Kariba Dam which has caused drastic reduction in power generation. By end of 2015 the Kariba Dam had only about 20 % of the normal water capacity and production of power was reduced to less than 300 MW which made ZESCO introduce load shedding for the entire country.

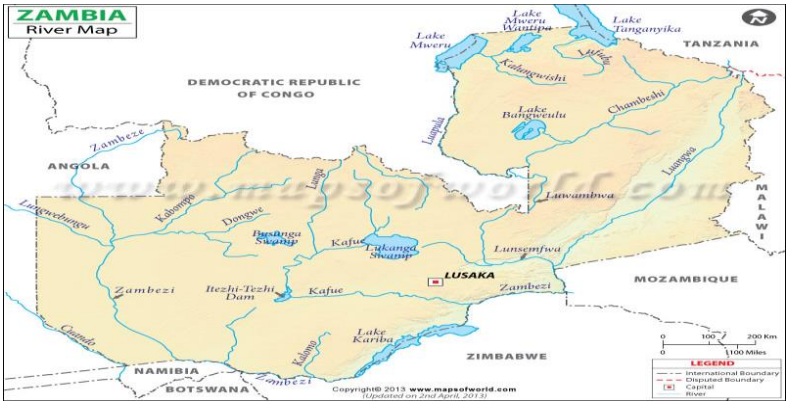

Figure 3: Zambia's Rivers

Figure 3 shows the many rivers Zambia has and it is on some of these rivers the small hydro power stations are also on the increase to meet the power deficit Zambia is facing. According to the MEWD, the country plans to have an additional 1500 MW hydro energy production by 2020.

Table 5: Hydro power stations

Station	Capacity (MW)	Generation 2014 (GWh)	Type	Owner
Zengamina	0.7		Run-of-river	Zengamina
Shiwa Ngandu	1	0.7	Run-of-river	ZESCO
Musonda Falls	5	20.5	Run-of-river	ZESCO
Chishimba Falls	6	23.7	Run-of-river	ZESCO
Lusiwasi	12	58.7	Dam	ZESCO
Lunzua	14.8	3.52	Run-of-river	ZESCO
Lunsefwa	24	98.8	Dam	ZESCO
Other SHP comb.*	24		combined	ZESCO
Mulungushi	32	198.2	Dam	ZESCO
Victoria Falls	108	811	Run-of-river	ZESCO
Itezhi-Tezhi	120		Dam	ZESCO
Kariba North Ext.	360	1,162	Dam	ZESCO
Kariba North	600	5,000	Dam	ZESCO
Kafue Gorge	900	6,666	Dam	ZESCO

*Other Small Hydro Power up to 3 MW owned by ZESCO

Source: Based on MWED 2014

2.5.4. Solar energy

There have been several studies done in Zambia on solar energy potential Zambia possess. It has been given that Zambia boast of high irradiance values. According to UNIDO (2012), the country has an average solar insolation of 5.5 KWh/m^2/day with more than 3,000 sunshine hours per year providing great potential for solar thermal and photovoltaic

applications. Some regions in Zambia records the highest global solar irradiance reaching 2,300KWh/m^2/year. The Rural Electrification Authority (REA) is developing solar mini-grids to electrify rural areas which are off-grid the national grid line.

One of the best examples of such solar powered mini-grid is the one under the UNIDO's Global Environment Facility agreement, REA got an interest-free loan from of the banks in Zambia to develop a solar mini-grid generating 60 KW of electricity and supplied to small villages around targeting about 6,000 people and 617 households. It is a big success and from this the government through MEWD and REA is receiving more offers to develop slightly bigger solar mini-grids like 10 MW in Eastern, Luapula and North-Western provinces. The discussions are still on going as an agreement on tariffs will need to be reached in comparison to ZESCO on-grid tariffs. Annually the PV sales in Zambia are as high as US$ 3 million of which 70 % is financed by donors. With the help of REA and donors, solar system panels have been installed in more than 250 rural schools and buildings of traditional leaders as well as more than 400 households under the Energy Service Companies (ESCO) pilot project funded by Swedish International Development Cooperation Agency

2.5.5. Bio Energy

Zambia has vast natural resources with regards to land, fertile soil and water and with about 80 % of the population depending on agricultural-related activities for their survival, there is a greater need to transform the agricultural sector to achieve the 2030 vision. Currently the agricultural sector has a lot of challenges which cause low agriculture productivity and this is mainly attributed to the traditional practices in the sector and lack of required machinery and infrastructure which would transform the harvest yields of the agricultural products. This in turn can help alleviate the high poverty levels faced by the country especially in rural areas. The government has confirmed that energy and specifically renewable energy can play a vital role in transforming the current subsistence farming into agro-industry and export oriented agricultural sector while at the same time making sure the country has enough food reserves for the population.

At the moment traditional biomass is Zambia's main energy source which accounts for almost 70 % of the energy consumption – almost 60 % of the urban population using traditional biomass and in rural areas as high as 97 % of the population depending on the biomass energy (CSO, 2013). According to Mwitwa and Makano (2012), firewood is the main energy used for cooking in rural areas while charcoal is the main energy used in urban areas for cooking and heating. It is believed charcoal industry provides employment to over half a million people nationwide which includes the supply chain, producers, distributers and marketers.

According to a study carried out by the Zambia's Ministry of Mines, Energy and Water Development (MMEWD, 2008) in corporation with IRENA[6], Zambia has biomass resource and bioenergy potential of 2.15 million tones which would generate up to an equivalent of about 500 Megawatts. At the moment *Jatropha* is the most commonly used and grown plant to produce biofuel with more than 6,000 hectares. Zambia needs approximately 84 million liters of bio-diesel and 43 million liters of bio-ethanol per year have the 20 % blending requirement (MWED, 2015).

Table 6 shows the great potential for energy production from biomass a renewable resource, but unfortunately the data on these energy resources is not readily available. Table 6 also shows how much biomass energy resources the country which is still under used because it's potential realization is taking too long. With high levels of urbanization, Zambia has vast land resources lying idle which can be used and developed to increase the produce of renewable, sustainable, clean and cheap energy for its population. The land can be used to produce biofuels which can be used locally and also has the potential to be exported to other countries. With high levels of traditional, unsustainable and unhealthy charcoal usage in the country, the renewable energy waste from *Jatropha* and elephant grass can be used to provide improved, sustainable and healthy charcoal for cooking and

[6] IRENA - International Renewable Energy Agency

heating purposes. Biomass can also be utilized to produce electricity which can be used especially in rural areas.

Table 6: Availability and Utilization of Renewable Sources in Zambia

Renewable Energy	Opportunities/use	Resource Availability	Potential Energy Output
Biomass (combustion and gasification)	Electricity generation	Agro wastes, forest wastes, sawmill waste	Requires elaboration and quantification
Biomass (biodigestion)	Electricity generation, heating and cooking	Animal waste, agro and industrial waste	Studies of quantity and potential still on going
Biomass (biofuels)	Ethanol and biodiesel for transport stationery engines	Sugarcane, sorghum, Jatropha, elephant grass	150,000 km^2 of agricultural land to meet current demand
Biomass (household energy)	Improved charcoal and improved cook stoves	Sawmill waste, trees from sustainable forest, waste from Jatropha, Elephant grass waste	Reasonable extensive

Source: MMEWD and IRENA

Zambia is continuing to encourage development of biomass as a source or clean renewable and sustainable energy. Some of the projects include ZESCO in corporation with UNIDO installed a 1 MW biomass electricity generation to replace 440 KW diesel powered electricity generation. The power plant uses feed-stock from sawmills and other agricultural waste in the region. Up on the successful implementation of this project, more such projects are being put in place with the help of UNIDO, SADC, African Union, World Bank financial assistance. Another big project has been done and implemented by the Zambia Sugar Plc in Sothern Province of Zambia at the Nakambala Sugar estate. It started with use of about 120,000 tons of bagasse from sugar cane crushing component of the estate to generate 17 MW of electricity which has gradually been increased and by 2015 they generated 40 MW from sugar cane planted at the farm and from out-growers.

Figure 4: Biomass electricity generation – Nakambala

Source: REA

A similar project although with lower electricity generation is being at Kafue Sugar to generate 3 MW of electricity. Zambia Sugar Plc is working the Zambian government to have more of such biomass power generation plants around the country as sugar cane grow very well in Zambia due to its climate and location. According to UN-REDD[7] report (2014), Zambia loses about 250,000 to 300,000 Hectares of its approximately 50 million hectares of forests to deforestation each year. This is attributed to the fact that firewood and traditional charcoal are the main source of cooking and heating energy in both rural and urban Zambia. In this regard a Zambia – Swedish joint has introduced cooking stoves which solely runs on

[7] The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries

clean fuel. Emerging Coking Solutions (ECS)[8] as part of their participation to reduce deforestation are producing and selling cooking stokes which use pellets produced from bio-waste from agricultural, forest and sawmills waste. Recently they have also been producing and selling bio-gas stoves which can be found mostly in urban areas, but are planning to sell more to rural areas as well where deforestation rates are extremely high. These stoves have praised for being sustainable, reliable and reduce health risks associated with traditional charcoal and during these periods of high load shedding schedules around the country their market base is increasing at a faster speed. There are more entrepreneurs joining this energy sector as the renewable and sustainable energy activities have good incentives for starting up business provided by the Zambian government through the Energy regulation Board as a way of encouraging clean energy in the country.

2.6. Why Bio energy

Zambia in deed has several options to produce clean, renewable and sustainable energy for the population. It can be noted that Hydro power which is it the main source electricity generated and used in Zambia is a renewable and clean energy, but recently Southern Africa is facing several droughts which has brought power generation to its lowest in the last 50 years as can be proved with the current power outages and load shedding most of the countries in the region are facing including South Africa. It also has to be noted that most of the hydro power plants in Zambia lack service and maintenance making the production of energy even less than usual even when the water levels are higher. The electricity sector is highly dependent on hydro such that when the country is faced with severe drought as was the case in 2015, then the country has no other reliable alternative and affects the population and its struggling economy. The fact that Zambia is a land locked country does not help the situation at all as it solely depend on the rainfall which is also seasonal and unpredictable with the current global warming and climate changes the world is facing.

[8] Emerging Cooking Solutions (ECS) is a private company that sells clean cooking stoves and sustainable fuel pellets.

Zambia also has geothermal energy potential mainly among the identified more than 80 hot and mineralized springs around the country. Production of energy from geothermal is very costly and needs very good technology to be cost effective and productive. The costs to build geothermal power plants, skills and manpower needed are too high for Zambia with its economic status does to financially afford the capacity to develop and fully benefit from geothermal energy resource which is indeed a renewable energy. Some scientists also argue that geothermal energy production if not done properly can release the harmful toxic gasses to the atmosphere. The geothermal energy can also be produced only in a few locations in Zambia and it is not easy to transport or link to the national grid line of the country. It surely another alternative if the country had enough resources due to its advantages.

With several studies done in Zambia, it has been show that the country has an average solar insolation of about 5.5 KW/m^2/day and more than 3,000 hours of sunshine per year. These figures surely shows the great potential of solar energy in Zambia. The production of electricity or energy will be mainly during the day and also depend on sunshine intensity on that particular day and so far it is believed that the most efficient solar cells can only convert about 20 % of the sun's rays to electricity. The biggest setback for solar energy in Zambia is the costs associated with Photovoltaic (PV) and initial investment which most of the ordinary Zambians cannot afford. Most of the currently installed PVs are co-funded by other agencies. And for Zambia to fully benefit from solar energy it would need to have largescale solar farms with panels that can rotate to follow the sunshine making the costs higher.

Zambia being a landlocked country does not have high winds needed to generate cost efficient energy. Most the winds are suitable small mechanical machines like pumps for irrigation in the agricultural sector which are mainly in rural areas. Zambia would also have to import the technology and equipment needed to generate energy from wind and the equipment is very costly for a country like Zambia to afford and for available winds might not be cost efficient investing more in this source of energy despite the fact that it is renewable and clean energy resource.

According to MEWD (2008), Zambia has a biomass resource and bio-energy potential of more than 2 million tons and 500 MW respectively. The agricultural waste accounts for the largest share accounting for more than 90 % of total potential, while forest waste accounts for about 9 % which is the second. This means that the already existing agricultural which is accumulated every year from crops grown locally and imported can be readily used to produce energy in many ways including biofuels in liquid and solid forms. Zambia's climate is favorable to most of the common energy crops such as *Jatropha,* elephant grass, palm oil plants, cassava, sorghum, sugar cane and cashew nuts trees which can all be used to produce biodiesel, bioethanol, biogas, clean charcoal, pellets which would greatly help reduce deforestation rates and dependency on imported fossil fuels and unreliable hydro power. Since the agricultural sector is among the top employment providers in the country, bioenergy sector would greatly contribute to the development of the agricultural sector and provide reliable and stable income for both small and large scale farmers in the country. This in turn would help improve the living standards of the Zambian people and help reduce high poverty and unemployment levels.

3. Aims of the Thesis

The main objectives of this thesis was to analyze bioenergy carriers in Zambia. The fact that the needs to develop and adaptation to renewable energy resources are growing, this thesis focused on potential of renewable energy resources including bioenergy carriers in Zambia.

3.1. Specific objectives included:

- Analyze the importance of moving from fossil fuel dependency to renewable, sustainable and clean energy
- Identify some of renewable energy resources potential the country posses
- Evaluate their availability, production and usage
- Analyze which bio energy resources have great potential in Zambia and their usage
- Analyze what are the constraints in bioenergy industry in a country like Zambia

3.2. The main hypotheses

- Zambia is among the countries with vast land and natural resources that remain unutilized which can be used to produce sustainable energy for the local people
- Bioenergy industry has a great economic value as it will bring new income to the local farmers and provide clean energy resources currently missing in rural areas
- The Government of the Republic Zambia has recognized the importance and value of bioenergy industry and providing incentives to those in the industry

3.3. Limitations of the study

- Unavailability of literature resources for bioenergy specifically for Zambia
- People not willing to give information due to fear that they might get into trouble

4. Materials and Methods

In this study the methodology used involved analyzing secondary and primary data which was collected in different ways to support this study.

4.1. Data Collections and analysis

4.1.1. Secondary data collection

Secondary data was collected from various sources which included previous study documents in the bioenergy sector, reports, information and bulletins from the Ministries of Zambia, UN Statistics and SADC Statistics, web of science, scientific journals and internet sources mentioned in the references chapter of this thesis.

4.1.2. Primary data collection

Primary data was collected with the help of a questionnaire which was sent to participants in Zambia through emails. In order to be able to reach some people in the rural areas who are not on social media or emails, 2 tablets with 4G Sim card slots were sent to Zambia for author's friend John S.K. Banda MSc. and his colleagues who work for the Ministry of Agriculture in the field to help have such people fill in the questionnaire. This was done in order to increase the base of participants. The questions in the questionnaire were multiple choice, check boxes where several answers could be selected and short answer type in case some information was to be given. The questionnaire is also attached at the end of the thesis.

4.2. Data processing

The collected data and responses were analyzed and grouped in categories. The responses presented with the help of graphs and charts to analyze them further.

5. Results

From the 93 respondents received, 7 bioenergy crops were recorded to be grown in the Eastern Province of Zambia where the questionnaire was sent. The energy crops included some the newly fast growing energy plants due to the high volume of feedstock needed by mostly Chinese energy firm doing research in Zambia. From the time China banned the use of corn or maize for energy production due to it being one the world's food staple and the firm investing more in Africa and in Zambia in particular in the bioenergy sector is Sunbird Bioenergy Africa which is the main bioenergy company in China and Sub-Sahara Africa. The questionnaire included some the questions below analyzed and illustrated with the help of graphs and charts.

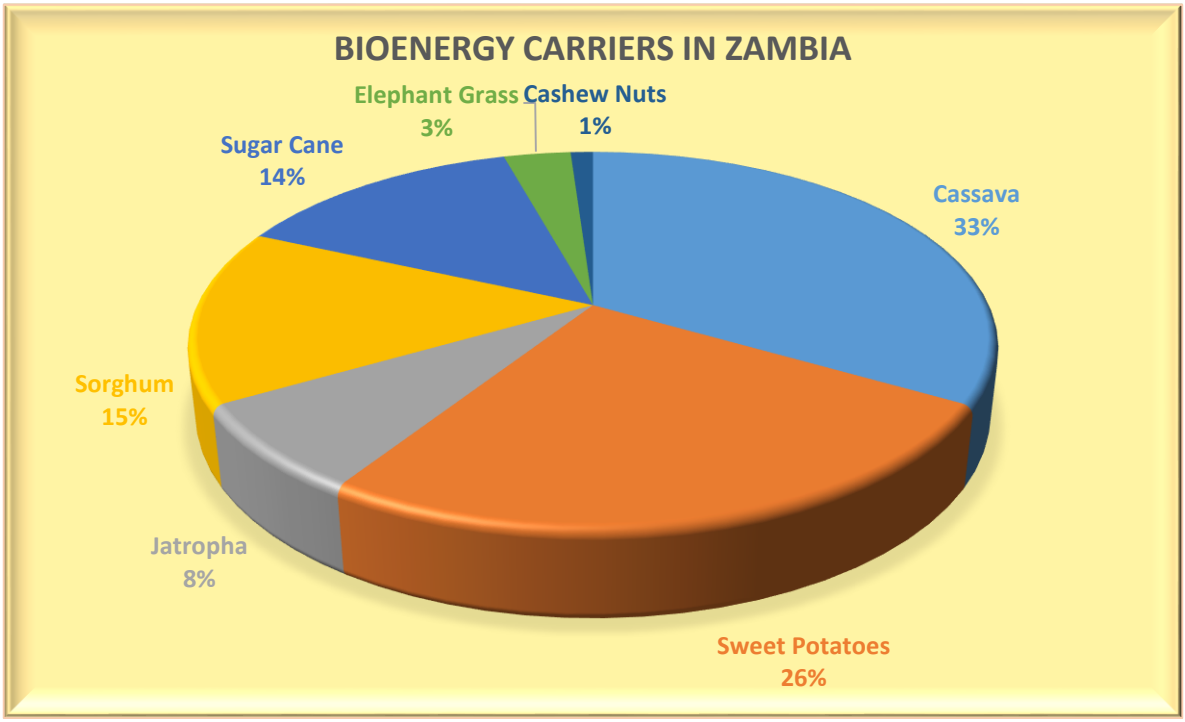

Figure 5: Bioenergy carriers in Zambia

Figure 5 shows the plants respondents grow as feedstock for bioenergy productions which include biodiesel, ethanol, pellets and lean charcoal among others. Improved Cassava was grown by 31 respondents representing 33 % of the total while orange sweet potatoes was

the second most grown energy crop in the region accounting for 26% of the total respondents. These 2 plants are newly being grown as energy crops due to the investments and high volume demand from the Sunbird Bioenergy Africa which is working on biofuel production in Zambia as a Chinese cooperating partner and part of the development plan. Sweet Sorghum and Sugar Cane are also on the increase due to demand from the same Chinese energy company and Zambia Sugar Plc. Company which buys most of the Sugar cane and also biggest employer in form of out-grower scheme for Sugar Cane growers in the region and generally in Zambia. These 4 plants showed high volume of yields and great potential for biofuel energy production in the country.

It seemed Sunbird Bioenergy Africa was the main source and provider of the out-grower scheme programme for Cassava, Sweet Potatoes and Sorghum due to high amounts of starch found in these crops which can be used to produce biofuels instead of using main staple food such as corn and also these plants appear to grow well even with these climate changes Zambia is experiencing the last years. The yields from the plants were also in great amount and also easy to transport to their processing bases. The farmers were to some extent satisfied with the prices and support received from Sunbird Bioenergy Africa during the entire season and also having the guarantee their energy crop will be bought. Cassava and Sweet Potatoes also provided source of food to the growers at the leaves for both plants are used as a nutritious vegetable for the local people. This also generated extra income when they sold these leaves to the surrounding community although not so much but sufficient enough to help cater other basic needs.

Jatropha growers accounted for 8 % of the energy plant growers mainly because of the time it takes to start producing fruits and bringing income to the farmers. *Jatropha* takes between 3 – 5 years to start producing fruits, this discourages many farmers who depend on the farming activities for their day to day lives and do not have enough capital to invest in energy plant for that long before they can benefit from it. It was noted that almost all *Jatropha* growers were people who had farms in the rural areas, but were living in urban areas doing other types of jobs to earn a living as they wait for the fruits to start producing.

It was also observed all of them were university graduates who knew the value of the plant and the great potential it has in future. While elephant grass and cashew nuts were the least grown energy crops account for 3 % and 1 % of the total respondents, respectively. Elephant grass was mainly grown and sold to a small local energy company that uses it to produce pellets and clean charcoal in the region as part of the campaign to reduce deforestation in Zambia. Cashew nut grower is part of the government initiative promoting the plant from Mozambique to be used for biofuel production in the country as part of an initiative to reduce the heavy dependent on hydropower and imported fossil fuels.

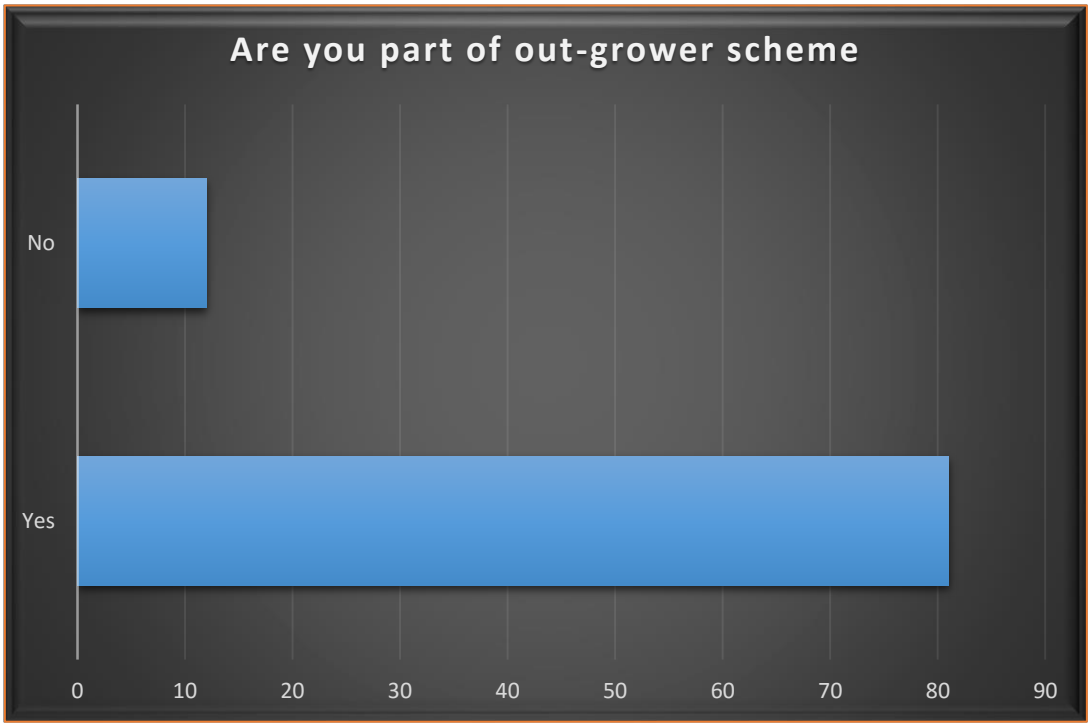

Figure 6: Out-grower scheme

When the respondents were asked if their energy crops farming was part of an out-grower scheme, 87 % of them answered they were while only 13 % were not under any agreement or part of an out-grower scheme. These were farmers with farm that were bigger than 5 ha and all 7 *Jatropha* growers were not part of any out-grower scheme. The other 3 were female farmers who were sponsored by Women for Change NGO aimed at empowering women in the rural areas. The 3 female energy crops farmers had farm size less than 5 ha

and were part of the only 8 female farmers representing 9 % of the total respondents and male energy crop farmers accounting for about 91 %. This showed the typical farming system in Zambia dominated by male as the heads of family although the entire family including wife, children and dependents participate in the labor force of each farm and household.

All the farmers under out-grower scheme had agreement with the scheme provider to buy their entire harvest and fixed price. The farmers were satisfied with this idea as the out-grower also helped during the entire farming season with inputs, technical advice and also assured buyer for their product. It was also noted that other people who had no formal contract with out-grower scheme provider sold their yields to Sunbird Bioenergy Africa contractors who were also the biggest out-grower scheme provider.

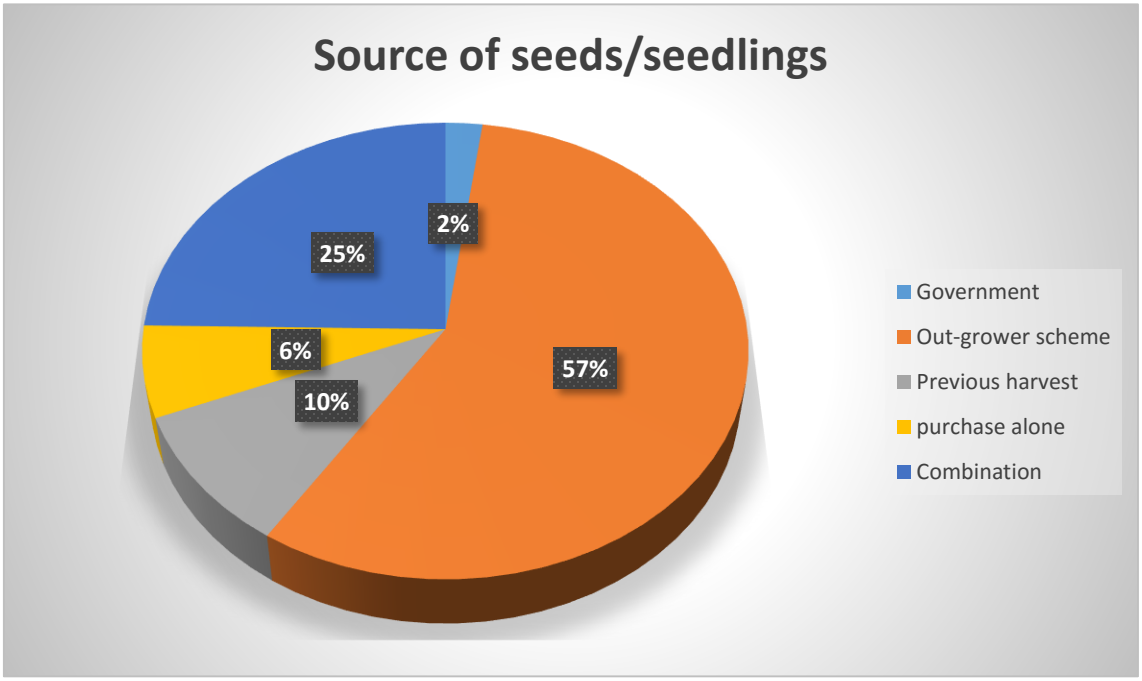

Figure 7: Source of planting material

Figure 7 shows 57 % of the respondents indicated that the out-grower scheme provider provided them with the planting material while 25 % of them used combination of out-grower scheme provider and from previous harvest – the out-grower scheme controlled

this input from previous harvest to make sure was healthy and suitable for planting. The farmers who purchased planting materials alone are all *Jatropha* growers and the farmer growing cashew nut trees got the seedlings from the government. As Figure 8 shows, most of the farmers used combination of chemical and organic fertilizers for their plants.

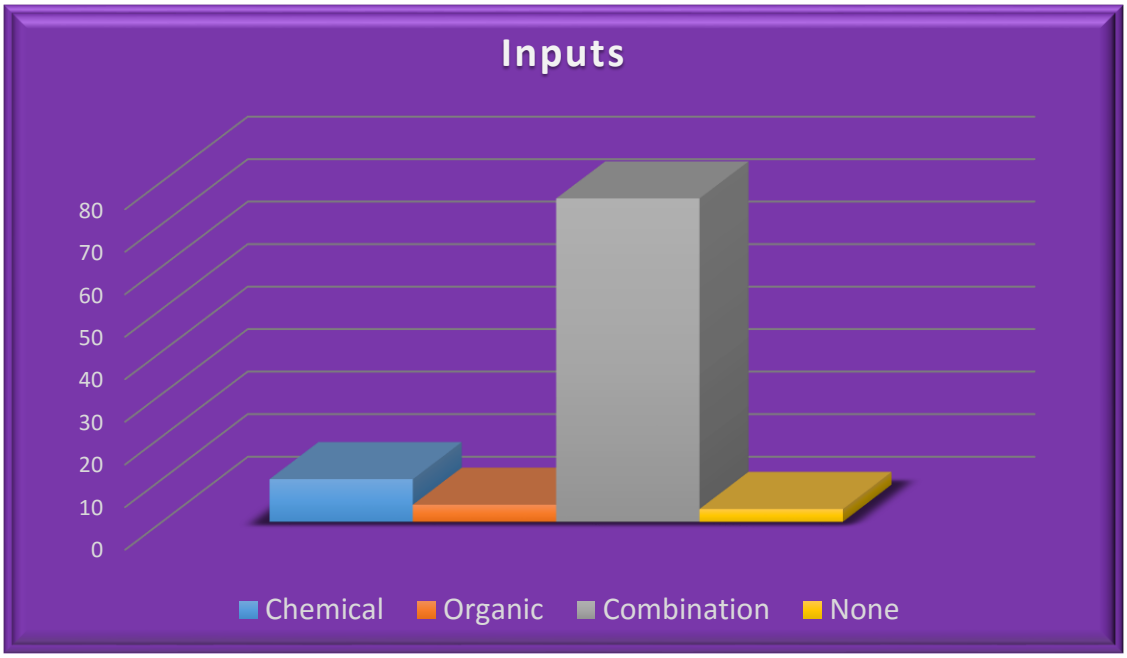

Figure 8: Inputs used

About 76 of the respondents used combination of chemical and organic fertilizers which was also provided by the out-grower scheme contractor. It was said that the combination was the start to promote organic fertilizers in place of chemical fertilizers and also to boost the yields and contents needed to efficiently produce the required biofuels. While only 10 of the respondents used chemical fertilizers alone, 4 of them used organic fertilizers only and the rest used none. It seems those used none were not part of any contract and did not have enough funds for fertilizers and also believed in the traditional way of farming. These also grew local Cassava plants instead on the improved varieties which had much higher yields.

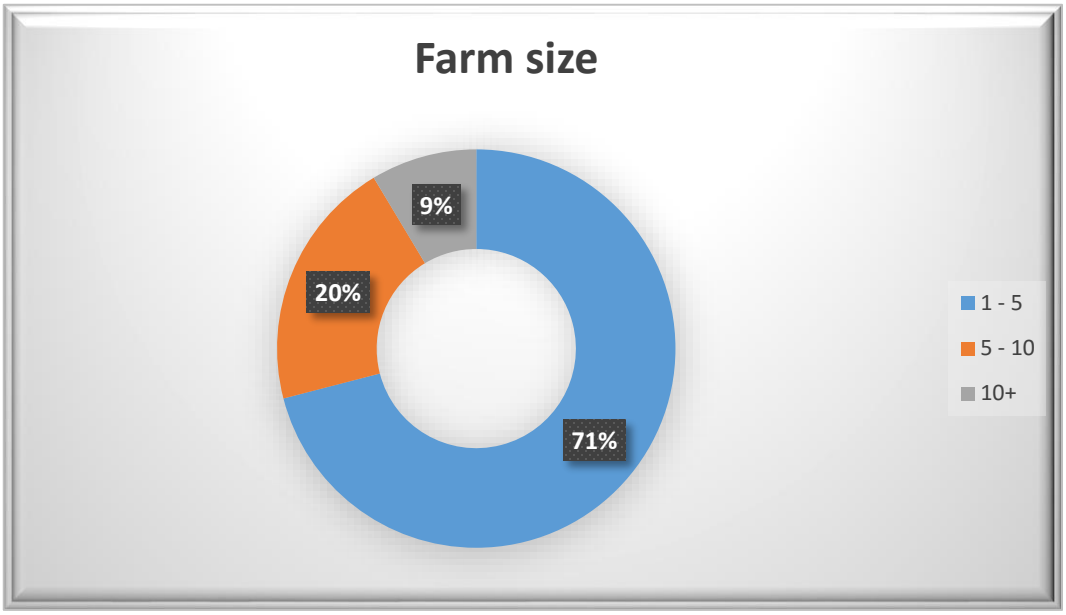

Figure 9: Farm size

As figure 9 shows, 66 of the farmers representing 71 % had farm of up to 5 ha which are not very huge pieces of land. For all of them with this pieces of land size confirmed it was enough to generate income and improve their standards of living. This seems to be related to high volume of yields and also having a guaranteed buyer. These farmers can be classified as small scale farmers who through the energy crops growing their lives are changing and living standards improved including sending their children and dependents to school. 20 % of the respondents had bigger farm size ranging between 5 and 10 ha and these even had greater harvests as most of them were also established and experienced farmers who have been steadily extending their farm sizes over time. Half of this group grew at least 2 energy crops other than the staple food – maize. Less than 10 % of the respondents had much bigger farm sizes exceeding 10 ha. These were much more established farmers and planted energy crops that take time to produce harvest, this is because they did not entirely depend on the farm revenue to live their daily lives and almost all of them live in urban areas. At the farms they have workers take care of day to day farming activities and they come to supervise from time to time. All the *Jatropha* growers belonged to this group of respondents.

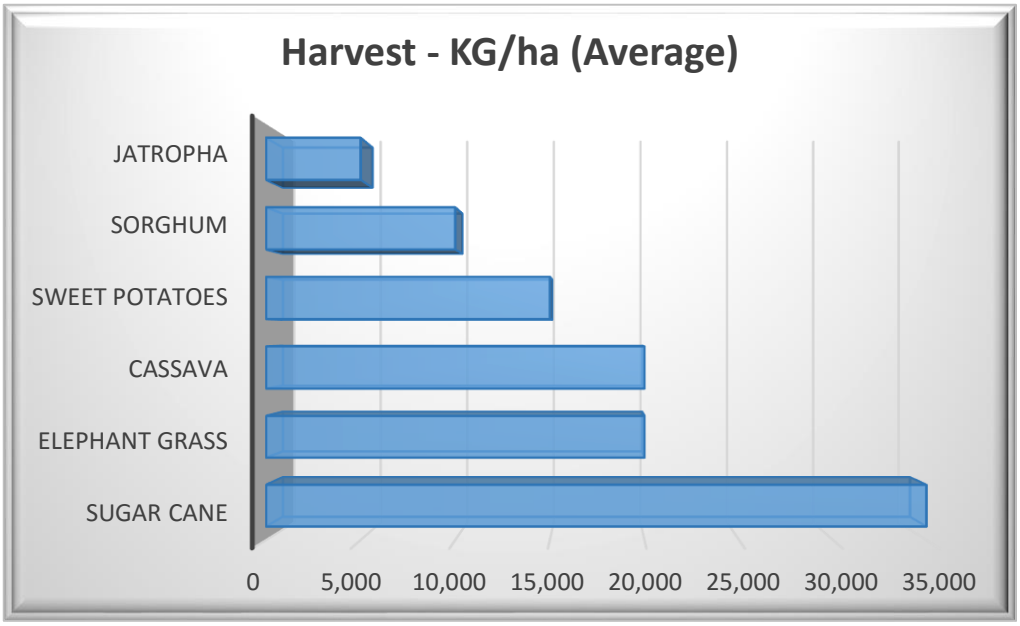

Figure 10: Average yields

When asked about their average yields per season, it showed that Sugar cane had the highest yields with an average of 35,000 kg/ha as Figure 10 shows. This was a big amount of harvest regardless of it being wet biomass. Elephant grass and Cassava had the second highest average yields of around 20,000 kg/ha of biomass to be converted into different forms of biofuels in Zambia. Sweet potatoes recorded an average yield of 15,000 kg/ha. For these 3 plants, Cassava, Elephant grass and sweet potatoes, the yields might even be much higher if irrigation is used to plant again in dry season as the plants do need take so much time to be ready for harvest. Sweet Sorghum growers responded to be getting an average of 10,000 kg/ha while *Jatropha* farmers whose plants were ready to produce fruits said they collected an average of about 5,000 kg/ha. There were no yields yet recorded for Cashew Nuts as they were recently grown. All these plants indicate great potential as biomass feedstock for bioenergy production and conversion in different forms of energy that can help Zambia sustain desired energy requirements even beyond its borders.

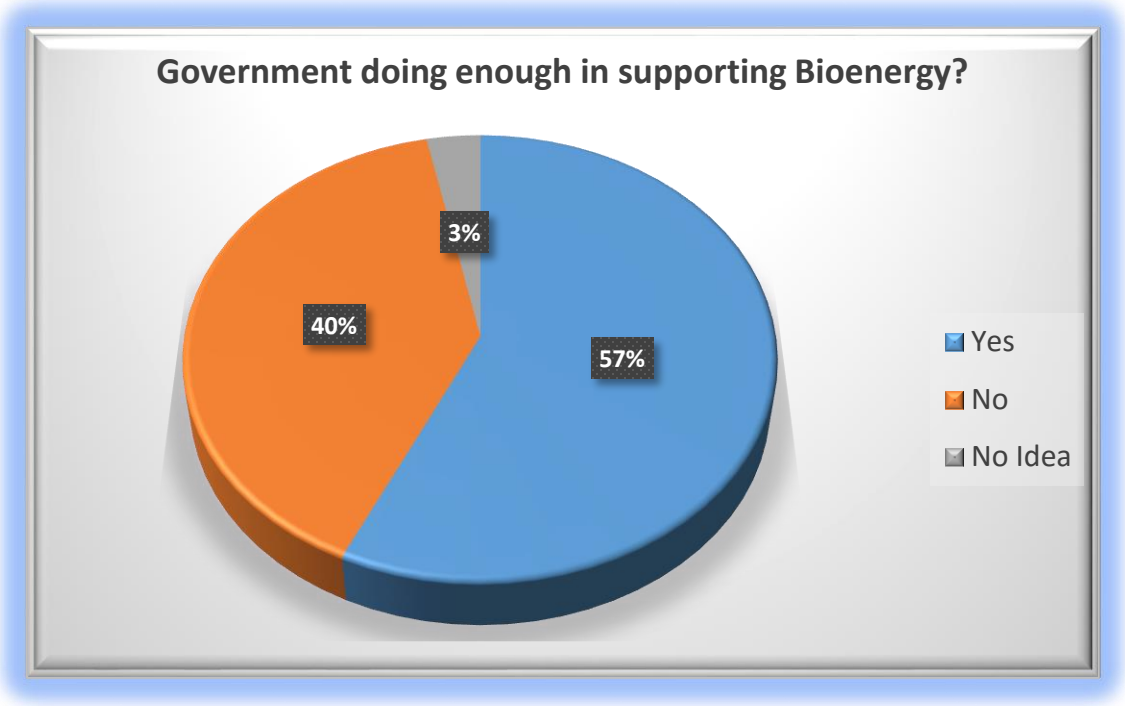

Figure 11: Government support

Figure 11 shows how the respondents responded when asked about if the feel the government was doing enough in supporting or promoting the bioenergy sector. 57 % of them were satisfied with the government's role in bioenergy sector as they saw the country gave permission to the giant Chinese bioenergy company which is contracting them and helping them alleviate their poverty levels and improve standards of living for them and their families. 40 % of the respondents felt the government can do more and their comments was mostly for the government to be involved in price regulation as the contractors is the only one who dictates the prices. The respondents also feel the promotion of the biomass as feedstock for biofuels and its importance on reducing the dependence of expensive imported fossil fuels and unreliable hydro energy power Zambia currently has.

It was appreciated that government has shown great interest in the development of bioenergy production, but they believed more needed to be done to encourage the required growth of the sector. They also expressed the long distance from the farmers' location to the processing companies' location which the buyers use as one of the excuses

to purchase the yields at lower prices. Most the farmers also strongly supported the use of energy crops as biomass feedstock for the production of biofuels in the country. They believed that this would greatly improve their standards of living, acquiring of basic needs, provide employment to the rural people who have no opportunity to go to urban areas to seek employment. And since the agricultural sector is among the biggest source of employment for Zambians, developing the country's agricultural sector would contribute to the wellbeing of the economy and agricultural contribution to the country's GDP. They also emphasized the growth of bioenergy cops and its conversion into different forms of biofuels would help Zambia achieve its goal of increasing the rural electrification rates which are currently below 5 %. When they were asked if they believe the growth of energy sector would help current energy shortages, both electricity and fossil fuels such as Petrol, Diesel and Kerosene which is used for lighting in rural areas, their response was positive.

SWOT Analysis of the energy crops

Table 7: SWOT Analysis of energy crops

Plants	Strengths	Weaknesses
Cassava **Sweet Potatoes** **Sugar Cane** **Elephant Grass** **Sorghum** ***Jatropha*** **Cashew Nuts**	- energy plants can be grown on deforested land - more harvests for most plants and rich in starch, sugars and oils - Zambia's climate supports all these energy crops - offer to convert to more forms of biofuels - all plants offer high yields - can help rural electrification - biofuels to power off-grid areas - offer abundant biomass feedstock - most crops are drought resistance - Improve rural standards of living - help provide energy security - provide more food – vegetables from Cassava and sweet Potatoes leaves - clean, renewable and sustainable - Government policy to blend petroleum products with biofuels	- start costs are too high - low availability of technology - low volume of fuel produced compared to fossil fuels - some feedstock are substitute to staple food - investors can exploit land and contribute to high deforestation

Table 7 shows the strengths and weaknesses of the energy crops the respondents grew for sale to biofuels producers. All the 7 plants have a lot of strengths which can be enough reason for the support of their growth to be encouraged and enhanced. The plants can be grown on most of the deforested pieces of land which would also help to cover the land with green material. The plants offered high volumes of yields and if done properly and with irrigation can produce more than one harvest. The energy crops grown have potential to be converted into many forms of biofuels which can benefit Zambia and its neighbors. A good example is the elephant grass grown and harvested in the regions is sold to one of the other elephant grass farmers who produces clean and sustainable charcoal and pellets sold to the local people. This shows the value of the plant and how it is helping reduce deforestation rates in the region.

The main buyer of Cassava and Sweet Potatoes uses these plants to produce bioethanol and also buying *Jatropha* seeds used to produce biodiesel ZESCO is buying to power some of its off-grid stand-alone power generators electrifying the rural areas which are off the national grid. It was also noted all the plants are drought resistance and do not need high volumes of fertilizers to collect enough yields. Plants like Cassava and Sweet Potatoes offered more food to the farmers and local people as the leaves are eaten as vegetables in Zambia. Another strength is that land and labor costs in Zambia are relatively cheap compared to developed countries and the government has made it mandatory for imported petroleum products to be blended with biofuels. Among the weaknesses were the high costs of investment in technology to produce biofuels at sustainable levels and prices as Zambia lack the technology countries like Republic of South Africa possess and the fear that investors might exploit unused forest land in Zambia instead of mainly using the already deforested areas.

Table 8 below also demonstrates the many opportunities the bioenergy crops grown offered compared to few threats. All the plants seemed to offer more potential than currently exploited with some of them looking promising to provide great medicinal values

for the people of Zambia and beyond. The greatest threat was for the local to accept prices for the biofuels products as they would cost a bit more than the traditional biomass used.

Table 8: SWOT Analysis of energy crops

Plants	Opportunities	Threats
Cassava **Sweet Potatoes** **Sugar Cane** **Elephant Grass** **Sorghum** ***Jatropha*** **Cashew Nuts**	- potential of the crops continue to develop - potential to export biofuel products to neighboring country - rising interest in biofuel in Zambia and surrounding countries - government support for blending - create stable and reliable employment for rural population - land is readily available - provide extra food to the local people - most plants have potential to offer more than biofuel value - cheap land and labor cost in Zambia - more improved energy crop varieties	- biofuels market is relatively new - local people's willingness to spend more - some feedstock are substitute to staple food - low fossil fuel prices

Source: Author's compilation

The results showed the most potential crops in Zambia to be used to produce biofuels in different forms have high yields which have huge potential to support the growth of Zambia's bioenergy sector and productions sustainable biofuels. The survey showed that the coming in of Sunbird Bioenergy Africa in Zambia is already bringing a difference in bioenergy sector and also helping farmers have assured sponsor throughout the season and also a guaranteed buyer of crops especially Cassava and Sweet Potatoes. The farmers are also having a stable and assured income helping them improve their standards of living. Zambia Sugar Plc also showed to be an active sponsor and buyer of high volume of Sugar Cane grown by the respondents for production of electricity. If these trends continue and increase countrywide, Zambia might achieve lowering deforestation rates currently experienced and also help achieve the goal of electrifying the rural areas which are off the national electricity grid.

6. Discussion

With the 7 energy crops that the respondents grew for bioenergy production, namely, Cassava, Sweet Potatoes, Sugar Cane, Sweet Sorghum, Elephant Grass, Cashew Nuts trees and Jatropha clearly shows they have great potential as bioenergy carriers in Zambia and need for further development of bioenergy sector and biofuels production. The results shows great potential of energy crops that can be used to produced biofuels and how important it is to move to sustainable energies and also how the government and cooperating partners are helping realize this goal. Because of lack of technology in Zambia, the bioenergy produced from these plants is still lower compared to other countries such as Brazil, since such countries are investing and emphasizing heavily in sustainable energy development compared to Zambia. If the country can have established refineries for biofuel – biodiesel, bioethanol, solid and gas biofuels, the usage and impact of biomass would be much greater than the current situation.

Although many literature states the high costs associated with growing, maintaining, yields and harvest related to energy crops, this is not the case for Zambia where labor is extremely cheap compared to many regions of the world. It is for this reason the need to invest more as it will also be economically valuable for the country by providing jobs to the farmers and the local people where such farms would be established around the country and especially the fact that Zambia has massive of land which remains unused. There is need for investors and the government to take advantage of this abundant land which many countries like in Europe do not have to produce sustainable biomass which would not have any impact on the food prices.

There have been argument about clearing land to increase production of energy crops which can further increase the production of biomass for biofuels. According to UN-REDD Report (2014), Zambia loses about 250,000 to 300,000 Hectares of its approximately 50 million hectares of forests to deforestation each year. This means there is a lot deforested land that investors and government can take advantage of for growth of some of these

energy crops with great potential. This would help cover the deforested land with crops that can help mitigate the effects of climate change and global warming the world is facing. This deforested land is quite a lot when compared to the farms owned by most of the small scare farmers who were able to produce huge volume of biomass from different crops they grew.

Table 9: SWOT analysis of using biomass

Strengths	**Weaknesses**
• Renewable • Clean and sustainable • Abundant agricultural waste • Energy plants can be grown on some of the deforested land • Good climate for drought resistance crops • Nonfood feedstock can be used • Plants like Jatropha and elephant grass provide several harvests • Conversion to more form of energy • Bioenergy: liquid, gas and solid - eco-friendly • Easier way to electrify rural areas • Alternative to other energy resources • Easier and cheaper fuel transportation • Reduce landfills • Biofuels are not as toxic as fossil fuel • Increase use of biofuels can reduces GHG emissions • National energy security • Can improve living standards in rural	• High initial costs • Exact potential data not clear • People are used to traditional charcoal and firewood • Inadequate technology • Efficiency compared to fossil fuel • Some investors can exploit the land – contribute to deforestation • Some of the feedstock can be fodder • Lower energy content per volume
Opportunities	**Threats**
• Create stable and reliable income and employment for rural • Potential to export to neighboring countries • New and more energy crops being found • Decrease dependency on fossil fuels • New efficient conversion technologies will be found and existing ones get improved • Rising interest for biofuels • Government policy to blend	• Consumers' willingness to spend more • Biofuel market is new • Political lobby for biofues not very strong • Some of the feedstock might cause competition with food production • Limited to agricultural waste and land availability

Source: author's compilation

Table 9 shows the SWOT analysis for use of energy crops and biomass as a source of renewable, clean and sustainable energy. This also shows the great potential of bioenergy sector for a country like Zambia with potential energy crops that can help produce high volume of yields of biomass feedstock. The strengths outweighs the weaknesses for the bioenergy sector which would bring about many benefits for Zambia and its inhabitants. The opportunities are also considerably good and worthy compared to the existing threats. One of the biggest threats many would argue is some energy crops such Cassava, Sweet Potatoes and sorghum are dibble crops which are often used as a substitute for staple food, maize. Since there is a lot of deforested land and unused land available, if properly controlled should not affect food prices and supply.

It also has to be noted that energy crops grown by the respondents in this research have huge potential due to their high contents of starch, fats and oils to produce biofuels in all forms of renewable energy. Energy crops like Cassava and Sweet potatoes have starch contents of around 40 % and 70 % respectively (FAO, 2014) and their yield among the respondents were as high as 20,000 kg/ha for Cassava and 15,000 kg/ha for Sweet Potatoes. Sorghum with starch contents as high as 75 % was also among the energy crops grown in Zambia. While other energy crops such as Sugar Cane, Elephant Grass were able to produce yields averaging 35,000 kg/ha and 20,000 kg/ha, respectively show greater potential as source of biomass for biofuels production and development.

Increase in growth of *Jatropha* and other plants like Cashew nuts would also boost the production of biodiesel production potential in Zambia. The production of biofuel from these plants is also not as sophisticated as biofuel production from elephant grass and sweet potatoes. Zambia's energy sector indeed has huge potential to satisfy the biofuel demand within Zambia and beyond its borders especially neighboring countries such as Democratic Republic of Congo (DRC) and Angola which are just coming out long civil wars and most of the land still having dangerous and deadly landmines making agriculture activity almost impossible.

Table 10: Values of Jatropha and elephant grass

	Advantages
Jatropha	❖ Non-food – no competition with food ❖ Rich in oil content ❖ Biodiesel from it reduce fossil fuel dependency ❖ Multi-purpose use ❖ Can be planted on unused and infertile/degraded land ❖ Can survive harsh weather conditions ❖ Long life of trees ❖ Environment and ecology friendly ❖ Potential medicinal and cosmetic value ❖ Remains after oil extraction as compost ❖ Seed cake can be used as animal fodder ❖ Provide employment to rural areas ❖ Increase and guarantee farmers' income for many years
Elephant grass	❖ Can grow naturally ❖ Non-food crop – no competition with food crops ❖ Survives harsh weather conditions ❖ Local people cut it and sale it to produce pellets – income ❖ Can be used as fodder, fencing and now biofuel ❖ Several harvests as it regenerates after being cut ❖ High level of yield ❖ Used as a wind breaker, prevent soil erosion ❖ Medicinal value ❖ No need for high fertilizer volumes ❖ Produce more biofuel than sugarcane, sorghum, corn

Source: Author's compilation

Table 10 shows an example of 2 of potential energy crops and some of the reasons why Jatropha and elephant grass should be encouraged as sources of bioenergy. The crops' value is still in development and it shows they have great potential to be multi-purpose plants which will be grown not only for biofuel production, but for other uses as well. Regardless the fact that both farmers spoken to do not have yet the advanced technologies needed to produce biofuel, their contribution to the sustainable energy in the areas they operate can already be seen and there is need to assist them grow and develop further. Both plants do provide multiple harvests in a year and no need to replant them every season. For Jatropha, it is estimated that when taken care of the tree can provide harvests

for 40 years (Brighton, 2010). While elephant grass can be replanted every after 5 – 6 years (Obok et al., 2012; Silva et al., 2002).

The government must do more than what is being done to promote sustainable energy in the country by educating the farmers, residents and especially the rural people the value of plants and potential in the energy crops; increase awareness of dangers of fossil fuels, charcoal, firewood, deforestation. The Zambian energy sector has great potential not only to have home energy security levels, but can also become an exporter of biofuel to other countries including to the West. The conditions to grow biomass which would not affect staple food growth and prices are very favorable in Zambia and can help realize the dreams of many especially in the rural areas to have access to energy, light, low levels of poverty among others.

If these plants can be encouraged together other energy crops, Zambians especially in rural areas would have stable income helping them attain a better standard of living. The agricultural sector's potential would be realized and the economy can diversify from the high dependence of copper production, exports especially with the unstable prices of the commodity. The sector would also offer employment and increase its share to the country's GDP and help Zambia as nation be self-sufficient in some way other than the current situation where it depends on donor aid to run most of the affairs of the country. With these energy crops Zambia has the potential to become a major energy supplier in the region as demand is rising faster than production of energy including in countries like Republic of South Africa, DRC, Angola and Zimbabwe.

After extraction of the biofuels from the biomass from these plants, animal fodder and organic fertilizers can be produced profiting even the livestock and the parties involved in this sector. Some plants like *Jatropha* and Elephant grass are still being investigated about their medicinal values they can offer to the societies. *Jatropha* oil is already used in rural areas in place of hazardous kerosene commonly known as paraffin, the rural people believe this chases away mosquitoes and burn longer than kerosene. This can be seen as another

advantage and way to help provide clean and sustainable energy to the rural areas which are off the national electricity grid. *Jatropha* soap is also already used to treat skin problems in rural areas where common soap prices are too high to afford.

It can be agreed that the biggest constraint Zambia faces to fully develop and benefit from bioenergy industry is lack or slow investment in this sector along with insufficient technology. The country does not have enough biofuel refinery companies although the Biofuel Energy Board does exist and is said to be bringing investors. At the moment it seems Sunbird Bioenergy Africa is the bioenergy company in Zambia that is in forefront of supporting the biofuel production in the country followed by the Nakambala Sugar Plc which is producing more electricity from Sugar Cane.

The copper mines in the Copperbelt Province are also starting to support the growth of energy crops especially Cassava to produce bioenergy as they have suffered a lot of setbacks with ZESCO load shedding. The Zambian Ministry of Energy and Water Development has to work extra hard to convince investors to bring the required technology. Another constraint is the mindset of the government workers in higher positions since Zambia is among the most corrupted countries, this deters many investors as they fear for them to be given permits and go ahead they will need to pay someone. Then comes the constraint from the local people and the dependency on aid and misuse of government and donor funds, instead of thinking what can be done to improve and be independent. Indeed there is still a lot of work to be done for Zambia to fully enjoy the benefits and potential of these new, clean and sustainable energy resources found in biomass.

7. Conclusion and recommendations

With the increase in technology, vehicles and globalization, the world's need to diversify its energy resources is urgent than never before with the depletion of fossil fuels the world has depended on for many centuries. And for a country like Zambia that need is even more urgent as the country already spends a lot of resources to purchase fossil fuels from overseas which can be used for many other development programs for its poor citizens. The researchers in bioenergy though still in development have shown that Zambia has a lot of energy crops with huge potential to move from the fossil fuel dependency to new sustainable energy resources. Zambia has the land to make this significant transformation and take advantage of the current resource the country has.

The country has a lot of deforested land which part of it can easily be used to increase and boost the growth of these energy crops. The yields of Cassava, Sweet Potatoes, Sorghum, Elephant Grass, *Jatropha* and Sugar Cane showed and proved the great potential the plant have in biofuel production in Zambia and beyond its borders. With the coming of key bioenergy companies in Zambia this would help the country move from its high dependence on fossil fuels and hydropower. The bioenergy companies should also take advantage of the government's policy on fossil fuel blending with bioenergy which makes it mandatory for petrol to be blended with bioethanol and has also introduced diesel blending with biodiesel and also encouraging engines that can run straight on biodiesel. The government through the relevant ministries is working on stabilizing security of fuel supplies and its fluctuating prices. Despite of all these measures there is still a shortage of biofuel to meet the growing demand in Zambia and this is again where the highly potential energy plants can prove vital.

When the technology arrives in the country, the energy plants can also be used to produce biogas and can also be used to run factory engines. These indeed are encouragements to invest more in these plants and other biomass as sustainable energy resources for the nation and also to export to other countries including its neighboring countries which do not have the capacity and land availability as Zambia has. Zambia's fight to become a

middle-class economy, low poverty level, employment creation, among others would be helped with increase in biomass growing and bioenergy production to reduce the big sum of money used to purchase fossil fuels. Zambia as a nation has the capacity to boost the bioenergy sector knowing this would greatly contribute to solving of many of its issues and fight for better lives for the citizens, for them to have access to clean, renewable, sustainable energy, lights, stable employment and income. Of course the transformation is not and will not be easy and need greater commitment from the government, cooperating partners, investors and the residents at large to fulfill this potential.

The research of this thesis further helped answer the question about cost effectiveness of bioenergy production in Zambia. The labor force in Zambia is still extremely low and that makes the diversification from fossil fuels to that of sustainable, renewable and clean energy resources much more valuable. In many countries production of bioenergy is extremely expensive due to high labor and land costs, which is not the case for Zambia. Land is also readily available to use for bioenergy production. The research also found that local people have discovered other advantages of biofuel and a good example is they realized that when *Jatropha* oil is used in lamps, it chases away mosquitoes which are a problem as they are responsible of transferring Malaria from one person to another and it is a deadly disease.

7.1. Recommendations

There is need for the Government of the Republic of Zambia to take effective measures in bioenergy production and these measures should or can include"

- Make the goals and objective in bioenergy production much clear than now
- Provide higher incentives for those bringing in and establishing bioenergy technology machines and refineries to produce biodiesel, ethanol, biogas

- Extend bioenergy projects to the rural areas as most of the rural areas are off-grid of the national electricity grid
- Make it easy for bioenergy sector investors to acquire land for this usage
- Educate the local people the importance and urgency of bioenergy sector development not only for environment and ecology protection but also as a source of employment and stable income for those employed in this field
- Take advantage of its land available to diversify the economy from copper dependence since prices for this commodity are very unstable
- Take advantage of the cheap labor costs in the continent to grow plants such as *Jatropha* and Elephant grass on the massive unused and infertile lands across the continent

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Appendices

List of appendices

1. Load shedding – Eastern Province
2. Load shedding – Livingstone
3. Load shedding - Lusaka
4. Questionnaire

Appendix 1: Electricity load shedding in Eastern Province

DATE	06:00HRS - 14:00HRS	14:00HRS- 22:00HRS	22:00HRS - 06:00HRS
	AZELE LINE	**BORDER AND NCL 11KV LINE**	**HSP, IND,WWK AND MFUWE LINE**
MONDAY	Katete District, Chadiza District Petauke District, Nyimba District,	Mwami Border,Feni, Magwero, Magwero plots, Rosemary, Magazine Mchini,Moth,Chimwemwe, Gondar, Chiparamba, kalichero, Early-Early, Madzimoyo, Mtenguleni, Motel Munga, Chikando, Chief Madzimawe	Town centre, litle Bombay, kalongwezi, Kapata, sido mthilansembe,Nabvutika,walela OLDJIM, DK,chizongwe,katopola, hills view and Mambwe District
TUESDAY	Mwami Border,Feni, Magwero, Magwero plots, Rosemary, Magazine Mchini,Moth,Chimwemwe, Gondar, Chiparamba, kalichero, Early-Early, Madzimoyo, Mtenguleni, Motel Munga, Chikando, Chief Madzimawe	Town centre, litle Bombay, kalongwezi, Kapata, sido mthilansembe,Nabvutika,walela OLDJIM, DK,chizongwe,katopola, hills view and Mambwe District	Katete District, Chadiza District Petauke District, Nyimba District,
WEDNESDAY	Town centre, litle Bombay, kalongwezi, Kapata, sido mthilansembe,Nabvutika,walela OLDJIM, DK,chizongwe,katopola, hills view and Mambwe District	Katete District, Chadiza District Petauke District, Nyimba District,	Mwami Border,Feni, Magwero, Magwero plots, Rosemary, Magazine Mchini,Moth,Chimwemwe, Gondar, Chiparamba, kalichero, Early-Early, Madzimoyo, Mtenguleni, Motel Munga, Chikando, Chief Madzimawe
THURSDAY	Katete District, Chadiza District Petauke District, Nyimba District,	Mwami Border,Feni, Magwero, Magwero plots, Rosemary, Magazine Mchini, Moth, Chimwemwe, Gondar, Chiparamba, kalichero, Early-Early, Madzimoyo, Mtenguleni, Munga, Chikando, Chief Madzimawe	Town centre, litle Bombay, kalongwezi, Kapata, sido mthilansembe,Nabvutika,walela OLDJIM, DK,chizongwe,katopola, hills view and Mambwe District
FRIDAY	Mwami Border, Feni, Magwero, Magwero plots, Rosemary, Magazine Mchini, Moth, Chimwemwe, Gondar, Chiparamba, kalichero, Early-Early, Madzimoyo, Mtenguleni, Motel Munga, Chikando, Chief Madzimawe	Town centre, litle Bombay, kalongwezi, Kapata, sido mthilansembe,Nabvutika,walela OLDJIM, DK,chizongwe,katopola, hills view and Mambwe District	Katete District, Chadiza District Petauke District, Nyimba District,
SATURDAY	Town centre, litle Bombay, kalongwezi, Kapata, sido mthilansembe,Nabvutika,walela OLDJIM, DK,chizongwe,katopola, hills view and Mambwe District	Katete District, Chadiza District Petauke District, Nyimba District,	Mwami Border,Feni, Magwero, Magwero plots, Rosemary, Magazine Mchini,Moth,Chimwemwe, Gondar, Chiparamba, kalichero, Early-Early, Madzimoyo, Mtenguleni, Motel Munga, Chikando, Chief Madzimawe
SUNDAY	Katete District, Chadiza District Petauke District, Nyimba District,	Mwami Border,Feni, Magwero, Magwero plots, Rosemary, Magazine Mchini,Moth,Chimwemwe, Gondar, Chiparamba, kalichero, Early-Early, Madzimoyo, Mtenguleni, Motel Munga, Chikando, Chief Madzimawe	Town centre, litle Bombay, kalongwezi, Kapata, sido mthilansembe,Nabvutika,walela OLDJIM, DK,chizongwe,katopola, hills view and Mambwe District

Appendix 2: Load shedding in tourist capital - Livingstone

	LIVINGSTONE LOADSHEDDING - JANUARY 2016 **Block A** (Capital Tyres, JR & Maramba Beer Hall); **Block B** (Choma, Linda, Nyasa, Townap); **Block C** (Parkline, Highlands & Ellain Britel): **Block D** (Railways, Mukuni & Sesheke): **Block E** (Cool Amarula, Livingstone); **Block F** (Sun)		
DATE	**06:00 - 14:00**	**14:00 - 22:00**	**22:00 - 06:00**
Monday	New Shoprite, FINTA, Batoka, Part I of 217, Mwandi & Dambwa(North & Ext), Falls park, Protea Hotel, Musanza Breweries, Cold Storage, Chrisma Hotel, Nottie Brodie & Maramba, Cool Amarura, Chundukwa, Chundu Farm, Kalonga Investment, Islands of Shankaba, Tobbaco farm, Kayube Estate, Simonga area, Katombora Reformatory, Royal Chundu & Sun Hotel **Block A,E&F**	Simango Village, Libuyu compounds, Eastwood Farms, Ngwenya and Linda compounds, Busiku and Muchindu farms, Sons of Thunder, BUK, Global Samaritan, Senkobo & Musokotwane Village, OP, Police Headquarters, Part of Town Centre (Fare Mount Hotel,), Dambwa (Central & Part of North), Kashitu, Sinde Plots, Nakatindi, LIBES, Park area & Zimba **Block B**	Highlands, DSV, DSS, Part of Indeco, Sewer Ponds, Ellain Brittel, Dutch Reformed, Hillcrest Sec., Radio Mosi o Tunya, GOTV, SWASCO, Part of Nottie Broadie, Aiport road Area, David Livingstone Teachers colledge, Mundolobela Clinic, ZAF compound, ZAF challets & ZAF base **Block C**
Tuesday	Zambia Railways area, ZESCO Villa, National Milling, ZRA, Post Office, Fire Brigade, ZNBC, ZAMTEL, Spar, Old Shoprite, Banks, Civic centre, Mukuni Village, Dry Manzi, Tunya Lodge, Munga, Palm Groove, David Livingstone Safari Lodge, Linda sewerage, Part II of 217, Zesco compound, Songwe Village, Sesheke, Mwandi, Simungoma, Mulobezi, Cool Amarura, Chundukwa, Chundu Farm, Kalonga Investment, Islands of Shankaba, Tobbaco farm, Kayube Estate, Simonga area, Katombora Reformatory & Royal Chundu **Block D&E**	New Shoprite, FINTA, Batoka, Part I of 217, Mwandi & Dambwa(North & Ext), Falls park, Protea Hotel, Musanza Breweries, Cold Storage, Chrisma Hotel, Nottie Brodie & Maramba **Block A**	Simango Village, Libuyu compounds, Eastwood Farms, Ngwenya and Linda compounds, Busiku and Muchindu farms, Sons of Thunder, BUK, Global Samaritan, Senkobo & Musokotwane Village, OP, Police Headquarters, Part of Town Centre (Fare Mount Hotel,), Dambwa (Central & Part of North), Kashitu, Sinde Plots, Nakatindi, LIBES, Park area & Zimba **Block B**
Wednesday	DSV, DSS, Part of Indeco, Sewer Ponds, Sun Hotel, Ellain Brittel, Part of Nottie Broadie, Dutch Reformed, Hillcrest Sec., Radio Mosi o Tunya, GOTV, SWASCO, Aiport road Area, David Livingstone Teachers colledge, Mundolobela Clinic, ZAF compound, ZAF challets & ZAF base, Cool Amarura, Chundukwa, Chundu Farm, Kalonga Investment, Islands of Shankaba, Tobbaco farm, Kayube Estate, Simonga area, Katombora Reformatory, Royal Chundu **Block C,E&F**	Zambia Railways area, ZESCO Villa, National Milling, ZRA, Post Office, Fire Brigade, ZNBC, ZAMTEL, Spar, Old Shoprite, Banks, Civic centre, Mukuni Village, Dry Manzi, Tunya Lodge, Munga Echo, Palm Groove, Linda sewerage, David Livingstone Safari Lodge, Part II of 217, Zesco compound, Songwe Village, Sesheke, Mwandi, Simungo & Mulobezi **Block D**	New Shoprite, FINTA, Batoka, Part I of 217, Mwandi & Dambwa(North & Ext), Falls park, Protea Hotel, Musanza Breweries, Cold Storage, Chrisma Hotel, Nottie Brodie & Maramba **Block A**
Thursday	Simango Village, Libuyu compounds, Eastwood Farms, Ngwenya and Linda compounds, Busiku and Muchindu farms, Sons of Thunder, BUK, Global Samaritan, Senkobo & Musokotwane Village, OP, Police HQ, Part of Town Centre (ZNBC, Fair Mount Hotel, Zamtel), Dambwa (Central & Part of North), Kashitu, Sinde Plots, Nakatindi, LIBES & Park area, Cool Amarura, Chundukwa, Chundu Farm, Kalonga Investment, Islands of Shankaba, Tobbaco farm, Kayube Estate, Simonga area, Katombora Reformatory, Royal Chundu, Zimba & Sun Hotel **Block B,E&F**	Highlands, DSV, DSS, Part of Indeco, Sewer Ponds, Ellain Brittel, Dutch Reformed, Hillcrest Sec., Radio Mosi o Tunya, GOTV, SWASCO, Part of Nottie Broadie, Aiport road Area, David Livingstone Teachers colledge, Mundolobela Clinic, ZAF compound, ZAF challets & ZAF base **Block C**	Zambia Railways area, ZESCO Villa, National Milling, ZRA, Post Office, Fire Brigade, ZNBC, ZAMTEL, Spar, Old Shoprite, Banks, Civic centre, Mukuni Village, Dry Manzi, Tunya Lodge, Munga Echo, Palm Groove, Linda sewerage, David Livingstone Safari Lodge, Part II of 217, Zesco compound, Songwe Village, Sesheke, Mwandi, Simungo & Mulobezi **Block D**
Friday	Highlands, DSV, DSS, Part of Indeco, Sewer Ponds, Sun Hotel, New Shoprite, FINTA, Batoka, Part I of 217, Mwandi & Dambwa (North & Ext), Falls park, Protea & Sun Hotel, Musanza Breweries, Cold Storage, Chrisma Hotel, Nottie Brodie & Maramba **Block A&F**	Simango Village, Libuyu compounds, Eastwood Farms, Ngwenya and Linda compounds, Busiku and Muchindu farms, Sons of Thunder, BUK, Global Samaritan, Senkobo & Musokotwane Village, OP, Police Headquarters, Part of Town Centre (Fare Mount Hotel,), Dambwa (Central & Part of North), Kashitu, Sinde Plots, Nakatindi, LIBES, Park area & Zimba **Block B**	Highlands, DSV, DSS, Part of Indeco, Sewer Ponds, Ellain Brittel, Dutch Reformed, Hillcrest Sec., Radio Mosi o Tunya, GOTV, SWASCO, Part of Nottie Broadie, Aiport road Area, David Livingstone Teachers colledge, Mundolobela Clinic, ZAF compound, ZAF challets & ZAF base **Block C**
Saturday	Zambia Railways area, ZESCO Villa, National Milling, ZRA, Post Office, Fire Brigade, ZNBC, ZAMTEL, Spar, Old Shoprite, Banks, Civic centre, Mukuni Village, Dry Manzi, Tunya Lodge, Munga Echo, Palm Groove, Linda sewerage, David Livingstone Safari Lodge, Part II of 217, Zesco compound, Songwe Village, Sesheke, Mwandi, Simungo & Mulobezi **Block D**	Cool Amarura, Chundukwa, Chundu Farm, Kalonga Investment, Islands of Shankaba, Tobbaco farm, Kayube Estate, Simonga area, Katombora Reformatory, Royal Chundu **Block E**	New Shoprite, FINTA, Batoka, Part I of 217, Mwandi & Dambwa(North & Ext), Falls park, Protea Hotel, Musanza Breweries, Cold Storage, Chrisma Hotel, Nottie Brodie & Maramba **Block A**
	Cool Amarura, Chundukwa, Chundu Farm, Kalonga Investment, Islands of Shankaba, Tobbaco farm, Kayube Estate, Simonga area,	Zambia Railways area, ZESCO Villa, National Milling, ZRA, Post Office, Fire Brigade, ZNBC, ZAMTEL, Spar, Old Shoprite, Banks, Civic centre,	Simango Village, Libuyu compounds, Eastwood Farms, Ngwenya and Linda compounds, Busiku and Muchindu farms,

Appendix 3: Electricity load shedding in Lusaka

Specific Procedure

ZESCO
Powering the Nation

Document No:
DS.13350.SPPR.00005

Title:
February Load Shedding schedule - Lusaka

Date of Approval:
20/01/2016

Version:
1

Division:
Lusaka Division

1.0 GROUP A – INDUSTRIAL

DAYS	AREAS AFFECTED	TIME
Monday To Sunday	Pembe milling, Varun beverages, Lusaka west bakery and surrounding areas, Happy metals, High protein, Alkal engineering, Superio milling, Sobi industries, Amiran and customers along Mumbwa road from Zambeef headquarters to Chat breweries turnoff, Stabic bank in light Industrial Area, NSCO industries, APG milling, Choma milling,Trade Kings, Musa Biscuits, Crest Chicken, Swiss Bake, Form King, New Soweto market, Spar Soweto, City market, Simoson building, Industries along Mukatasha and Kachinza Roads, Mukatasha enterprises, Real Meat, Polythene products, Amalgamated steel, SAFINTRA, Dairy king, Melcome, Nambala Road, Soweto area, Mumbwa road, MMI Steel to katanga road, Goodtime steel, Industries after learne Investments, Industries along Lumumba Road, Lamasat, Lamise, Makeni shopping Mall, Shabico milling, Deco and surrounding areas, Majestic casino, Garden House, New Chinese Hotel, Crown millers, Star milling, Chat breweries, Lusaka bread, Kings chemicals, Petroda house great north road, Boc gases, National breweries, Emmasdale police camp and surrounding areas, Nampack, Barloworld, Government stores, Lenco, Shell, ZAMHORT, Steel tube, Medical stores, Bata shoe company, Crop pack limited, Industries along Buyatanshi and Mukwa roads, Zambia Breweries, Guras, Tiger Animal feeds, FRA sheds, Chinika Industrial Area, Zambeef, Zamanita, Trade kings Maheu, Customers along Manda Road, Oriental Quarries, Some industries along Buyatanshi road, Industries along Malambo and Shekisheki roads, Agip, Girrhad milling, Family biscuits and surrounding areas, Tombwe tobacco processing, GBM milling, SEBA foods limited, African milling, Namboard, Novatek, Star beef, capital fisheries, Joma breweries	16:00hrs To 00:00hrs

1.1 GROUP B – COMMERCIAL

DAYS	AREAS AFFECTED	TIME
Monday To Sunday	State Lodge area, New Kasama / Oxygen Gym, Russian embassy, Japanese embassy, Chinese embassy, Botswana embassy, Highland house, UTH traffic lights, OAU Millennium Village, Supreme court, High court, Customers near Elunda Park, Post Newspaper, Pamodzi Hotel and parts of Fairview, World bank, Lusaka Water and sewerage, Immigration department, Neil Farms, Kuomboka, York Farm, Embassy Shopping Mall, Polar ice, Spar Chawama, SDA eye clinic, Quality feeds, Parts of Lilayi/Kafue Rd, Linda, Baobao College, Backley, Eureka Park, Sandis Creation, Mount Makulu Research, Mount Makulu farm, Rose breeders, Mimosa, RTSA along Lumumba road, Customers along Luanshya and Lumumba roads upto family 24, Villa Elizabertha (ZRA to Aquila printers), Ideal funeral home, Parts of light industrial area, Town Centre, BOZ, Down town shopping mall, Mukuba pension house and surrounding areas, Kamwala trading area, Zambia army staff college, Kamwala secondary school, St Patricks basic school, Makeni breweries, Parts of Makeni from Ndipo substation, Aquasavanna company and customers along Ndipo road, Zambia Fairy bottling company, Areas along Malambo road, National milling Malambo road, Zambia sugar, Manda Hill Shopping Mall, Rhodes Park Nangwenya road, National Assembly Motel, Toyota Zambia Nangwenya road, ERB, MTN main switch, Trinity park, Multi Choice Zambia, Corporate park, RDA, Base park, Alliance Francais, Lusaka University, ZPPA, Pope square, Football house, Civic centre, Ministry of education, Central SDA, Pamodzi Hotel, Zamtel Lamya House, Government printers, Central police, Boma local court, Ministry of community development, Grand western hotel opposite ZESCO head office, Daily mail in Kabelenga road, MUMS care clinic, Rhodes park around Wimpy along great east road, Associated printers, Godfrey house opposite Levy mall, Kudu Holdings, Dwembe Farm, Mulungushi International Conference Centre, Arcades Shopping Mall, East Park Shopping Mall, Areas along Thabo Mbeki road, Arcacia park, Go Centre, MUVI TV, Parts of Kalingalinga, Mass Media area, Cross Roads Shopping Mall and surrounding areas, South African high commission, Engine filling station along Leopards hill road, Saint Marys school, Lake road school, Twin palm school, Hill top hospital, Levy Park Shopping Mall, Parts of showgrounds, Parts of areas along Addis Ababa drive, Sable Consolidated Farms, Christian voice.	00:00hrs To 08:00hrs

1.2 GROUP C – COMMERCIAL FARMERS

DAYS	AREAS AFFECTED	TIME
Monday To Sunday	Barlastone area, Twikatane farms, Eden institute, Ferngroove, Kasupe, Mwaka lodge, Sunshare industries, Wonderful ceiling, Mt Meru filling station along Mungwi road, Parts of Ibex Hill, ZAF Twin Palm Base and surrounding areas, Palabana, Kyindu ranch, New Kasama between Mikango and Kyindu ranch, Southern part of new Kasama/Mikango Barracks, Calamazi Farm, Schemeta Farm, Sun Rose Farm, Taico Farm, Chimwala Farm, Mbozi Farm, Ongan Farm, Asando Farm, MRI Farm, Kakumba Farm, Howard Farm, Honda Farm, Morester Farm, Lwimba Farm, Kamina Farm, Gwaza Farm, Kalix Farm, Rose breeders, Seven kings, Chilumenda farm, Majoru Farms, Makeni west school, customers near general Miyanda, Eureka Park/Jan Japan, Lamasat, Neil Farms, Lilayi/Miller Farms, Chisamba, Nkongolo, John Ken, Kalangwa, Sable, Matongo, Kamaila, Kaposhi, Ngwerere, Kasisi, ZASIT and surrounding areas, Cena Farms and surrounding areas, Sopelo camp, Mundengwa area, Muzimbili ranch and surrounding areas, Jakana Estates, Bunde Farms, Chikupi area, Water Wells Farms, Hybrid Farms, Ambrosia Farms, Sunrise Farms, Zambia China Farms, Makeni Islamic society, Buffalo village and customers along Makeni road upto Oriental turnoff, Mumbwa, Mwembeshi and surrounding areas, NIPA area, Fairview area, Evelyn Horn, NIPA, ZCAS, ZAMTEL along Chilubi road, Customers along Parirenyatwa road near DHL, 6miles and surrounding areas, 10miles, 13miles, 22miles, Mungule area, DMI ST. Eugene University, Kabangwe area, Shakas Kraal, Zanimuone, Precem area, Parts of Chunga, Parts of Kabanana, Parts of Chazanga, Chibombo, Mwachisopola, Kembe, Western parts of Shimabala / Mapepe aggregate quarry, Basset farms, Sunrise Estate Farms along Mumbwa Road, Okapy Farms, Kaype Farms, Sunlight Farms and customers along Mumbwa Road between Makeni Police (Villa Lucia) check point, Kalundu area, Mwembeshi Satelite Station, Mwembeshi open prison, Sable Farms, Parogate ginnery, Mwembeshi Maximum prison, Hatley Farms, Westhood police station, Customers in Mwembeshi between Westhood police and Mwembeshi river, Evergreen Farms, Mayflower Farms, Kashima Farms, Sobi Farms, Merydale Farms, Zambia China Farms and customers between Shorthorn and Kacheta up to Nampundwe road.	06:00hrs To 14:00hrs 12:00hrs To 20:00hrs 14:00hrs To 22:00hrs

GROUP C – COMMERCIAL FARMERS

Appendix 4: Questionnaire

Bio-Energy Carriers in Agriculture in Zambia

My name is Odjukwu Banda, I am doing master thesis at Faculty of Tropical AgriSciences at Czech University of Life Sciences in Prague in the Czech Republic. My thesis is entitled: Bio-Energy Carriers in Agriculture in the Republic of Zambia. The thesis is part of the requirements to finish the master studies. The thesis focuses on Renewable energy sources in Zambia. I have asked colleagues to help in asking you to fill in this questionnaire as I am currently in the Czech Republic. If translation to local language is needed my colleagues will help with that. The questionnaire is anonymous and it will take about 20 minutes of your time. Thank you in advance for your participation

* Required

1. **Gender** *
   Mark only one oval.
   - ◯ Male
   - ◯ Female

2. **Age Range** *
   Mark only one oval.
   - ◯ 15 - 25
   - ◯ 26 - 35
   - ◯ 36 - 50
   - ◯ 50+

3. **What level of education do you have?** *
   Mark only one oval.
   - ◯ Primary School
   - ◯ Secondary School - Finished
   - ◯ University
   - ◯ None

4. **Which province of Zambia are you located?** *
   .....

5. **Which of the following terms are you familiar with?** *
   Check all that apply.

   - [ ] Renewable energy
   - [ ] Bio energy
   - [ ] Climate change
   - [ ] Sustainable development
   - [ ] Hydro energy
   - [ ] Biofuels
   - [ ] None

6. **Where have you heard these terms if any?**
   Check all that apply.

   - [ ] Radio
   - [ ] TV
   - [ ] Newspaper
   - [ ] School/Educators
   - [ ] Internet
   - [ ] Friend
   - [ ] Other: .....

7. **What type of energy does your household use for heating the house?** *

   .....

8. **What type of energy does your household use for cooking?** *

   .....

9. **What type of energy does your household use for heating water?** *

   .....

10. **How big is your farm (hectares)?**
    Mark only one oval.

    - ◯ 1 - 5
    - ◯ 5 - 10
    - ◯ 10+

11. **What energy crops do you grow?**

.....

12. **Why did you choose this/these crops?** *
Check all that apply.

- [ ] Offer from current/future buyers - marketability
- [ ] Quick yield
- [ ] Investment benefits
- [ ] Crop can adapt even with less water availability
- [ ] High yield
- [ ] Other: .....

13. **What is the source of your seeds/seedlings?** *
Check all that apply.

- [ ] Seeds/seedlings from government
- [ ] Seeds/seedlings from out-grower scheme
- [ ] Use from previous harvests
- [ ] Purchase alone
- [ ] Other: .....

14. **Do you use any inputs for your energy crops?** *
Mark only one oval.

- ◯ Organic fertilizers
- ◯ Chemical Fertilizer
- ◯ Combination of organic and chemical fertilizers
- ◯ None

15. **If you use any inputs, what is the source of these inputs?** *
Mark only one oval.

- ◯ Goverment
- ◯ Out-grower scheme
- ◯ Purchase alone
- ◯ I use none

16. **Are you part of any of the out-grower schemes?** *
Mark only one oval.

- ◯ Yes
- ◯ No

17. **If yes, do they support you throughout the season?** *
Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Not part of any

18. **If part of out-grower scheme, do they buy your whole yield?** *
Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Not part of any

19. **If not on any out-grower scheme, where do you sell your yield?**

.....

20. **How many kilograms per hectare do you collect?** *

.....

21. **Do you feel the government is doing enough to support the growth of bio energy crops?** *
Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ No idea

22. **If not, what do you think the government should do**

.....

23. **What is your opinion on supporting bio energy raw materials as the source for renewable energy?** *
Mark only one oval.

- ◯ Strongly Support
- ◯ Support
- ◯ Neutral
- ◯ Strongly Oppose
- ◯ Oppose

24. **What do you think would be advantage of bio plants as raw materials for the energy in Zambia?** *

Check all that apply.

- [ ] Would help local farmers have stable and assured income
- [ ] Would help alleviate current high poverty levels
- [ ] The agricultural sector would be developed further and provide more employment
- [ ] If Zambia would produce more energy from these plant and export some would help stabilize Kwacha
- [ ] The power outages and shortages would be improved