International Journal of Environmental Science: Development and Monitoring (IJESDM)
ISSN No. 2231-1289, Volume 4 No. 2 (2013)

Potential to replace petro diesel & reduce greenhouse gas emissions in India by integration of power plants with algae cultivation

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ABSTRACT

Algae–based biofuel is a new energy source that has been gaining significant attention for climate change mitigation and clean development mechanism .The present study aims to establish the potential of algal biodiesel, produced using flue gas from power plant, to reduce GHG emissions replace our current petro diesel supply. The results suggest that using 92% of all coal and gas power plants would allow this algal biofuel source to replace petro diesel entirely and has the potential to sequester approximately 13 to 14% of greenhouse gas emissions. The challenge at the present is to improve the efficiency of algal fuel production technology so as to lower the cost of algal biodiesel and thereby make it commercially competitive with petro diesel. Additional economic sensitivity studies were established to identify the future cost of algal biofuels. Researchers are currently developing various means of accomplishing this and successful commercialization is anticipated by 2023-24.
Keywords: Algae, Bio-fuel, Co_2 emission, Petro diesel.

1 INTRODUCTION

Global pollution, price rise in energy sector and the threat regarding the resource consumption and its availability are the major concerns of 21 century. The core issue is global warming caused by greenhouse gas emissions from human activities, concerns and cerebration about time of peak oil production and the feasibility of various sustainable alternatives. Overall it is estimated that more than half of these greenhouse gases result from the use of fossil fuels [1].Switching to alternative sources of energy is one obvious solution. In past decades, the conventional fuels oil, coal and natural gas, respectively, made up 52%, 26% and 6% of India's energy consumption [2]. This represents alternatives make up only 18% of our energy supply contribution. Other alternatives available for power generation and thermal application including: solar, wind, hydro, geothermal, biomass, nuclear, biomass, hydrogen and fuel cell systems. A second alternative is to keep our existing engine technology and use fuels that do not contribute to global warming. Plants and similar organisms are an ideal source for fuel because they store energy and are abundant and renewable. True sustainability benefits of algae require doing a detailed study of inputs and outputs and that will be difficult until big algae farms are built. This paper explores the production of bio-fuel from algae, its benefits and future potential.

2 OVERVIEW OF ALGAE BIOFUEL TECHNOLOGY

2.1 Why Use Algae for Fuel Feedstock?

There are numbers of options for fuel feedstock like oil crops (jatropha, corn, palm soya etc), waste cooking oil, and animal fats as feedstock for bio-fuel production then why are we turning to algae? Actually all the previous feedstock need lot of resources like fertile land, nutrients etc & production of oil is very less as compare to algae, but algae uses very few resources to grow & yields a higher rate of oil production so it is a far better option as feedstock for bio-fuel production.

Algae fuel or Algal bio-fuel is an alternative to fossil fuel that uses algae as its source of natural deposits. Several companies and government agencies are funding efforts to reduce capital and operating costs and make algae fuel production commercially viable. Harvested algae, like fossil fuel, releases CO_2 when burnt but unlike fossil fuel the CO_2 is taken out of the atmosphere by the growing of algae and other bio-fuel sources, and the world food crisis, have ignited interest in alga culture (farming algae) for making vegetable oil, biodiesel, bio-ethanol, bio-gasoline, and other bio-fuels, using land that is not suitable for agriculture. Algae can grow in salt water, freshwater or even contaminated water, at sea or in ponds, and on land not suitable for food production. Performance of algae is best with the concentrated sources of carbon dioxide. This is the property which allows us to use flue gases from power plant [6]. Algae absorbs significant amount of carbon dioxide & nitrogen oxide, hence reduces the emission of greenhouse gases.

2.2 Algae production systems

Algae can also be grown in salt water and covered ponds. Today's commercial algae production is done in open freshwater ponds. There is lot of structures to make an algae production system. The most simple is open pond system water & nutrient rich materials are added in the pond, this system is best option for sewage ponds , high level of impurity in sewage water provides high level of nutrients like nitrogen , phosphorus ,sulphur,etc that yields in a fast growth rate. This kind of system is cheap in construction & operation but there are some disadvantages; loss of water occurs due to evaporation, efficiency control is not good, harvesting is also difficult in this kind of system. [7] The second system is racetrack type design. It is an open pond but it has circulation axillaries that keep rotating the fluid in an oval circuit by a paddle wheel at one location of circuit & algae can be fetched up on another location. The rotation & mixing by the paddle wheel keeps the mixture homogeneous & doesn't let the solids to settle down [6].

2.3 Extraction and Processing of Algal Biomass

There are several methods of extraction like some of most popular methods are filtration, flotation, flocculation or centrifugation. After harvesting the algae from water we need to extract the oil of algae. There are various methods to extract the oil from algae. The first one is very simple & traditional the mechanical press which presses the biomass with a high pressure & extracts most of its oil. Other method is extraction by organic solvents; hexane is a suitable solvent because it is cheap & economical. But the most effective method till now is supercritical fluid extraction, in this method a gas is liquefied & heated, & then acting as a solvent it can extract almost 100% oil from the algae biomass.

2.4 Algal Biodiesel

Algae biodiesel is slightly different from petro diesel in its chemical & physical properties; higher nitrogen oxide emission & little denser than petrodiesel, since it is an ester so it contains oxygen in its molecules that lowers its energy density relatively than petro diesel. But algae biodiesel has its own benefits over the petro diesel; emission of unburned hydrocarbon is less than petro diesel, approximately zero emission of sulphur oxide, lower toxicity than diesel, existence of polyunsaturated oils in algae biodiesels means it can degrade prematurely & also provides lower viscosity so better performance in cold weather than other crop oils[6].

3 METHODOLOGIES

3.1 Approach Used for Analysis:

Due to concerns about its impact on global warming, researchers have been looking for ways to reduce the amount of carbon dioxide entering the atmosphere. One method is to capture the exhaust CO_2 from fossil fuel power plants and pump it underground. Another option, as mentioned previously, is to use exhaust CO_2 to produce algal fuel and thus eliminate the CO_2 emissions from the fossil fuel it displaces. U.S. daily oil consumption is 18.8 million barrels. Calculation procedure for finding out the amount of algal biodiesel produced from power plant exhaust begins with 1 kg of CO_2. This amount is multiplied by the fraction of exhaust CO_2 actually consumed by the algae. This is then multiplied by four important factors i.e. the CO_2 conversion factor, Oil conversion factor, Biodiesel conversion factor and biodiesel specific volume which represents the amount of algal biomass produced per kilogram of consumed CO_2, accounts for the fraction of the algal mass which is converted into oil, the portion of the oil which is converted into biodiesel and specific volume of diesel (liter/kg) respectively. The result, **'σ'** (liters of bd /kg of CO_2), is the amount of algal biodiesel that can potentially be produced from 1 kg of CO_2 exhaust.

σ = fraction of plant exhaust CO_2 utilized * CO_2 conversion factor (kg of algae/kg of CO_2) * oil conversion factor (kg of oil/kg of algae) * biodiesel conversion factor (kg bd/kg of oil) * biodiesel specific volume (liter of bd/kg bd)
(1)

Further, to calculate the potential capacity of India to produce algal biodiesel from power plant exhaust, start with the annual electrical production from all coal plants. This value is multiplied by two factors i.e. the rate at which CO_2 is exhausted from coal plants and the rate at which biodiesel is produced from CO_2. This rate is found using Equation (1). India,s potential for producing algal biodiesel from power plant exhaust **'δ'** (liters of biodiesel per year) is calculated using the following equations:

δ_c = India's Coal Electricity Production (MWh/year) *Coal CO_2 exhaust rate (kg of CO_2 /MWh) * biodiesel production rate (liter of bd/kg of CO_2) (2)

δ_{ng} = India's NG Electricity Production (MWh/year) * NG CO2 exhaust rate (kg of CO_2 /MWh) * biodiesel production rate (liter of bd/kg of CO_2) (3)

$$\boldsymbol{\delta_{total} = \delta_c + \delta_{ng}} \quad (4)$$

To measure the potential reduction in GHG emissions as a result of entirely replacing petro diesel with biodiesel, it is to start with our total current diesel fuel demand. Therefore, the reduction in global greenhouse gas emissions **'Φ'** (%) is as follows:

Φ = diesel fuel demand (liters/year)* diesel CO_2 conversion ratio (kg of CO_2 / liter of petrodiesel*India's greenhouse gas emissions (year/kg of CO_2 equivalent)* 100% (5)

3.2 Assumptions

Certain assumptions are taken in order to complete the calculations required to obtain the desired results which includes the characteristics of algae and current production and processing technology. All assumed values are listed and referenced below.
(i) Algae can consume 80% of exhaust CO_2 (based on an average of 50% on cloudy days and 82% on sunny days) [10] .

(ii) 1.83 kg of 'utilized' CO_2 makes ~1 kg of algal bio mass [12].
(iii) The algae species cultivated yield 60% oil by weight and all can be extracted [13].
(iv) Nearly 60% of the mass of algal oil is converted into fatty acids (biodiesel). The remaining 40% consists of glycerides and impurities [14].
(v) Algal oil has a similar density as soybean oil: 0.92 kg/liter [15].

4 RESULTS AND DISCUSS

4.1 Potential of reduction in green house emissions

As shown in Table 1, algal biodiesel can be produced at a rate of 0.18 liter/kg of exhaust CO_2. This is equivalent to a rate of 90–173 liters/MWh depending on the plant's fuel type. The current cost of producing algal biodiesel using a photobioreactor and power plant exhaust is estimated to be ₹75 /liter [10]. However, a production cost of ₹20/liter is currently considered competitive.

Table 1. Case study results

	Natural gas power plant	Coal fired power plant
Algal biodiesel production rate	90 liters/MWh	173 liters/MWh
Algal biodiesel production cost	₹75.00 /liter	
Algal biodiesel competitive production cost	₹20.00 / liter	
Algal biodiesel production capacity (potential) of India	94.734 billion liters	10.2585 billion liters
Portion of coal and NG power plants requiring refit to replace petrodiesel with biodiesel	92%	
Reduction in greenhouse gas emissions if algal biodiesel replaced petrodiesel	13.258%	

4.2 Sensitivity Analysis

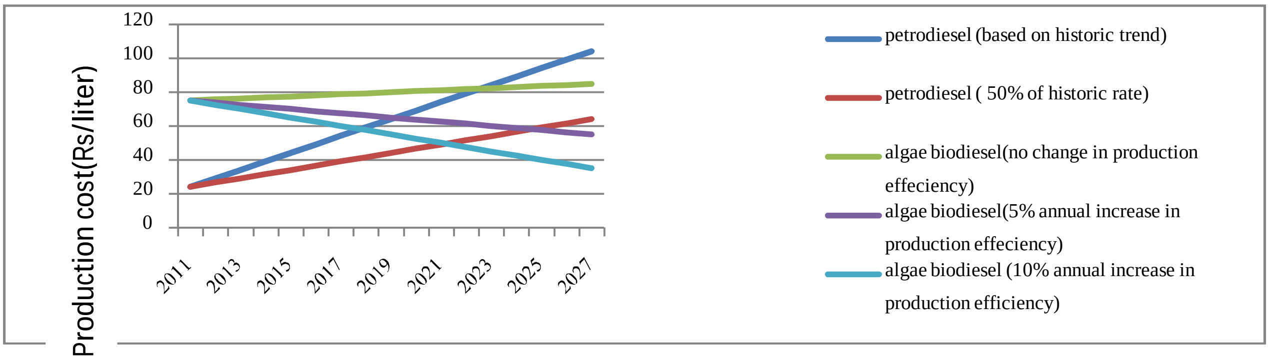

Figure 1. Projected production costs of petro diesel and algal biodiesel.

Figure 1 illustrates how algal biodiesel is expected to be economically competitive with petrodiesel by 2023-24 in all,If all natural gas and coal power plants were utilized, the total global potential to produce algal biodiesel is estimated to be ~104.99 billion liters per year. The result would be a 13.258% reduction in greenhouse gas emissions.

5. Discussion

The content of the initial literature review and the results of the case study both indicate that algal biodiesel has enormous potential as a future fuel source. Algae require minimal land resources and have minimal impact on the food supply. They have a rapid growth rate, high oil content and can utilize waste streams for nutrition. If all global coal and gas power plants were harnessed to supply exhaust for photobioreactors, ~104.99 billion liters of algal biodiesel could be produced annually. The current consumption of diesel in India is only 96.386 billion litres per year [10]. Replacing petrodiesel with algal biodiesel would reduce global greenhouse gas emissions by ~13.258%.

Currently, the production cost of algal biodiesel is 3 time higher than the production cost of petrodiesel. However, due to anticipated increases in algal fuel production technology, increasing demand for diesel fuel and increasing petrodiesel production costs, it is forecasted that, in all but the worst-case scenario, algal biodiesel will become commercially competitive with petrodiesel by 2023-24.

6.CONCLUSIONS

In summary, algae-based bio-fuel is a promising renewable energy source that is in the latter stages of development. In conclusion, two important points can be made with regard to algal biofuel. The first is that algae shows great potential as a biofuel source with several major advantages over other sources. Algal biofuel could provide us a highly positive and potential impact on environemnt .Some of them is: low impact on land use and the food chain; ability to utilize waste streams for nutrients; rapid growth rate and high oil content. Due to the positive characteristics of algae and an abundant supply of power plant emissions, algal biofuel has the potential to be produced on a scale large enough to entirely replace petro-diesel and thereby reduce global greenhouse gas emissions by around 13–14%.

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