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REVIEW AND QUALITATIVE ASSESSMENT OF BIODIESEL AS AN ALTERNATIVE FUEL FOR BUS TRANSPORT

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Abstract
This article provides a state of art review on international research and practices on the benefits and challenges of biodiesel usage for transport. Further, the recent national policy of biofuels – 2018 furnished by the Government of India has been briefly captured. A qualitative assessment of biofuels based on twenty different criteria has been performed and presented. The findings of this research conclude that at this point of time the use of biodiesel for bus transport in India poses numerous challenges and is not feasible at the scale of urban bus transit operation. The authors suggest development of a more robust model that incorporates reforms in policy, implementation and R&D in order to optimize the biodiesel application for bus transport.

Keywords: Biodiesel, Alternative fuel, bus transport, sustainability

1. Introduction

The Ministry of new and renewable energy (MNRE), Government of India recognizes the energy as a critical input to socio-economic development and strategizes on energy efficiency, security and environment friendliness with an objective to attain such a development. The national policy on biofuels by the MNRE that has been last revised in 2018, was brought out in order to address such development goals by promoting the use of biofuels as an alternative to fossil fuels. [28]

Biofuels are derived from natural sources like crops which can be replenished more often than the fossil fuel based sources such as diesel and petrol. A variety of feedstock, for example, corn, wheat, sweet sorghum, cassava, sugarcane, soybean, rapeseed, jatropha can be used individually or in blended form for the purpose of locomotion. The feedstock may be first generation (vegetable oils, corn, sunflower oil etc.), second generation (agriculture and forest residues, grass, waste vegetables oil, jatropha etc.) or third generation (algal biomass). [29]

This article first presents a literature review on various aspects of biofuel usage including few case studies of specific countries and provides an international perspective on this front. Next, the key features pertaining to the national biofuel policy in India are captured and presented. Finally, a qualitative analysis on twenty different indicators in performed and the observations made from this assessment are used to deduct the present and near future state of biofuel usage for bus transport.

2. Literature Review

This section provides a state of art international review of research and practices in context of biofuel usage. Plenty of research has been done in the area of biofuels and a lot of literature is available for review in the matter. Broadly, it can be identified that the following discussions have been made in the context of biofuels in the available literature.

(A) Case Studies of various nations
(B) Feasibility of using biofuels: Technical, Environmental and Economic feasibility
(C) Energy and Emission effects of biofuels
(D) Performance effects of various blends
(E) Effect of nanoparticles and other additives on biofuels
(F) Other sustainability effects

2.1. Case Studies of various nations

The state of biodiesel usage, their success or failure level and observations made by researchers for the case of three nations, namely, Pakistan, Serbia and Spain are captured in this section.

2.1.1. Pakistan: Biodiesel potential and promotion

A review on the potential of biodiesel in Pakistan [1], gives insight on feed stocks, biodiesel production process, barriers and future developments. Future policies on biofuels, trends, recommendations, and the implication of existing policies are also discussed with research and developments goals for the promotion of biodiesel in Pakistan. Various factors to meet the energy demands have been identified.

The authors positively find that Pakistan has a strong potential of biodiesel production. In particular, it has been highlighted that Pakistan is enriched with a wide variety of feed stocks which can be used for biodiesel production.

Pakistan has an enormous potential of biodiesel production from jatropha, plants seed oil and microalgae which needs more consideration and practical applications. Harvesting the potential of microalgae for biodiesel production in Pakistan can be helpful to make the nation self sufficient for energy demands.

The major challenges in biofuel usage identified by the authors are climate change, lack of financial resources and state of art technology and absence of appropriate government policies. They feel that this limits the commercialization of biodiesel. They observe that the various policies by the Government of Pakistan to promote and develop alternative energy technologies and to achieve 10% share of bioenergy in the energy sector by 2020, are failing to achieve the targets.

Like many other countries, they feel that the available feedstock resources if used sustainably and implementable policies if made in appropriate direction can help improve the biofuel scenario for the nation.

2.1.2. Serbia: Biodiesel production potential

The biodiesel production capacities and the indigenous oil-based feedstock potential of Serbia has also been addressed in literature [2]. Their research suggests that the Serbian agriculture can provide oilseed crops for the production of 128,000–266,000 t of biodiesel annually in addition to the quantities of oilseed crops required by the domestic food and fodder industries.

It is noted that there can be potential competition of resources like land and water in trying to meet agricultural goals of food and biofuel feedstocks. Therefore, the authors recommend exploring the non-edible waste feedstock and positively predict a large amount of biodiesel production from second generation feedstocks.

The researchers identify that the two major factors affecting the current biofuel operations are lack of governmental incentives and higher profitability of the edible oil sector. They further predict the annual biodiesel production by 2020 to be 98,000 t with support of appropriate measures and the National Renewable Energy Action Plan.

2.1.3. Spain: Market acceptance of biodiesel

The the active market acceptance and barriers of using biodiesel in Spain through a model has been examined [3]. The important factors identified in their model were attitudes towards the use, knowledge and self-identity. The effects of all the factors were different depending on price and availability, thereby establishing the sensitivity of these parameters on the market acceptance.

2.2. Technical, Environmental and Economic Feasibility

An extensive review [4] of the production, properties, performance and emission analysis of different feedstock of blends of biodiesel and experimental work carried out in the various parts of the world is also found in literature.

The environmental effects of biodiesel through the established methods of Life Cycle Analysis (LCA) have also been examined [5]. Following the principles of the ISO 14040 and 14044 standards for LCA, the variations in LCA methodology and parameter choices in a comparative analysis of 11 published studies of the production of biodiesel from palm oil have been explored. This study highlights inconsistencies between individual studies in various aspects and highlights multiple factors including geographical location that must be considered for LCA.

A review of the economics of biodiesel production and usage [6] has also been noted. The researchers identify that the installed equipment forms major capital investment. Economic feasibility of biodiesel production is highly dependent on feedstock cost and the unit cost of biodiesel production is very high.

2.3. Energy and Emission Effects

One of the researches [7] simulated Life cycle energy and greenhouse gas emission effects of biodiesel in the United States and computed that 60-70 % reduction in overall GHG emissions as compared to petrol are possible for various types of biodiesel feedstocks.

Similarly, another research [8] carried out numerical modelling of biodiesel blends in a diesel engine and the models suggested that biodiesel assists in reducing NO_x and soot emissions, however the variation was also found to be temperature sensitive.

One more research [9] investigated the influence of two biodiesel blends with diesel by emission tests on diesel engine for CO, CO_2, HC, NO_x and smoke opacity. The brake thermal efficiency of blend biodiesel was found higher than the diesel. The emissions of smoke, hydrocarbon and nitrogen oxides of dual biodiesel blends were higher than that of diesel. But the exhaust gas temperature for dual biodiesel blends was lower than diesel.

A team of researchers [10] estimated energy balance of biodiesel production from jojoba seed oil. Energy efficiency as expressed in terms of the net energy balance (NEB) and the net energy ratio (NER) were calculated at 28.9 MJ/L biodiesel and 2.16, and the maximum energy use was during biodiesel production followed by crop protection. The GHG emissions were estimated at 66.0 gCO2eq/MJ biodiesel produced.

2.4. Feedstock types, blends and fundamental performance effects

A comprehensive overview [11] on fuel properties and prospects of Jatropha biodiesel as fuel for engines has also been performed. Similarly, the fuel properties of blended mahua biodiesel [12] has also been analyzed wherein the researcher arrives at an optimum blending ratio.

Experimental analysis of combustion characteristics of internal combustion engine performed with variable compression ratio (VCR) using mixture of two biodiesel blend with diesel has been investigated [13]. Results of another experimental investigation in context of performance evaluation of diesel engine using rice bran biodiesel [14] provided detail of biodiesel production process, fuel property evaluation, impact on engine performance and compression ratio optimization. The investigation revealed that blends of crude rice bran biodiesel can be used as fuel in diesel engine without modifying the engine. Similarly, it was identified [15] that biodiesel could be utilized in variable compression ratio engines without any modification in the engine.

It has also been identified [16] that NO_x emission of biodiesel is higher than that of diesel in most cases, except in the condition of low loads under low and medium speeds. In one of the other researches [17], the effects of high bioethanol proportion in the biodiesel-diesel blends in a CRDI engine have been estimated and it was identified that higher thermal efficiency values, lower NO_x and smoke emissions were obtained with using higher bioethanol amount. Another research [18] examines the influence of biodiesel on the performances of farm tractors through experimental testing in stationary and non-stationary conditions. It was found that biodiesel gives less power, lower drawbar power, and higher specific fuel consumption at all loads. It was also found that biodiesel gives lower CO emission and higher emission of NO_x and CO_2 at all loads.

The effect of biodiesel-ethanol and biodiesel-butanol blends on the combustion, performance and emissions of a diesel engine have also been identified [19]. An experimental investigation [20] conducted for physicochemical properties of diesel, biodiesel and Thész-Boros-Király(TBK)-biodiesel fuels provided for analysis of the combustion and emission effects on internal combustion engine.

2.5. Effect of nanoparticles and other additives

It has been identified [21] that biodiesel has certain disadvantages from point of view of combustion, performance and emissions and with use of additives these could be improved to maintain fuel standards, especially those of second generation biofuels.

Experimental investigations [22] conducted on diesel engine performance and emissions using biodiesel adding with carbon coated aluminum nanoparticles revealed reduction in fuel consumption as well as NO_x and CO emission due to this addition. One of the researches [23] used microscopic techniques and identified that biodiesel with nano additives from coconut shell can decrease emissions in diesel engines.

The properties of various biofuel blends with ethanol and performance analysis were investigated and [24] indicated that there is an improved BP (Brake Power), increased BSFC (Brake Specific Fuel Consumption) and increased BTE (Brake Thermal Efficiency) for various loads on engine for Jatropha, Soybean, Palm and Cottonseed biodiesel- diesel blend with ethanol as an additive.

2.6. Sustainability impacts

A review on the implications due to rise in global biodiesel production on food security has been commented upon thus questioning the food-energy nexus. [25]

The food-fuel competition of first generation biodiesel has also been addressed by researchers [26] and investigates second generation biodiesel such as vegetable oils and waste cooking oils, in terms of feedstock, conversion technology, performance and emission characteristics and finds them as a potential alternative to edible oil derived biodiesel.

Another group of researchers [27] reviewed the potential, efforts and supply chain planning of biodiesel in Israel with the concern of water and emissions nexus and developed a multiobjective model and assessed it to evaluate water emission tradeoff for the case of Israel.

3. Salient features of the National biofuel policy-India

Certain key features of the national biofuel policy (2018) of India are highlighted in this section.[28]

(A) Use of biofuels has been emphasized for better vehicle emission standards to reduce air pollution.
(B) The policy is applicable solely for non-food feedstocks raised on non-agricultural land.
(C) The policy is envisaged to bring fast development and promotion of cultivation, production and use of biofuel feedstocks.
(D) A 20% blending of biofuels has been proposed currently.
(E) Plantation of non-edible oil seeds on government wastelands as well as private contract farming are supported by minimum support price mechanism.
(F) The potential of various species under this category and their quality will be identified.
(G) Employment provided in this area will be classified under the national rural employment guarantee program (NREGP).
(H) Blending of ethanol is encouraged.
(I) Processing units required to be set up are recommended.
(J) Entire value chain is considered for distribution and marketing of biofuels.
(K) Many institutions such as NABARD, IREDA, SRDBI are linked to provide finance for promoting biofuel infrastructure.
(L) Carbon financing opportunities and foreign direct investment are allowed for biofuel projects.
(M) Subsidies, grants, concessions, exemption from excise duty and other fiscal incentives are provided.
(N) Innovation, R&D and project demonstrations in the area of biofuels are given importance.
(O) Some national standards for biofuels have been brought out by the Bureau of Indian Standards (BIS) and enforcement of these will be strictly checked.
(P) Conditions for international cooperation, import and export are mentioned.
(Q) Role of state governments, awareness capacity building mechanisms and institutional mechanisms has also been addressed.

4. Qualitative assessment of biodiesel usage for bus transport

Quantitative evaluation is often not possible or not sufficient for certain sustainability advantages or disadvantages and similar is the case for use of biofuels. The qualitative assessment for assessing the sustainability of using biodiesel for transport sector is reflected through grading that compares the effect of biodiesel usage as opposed to the baseline. The baseline scenario is the use

of diesel which is presently the business as usual case for the bus transport in the city. The effects indicated by grades A-D are listed in Table 1.

Table 1. Grading scheme for qualitative assessment

Grade	Effect
A	Very good or positive effect of biofuel usage
B	Good trait that renders biofuel comparable or better as compared to diesel
C	Weak trait that renders biofuel less competitive as compared to diesel
D	Very poor or negative effect of biofuel usage

Enlisted in Table 2 are twenty qualitative indicators that have been identified as applicable for the thought process to address the sustainability paradigm of such applications. A brief description of the indicator and corresponding remark to enable judgement of the benefits or challenges has been explained in section 4.1. Based on this judgement, the grades on the scale of A-D that indicates comparison with the baseline scenario are provided in Table 2.

4.1. Indicators for qualitative assessment

Biodiesel availability: This refers to the biofuel availability for a bus vehicle typically expected from fuel stations. As per field observation, there is very scarce availability in current scenario.

Biodiesel plant cost: This refers to the biofuel plant setup cost which is the capital expense as well. Various Indian as well as international sources have quoted that the biodiesel plant costs very high.

Biodiesel production cost: This refers to the biofuel plant operating cost which has major component of feedstock cost. The cost of feedstock is extravagant as identified by various Indian and international sources.

Biodiesel production demand versus supply: This refers to the scenario where demand equivalent is that all fleet of BRTS-Ahmedabad may be using biodiesel, and supply equivalent is the market availability. For the purpose of an urban bus transit it can be anticipated that a very high amount of fuel demand exists and the commercial supply is still in nascent stage in the city, many suppliers are advertised in the state but not directly connected and supplying for city bus transport as per field observation.

Biodiesel knowledge: This refers to training and campaigns by transport authorities as well as educational initiatives in institutes and centers dealing with public transport and alternative technologies. Apart from research being published, no specific biofuel campaigns or training programs in the city are organized in order to promote biofuels.

Combustion characteristics: This refers to the internal combustion process in the engine which results in power generation. This is often indicated by burning temperature and burning rate which can be compared with diesel and petrol. The combustion characteristics are more or less similar for the biodiesel.

Commercialization: This refers to the commercialization of biofuel as a product in terms of regular and mass availability, multiple branding and cost competitiveness. At present the biodiesel is not commercially available at most fuel stations in the city. Wherever available in outskirts, the price of biodiesel is more or less same as diesel.

Emissions: This refers to the increase or reduction in air pollutants that include CO_2, CO, NO_x, SO_x and PM; which can be compared in quantity with diesel and other alternate fuels. Biodiesel usage is expected to reduce most air pollutants/emissions by 24 %. However, controversial indications are present in literature for NO_x emissions.

Energy generation: This refers to the energy or power generated per unit mass or volume of biofuel consumed, which can then be compared to diesel or petrol. A large volume or mass of crop is required to produce the same amount of energy as compared to diesel or petrol.

Energy renewability: This refers to the renewability or non-renewability of the energy source. Biodiesel depends on agricultural crop and therefore apart from seasonal variations, the source can be called renewable.

Energy security: This refers to the self-sustenance of providing the energy locally or nationally and not having to depend on external sources like imported fuel. Biodiesel offers more security than diesel or petrol as national dependence is reduced. However, availability of biodiesel crop in different parts of the country is also highly variable.

Engine performance: This refers to the effect of using biofuel on engine parts and engine life. Mostly, literature states that similar to diesel, biodiesel helps clean engine parts. Not much evidence or pilot projects exist to show engine life performance.

Feedstock availability: This refers to the availability of the different kinds of feedstock that may be required as input commodity for production of biofuel. In spite of being an agricultural nation, the temporal and spatial variation of feedstock differs in different parts of the country.

Food-energy nexus: This refers to a fundamental competition that questions the worth of food necessities of edible agricultural crop with energy requirements of biofuel feedstock in terms of land and other resources. At present, a major share of the population is deprived of sufficient food and therefore using land and water for purpose of energy might have a negative impact on fundamental need of growing agricultural crop.

Policies and subsidies: This refers to all applicable policies related to biofuels in transport sector. A national policy to promote biofuels exists however, it needs to be more localized seeing that the application if required is likely to happen through local governance. Besides this implementation of a policy is a major issue in absence of a regulatory mechanism.

Public awareness: This refers to basic awareness of biofuels among the general society. There is huge lack of basic awareness of biofuels among general public. Though it is less likely to impact bus transport situation, it may be important for private vehicle sector.

Regulatory mechanisms: This refers to the regulatory mechanisms or institutional set up to have a controlled and regulated demand or supply of the biofuel or it's pricing. No regulatory mechanism exists that can ensure or regulate the demand-supply or control price or ensure exemption of duties as promised by the national policy.

Research & development: This refers to the R&D including experimental and pilot projects being carried out

in this sector. There has been sufficient R&D worldwide and India too in overall sector but certain areas like mapping of feedstock and blending effects and management practices in biofuels need to be addressed in Indian scenario.

Scale of application: This refers to the scale of application in the transport sector as maybe defined by daily or annual biodiesel production and consumption in liters. As can be identified from pilot cases, small application using less biofuel are predominant. Large scale application like mass transits almost cannot exist on biodiesel. And in case of blends requiring small proportion of biodiesel, the environmental effect is nullified by the high cost that gets incurred in production.

Water –emissions nexus: This refers to a fundamental competition that questions the worth of sustainability values of using more water against reducing a certain amount of emissions. Both water use reduction and emissions reductions are sustainability goals. It is questionable if for reducing a small amount of emissions, the use of so much additional water is justifiable or not.

Table 2. Qualitative indicators and assessment

Sr. No.	Indicator	Grade
1	Biodiesel availability	D
2	Biodiesel plant cost	D
3	Biodiesel production cost	D
4	Biodiesel production demand Vs. supply	D
5	Biodiesel knowledge	C
6	Combustion characteristics	C
7	Commercialization	D
8	Emissions	B
9	Energy generation	C
10	Energy renewability	A
11	Energy security	A
12	Engine performance	B
13	Feedstock availability	C
14	Food-energy nexus	D
15	Policies and subsidies	B
16	Public awareness	C
17	Regulatory mechanisms	D
18	Research & development	C
19	Scale of application	D
20	Water –emissions nexus	D

5. Stakeholders identification

It is natural that the effect of such a technology change may be different on different groups of people and in order to assess the complete effect of biodiesel sustainability, it is necessary to identify the stakeholders who will actually be affected by such a fuel switch. The various groups of stakeholder agents identified to provide specific qualitative perspectives are: (a) Biofuel feedstock farmers (b) Biofuel producers (c) Biofuel suppliers (d) Government (e) Transport agency (f) Riders/Passengers (g) Citizens residing in vicinity of corridor (h) Other citizens (i) Rest of the world. The study is being carried out separately and in this article it is just recommended as a part of future scope.

5. Conclusion

As a summary, the article presents perspectives on the various aspects of biodiesel usage for transport sector that include the technical, environmental and economic feasibility ; energy related effects, emissions, performance effects such as combustion characteristics, effects of additives like nano-particles and ethanol and various other sustainability concerns. Three case studies have been reviewed that throw light on biodiesel potential, promotion through policies, production and market acceptance. The authors identify the need of such a holistic study for India to address the variety of regional variation in climate and feedstock and other parameters such as demand-supply imbalance in order to make a more robust model for biofuel applications.

A qualitative assessment for biodiesel usage for bus transport has been conducted by identifying twenty indicators for practicability and sustainability concerns. The indicators have been graded on a scale of A-D based on knowledge available through literature, market study and interaction with field professionals. The study indicates that energy renewability and energy security are really the only two out of twenty indicators that fare well for biodiesel usage. This means that a more robust policy, implementation and R&D are required in order to optimize the biodiesel application in the Indian context currently.

5. Future Scope

As future study, it may be worthwhile to conduct a more comprehensive field investigation for assessing the biodiesel potential of India. Subsequent to that a simulation model based on the effects of these twenty indicators may be developed.

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