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## Research Paper

# ASSESSMENT AND PROJECTION OF WASTE VEGETABLE OILS FROM HOTELS FOR BIODIESEL FEEDSTOCK AND CO<sub>2</sub> SAVINGS IN GHANA

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Waste Vegetable Oils (WVOs) are used cooking oils generated as by-products from factories producing foods, fast foods, restaurants, households and hotels. In Ghana the quantities of WVOs being generated are not known. This makes it difficult for prospective investors intending to use WVOs as feedstock to size their processing plant. Further, carbon dioxide savings likely to be made from the use of WVOs biodiesel is uncertain owing to lack of data on quantities of feedstock. This study was carried out using structured questionnaires in a cross-sectional survey of 340 hotels in five major cities (Accra, Kumasi, Tamale, Sunyani and Takoradi) of Ghana. Plastic containers were used to collect stored quantities of oils from hotels and measured using funnel and beaker. The results showed that competitors for the use of WVOs were soap makers, commercial shitto (traditional sauce) producers, domestic users, food vendors, etc. The results further indicated that fresh vegetable oils were re-used 3-6 times before discarded as waste. Nearly 20% of WVOs generated were poured into drains and the ground. From data analysis and scenarios based on hotels in the five major cities, it is estimated that in 2013, Ghana could be producing 70,000-78,000 tons of biodiesel from WVOs. This could be projected to 82,361-85,904 tons of biodiesel from WVOs generated by hotels by 2015. Average production of WVO biodiesel from hotels in Ghana could be about 3,765 tons per year. By 2015, use of biodiesel could produce about 348 tons of CO<sub>2</sub> compared to 1582 tons of CO<sub>2</sub> from diesel.

**Keywords:** Waste vegetable oil, Biodiesel, Batch frying, Discarded oil, Feedstock, Ghana

## INTRODUCTION

Energy sources have been a major determinant in man's development as well as economies of various countries. For some years now fossil fuel

has been a major source of energy for the transportation sector and prime mover of second generation sources like the compression ignition engines. In a time when fossil fuel supplies are getting depleted and their prices keep on

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fluctuating at an increasing rate, the need to have alternative renewable sources is paramount. Among the renewable sources of fuel for the transport, agriculture, small business and industry is the use of Waste Vegetable Oils (WVOs) either straight or as biodiesel. Biodiesel is a vegetable oil or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, propyl or ethyl) esters. Biodiesel is made by combining alcohol (usually bioethanol) with vegetable oil, animal fat, or recycled cooking grease (WEC, 2010). To produce biodiesel fuels the oils undergo alcoholysis or transesterification during which fatty acids in oils are separated from the glycerol components using ethanol or methanol. The glycerol components are replaced with specific types of alcohols known as short linear alcohols during the process (Schuchardt *et al.*, 1998; Knothe, 2001).

WVOs are used vegetable oils found in almost every kitchen. Unlike Pure Plant Oil (PPO) or straight vegetable oil, WVO is a by-product of other industries like deep fryers used in industrial potato processing plants, factories producing snack foods and fast food restaurants (Griffin, 2009). In Ghana, this may include fish, yam and ripe plantain frying as well as doughnut fryers on small, medium and large scales. Vegetable oils used to fry food items in Ghana include oils from palm kernel, coconut, groundnut and soya bean. *Trans* isomers of fatty acids, formed by the partial hydrogenation of vegetable oils to produce margarine and vegetable shortening, increase the ratio of plasma low-density-lipoprotein to high-density-lipoprotein cholesterol, so it is possible that they adversely influence risk of coronary heart disease (Willett *et al.*, 1993; Mozaffarian *et al.*, 2006, 2007, 2009; L'Abbe *et al.*, 2009).

In most countries waste vegetable oil has had two destinations, either it is discharged into local

sewage systems as "ditch oil" or reused in some kitchens and as raw materials for other products.

In Ghana, however, the volumes or quantities of WVOs being generated are not known. This makes it difficult for a prospective investor intending to use WVO as feedstock to size his processing plant. Poor management of waste vegetable oils has also detrimental effect on the environment through generation of unpleasant stench in the immediate environs and on surface water bodies and aquatic lives. Studies have shown that WVOs work best in diesel engines like diesel generators and compression ignition engines in vehicles when processed into biodiesel, hence a major feedstock for biodiesel fuel.

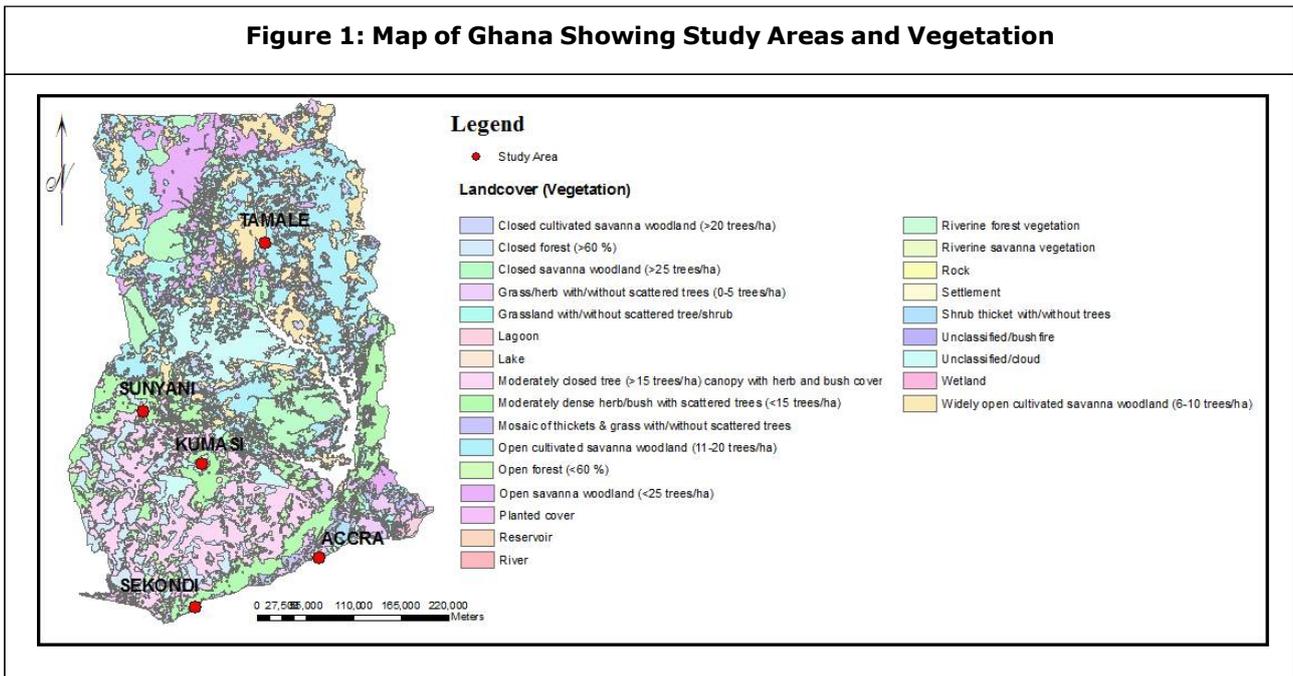
There may be other activities that will affect the potential of WVOs becoming a feedstock for biodiesel production in Ghana as a substitute or complement to fossil diesel. For any informed and appropriate decision to be taken on the processing of WVOs into biodiesel as substitute or supplement of fossil diesel on commercial quantity level there is the need to know the competitors of users of waste vegetable oils with biodiesel. The main objectives of the study were to: (1) determine the number of times a batch of fresh vegetable oil is used before discarded and competitors for the use of WVOs; (2) determine the quantities of WVOs being generated by hotels in the major cities of Ghana within a year; (3) project the annual quantities of WVOs for Ghana's biodiesel feedstock and carbon dioxide savings when compared with fossil diesel.

## STUDY AREAS AND METHODS

### Study Areas and Data Collection

The study was carried out using structured questionnaires in a cross-sectional survey to elicit

**Figure 1: Map of Ghana Showing Study Areas and Vegetation**



information from hotels in five major cities of Ghana, namely Accra, Kumasi, Takoradi, Sunyani and Tamale. Figure 1 is the map of Ghana showing the study areas and vegetation. Out of a total number of 780 hotels that was compiled from a directory of hotels and restaurants obtained from the Ghana Tourist Board, Accra, the number of hotels sampled for the study using random sampling technique was 340. In addition, quantities of oils stored in plastic containers in the hotels studied were measured using funnel

and beaker. In hotels where waste vegetable oils were discarded before the study, some arrangements were made to get them some plastic containers for storage of oils, which were later measured.

Table 1 shows the population of hotels in the study areas. Research assistants from the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana who speak the local languages of the respondents were engaged in the administration of the questionnaires.

**Table 1: Population and Sample Sizes of Hotels in the Major Cities**

Major Cities	Sampled Hotels	Total Population of Hotels*
Accra	215	494
Kumasi	80	182
Takoradi	14	33
Sunyani	16	37
Tamale	15	34
<b>TOTAL</b>	<b>340</b>	<b>780</b>

\*Source: Ghana Tourist Board Directory, 2007

The purpose of the questionnaires was to gather information on the potential of waste vegetable oil as feedstock for biodiesel production in commercial quantities in Ghana.

### Data Analysis and Assumptions

The questionnaires were statistically analyzed using Excel and SPSS software version 16. The data were cleaned by visually cross-checking the data base with the individual questionnaires to find out wrong entries and by using box-plot to identify extreme values and outliers. To provide understanding of the relationship, descriptive statistics was used for data analysis. Statistical analysis was done at 95% significance level. To project the quantities of WVOs being generated by hotels in the five major cities into the entire country of Ghana, the following variables were considered: (1) projected hotels of 1135 likely to be in the five major cities by 2015; (2) total hotels of 2001 likely to be established in Ghana by 2015; and (3) growth rate of hotels of 4.8%. Scenarios of annual quantities of biodiesel that could be produced from discarded oils from the study areas as well as projections for Ghana were carried out and presented. First of all, the current quantities of WVOs were assessed and the results were used to estimate biodiesel equivalent using conversion efficiencies of 93%, 95% and 97% (Issariyakul *et al.*, 2007; Chhetri *et al.*, 2008). Assuming a life cycle savings of 78% of carbon dioxide produced from biodiesel compared to fossil diesel, the quantities of carbon dioxide likely to be produced from WVO biodiesel compared to same quantities from fossil diesel were determined.

## RESULTS AND DISCUSSION

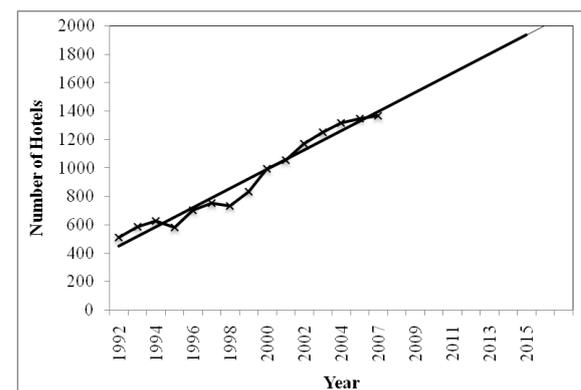
Waste vegetable oils likely to be considered as potential feedstock for biodiesel production in Ghana can be generated from three main

sources: hotels, restaurants and traditional and likely to be generated by the hotels in the study areas.

### Population of Hotels

The population of hotels in Ghana and the projected number up to the year 2015 are presented in Figure 2 below. The growth rate and projected population of hotels in Ghana were determined using data from 2007 edition of Ghana Tourist Board Directory and Tourism Data Series 2005. From the data, the annual growth rate of hotels in Ghana was estimated to be 4.8%. Thus by year 2015 a total of 2001 hotels would be in

**Figure 2: Population of Hotels in Ghana and the Projected Number up to the year 2015**



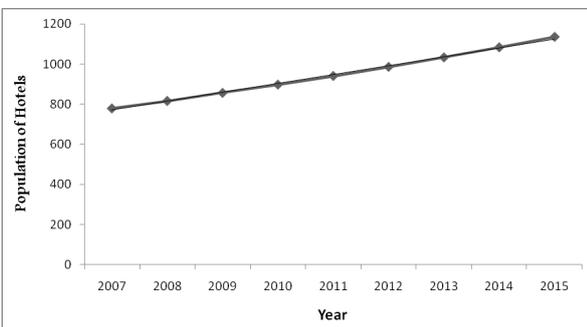
Ghana.

The projected population of hotels in the five major cities up to the year 2015 is presented in Figure 3 below. Using the annual growth rate of 4.8% of hotels in Ghana, it is estimated that about 1135 hotels are likely to be established in the five major cities by the year 2015.

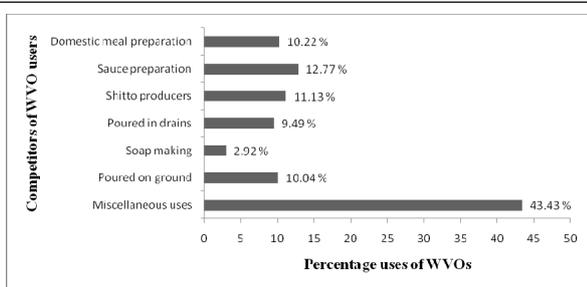
### Competitors of WVOs Alongside Biodiesel Production

Figure 4 represents competitors of WVOs generated in the major cities of Ghana. The bar plots revealed that competitors for the use of

**Figure 3: Projected Population of Hotels in the Five Major Cities up to the year 2015**



**Figure 4: A Chart Showing Competitors of WVO Users**



WVOs were soap makers (3%), commercial *shitto* producers (11%), domestic users (10%) and sauce preparation (13%). About 20% were poured into drains and on the ground. A sizeable percentage of the hotels (43%) did not know what to do with the WVOs generated and hence

sometimes leave them to go rancid. From the results, potential quantity of WVO to be considered as feedstock for biodiesel production would be:

- Those poured into the drains;
- Those poured on the ground
- Those left to go rancid,

These would range between 20% and 63% of WVOs generated in the study areas.

**Major Types of Food Fried With Vegetable Oils and Number of Times A Batch Is Used**

From the results in Table 2, the differences in types of dishes being prepared and cooking habits influence quantities of oils used for cooking and what is discarded as waste. The diets prepared are influenced by the culture and tradition of the locality of the hotel; hence the variation in the consumption of fresh vegetable oils by hotels in different Major cities. The results indicated that the average number of times a batch of vegetable oil is used before discarding ranges between 3 and 6. Repetitive or continual reuse of vegetable oil lowers the smoke point, which is the temperature at which the oil breaks down creating acrolein, an obnoxious smelling compound and

**Table 2: Major types of Food Fried with Vegetable Oils and Number of Times a Batch is Used in a Regional Capital**

Major Cities	Major Types of Food Being Fried With Vegetable Oils	Average Number of Times a Batch of Vegetable Oil is Used Before Discarding
Accra	Yam, fish, sausages, pastries, chicken, rice, sauce, doughnuts	3
Kumasi	Yam, fish, doughnuts, meat pie, plantain, chips, rice	4
Sunyani	Plantain, meat, yam, fish, potatoes, rice	3
Takoradi	Yam, fish, meat, pastries, rice	4
Tamale	Yam, fish, chicken, <i>koose</i> , pastries, meat pie, potatoes	6

visible fumes are given off (Good, 2012). This makes the oil for frying smoke at a lower temperature in heating (Rossell, 1998). The decomposition of the vegetable oil renders the waste oil toxic making it unwholesome to be used for food preparation. Waste vegetable oil then becomes useful feedstock for biodiesel production. The potential WVO to be considered as feedstock for biodiesel production would constitute what is poured into the drains, those poured on the ground and those left to go rancid which ranged between 20% and 63% of WVOs generated in the study areas.

### Mean Quantities of Fresh and Waste Oils

Table 3 shows the results of fresh vegetable oils used and oils discarded as waste by hotels in the study areas. From the table, the quantities of fresh vegetable oils used by the hotels was 65-269 L/month with hotels in Kumasi having the least while hotels in Tamale recorded the highest.

In terms of the percent of fresh vegetable oils discarded as waste, hotels in Accra generated 34%, Takoradi generated 27%, Sunyani (22%), Kumasi (20%), while Tamale generated (15%) of the quantities of fresh vegetable oils used per month as depicted in Figure 5.

### Monthly Quantities of Oil Being Used and Discarded

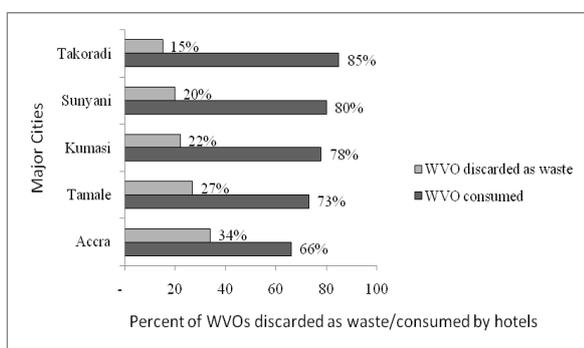
The proportion of vegetable oils used in a month by hotels is demonstrated in Figure 6 below. From the bar plots, 89.2% of the hotels used 1-300 L per month, 4.8% used 301-600 litres per month and 6.0% used more than 600 L per month.

Waste vegetable oils that are discarded can be potential feedstock for biodiesel production. The reason being that heating oil produces free fatty acid and as heating time increases more free fatty acids are produced thereby decreasing smoke point. This is one reason not to use the same oil to deep fry more than twice. The glycerol breaks down to acrolein which is a component of the smoke. The presence of acrolein causes the smoke to be extremely irritating to the eyes and throat (Rossell, 1998). The bar plots in Figure 7 showed that about 67% of the hotels sampled discarded the oils as waste, while only 33% reused the waste oils. The results also indicated that about 57% of the hotels discarded 1-100 L per month about 6% discarded 101-200 L per month, while 4.5% of the hotels discarded over 200 L per month.

**Table 3: Quantities of Fresh Vegetable Oils Used and Discarded as Waste by the Hotels**

City	Mean Quantity of Fresh Vegetable Oil Used per Hotel per Month (litres)	Mean Quantity Discarded as Waste per Hotel per Month (litres)	Percent of Fresh Vegetable Oils Discarded as Waste
Accra	162.63	54.46	34%
Kumasi	64.75	12.62	20%
Sunyani	220.00	48.29	22%
Takoradi	168.31	45.00	27%
Tamale	269.13	40.20	15%

**Figure 5: Percent of WVOs discarded as waste/consumed**



**Estimated Quantity of WVO Discarded per Month**

Table 4 represents the estimated quantities of discarded vegetable oil by hotels in the studied cities. The table showed that about 90% of the hotels that used the WVOs were found in Accra (49%) and Kumasi (41%) with the remaining 10% spread in the other cities. Over 70% of the hotels

in Accra and Kumasi discarded 1-100 L of WVOs per month. About 12%, 11% and 6% of the hotels that discarded 1-100 L of WVOs were in Tamale, Takoradi and Sunyani respectively. Majority of the hotels in Accra (60%) discarded 101-200 L of WVOs per month, while 10% of the hotels in each of the remaining cities discarded 101-200 L of WVOs per month. Surprisingly, only the hotels in Accra discarded over 200 L of vegetable oils per month. The hotels that did not discard their oils recycled them for the preparation of *shito* and other sauces while others gave them out for soap making. Navitron (2013) reported that 2-fryer could generate 20-30 L/month while 4-fryer could generate 40-50 L/month waste vegetable oil. Also a small turnover chip shop generates 20 L per month while a large turnover one generates more than 60 L per month. The results also indicated that about 57% of the hotels discarded 1-100 L/month, about 6% discarded 101-200 L/month

**Table 4: Estimated Quantities of WVO Discarded per Month by Hotels**

City	Estimated WVO Discarded per Month				Total
	No waste / Waste is Reused	1-100L	101-200L	>200L	
Accra	29	41	6	8	84
	49.2%	40.6%	60%	100%	
Kumasi	24	31	1	0	56
	40.7%	30.7%	10%	0	
Sunyani	1	6	1	0	8
	1.7%	6.2%	10%	0	
Takoradi	1	11	1	0	13
	1.7%	11%	10%	0	
Tamale	4	12	1	0	17
	6.7%	11.5%	10%	0	
Total	59	101	10	8	178
	100%	100%	100%	100%	

while the hotels that discarded more than 200 L per month were only 4%.

The quantities of WVOs generated in each major city are presented in Table 5. The results showed that the hotels in Accra generated the highest quantity (35,617 L), followed by Kumasi (3,041 L), Takoradi (2,205 litres), Sunyani (2,125 litres), and Tamale (1,809 L) of WVOs per month. From the results it is obvious that hotels in Accra are most likely to generate WVOs that can be targeted as feedstock for future production of biodiesel in Ghana.

### Projected Annual Quantities of WVOs from Hotels

Using the growth rate of hotels of 4.8%, the corresponding annual quantities of WVO likely to be generated by hotels in the major cities are presented in Table 6. From the results, by the year 2015 the following quantities of WVOs are likely to be generated from the major cities: Accra 42,248 tons; Kumasi 3,608 tons; Sunyani 2,520 tons; Takoradi 2,616 tons and Tamale 2,146 tons. The quantities of WVOs likely to be generated by the major cities have implications for the location of biodiesel plants as the cost of production will

be influenced by proximity to feedstock. This suggests that it will be economically viable and prudent to site a commercial processing plant of WVO biodiesel in Accra. The results indicated that by the year 2015 about 53,137 tons of biodiesel from waste vegetable oil could be produced and this could replace significant amount of fossil fuel, which would reduce the emission of carbon dioxide into the atmosphere leading to minimization of global warming effect on climate change.

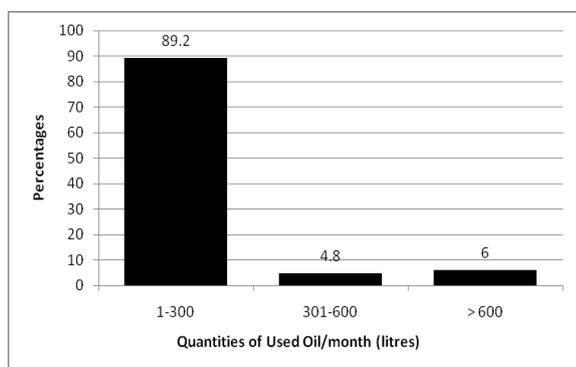
### Scenarios for Annual Quantities of Biodiesel Production

In Table 7 below, different scenarios of annual quantities of biodiesel that could be produced from discarded oils from the study areas as well as projections for Ghana are presented. First of all, the current quantities of WVOs were assessed and the results were used to estimate biodiesel equivalent using conversion efficiencies of 93%, 95% and 97% based on various studies (see Issariyakul *et al.*, 2007; Chhetri *et al.*, 2008). The results indicated that using conversion efficiencies of 93-97%, about 44,994-46,930 tons of biodiesel could be produced from the WVOs to be collected from hotels in the study areas in

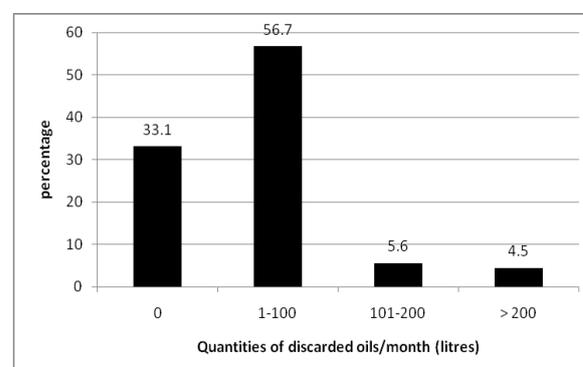
**Table 5: Estimated Quantities of WVOs from Hotels in Each Major City**

Major Cities	Population of Hotels in Each City in 2013	Mean Quantity Discarded as Waste by a Hotel/Month (litres)	Estimated Quantities of WVOs from Hotels in each City per Month	
			Litres	Gallons
Accra	654	54.46	35616.84	7914.853
Kumasi	241	12.62	3041.42	675.8711
Sunyani	44	48.29	2124.76	472.1689
Takoradi	49	45.00	2205	490
Tamale	45	40.20	1809	402
<b>Total</b>	1033		44797.02	9954.893

**Figure 6: Percentage Quantities of Waste Vegetable Oil by Hotels**



**Figure 7: Percentage Quantities of Discarded Vegetable Oils by Hotels**



**Table 6: Projected Annual Quantities of WVOs from Hotels in the Study Areas**

Major Cities	Projected Annual Quantities of WVOs					
	Year 2013		Year 2014		Year 2015	
	Litres	Tons	Litres	Tons	Litres	Tons
Accra	427,402.1	38,466.2	447,917.4	40,312.6	469,417.4	42,247.6
Kumasi	36,497	32,84.7	38,249	3,442.4	40,084.9	3,607.6
Sunyani	25,497.1	22,94.7	26,721	2,404.9	28,003.6	2,520.3
Takoradi	26,460	2381.4	27,730.1	2,495.7	29,061.1	2,615.5
Tamale	21,708	1,953.7	22,750	2,047.5	23,842	2,145.8
TOTAL	537,564.2	48,380.8	56,3367.3	50,703.1	590,409	53,136.8

**Table 7: Scenarios of Annual Quantities of Biodiesel Production**

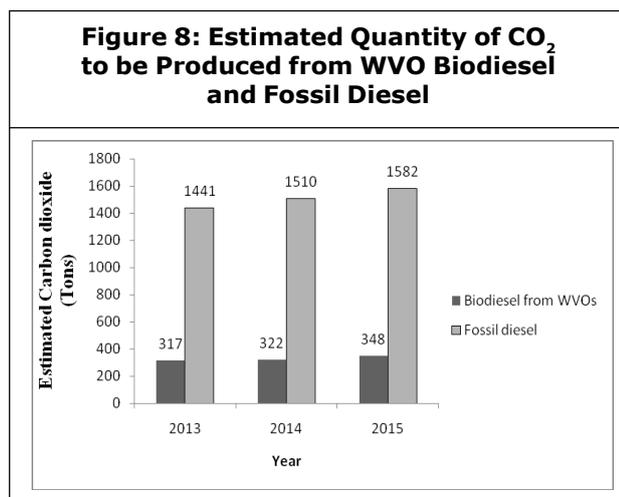
Conversion Efficiency	Year 2013		Year 2014		Year 2015	
	Est. Quantity from 5 Major Cities (Tons)	Est.Quantity Ghana (Tons)	Projected Quantity from 5 Major Cities (Tons)	Projected Quantity For Ghana (Tons)	Projected Quantity from 5 Major Cities (Tons)	Projected Quantity For Ghana (Tons)
93%	44, 994	74,990	47,154	78,590	49,417	82,361
95%	45,962	76,602	48,168	80,280	50,480	84,133
97%	46,930	78,215	49,181	81,970	51,543	85,904

the year 2013. The projection for Ghana comes to about 74,990-78,215 tons in the year 2013. It is projected that by the year 2015, Ghana could produce 82,361-85,904 tons of WVO biodiesel from hotels. The average production of biodiesel

from WVOs generated by hotels in Ghana could be approximately 3,765 tons per year. It is reported that Canada could be producing approximately 135,000 tons/year of waste cooking oil. In the EU countries, the total waste cooking

oil production was approximately 700,000-1,000,000 tons/yr. The UK produces over 200,000 tons of waste cooking oil per year (Carter *et al*, 2005; Statistics Canada, 2006; Kulkarni and Dalai, 2006; cited in Chherti *et al.*, 2008).

In Figure 8 the quantities of CO<sub>2</sub> likely to be produced from WVO biodiesel compared to same quantities from fossil diesel are presented. The results indicated that biodiesel from WVOs could produce about 317 tons of CO<sub>2</sub> in the year 2013 and 348 tons of CO<sub>2</sub> in 2015. For fossil diesel the CO<sub>2</sub> to be produced is estimated to be 1441 tons in 2013 and 1582 tons in 2015. This shows a reduction in CO<sub>2</sub> emissions of 78% by using biodiesel from WVOs as alternative to fossil diesel.



According to Jaichandar and Annamalai (2011), the US Environmental Protection Agency (EPA) review reported in EPA (2002) showed a 70% mean reduction with pure biodiesel with respect to conventional diesel.

## CONCLUSION

The main objectives of the study were to determine the number of times a batch of fresh vegetable oil was used before discarded and competitors for the use of WVOs; determine the

quantities of WVOs being generated by hotels in the major cities of Ghana within a year; and project the annual quantities of WVOs for Ghana's biodiesel feedstock and carbon dioxide savings when compared with fossil diesel. The data generated from the study were analyzed and presented and the following conclusions were drawn.

- The study results revealed that the studied hotels re-used fresh vegetable oils 3-6 times before discarding as waste.
- The main competitors for the use of WVOs were soap makers, commercial *shitto* producers, domestic users and other food vendors. The potential waste vegetable oils to be considered as feedstock for biodiesel production would constitute what is poured into the drains, those poured on the ground and those left to go rancid, which would range between 20% and 63% of waste vegetable oils generated in the study areas.
- The quantities of WVOs likely to be generated from the five major cities have implications for the location of biodiesel plants. Accra, Kumasi and Takoradi emerged as promising major cities for the location of biodiesel plants in Ghana.
- Data analysis and scenarios based on hotels in the five major cities indicated that in 2013, Ghana could be producing 70,000-78,000 tons of biodiesel from WVOs. This could be projected to 82,361-85,904 tons of biodiesel from WVOs generated by hotels by 2015. The average production of biodiesel from WVOs generated by hotels in Ghana could be approximately 3,765 tons per year. By 2015,

the projected biodiesel could produce about 348 tons of CO<sub>2</sub>, which is lower than 1582 tons of CO<sub>2</sub> compared to fossil diesel.

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