Our Take

January 2023

pwc

Fuelling India's future with bioenergy

Although India can produce reliable, cost-effective and environmentally sustainable bioenergy to meet its energy demand, progress has been slow. Implementing a few key action plans centred around the market ecosystem, collaboration and financing could accelerate its production

In November 2022, the Ministry of New and Renewable Energy (MNRE) announced that it would continue with the National Bioenergy Programme for energy recovery till 2025–2026 with a budget outlay of INR 858 crore for the first of the two phases.[1] The programme is meant to enable the use of cattle dung, biomass, and urban and industrial biowaste for energy recovery. The announcement has put the spotlight on the green sector and demonstrates the Government of India's sustained focus on bioenergy. The International Energy Agency (IEA) estimates that once such government policies are in place, bioenergy may produce 130 million tonnes of oil equivalent (Mtoe) of useful energy by 2040, or about 15% of India's total energy demand at that time.[2]

India's bioenergy production potential

Parameter	Quantity
Power generation potential	Annual power generation potential of 208 billion units (BU) from 28 GW[3]
Additional bagasse-based cogeneration potential	Annual power generation potential of 65 BU[4] from 14 GW[5]
Bioethanol production potential from agri-waste[6]	From sugarcane (1 G): • Sugar/sugar syrup – 9,523.52 KLPD • B molasses – 24,843.98 KLPD • C molasses – 13,309.27 KLPD From rice (2G) – 897.25 KLPD From maize (2G) – 395.67 KLPD
Compressed biogas production potential[7]	• From cattle dung – 38,981.25 TPD • From municipal solid waste – 4,853.98 TPD • From paddy straw – 16,377.03 TPD

1 *Continuation of Bioenergy Programme*
2 *International Energy Agency – India Energy Outlook 2021*
3 *Central Electricity Regulatory Commission – RE Tariff Order for FY 2022-23*
4 *Central Electricity Regulatory Commission – RE Tariff Order for FY 2022-23*
5 *PwC analysis*
6 *PwC analysis*
7 *PwC analysis*

Of smog and black carbon emissions

India, an agricultural powerhouse, is one of the largest producers of rice, wheat, cotton, sugar, and horticulture and dairy products[8] in the world. The crops also generate biomass, a proven energy source that offers many benefits. The available biomass in India currently stands at 750 million metric tonnes (MMT)/year with surplus biomass availability of 230 MMT/year.[9]

At present, an estimated 32% of total primary energy use in India is principally derived from biomass and over 70% of Indians depend on biomass for their energy use across the value chain. Despite its widespread utility as an energy source, biomass poses certain challenges such as stubble burning by farmers in parts of northern India. With a short time span between harvesting and sowing the next crop, farmers burn stubble, or crop residue, in their fields. It contributes to India's poor air quality, which, in turn, adversely affects people's health. Biomass combustion leads to black carbon emissions (46% of elemental carbon and 68% of soot carbon).[10]

These emissions contribute to the thick smog that envelopes Delhi and adjacent areas every year, causing serious respiratory and other health issues. Recent statistics show that in 2022, stubble burning in Delhi caused an increase of over 20% in the PM2.5 pollution level in October and November, the stubble-burning months.[11] According to the National Institute of Public Finance and Policy (NIPFP),[12] the annual cost of air pollution is estimated at USD 300 million in terms of health problems and economic disruptions such as flight and train delays and visibility-related accidents.

India is one of the world's largest producers of crops, but it is also the second-most populated nation, generating municipal solid waste of about 160,038.9 tonnes per day (TPD). This waste is another source of biomass. Of the total waste generated daily, roughly 95% is collected, about 79,956.3 TPD is treated and 29,427.2 TPD is landfilled.[13] These landfills are super-emitters of methane, a major contributor to global warming. Around 11% of greenhouse gas emissions are released by methane into the atmosphere. As a result, this traps around 80 times more heat in the atmosphere than carbon dioxide (CO2).[14] By 2031, India is projected to produce 125 million tonnes of garbage annually[15] and methane emissions will increase exponentially. Garbage generation in India is colossal, and needs to be addressed on priority.

Government initiatives to develop the bioenergy sector

The MNRE, since its inception, has been focusing on the development of the bioenergy sector, dealing with problems related to the management of biomass – whether agri-waste or municipal solid waste – and the poor realisation of its energy potential. The ministry's concerted efforts have resulted in the following achievements:

Over **800** biomass power projects, bagasse cogeneration and non-bagasse cogeneration projects have been installed in the country with an aggregated capacity of **10,632 MW** for power generation and **140 TPD** for compressed biogas (CBG) production.[16]

India is also developing a bankable market for bioproducts such as biomass pellets and briquettes. There are close to **230** biomass pellet manufacturers and close to **1,030** briquette manufacturers spread across different states, supplying these products to power plants and industries.[17]

8 *The International Trade Administration – Food and Agriculture Value Chain*

9 *Ministry of New and Renewable Energy – Bioenergy*

10 *MDPI – Understanding Sources and Composition of Black Carbon and PM2.5 in Urban Environments in East India*

11 *Mint report*

12 *International Journal of Epidemiology – Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons*

13 *Central Pollution Control Board (CPCB) Delhi – Annual Report 2020-21*

14 *UN Environment Programme – Climate Action*

15 *Indian Council for Research on International Economic Relations – Solid waste management in India: An assessment of resource recovery and environmental impact*

16 *Ministry of New and Renewable Energy – Statistics*

17 *PwC analysis*

This growth in the bioenergy sector has been supplemented by various central level schemes and initiatives such as:

Policy for co-firing of biomass in thermal power plants, which mandates minimum 5% co-firing of biomass along with coal in thermal power plants.[18] Currently, biomass pellet manufacturing capacity in India stands at 2.38 MMT[19] and 83,066 MT of biomass has been co-fired in 39 thermal power plants across the country.[20]
The Sustainable Alternative Towards Affordable Transportation (SATAT) scheme promotes the use of CBG in the transportation sector. Under the scheme, 9,019 MT of CBG has been sold until August 2022.[21]
Scheme to Support Promotion of Biomass-Based Cogeneration in Sugar Mills and Other Industries[22]
New National Biogas and Organic Manure Programme (NNBOMP)[23]
The Central Pollution Control Board's (CPCB) fund of INR 50 crore to be provided as subsidy to manufacturers in Punjab, Haryana, Rajasthan, Uttar Pradesh and Delhi to incentivise pellet manufacturing to curb stubble burning.[24]
Amendments to the National Policy on Biofuels, 2018, allowing more feedstocks for production of biofuels and 20% blending of ethanol in petrol to ESY 2025–26 from 2030[25]
The Government of India's direction to appropriate Commissions to consider (a) exemption of all applicable charges (except wheeling and transmission charges) under inter-state open access sale of power from municipal solid waste to power plants and (b) relaxation of the Deviation Settlement Mechanism (DSM) for municipal solid waste to power plants similar to the relaxation given to solar and wind power plants[26]
Scheme to support the promotion of manufacturing of briquettes and pellets and biomass (non-bagasse) based cogeneration in industries in the country (up to March 2026) providing INR 9 lakh per metric tonne/hour (MTPH) pellet/briquette manufacturing capacity (maximum Central Financial Assistance or CFA of INR 45 lakh per plant) and INR 40 lakh/MW on installed capacity (maximum CFA of INR 5 crore per project) for biomass (non-bagasse) cogeneration projects.[27]

18 *Ministry of Power – Revised Policy for Biomass Utilization for Power Generation through Co-firing in Coal based Power Plants*

19 *PwC analysis*

20 *Press Information Bureau – Press Release*

21 *SATAT*

22 *Ministry of New and Renewable Energy – Scheme to Support Promotion of Biomass Based Cogeneration in Sugar Mills and Other Industries in the Country (up to March 2020)*

23 *Ministry of New and Renewable Energy – Bio-energy Schemes*

24 *Press Information Bureau – press release*

25 *Ministry of Petroleum and Natural Gas, Government of India – National Biofuel Policy with amendment 2022*

26 *Ministry of Power – Reforms in the Power Sector*

27 *Ministry of New and Renewable Energy - Guidelines for implementation of Biomass Programme*

These policies and schemes have given a much-needed impetus to the sector in the form of several financial and fiscal incentives, including capital subsidy, CFA and guaranteed offtake.

Furthermore, the Union Budget 2023 is likely to act as a catalyst for the bioenergy sector, with the announcement to establish 500 new 'waste to wealth' plants under the Galvanising Organic Bio-Agro Resources Dhan (GOBARdhan) scheme for promoting circular economy. These will include 200 CBG plants, including 75 plants in urban areas, and 300 community or cluster-based plants with a total investment budget of INR 10,000 crore.

In addition, a 5% CBG mandate will be introduced in due course for all organisations marketing natural and biogas. With this, collection of biomass and distribution of biomanure will be backed by appropriate fiscal support. The Union Budget also provides tax relief on CBG-based fuel blending such that to avoid cascading of taxes on blended compressed natural gas, excise duty on GST-paid CBG contained in it will be exempted from excise duty. *(PIB press release)*

India's commitment towards bioenergy development in the country is also substantiated through various recent non-policy developments such as:

allowing maize and surplus rice available with the Food Corporation of India (FCI) to be used for ethanol production[28]	India's commitment towards developing and demonstrating technologies for bio-based renewable fuels, chemicals and materials to replace petrochemical products contributing to the reduction of greenhouse gas emissions	Mission Innovation 2.0, under which India and the US are co-leading the Mission Innovation collaborative platform initiative on 'Innovation for Sustainable Aviation Fuel' (ISAF), including biofuel[29]
emergence of hydrogen-blended compressed natural gas (HCNG) as an interim technology for achieving emission reduction and import substitution – one compact reformer plant and a trial run of 50 buses were started on 20 October 2020[30]	inclusion of biomanure produced from CBG as fermented organic manure and fermented liquid organic manure under the fertiliser category for retail sale in the country[31]	set-up of the National Mission on use of Biomass in Thermal Power Plants by the Ministry of Power to address the issue of air pollution due to farm stubble burning and to reduce carbon footprints of thermal power generation and thereby support the energy transition in the country and progress towards India's targets of shifting to cleaner energy sources.[32]

28 Press Information Bureau – press release

29 IEA Bioenergy – Implementation of bioenergy in India

30 Press Information Bureau – press release

31 Ministry of Petroleum and Natural gas – Compressed biogas

32 National Power Training Institute – National Mission on Use of Biomass in Thermal Power Plants

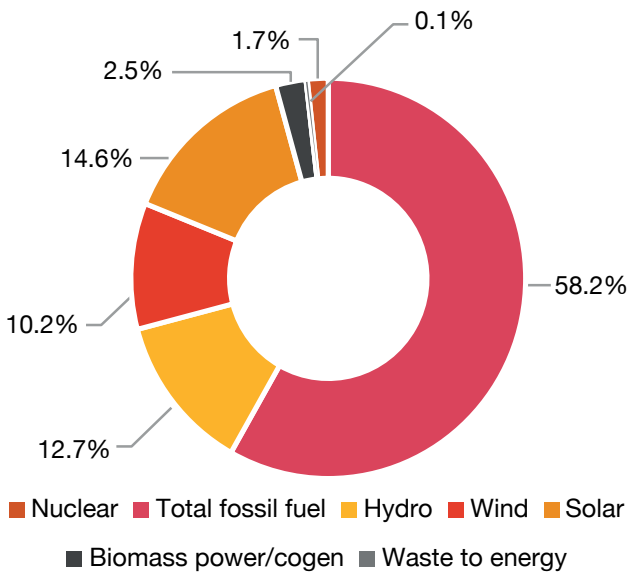
33 Ministry of Power – Power sector at a glance All India

The private sector in India is also looking at creating advancements in technology through various means including the increased efficiency of biomass energy conversion technologies, end-use technologies, and improved fuel processing technologies

Challenges that hamper growth in the bioenergy sector

Although India can produce reliable, cost-competitive and ecologically sustainable bioenergy to meet the country's energy demand for power and non-power uses such as transportation and modern heating applications, progress has been slow. As of August 2022, less than 3% of the installed generation capacity in India came from biomass power, cogeneration and waste-to-energy projects.[33] Besides, the bioenergy sector is exposed to certain risks and challenges, which hamper its growth and adoption.

Installed power capacity – India



33 *Ministry of Power – Power sector at a glance All India*

Following are the risks and challenges:

- **State policies focus on biomass in power generation:** State policies are currently more focused on the utilisation of biomass in power generation, though biomass resources also have other uses. These include biofuel production and biomass processing for industrial heating purposes.
- **Inadequate feedstock supply (fuel reliability and quality):** This is one of the key challenges that requires immediate attention. Any bioenergy project is unlikely to succeed if the long-term fuel supply is unpredictable or the fuel quality is uncertain. Project economics would typically depend on a specific quantity of energy produced. Project developers desire an ironclad, long-term contract with a feedstock supplier and would ideally like to avoid situations that allow the supplier to accept competing offers from other feedstock users. Having a long-term contract for feedstock supply would also provide a level of comfort to the lender, resulting in lower risk perception of the bioenergy project.
- **Lack of public data on biomass availability across geographies:** The data related to availability of biomass across geographies, especially at the district/block level, is not easily available and requires case-by-case research. This affects the planning of such projects. Hence, most stakeholders conduct their own analysis to assess the availability of biomass. Subsequently, availability of surplus biomass for bioenergy production may or may not be accurate, time efficient and cost-effective.
- **Limited storage options:** Storing biomass residue is a long-standing issue in India. For agri-based biomass residue, limited storage capacity is among the primary reasons for stubble burning. This is more of an issue in the northern Indian states, where with limited offtake and storage options, excess biomass is disposed of by burning crop residue in open fields.
- **Supply chain bottlenecks:** Carriage and transportation of biomass require customised vehicles, especially for agri-waste due to its varying sizes and density. So far, this has seen limited commercialised options and is done mostly through make-shift arrangements.
- **Limited offtake of biofertilisers:** There is a pressing need to promote the use of biofertilisers by farmers. There is still lack of awareness in the farming community on how the use of biofertilisers can enhance the nutrient uptake, growth, yield, nutrition efficiency and quality of crops, besides helping local allied industries to flourish. The slow uptake of biofertilisers is one of the major discouraging factors for private sector investment in the biogas sector in the country.
- **Limited platforms for biomass trading:** There are limited platforms available for trading and exchange of raw and processed biomass wherein sourcing agencies, aggregators and processed biomass producers can list available resources and sell them to prospective buyers. At present, biomass trading in the country is fragmented and exists only in a handful of states, despite the need for biomass or waste for bioenergy projects in the country.
- **Lack of adequate financing mechanisms:** Lenders are largely reluctant to support either short-term or long-term loans. When such loans are available, the rate of interest is higher than it is for loans for other clean energy sources, thus inflating the costs of such projects.

Bioenergy has the potential to reduce carbon emissions, especially in the ‘difficult to de-carbonise’ sectors such as power, long-haul or heavy transport, manufacturing, iron and steel, cement, aluminium, chemicals and other heavy industries. When biomass is used to produce energy, it can reduce atmospheric CO2 emissions, caused by other fuels or other reasons. Similarly, if bioenergy is utilised for carbon capture and storage, the carbon that is not returned to the atmosphere leads to a net reduction in CO2, resulting in negative CO2 emissions. Though we are yet to witness the deployment of carbon capture and storage at an industrial scale, some applications can be seen in bioethanol production, waste-to-energy plants and power generation.

Our take

Bioenergy's role in India's decarbonisation efforts

Bioenergy has started to provide promising results in India's decarbonisation efforts. It is no more the 'sleeping giant' of renewables in the country and has a significant role to play in India achieving its 2030 Conference of Parties 26 (COP26) target of achieving a cumulative non-fossil fuel-based energy capacity of 500 GW and reduction of total projected carbon emissions by 1 billion tonnes.[34] It can also help to achieve the low-carbon transition pathway by focusing on rational utilisation of national resources as committed by India in COP27.[35]

In terms of its socioeconomic impact, bioenergy also bodes well for the Government of India's push for home-grown initiatives – underlined in programmes and campaigns such as Make in India, Aatmanirbhar Bharat Abhiyaan and Swachh Bharat Abhiyan. It also offers opportunities for augmenting farmers' income, easing the pressure on India's exchequer, and generating employment and waste-to-wealth creation.

As of August 2022, based on the total installed capacity of bioenergy projects in India, an estimated 0.43 million direct jobs and 0.66 million indirect jobs had been created in the economy. Of these, approximately 0.25 million jobs across the value chain of bioenergy projects are for women.[36]

Within the bioenergy sector, the breakup of direct, indirect and women-oriented jobs, based on PwC analysis, is highlighted in the figure below:

Job creation in the bioenergy sector in India

Bioenergy projects are able to generate at least twice the number of direct jobs as compared to solar and wind projects.[37] This is due to the labour-intensive nature of bioenergy projects. A comparison of per MW direct jobs created by the three technologies is provided below:

Technology[38]	Solar	Wind	Bioenergy
White collar jobs created per MW	**5-10**	**7-8**	**12-18**

34 Press Information Bureau – press release

35 Press Information Bureau – India submits its long-term low emission development strategy to UNFCCC

36 PwC analysis

37 PwC analysis

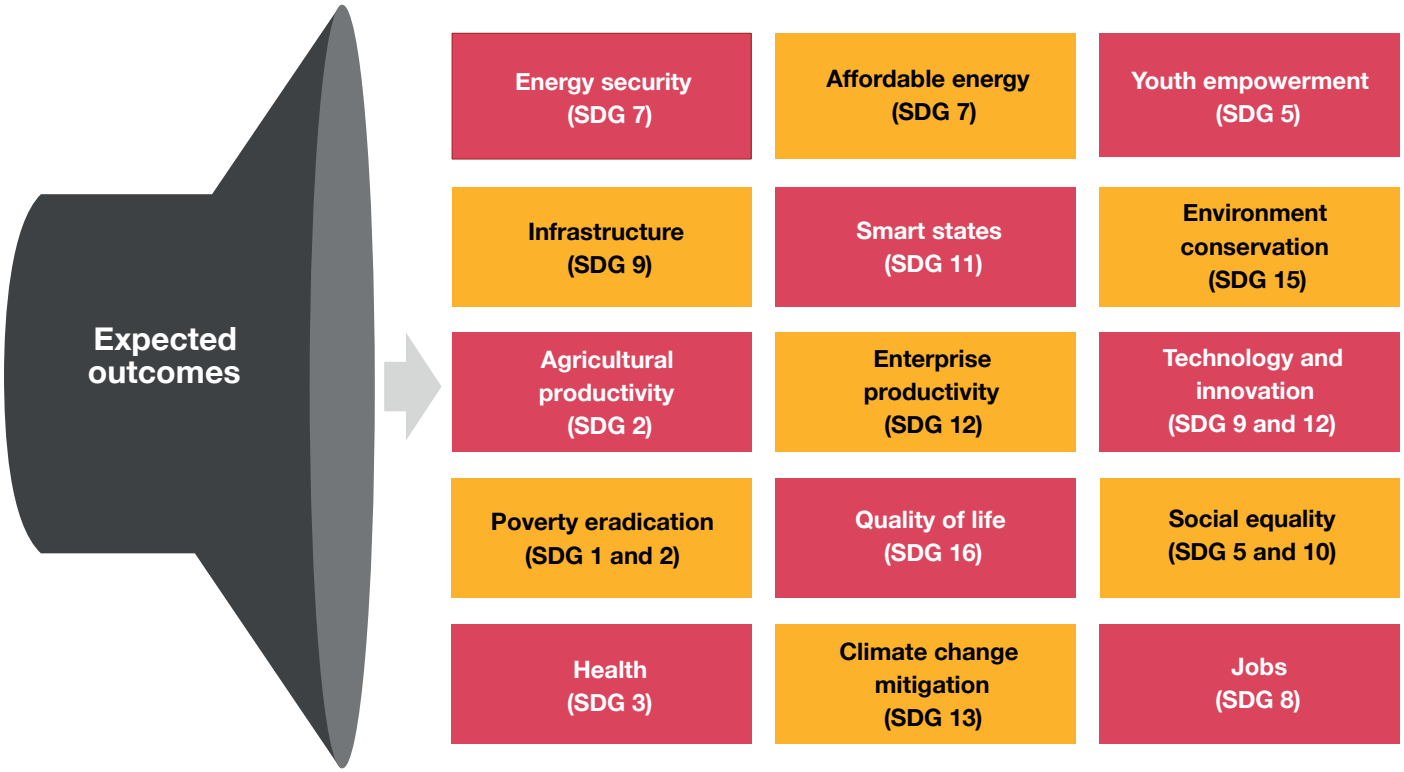
38 PwC analysis

These bioenergy projects, by providing sustained employment opportunities for both skilled and unskilled manpower, have led to increased market spending and, accordingly, an increase in private consumption, thereby augmenting the country's GDP. During the lifetime of these projects, the investment flow in the manufacturing sector is also likely to increase substantially when the equipment to operate the plants is developed and for the operation and maintenance of such equipment.

Following are the key outcomes expected from the implementation of bioenergy projects in the country:

Energy security: Enhancing energy security in the country such that it does not hinder the economic infrastructure, industrial and other developmental goals	**Infrastructure:** Developing transport, communication, energy, irrigation and basic infrastructure	**Agriculture productivity:** Mechanising agriculture and ensuring in-situ and ex-situ crop residue management	**Poverty eradication:** Creating avenues for employment and income generation opportunities in the country
Health: Providing health and social benefits to the masses	**Jobs:** Opening new work avenues and opportunities in the country	**Social equality:** Bringing discrimination on any basis to an end	**Smart states:** Building states in India as smart states
Enterprise productivity: Increasing enterprise productivity by extracting more from the same resources	**Quality of life:** Providing a high quality of life to country's residents with citizens	**Climate change mitigation:** Mitigating the impact of climate change expected due to growing energy demands	**Youth empowerment:** Empowering the youth to lead society by building their skills
Environment conservation: Conserving and preserving the environment by reducing dependence on conventional fuels	**Technology and innovation:** Improving existing technologies and adopting newer technologies	**Utilisation of local resources:** Using biomass for creation of energy in the country	**Affordable energy:** Providing energy at affordable prices to all

According to PwC's assessment, the expected outcomes from the development of the bioenergy projects can help meet the following Sustainable Development Goals (SDGs):



Application of bioenergy in India's future energy mix

India is home to a considerable amount of biomass resources, as highlighted in the earlier sections. These resources can be used to replace conventional fuels such as coal, petrol, diesel and aviation fuel. With the increased adoption of bioenergy resources, new investments in the conventional sectors can be avoided. This would help India to reduce its:

- dependence on fossil fuels, which are usually imported
- import bills
- carbon footprint due to energy supply and demand sectors.

Thus, it is important to promote and increase the utilisation of these resources from the current levels in order to leverage their underlying benefits. At present, these resources are being adopted for use in both the power and non-power sectors. Their current form of usage and future potential have been highlighted below.

Power generation	
Biomass power plants	Raw biomass can be used as fuel for combustion and subsequent power generation. The surplus biomass of about 230 MMT can help generate 208 BU of electricity from 28 GW of power capacity annually.[39]
Coal-fired thermal power plants	Raw biomass can be processed into a pellet for co-firing in coal-fired thermal power plants, offsetting a portion of coal usage.
Waste to energy plants	Waste from industries, urban areas and agricultural areas is treated to produce various forms of energy such as biogas and CBG, which can be further used for generating power.
Non-power applications	
Compressed biogas (CBG)	Upon anaerobic digestion, organic waste such as cattle dung and municipal solid waste can produce biogas. This biogas, when compressed further, produces CBG for use in vehicles. CBG has a calorific value of about 52,000 KJ/Kg[40] and can replace petrol and diesel in vehicles with engine cycle modifications.
Bio-ethanol	Biomass with a high starch content, or sugar base, can be used to produce bioethanol through fermentation for blending with petrol in vehicles for transportation. The blending of 300 crore litres of bioethanol during Ethanol Supply Year (ESY – December to November) 2021–22[41] makes a strong case for the increased usage of bioethanol in the future.
Bio-diesel	Through the transesterification of crops such as plant seeds, vegetable oils, animal fats and jatropha, biodiesel is being produced for blending with diesels in vehicles for transportation. Moreover, it has properties comparable with those of diesel.

39 PwC analysis

40 Press Information Bureau – press release

41 Press Information Bureau – press release

Bi-jet ATF	Biomass resources such as agricultural waste and vegetable oils have the potential to produce biojet ATF. A flight from Dehradun to Delhi, wherein 25%[42] of the fuel used was biojet ATF, has boosted the confidence of stakeholders about its large-scale adoption to operate flights.
Pellets and briquettes for industries	Pellets and briquettes, a compressed and refined form of biomass, offer a reliable alternative to coal in industries for thermal applications. These can help industries and corporate houses to considerably reduce their carbon footprint.

For India to reach its net zero goal, a sustained focus needs to be placed on deeper decarbonisation which can be achieved using carbon-neutral and carbon-negative solutions.

Creating a market ecosystem for bioenergy

Devising avenues for waste management: The need of the hour is to establish a reliable supply chain for biomass which includes collection, transportation and handling of biomass feedstock. Given that biomass resources are available across various geographies in India, waste processing plants can be set up and mapped using the geographic information system (GIS). As these plants would supply biomass, the real-time location of transport vehicles from these plants to consumption centres can be tracked using GIS mapping in order to ensure supply chain optimisation. Subsequently, storage options can also be planned in the vicinity of these consumption centres.

Segregating waste at source: To generate energy from municipal solid waste, the first consideration is to ensure the segregation of this waste at source. At present, India has only a handful of cities with a waste segregation rate of more than 90%.[43] Moreover, resource recovery from the waste for energy generation and safe disposal of the residue is a costly proposition for companies. Unsafe disposal of waste leads to the release of toxic pollutants such as leachate and methane into the air. Therefore, it is important to establish a system for the streamlined segregation of waste by proper recycling and secure the operation of waste-to-energy and CBG plants.

Developing a biomass trading platform: To mitigate the effects of stubble burning and establish a streamlined price mechanism for dry biomass procurement (including agri-waste, animal dung and poultry litter), there is a pressing need to set up a trading platform/marketplace for raw and processed biomass trading. The main aim of intervention is the collection and mobilisation of raw material to the plant/industry, which could be facilitated by a biomass trading platform. On the supply side, developing a platform to collect and process biomass will help generate additional employment opportunities in rural areas and increase the source of income for biomass suppliers. On the demand side, a trading platform will ensure regular and consistent biomass supply for processing in industries and power plants. In the absence of a formal trading exchange, it is necessary to ensure high levels of transparency and clear regulatory frameworks to reduce uncertainty for economic agents and build trust between them. This can incentivise the development of the bioenergy sector in the country.

Ensuring efficient aggregation of biomass: Companies involved in waste utilisation often face challenges related to the timely and adequate availability of waste, especially biomass, for their processes. Such companies or industries could facilitate waste segregation by entering into long-term contracts with third parties or aggregators specialising in such activities, who would then take up the role of waste aggregation and supply it to the end users, based on their requirements. The two parties can agree on a price per unit of waste supply, along with a delivery schedule. Such agreements will also reduce the need for the end users to maintain a dedicated storage facility while increasing employment opportunities across the value chain.

42 International Energy Agency (IEA), Country Report: Implementation of bioenergy in India

43 Observer Research Foundation - Solid Waste Management in Urban India: Imperatives for Improvement

Developing a market mechanism for biofertilisers: In 2021, NITI Aayog set up a task force for the production and promotion of cattle dung-based biofertilisers and organic fertilisers.[44] This task force aims to encourage commercial production, packaging, marketing and distribution of biofertilisers – including the development of brands – and address challenges in marketing and certification. In addition, the marketing and distribution of biofertilisers and biomanure which are by-products of CBG production or biogas-to-power production also require sustained focus. The slow uptake of biomanure discourages private sector investment in the biogas and CBG sectors in the country. Thus, there is an urgent need for a structured market for selling biomanure at fixed prices so that the returns from such sales can add to project returns and improve project financials, further creating incentives for private sector investments. Moreover, a CBG plant of 1 TPD capacity can normally produce nearly 3 TPD of biomanure, which can replace the fertiliser currently being used for crops and reduce the burden of fertiliser subsidies on India's exchequer. Therefore, typically, a 1-TPD CBG plant can help save approximately INR 2.2 crore of fertiliser subsidy.[45]

The recent Union Budget is likely to create a market mechanism for biofertilisers. The Centre aims to set up 10,000 Bhartiya Prakritik Kheti Bio-Input Resource Centres over the next three years to create a national-level distributed micro-fertiliser and pesticide manufacturing network and promote natural farming among farmers. This can provide impetus to the biofertiliser sector if this platform is utilised sufficiently to promote biofertlisers resulting as a byproduct of CBG production or biogas-to-power production. *(PIB press release)*

Facilitating cross-sectoral collaborations

Collaboration with vehicle manufacturers to support higher biofuel blends: With India setting its vision for E20 fuel by 2025 (from the earlier target of 2030), it is crucial for the bioenergy sector to work closely with vehicle manufacturers, the Society of Indian Automobile Manufacturers (SIAM) and the Automotive Research Association of India (ARAI) to explore opportunities for customising vehicle designs – including engines – to accommodate a higher ethanol-blending proportion in the overall fuel mix. Experiences of biofuel blending in international markets could also be useful for the industrial and transport sectors. In Brazil, for instance, bioethanol blending has been a success and the country is considered a leader in the sector.[46] Therefore, further technical R&D needs to be undertaken to explore opportunities with flexible fuel vehicles (FFVs), which would be crucial with the increasing ethanol blending envisaged in the future.

Collaboration between industry and academia on sectoral R&D: It is important to promote R&D in the bioenergy sector in India, especially through collaborations with foreign research institutes. The Treasuries and Accounts (T&A) funds of the Government of India could be utilised for such collaborations with government-to-government cooperation channelled through central-level research institutes. This could also be routed through bilateral or multilateral agencies to foster a good R&D base in biomass supply chain, technology and logistics, which will help define a clear roadmap for Indian investments in the sector, creating a win-win situation for both the private and public sectors.

44 *NITI Aayog – Report on "Roadmap for Ethanol Blending in India 2020-25"*

45 *PwC analysis*

46 *NITI Aayog Task Force on Production and Promotion of Biofertilizers and Organic Fertilizers*

Concessional financing for the bioenergy sector: One of the most effective ways to make affordable financing accessible to the private sector is by facilitating concessional financing or soft loans by way of a line of credit to financial instituions (FIs)/public sector undertakings for funding bioethanol, CBG, biomass-based cogeneration and biomass power plants in the country. Further, interest subvention could be enabled to motivate companies or industry players to install such technology. Support in the form of an interest rate subsidy can also be extended to the proposed depots for setting up state-of-the-art facilities at the block and/or district levels.

Supporting bioenergy projects under partial risk sharing facility and similar programmes: The International Bank for Reconstruction and Development (IBRD) has provided support for a project titled Partial Risk Sharing Facility for Energy Efficiency (PRSF)[47] which aims at providing guarantees to participating financial institutions (PFIs) – i.e. banks, FIs and non-banking financial companies (NBFCs) – for energy efficiency loans extended to energy service companies (ESCOs). The implementation of bioenergy projects reduces or eliminates the use of conventional fuels, and such programmes under similar mechanisms can help improve the affordability and access to finance for bioenergy projects.

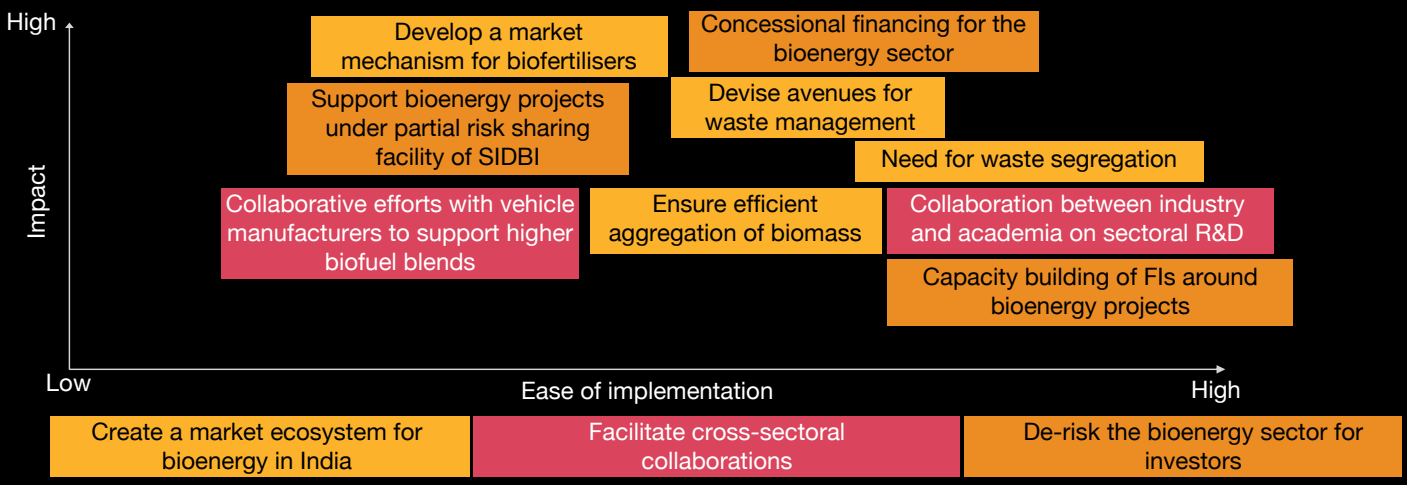
Capacity-building of FIs around bioenergy projects: Availability of finance in the bioenergy sector continues to be a challenge, with projects in the sector being categorised as risky by the financing community. Therefore, it is important that FIs and banks effectively appraise such projects while protecting themselves from the risk of default. Moreover, it is important to undertake capacity building of FIs and banks on the usage of biomass and other organic waste, evaluating the financial soundness of such projects, sustainable business models and associated benefits, and managing offtaker arrangements to boost the confidence of the financing community and ensure a seamless flow of funds into the sector.

47 Small Industries Development Bank of India – Partial Risk Sharing Facility for Energy Efficiency (PRSF)

Way forward

The Government of India's net zero pledge may prove instrumental in accomplishing the national climatic goals, given the prevailing emissions trajectory and widening intensity of climate change. To this end, an achievable target for India's progress towards attaining these goals is the scaling up of bioenergy solutions which can mitigate the environmental impact of energy generation.

For the effective implementation of bioenergy projects in the country, the key action plans suggested in this paper and derived from our analysis have been plotted in the graph below, based on their ease of implementation and impact potential:



Sustained private sector investment is vital for the bioenergy sector to achieve compound growth and contribute to the successful progression of India's clean energy trajectory. This would require developing resilient supply chains, which can ensure viable long-term biomass sourcing for power plants and private sector use. This can also streamline the price of biomass in the market.

In this regard, the sources of biomass that can be used as feedstock in modern bioenergy supply chains need to be well understood. It was highlighted at the beginning of this paper that 750 MMT of agri-based biomass is available in the country. However, only a small fraction of the surplus being generated (230 MMT) is utilised for energy conversion. There is also a need to focus on other sources of waste such as non-food crop residues and organic waste, which offer similar or, in some cases, better calorific value and can feature as potential feedstock for bioenergy generation in India. Forest industries are also coming up as potential feedstock suppliers of products such as saw wood and pine wood, which are cheaper and abundantly available. According to the IEA, the useful energy content of the feedstock can become as high as 130 Mtoe by 2040.[48] Therefore, a sustainable and viable long-term supply chain of biomass feedstock has to be established.

Another focal point is the provision of bankable innovative conversion technologies for bioenergy production, alongside a stable and supportive policy and regulatory regime, which would provide the much-needed impetus for sectoral development. Banks still lack the requisite knowledge on how to viably appraise bioenergy projects and often deem them as risky. Thus, concessional financing and partial risk facilities could encourage private sector investment in the bioenergy sector. Moreover, strategic financial solutions such as credit enhancement could boost banks' confidence in lending to the sector.

Bioenergy has the potential to decarbonise not only the electricity sector but also the industrial, transport and aviation sectors, in addition to others. Therefore, it is all the more crucial for relevant stakeholders in the market to maintain a sharp focus on this sector.

48 International Energy Agency – India Energy Outlook 2021

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