POLICY BRIEF

ACCELERATING BIODIESEL BLENDING IN INDIA

THE ENERGY AND RESOURCES INSTITUTE

Creating Innovative Solutions for a Sustainable Future

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Author

Mr Faiz Jamal, *Research Associate*

Principal Investigator

Mr Sharif Qamar, *Associate Director*

Reviewers

Mr Shri Prakash, *Distinguished Fellow*

Mr I V Rao, *Distinguished Fellow*

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FOR MORE INFORMATION

Transport and Urban Governance Division, TERI, Core – 1B, 3rd Floor, Indian Habitat Centre, Lodhi Road, New Delhi 110003, India. Tel: +91 11 2468 2100 or 2468 2111 | Fax: +91 11 2468 2144 or 2468 2145 Email: sharif.qamar@teri.res.in | Web: www.teriin.org

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List of Abbreviations

BAU	Business As Usual
BDAI	Biodiesel Association of India
BMAI	Biodiesel Manufacturers Association of India
DI engines	Direct Injection Engines
EBP	Ethanol Blending Programme
FAME	Fatty Acid Methyl Ester
GHG	Greenhouse Gases
GoI	Government of India
ha	Hectare
HDRD	Hydrogenation-Derived Renewable Diesel
HDV	Heavy-Duty Vehicles
HSD	High-Speed Diesel
LDV	Light -Duty Vehicles
MDV	Medium-Duty Vehicles
MTPA	Million Tonnes Per Annum
MoP&NG	Ministry of Petroleum and Natural Gas
OMCs	Oil Marketing Companies
PME	Palm Oil Methyl Ester
PPAC	Petroleum Planning and Analysis Cell
PSO	Palm Stearin Oil
PSO	Public Sector Obligation
RUCO	Repurpose Used Cooking Oil
STEPS	Stated Policies Scenarios
UCO	Used Cooking Oil
WCO	Waste Cooking Oil

1. Background

With continuous growth in the world's population, rapid industrialization, urbanization, and economic growth, fossil fuel consumption is escalating to meet the global energy demand. According to the STEPS[1], India's energy demand for road transport is projected to increase two-folds by 2040—half of which will be fuelled by diesel-based freight transport.

According to TERI's estimates (TERI, 2021), overall energy demand from the transport sector may increase more than four-folds; between 2016 and 2050. In recent years, India has been the fastest- growing sector in terms of end-use and is already set for a huge expansion of transport infrastructure in every mode. India's oil demand, as per STEPS, will rise by almost 4 million barrels per day (mb/d) to reach 8.7mb/d[2] by the year 2040. As the domestic oil resources in India are limited, it imports large quantities of crude oil (the second largest importer) to meet the energy demands. The country's dependence on imported oil is around 75% (IEA, 2021) and costs a massive foreign exchange investment.

The contribution of fossil fuel to global energy is around 80% (Ritchie, Roser, & Rosado, 2020). According to the Bureau of Energy Efficiency[3], India's dependency on imported fossil fuels is mounting incessantly. India is the fourth-largest petroleum consumer in the world after China, the United States, and Russia. Due to modernization and its dynamic economic growth, India's energy demand will continue to have a robust increase. The petroleum products consumption in the country has increased about 38.2% from the past decade, resulting in a substantial expenditure on oil imports. Considering the growing demand for fossil fuel and the rapidly growing motor vehicle fleet in India, the Government of India had set a target to reduce 10% oil imports by 2022.[4]

2. Introduction to Biodiesel

According to a recent report by the Petroleum Planning and Analysis Cell (PPAC) on an all-India study for sectorial demand of petrol and diesel (PPAC, 2021), retail diesel sales constitute 68% share of the petrol-diesel basket. India's transport sector accounts for 87% and the remaining 13% is with the non-transport sector. Heavy-duty vehicle (HDV) and light-duty vehicle (LDV) together consume more than 64% of total diesel consumption (PPAC, 2021). As freight activity is expected to grow[5], the commercial vehicle segment will likely continue to dominate the demand for diesel and impact oil import dependency.

The number of vehicles on the road is increasing day-by-day, leading to an increase in fuel consumption. Hydrocarbon fuel combustion contributes to the generation of carbon-based particles in the exhaust and pollutes the environment. Compared to renewable biofuels, non-renewable fuels emit more hydrocarbons, nitrogen oxides, sulphur oxides, and carbon monoxide.

1 Stated Policies Scenario (STEPS) provides a balanced assessment of the direction in which India's energy system is heading based upon today's policy settings and contains and an assumption that the spread of Covid-19 is largely brought under control in 2021.
2 mb/d = million barrels per day
3 Details available at https://beeindia.gov.in/content/fuel-efficiency
4 Details available at https://beeindia.gov.in/content/fuel-efficiency
5 Details available at Microsoft PowerPoint - NTDPC Presentation vFF.pptx (niti.gov.in)

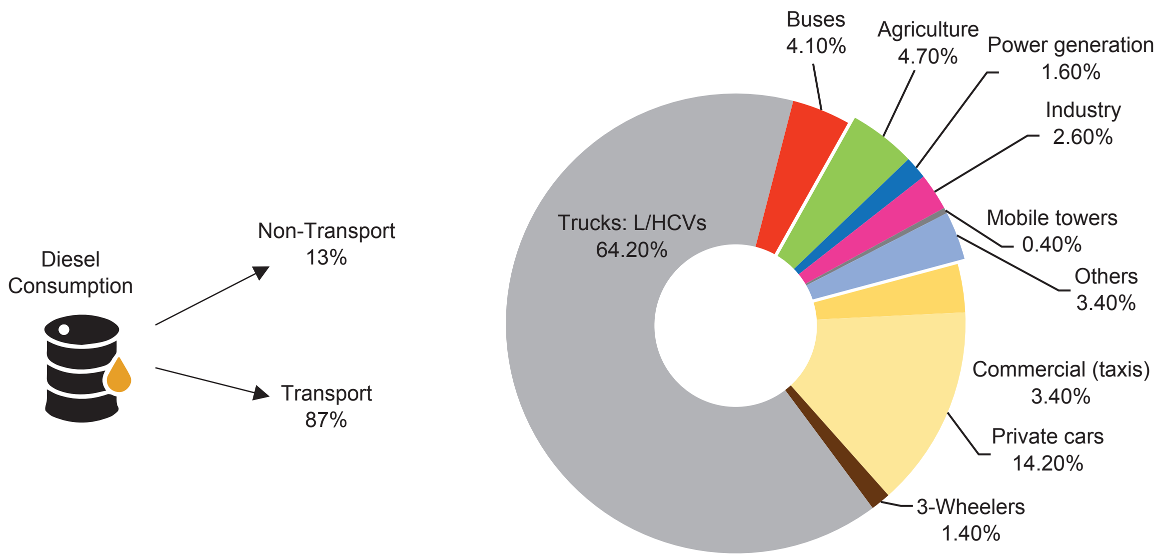


Figure 1: Diesel retail sales by sector and segment in India

Source: PPAC, 2021

Various alternative fuels are considered substitutes for petroleum products and efforts were made to analyse their suitability. Increasing attention has been paid to renewable fuels to reduce pollution (by completing the carbon cycle) and reduce petroleum imports. Consequently, scientists worldwide have focused on developing biodiesel and optimizing its production processes to meet the required standards and specifications.

Currently, India has a limited variety of alternative fuel options for diesel vehicles and is in the initial stages of electrification. The use of hydrogen fuel cells, battery operated vehicles, are in the commercialization phase; especially in medium and heavy-duty bus segments. At the same time, the issue remains with availability and reliability of the prime energy source. In this regard, biodiesel is the most prominent source and one of the relatively cleaner options in medium/heavy-duty vehicles: SUVs, taxis, buses, etc.

Biodiesel is one of the alternative fuels that can be produced from renewable sources like vegetable oil, soybean oil, canola oil, non-edible sources, and animal fats. India's government is emphasizing energy security with a target of reducing the usage of fossil fuels and import burdens. In tandem with emission problems, this has driven the requirement for alternative fuels that benefit the environment and are economically competitive.

In India, biodiesel is produced primarily from non-edible vegetable oil, acid oils, animal tallow, and palm stearin oil. Domestically available used cooking oil (UCO) has been identified as a potential raw material for biodiesel production in the National Policy on Biofuels, 2018. The waste cooking oil can be collected in bulk from consumers such as restaurants, hotels, etc., for conversion into biodiesel. Biodiesel in its pure form is termed B100, or neat biodiesel and can also be blended with conventional diesel as B5[6] and B20[7] (Konishi, 2010).

6 5% biodiesel and 95% diesel by volume
7 20% biodiesel and 80% diesel by volume

2.1 Biodiesel as a potential energy source

There is a need for sustainable and appropriate replacement of fossil fuels to reduce import of oil and lower exhaust emissions. In addition to being renewable, non-toxic, and eco-friendly, biodiesel is an ideal alternative to diesel engines. Various other potentials related to biodiesel are:

- it can reduce our dependence on petroleum imports
- it can control limited supplies of fossil fuels
- it can help in reducing GHG emissions
- it can support boosting our domestic economy
- it maintains the payload capacity and range of petroleum-derived diesel

2.2 Emission reduction from biodiesel

Biodiesel significantly reduces the tailpipe emissions of carbon monoxide, unburned hydrocarbons, and other particulate matter, compared to conventional diesel and supports the environment. A major component of acid rain—sulphur dioxide and sulphates—are virtually eliminated with biodiesel.

Nitrogen oxide emissions, however, either increase or decrease depending on the engine duty cycle and testing methods. The overall ozone-forming potential of emissions from biodiesel is less than half of that measured for the diesel counterpart. Hence, it can be used as a replacement for conventional petroleum-based diesel and could be named a 'clean energy source'.

2.3 Challenges of biodiesel

There are few challenges associated with using biodiesel as fuel:

- Due to its lower calorific value, the fuel consumption becomes higher
- NO_x emissions are slightly higher than conventional diesel
- Biodiesel has a higher freezing point in comparison with diesel
- Biodiesel used in its pure form for a longer period of time can cause corrosion; especially if used without any coating, etc.

Table 1: Biodiesel emissions compared to conventional diesel

Biodiesel Mix Percentage	B5	B7	B10	B20	B50	B100
Particulate matter	-3%	-4%	-6%	-12%	-27%	-47%
Hydrocarbons	-5%	-8%	-11%	-20%	-43%	-67%
Carbon monoxide	-3%	-4%	-6%	-12%	-28%	-48%
SO_x	-5%	-7%	-10%	-20%	-50%	-100%
CO_2	-4%	-5%	-8%	-15%	-38%	-76%

**Note on emission reductions:* *The above analysis is based on research and studies conducted by the University of Idaho and the USDA, including the complete direct and indirect GHG emissions of biodiesel production. This latest study is a further update to the previous methods used by USEPA in 2010. Global warming potentials of various greenhouse gases are weighted to present results in CO_2 equivalents.*

Source: BMAI

3. Biodiesel Policy Initiatives in India

As an initiative to limit oil import and support its energy needs, back in the early 2000s, India took several policy steps to encourage biodiesel production and use in the country:

1. As part of a commitment to promote biodiesel production, MoP&NG announced a Biodiesel Purchase Policy[8] in October 2005, which became effective from January 1, 2006. As per this policy, OMCs were required to purchase biodiesel for blending with high-speed diesel (HSD) at 5%, while meeting the Bureau of India Standards (BIS).

2. At its meeting on January 16, 2015, the Cabinet determined that private biodiesel manufacturers, their authorized dealers, and joint ventures of oil marketing companies (OMCs) authorized by MoP&NG, would be allowed to sell biodiesel directly to consumers.

3. On August 10, 2015, the government amended the Motor Spirit and High-Speed Diesel (Regulation of Supply, Distribution, and Prevention of Malpractices) Order, 2005, to allow the direct sale of biodiesel to large bulk consumers, such as railways, state road transport corporations, and others. From August 10, 2015, oil marketing companies also started selling blended biodiesel from selected retail outlets throughout the country.

4. As per MoP&NG's Gazette Notification: GSR 728 (E) issued on June 29, 2017[9], the reserve state government may permit the direct sale of biodiesel (B100) for blending with high-speed diesel, to all consumers under the conditions outlined in the notification.

5. The latest amendments to IS:1460 (Automotive Diesel Fuel Specification) issued in December 2017, allow biodiesel to be blended up to 7% with automotive diesel fuel.

6. MoP&NG has issued the National Policy on Biofuel, 2018[10], in which an indicative target of 5% blending of biodiesel in diesel is proposed by 2030.

7. According to the policy, UCO and WCO have produced in-house are potential sources of biodiesel. Nevertheless, UCO is diverted into the edible stream by various small eateries/vendors and traders. Attention may be focused on defining strict norms for preventing UCO from entering food channels and developing a suitable collection mechanism to augment its availability for biodiesel production.

8. The government has notified the guidelines for the sale of biodiesel to blend with high-speed diesel for transportation purposes in the extraordinary gazette of India in 2019[11].

3.1 Biodiesel policy: Current status and gaps

In 2021, the national average blend rate of biodiesel was estimated at 0.02%.* Biodiesel is manufactured from imported palm stearin, domestically sourced animal fats, UCO, and small volumes of non-edible oils.

- Usage of biodiesel remains negligible due to the:
- limited availability of feedstock

**Note: According to the latest report published by (USDA,2023) on June 20,2023, the blend rate has increased to 0.07% in 2022*

8 Details available at: https://MoP&NG.gov.in/files/uploads/Bio-Diesel_Purchase_Policy.pdf
9 Details available at: http://petroleum.nic.in/sites/default/files/Order-Distr_GSR728_29_06_2017.pdf
10 Details available at: https://MoP&NG.gov.in/files/uploads/NATIONAL_POLICY_ON_BIOFUELS-2018.pdf
11 Details available at: https://ppac.gov.in/WriteReadData/userfiles/file/Sale%20of%20Bio%20Diesel%20policyr%20Apr%202019.pdf

- high feedstock prices
- lack of an integrated and dedicated supply chain
- dependence upon the imported feedstock
- import restrictions
- limited consumers (only a few OMC retail outlets)

To meet its biodiesel blending goal by 2030, India would need to invest in new plants substantially to enhance the production capacity from its current effective capacity of 520 million litres (as of 2021) and form a supply chain infrastructure for UCO; while imposing some essential collection mechanisms. In India, the entrepreneurs who are typically fuel traders with comparatively better access to the domestic fuels market dominate biodiesel manufacturing and operate micro, small, and medium enterprises, in contrast to other countries that mostly rely on manufacturing units set up by vegetable oil refineries or large oil companies. It is important for the government to encourage and/or induce noticeably greater biodiesel production (Chandra, 2021).

4. International Experience

In 2021, the biodiesel consumption in the US, Brazil, Argentina, and China was 9.44, 5.6, 0.92, and 0.81 billion litres, respectively and the blend rates have been shown in Figure 2.[12] The production resources are locally available in majority of these countries, thus making them viable for optimum production.

The European Union, currently, is one of the largest producers of biodiesel from feedstock like rapeseed oil, palm oil, and used cooking oil, in the world with 32.3% share; followed by the US with 18.1% share from soybean oil and used cooking oil; Indonesia with 15% from palm oil; Brazil with 12.2% with soybean oil; and Argentina with 5% from soybean and others.

12 Details available at: https://www.oecd-ilibrary.org/sites/89d2ac54-en/index.html?itemId=/content/component/89d2ac54-en#figure-d1e22758

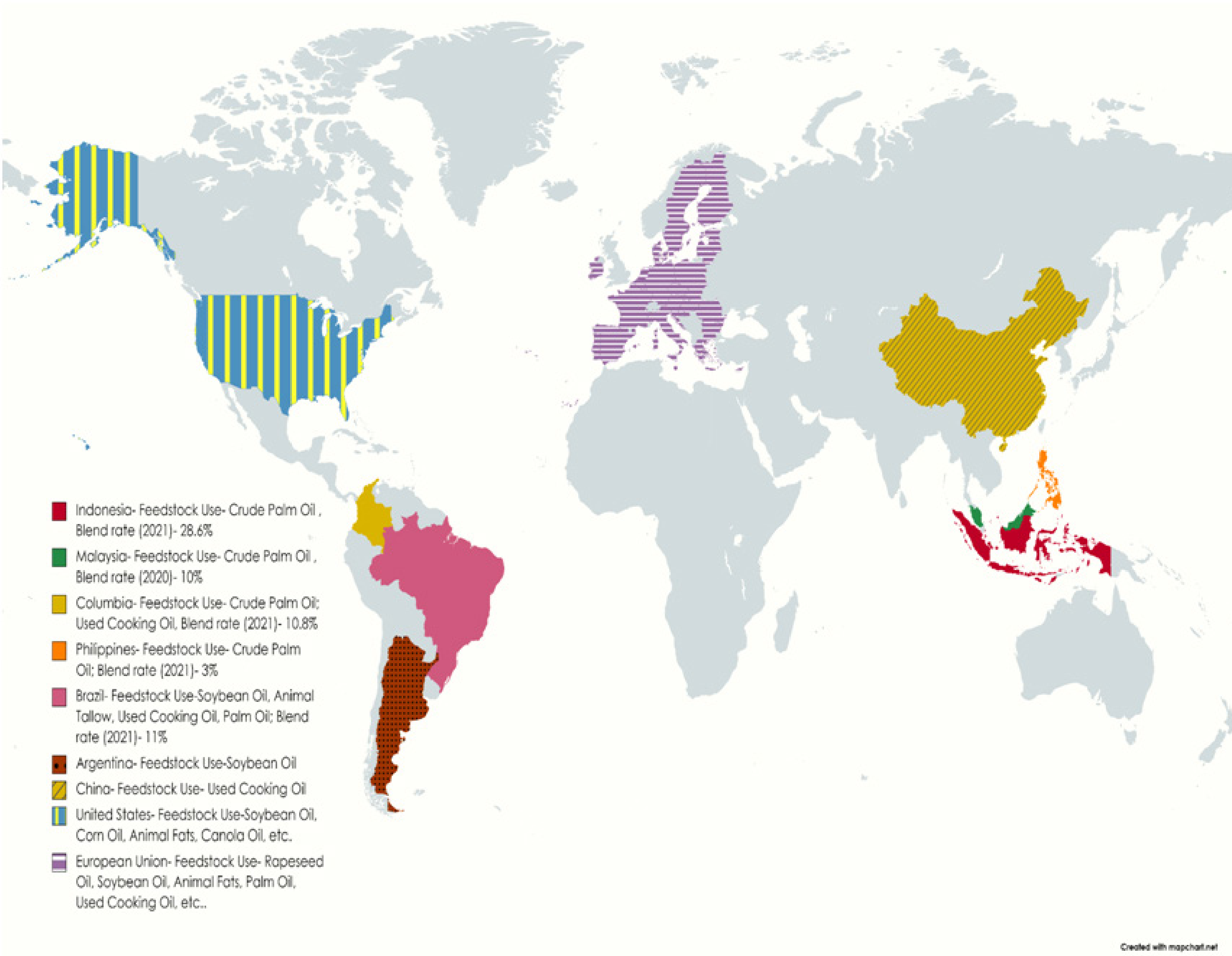


Figure 2: Countries with type-wise feedstock for biodiesel production*

Data Source: USDA Annual Biofuel Report

** Map created with mapchart.net*

5. The Biodiesel Market in India

After the US and China, India is the fastest-growing economy and the third-largest consumer of primary energy in the world.[13] Until alternative fuels based on renewable feedstock are developed, India's fuel energy security will remain compromised. Under its Nationally Determined Contributions (NDCs), India aims to reduce its carbon footprint by 30–35% till 2030.[14] To achieve these targets, five strategies will be implemented:

13 Details available at: https://www.iea.org/reports/india-energy-outlook-2021/energy-in-india-today
14 Details available at: https://moef.gov.in/wp-content/uploads/2018/04/revised-PPT-Press-Conference-INDC-v5.pdf

- increasing domestic production,
- utilizing biofuels and renewable energy,
- implementing energy efficiency norms,
- enhancing refinery processes, and
- substituting demand.

As part of the Indian energy basket, biofuels have a strategic role to play. Several initiatives have been introduced to increase indigenous production of biofuels, as part of the Indian government's aggressive plan of 20% ethanol in petrol by 2025–26 and 5% biodiesel in diesel by 2030.[15]

In India, the key drivers for sustainable and commercial production of biofuels are feedstock availability and production cost. The implementation of India's biofuel blending program will be effective only if all stakeholders work together.

The country's national blending rate has been estimated to be 0.071% in 2022.[16] Contributing factors include a surge in feedstock prices observed globally due to the various supply restraints, the Russian-Ukraine conflict, and instability in energy prices. The COVID-19 pandemic and high operational costs have stressed the Indian biodiesel industry in the last couple of years. The country is still trying to develop a consistent supply chain for used cooking oil (UCO). Indian oil marketing companies (OMCs) fail to support biodiesel production in the informal sectors and demand continues to be inadequate. Furthermore, a lack of feedstock supplies has prohibited market development (USDA, 2022).

5.1 Production, supply, and consumption

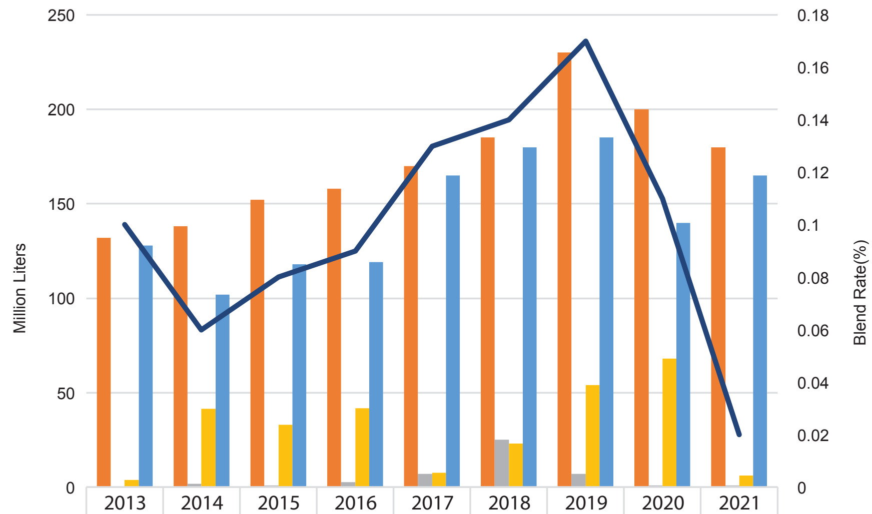
India's annual biodiesel consumption experienced a healthy growth of 8% between 2013 to 2019 (CAGR). The biodiesel market in the country is still majorly informal and is dispersed and segregated, with limited domestic production. Due to high feedstock prices and anti-inflation measures, many countries operate at a minimum B5 fuel level and several run below B10 fuel level—like Brazil, Thailand, Argentina, and Malaysia, which leaves India's biodiesel market with a considerable growth potential. Most of the capacity is left unused as there is a lack of suitable feedstock sources and government support mechanisms to create demand. The country's biodiesel usage from past years has been presented in Figure 3.

India's biodiesel production lacks sufficient production and supply from OMCs to build commercial sales; hence, it is mostly consumed by locally dispersed groups to generate power.

For decades in the country, it has been a concerning issue that field trials have used jatropha, a few tree-borne oilseeds, and non-edible oilseeds (grown on non-arable, rain-fed lands) as multiple options for feedstock due to low yields. However, the country experienced a surge in production due to various policy initiatives; yet it lacks consistency. The blended rate is directly linked to the amount of production, which has been affected badly during the COVID-19 pandemic. Figure 4 illustrates India's biodiesel production trend from different feedstocks.

Most of the share is through non-edible sources like jatropha, karanja, etc., backed by government policies. The share of edible oil has been limited owing to food

15 Details available at: IEA-Bioenergy-Task-39-Newsletter-Issue-56-Final-Draft.pdf (ubc.ca)
16 Details provided by PPAC



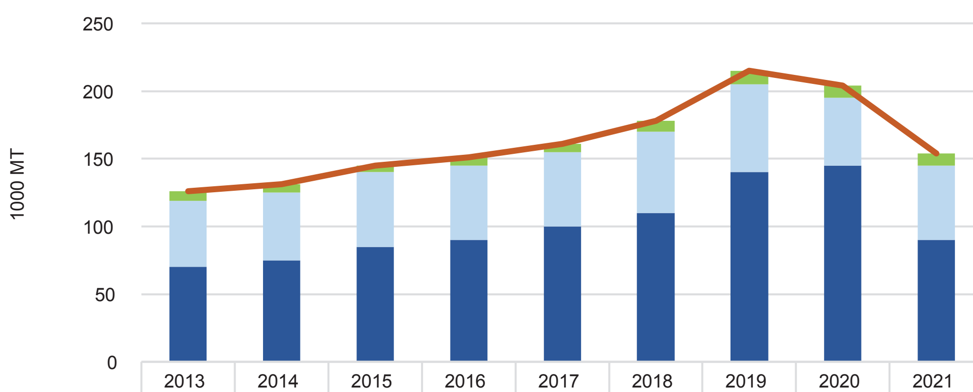
	2013	2014	2015	2016	2017	2018	2019	2020	2021
Production	132	138	152	158	170	185	230	200	180
Imports	0.3	1.7	0.8	2.7	7.1	25.2	7	1	1
Exports	3.9	41.5	33.1	41.7	7.6	23.1	54	68	6
Consumption	128	102	118	119	165	180	185	140	165
Blend Rate (%)	0.1	0.06	0.08	0.09	0.13	0.14	0.17	0.11	0.02

Production Imports Exports Consumption Blend Rate (%)

Figure 3: India biodiesel stats *

Source: (USDA, 2022)

**Note: According to the latest report published by (USDA,2023) on June 20,2023, the blend rate has increased to 0.07% in 2022*



	2013	2014	2015	2016	2017	2018	2019	2020	2021
Animal Fats & Tallow	7	6	5	6	6	8	10	9	9
Used Cooking Oil	49	50	55	55	55	60	65	50	55
Non-edible Industrial	70	75	85	90	100	110	140	145	90
Total	126	131	145	151	161	178	215	204	154

Non-edible Industrial Used Cooking Oil Animal Fats & Tallow Total

Figure 4: India's biodiesel production from multiple feedstock

Source: (USDA, 2022)

security reasons, but the share of UCO has been steady despite the RUCO initiatives launched by the Food Safety and Standards Authority of India (FSSAI) in 2018. If the biodiesel sector is regularized and structured properly, animal tallow could also produce enough biodiesel to meet the demand.

India has a huge amount of on-road diesel consumption, and for success of the blending programme the availability of biodiesel becomes crucial. The share and production of biodiesel are sparse when compared with conventional diesel. Table 2 illustrates the biodiesel market penetration in the country today, which clearly explains the need and urgency for proper and well-planned measures to achieve the B5 targets.

Table 2: India biodiesel market penetration (million litres)

Calendar Year	2013	2014	2015	2016	2017	2018	2019	2020	2021
Biodiesel, on-road use	**49**	**32**	**41**	**48**	**72**	**83**	**100**	**50**	**10**
Diesel, on-road use	49,354	49,605	52,239	55,179	56,715	59,220	60,145	44,400	52,927
Blend Rate (%)	0.10	0.06	0.08	0.09	0.13	0.14	0.17	0.11	0.02 *
Diesel, total use	**82,256**	**82,674**	**87,064**	**91,965**	**94,524**	**98,700**	**1,00,241**	**74,000**	**76,270**

Source: USDA, 2022

**Note: According to the latest report published by (USDA,2023) on June 20,2023, the blend rate has increased to 0.07% in 2022*

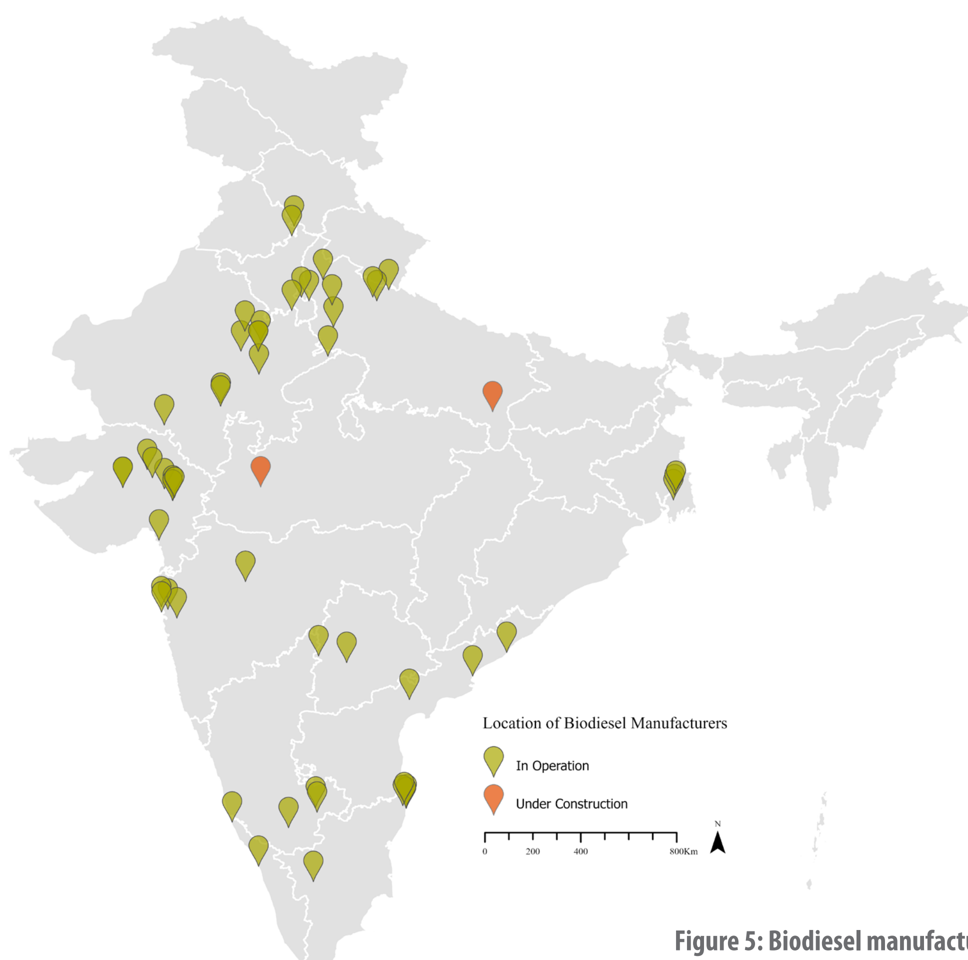


Figure 5: Biodiesel manufacturers in India

Source: BMAI

India has 1 billion litres of annual biodiesel production capacity. Still, due to the COVID-19 pandemic, most plants remained closed, and many ran out of production, limiting total operating capacity to 577 million litres. As a result of the high feedstock prices, such as imported palm oil and palm stearin, as well as domestically available animal tallow, operating margins have declined. Current refineries have a production capacity between 11 million and 225 million litres. There is no glycine refining, methanol recovery, or post-processing at smaller production facilities (USDA, 2022). There are 54 manufacturers, among which 52 are operational and 2 are under-construction biodiesel manufacturers, with their locations shown in Figure 5. Most manufacturers are in the country's north, west, and coastal regions due to the availability of feedstock, land, and ease of transportation.

6. Feedstock in India

6.1 Production and use

India is a very diverse country with immense potential for oil seeds cultivation. Oilseed production in India has steadily increased since 2016–17 and has shown a healthy surge of nearly 43% from 2015–16 to 2020–21. India produced around 36.5 million tons of total oilseeds in 2020–21, with a yield of 1.3 kg/ha.[17] Domestic oil production is, however, lagging behind—its consumption necessitating the import of edible oils. The year 2019–20 witnessed the production of about 8 million tonnes of edible oil, alongside net imports of around 13.4 million tonnes.[18]

Regarding vegetable oil consumption and imports, as per India's economic survey 2021–22,[19] India is the world's second-largest consumer. There is a likelihood that dietary habits and traditional meal patterns will shift away from traditional foods that contain high levels of vegetable oil as urbanization increases in the developing countries. However, edible oil consumption is expected to remain high in the coming future. Indian vegetable oil consumption is projected to increase by 2.6% per year between 2021 and 2030, reaching 14 kg/capita by 2030, which will necessitate a 3.4% increase in imports. India presently imports nearly 60% of its total consumption of edible oils; palm oils (crude as well as refined) constitute nearly 60% of the imports of edible oils.[20] Hence, to safeguard food security in the country, India should invest in other feedstock varieties like non-edible sources, etc.

Biodiesel production in the country is currently happening with non-edible oilseeds, used cooking oil (UCO), animal tallow, acid oil, algal feedstock, etc. The majority share is through non-edible sources, followed by UCOs and animal tallows (refer Figure 4).

However, palm stearin has been one of the country's most preferred source for feedstock production (due to its high yield) for quite a long time thus making it feasible for mass production without any upgradation needed in the production plants.[21] Currently, only 3.70 lakh hectares of palm oil are cultivated in the country.[22]

17 Details available at: https://oilseeds.dac.gov.in/doddocuments/APYTotalOilseeds.pdf
18 Details available at:https://www.indiabudget.gov.in/economicsurvey/ebook_es2022/index.html#p=265
19 Details available at:https://www.indiabudget.gov.in/economicsurvey/ebook_es2022/index.html#p=265
20 Details available at: https://pib.gov.in/PressReleseDetailm.aspx?PRID=1753462
21 As per stakeholder workshop held on August 24, 2022.
22 Details available at: https://nfsm.gov.in/Guidelines/NMEO-OPGUIEDELINES.pdf

Table 3: Common feedstock and technology used for biodiesel production

Feedstock	Technology Used
Palm Stearin	Transesterification
Jatropha and other non-edible oils	Transesterification
Palm fatty acid distillate (PFAD)	Multistage acid esterification/enzymatic
Animal oil/waste oil and others (UCO)	Pre-treatment, multistage esterification-transesterification-glycerolysis
Animal fat/tallow	Pre-treatment, multistage esterification-transesterification-glycerolysis- finishing by sulphur removal

Source: *BDAI and BMAI*

This produces 10 to 46 times more oil per hectare as compared to the other oilseed crops and yields around 4 tons per hectare. Even today, nearly 98% of crude palm oil is being imported which is a major problem.[23] India in 2021–22 imported about 6.3 million tons of crude palm oil,[24] which observed a reduction of 14.72% as compared to the previous year. This may be due to various factors like the COVID-19 pandemic and export constrains by Indonesia.

6.2 Potential and land availability

The National Policy on Biofuels, 2018 requires the growth of non-edible oil crops in wastelands, both in forests and non-forest areas (Agarwal, Prakash, & Bala, 2021). According to the Department of Land Resource, about 56 million hectares[25] of wasteland are available in India. These can be explored for feedstock cultivation in India depending upon their suitability. There are 23 categories listed in the Wasteland Atlas of India, 2019.[26] Oilseeds plantations can be set up on lands that meet certain criteria recommended by the Department of Land Resources, under the Ministry of Rural Development. These are the following (Gunatilake, 2011):

- annual rainfall should exceed 600 millimetres
- the pH of the soil should be less than 9
- temperature should not fall below 0°C, and frost conditions should not prevail
- slope of the land should not exceed 30°
- land should not be waterlogged
- land should not be barren or rocky

Based on these, oilseed plantations could be established on six types of wastelands. According to this assessment, the total potential area available was estimated to be 26.46 million ha—the distribution is shown in Figure 6. The term availability here only refers to physical availability. There still remain many factors to consider when selecting land for biofuel plantations, such as climatic and soil conditions, access to infrastructure (such as roads and electricity), and ownership.

23 Details available at:https://www.indiabudget.gov.in/economicsurvey/ebook_es2022/index.html#p=265
24 Annual Export-Import databank, Ministry of Commerce and Industry
25 Details available at:https://dolr.gov.in/documents/wasteland-atlas-of-india
26 Details available at:https://dolr.gov.in/sites/default/files/Wastelands%20Map%20of%20India%202015-16%2C%20State-wise%20and%20Category-wise%20distribution%20of%20Wastelands%20during%202015-16%20vis-a%20vis%202008-09.pdf

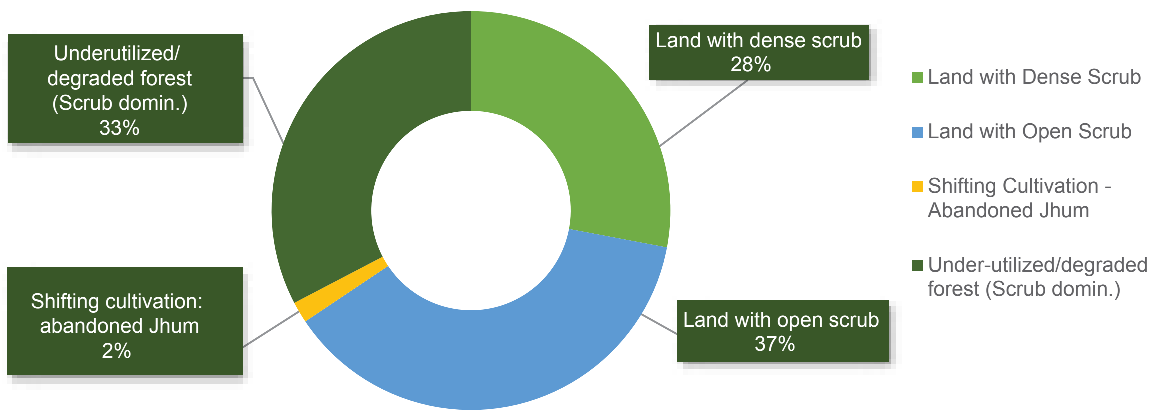


Figure 6: Categories of wasteland suitable for biodiesel plantation

**Note: The calculations exclude "Land affected by salinity/alkalinity", which constitutes about 1 hectare of suitable land, but has a pH over 9. However, this option could also be explored with some chemical or technological treatments.*

Source: Wasteland Atlas of India (2019), (Gunatilake, 2011)

To meet the 5% blend target by 2030, the total land required for biodiesel production will depend on the amount of diesel consumed and its growth. The pandemic has hit the sector growth very hard, and diesel consumption during the year 2020–21 has fallen by almost 12% from the previous financial year, i.e., 2019–20.[27] According to the estimates based on previous trends, diesel consumption is expected to reach around 92.85 million tonnes by 2030[28] (as shown in Figure 7). The biodiesel requirement for the 5% blending target will be 4.64 million tonnes by 2030. Even though these estimates differ, we have used 4.64 million tons by 2030 as the most appropriate estimate for assessing the land requirements for feedstock production.

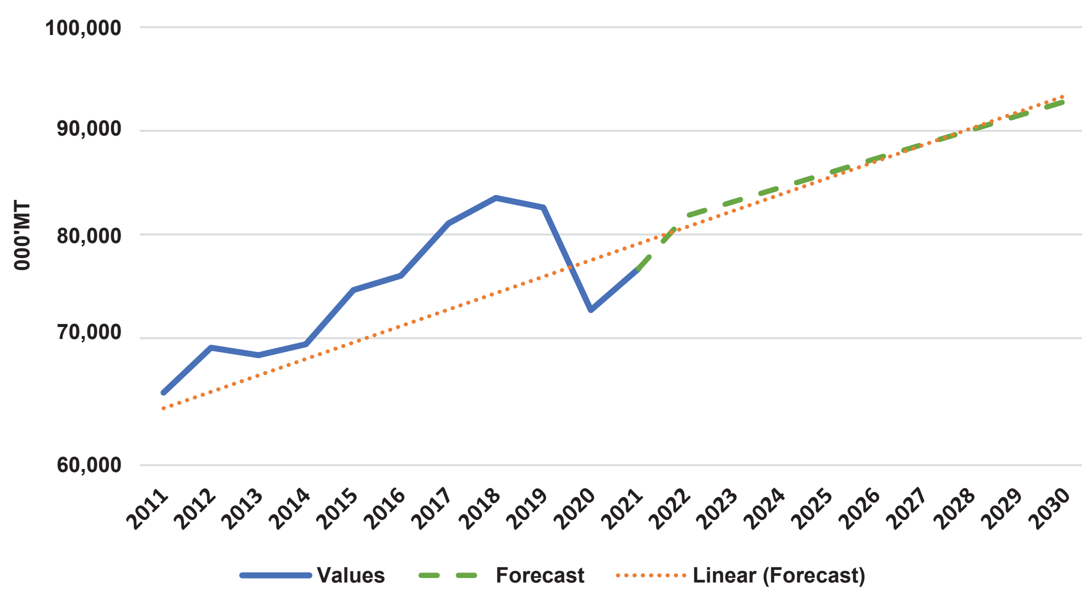


Figure 7: Diesel consumption predictions

Source: TERI's estimate based upon previous trends (BAU Scenario)

27 Details available at:https://www.ppac.gov.in/content/147_1_ConsumptionPetroleum.aspx
28 BAU Scenario: TERI's linear estimates, based upon past 10 years data on consumption of HSD (Data source: PPAC).

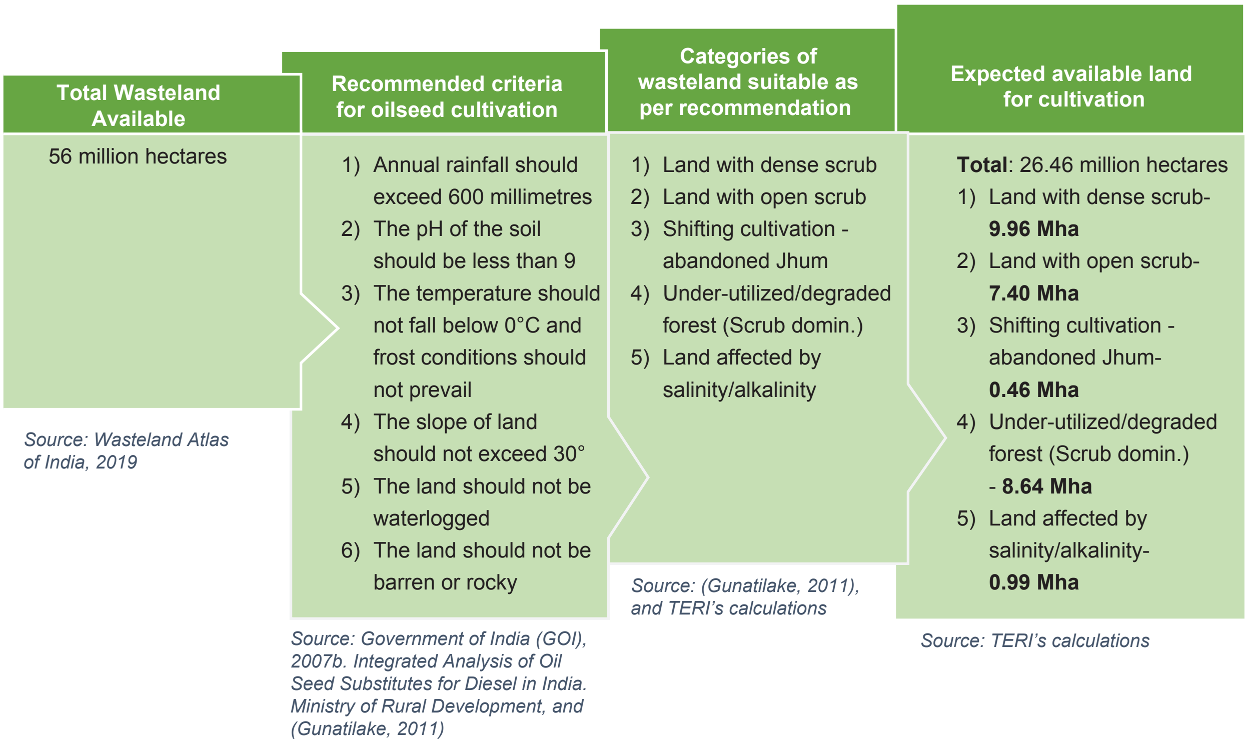


Figure 8: Methodology followed for available land calculations

6.3 Land requirement

Total land requirement depends on the productivity of the plantation, which is subject to climate, planting material, irrigation water, fertilizer application practices, etc. (Gunatilake, 2011). It is estimated that even a less fertile wasteland, with little rainfall, can yield about 1 ton per hectare oilseeds. (Brittaine & Lutaladio, 2010)

The oil content of the seeds is another factor that affects biodiesel yield. A conservative estimate of 1 ton per hectare and 30% oil content can yield 32 kilolitres per hectare of biodiesel (Gunatilake, 2011). According to the current understanding of the yield potential of the oilseed (mentioned in Table 4) that the Indian government is widely promoting, it is reasonable to assume that about 7 million hectares would be required to meet the 5% blending target in the case of Jatropha;

Table 4: Yields of non-edible oilseeds and land required

Name	Crop Yield (T/Ha)	Oil Content (%) (Avg.)	Land required to achieve B5 till 2030 (Million Hectares)
Jatropha	2	35	7
Karanja	3	35	4.7
Mahua	2.7	38	4.7

**Note: Calculations are based upon the closest self-estimates based upon previous estimates and stakeholder conversations.*
Source: TERI's calculation based upon: (Patel & Sankhavara, 2016), (Aransiola, Ehinmitola, Adebimpe, Shittu, & Solomon, 2019)

4.7 million hectares in case of Karanja and Mahua plantation is required as well. This analysis concluded that improving agronomic practices and high-yielding varieties will be essential to reach the biodiesel target on the wasteland.

Biodiesel can also be produced on other types of unused land in the country, besides wasteland. The National Policy on Biofuels, 2018 has identified other resources suitable for biodiesel production, such as used cooking oil (UCO), animal tallow, acid oil, algal feedstock, etc. If all these resources and idle land are used, moreover productivity increases through selection and breeding, the land requirement and feedstock commitment for 5% biodiesel blending can be met.

7. Conclusion

A challenge that is now being faced by almost all developing nations is how to meet the relatively increasing energy demand and sustain economic growth, while keeping GHG emissions low. The world energy market continues to heavily count on fossil fuels, and India is not much different—being highly dependent on imports to fulfil its oil needs. However, it has immense potential for building its biofuel resources, especially biodiesel, which could be a good source for blending with conventional diesel that forms about 87% of the total transport fuel demand. India imports more than 80% of its crude oil to meet the annual demand, draining its forex reserves. The crude oil production in India only meets 25% of the national demand; thus, blending biofuel into transportation fuel enables India to reduce its dependence on foreign oil imports (Ganguli, Abhishek, Motkuri, & Bloyd, 2018).

7.1 Feedstock options

Manufacturers use non-edible industrial oil, palm stearin, UCO, animal fat, tallow, and other oils as feedstock to produce biodiesel, utilizing about 32% of the total installed capacity. Many functional producers utilized palm acid oil in 2021, due to the bull run in palm oil and a limited supply of animal tallow (USDA, 2022). Owing to the operational impacts posed by high

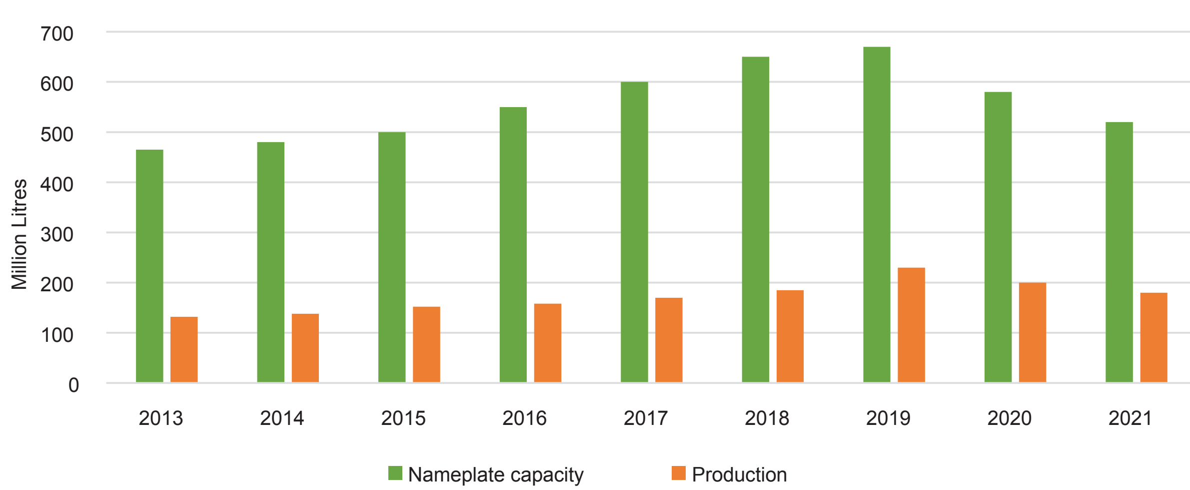


Figure 9: Nameplate capacity vs actual production of biodiesel

**Note: The nameplate capacity is the volume of biodiesel that can be produced during a period of 12 months under normal operating conditions.*

***Source:** (USDA, 2022) and Statista*

palm growth cycles, only a few biodiesel plants operate during the winter months. The sector does not have proper regulations (apart from UCO) to supply available feedstock for biodiesel production. Figure 9 illustrates the difference in the nameplate capacity with actual biodiesel production in India for the past few years, which is also one of the defining factors to prove the sector's underperformance.

India's biodiesel industry is in its infancy and there is a lack of virgin (first-use) animal fat, or vegetable oils available for biodiesel production. Jatropha and other inedible oilseeds are not producing enough yields to make cultivation economically feasible on non-arable lands. This translates into volatility in vegetable oil prices for most biodiesel manufacturers. Supply chain and shipment issues will continue to affect the industry this year (USDA, 2022).

7.1.1 Edible sources

Using vegetable oil sources for biodiesel production is a hurdle for the country's food security. It will result in food vs fuel debates, as palm stearin is one of the most common imported feedstocks used for biodiesel production. Instead, increasing domestic production using non-edible domestic sources will result in less dependency on imports.

7.1.2 Non-edible sources

Non-edible sources are some of the country's most promising sources of biodiesel production. In response to rapid population growth, urbanization, and industrialization, food production has been impacted by decreased land availability. Proper land distribution is required for agriculture, urbanization, commercial application, and forest reserve distribution. It will burden the land area for food production if edible oil crops are used as feedstock for biodiesel production. However, nonedible crops can be grown in non-fertile land—like saline, sandy soil, and even on wastelands that are unsuitable for crop production. India has a major chunk of land that will require crop cultivation to meet B5 till 2030. The major challenge rests with the gestation period of the selected crops.

National Policy on Biofuels, 2018 also promotes using non-edible sources like jatropha, karanja, mahua, etc., because of their growth potential, wasteland availability,

Table 5: Annual production and oil yield of potential non-edible oil crops

Non-edible oil crops	Scientific name	Major crop	Yield (kg per ha per year)	Oil content (wt. %)
Jatropha	*Jatropha curcas*	Seed	2,500	40–60
Mahua	*Madhuca longifolia*	Seed	20–200 (per tree)	35–50
Candlenut	*Aleurites moluccanus*	Seed	16,000	60–65
Rubber	*Hevea brasiliensis*	Seed	100–150	40–50
Soapnut	*Sapindus mukorossi*	Seed	—	23–30
Jojoba	*Simmondsia chinensis*	Seed	500–5,000	40–50
Tobacco	*Nicotiana tabacum*	Seed	1,170	35–49
Neem	*Azadirachta indica*	Seed	2,670	25–45
Karanja	*Millettia pinnata*	Seed	900–9,000	30–50
Castor	*Ricinus communis*	Seed	450	45–50
Polanga	*Calophyllum inophyllum* L.	Seed	3,700	65–75
Cotton	*Gossypium*	Seed	649	17–23
Kusum	*Carthamus tinctorius*	Seed	—	51–62
Yellow oleander	*Cascabela thevetia*	Seed	52,000	60–65
Sea mango	*Cerbera odollam*	Seed	1,900–2,500	40–50
Tung	*Vernicia fordii*	Seed	450–600	30–40
Bottle tree	*Brachychiton rupestris*	Seed	250–300	50–60

Source: (Shaah, et al., 2021)

yield, among other reasons. The crops mentioned in table 5 could be explored as feedstock for biodiesel production.

Major challenges and barriers with the non-edible source are its current unavailability, proper cultivation, regularization, high polyunsaturated fatty acids, low unsaturated fatty acids content, etc. However, this could be taken care of with technological advancements.

7.1.3 Used cooking oil, acid oil, and animal tallow

High-potential second-generation feedstock for biodiesel production uses cooking oil, acid oil, and animal tallow. A high conversion and yield percent from raw material to biodiesel, cheap rates, and availability are some positives for these feedstocks. The major barriers include the poor collection mechanism, disrupted supply-chain network, proper regulation mechanism, etc.

Used cooking oil has been a potential feedstock in India because of its availability and high procurement. According to MoP&NG, India uses approximately 27 billion litres of cooking oil annually, of which about 1.4 billion litres of used oil could be collected from bulk users (restaurants, railways, etc.) to generate about 1.1 billion litres of biodiesel.[29] Though the potential is very high, the supply-chain network, proper regulations in line, and other policy loopholes make achieving the target difficult. The COVID-19 pandemic has hit this industry very hard; the use of cooking oils was almost negligible during the pandemic from bulk users. However, in the post-pandemic period, it is expected to show some healthy growth.

FSSAI estimated that the country generates around 2.7 million tonnes of UCO annually, about 60% of which re-enters the food chain, posing a serious threat to people's health.[30] To make this used oil industry regularized and prevent UCO from re-entering the food chain, FSSAI took the initiative to form RUCO (Repurposed Used Cooking Oil), which also has several biodiesel manufacturers registered with them to facilitate the flow of UCO from the industry to the manufacturers. However, the industry still struggles with seamless collection and supply chain management because of a lack of aggregators in tier 2 and 3 cities, smaller private collectors, diversion to the soap industries, etc.[31]

Some oil is rejected as part of the refinement process, known as 'Acid Oil'. The amount of acid oil produced is approximately 5% to 7% of refined cooking oil, containing approximately 5%–10% free fatty acids. Acid oil is one of the potential sources identified by the MoP&NG in the National Policy on Biofuel, 2018. This sector, however, is still in the initial stage and requires a deep-dive, compared to other potential sources.

Animal tallow is yet another potential feedstock available in India for biodiesel production.[32] However, exporting animal tallow to European countries makes it difficult for manufacturers to produce biodiesel at a similar rate. The unorganized tallow industry makes it much more difficult. The scope of animal tallow is higher in north India, but with limited suppliers it becomes much more difficult to regularize this sector.

7.2 Pricing of biodiesel

The pricing of biodiesel has become one of the most debatable topics. The pricing depends upon several factors, such as feedstock availability, feedstock type, feedstock prices, cost of operations, transportation cost, handling and storage costs, etc. Major components of biodiesel price are the feedstock prices and transportation or collection cost in the case of used cooking oil. The high cost of biodiesel, when compared to conventional diesel, is the main barrier to its commercialization on a large scale.

29 Details available at:https://pib.gov.in/PressReleasePage.aspx?PRID=1581544
30 Details available at:https://eatrightindia.gov.in/ruco/file/ruco_booklet.pdf
31 Through workshop discussions held on Aug. 24, 2022 under NTDC
32 Through stakeholder consultation with biodiesel manufacturers

Various factors contribute to variations in feedstock cost, such as geography, crop yields, and the season. Fertilizers, herbicides, and insecticides contribute to the difference in plantation costs. A good irrigation system and high soil nutrients are generally needed for edible oil crops, resulting in higher plantation costs. Despite its high plantation cost per hectare, palm oil is extremely economically competitive due to its high oil yield; even though its availability in India is the major barrier. Non-edible oils, on the other hand, have a lower cost than edible oils. UCO and animal tallow, so far, are an ideal option, but the unorganized sector makes its collection a major challenge.

A recent tender by the OMCs in India has given biodiesel a flat rate of INR 106.86/litre, exclusive of transportation costs and taxes. The details are as mentioned below:[33]

- **Basic rate of biodiesel:** INR 106,860 per kilolitre
- **Transportation slab would be as follows:**

Distance slab in km (One-way)	Transportation rate (INR/kilolitre)
0 to 75	168
>75 to 200	391
>200 to 400	833
>400 to 600	1,394
>600 to 800	1,956
>800 to 1000	2,751
>1000 to 1200	3,596
>1200	3,596+2.72 for additional km beyond 1200 km

- **Goods and Service Tax (GST) in %:** GST @5% applies to HSN code 3826 for biodiesel.
- The delivered cost will be a total of the basic rate for biodiesel, transportation rates, and GST as applicable.

Keeping the current rate as the base year and considering the average WPI rate for the last five years to be 6%, under the BAU scenario, biodiesel prices are expected to rise to INR 170/litre.[34] This would have negative economic and social implications. India must develop a reliable feedstock supply as well as infrastructure for storage and delivery to ensure financial sustainability in its domestic industry and biodiesel prices.

However, this price increase will also directly be correlated to inflation, higher fuel costs, foreign currency differences, rise in prices of raw materials and other derivative products. Hence, the price of INR 170 per litre will be at about par with future prices of other goods.

7.3 Land requirement

The National Policy on Biofuels, 2018, promotes the cultivation of non-edible oilseed crops (mahua, karanja, and jatropha curcas) for biodiesel production only on unused degraded land. Plantation productivity and other management practices, such as irrigation water and fertilizer application, determine the total land required for a plantation. As oilseeds can be grown on dry wastelands, these plantations do not need much irrigation. Assuming that trees and the environment in which they usually grow are similar, it can be said that biodiesel crops do not contribute significantly to irrigation water consumption in India. (Mishra, Patnaik, Akbari, Kumar, & Patro, 2013)

The land requirement for biodiesel for blending purposes depends on fossil fuel consumption and their progressions. Following the linear BAU trend rate of diesel consumption growth in the past decade, India will consume about 92.85 million tonnes of the same by 2030. A 5% blending requirement implies the need for 4.64 million tonnes of biodiesel annually. Thus arises the question: whether enough land is available within

33 EOI no. – OMC/EOI/NUCO/BD/JUL22 dated 23 July 2022
34 As per TERI's estimates

the country to meet the B5 target? According to TERI's estimate, about 56 million hectares of wasteland is available in India, which could be explored for feedstock cultivation depending upon their suitability—amongst which the total potential area available was estimated to be 26.46 million ha[35] depending upon various factors mentioned in section 6.2: Potential and land availability section.

Regarding land requirement for cultivating major crops (like jatropha, karanja and mahua), to achieve the B5 blending target the land requirements are estimated as (100% capacity each):[36]

- **Jatropha** – 7 million hectares
- **Karanja** – 4 million hectares
- **Mahua** – 4 million hectares

States like Chhattisgarh, Jharkhand, Bihar, Uttar Pradesh, and Rajasthan are among the favourites to host these cultivation programs because of the availability of land, resources, and local support. The tribal population living in states like Chhattisgarh and Jharkhand could be a very optimum source for feedstock cultivation. The business would be beneficial for both parties: tribals will get the best out of their lands in the shape of steady employment, while production companies will get the domestically available feedstock at the best prices for further processing.

7.4 Engine modifications for biodiesel use

A biodiesel engine does not require major modifications. It is not a technical challenge to run a vehicle's existing engine on biodiesel; rather, it is a matter of producing biodiesel that meets the engine specifications.[37]

8. Recommendations

Biodiesel is a potential fuel especially for the transportation sector, as diesel dominates the road transport sector in the country. Using biodiesel will not only result in decreasing the emission levels from this sector, but will also have a huge impact on foreign exchange and crude imports. Based upon our observations, findings, and most importantly, interactions and feedback from the concerned stakeholders—from different domains like industry, academia, civil society, etc.—various recommendations have been proposed to facilitate an increase in biodiesel production in the country.

8.1 Identification of domestically available potential feedstock

Despite having numerous feedstock options, identifying the best-suited potential source for biodiesel production is challenging. With so much diversity, India has a great opportunity to use different kinds of feedstock that are domestically produced. Countries like Indonesia, Malaysia, the US, etc., are currently world leaders in biodiesel production. The major reason for this is the utilization of locally available feedstock for production, enabling them to increase production as required.

35 As per TERI's estimates
36 Calculations are based upon the closest self-estimates based upon previous estimates and stakeholder conversations. Refer section: 6.2 Land requirement
37 Through workshop discussions held on Aug. 24, 2022 under NTDC

Likewise, India needs to invest in domestically grown feedstock varieties like UCO, animal tallow, and non-edible sources—jatropha, Karanja, etc.

8.2 Rising cost of feedstock needs to be controlled

The cost of feedstock used in the production of biodiesel is a major component of the final price. As discussed in the paper, feedstock costs depend on numerous factors, but, at the same time, domestic feedstock can reduce costs and eventually positively impact biodiesel prices. As India relies heavily on imported feedstock like palm oils, which come with high import duties and fluctuating prices, high production costs are associated with them.

Additionally, animal tallow is one of the potential domestically produced feedstocks. It is produced sufficiently to meet the country's basic needs. Nevertheless, since it is in high demand and offers a better price on the international market, it is being exported to major countries—like Afghanistan, Malaysia, Pakistan, UAE, etc. This creates a shortage of raw materials for biodiesel production within the country and creating a high demand, which ultimately translates into high prices.[38] It is a problem that needs to be addressed and requires stringent policy guidelines in place.

8.3 Involving locals' support for optimum production: the role of manufacturers

As per TERI's estimates and wasteland Atlas of India's numbers, plenty of wastelands are available for feedstock cultivation in the country. However, a major portion of these lands is already occupied by local villagers and tribal populations unwilling to provide those lands and their support. Hence, for optimum land utilization and to increase feedstock production, the involvement of these locals becomes crucial.

Initially, one can sign a deal with the locals where the land ownership will remain with the locals only. Producers/manufacturers will use the land for crop cultivation and remunerate the locals/farmers for taking care of the crops and providing them employment opportunities.

Making them a part of the process by providing employment will simultaneously enhance productivity as well as facilitate many benefits, like the security of land and crops, better yield capacities, etc.

Apart from this, a robust study of the supply-chain is imperative—from the collection of raw materials to the final product.

8.4 Role of government and other concerned organizations

When setting regulations and implementing them, the government and its arm play a crucial role. Biodiesel production needs a special point of interest for each case. In some states (like Rajasthan, Uttar Pradesh, Karnataka, among others) a biofuel department looks after the sector at the state level. Despite this, there are few areas that needs a closer attention that will enable the optimum use of the resources. The lessons learned from these states could be applied to all states and UTs in the country to facilitate increased biodiesel production.

It might be possible to enhance biodiesel production by introducing a National Feedstock Programme (NFP) or a Production Linked Incentives (PLI) scheme to facilitate optimal production, regularization, and feedstock utilization.

For UCO and animal tallow, it is imperative to implement proper supply-chain management guidelines to prevent and minimize loopholes and improve collection mechanisms. The FSSAI's RUCO guidelines must be mandated with minor updates per current criteria,

38 Information received from one of the biodiesel manufacturers during stakeholder interactions.

keeping soap manufacturers' uses in mind. Aggregators in tier 2 and tier 3 cities need to be explored to collect used oil from different sources to ensure optimal use and collection of UCO and introduce technological enhancements like tracking to enable traceability across the supply chain.

8.5 Utilizing by-products generated from biodiesel production to off-setting biodiesel price

Another important aspect is generating money out of by-products, which are left as waste after the conversion of raw material to biodiesel (like methanol, glycerol, and seed waste) by converting them into useful products. Glycerin is the major by-product generated, which is of the largest interest because it acts as revenue for manufacturers by selling it to major industries like food, pharmaceuticals, etc. Similarly, seed waste could also be used for agricultural purposes, such as manure.

8.6 Biodiesel: setting attainable goals

Despite having numerous advantages over conventional diesel, the biodiesel industry is still struggling in the country because of various reasons and challenges like availability and high feedstock pricing, operational hurdles, supply-chain management challenges, etc., as discussed in this paper.

Therefore, adopting a baby-step approach and setting attainable short-term goals will be a building block for the goal of B5 by 2030. For instance, keeping in mind the current 0.02%* blending rate and based upon the inputs from various stakeholders, it is recommended that India should target 2% blending by the next couple of years (2024-25), and in the future, higher biodiesel blending targets can be set, depending on availability of feedstock.

8.7 Short-term and long-term solutions

During the study, several stakeholders provided their input regarding biodiesel blending. One of the important common inputs was that biodiesel from FAME (Fatty Acid Methyl Ester) should be seen as a short-term solution, understanding its challenges and barriers.

As potential long-term solution, synthetics such as methanol to dimethyl ethers blended with diesel or a green diesel are recommended. Green diesel is made from the same feedstock as biodiesel (primarily animal fats and vegetable oils), but the production process differs considerably. Moreover, green diesel has the same chemical properties as regular diesel, so no engine modifications are necessary—nor is it necessary to change the existing infrastructure to distribute petroleum-based diesel (Morone & Cottoni, 2016).

Using these recommendations as a guide to formulate and implement the required actions—through on ground initiatives as well as policy changes—can help India in achieving the B5 goal for 2030. Alongside this, the various social and economic benefits of optimal utilization of India's capacities, in term of biodiesel production, will ultimately contribute towards a holistic development path for the country.

**Note: According to the latest report published by (USDA,2023) on June 20,2023, the blend rate has increased to 0.07% in 2022*

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