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Research Paper

Energy from Biomass – Its Future in India

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ABSTRACT

Biomass is any organic matter from plants and animals that can be used as an energy source. This includes materials like wood, crops, agricultural waste, and animal waste, which can be burned directly for heat or converted into liquid and gaseous fuels like bioethanol and biogas. India produces an estimated 500 million metric tonnes of biomass annually. This can be used to generate 50,000 MW of clean power called 'bioenergy'. This paper makes a thorough study of India's National Bioenergy Policy (NBP), being implemented by the Ministry of New and Renewable Energy (MNRE) for 2021–2026. The Policy aims to reduce fossil fuel dependence, curb pollution, efficient waste management, create rural job opportunities and support India's transition toward 'net zero' emissions by 2070. In this respect, the NBP has three key programmes: the Waste-to-Energy Programme, the Biomass Programme and the Biogas Programme. The technologies are already matured and available in the market like that of mechanical processing, combustion, anaerobic digestion and fermentation. But in order to realise this goal, several challenges need to be overcome. These include sustainable supply and logistics, energy efficiency factor based on technology, environmental impact, economic factors and social inhibitions.

Keywords: *National Bioenergy Policy, renewable energy, biomass, bioenergy, pyrolysis, fermentation*

The World is facing an unprecedented crisis. The constant warnings from scientists about 'Climate Change' is no longer a future threat to human civilisation. It is here now. Over the last few years countries are facing severe heatwaves, excessive rainfall, melting of glaciers, severe storms and what not. People, though late, have understood the consequence of using fossil fuels, deforestation, destruction of natural habitats, unplanned growth of cities etc.

World leaders have taken serious note of this change. They have initiated a time-bound action programme under the aegis of the United Nations. Annual meetings are held across the world to take stock of the progress made by the countries. The first Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) was organised by Berlin, during March-April, 1995. This event marked the first time that nations convened to address climate change under the UNFCCC framework. Thereafter there have

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been twenty-nine such meetings so far. The last one took place in Baku, Azerbaijan in November 2024. It focused on the concept of 'climate finance'.

During the COP26 meeting, India committed to an ambitious target of achieving **'net zero'** carbon emissions by the year 2070. **Net zero goals** refer to the global effort to balance the generation and emission of greenhouse gas by their removal from the atmosphere, effectively stopping further global warming. Most developed countries have planned to achieve net zero by 2050 while China wants to do it by 2060. These measures are expected to restrict the rise in global temperature to 1.5°C only.

India has set itself the following pathways to achieve 'net zero' by 2070 or even before it. India's strategy involves a multi-pronged approach, focussing on:

- **Renewable Energy Expansion:** India is rapidly scaling up its renewable energy production from solar and wind, with a projected target of setting up 50,000 MW capacity by the year 2030 and to meet 50% of its energy demand through 'renewables'.
- **Green Hydrogen:** Indian companies backed by Government policies are heavily exploring green hydrogen production and its application as a clean fuel in sectors like steel, cement, and heavy transportation.
- **Energy Storage Technologies:** India is also investing in battery storage systems (BESS) and pumped hydroelectric storage systems to address irregular supply of renewable energy sources and ensure grid stability.
- **Decarbonisation of Industries:** It is implementing strategies to reduce emissions in industries like power generation, manufacturing, transportation, and agriculture.
- **Sustainable Urban Development:** Government is supporting construction of green buildings (mostly for office use), efficient public transport, and waste-to-energy solutions in urban centres.
- **International Cooperation:** Indian public and private sector companies are seeking partnerships and collaborations to access advanced technologies, financial assistance, and knowledge sharing from across the world.

But achieving these goals have given rise to a number of challenges for India. They are –

- **Coal Dependency:** India still relies heavily on coal for heat and electricity.
- **Policy and Economic Costs:** The transition requires supportive Government policies both from central and state levels and substantial investments in clean energy infrastructure and technology.
- **Technological Gaps:** Further advancements are needed in areas like energy storage and carbon capture technologies.
- **Political Considerations:** Countries need a proper transition policy for workers in fossil fuel-dependent sectors to other industries.
- **Social and Behavioural changes:** Individual and societal changes in consumption patterns, energy use, and lifestyle choices are also vital.

Introduction

In the light of these COP goals, the Government has initiated several measures to reduce the use of non-renewable energy and clean our rivers, air and cities. This transition presents significant opportunities, such as job creation in new industries, enhanced energy security, and improved public health.

As we know, there has been a steady push for increasing the use of biofuel in petrol, diesel and gas. Our solar and wind based power generation have grown tremendously over the past two decades. India's renewable energy (RE) capacity has reached 220.10 GW by 31st March 2025. The next table provides a snapshot over the last five years. Please note that the table excludes power generation by large hydro projects.

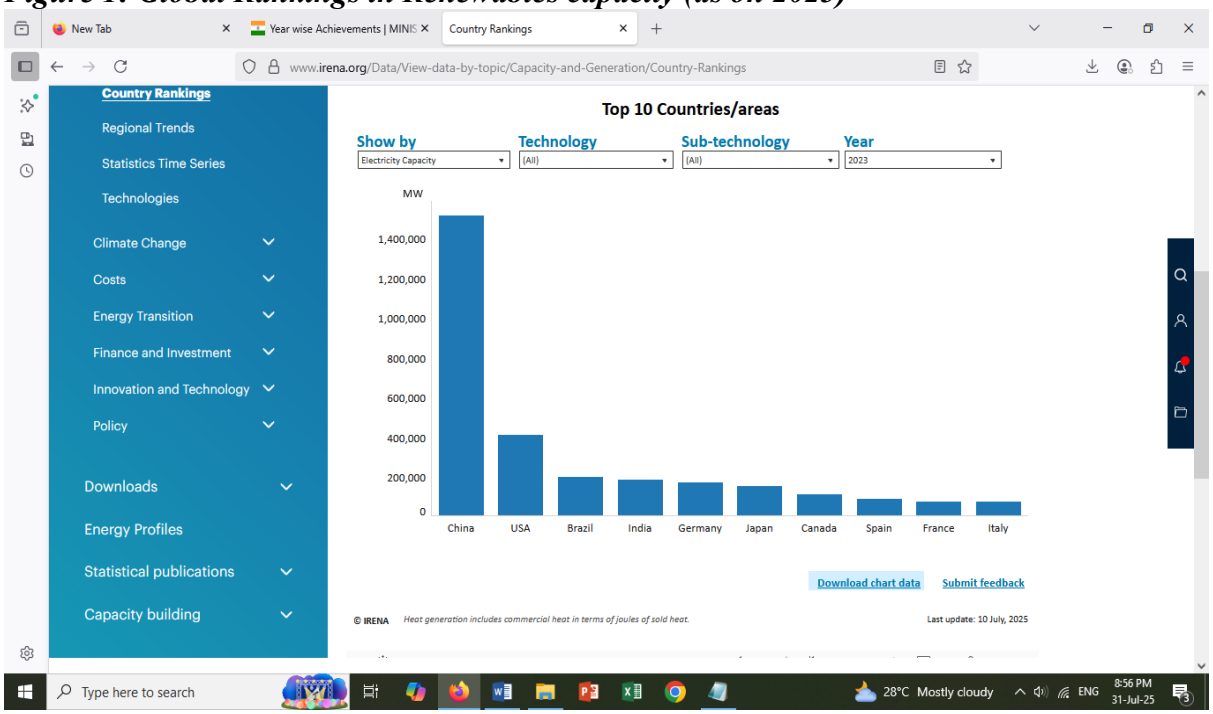
Table 1: Renewables capacity addition (latest 5 years) in India
(units in MW)

Sector	2020-21	2021-22	2022-23	2023-24	2024-25	Cum. till 30.06.2025
Wind Power	1503.3	1110.53	2275.55	3253.38	4151.31	51674.85
Solar Power	5628.8	12760.5	12783.8	15033.24	23832.87	116247.83
Small Hydro Power	103.65	62.09	95.4	58.95	97.30	5102.05
Biomass (Bagasse) Co-generation	173.37	59.69	0.00	0.00	387.76	9821.32
Biomass (Non-bagasse) Co-generation	97.24	0.00	42.4	107.34	0.00	921.79
Waste to Power	21	54.5	25	1.60	59.60	309.34
Waste to Energy (Off-grid)	20.75	34.66	52.28	30.17	194.81	543.86
Total	**7548.11**	**14081.97**	**15274.43**	**18484.68**	**28723.65**	**184621.04**

[Source: https://mnre.gov.in/en/year-wise-achievement/]

In the global rankings too, India has made tremendous progress over the last several years. It was the fourth country in 2023 just after Brazil in terms of its installed renewable capacity. This is shown in the following graph. But as per latest data, it has already achieved the third position surpassing Brazil.

Figure 1: Global Rankings in Renewables capacity (as on 2023)



[Source: https://www.irena.org/Data/View-data-by-topic/Capacity-and-Generation/Country-Rankings]

The next step for the Government is to cut using coal and natural gas and replace them with biomass energy and biogas.

India is blessed with substantial amount biomass and other organic wastes. It is well known that modern bioenergy provides many social and environmental benefits too. They help to control air, water, and land pollution. They can boost local job creation, provide new business opportunities, and reduce energy import bills. India can also save on fertiliser subsidies and better management of wastes. So, the Ministry of New and Renewable Energy (MNRE) notified the Phase-I of National Bioenergy Programme for a period 2021 to 2026 with an outlay of Rs.858.

LITERATURE SURVEY

Ladanai, *et. al.* (2009) paints a very optimistic scenario. Their report has shown that 'biomass' can become the world's largest and most sustainable energy source. The present annual supply of biomass is comparable to 4,500 EJ of solar energy generated each year. The supply of just 270 EJ of bioenergy can cover half of the world's primary energy demand. A supply of global bioenergy production potential of 1,135 EJ in 2050, without affecting the supply of food crops, can very well satisfy the maximum global primary energy demand of 1,041 EJ in 2050.

David, *et. al.* (2019) states the technologies that can extract energy from biomass, it also gives the advantages and disadvantages of using of biomass as an energy source. It mentions hydrogen gas as an important alternative. Biomass and its by-products can produce hydrogen rich gas sustainably. Biomass pyrolysis and gasification offers an efficient and economical route for green hydrogen production.

Tursi, *et. al.* (2019) mentions that replacing fossil based energy sources with biomass-derived sources could bring about positive impact on economy, environment and health. It highlights that production of biomass-derived energy can meet some of the main Sustainable Development Goals (SDGs) set by the United Nations General Assembly in 2015.

Banerjee, *et. al.* (2021) states that India produces biomass annually of about 500 MMT. But only 120-150 MMT are utilised annually for energy production. The government targets 50GW of electricity from biomass. This would provide both rural and urban areas many social and economic benefits.

The **MNRE Review Report (2020)** is a policy document that outlines India's ambitious energy transition journey. India wants fifty percent of installed electricity capacity from non-fossil fuel-based energy resources by 2030, reduce the emission intensity of GDP by 45% below 2005 levels by 2030 and achieve net zero by 2070. The use of domestically available Renewable Energy sources can provide bioenergy optimally.

After a thorough study of the above literatures, this paper has put its focus on the latest NBP being rolled out by the Government. The economic feasibility of the biomass energy in India's energy mix has been studied. The following objectives has been framed accordingly.

Objectives

The three broad objectives of this research paper are as follows:

1. To understand the relevance of bio-energy in India
2. To analyse the key goals of the National Bioenergy Programme

3. To measure the present and future market potential bioethanol, pellets and biogas in India

BIOMASS ENERGY

Biomass energy is energy derived from plant and animal waste which were recently living materials. The process of photosynthesis converts light energy from the sun to chemical energy which is stored in plants. Similarly, animals eat plants and store the chemical energy. This stored chemical energy in the biomass can be converted into electricity, fuel and heat. *This is called bioenergy.* In India, bioenergy is preferred from plant sources like from woody, cellulosic and oil rich plants.

Biomass is broadly divided into primary and secondary depending on its source.

- **Primary biomass energy** sources are plant materials like wood, crops, fruits, maize, sugar cane, and sunflower seeds which get converted to sunflower oil.
- **Secondary biomass energy** sources are 'waste' materials or by-products which can be used for energy production. These include:
  – Plant residues: agricultural and forestry residues
  – Fish and animal waste: manure, fish heads and abattoir waste
  – Waste yeast from the beer-brewing industry
  – Paper mill sludge
  – Sewage

The best sources of primary biomass have low moisture content and requires minimal land for their cultivation. If these biological sources are harvested sustainably, are carbon dioxide neutral. This is because the gas emitted during conversion into energy gets balanced by the carbon dioxide absorbed from atmosphere during the growth of plants.

The following table gives a snapshot of the energy available from various common sources of biomass found in India. Bamboo has the highest while rice husk has the lowest energy content.

Table 2: Energy content for various biomass (dry weight basis)

Raw material	**KJ/Kg (KiloJoule/Kg)**	
	lower calorific value / GCV	**higher calorific value / NCV**
Softwood	17500	21100
Hardwood	18600	20700
Coconut trunk wood	16600	17800
Miscanthus/Napier grass	17800	19100
Bamboo	19000	19800
Cotton stalks	17000	18300
Jute stick	17800	19400
Grass	17000	18100
Hay	16200	18300
Sugarcane bagasse	17700	19400
Wheat straw	15000	18900
Rice straw	13500	14800
Rice husk	14200	15400

[Source: Energy Research Centre of the Netherlands (ECN)]

The following table gives the comparable values for various non-renewable sources.

Table 3: Energy Value of Non-renewables

Fuel	**Calorific Value of Fuel** (in kJ/kg)
Coal	33,000
Diesel	45,000
kerosene	45,000
Petrol	45,000
Methane / CNG	50,000
LPG	55,000
Hydrogen	150,000

[multiple sources]

SALIENT FEATURES OF NBP

As already discussed, the National Bioenergy Programme or NBP has three main programmes which are already in various stages of implementation.

Under the **Waste to Energy Programme,** MNRE has been giving financial assistance to generate energy from urban, industrial, agricultural wastes/ residues and municipal solid waste since 2018 for recovery of energy in the form of Biogas/BioCNG/Power.

Both private and public sector companies are setting up Biogas, BioCNG (Compressed Biogas-CBG) and power plants besides generating bio-fertilizers. The Government had a plan to produce 15 MMT of CBG from 5000 plants by the year 2023. The oil marketing companies like HP Gas, Bharat Gas etc. have offered long-term purchase contracts on CBG to make the projects feasible.

In the **Biomass Programme,** MNRE has incentivised sugar mills and other industries (rice, paper mills, etc.) to use biomass-based cogeneration plants. The programme now supports manufacturing of biomass pellets and briquettes. These can be directly used for co-firing in Thermal Power Plants or small furnaces.

In the case of **Biogas Programme,** MNRE is promoting the use of small biogas plants that can provide clean gaseous fuel for cooking and lighting in rural areas. Support for medium size biogas plants (25 cu.m. to 2,500 cu.m. per day) is provided for power generation in the range of 3-250 kW capacity.

MARKET POTENTIAL OF BIOENERGY

As the country tries to the contain pollution and move towards renewable sources of energy, there is a constant push from the Government to incorporate more of renewable sources in our daily energy use. The result is the continuous rise in use of bioenergy in India. The next figure highlights this steady growth of about 5.2% between 2024 till 2035.

Figure 2: Revenue from Indian Biomass market

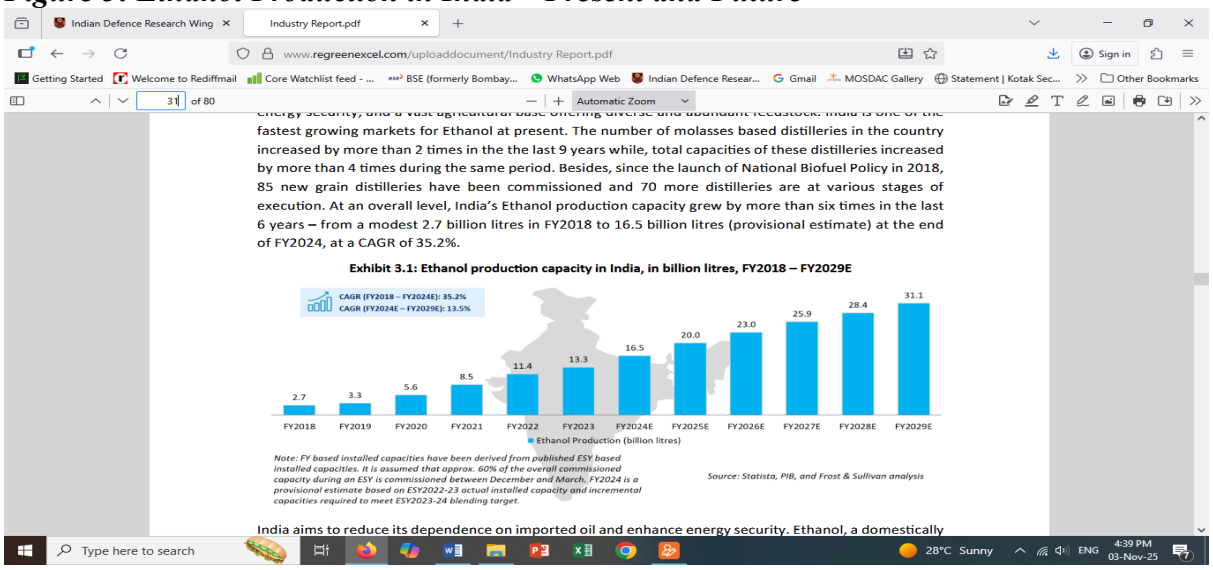
[Source: https://www.transparencymarketresearch.com/india-biomass-market.html]

The overall market is expanding because of the focus of the Government under NBP to – 1) manage and convert biomass to ethanol, 2) produce biogas and 3) supply of briquettes and pellets for co-firing in furnaces.

The next few graphs in this section provides visual proof of how Government incentives are fuelling a boom in biomass based energy production.

As we already know, India has already achieved 20% ethanol blending (E20) in petrol well before the original target date of 2030. This was possible because of the remunerative pricing of bio-ethanol sourced from various domestic sources. Figure 3 shows that the growth (CAGR) in ethanol production was 35.2% over the period 2018-2024. This trajectory shall continue in future with production expected to touch 25.9 billion litres in 2027.

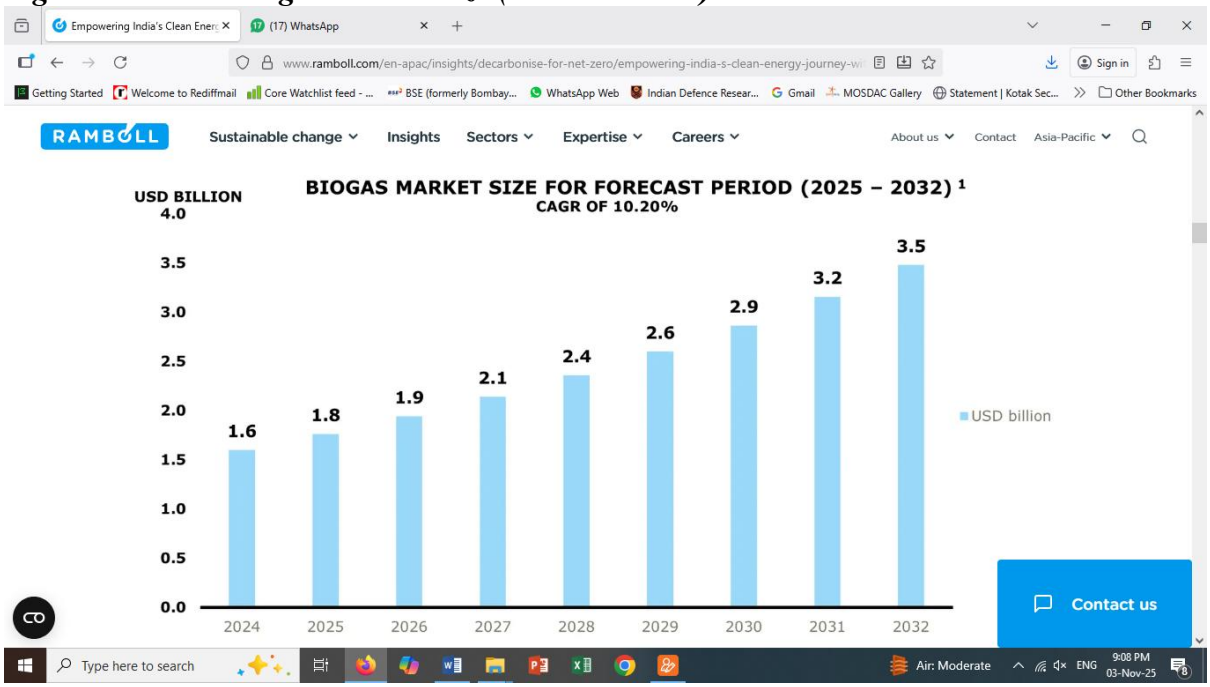
Figure 3: Ethanol Production in India – Present and Future



[Source: Statista, PIB and Frost & Sullivan]

The same trend is being seen in the production of compressed biogas (CBG). Biogas can be directly used for cooking, as a fuel in industrial high compression spark ignition engines, or to generate electricity through induction generator.

Figure 4: Indian Biogas Market Size (in billion USD)



[https://www.ramboll.com/en-apac/insights/]

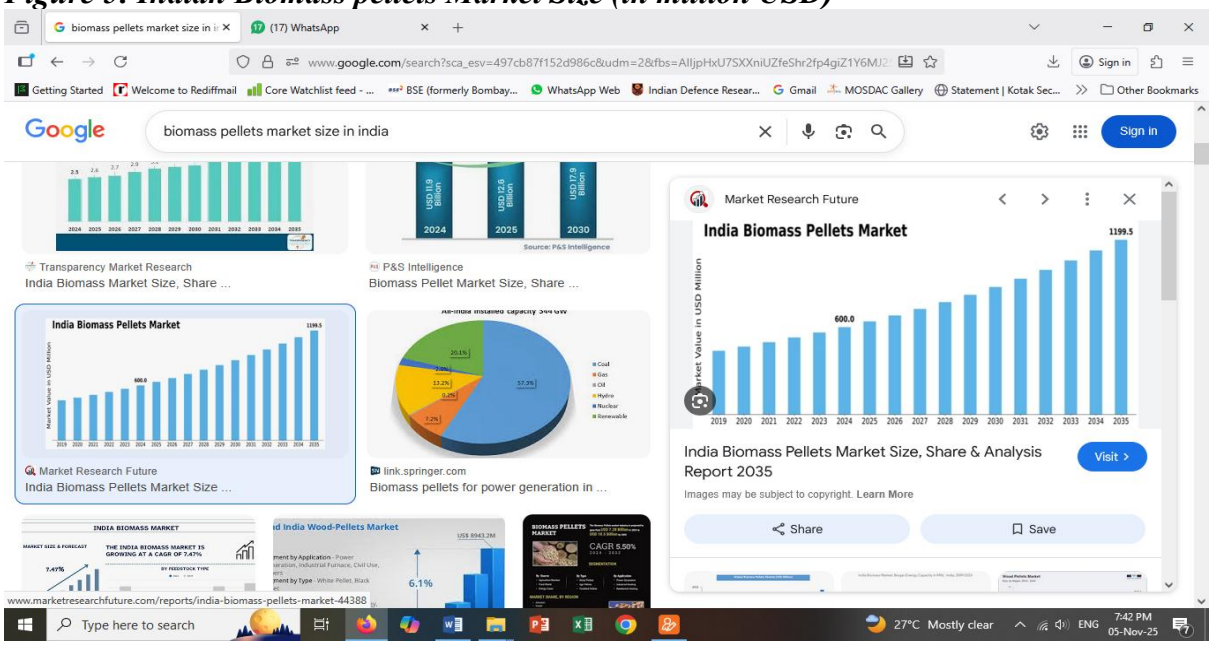
In June 2025, Hindustan Petroleum (HPCL) announced Rs. 2000 crores investment to develop 24 compressed biogas plants over the next two to three years.

Reliance Bioenergy Ltd. is investing Rs. 65,000 crores in Andhra Pradesh to set up 500 Biogas plants based on Napier grass as feedstock. They claim their CBG exceeds industry standards, with methane content exceeding 96% (v/v) and calorific value similar to Compressed Natural Gas (CNG). Around 500,000 acres of barren and waste lands in 4 districts will be utilised. Once all plants are fully operational, they will produce 40 lakh tonne of CBG and 1.1 million metric tonnes of organic fertiliser annually. It is expected to create 250,000 jobs for rural youth.

The biogas sector got a further boost by reduction of GST on biogas plants and devices to 5 per cent from 12 per cent, effective October 22, 2025.

In this third part, the production of briquettes and pellets (torrified or not) has been looked into. While briquettes are large, biomass pellets are small, cylindrical items made of compressed organic materials like wood waste, agricultural residues, and other plant matter. They are used for heating, power generation, and industrial processes. They are preferred to fossil fuels because of their high energy density and reduced carbon footprint.

Figure 5: Indian Biomass pellets Market Size (in million USD)



[https://www.marketresearchfuture.com/reports/]

The Ministry of Power has directed all coal-based power plants co-fire biomass pellets, starting with a 5% blend from October 2022 and increasing it to 7% subsequently. To meet this requirement, India needs around 35 million tonnes of biomass pellets annually, translating to approximately 96,000 tonnes per day.

India has about 217 operational biomass pellet manufacturing units as of 2023, collectively producing just 7,000 tonnes per day. On average, each unit manufactures 32 tonnes per day, though some larger manufacturers have capacities ranging from 200 to 800 tonnes per day. Despite this production, the massive supply-demand gap presents a significant investment opportunity in the biomass pellet industry.

KEY CHALLENGES

In spite of obvious advantages and importance of this emerging business opportunity, there are some challenges and problems that entrepreneurs can face during implementation. Here's a more detailed breakdown of the challenges under five different categories.

1. Sustainable Supply and Logistics:

- **Availability and Collection of Biomass**: They are geographically dispersed, and are available depending on seasons.
- **Transportation and Storage:** Biomass is usually bulky and less energy-dense, making transportation costly. It's also susceptible to moisture and decay.
- **Competing with Food Production:** Increased demand for biomass resources can divert agricultural land for its production.
- **Deforestation:** Large-scale biomass production can lead to deforestation and soil erosion if not managed properly.

2. Efficiency and Conversion:

- **Moisture Content:** High moisture content in biomass is not suitable for use in conventional furnaces.

- **Density and Pre-treatment:** Biomass often requires pre-treatment that can further increase its cost.
- **Presence of lignin:** Lignin, a component of biomass, is difficult to break down, affecting the efficiency of biofuel production.
- **Conversion Technology:** It is imperative to develop cost-effective technologies suited to local conditions for converting biomass.

3. Environmental Impacts:

- **Air Pollution:** Open combustion of biomass leads to rise in air pollutants like particulate matter (SPM 2.5, 5, 10), carbon monoxide and nitrogen oxides.
- **Greenhouse Gas Emissions:** Biomass is considered renewable, but its combustion can still release greenhouse gases.
- **Ash Management:** Biomass combustion produces ash, which can be difficult to dispose of.

4. Economic Factors:

- **Cost:** Biomass energy can become more expensive than fossil fuels due to addition of collection, processing, and transportation costs.
- **Fossil Fuel Subsidies:** Subsidies by Government for fossil fuels in some countries can make biomass less competitive.
- **Lack of Access to Finance:** There is shortage of low-cost financing to deploy biomass energy technologies.

5. Social Challenges:

- **Impact on Rural Communities:** Biomass energy projects shall affect rural communities as it changes land use, increased traffic, and potential impacts on livelihoods.
- **Competition with other Land Uses:** Balancing the need for biomass energy with other land uses, such as agriculture and forestry, is also very crucial.

CONCLUSION

India is a net importer of energy mostly in the form of fossil fuels. But it is causing quite a few problems for India – demand for foreign exchange, rising pollution levels across the country, problem of unemployment and international commitments to achieve 'net zero' status by the year 2070. The Government has been taking a number of steps to overcome these challenges.

One of these is the National Bioenergy Programme (NBP). The first phase of which spans from 2021 to 2026. We have already covered in details the features of NBP. The serious support given by the Government is evident in the form of positive growth in bioethanol, biogas and pellet production over the past several years. The growth momentum is expected to continue till 2035 based on the already provided incentives. However, the potential for further growth remains immense.

India is blessed with vast agricultural resources which can be a game-changer not only in generating renewable energy but also solving the scourge of unemployment in rural areas. The NBP seems to be the right step which if managed scientifically and commercially can uplift large portion of low-skilled population without depending on foreign resources.

REFERENCES

Biomass Conversion Technologies - Steamaxindia. (2023, July 18). Steamaxindia.com. https://steamaxindia.com/biomass-conversion-technologies/

David E., Kopac J., Armeanu A., Niculescu V., Sandru C., and Badescu V. (2019), "Biomass -alternative renewable energy source and its conversion for hydrogen rich gas production", E3S Web of Conferences, https://doi.org/10.1051/e3sconf/201912201001, pp. 1-5

EAC International Consulting (2023), "Introduction to CBG Industry: Need-Potential-Enablers", pp. 1-31

Ghosh U., Das D., Banerjee D., Karmakar S. and Das J. (2021), "Biomass Energy Potential in India: A Review", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, pp. 1-5

India Biomass Market Share, Trends | Forecast 2030. (n.d.). www.transparencymarketresearch.com. https://www.transparencymarketresearch.com/india-biomass-market.html

Joshi, A. (2023), "Market Report India", World Biogas Association, pp. 1-8.

Kewat D.K. and Kumar A. (2023), "Unlocking the Potential of Biomass in India's Renewable Energy Landscape: A Comprehensive Approach", Vol-I, pp. 1-12

Kumar Kewat, D., & Kumar, A. (n.d.). *Unlocking India's Biomass Market Potential*. https://samarth.powermin.gov.in/content/policies/4535f436-617d-4ced-90a2-8e70e95382ee.pdf

Ladanai, S. and Vinterbäck, J. (2009),"Global Potential of Sustainable Biomass for Energy", Swedish University of Agricultural Sciences, ISSN 1654-9406, pp. 1-32

Ministry of Environment, Forest and Climate Change, Government of India (2022), "India's Long-Term Low-Carbon Development Strategy", Submission to the United Nations Framework Convention on Climate Change, pp. 1-121

Ministry of New and Renewable Energy (MNRE) (2021),"Evaluation Study for Assessment of Biomass Power and Bagasse Cogeneration Potential in India", Centre for Energy Studies (CES), Administrative Staff College of India (ASCI), Hyderabad

Regreen Excel EPC India Ltd. (2024), "Industry Report on Indian Ethanol Market", Prepared by Frost & Sullivan, pp. 1-80

Salih T.W.M., (2021), "Biomass Energy", https://www.researchgate.net/publication/ 355204245, pp. 1-9

Tshikovhi A. and Motaung T.E. (2023), "Technologies and Innovations for Biomass Energy Production", https://doi.org/10.3390/su151612121, pp. 1-21.

Tursi A. (2019), "A review on biomass: importance, chemistry, classification, and conversion", Biofuel Research Journal, pp. 962-979

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Conflict of Interest

The author(s) declared no conflict of interest.

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