Experimental and Economical study on applications of Biogas and Biodiesel

Aashish Singh

Abstract— Today there is acute shortage of energy sources all around the world. With India alone standing a debt of $6.5 billion from oil rich Iran[1], many countries in the world are facing energy crisis. Like India, China experienced severe energy shortages towards the end of 2005 and again in early 2008. During the latter crisis they suffered severe damage to power networks along with diesel and coal shortages [2]. Supplies of electricity in Guangdong province, the manufacturing hub of China, are predicted to fall short by an estimated 10 GW. Thus there is a need to resort to alternative fuel sources. Biofuel presents one such example of clean burning, economical and renewable alternative fuel. Thus the main objective of the project is to evaluate the different applications of Biogas and Biodiesel and their proper and economical implementation in developing countries so that the growing economies can become more independent from fast depleting traditional fuel sources. For this purpose, a study on using biodiesel to power fishing boats (through B2, B5, and B20 engines) has been carried out. Further a comparative study of the usage of biogas, kerosene, firewood and LPG for domestic purposes has been conducted keeping in mind the economics, pollution effects and efficiency.

Index Terms— Biofuel, energy crisis, Biodiesel, Biogas, B2, B5, B20 engines, Alternative fuel, fishing boat

1 INTRODUCTION

Today many developing economies are emerging as one of the fastest growing economies in the world. For instance, the economy of India is 7th largest in the world by nominal GDP [3]. While many developing economies in the world are quickly emerging, they are still facing the problem of energy crisis. There is a shortage of energy all over the world. Currently India owes about $6.5 billion to Iran for the oil India imported from the Middle East country. With increasing number of cars on the road, the oil and petrol consumption is bound to grow. Also oil, kerosene, petrol, diesel are required to run rural homes and agricultural farms thus increasing the demand for fuels than ever before. Therefore, there is an urgent need to resort to an alternative source of energy which is cheap, long lasting, and efficient and minimizes the pollution caused by using it on a large scale. Clean burning, renewable, cheap Biofuel provide such an alternative. Thus this paper has been made to evaluate and conduct a comparative study on the usage of biogas and biodiesel.

1.1. Objectives

a) Evaluating the pros and cons of using biodiesel in fishing boat

b) Comparing biogas with other traditional fuels by evaluating efficiency and considering performance and cost for use in domestic purposes.

2. METHODOLOGY

This Socio-scientific project has been made by presenting a holistic view of Biofuel its varied applications and potential applications along with its proper implementation on a large scale. For this extensive research has been done through various journals, books, articles, websites and field surveys. Various experiments pertaining to evaluation of efficiency in varied conditions were conducted in Biotechnology lab of Birla College, Mumbai University. After analyzing the viability of using biodiesel for powering fishing boats, survey was done in Trombay Koliwada fishing community, Trombay Koliwada in Mumbai to gain information about its economic feasibility. Further research was done on comparing biogas with other traditional fuel sources to be used for domestic purposes. Multiple experiments to evaluate the efficiency of Biogas in different conditions was conducted. Consequrntly a study was carried out in Trombay Koliwada village on the outskirts of Mumbai to analyze the viability of the undertaking.

3. BIODIESEL POWERED FISHING BOAT:

3.1. Comparative analysis of biodiesel and petrodiesel

• *Aashish Singh is currently pursuing high school graduate degree program in Jaipuriar School, Navi Mumbai, PH: +91-9167093061. E-mail: aashishsingh2k@gmail.com*

Sr. No.	Property	Petrodiesel	Biodiesel
1.	Cetane	42-54	52-65
2.	Sulphur content	<10ppm	<5ppm
3.	Nitric oxide emission	less	More
4.	Lubricant	less	More
5.	Energy density (MJ/litre)	36	34.5
6.	Energy content (BTU/gallon)	128	118
7.	Cloud point (degree Celsius)	-5	20

Table #1

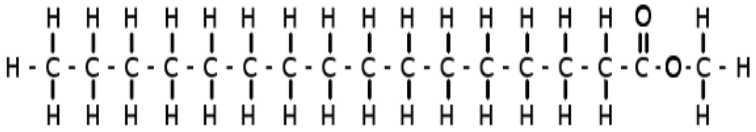
According to the table some specifications of biodiesel are better while at others vice-versa is true. Thus a more detailed analysis is given below-

(i) Performance comparative study-

1. The energy density of petro-diesel is higher in comparison to bio-diesel. This means that higher amount of energy is stored in same volume of petro-diesel as compared to the energy stored in bio-diesel. Therefore more amount of bio-diesel is required to produce the same amount of electricity. However, a point to be noted here is the cheap cost of bio-diesel as compared to petro-diesel which more than compensates for the extra bio-diesel used. Thus still the bio-diesel leads as far as cost competitiveness is concerned.
2. The lubricity of petro-diesel is quite less as compared to biodiesel. This is because of polarity on the biodiesel molecule. Thus the biodiesel fuel itself lubricates the engine in which it produces energy ensuring longer life of the engine. However the negative side of this polarity of the molecule is that it can form crystallized structure and thus biodiesel freezes at higher temperatures resulting in higher cloud number.
3. Another plus point of bio-diesel is that the Cetane value in biodiesel is less as compared to petro-diesel.

(ii) Emission comparative study-

The emission of the bio-diesel depends on a variety of factors including the source from which it is made and in



which conditions it is used. Generally it is observed that bio-diesel are cleaner fuels in the sense that they do not contain Hydrogen Sulphide and thus their combustion does not produce harmful sulphur oxides, unlike petro-diesels which do produce harmful sulphur oxides. Also CO2 emission released by biodiesel is less as compared to that released by petrodiesel. For example, a B20 engine produces 15% less CO emission as compared to that produced by petrodiesel [4]. However, as far as harmful nitric oxides are concerned, the emission of bio-diesel is more as compared to petro-diesel.

The low emission of CO is due to extra availability of oxygen (in the ester) as shown in the figure above which is not present in petrodiesel

(iii) Cost comparative study- Biodiesel tends to be cheaper as compared to pure petrodiesel when a mixture of petrodiesel having 2%-5% biodiesel is used. However any mixture containing biodiesel in more quantity increases the price a little, enough to become more expensive than pure petrodiesel.

Conclusion: From the above comparative analysis it is clear that biodiesel in the form of a mixture of both bio and petro-diesel is cheaper (for certain mixtures only) and reduces carbon dioxide emission. It also decreases the sulphur oxides emission. On the negative side, its energy density is less than that of petrodiesel. Biodiesel also tends to produces more amount of nitric oxides during combustion leading to pollution.

3.2. About the study-

The study was conducted in the Trombay Koliwada fishing village in Mumbai. Most of the people here are part of the Trombay Koliwada fishing community and their main source of income is fishing. The fishermen spend daily about 8-10 hours in the sea.

3.2.1. Size of the boat used by fishermen in the area-

(i)*Small boats*- These boats usually do not go deep in the sea; they generally stay within 5-7km from the coast. These boats are called trawlers and are also used to carry the catch of large boats to the coast. This is the most common fishing boats used by fishermen in Trombay Koliwada . Operation hours of this boat vary from 7 to 10 hours and it can carry load of up to ½ to 2 tons of fish. This kind of boat usually comes in two sizes: 12 feet x 5 feet and 15 feet x 5 feet. One cylinder engine is sufficient to power these kinds of boats

(ii) *Medium and large boats*- These boats can go deep into the sea and are strong enough to face rough sea and winds of up to 10 km/hr. These kinds of boats are generally used by economically well-off fishermen who usually own 2 to 3 of such boats. Operation hours of these boats vary from 10-12 hours. They are capable of carrying fish of load up to 15 tons. This kind of boats varies in size from 25 feet x 10 feet to 65 feet x 15 feet.

3.3. Conducting the study

The study was conducted on a small boat (15 feet x 5 feet) single cylinder boat that is used for approximately 8 hours daily: 2 hours for going into the sea, 4 hours for fishing and 2 hours for coming back. The power of the engine is 5hp

Calculating petrodiesel used per month-

Power of engine 5hp= (approx.) 3.72kW

Therefore energy used per month= Power x time

= 3.72 kW x 30x8x3600

=3.21 x 10^9 J

Energy density of petrodiesel = 36 MJ/litre

No. of litres of petrodiesel required for running the boat for 1 month

= (total energy used/month)/energy density= (3.21 x 10^9)/(36 x 10^6)=90 lit

Thus the boat consumes about 90 litre of diesel per month.

Powering boats through biodiesel-

If 100% biodiesel is used then-

No. of litres of biodiesel required per month

= (total energy used/month)/energy density

= (3.21 x 10^9)/ (34.5 x 10^6) = (approx.) 93 litres.

Thus approximately same amount of petrodiesel and biodiesel are used for powering a B100 engine.

3.4. Advantages

a. **No modification in engine of the boat required-** The best part of using biodiesel is that for relatively new engines biodiesel can be used in place of petrodiesel without much or no modification to the engine.

b. **Biodegradable-** In a test conducted by the University of Idaho it was found that C 16-18 methy esters (which commonly make up the biodiesel) was 95% degraded in 28 days whereas petrodiesel was only 40% degraded. Thus even if there is a leakage in the engine if the boat or oil spills in the ocean biodiesel would not cause much harm to the marine life and this would help preserve the chemical composition of water as well. All of this is very crucial for continuing trade in the fishing sector.

c. **Biodiesel is safe and has high lubricative properties.-** Biodiesel has a higher flashpoint- a min. of 200 degree Celsius as compared to 125 degree Celsius of petrodiesel.

d. **Biodiesel does not harm marine life-** The lethal concentration of biodiesel having 16-18 carbon with the esters is greater than 1000mg/l which is proven safe by NIOSH (National Institute for Occupational Safety and Health)

e. **Biodiesel is renewable-** Biodiesel is made from abundantly available plant fats and vegetable oils and involves simple refining process. Also by-product glycerine is used to make a no. of commercial products.

f. Biodiesel is more environmental friendly

3.5. Disadvantages-

a. Using 100% biodiesel is currently problematic to use in European countries and USA because biodiesel have a polarized molecule which tend to form crystals and thus freeze at even 10 degree Celsius and is therefore not usable in pure forms in freezing parts of USA and the European countries. However this model will work for fishermen in countries which have tropical weather and where temperature rarely falls below 20 degree Celsius.

b. Another reason why using 100% pure biodiesel is not so popular yet is that oxygenated biodiesel has a property of eroding the surfaces in which it comes in contact with. Thus rubber pipes, hoses and other parts of the engines have to be regularly replaced. However, with current progress in the field of biodiesel, new ways of curbing the eroding property of biodiesel is underway. A survey conducted on 100 boaters, as part of research conducted by a university, who used biodiesel for a year only about 6% of them reported problems with their engine when biodiesel was used in higher concentration [5]. Another possible solution is to use a blend of biodiesel and petrodiesel which has been mentioned later in this report.

3.6. Using a blend of petro diesel and biodiesel

Generally a blend of biodiesel and petro diesel is used to power cars and buses. Similar concept can be applied to boats. This concept ensures that if a correct mixture of biodiesel and petrodiesel is used then benefits of both can be gained.

Types of engines-

(i) B1/ B2 engine-A B1 engine uses a mixture of biodiesel and petrodiesel having 1% biodiesel and the rest petrodiesel. Similarly with B2 engine, it uses 2% biodiesel and the rest petrodiesel. They are one of the most common type of engine and they were the first ones to be used when biodiesel was discovered.

(ii) B5 engine- This engine uses 5% biodiesel and the rest petrodiesel.

3.7. Advantages of using a blend of biodiesel and petrodiesel

(i) One of the main problems of using pure biodiesel is that its cost is higher as compared to petrodiesel. Thus a blend of biodiesel and petrodiesel helps to reduce the cost.

National Average Price Between April 1 and April 15, 2015	
Fuel	**Price**
Biodiesel (B20)	$2.92/gallon
Biodiesel (B99-B100)	$3.77/gallon
Electricity	$0.12/kWh
Ethanol (E85)	$2.13/gallon
Natural Gas (CNG)	$2.09/GGE
Propane	$2.92/gallon
Gasoline	$2.42/gallon
Diesel	$3.06/gallon

Table 2: Cost comparison of different forms of fuel (In USA, April 2015)[6]

From Table 2 it is clear that Biodiesel used in a B20 engine is cheaper than petrodiesel whereas Biodiesel used in B99/B100 engine is quite expensive as compared to petrodiesel. Thus a blend of petrodiesel and biodiesel seems to be a better alterative currently as far as cost is concerned.

(ii) The benefits of both petrodiesel and biodiesel can be harnessed efficiently. For example greater energy density of petrodiesel and comparatively cleaner burning capacity of Biofuel, provide dual benefit to the blend.

(iii) The gelling point (or freezing point) of a blend of biodiesel and petrodiesel is -15 degree Celsius as opposed to 15 degree Celsius of pure biodiesel. This helps biodiesel to be

used even in colder regions.

3.7. Results and Discussion

a. There is a vast potential for biodiesel to develop and be used widely if it is efficiently used to power fishing boats.
b. With the current scenario of only a few companies commercially providing biodiesel in India, it is better that fishing boats be used on a blend of biodiesel and petrodiesel.
c. Also at current price of pure biodiesel and the clogging of the filters that it causes it is better to stick with the blends of petrodiesel and biodiesel from an economic point of view.
d. Keeping the operation hours, engine power, size of the boat and other technicalities in mind it is best for the fishermen and for the environment that a blend of biodiesel not exceeding B20 be used, since up to this mark the cost of the blend is less than petrodiesel and also the sulphur oxide emission is less than traditional diesel. Moreover the chances clogging of filter of the engine of the boat are decreased and the small percent of biodiesel (acting as a lubricant) is sufficient to keep the engine of the boat running smoothly.
e. This method of using a blend of biodiesel and petrodiesel can also be extended to powering boats for recreational purposes in colder regions as well (unlike the usage of pure biodiesel which would crystallize at temperatures going below 20 degree Celsius). This will also help prevent the pure environment of the area because of low CO2 and sulphur oxide emissions.

4. COMPARATIVE ANALYSIS OF BIOGAS WITH OTHER TRADITIONAL FUEL FOR DOMESTIC USES:

4.1. Biogas

a) Preparation-

Biogas is essentially a mixture of methane (CH4) which forms 55-80% of the mixture, carbon dioxide (15-20%) and other gases like hydrogen sulphide and water in varying and small amounts. Biogas is produced using dung, manure, human excreta, and plant and crop excretion/residue. The process mainly involves breakdown of organic products to produce the biogas and since this process happens in the absence of air, it is termed as anaerobic digestion.

b) Energy released and uses-

Biogas having an average of about 60-75% of methane generally have energy content of 6-6.6 KWh/(m)^3.
In principle biogas can be used like any other fuel but it is mainly used for household consumption and electricity generation in rural areas.

4.2. Comparative analysis

Table#2 comparison of various fuels used for domestic purpose

Sr.No.	Property	LPG	Biogas	Kero-sene	Fire-wood
1.	Efficiency (%)	54	50	45	23
2.	Calorific value (MJ/Kg)	44	32-36	42	19
3.	Density (kg/m^3)	.560	1.14	0.78	600
4.	specific Carbon dioxide emission (kg/KWh)	0.23	0.20	0.26	0.39
5.	Renewing property	Non-re-new-able	Ren-ewable	Non-renew-able	Non-renew-able

4.3. Context of the study:

Currently India's per capita energy usage is 1/4th of the world's average. There is around 15% peak shortage and 9% energy shortage in households in India. With over 121 crore population even these seemingly small percentages represents millions of people with severe energy shortage mainly in the rural parts of the country. According to 2011 census over 85% of rural households in India rely on firewood for cooking, heating and other domestic purposes. Around 43% of the household still use Kerosene for lighting purpose. With this current usage of kerosene, diesel etc, oil imports are all set to further increase from the current 77% of the oil imported. Such large-scale use of firewood would result in rapid deforestation and current oil usage would result in depletion of useful fossil fuels. Thus there is a need to find an alternative fuel especially for use in cooking and other domestic purposes in rural households. Biogas provides one such novel, alternative solution for use as a clean burning fuel for use in domestic purposes in rural parts of many developing countries.

4.4. Evaluating the efficiency of biogas

4.4.1. About the experiment

The experiment was conducted in Biotechnology laboratory of Birla college in Kalyan, Mumbai. The objective was to find out the efficiency of Biogas stove in different conditions, noting down the results, verifying it and making observations about its usage in practical applications on a large scale.

4.4.2. Methodology-

The efficiency was found out using the basic formula of efficiency i.e. the output energy divided by the input energy. For this water (initial temperature noted) was taken in an aluminum vessel and then boiled up to 100 degree Celsius (ideal conditions). Then water at 100 degrees Celsius was further but just for 5 minutes heated to form steam at 100 degrees Celsius. Thus efficiency can be calculated by energy taken by water to convert to steam at 100 degree Celsius and also the heat taken by the vessel divided by the energy given by biogas.

4.4.3. Materials used-

1. Water at initial temperature 27 degree Celsius and weight of water taken was 1 Kg
2. Aluminum vessel of weight 0.5 Kg

3. Manometer
4. Thermometer
5. Biogas with biogas valve showing reading of the no. of litres of biogas used
6. Stove

4.4.4. Observation-

Water, which was heated from initial temperature of 27 degree Celsius was just about to turn into steam at approx. 99 degree Celsius. It took around 18 minutes to reach this stage. Thereafter the water at this temperature was further heated for 5 minutes. No change in temperature was noted in this period. After 5 minutes about 0.12 kg of water had been evaporated. Using this information efficiency was calculated as given below. Till this time a total of about 53.15 litre of biogas had been used.

4.4.5. Efficiency Calculation [7]

Efficiency
= output energy/input energy
= Efficiency (overall) ={M(water)*S(water)* (T(boiling) – T(initial)) + (M(water) *L(vaporization of water)) + M(vessel) * S(vessel) * (T(boiling) – T(initial),) } / (M(fuel)*C(fuel)) .
→Some important constants used and observations made-
Specific Heat Capacity of Water -S (water)= 4.190KJ/Kg°C
Latent heat of water - L (vaporization of water) = 2260 KJ/Kg
Specific Heat Capacity of Aluminum - S (vessel) = 0.91 KJ/ kg °C
Calorific value of Kerosene- C (Fuel) = 42 MJ/kg
Final Temperature {T (boiling) } = 99 degree celsius
Initial Temperature { T (initial) } = 27 degree Celsius

Substitution in formula-

Efficiency =
= [{1 x 4.19 x (99-27)} + {0.5 x 0.91 x (99-27)} + {0.12 x 2260}]/ (53.15 x 23)
= 0.4954
Percentage Efficiency = 49.54%

4.4.6. Results-

Thus the calculated efficiency approximately matches that obtained from (a little greater than) Kerosene or (a little less than) LPG. Also the efficiency is quite greater than that yielded by firewood which further enforces the need to use biogas instead of Kerosene or firewood for use in domestic purposes especially cooking. Further since this experiment was conducted in Mumbai the conditions like pressure and temperature are almost identical for villages on the outskirts of Mumbai (& other tropical/sub tropical areas). Thus biogas usage in villages will have an approximate efficiency yield of 49.5% which is quite good considering its low cost and less carbon dioxide emission.

4.5. Advantages

1. It is a renewable source of energy
2. Non polluting (refer table #2 for carbon dioxide emissions of various fuels)
3. It is an efficient way to recycle plant and animal waste (which his available abundantly in rural farmlands) thereby reducing landfills
4. Less cost. In fact farms can become energy independent if small scale biogas plant is installed
5. Reduces green house effect

4.6. Payback Period

To install a 15 cubic metre biogas plant which can produce biogas of up to 5 cubic metre per day costs around INR 90,000 to INR 1, 30,000. A 15 cubic metre biogas plant can easily power a medium sized farm along with providing energy for cooking and for other domestic purposes for a family of 6-8.
The government in many countries provide subsidy for use and installation of Biogas plants. In India the Government provides a subsidy of 22% (as of 2009) for the weaker sections and or financial assistance from government in states like U.P., Maharashtra etc, thus the cost of installation comes down to (considering cost of installation of plant = INR1,00,000) INR 78000
Considering 14.2 kg HP LPG cylinder, which is available at a subsidized rate of INR 419 (approx.), generally serves a big family of 6-8 plus the farm activities (like heating, lighting etc) for 10 days .Thus per month cost of LPG is around INR 1260.
Thus INR 1260 is saved per month after installation of a 10 cubic metre biogas plant.
So payback period (in months)
= (total money spent)/ (money saved per month)
= 78000/1260 = (approx.) 63 months = (approx.) 5 years
Payback period= 5 years.

4.7. Results and Discussion

Thus with the above advantages and the high efficiency of biogas (which is comparable with LPG and greater than other fuels), it makes an excellent alternative fuel source for use in cooking and other domestic purposes. Plus the cost of producing biogas (post installation), apart from the heat required to proceed the anaerobic reaction that produces the fuel, is nil since the raw material is all waste products of plants and animals which is abundantly available in farms. Another important factor of that makes biogas a much better alternative as a fuel source as compared to traditional usage of firewood and kerosene is that it has low carbon dioxide emission which helps maintain the balance in environment and also reduces greenhouse effect.

This technology is almost 100% suited to the Indian conditions (and most other developing countries in Africa for that purpose) and can yield maximum results id effectively implemented. Some suggestions for the same are-

1. Although the Government has made significant efforts by making Biogas available in some of the villages in a few states of India, majority of the rural areas still have no supply of Biogas or even a single Biogas plant installed. Therefore the people are not aware of the technology and those few who are still have some misconceptions regarding its price, installation etc and do not have the exact picture of its immense potential. Thus generating awareness is the first approach to spreading this technology.
2. Although the payback period for installing small scale biogas in a farm is not so high (considering its potential benefits), the government still needs to make attractive schemes and policy like making loans available at special (low) rate of in-

terests to attract mid and big sized farmers to use this technology on a small scale in their farms.
3. For large scale use of biogas to produce electricity etc the government needs to allot a lot more than it presently does in the budget for development of rural areas. Also special budget dedicated to village panchayats for making large scale Biogas plant would be the first step in using this technology to create electricity.
4. For creating large scale biogas plants in villages for generating electricity another important factor is that the government should make its representatives that network with the local farmers, generating awareness among them ,advertising the technology and offering them cheap electricity from this plant in return for free or nominal charged plant and animal waste.
5. The government should ensure that the Biogas produced commercially through large scale Biogas plants is available to farmers at high subsidy rates for first few years to gain the trust of farmers on Biogas fuel and then subsidy rates can be altered a little according to the economy and need.

5. CONCLUSIONS:

1. According to the study the usage of biodiesel in fishing boats was found feasible because of characteristics such as low sulphur oxide emissions, cheap, no modifications to existing engine etc.
2. The usage of biogas to replace LPG (where currently there is shortage of this fuel) and unclean burning fuels like kerosene and firewood was found viable. Also with efficiency of about 50%, biogas form one of the most efficient Biofuel to be used for domestic purposes.

6. ACKNOWLEGMENTS:

I am thankful to Dr Naresh Chandra, Principal, Birla College and former Pro Vice Chancellor, Mumbai University for his overall guidance and supervision during the project.
I would like to especially acknowledge Dr A.K. Singh, Professor, Department of Chemistry, IIT Bombay and former Vice Chancellor of Allahabad University for his advice and help throughout the course of the project.
I am also thankful to Dr Sandesh Jayabhai, Birla College for his help.

7. REFERENCE:

[1] Economic Times, India, 2015, *Iran asks India to clear $6.5 billion oil dues in two months,* Available (online):http://articles.economictimes.indiatimes.com/2015-08-20/news/65667333_1_rupee-payment-indian-oil-corp-iran
[2] International Society of Automation, 2008 *"Coal shortage has China living on theedge"*.Available(online):https://www.isa.org/InTechTemplate.cfm?Section=Departments5&template=/ContentManagement/ContentDisplay.cfm&ContentID=68134
[3]Sandhya Lakshmi P.,2015, *The new development of BRICS nations: an analysis*, International journal of Business Management, 3(5),305
[4] L.G. Anderson, 2012, *Effects of biodiesel fuel use on vehicle emissions*, 3(2012), 36.
[5] Cytoculture international inc., 1997, *Survey of 100 recreational boats using Biodiesel 1994-97*, 1-10.
[6] Alternate Fuel data centre, 2015, *Clean cities alternate fuel price report,* April (2015), 3.
[7]H S Mukunda. (1998). "Understanding Combustion" , Indian Institute of Science,Published by Macmillan India Limited and B Lai & S. Sub. (1998). "Heat and Thermodynamics". Published by S.Chand and Company. India

Further data/information from following websites:
www.biofuel.org.uk/
http://biodiesel.org/
http://www.afdc.energy.gov