



**INDIAN RAILWAYS ORGANISATION FOR ALTERNATE
FUELS**

**MINISTRY OF RAILWAYS
GOVERNMENT OF INDIA
NEW DELHI**

BIO-DIESEL

**A CONCEPT PAPER
ON
ALTERNATE FUELS FOR INDIAN
RAILWAYS**

MAY, 2013

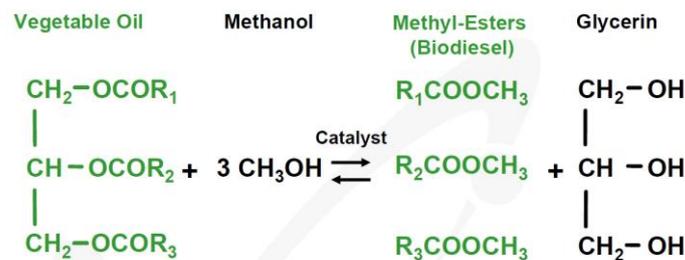
BIO-DIESEL – ROADMAP FOR INDIAN RAILWAYS

Biodiesel is a renewable, cleaner-burning diesel fuel replacement for any diesel engine. Made from an increasingly diverse mix of resources such as recycled cooking oil, agricultural oils, fatty acids, animal fats and algae, biodiesel is truly a green fuel. It contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression-ignition (diesel) engines without any major modifications. Biodiesel is simple to use, biodegradable, nontoxic, and free of sulfur and aromatics. Bio Diesel is carbon neutral, that is to say, the CO₂ produced in burning Bio Diesel, is consumed by the oil seed plants (or other organic matter), used for making Bio-Diesel.

A. WHAT IS BIO-DIESEL

Chemically Bio-Diesel is alkyl (methyl or ethyl) ester of long chain fatty acids. The process of making Bio-Diesel involves transesterification. Triglyceride molecule is reacted with an excess of alcohol in the presence of an alkaline catalyst. The chemical reaction is schematically shown below:

A Three-Step, Catalytic, Reversible Reaction



Biodiesel fuel typically contains up to 14 different types of fatty acids that are chemically transformed into Fatty Acids Methyl Esters (FAME). Transportation grade Bio Diesel is governed by IS15607:2005 or ASTM D6751, DIN 952 or EN 14214. Some critical properties of Bio-Diesel as compared to Petro-Diesel are tabulated below:

S. No.	Physical Characteristics	Petrodiesel as per IS 1460 : 2000	Biodiesel as per ASTM D 6751
1	Fuel Composition	Hydrocarbons	FAME*
2	Kinematic Viscosity @ 40 °C	2.0 to 5.0	1.9-6.0 mm ² /s
3	Cetane Number	48 Min.	47 min.
4	Sulfur, % mass	0.25 max.	0.05 max.
5	Cloud Point (°C).	—	**
6	Pour Point (°C) max	3°C for winter & 15°C for summer	
7	Flash Point (°C)	35°C min.	130.0 °C min.

*Source: RDSO Report:
No. MP.Misc – 150
(DECEMBER – 2003)
(REVISION - 0.00)*

While the pure (100%) Bio diesel is referred as B100, a 20% blend of Bio Diesel with regular Petro diesel is referred as B20 and so on. While no separate standards (from the petro diesel standards) are needed for any blends up to B5, the blended Bio Diesel B6 to B20 is governed by ASTM D7467.

B. WHY BIO-DIESEL

The most fundamental concern of the human civilization is that, petroleum is a limited resource. While there might be wide variation in their perceived duration of availability, there is absolute unanimity in accepting that they shall one day be over. Thus there is a need to look for alternatives.

The bulk of these crude reserves are held by a clutch of nations who can, and at times do, hold the entire world economy to ransom. The crude prices burn the biggest hole in our nation's forex reserves. With the crude import bill of the country running to a staggering 156 billion dollars or 32% of the net imports, any reduction in the crude imports goes that much in correcting the trade deficit. As far as Indian Railways are concerned, we will spend a whopping 17000 crores on diesel fuel alone in the year 2013-14.

Moreover the amount of Green House Gases (GHG) spewed by the transportation sector along with other sources have today pushed the environment to the brink of disaster with the tangible ill effects of the global warming are being increasingly felt in our climate.

Besides, Biodiesel will help diversify our fuel supplies so that we're not as vulnerable to global petroleum markets that constantly disrupt our economic stability and threaten our national security. A strong domestic energy production is critical to our national security.

Bio-Diesel being made from renewable resources addresses all these concerns effectively. It can be made from byproducts of edible oil industry or from non edible oils, or from animal fats or byproducts from various agri-industries. Bio Diesel can be produced from resources within the country and the cost of the production will help the nation's economy, while tackling the energy security.

Even low level blending with Bio-Diesel (such as B20) can bring about substantial reduction in GHG and polluting emissions, as seen in the table below:

Emission Type	B100	B20
Carbon monoxide	-43.2 %	-12.6 %
Hydrocarbons	-56.3 %	-11.0 %
Particulates	-55.4 %	-18.0 %
Nitrogen oxides	+5.8 %	+1.2 %
Air toxics	-60 % / -90 %	-12 % / -20 %
Mutagenicity	-80 % / -90 %	-20 %
Carbon Dioxide (Life Cycle Emissions)	-78.3 %	-15.7 %

Source: US Department of Energy (DOE) – National Renewable Energy Laboratory

Compared with using petroleum diesel, using biodiesel in a conventional petroleum diesel engine substantially reduces exhaust emissions of unburned hydrocarbons (HC), carbon monoxide (CO), sulfates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and particulate matter (PM).

It has also been established that Bio-Diesel improves fuel lubricity and raises the cetane number of the fuel. Diesel engines depend on the lubricity of the fuel to keep moving parts from wearing prematurely. Biodiesel can impart adequate lubricity to diesel fuels at blend levels as low as 1%.

Most engine OEMS worldwide have clearly stated policies of extending warranties on diesel engines using various levels of Bio-Diesel blends (up to B100 in some cases). They include Cummins, Caterpillar, Fairbank Morse, Detroit Diesel, Mercedes, BMW, Chrysler, GM, Ford and many more. (Source: www.biodiesel.org/resources/oems).

B20 and lower-level blends do not require engine modifications. Engines operating on B20 have similar fuel consumption, horsepower, and torque to engines running on petroleum diesel. It has been established that there is no adverse impact on engine parts including rubber, polymers, non-ferrous components and filters.

C. GLOBAL SCENARIO

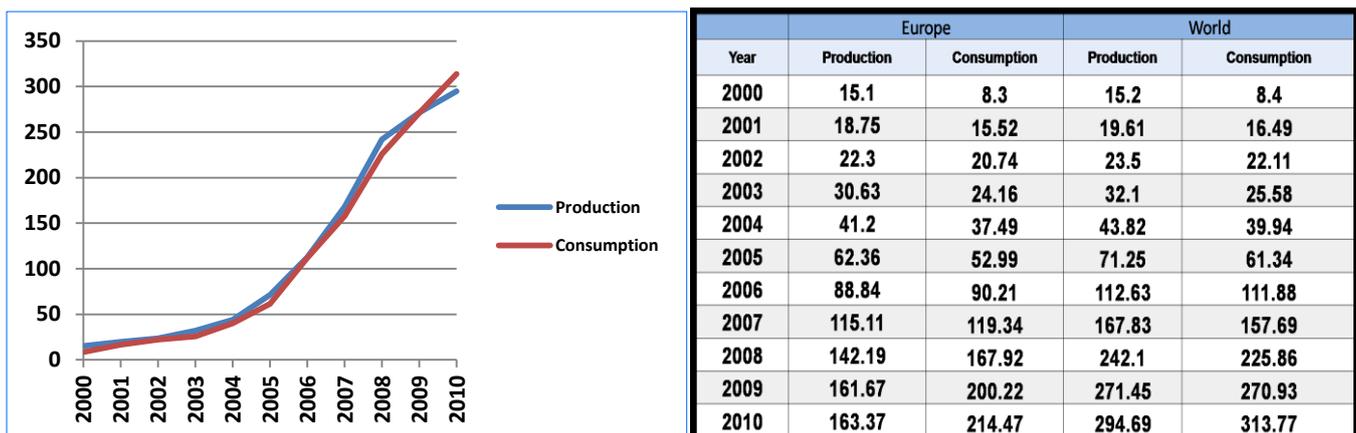
World over the countries realizing the importance of the Bio fuels have legislated mandatory blends of Bio Diesel with the regular petro diesel, and Ethanol with Petrol. The mandated blends range from B2 to B20 for Bio Diesel. Bio-Diesel blend is mandatory in EU, and is being encouraged by the government in USA.

C.1 Bio-Diesel in Rail Traction:

Amtrak’s year-long trial with B20 Diesel was on the Time’s list of “The 50 Best Inventions of 2010.” The project was initiated by two state governments and funded by an FRA grant.

C.2 Bio-Diesel industry worldwide

There has been a steep increase in Bio-Diesel production and consumption worldwide:



Bio-Diesel: Production and Consumption (1000 barrels per day)

Source: [United States Energy Information Administration](http://www.eia.doe.gov)

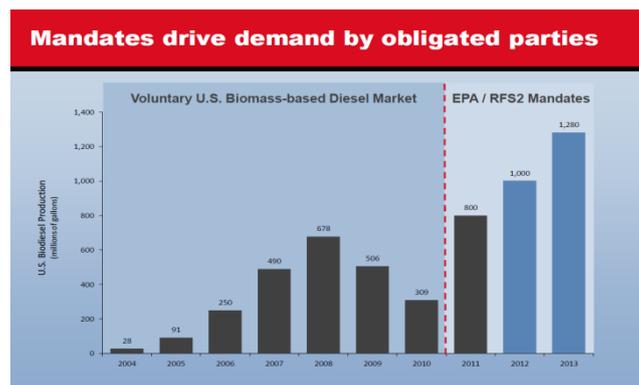
Germany, France, Brazil, Argentina are largest producers of Bio-Diesel in the world. EU produces nearly 60% of world's bio-diesel. Major producers and Consumers of Bio-Diesel are listed below:

Rank	Country	Production (Thousand Barrels per Day)	Rank	Country	Consumption (Thousand Barrels per Day)
1	Germany	49	1	Germany	50.5
2	Brazil	41.31	2	Brazil	42.43
3	France	37	3	France	40
4	Argentina	36	4	Italy	30
5	United States	20.18	5	Spain	26
6	Spain	16	6	United Kingdom	18
7	Italy	14.5	7	United States	14.92
8	Thailand	11	8	Poland	12
9	Belgium	8.5	9	Thailand	11
10	Netherlands	7.5	10	Austria	10.3

(Source: www.indexmundi.com/energy.aspx?region=af&product=biodiesel&graph=production)

As can be seen from the figures and charts above, India does not figure in even the top ten producers or consumers of Bio-Diesel in the world.

The US Government has in recent years, through its Renewable Fuel Standards 2 (RFS2) scheme has moved from a voluntary regime to a programmed one, as can be seen below:



Source: www.epa.gov

The US Government has estimated that apart from strategic gains of reducing dependence on imported oil from troubled regions of the world, Bio-Diesel significantly contributes to the U.S. economy in multiple ways. It is estimated that between 2005 and 2015, the Bio-Diesel industry will

- add \$24 billion to the U.S. economy
- create a projected 39,102 new jobs
- keep \$13.6 billion in America that would otherwise be spent on foreign oil
- generate \$8.3 billion of new revenue for the Federal Treasury
- add \$15.6 billion (2005 dollars) to America's GDP

Quite clearly, similar gains are expected in India as well, once the Bio-Diesel industry takes the growth path.

D. INDIAN SCENARIO

The Government of India (Ministry of New and Renewable Energy), in its National Policy on Bio-Fuels, has emphasized the need to develop Bio- Fuels in view of India's energy security, reduced dependence on imports and containment of carbon emissions and air pollution. It has laid down an indicative target of achieving 20% blending of bio-diesel in diesel and 20% blending of ethanol in petrol by the year 2017. Whereas some progress is seen in the area of ethanol blending, very little has been achieved in the area of Bio-Diesel.

D.1 Indian Bio-Diesel Industry

Bio-Diesel Plants have been set-up in the private sector in Vizag, Kakinada, Hyderabad, Mumbai, Kolkata and other places. Some of the Major Players are Emami, Reliance, Indian Oil, Southern Online, Universal Biofuels, Royal Energy, Ruchi Soya, Garware and Nova. Plants of capacities up to 300 tonnes per day exist, but most work at part loads. Indian Industry primarily caters to exports – US, Europe. Cellphone towers planning to migrate to bio-diesel blends. Their diesel consumption is 1.8 billion litres, compared to IR's 2.5 billion litres.

D.2 Scenario on Indian Railways

Plantations of Jatropha on Railway land have yielded virtually no oil. IOC's collaborative project for plantation on IR land has also failed. Attempts to procure Bio-Diesel from open market evoked poor response due to fluctuating rates and uncertainties of raw material, low level of industrial activity and the emphasis of existing players on export, where they get higher prices.

Two Bio-Diesel plants of 30 tonnes per day capacity each are, being built at RAIPUR and TONDIARPET at a cost of Rs 30 Crores per plant. These plants will use state of the art European "dry-wash". They will be capable of using multiple types of raw material. Contracts were awarded in April 2011 but, construction has been delayed due to resource crunch. The plants are likely to go on stream in December 2014. It is possible to earn Carbon Credit to the tune of Rs 8 Crores from these projects.

With diesel prices for IR going up to Rs 60 per litre, bio-diesel has suddenly become viable. Requirement of IR for 20% blend is nearly 1200 tonnes per day – nearly equals present installed capacity in India. In-house plants are capital intensive and slow to come up. Need 40 such plants needing capital investment of 1200 Crores. Hence a need to procure directly and let markets develop. BOOT model, similar to the successful Mechanical Laundry Model too needs to be explored. Some players have shown interest during preliminary discussions and an EOI or a Tender is likely to evoke good response.

D.3 Indian Railways' Initiatives in the Field of Bio-Diesel So Far

D.3.1 RDSO Trials

Extensive Trials have been conducted by RDSO with various levels of blends of Bio-Diesel and with Bio-Diesel sourced from multiple feed-stocks. Detailed engine characterization studies with different non-edible oil base Bio-Diesel have been done by RDSO. The studies have been conducted on following types of Bio-Diesel:

- Waste Fish Fatty Acid Methyl Ester (WFFAME)
- Waste Mahua Oil Fatty Acid Methyl Ester (WMFAME)
- Waste Cotton Seed Fatty Acid Methyl Ester (WCFAME)
- Pongamia Fatty Acid Methyl Ester (PFAME)

Tests were done at the Engine Development Directorate of RDSO on Engine Test beds for 3100 HP 16 cylinder ALCO engine and 4000 HP EMD 710 G3B 16 cylinders two stroke Engine. Results of the tests are summarized in the table below:

	Regular Diesel	Bio Diesel Blends with Regular Diesel		
		5 %	10%	20%
Horsepower (HP)	3064	3070	3071	3068
SFC (gms/bhp-hr)	150.59	152.12	152.47	154.83
Firing pressure (psi)	1990	1940	1930	1895
Exhaust Gas Temp. in °C	472	480	473	477

*Source: RDSO Report:
No. MP.Misc – 150
(DECEMBER – 2003)
(REVISION - 0.00)*

As can be seen from the results, the test engine was capable of obtaining full power output with biodiesel.

D.3.2 Setting up of IROAF and Efforts Thereof

A dedicated organisation, the **Indian Railways Organisation for Alternate Fuels** was set up in the year 2008 to pilot specific projects on Bio-Diesel and CNG on Indian Railways. The mandate of IROAF has subsequently been enhanced through executive orders and through sanction of several alternate energy projects in the RSP.

Attempts to procure Bio-Diesel from market have not been successful. However, two in-house Bio-Diesel plants are under construction, one each at Raipur and Tondiarpet.

IROAF is constantly striving to find ways to move up from experimental and trial stages to commercial use of Bio-Diesel.

D.3.2 Earlier Efforts

Even earlier, some small scale, but concrete initiatives were taken by various Zonal Railways in use of Bio-Diesel. These efforts were either experimental or were undertaken on small scales. Hence, these could not be sustained due to clear policy directives and non availability of Bio-Diesel on long term basis. Some of the key efforts are listed below:

- a) Three small scale experimental Bio-Diesel plants of limited capacities were set up during the last few years as follows:
 - A 1000 litres per day plant in Loco works, Perambur in 2005. This plant is still functioning and produced 12,980 ltrs of Bio-Diesel in 2012-13.

- *A 2000 litres per day plant in Kharagpur Diesel Shed in 2006. The plant uses seeds as well as vegetable oil as raw-material. The plant has produced only 8000 litres of bio-diesel so far and is currently dysfunctional.*
 - *A 2000 litres per day plant in Shakurbasti Diesel Shed in 2003. The plant used waste cooking oil as raw-material. It is currently dysfunctional.*
- b) Field trial successfully conducted on Delhi Amritsar Shatabadi on 31.12.2002 with a blend of 5% Bio-Diesel.
 - c) In May 2004 Jan-Shatabdi Exp. from Lucknow to Allahabad was fuelled with B10 and performance monitored for 5 days. Found to be successful.
 - d) The Bio-Diesel produced in LW/Perambur is being regularly used in locomotives of TNPM shed and GOC Workshop and DPC of TPJ Division.

E. ACTION PLAN FOR INTRODUCTION OF BIO-DIESEL ON INDIAN RAILWAYS

Even though a National Policy for bio-fuels exists, Indian Railways have been slow in taking concrete steps in this direction. There is an urgent need to speed up the process of introducing Bio-Diesel in diesel traction so that the targets of the National Policy on Bio-Fuels are met to a significant degree.

Bio-Diesel on IR will be inducted in the following manner. The plan given below takes care of short term, medium term and long term perspectives.

E.1 Procure Bio-Diesel from open market.

While previous attempts to procure Bio-Diesel from the open market have not fructified, there appears to be a renewed interest in the Indian Bio-Diesel industry in supplying Bio-Diesel to bulk users, who are burdened with complete removal of subsidy. The total installed capacity for Bio-Diesel production in the country is small. Moreover, many of them are located in SEZs, which are catering to foreign markets alone, where they also fetch a good price, in the range of ₹90-100 per ltr. However, some suppliers are willing to supply Bio-Diesel to IR at a price matching that of unsubsidized diesel or even at marginally lower prices. But, suppliers are generally wary of committing large production capacities to IR given the uncertainty they face due to our year-to-year procurement system. It should still be possible due to change in the pricing of HSD and some of the Bio-Diesel plants going back on stream to procure modest quantities of Bio-Diesel at one go.

E.1.1 The benefits of direct procurement are as follows:

- a) Extended trials of locomotives will be possible in the field as different from test-bed trials in RDSO.
- b) Field units will become familiar with handling, issue, accountal, bending and safety related matters of Bio-Diesel. This will go a long way in successful induction of Bio-Diesel on larger scale.

- c) There will be price discovery at multiple purchase locations, which will refine the procurement decisions when large scale introduction of Bio-Diesel is made.
- d) The Indian Bio-Diesel industry will be spurred by the entry of largest single HSD consumer in the country in the Bio-Diesel market.

E.1.2 The disadvantages of this route are as follows:

- a) Price advantage of long term contract will not be available.
- b) Since the demand of Bio-Diesel in Western countries is also seasonal, there may be periods of non-supply or delayed supplies.
- c) Since quality of Bio-Diesel from various sources and from various feedstock may vary, consistent quality from multiple purchases will be difficult to ensure.

E.2 Production of Bio-Diesel by Indian Railways

Two Bio-Diesel plants are under construction, one each at Raipur and Tondiarpet. These plants are of 30 tonnes per day (TPD) capacity each. The plants are being built at Govt. expense under PH-42 and cost ₹30 crores each. Even though contracts were awarded in April, 2011, the progress has been slow due to shortage of funds in PH-42. These plants are, however, of industrial scales, unlike smaller plants built at KGP, SSB or LW/PER, which are experimental in nature. The Plants at R and TNPM will use state of the art European dry-wash technology.

E.2.1 There are following advantages of this route:

- a) Assured supply, since the plants are owned by IR.
- b) IR sets its own standards of quality and pricing.
- c) The contract conditions provide for supplies at prices lower than that of HSD, thus there is also an element of economy.
- d) The benchmarks of quality and pricing will come in useful in large scale procurement of Bio-Diesel directly from the market at later stages.
- e) Familiarization of field units on a larger scale in matters related to Bio-Diesel.

E.2.2 Disadvantages of this route are as follows:

- a) It is capital intensive and requires IR to invest its own scarce capital.
- b) Given the total requirement of 1200 TPD of Bio-Diesel for 20% blending, even at current volumes, IR would require to invest in 40 such plants at Rs 1200 Crores. Such financial resources are not likely to be available.
- c) The speed of execution is dependent on availability of funds from year to year.
- d) Requires supervision and some manpower, even though minimal.

E.3 BOOT Model of Procurement

BOOT model enables IR to overcome the difficulties encountered in year-to-year procurement. The successful contractor is assured of a long term offtake and works in a spirit of partnership. Ironclad contract, however, is the key to success in this route.

E.3.1 There are following advantages of this route:

- a) Will attract large players, since the volume of business is large and also assured.
- b) Good price is expected due to long term contract.
- c) Encourages investment in high quality production systems.
- d) Has high employment potential – good for the economy.
- e) IR is free from issues of production, manpower and capital investment.
- f) Similar model has been successfully tried out for Mechanised Laundries.

E.3.2 Disadvantages of this route are as follows:

- a) Complexity of contract.
- b) Long term PVC has uncertainties.
- c) Can be set up only where land is available easily (Approx. 6-8 acres is needed).

E.4 Direct Procurement of Bio-Diesel from Oil Marketing Companies

Oil Marketing Companies (OMC) can be persuaded to sell blended fuel (B20) to Indian Railways. Though this would be the easiest route as it will minimize IR's own efforts. But, it is unlikely that OMCs will be in a position to do so in near future. They too face the same problems as IR's, i.e. non-availability of Bio-Diesel in large quantities at consistent qualities and at predictable prices. Besides, IR's business being a miniscule portion of theirs, it may not be possible to impress upon them to do so selectively for us.

E.4.1 There are following advantages of this route:

- a) No investment needed by IR.
- b) Least effort on the part of IR – technical, quality control, blending facilities.
- c) Single storage and fuel-accountal system.
- d) Single vendor for each fuelling point (RCD)

E.4.2 The disadvantages of this route are as follows:

- a) It may not happen for several more years.
- b) The price of blended B20 diesel will be higher, since it attracts same duties and taxes as that of Petro-Diesel. Pure Bio-Diesel, on the other hand is taxed at lower rates.

F. RECOMMENDATIONS

The National Policy on Bio-Fuels lays down an indicative target of 20% universal blending of Bio-Diesel in Petro-Diesel by the year 2017. It is very likely, given the developments worldwide, that this may become a mandatory requirement and catch us by surprise. It is therefore necessary to begin work in this direction with emphasis on projects of various time-spans. IROAF recommends that following short, medium and long term steps be taken to introduce Bio-Diesel in diesel traction on a significant scale:

F.1 Short Term Steps (4-8 months)

1. Begin procurement of small to modest quantities of Bio-Diesel by Zonal Railways for blending. This should give us experience in handling and account of this new fuel on larger scale. Railway board has already issued directives to all the Zonal Railways in this matter vide letter no. 2010/Fuel/282/2/Pt.1, dated: 30-04-13. (Time Frame: Nov 2013).
2. Begin production in the existing in-house plants at KGP and SSB and scale up production at LW/PER. This should give us about 6000 litres of Bio-Diesel every day. (Time Frame: Sept 2013)

F.2 Medium Term Steps (1-2 Years)

1. Put the Raipur and TNPM Bio-Diesel plants on fast track. If funded properly, it should be possible to begin production by December 2014. (Time Frame: Dec 2014)
2. Take up open market procurement on a larger scale, with each contract in the range of 15000-20000 KL. This should be possible since the small volume purchase will have established price levels and also helped build the confidence to store and handle this fuel widely. (Time Frame: Dec 2014)

F.2 Long Term Steps (2+ Years)

1. Set up at least three to four Bio-Diesel plants to start with on BOOT model, with capacities of 50TPD. (Time Frame: Plants in place by Dec 2016). A Draft Policy for setting up Bio-Diesel plants under BOOT model has already been sent to the Railway Board by IROAF vide Letter no. IROAF/CME/BD/BOOT Dated:01-04-2013 and is under active consideration in the Board.
2. Persuade Oil Marketing Companies to supply blended fuel (B20). (Time Frame: 4+ Years to Uncertain)

---000---