Making Aviation Greener : An ecosystem analysis for Aviation Biofuels in India

Executive Summary

The global need for the sustainable aviation fuel is increasing and efforts for the carbon emission reduction are intimated from various stakeholders in the industry. Internationally there are two impactful policies introduced - CORSIA and EU-ETS which will drive strategic actions towards carbon emission reduction measures. Currently there are three options available for green propulsion which are hydrogen fuel, Electric Propulsion and Bio-fuels.

Biofuel Ecosystem in India possess potential to solve carbon emission reduction problems of Aviation industry, with recent introduction of governmental policy and programs supporting it and increase in R&D activities, Collaboration with research labs and institutions is an initiative worth consideration

Government of India has introduced National Biofuel Policy 2018 which aims 20% blending of ethanol and 5% blending of biodiesel in transportation fuels, this has created a demand in the Biofuel ecosystem triggering Industrial growth towards biofuel production as well as research and development activities. Government is providing support and subsidies, There has been introduction of research programs in Technical Institutions - IITs, CSIR, other universities and public companies. There has been successful demonstration of Bio-Jet fuel usage by CSIR and Spice-jet collaboration in 2018, also Pan-IIT virtual centre is setup specifically for Bioenergy research.

Among the approved production pathways for Bio-Jet fuel production, Three pathways are effective in Indian perspective - 1) HEFA pathway (Biodiesel) 2) ATJ pathway (Ethanol intermediary) 3) ATJ Pathway (Organic waste as primary feedstock).
To quantify the effectiveness and Potential/Opportunity available from them following criteria were studied 1) Primary Feedstock availability 2) Production Capacity of intermediaries 3) End Process (Technological Maturity)

One prominent feature found among different pathways is feedstock availability and underproduction of end products, In case of biodiesel pathways 2.2 billion litres of used cooking oil is available (FSSAI) while biodiesel production is around 300 million litres, while ethanol supply is relatively higher 0.94 billion litres for transportation fuel purpose but chemical technology for bio-Jet fuel production from ethanol is unavailable. Bio-jet fuel production from Organic waste follows ATJ (alcohol to Jet-fuel) pathway only with different primary feedstock. From the available data the total biogas production (one of the intermediary) is 2.07 billion m3/year. This is quite low compared to its potential, which is estimated to be in the range of 29–48 billion m3/year

Due to various socio-economic problems majorly inefficient supply chain network and lack of investment, the biomass potential in india is under-utilised. For initiation of pilot projects biodiesel pathway can be considered. Overall the opportunity for Bio-Jet fuel production through international collaboration is favourable in India

Introduction

There is an increasing global interest in sustainable aviation technologies as a result of concerns associated with the carbon-intensive nature of the industry and the imminence of reaching peak in oil prices

Available options such as biofuels, liquid hydrogen and electric propulsion will not only impact on the design and functionality of commercial airplanes, but also will affect the entire industry

Aviation Industry contributes about 2.5% to the total CO2 Emissions, Total Emission is 918 [1] megatons; of which US and China contributes 24% and 13% respectively, Major Countries from Asia Pacific region are China, Japan, India and Australia in terms of Carbon emission percentage

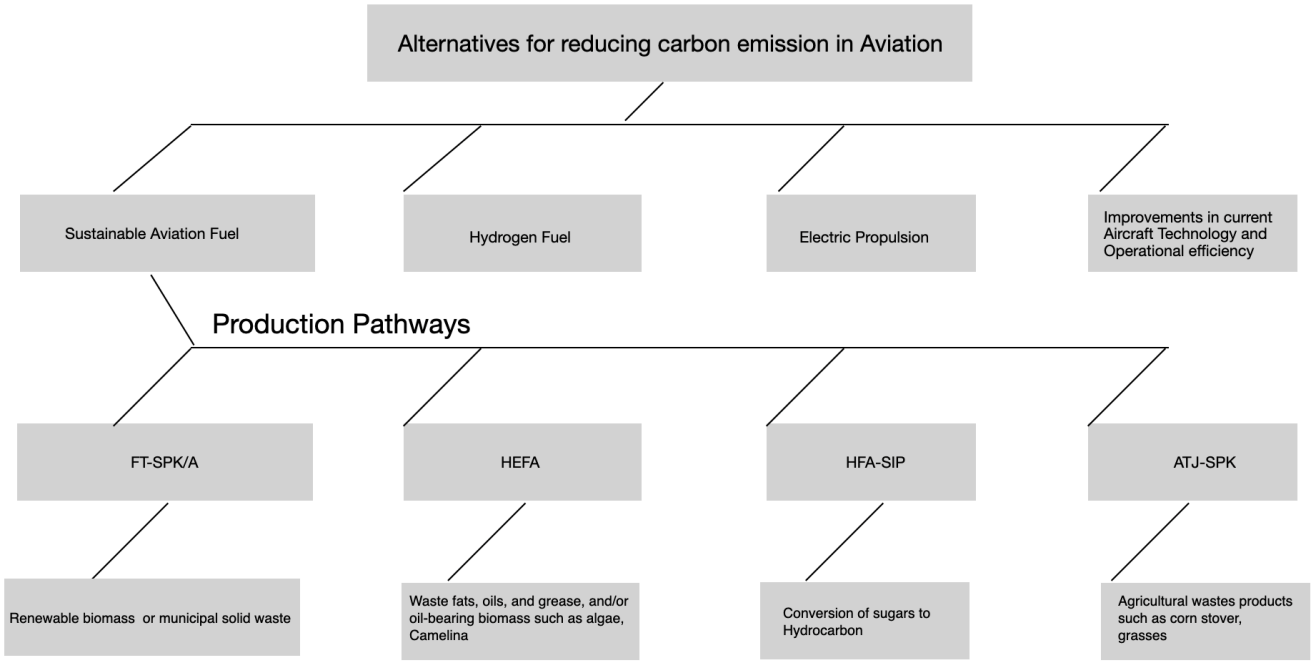


Figure 1 [2]

Biofuels and other alternatives:

Bio-fuels are drop-in fuels and requires minimal to no change in Aviation Technology whereas hydrogen fuel and Electro-fuel requires significant change in Aviation Technology [3] . Government of India promotes and aims to blend 20% bio-fuel in petroleum and 5% in diesel as well as provide subsidies for its promotion. [5a]

Biofuel available volume is low and Production infrastructure is not well developed across countries, feedstock based bio-fuel has negative impact on food prices. Residue and waste based biofuel in contrast is more favoured for usage[4]

Government Policy and Implications

In 2016, a decision was made by its 192 countries to introduce CORSIA, which aims to facilitate 'carbon neutral growth' for international aviation from 2020 [5], which will be mandatory for all countries by 2027.

Government of India hasn't signed CORSIA Policy and supports as well as promotes Biofuel and Bioenergy production in the country through subsidies. India's 2018 National Policy on Biofuels sets ambitious biofuel blending targets and aims to source biofuels only from sustainable feed-stocks. Such feedstocks are
primarily defined as non-food feedstocks that do not threaten food security.

India's First Bio-Jet Fuel Flight

In Aug 27, 2018 spiceJet aircraft flown in 75 per cent aviation turbine fuel (ATF) and 25 per cent of biojet fuel, made from Jatropha plant. The fuel was prepared by the **CSIR**-Indian Institute of Petroleum (IIP), Dehradun this opened a new chapter in Biofuel Research in the Country

Biofuel Research and Development activities in India

It is estimated that the ethanol market in India alone is projected to grow from $2.50 billion in 2018 to $ 7.38 billion by 2024, exhibiting a CAGR of 14.50% during 2019-2024 and it is forecasted to grow 11% from 2019 to 2024.

Scientists from India-based **CSIR-CMERI** even developed a simplified, semi-continuous process to produce biodiesel from any feedstock with fatty acid content of up to 10%, from jatropha to jojoba to animal fats, be it virgin oils or waste fats. The technology was developed with small and medium enterprises in mind.[6]

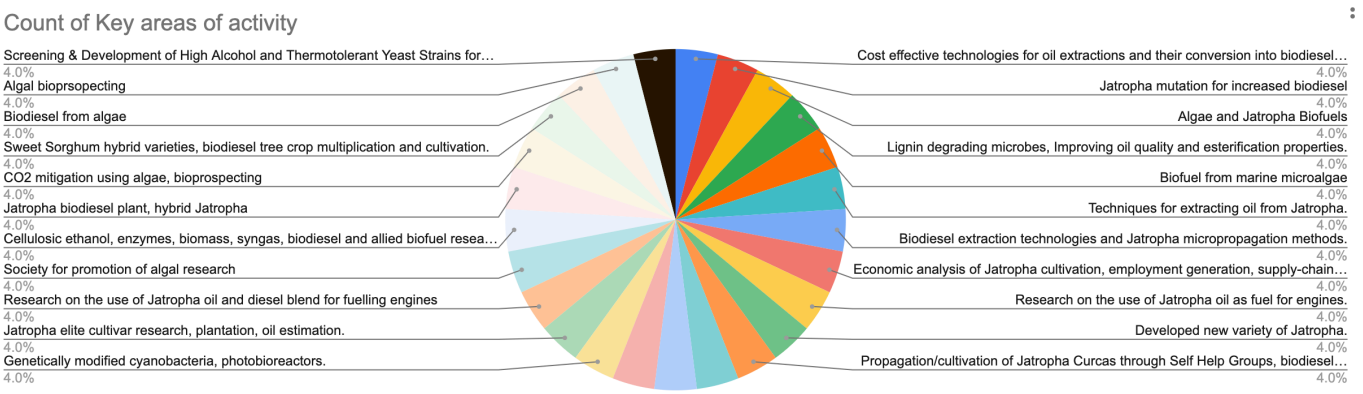
Various aspects of bioenergy sector are being researched by various research institutions, IITs and universities. The spectrum of research is very broad from development of biomass using molecular and synthetic biology approach to assessing biofuels for vehicles.

A Pan-IIT 'virtual' centre for Bioenergy Research and Innovation funded by the Department of Biotechnology (DBT), Government of India, was formed to unite scientists from some of the premier technical institutes of the country under one umbrella mission to solve the big problems in the field of Bioenergy in India.

Apart from governmental and institutional research, some startups are also doing impactful work in the same sector one such startup is Sea6 Chennai initiated by four students and professor from IIT Madras startup is using seaweed(microalgae) for biofuel production

Database_1 of Research institutions in Biofuel Sector India: https://docs.google.com/spreadsheets/d/15s9dbvTfreJpcOxae_1UPyxRJMmyhSIiO4JdU_DzpW8/edit?usp=sharing

Research Labs' Key Activity Areas



Research Publications in Biofuel production Technology in India

There are **3182** documents published by Indian researchers over the years on biofuels production in India Also the number of documents published per year is increasing steeply after 2010, [8]

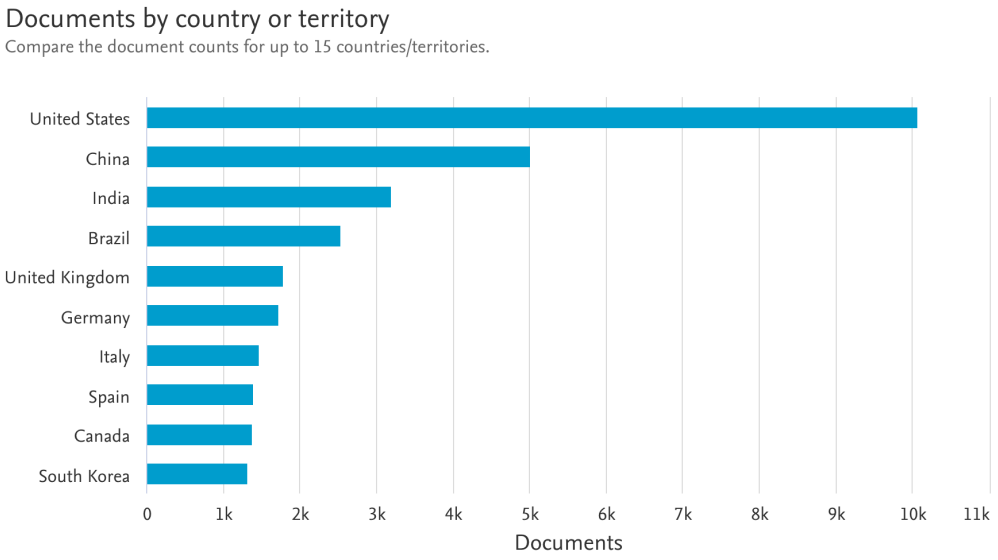


Figure : Biofuel production related publications - worldwide comparison

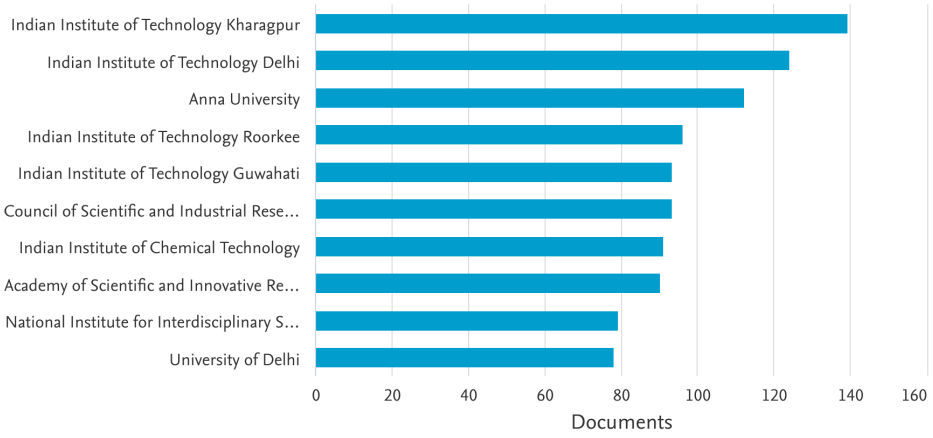


Figure : Technical Institutions and their research publication on biofuel production

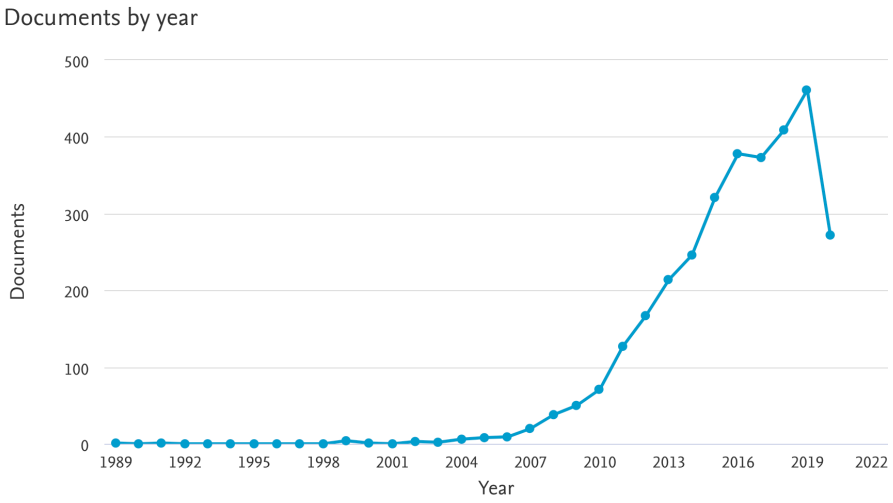


Figure : Research Publications Surge after 2010 on biofuel production

Bio-Jet Fuel Production : its connection with other Biofuels, and production Pathways

There are multiple pathways involving several intermediaries for the production of Jet-fuel from biomass feedstock, A study was conducted to find Bio-Jet Fuel Production Pathways best suitable for biomass feedstock available in Brazil. Similar roadmap can be created for India under experts' consultation considering India's feedstock and chemical technological progress. [7]

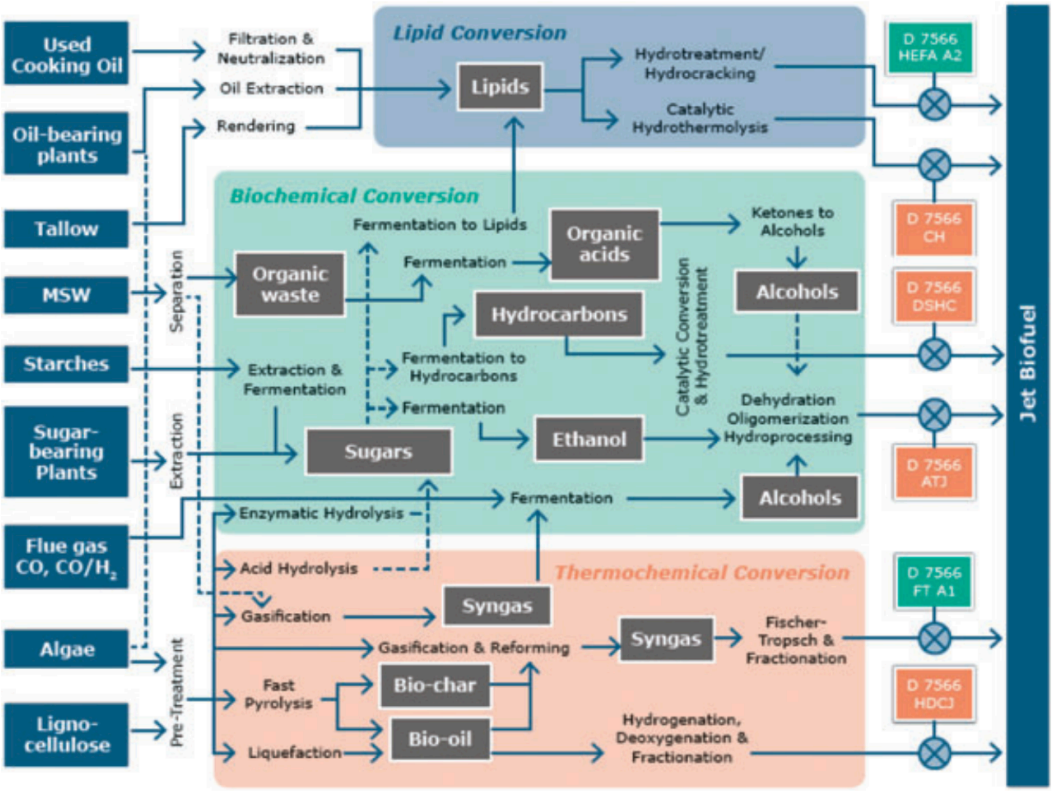


Figure 1. Identified pathways for the production of sustainable jet biofuel in Brazil (HEFA: hydroprocessed esters and fatty acids; CH: catalytic hydrothermolysis; DSHC: direct fermentation of sugars to hydrocarbons; ATJ: alcohol to jet; FT: Fischer-Tropsch paraffinic kerosene; HDCJ: hydrotreated depolymerized cellulosics to Jet) (Flightpath to aviation biofuels in Brazil, 2013).

This Approach of creating production pathway, designing according to specific exploitation of opportunities creates better way to Access the Biomass Potential of India and Progress made in Biofuel - Biodiesel and Ethanol production technology

Biofuel Industry Scenario

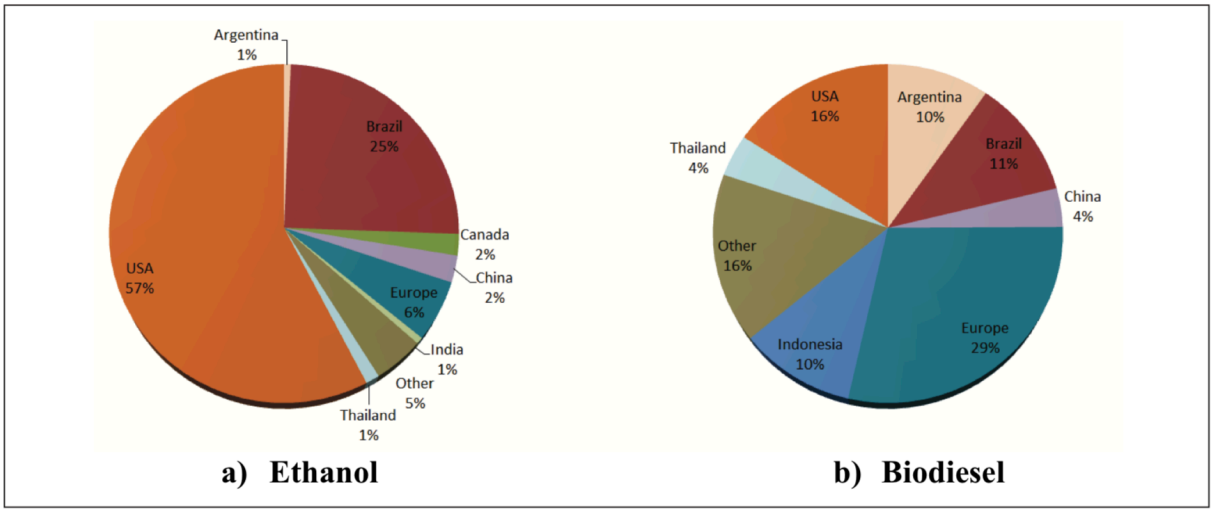
Biofuel producing companies in India majorly produce ethanol and Bio-diesel and possess localised supply chain network of feedstock near the refineries for production.

Current ethanol (from sugarcane) and biodiesel (from Jatropha) availability is not sufficient to meet the NPB's target of 20 percent blending by 2017.after taking into account the demand for ethanol in potable, industrial and other applications. The shares of molasses being used for potable, industrial, and other applications are 32.5 percent, 25 percent, and 3.5 percent, respectively. The available surplus alcohol is being diverted for blending with transportation fuel. [10]

Feedstock to be used for Bio-Jet Fuel need to distributed from these current utilisations, or Production pathway involving ethanol, or Bio-diesel(intermediaries) as intermediaries should be created.

Database_Biofuel_Companies india: https://docs.google.com/spreadsheets/d/1pwWZvJRsJPsGYZQ-327zypyq9fH9-QbVtggom6VJGZc/edit?usp=sharing

Figure 3: Biofuel production by country in 2014



Biomass Feedstock Potential in India

Available biomass feedstock in the country are namely : agriculture residue, forestry residue, municipal waste, used cooling oil, livestock manure and energy crops. [9]

Biomass Power generation potential based on available feedstock for every generation in each regions of India

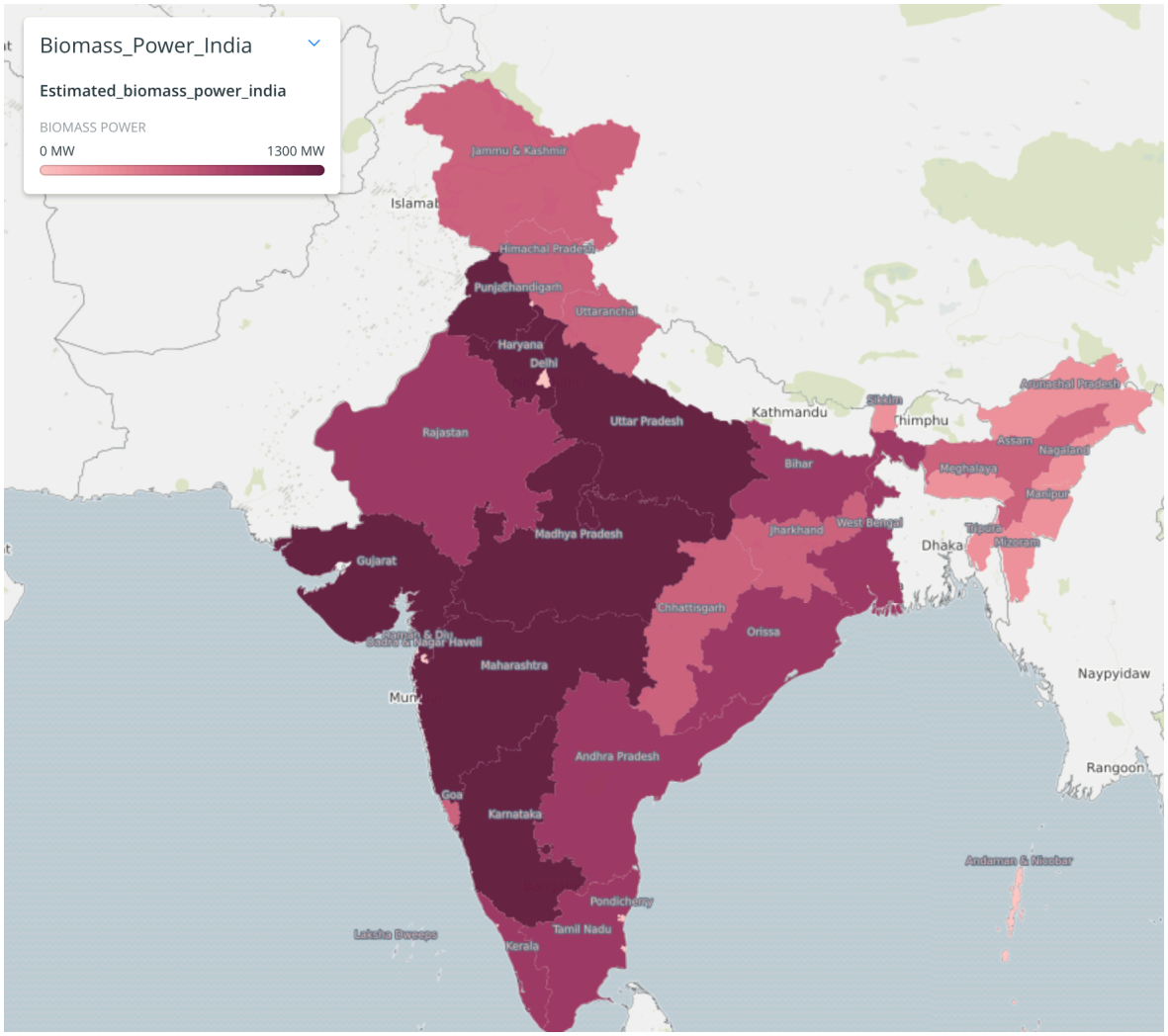


Table 3: Sustainable biofuel feedstock potential in India in 2030

Feedstock	Crop residues	Forestry residues	Used cooking oil	Municipal solid waste	Energy crops	Livestock manure
Estimated total production in 2030 (million tonnes per year)	868	10.5	6.9	165	39	745
Sustainable availability in 2030 (million tonnes per year)	71	2.6	3.1	135	39	N/A[a]

Comparing Bio-Jet Fuel Production Pathways in India

Following criteria are considered for evaluating the relative scope of each production pathway from India's point of view

1) Primary Feedstock availability
2) Production Capacity of intermediaries
3) End Process (Technological Maturity)

The Three major pathways explored for the Bio-Jet Fuel Production are:

1) HEFA - Biodiesel Pathway
2) ATJ - ethanol Pathway
3) Biochemical ATJ - organic waste Pathway

HEFA Biodiesel Pathway

Major sources of feedstock for HEFA pathway is Jhatropa plantation and Used Cooking Oil as well as tallow and animal fats these feedstocks are currently used for biodiesel production.

The Food Safety and Standards Authority of India (FSSAI) says that by 2020, it should be possible to recover about 2.2 billion litres of used cooking oil for conversion into bio-fuel

With the same feedstock processing the lipids extracted from it by Hydro-treatment or hydrocracking process Bio-Jet Fuel can be prepared.

End-Process Feasibility was demonstrated by CSIR - CMERI and was the only demonstrated Technological Production of Bio-Jet Fuel in India.

Approximately, 20 Indian biodiesel plants annually produce 140 to 300 million litres of biodiesel which is mostly utilised by the informal sector locally for irrigation, electricity etc and by automotive companies for experimental projects

This figure demonstrates the demand and production availability of biodiesel [13]

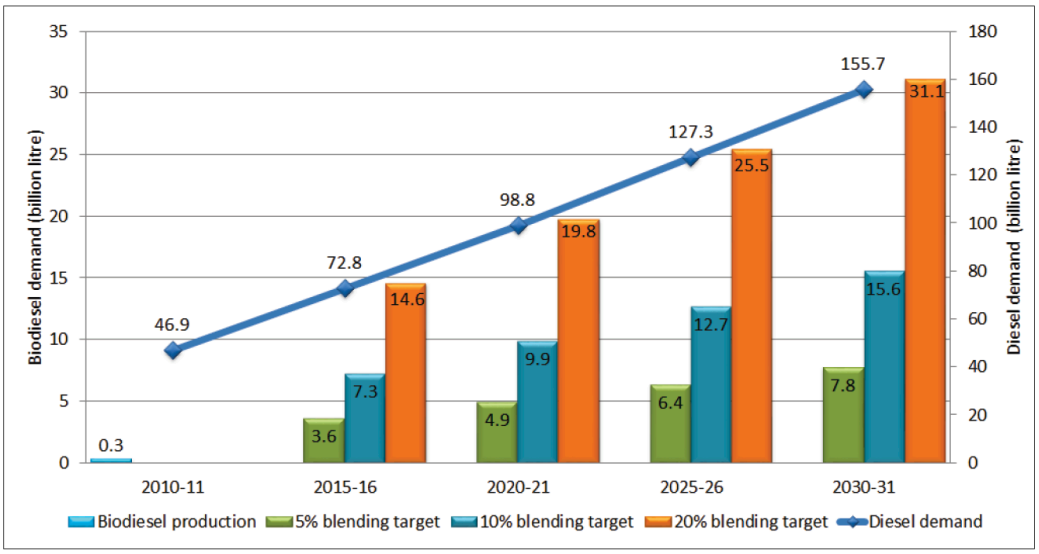


Figure : Biodiesel demand with blending targets(%) in India

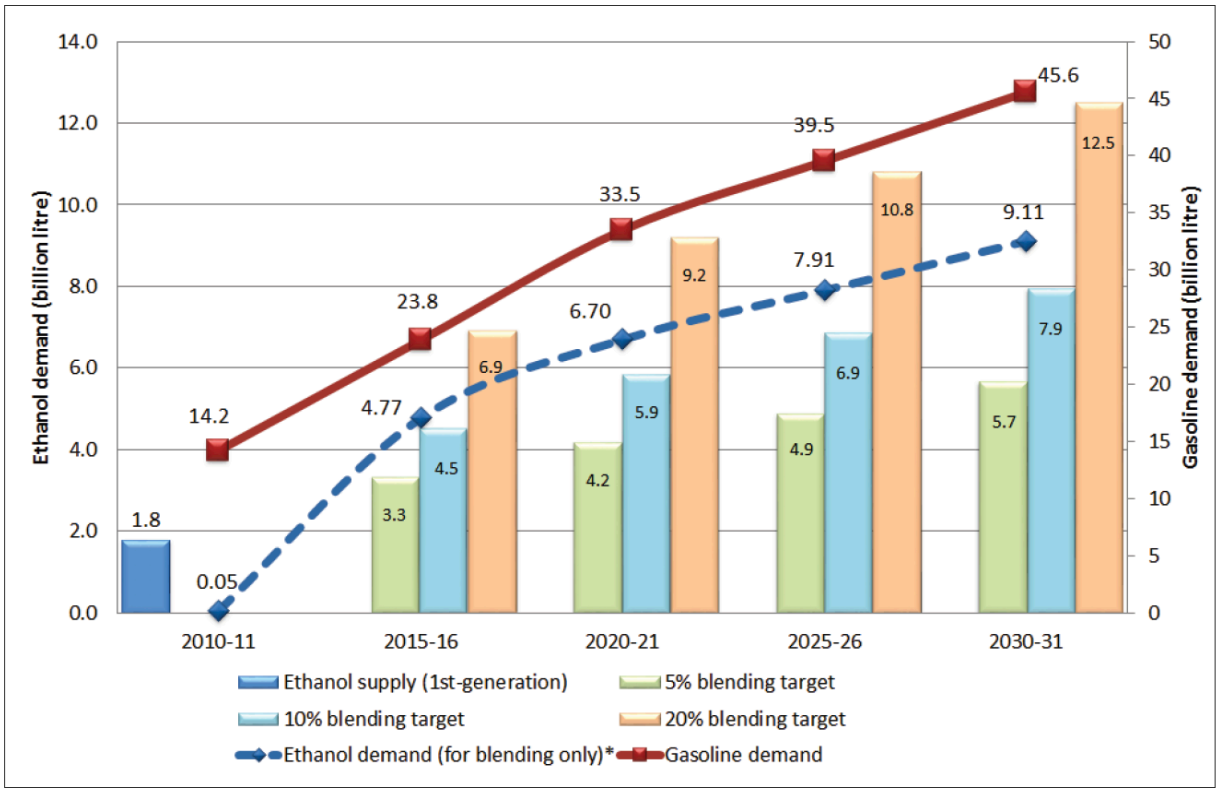
ATJ Ethanol Pathway

India is the world's second largest sugarcane producer and a major manufacturer of molasses-derived ethanol. Which is the primary feedstock for Alcohol-to-Jet Fuel Pathway with ethanol as intermediary

Currently research and development activities are taking place but No definitive End Process ATJ production technology is available in India, collaboration with international companies can be fruitful in this case

12 2G bio-refineries are going to set up with an investment of10,000 crore [14]

Ethanol suppliers, OMCs could allocate 2.68 billion litres of ethanol and government have procured 0.94 billion litres till 30.04.2019 achieving average 6.10% blending. Since only 30-40 % ethanol can be supplied and prepared for transportation purposes rest are used for alcohol beverages and diverted for sugar production



**with 20% blending target*

Figure : Ethanol demand with blending targets(%) in India

Biochemical ATJ - Organic Waste [15]

Biochemical ATJ production pathway for Jet fuel involves many intermediate conversion processes Organic waste - Organic Acid - Ketones - Alcohol - Jet Fuel

Biogas is the prominent product out of Organic waste and its pathway can be utilised for Jet fuel, it emerged as a promising renewable technology to convert agricultural, animal, industrial and municipal wastes into energy. Currently, the total biogas production in India is 2.07 billion m3/year. This is quite low compared to its potential, which is estimated to be in the range of 29–48 billion m3/year

Since Biochemical organic waste production pathway is inclusive of ATJ pathway same End-Process Feasibility problems arises. And solutions will also be the same for end process but for intermediate process too which is conversion

Around five million family biogas plants have been installed till 2015, under the biogas development program against the total potential of 12 million domestic biogas gas plants estimated by the MNRE In addition to family type biogas plants, 400 biogas off-grid power plants have been set up with a power generation capacity of about 5.5 MW in india (MNRE, 2015). The share of anaerobic digestion in biological waste treatment in urban areas is presently very low due to high capital cost and low revenue growth

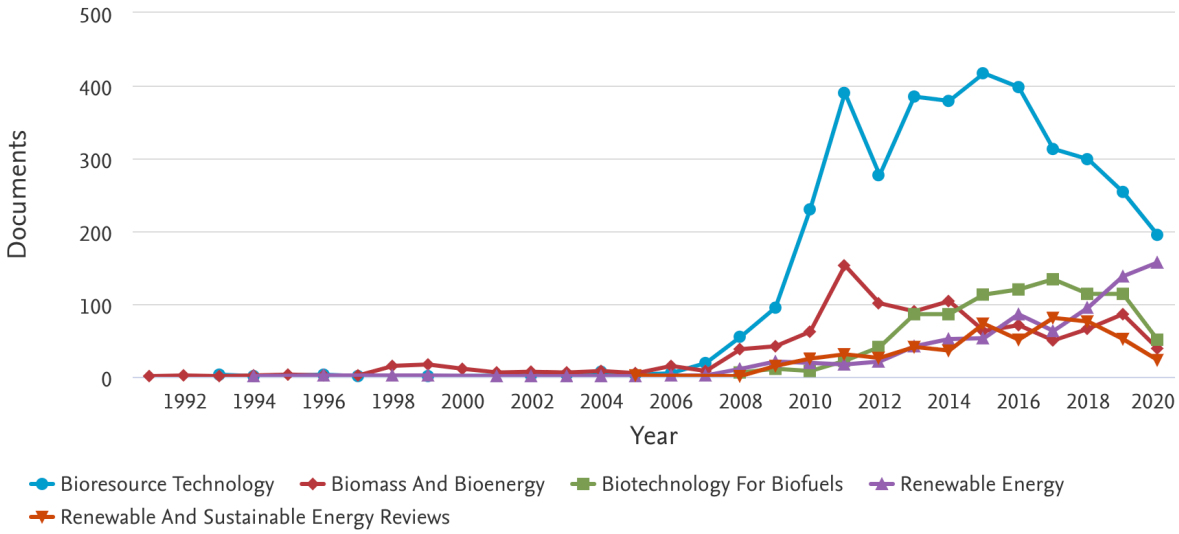
Problems and Barriers

Category	Barriers	Rural	Urban
Financial & Economical Barrier	High initial investment	✓	✓
	High transaction cost	✓	✓
	Lack of financing mechanism		✓
Market Barriers	Competition from other fuels	✓	✓
	Competition from alternative technologies/ uses	✓	✓
Social and cultural barrier	Social biases	✓	
	Gender participation	✓	
Regulatory and institutional barrier	Top down policy approach	✓	
	Limited urban municipal capabilities		✓
	Lack of coordination between different stakeholders	✓	✓
	Low private player involvement		✓
Technical & Infrastructural barriers	Lack of technical services	✓	
	Lack of waste treatment and storage facilities		✓
	Feedstock of poor quality		✓
	Unavailability of sufficient feedstock	✓	
Information	Lack of awareness about the policies, technology and its benefits	✓	

Supply Chain Network and Research in the field

Considering the available surplus Biomass which is agricultural residue and municipal waste in India :
144 M tons-Surplus Biomass produced by India every year which can be used for generating bioenergy
and India generates **62** M tons of waste every year. [11][12]

Shortage in biofuel production signals supply chain problem in the Industry, which is also of interest in the Research community.



Conclusion :

Overall Trend of The Tech Ecosystem in India:

There are 7 Key determinants which helps to understand the tech ecosystem of Biofuels in India, which signals the growth opportunities as well as Problem areas in the Industry.

1. Research and Development Activities
2. Governmental Support and Programs
3. Potential in terms of feedstock availability
4. Industry Scenario
5. Research and Publications
6. Startups and SMEs
7. Supply Chain network

It's the Synergy between these factors that is driving the Industry trend in Positive direction