Evaluation of Energy Ratios for Karanja and Neem Biodiesel Life Cycles

Ashok Yadav[1*], Onkar Singh[2], and Naveen Kumar[3]

ABSTRACT

Biodiesel is one of the best substitutes to the fossil diesel fuel today in the world. Owing to big climatic diversity, there are numerous oil bearing seed plants/trees available in India. Extraction of the oil from these plants and its conversion to bio-diesel involves energy consumption at various stages starting from the plantation to the end use in the compression ignition engine. This paper gives the systematic evaluation of the energy consumed by Karanja and Neem trees at each stage during the growth cycle and conversion its seed oils to bio-diesel fuels. Results obtained verify that the total energy consumption during life cycles of the plants under study is lower than the energy output during combustion in IC engine.

Keywords : Bio-diesel, life cycle analysis, non-edible vegetable oil, energy consumption.

I. INTRODUCTION

Among various seed bearing trees rich in oil, Jatropha (jatropha curcas), Neem (azadirachta indica) and karanja (pongamia pinnata) are the favorable species as they can be grown almost on all types of sands all over India. Neem and Karanja are large trees and under utilized while jatropha is a small tree with 3-5meters in height. Jatropha has highest yield of oil, an animal repellent and can be grown in areas of low rain fall. Life cycle analysis is a method to evaluate the environmental impacts of a product during its life cycle [1-4]. Energy life cycle of the biodiesel starts with the extraction of raw material i.e. plant nursery and ends with conversion to the biodiesels. Life cycle analysis shows the inputs of extra energy needs to convert the energy present in the raw material in to useable energy of the fuel. The life cycle analysis calculates the net energy ratio which is evaluated by dividing the energy output of the system in the form of fuel energy delivered to the compression ignition engine by the cumulative energy demand of the system. The study analyzes biodiesel production and identifies resource consumption and energy use for various life cycle stages and sub-processes. In the present study, energy life cycle analysis for biodiesels obtained from three oils (jatropha, karanja and neem) is carried out. Variations in net energy ratios under different environmental conditions are analyzed.

II. METHODOLOGY

To evaluate the energy consumption during the life cycle of the plants derived biodiesel as fuel for compression ignition engine, a cradle to grave analysis is carried out. For this, energy inputs at each stage of the cycle during plant nursery, plantation, growth, seed collection, oil extraction, transesterification and care & safety are calculated. Sum of all energy inputs gives us the total energy input and it is compared with the energy contained in the fuel. For calculation purposes, one hectare of land is considered as reference area.

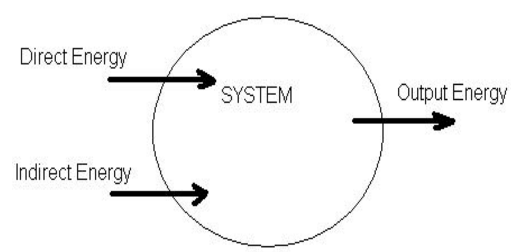

Fig. 1: System and types of energy interaction

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Energy considered in interaction during life cycle is indirect energy, given to the system and not direct energy like energy contained in the soil and solar energy taken by plant.

III. SYSTEM BOUNDARIES AND ASSUMPTIONS

The study analyzes biodiesel production and identifies resource consumption and energy use for the following life cycle stages and sub-processes, (i) karanja and neem cultivation; (ii) karanja and neem oil extraction; (iii) Biodiesel production via the oil transesterification.

A. Assumptions [5,6,7]

(i) Karanja and neem cultivation starts from nursery.

(ii) Planting densities are 550 trees/ha for karanja and 350 trees/ha for neem.

(iii) Average quality soil and rainfall at the plantation site

(iv) Neem & karanja get full maturity in 10 years of plantation when full seed yield is expected.

(v) Seed pod yield for karanja and neem is 60 and 35 kg/tree respectively.

(vi) Seed yield for karanja and neem is 14 and 15 kg/tree respectively.

(vii) Seed yield per hectare for karanja and neem is 7.7 and 5.25 tones respectively.

(viii) Percentage oil yield and oil extraction efficiency for karanja and neem oils are 25% & 94%; and 28% & 94% respectively.

(ix) Seed oil yield per hectare for karanja and neem is 1.8095 and 1.3818 tones respectively.

(x) No pesticides, insecticides, or herbicides are applied to the crops.

(xi) It is assumed that the amount of NPK fertilizers needed equals the amount of the seed cake which is used to offset fertilizer use on the plantation.

(xii) The energy used in creating/manufacturing of the materials and machinery used to assist the life cycle of the plant oil is not considered in this analysis.

(xiii) An alternative use of the seed cake i.e. combustion to produce useable heat or power, is not considered.

Net energy ratio is evaluated by dividing the energy output of the system in the form of fuel energy delivered to the compression ignition engine by the cumulative energy demand of the system.

IV. SYSTEM INPUTS

The energy consumption/inputs starting from plant nursery to the transesterification process i.e. bio-diesel production is divided in 7 categories as detailed below:

1. **Plant Nursery :** It covers energy inputs in soil preparation, soil bag fillings, watering the soil bags, machinery and man power used, care and safety up to one month. Four type of energy inputs are involved, energy in machinery for ploughing, irrigation, manures and manpower for all the activities of plant nursery [8].
2. **Plantation :** Factors like land type, land preparation, irrigation, care & safety etc are analyzed for energy use in plantation and caring up to the age of one year of the plant. Four type of energy inputs as required in plant nursery are involved here also, energy in machinery for ploughing, irrigation, manures and manpower for all the activities of plant nursery.
3. **Growth :** Care and safety one year onwards is considered up to 3 years of age of the plant. So man power is the input for the 2 years of growth [8].
4. **Seed Collection :** Pod collection, pod drying, de-poding (de-husking), seed drying are carried out manually and hence no machinery inputs are considered.
5. **Transportation of Seeds :** Energy input in transportation of seeds from the field to the bio-diesel unit through IC engine tractor trolley is analyzed.
6. **Oil Extraction :** Oil expeller of capacity (1 Ton of seed/hour) is selected for energy calculation.
7. **Transesterification :** A transesteri-fication unit of capacity (100,000 tons/annum) is considered for analysis. Energy contained in alcohol used for transesterification process is not considered here as equivalent amount (slightly less than the mass of alcohol) of glycerin is produced as byproduct during the chemical process.

Total of energy inputs in all the sub-processes gives the total energy demand of the biodiesel life cycle

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which is energy input (E_{input}) to the system. This energy input is indirect energy. Other energies like solar energy, energy contained in soil are not considered.

V. SYSTEM OUTPUTS

Methyl esters of the oils (biodiesels) contain the energy, which is given by

$$E = CV_{BD}*T*1,000$$

where, CV_{BD} = calorific value of biodiesel (MJ/kg); T- quantity of biodiesel (ton).

Considering brake thermal efficiency of a C.I. Engine as 20%, brake out put energy will give the following amount,

$$E_{output} = 0.20*E$$

VI. NET ENERGY RATIO

Net energy ratio can be calculated as,

$$NetEnergyRatio,\ R = \frac{E_{output}}{E_{input}}$$

VII. RESULTS AND DISCUSSIONS

Net energy ratios for different parameters of soil conditions are evaluated. Table 1 shows the results with changing parameters.

The table 1 shows the energy inputs and output for the energy life cycle of the three biodiesels. It can be evaluated from the data obtained in the table 1 that the sum of energy inputs required to convert the energy contained in the raw material into useable form as IC engine liquid fuel is lower than the energy output by the system. Energy values represented in the table 1 are indirect energy which are given to the system and not direct energy like energy contained in the soil and solar energy taken by plant.

Table 1: Energy/ha for different subsystems of biodiesel energy life cycle

Sl. No.	Items		Para meters	Karanja, kJ	Neem, kJ
1	Plant Nursery	Ploug-hing	normal soil	0.726	0.462
			hard soil	0.871	0.554
			soft soil	0.581	0.369
		Water spray		1.980	1.260
		Manures		0	0
		Manpower	normal soil	268.206	248.204
			hard soil	321.847	297.845
			soft soil	214.565	198.563
2	Plant-ation and care up to one year	Ploughing	normal soil	527.85	527.85
			hard soil	633.42	633.42
			soft soil	422.28	442.28
		Water spray		5.4	3.6
		Manures		0	0
		Man-power	normal soil	1348	1304.8
			hard soil	1617.6	1565.76
			soft soil	1078.4	1043.84
3.	Growth		care & safety	1239.9	1235.4
			normal soil	2282	1448
4.	Seed collection		hard soil	2738.4	1737.6
			soft soil	1825.6	1158.4
5.	Transportation		Manpower & m/c	133.33	109.75
6.	Oil extraction		Manpower & m/c	847	577.5
7	Transesterification		Manpower & m/c	238.511	183.081
8.	Energy output by engine using biodiesel			11,322	9,294.474

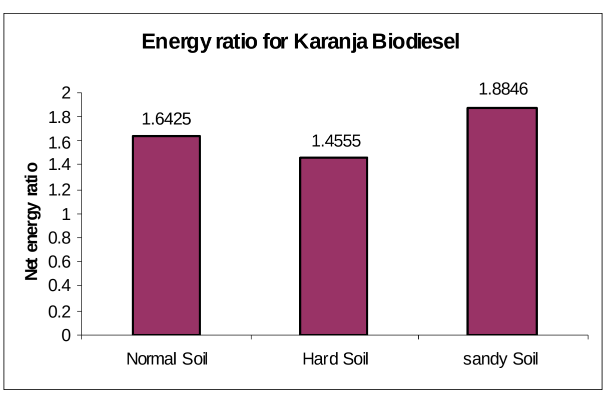

Fig. 2: Energy ratio for Karanja biodiesel

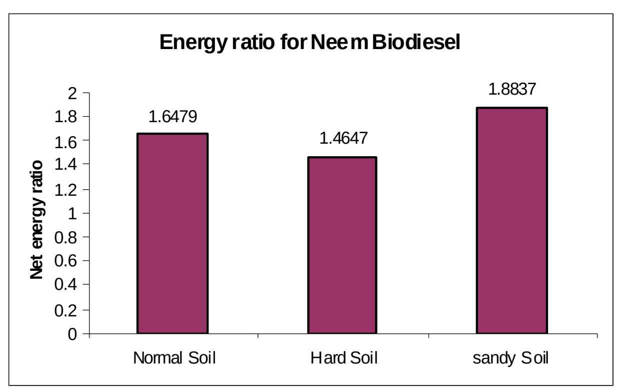

Fig. 3: Energy ratio for Neem biodiesel

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Figure 2 depicts the variation of net energy ratio with variation in soil conditions when energy life cycle of karanja biodiesel is considered. Under normal conditions of soil karanja biodiesel life cycle has an energy ratio, R_2=1.6425.

The energy ratio ranges 1.4555 to 1.8846 for all the cases considered. Karanja biodiesel has highest energy ratio for all conditions pointing to high yield of the karanja biodiesel. High energy ratio depicts the higher amount of yield for the same inputs. Apart from having this higher energy ratio, karanja tree helps in permanent sequestration of green house gases as the wood of the tree may be used for manufacturing of furniture and buildings.

Energy life cycle analysis of neem biodiesel calculates the net energy ratio of which variation relative soil type is depicted in Figure 3. Neem biodiesel has an energy ratio, R3 = 1.6479, for normal agro-environmental conditions. The variation of energy ratio shows that hard/rocky soil has minimum value, 1.4647 for yield conditions. High yield of the neem crop with good/sandy soil conditions gives the value of net energy ratio as 1.8837.

As the energy ratio is well above unity, neem biodiesel promises to be a good renewable fuel in view of environmental impacts. Higher net energy ratio is the result of less input of indirect energy during growth as this plant has ability to sustain in unfavorable conditions of environment like rainfall and soil condition.

Variation of net energy ratio for all biodiesels considered is depicted in Figure 4. these energy ratios are compared with jatropha energy ratio [10]. Net energy ratio for karanja and neem biodiesels is nearly same while jatropha has a lower value at all types of soils. The figure reflects that the energy inputs to the life cycle of karanja and neem are equivalent. This may be due to the fact that in processing the seeds of these trees almost same energy units are employed and growths of these plants require minimum inputs. Neem biodiesel has highest values of net energy ratio among the three biodiesels at normal and hard soil. The lowest energy ratio is for jatropha biodiesel for all soil types. The highest variation in net energy ratio is among jatropha and karanja biodiesel (1.4237 - 1.8846) for sandy soil.

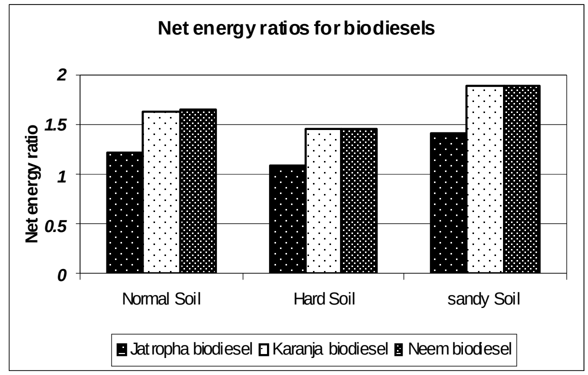

Fig. 4: Variation in energy ratios for biodiesels [10]

CONCLUSIONS

A life cycle energy ratio of biodiesels shows that all the two fuels are renewable. All the biodiesel have higher output than inputs in terms of energy. Neem and karanja biodiesels have equivalent energy ratio for hard and good soil conditions. Under normal conditions of soil and crop yield, karanja and neem biodiesel life cycle have energy ratios, R1=1.6425 and R2 = 1.6479 respectively. The highest variation in net energy ratio is among jatropha [10] and karanja biodiesel (1.4237 - 1.8846) for high yield. Karanja biodiesel has highest energy ratio if agricultural conditions like soils are better resulting in to high yield of the karanja biodiesel. As the wood of the trees can be used in furniture and manufacturing of buildings, from green house gas emissions point of view karanja and neem trees present advantage of carbon sequestration. The energy ratios may be improved with using latest technology in agriculture.

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