CLIMAKE

ASPEN NETWORK OF DEVELOPMENT ENTREPRENEURS
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INVESTING IN THE WASTE AND CIRCULARITY SECTOR IN INDIA

Agricultural, Food and Biomass Waste Recycling Guide

ABOUT ANDE

The Aspen Network of Development Entrepreneurs (ANDE) is a global network of organizations that propel entrepreneurship in developing economies. ANDE members provide critical financial, educational, and business support services to small and growing businesses (SGBs) based on the conviction that SGBs create jobs, stimulate long-term economic growth, and produce environmental and social benefits.

As the leading global voice of the SGB sector, ANDE believes that SGBs are a powerful, yet underleveraged, tool in addressing social and environmental challenges. Since 2009, ANDE has grown into a trusted network of over 250 collaborative members that operate in nearly every developing economy. ANDE grows the body of knowledge, mobilizes resources, undertakes ecosystem support projects, and connects the institutions that support the small business entrepreneurs who build inclusive prosperity in the developing world. ANDE is part of the Aspen Institute, a global non-profit organization committed to realizing a free, just, and equitable society.

ABOUT CLIMAKE

Climake was founded in 2020 as a platform to make climate finance more accessible. Climake focuses on improving access to equity and non-dilutive capital, for startups, and to support investors to improve funding flows to the climate action, especially into emerging sectors. Climake's work focuses on 4 core areas: investment advisory for high-potential climate startups, development and adoption of innovative financing structures to mainstream climate innovations, research and knowledge sharing on climate finance trends, and advocacy with investors to focus on climate action.

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IKEA Foundation

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ABBREVIATIONS

2G:	Second-generation
AIF:	Alternative Investment Fund
bio-CNG:	Bio-compressed natural gas
CSR:	Corporate social responsibility
DFI:	Development finance institution
EBITDA:	Earnings before interest, taxes, depreciation, and amortisation
EPC:	Engineering, procurement and construction
FY:	Financial year
INR:	Indian rupee
kL:	Kilolitre
MoPNG:	Ministry of Petroleum and Natural Gas
MSWM:	Municipal solid waste management
MW:	Megawatt
NBFC:	Non-banking financial company
NTPC:	National Thermal Power Corporation
PAT:	Profit after tax
PE:	Private equity
PES:	Payments for ecosystem services
RPO:	Renewable purchase obligations
SAF:	Sustainable aviation fuel
SDG:	Sustainable Development Goal
SGBs:	Small and growing businesses
TReDS:	Trade receivables electronic discounting system
USAID:	United States Agency for International Development
VC:	Venture capital

CHAPTER 1: THE OPPORTUNITY IN AGRICULTURAL, FOOD AND BIOMASS WASTE RECYCLING

Biomass, sourced from various sectors, follows a hierarchy of availability, with agriculture ranking highest, followed by municipal waste, forests, industries and aquatic ecosystems.[1] Agricultural biomass, which primarily consists of post-harvest crop residue and waste from livestock, is the largest source of waste in India – the country generates approximately 350 million tonnes annually.[2] Agricultural and biomass waste generation is also expected to increase as food production increases, especially for staple and cash crops like rice, wheat, maize and cotton.

Biomass is used in diverse applications from fodder for cattle and household cooking to the production of biogas, manure and renewable fuels such as bioethanol and biodiesel. Biomass caters to a substantial portion of India's rural energy demand, fulfilling approximately 80% of it.[3] Low-cost biomass solutions play a particularly significant role in rural settings, where small-scale energy needs predominate. Conversely, more sophisticated biomass technologies are used in applications such as energy generation or fuel production, especially for large-scale operations.

THE OPPORTUNITY

India presents significant opportunities for new businesses to create value by leveraging agricultural, food and biomass waste. These opportunities relate to improved collection, waste-to-energy solutions, and diverse biomaterials. These cascade into specific opportunity areas across the value chain, which are summarised below (and detailed further later in this guide):

- Implementing systems for the collection of on-farm stubble and crop waste can mitigate crop burning by converting agricultural waste into briquettes for industrial fuel. This initiative benefits from government support, which can facilitate adoption and scale.
- Early-stage business models focused on the collection of used cooking oil can pave the way for producing biodiesel and sustainable aviation fuel (SAF), addressing both waste management and renewable energy needs.
- There is a growing demand for bioenergy solutions, particularly biogas, which can provide additional value for small farms. Biomass-based compressed natural gas (Bio-CNG) is emerging as a sustainable alternative in the automotive sector, offering a cleaner fuel option.

1. Negi H., Suyal D.C., Soni R., Giri K., Goel R., 2023, Indian Scenario of Biomass Availability and Its Bioenergy-Conversion Potential. Energies. Retrieved from: https://www.mdpi.com/1996-1073/16/15/5805
2. Indian Council of Agricultural Research (ICAR), 2020, Creating Wealth From Agricultural Waste. Retrieved from: https://icar.org.in/sites/default/files/Circulars/Creating-Wealth-From-Agricultural-Waste.pdf
3. Chauhan K., Singh V.P., 2023, Prospect of Biomass to Bioenergy in India: An Overview, Materials Today: Proceedings. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S2214785323005151

- Innovations in biochar technology present an opportunity to transform agricultural waste into carbon-sequestering biochar, which can enhance soil quality and support sustainable agricultural practices.
- The production of drop-in biofuels, such as biodiesel and bio-jet fuel derived from agricultural waste, aligns with national objectives to increase non-fossil fuel sources and promote sustainable energy solutions.
- Biomaterials offer improved material characteristics and lower carbon footprint for a wide range of industrial and commercial applications, especially as replacements for rare earths and virgin plastics.

These opportunities illustrate the potential for small and growing businesses (SGBs) to engage in innovative waste management practices that contribute to environmental sustainability while driving economic growth in India's agricultural sectors.

THE OPPORTUNITY DRIVERS

The opportunities in agricultural, food and biomass waste recycling make it one of the highest potential segments of India's waste and circularity sector, presenting significant growth opportunities for companies and investment opportunities for investors. There are three main reasons for the growth of the agricultural, food and biomass waste recycling industry in India:

Figure 1: The three main drivers for agricultural, biomass and food waste circularity (Climake analysis)

1 High-value applications and opportunities in new bioenergy and biofuels are creating a greater focus on recycling

Traditionally, biomass has been extensively utilised for residential heating, especially in northern India. A substantial portion of India's population, around 41%,[4] still relies on biomass for cooking. However, this reliance comes with environmental consequences, as the combustion of biomass emits carbon, contributing to environmental pollution. India's traditional usage of biomass for heating is declining, with oil and gas gradually replacing it. Concurrently, the utilisation of biomass for power generation is steadily gaining momentum, marking a significant shift in its application.

To incentivise the adoption of cleaner biomass alternatives, India offers financial support to manufacturers of biomass pellets or briquettes,[5] promoting their utilisation in heating and power generation industries. Additionally, there is a burgeoning interest in biofuels derived from biomass feedstock. Presently, biofuels constitute a negligible fraction of India's transport fuels, with bioethanol representing 3% of gasoline consumption in 2019.[6] Paddy straw, a by-product of rice cultivation, holds promise as a sustainable raw material for various industries. Pilot projects[7] have demonstrated the viability of using biomass to produce sustainable paper, packaging materials and furniture panels, offering a potential avenue for reducing agricultural waste.

Further bolstering the bioenergy sector, the Ministry of Power mandates a 5% biomass co-firing requirement in coal-based thermal power plants.[8] This initiative not only promotes renewable energy but also helps energy companies and large enterprises meet their non-solar renewable purchase obligations (RPOs). Initiatives such as the development of bio-jet fuel[53] for aeroplanes and the promotion of bio-CNG[9] highlight India's commitment to advancing sustainable energy alternatives across sectors.

2 The burning of crop residue is being curbed at the source in line with new policy directions

The open-air burning of agricultural residue poses significant environmental and public health challenges across India. In regions such as New Delhi and its environs, where air quality is notoriously poor, approximately 30%[10] of the smog faced by the city is attributed to burning crop residue. Despite its detrimental effects, residual biomass from agricultural activities, including paddy straw and sugarcane residue, holds immense potential for reuse and upcycling.

4. Centre for Society and Environment, 2023, India's Transition to E-cooking. Retrieved from: https://www.cseindia.org/india-s-transition-to-electric-cooking-12024
5. Ministry Of New and Renewable Energy, Biomass Programme. Retrieved from: https://mnre.gov.in/bio-mass/
6. IEA Bioenergy, 2021, Implementation of Bioenergy in India. Retrieved from: https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_India_final.pdf
7. van de Pas B., 2022, Biomass India: turning waste into valuable products. Retrieved from: https://nlplatform.com/articles/biomass-india-turning-waste-valuable-products
8. Ministry of Power, 2023, Revised Biomass Policy mandates 5% biomass co-firing in Thermal Power Plants from FY 2024-25: Union Minister for Power and New & Renewable Energy. Retrieved from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1945245
9. The Energy and Resources Institute, 2023, Comprehensive Environmental and Social Sustainability Assessment of Bio-CNG as a Vehicular Fuel in India. Retrieved from: https://www.teriin.org/policy-brief/assessment-bio-cng-vehicular-fuel-india
10. Maas K., Joshi S., 2021, Final Evaluation of 'Omzet met Impact' Programme. Retrieved from: https://www.government.nl/binaries/government/documenten/reports/2021/10/22/final-evaluation-of-omzet-met-impact-programme/Case%2Bstudy%2Breport%2BBiomass.pdf

India introduced a blanket ban on burning crop residue in 2015. Then, in 2019, the country introduced payments for ecosystem services (PES) contracts, which pay farmers directly if they stop burning.[11] In recent times, attempts have been made to create uses for stubble to make it economically lucrative. Producing power from this biomass is an option that has received attention. There is a plant in Punjab state that uses rice straw to produce power. The company that runs this power plant gives farmers machines to remove the stubble and ensures that they are collected in a timely fashion from the fields. The plant generates 12 MW of power using 120,000 tonnes of stubble collected from close to 15,000 farmers.[12]

Currently, the cost of mechanised harvesting per hectare is far more economical than the cost of mechanised removal of crop residue. Subsidies from the government and continued demand for crop residue as a resource are key to reduced emissions from its burning. For instance, the National Thermal Power Corporation (NTPC) has been instructed by the Indian government to combine close to 10% of crop residue pellets with coal to generate electricity. Through that programme, the farmers receive a financial return of about $77 per tonne of agricultural leftovers.[13]

3 New technology has been established that offers the chance to unlock novel, high-value outputs and deliver scale

Today, biomass caters to a significant portion of India's rural energy demand.[14] Pelletisation and briquetting[15] are the most common ways to enhance the energy density of biomass and improve its handling, storage and combustion characteristics. Beyond these established methods, advanced technology-driven approaches for generating biomass energy include thermochemical processes like combustion, gasification and pyrolysis, as well as biochemical processes such as anaerobic digestion, fermentation and trans-esterification. The selection of processing methods depends on various factors including feedstock characteristics, physio-chemical state and the intended applications of the fuel products derived from the process, which may encompass key commercial use cases like heating, electricity or transportation fuel.

Apart from energy generation, biomass and its feedstock offer avenues for creating a diverse range of products across multiple categories. These include agricultural products such as biochar, organic manure and high-quality animal feed, as well as consumer products like handmade paper and food items. Moreover, biomass can be used to produce other commodities such as dyes and microbial proteins. Based on the type of technology used and the context, biomass can lead to direct end products or it can act as an input for producing diverse types of new and high-value outputs, particularly bioenergy, biofuel and bioplastics.

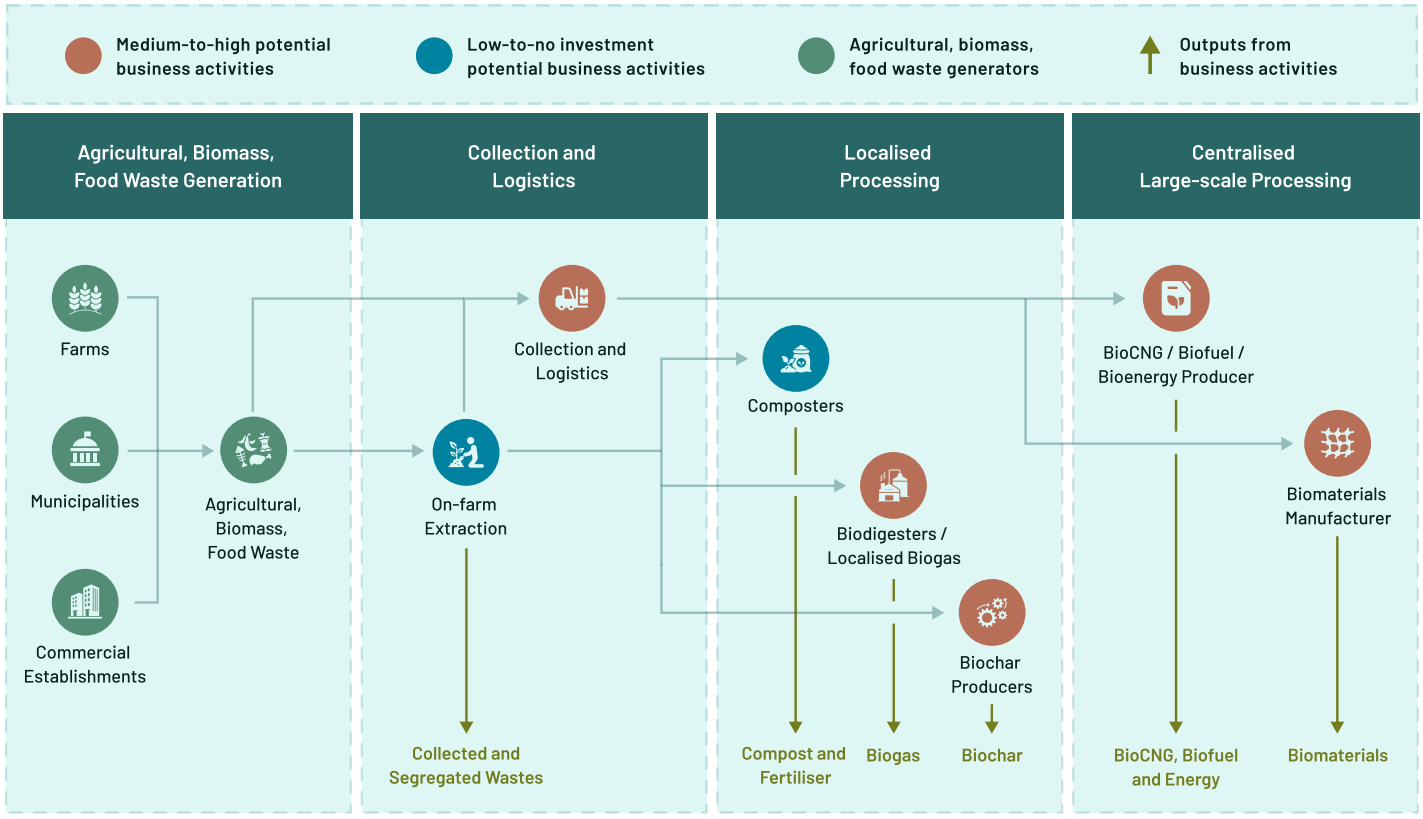
11. National Bureau of Economic Research, 2023, Paying Indian Farmers Not to Burn Agricultural Residue. Retrieved from: https://www.nber.org/digest/20232/paying-indian-farmers-not-burn-agricultural-residue
12. Down To Earth, India's burning issue of crop burning takes a new turn. Retrieved from: https://www.downtoearth.org.in/agriculture/river-of-fire-57924
13. Kaur K., Singh P., 2022, Crop Residue Burning in India: Potential Solutions. Retrieved from: https://www.intechopen.com/chapters/84274
14. Chauhan K., Singh V.P., 2023, Prospect of biomass to bioenergy in India: An overview, Materials Today: Proceedings
15. Steamax, Pelletization and Briquetting, Retrieved from: https://steamaxindia.com/pelletization-and-briquetting/

CHAPTER 2: THE CASE FOR INNOVATION IN AGRICULTURAL, FOOD AND BIOMASS WASTE RECYCLING

The Agricultural, Food and Biomass Waste Recycling Value Chain

Waste from agriculture, food, and biomass is being harnessed as recycled products that can be used either directly or as input materials in other processes. Startups and established companies in the farming, fuel and energy sectors are building solutions to tap into this organic waste and recycle it for diverse use cases. Currently, most of those uses are relatively low-value applications in farms in rural areas, but many new initiatives are focusing on relatively high-value applications in urban locales. As regulations related to biomass sourcing and quality become more defined, there is anticipated to be a shift towards increased formal, high-value usage of biomass. The agricultural, food and biomass recycling value chain is shown below alongside the key business models and outputs generated at each stage of that chain.

Figure 2: Agricultural, food and biomass waste recycling value chain (Climake analysis)



The main business models that form part of the agricultural, food and biomass waste recycling value chain are described below:

Collection and Logistics

Logistics and traceability solutions are critical to aggregating agricultural, biomass and food waste from various sources; directing these materials to biofuel, bio-CNG producers and biomaterials manufacturers. Implementing traceability-enabled logistics provides critical information regarding the source, type and nature of the collected waste, enhancing transparency and efficiency within the supply chain.

In India, we have identified that the existing infrastructure for collecting and managing agricultural, biomass and food waste mainly targets pre-consumer waste: agriculture wastes farms or wastes generated at food processing facilities. This focus allows for better control over the volume and characteristics of the waste, making it a more viable option for SGBs in this sector.

In contrast, post-consumer organic waste is primarily managed by municipalities and is generally directed to landfills as part of municipal solid waste management practices.[16] This is a significant gap, as the collection and processing of post-consumer waste remain largely unoptimised.

In the short-term SGBs will find most value by focusing on pre-consumer waste. SGBs can leverage logistics and traceability solutions to enhance waste aggregation processes, improve resource recovery and eventually contribute to the production of sustainable biofuel and biomaterial industries in India.

On-farm Extraction

Extractors address the challenge of managing standing agricultural waste, specifically crop stubble, which is frequently burned due to the inconvenience of manual removal. This results in substantial losses of valuable materials that typically end up being burned, thereby exacerbating environmental issues.

Mechanical extractors facilitate the removal of these waste materials, which are then further processed and utilised. These mechanical machines mitigate the labour-intensive task of collecting and extracting waste on farms.

16. The Energy and Resources Institute, State of Waste Management Report, 2023. Retrieved from: https://www.teriin.org/sites/default/files/2023-10/1695795956State%20of%20Waste%20Management%20Report.pdf

The adoption of on-farm stubble and crop waste extractors equipment in India is limited,[17] primarily because of concerns about its financial viability. Many farmers find it challenging to justify the costs associated with using mechanical solutions. This hinders their wider implementation. Increasing government support for encouraging the adoption of these solutions is an important systems-level opportunity. If new businesses can provide solutions for on-farm extraction that do not impose additional costs or effort on farmers - such as zero capex or low opex - it would significantly enhance the adoption rates of such technologies.

Other than systems-level change and accessible solutions, adoption is driven by integrating extraction services with a value chain that converts the collected waste into valuable products. While offering extraction alone may not be financially viable, there is considerable potential for innovation in developing low-cost, efficient extractors that align with farmers' economic needs.

Composters

Composters employ various processes – aerobic composting, vermicomposting and industrial-scale methods like windrow and in-vessel composting – to transform food and agricultural waste into nutrient-rich compost. The scale of composting operations vary significantly, from small-scale home units to large industrial facilities designed to manage agricultural waste.

Composting solutions are relatively simple to implement in India, which isa challenge in differentiating these options as viable investment opportunities. Informal composting practices are common within local communities, utilising small to medium-scale composting units given the absence of structured waste collection systems, particularly in rural and semi-urban areas.

The nutrient-rich compost produced by these operations often competes with other agricultural inputs, such as cheaper, commercially available fertilisers, which can limit farmers' willingness to adopt composting practices. SGBs in this space would benefit from strengthening the value proposition of composting to encourage farmers to use compost rather than commercial fertilisers.

To improve investability, larger-scale composting operations should be integrated into complementary business models that provide additional value. For instance,partnerships with local farmers, retailers or food producers to create a closed-loop system that benefits all stakeholders.

17. DTE Staff, CSE experts explain: Strategies to reduce crop residue burning for air pollution mitigation, Down to Earth, 2023 Retrieved from: https://www.downtoearth.org.in/pollution/cse-experts-explain-strategies-to-reduce-crop-residue-burning-for-air-pollution-mitigation-92749

In urban regions, there is a growing opportunity for automated, low-cost composting solutions targeted at homes and apartments, particularly among India's eco-conscious consumers. These innovations would appeal to urban dwellers looking to contribute to sustainability efforts while managing their organic waste more effectively.

Biodigesters / Localised Biogas

Biogas solution providers offer biodigesters integrated into biomethanation systems. This enables farmers to harness their agricultural waste as an alternative energy source while also generating valuable by-products like fertilisers. On-farm processing empowers farmers to repurpose waste, ultimately reducing costs and fostering energy independence.

Biogas solutions are technologically validated in India, demonstrating efficiency and reliability.[18] However, India's vast expanse of agricultural land (over 1.5 million square kilometres[19]) combined with the fragmented structure of the farming community – where over 50% of farms are operated as smallholder lands – presents a unique opportunity for new entrants to the biogas market.

The prevalence of smallholder farms creates a significant market for biogas solutions, as these smallholder farmers seek affordable and efficient ways to manage waste and reduce reliance on external energy sources. Biogas systems can provide a sustainable energy alternative tailored to their specific needs.

SGBs have the potential to innovate in the design and engineering, procurement and construction (EPC) of biogas systems. By focusing on capex cost reduction and enhancing the user experience, these companies can develop solutions that are scalable and accessible to a diverse range of agricultural customers.

Biochar Producers

Biochar, a carbon-rich material generated through the thermochemical process of pyrolysis, offers a range of beneficial applications. It enhances soil fertility, improves water retention and promotes microbial activity, serving as a valuable tool for sustainable agriculture. Additionally, biochar plays a critical role in high-quality carbon sequestration, contributing to climate change mitigation, and can also be utilised for water filtration to eliminate contaminants. It also has potential as a livestock feed additive[20], and reducing methane emissions.[21]

18. R. Prajapati, The potential of Biogas to reduce India's dependency on fossil fuels and lower energy costs, ET Insights, 2024. Retrieved from: https://etedge-insights.com/industry/energy/the-potential-of-biogas-to-reduce-indias-dependency-on-fossil-fuels-and-lower-energy-costs/
19. Statista, 2024. Agricultural land in India 2009-2021. Retrieved from: https://www.statista.com/statistics/1455241/india-agricultural-land/
20. Schmidt, H. & Hagemann, N. & Draper, K. & Kammann, C. (2019), The use of biochar in animal feeding. PeerJ. 7. 10.7717/peerj.7373. Retrieved from: https://www.researchgate.net/publication/334805975_The_use_of_biochar_in_animal_feeding
21. Biochar: The nature-based solution to the growing threat of methane emissions, Insight Brief, International Biochar Initiative, 2023. Retrieved from: https://biochar-international.org/wp-content/uploads/2023/05/Biochar-Methane-Paper-3.pdf

The production of biochar varies significantly depending on the feedstock, desired end product and operational scale. Methods range from simple kilns for small-scale production to advanced pyrolysis reactors suitable for industrial-scale manufacturing. This versatility in production techniques allows for adaptability to diverse market demands.

In India, emerging biochar technology providers are focusing on developing pyrolysis solutions that yield higher-efficiency products.[22] However, these providers face challenges similar to those encountered in the biogas sector, particularly the fragmented nature of the farming community. SGBs co-solving these challenges is essential for achieving scale, to maximise the potential of biochar production and utilisation.

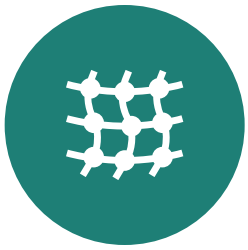
Bio-CNG / Biofuels / Bioenergy Producers

Producers of bio-CNG and biofuels source agricultural and biomass waste to establish centralised facilities aimed at generating large-scale supplies for industrial, automotive and other high-value applications. These biofuels are cleaner and cost-effective alternatives to traditional fossil fuels, aligning with global sustainability goals. Government policies, from energy and fuel related ministries, in India facilitate the adoption of these fuels by promoting biofuels and bio-CNG derived from second-generation or waste sources.

The success of centralised biofuel facilities hinges on the development of effective logistics and sourcing supply chains for agricultural and biomass waste. This centralisation allows for economies of scale but also requires robust systems to ensure a consistent and reliable feedstock supply.

India's bio-CNG and biofuels sector is relatively nascent yet poised for significant growth, especially as the Ministry of Petroleum and Natural Gas (MoPNG) mandates stipulate that 20% of fuels must come from ethanol and non-fossil sources.[23] Utilising agricultural waste is advantageous because it mitigates concerns related to food security and supply shortages that could arise from direct crop extraction. Some SGBs are also innovating by cultivating non-edible plants on barren land to serve as feedstock for energy production. This approach not only helps control the characteristics of plant inputs used in energy and fuel generation but also contributes to sustainable land use.

22. M. Kumar, Can engineered biochar solve India's agricultural emissions?, Land & Climate Review, 2022. Retrieved from: https://www.landclimate.org/can-engineered-biochar-solve-indias-agricultural-emissions/
23. Press Information Bureau, Government of India. Ministry of Petroleum and Natural Gas. India's Ethanol Push: A Path to Energy Security. Retrieved from: https://pib.gov.in/PressNoteDetails.aspx?NoteId=153363&ModuleId=3&reg=3&lang=1



Biomaterials Manufacturers

Biomaterials manufacturers are turning to agricultural waste as a raw material for non-energy applications, like creating textile fibres. Using agricultural and biomass waste in such ways not only provides an affordable source of raw materials but also addresses critical issues associated with diverting crops from food security. This is significant in a country like India, where access to nutritious food isa pressing concern.[24]

India has abundant resources for biomaterial manufacturing from biomass wastes, to natural materials, positioning itself as an opportunity sector. However, manufacturers face challenges related to the predictability of supply, including factors like volume, quality and the specific characteristics of the agricultural waste. These variables influence the properties of the resulting biomaterials.

If manufacturers can effectively address supply chain predictability, the potential applications for commercially produced biomaterials are vast. These materials would serve as sustainable alternatives to plastics and precious metals across industries, from packaging to construction. By harnessing agricultural waste, biomaterials manufacturers can not only contribute to environmental sustainability but also align with India's broader goals of enhancing food security and promoting circular economy practices.

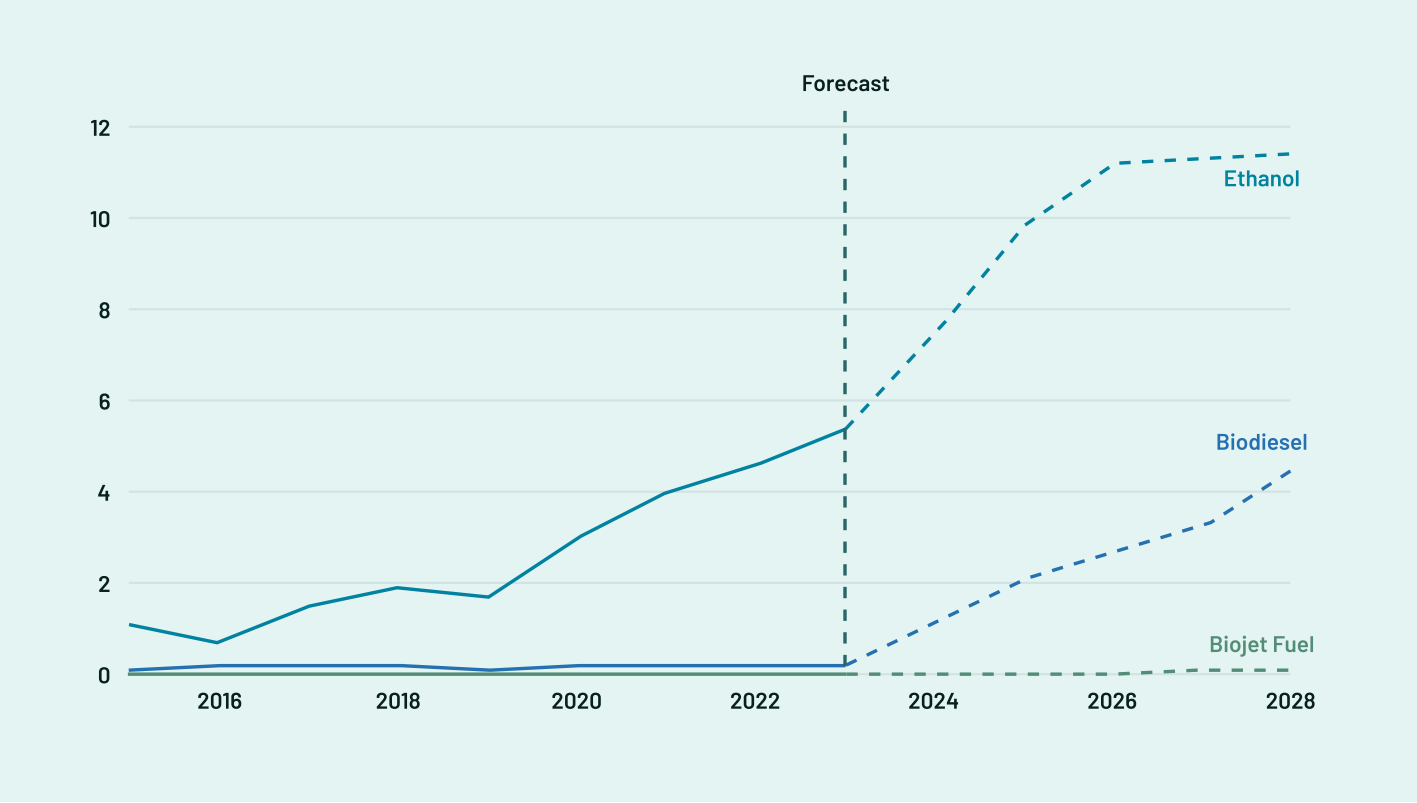
24. Ministry of Family and Health Welfare, Government of India, National Family Health Survey 2019-21. Retrieved from: https://mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf

The Current State of Agricultural, Food and Biomass Waste Recycling in India

Even though a significant amount of India's crop residue is burnt off, the country still has a biomass surplus.[25] If collection rates increase, that surplus will grow. Today, recycled agriculture and biomass waste meet 32% of India's primary energy demand,[26] mainly in rural regions. However, the current share of biofuels in total fuel consumption is extremely low and mostly restricted to the 5% blending of ethanol in gasoline, which the Indian government has made mandatory in ten states.

India is the world's third-largest producer and consumer of ethanol, and demand for the biofuel, which nearly tripled between 2018 and 2023, now stands at nearly 12%. Most of that ethanol comes from sugarcane, with the remainder from food grains such as maize and surplus rice stocks.[27]

Figure 3: Increasing biofuel consumption in India, 2015 to 2028 (Source: IEA[28])



25. Ministry of New and Renewable Energy, 2023. Bio-Energy and Waste to Energy – Recovery of Energy From Urban, Industrial and Agricultural Wastes/Residues and Role of Urban Local Bodies In Energy Management. Retrieved from: https://sansad.in/getFile/lsscommittee/Energy/17_Energy_41.pdf?source=loksabhadocs#page=30
26. EAI, India Biomass Energy. Retrieved from: https://www.eai.in/ref/ae/bio/bio.html
27. IEA, 2024, India could triple its biofuel use and accelerate global deployment. Retrieved from: https://www.iea.org/commentaries/india-could-triple-its-biofuel-use-and-accelerate-global-deployment
28. IEA Bioenergy, 2021, Implementation of Bioenergy in India. Retrieved from: https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_India_final.pdf

In 2018, India's National Policy on Biofuels[29] set blending targets for ethanol (20% blending by 2030) and biodiesel (5% by 2030), detailed feedstock requirements for different fuels and laid out the responsibilities of 11 government ministries to coordinate actions. If the blending targets are to be met, the use of feedstock (sugar, starch and other residues) will increase by almost three times in the same period.

To diversify feedstocks beyond sugar cane, India provides separate pricing for maize-based ethanol. This also includes ethanol produced from agricultural residues such as cotton stalks, wheat straw, rice straw, bagasse and bamboo. These types of residues are obtained after harvesting on fertile land. In addition to these farmed crops, India also has various wild plants that could potentially be used for biodiesel production, including Jatropha curcas, Napier grass, neem and mahua. These wild plants can be grown on wasteland, of which India has about 50 million hectares.[30]

29. Ministry of Petroleum and Natural Gas, National Policy on Biofuels. Retrieved from: https://mopng.gov.in/en/page/11
30. Ministry of Rural Development, Department of Land Resources. Wasteland Atlas of India-2019. Retrieved from: https://dolr.gov.in/wasteland-atlas-of-india-2019/

Investable Business Models for SGBs

The following four emerging areas in the agricultural, food and biomass waste recycling ecosystem could offer the potential for innovative SGBs to attract significant investment in the next decade.

1 COLLECTION OF ON-FARM STUBBLE AND WASTE CROPS

Context and opportunity

Crop burning is a significant issue in India, which is often related to the difficulties of extracting and collecting on-farm stubble and waste crops – it is cheaper and less intensive for farmers to burn fields to remove them. On-farm stubble and waste crop extractors have been developed and introduced but adoption is low because of the financial barriers farmers face. However, government support for such solutions is increasing, making the adoption of new technology in this field increasingly viable.

The Solid Waste Management Rules, 2016 mainly focus on the proper segregation and disposal of agricultural waste and biomass.[31] Transforming such waste into resources is being driven at the state level, particularly for waste-to-energy use cases. At its most basic level, biomass is compressed into briquettes and can be used to replace coal in steam boilers for several industries. Most startups that focus on the collection and logistics of biomass are also forward-integrated into briquetting, in addition to supplying biomass to high-value generating activities.

Some early examples of startups managing the collection and reuse of used cooking oil have also emerged; this has potential for biodiesel and sustainable aviation fuel (SAF), though early-stage models are currently focused on the logistics of used oil collection.

EXAMPLES OF STARTUPS IN THIS BUSINESS MODEL

Agricultural Residue/Biomass	PRESPL, Biofuels Junction, BiofuelCircle, Buyofuel
Used Cooking Oil	ECOIL, Uranus Oil

31. Central Pollution Control Board, 2021, Annual Report 2020-21 on Implementation of Solid Waste Management Rules, 2016. Retrieved from: https://cpcb.nic.in/uploads/MSW/MSW_AnnualReport_2020-21.pdf#page=8

BIOFUELS JUNCTION - CASE STUDY

ORGANISATION SUMMARY

Year of foundation: 2016
Number of employees: 54
Biofuels produced: 20,000 tonnes monthly
Collection partners: 100+ partners

Biofuels Junction began with a mission to address agricultural waste challenges while advancing eco-friendly fuel alternatives. They operate across the biomass value chain, specialising in the collection and aggregation of agricultural residue from multiple crops across India, which it then converts into briquettes and pellets. These biomass products serve as a cost-effective, renewable alternative to coal for industrial applications such as steam boilers. The company has secured long-term contracts with over 50 large corporations to supply biomass as a substitute for coal, reinforcing its position as a reliable partner in clean fuel supply. To maintain this supply, the company has developed a network of more than 100 local entrepreneurs who aggregate biomass at the village level, ensuring a decentralised and resilient supply chain.

Biofuels Junction technology-enabled platform optimises collections and logistics, enhancing cost efficiencies that create improved viability to collect agriculture wastes from farmers and provide them with a revenue stream. Initially focused on aggregation with limited engagement with farmers, the company faced hurdles in the seasonal availability of agricultural residue and practices such as crop burning. In response, Biofuels Junction actively engaged with farmers and local suppliers to promote the value of crop residues as viable biomass, thereby creating a stable feedstock supply chain. This stable base in ensuring supply has enabled Biofuels Junction to expand into producing solid biofuel pellets, adding value to the agricultural residue it collected and strengthening its product offerings.

SCALE

- **Existing revenue (FY22–23):** US$ 8.4 million
- **Break-even:** 2022
- **EBITDA:** Positive
- **PAT:** Positive

IMPACT

3,000 rural jobs created

Supporting over 35,000 farmers with an additional income of INR 2,500 per farmer

50,000 tonnes of biomass salvaged into biofuels

Saved 300,000 tons of CO2 emissions

AWARDS AND RECOGNITION

- India's Most Sustainable Startup of the Year, BW BusinessWorld
- Supply Chain Excellence and Management Award, ISAN, 2024

FUNDING RAISED

Type of Funding	Year	Purpose	Funders / Investors
Equity	2021, 2023	Growth and working capital	Schneider Electric, Disruptors Capital
Debt	2022	Working capital	NBFCs, venture debt AIFs

INVESTMENT OPPORTUNITY

Total funding raised to date	Equity: US$ 2 million

The biomass briquettes and pellets market is projected to reach an estimated US$ 16 billion by 2030,[32] globally, driven by increasing demand for sustainable fuel alternatives. With the significant amounts of agriculture waste generated in India, Biofuels Junction is looking to capture the potential on offer and aims to scale operations 10 times over the next five years. The organization has focused on scaling their higher valued add outputs offerings, by expanding its pellet manufacturing capacity and increasing its reach in sourcing agricultural waste biomass to ensure a sufficient supply to meet growing demand. To meet these ambitious goals, Biofuels Junction will require significant growth equity to expand production infrastructure, along with substantial working capital to navigate the seasonal nature of biomass collection while maintaining a consistent supply for its customers year-round.

SUCCESS FACTORS

The solid biomass collection market in India presents a unique opportunity, driven by abundant biomass availability and policy initiatives aimed at curbing crop burning by promoting the circular use of agricultural waste as solid fuel. However, that market also poses significant logistical challenges. Agricultural waste is dispersed across fragmented farm locations, and collecting crop residue often entails additional steps and expenses, which are typically absorbed by biofuel producers. Biofuels Junction has started to successfully navigate these challenges to make eco-friendly fuels from agriculture waste viable and cost-effective, by addressing both demand and supply dynamics: from working with farmers directly to secure supply, to making value-add fuels such as biomass briquettes. This dual approach has positioned Biofuels Junction as one of the few profitable players within this complex segment.

32. The Insight Partners, 2023. Biomass Pellets Market Share, Size, Growth Factors, Opportunity and Forecast to 2030 – COVID-19 Impact and Global Analysis – by Source, Application, and Geography. Retreived from: https://www.globenewswire.com/news-release/2023/08/08/2720893/0/en/Biomass-Pellets-Market-Set-to-Surpass-16-14-Billion-by-2030-with-a-4-9-CAGR-from-2022-to-2030-Wood-Segment-Propels-Market-Growth-The-Insight-Partners.html

2 BIOENERGY, BIOGAS AND HIGH-EFFICIENCY BIO-CNG PROVIDERS

Context and opportunity

Biogas solutions are technologically validated, but the vastness of India's agricultural land and the fragmented nature of farms — more than 50% of which are operated as smallholder lands – still create opportunities for new biogas solution providers to evolve and provide value to farmers.

The Electricity Act of 2003[33] (and its amendments) encourages Electricity Regulatory Commissions at the state level to promote electricity from non-conventional sources, including bioenergy from biomass. The tariff policy under the Act enables the procurement of energy produced by licensed waste-to-energy plants in every state.

In the automotive sector, India has witnessed a notable uptake in the sales of compressed-natural-gas (CNG)-powered vehicles, constituting 8.6% of total sales in 2022.[34] This trend is expected to further evolve with the integration of biomass-based CNG, driven by escalating concerns over vehicular emissions. As manufacturing capacities expand and viable feedstock combinations emerge,[35] the proportion of biomass-derived CNG is poised to increase, signalling a concerted effort to mitigate environmental pollution from vehicular sources.

EXAMPLES OF SCALED-UP BUSINESSES IN THIS SEGMENT

Early stage	ARED, Synod bioscience
Mature stage	gps, EverEnviro, SAEL

33. Ministry of Power, Electricity Act, 2003. Retrieved from: https://powermin.gov.in/en/content/electricity-act-2003
34. Tiwari N., 2022, How Bio CNG rapidly makes inroads into India's automobile market. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S2214785323005151
35. The Energy and Resources Institute, 2023, Comprehensive Environmental and Social Sustainability Assessment of Bio-CNG as a Vehicular Fuel in India. Retrieved from: https://www.teriin.org/policy-brief/assessment-bio-cng-vehicular-fuel-india

RENERGY DYNAMICS - CASE STUDY

ORGANISATION SUMMARY

Year of foundation: 2023
Number of employees: 30
Bioenergy production capacity: 120 tonnes per day

REnergy Dynamics (RED) is a techno-financial platform that develops sustainable bioenergy projects aimed at helping industries reduce their carbon footprints. Specialising in turnkey bioenergy projects, RED aggregates diverse feedstocks for bioenergy generation and produces bioenergy products such as steel tanks and storage balloons.

RED's comprehensive bioenergy production process consists of several stages: feedstock collection, preparation, conversion and energy production. The feedstock is sourced from a variety of streams, including agro-waste (such as stubble and Napier grass) and municipal solid waste. After collection, the feedstock is processed to create pure organic matter suitable for anaerobic digestion. The digestion process results in bioethanol via fermentation and bio-CNG through gasification, a clean renewable fuel that can replace traditional natural gas. Byproducts of the process are converted into organic fertilisers, adding another revenue stream.

RED's bioenergy projects are designed for mid- to large-scale plants (15–30 tonnes per day), and the company differentiates itself by focusing not only on engineering, procurement and construction (EPC) services but also on feedstock aggregation and providing a full-stack solution, including asset financing tie-ups.

Despite being a nascent company, RED has benefited from the extensive experience of its founders in both bioenergy and renewable energy. This deep expertise, coupled with their track record as second-time entrepreneurs, has enabled RED to scale operations quickly, leveraging a combination of technical, commercial and market knowledge. This unique blend of capabilities has allowed RED to establish a strong position in an emerging sector and grow at an accelerated pace relative to other early-stage ventures.

SCALE

- **Existing revenue (FY23–24):** US$ 5 million
- **Break-even:** Not realised yet

IMPACT (numbers not quantified due to the nascence of the organisation)

Supporting farmers with additional income

Biomass salvaged into biofuels

CO2 emissions saved

FUNDING RAISED

Type of Funding	Year	Purpose	Funders / Investors
Founder equity	2023	Growth capital	Founders

INVESTMENT OPPORTUNITY

Total funding raised to date	Bootstrapped

RED operates under an asset-based financing model that is designed to offer project-specific returns to investors, a structure that has proven successful in other renewable energy sectors such as solar and wind. This approach allows RED to attract capital by linking investor returns directly to the performance of individual bioenergy projects. Looking ahead, RED intends to broaden its focus beyond bio-CNG, with plans to explore opportunities in carbon capture and other biofuel technologies, signalling a long-term vision for growth and diversification in the sustainable energy space.

The company is actively seeking both debt and equity financing to fund its ambitious growth plans. The capital will be used to scale the development of bio-CNG plants, enhance its biomass sourcing network and bring in investors to participate directly at the project level. This funding strategy is intended to align with RED's growing order book pipeline, enabling the company to meet increasing demand and accelerate its growth trajectory in the bioenergy sector.

SUCCESS FACTORS

RED has strategically focused on mid-to-large-scale bio-CNG plants, a focus that is focused to meet growing commercial-scale demand, by ensuring cost-efficiencies and scaled outputs. While the bioenergy sector typically requires substantial upfront capital investment, RED has leveraged an asset-based equity investment model that lowers the barriers to entry for new projects, making it easier for industries to move forward with bioenergy initiatives.

In addition to its financial strategy, RED places significant emphasis on understanding the dynamics of rural economies and logistics – key factors that are critical to the successful execution and long-term sustainability of bioenergy projects. The founders' prior experience, including their involvement in large bioenergy and renewable energy firms and successful exits, provides RED with a distinct competitive advantage. This expertise offers the company access to critical capital, advanced technology, industry insights and established market connections, positioning it favourably against many other emerging players in the bioenergy sector, who are typically led by first-time entrepreneurs.

3 DROP-IN FUELS FOR HIGH-EFFICIENCY BIOFUEL FROM BIOMASS AND AGRI-WASTE

Context and opportunity

Biofuels – like biodiesel and bio-jet fuel – are increasingly being supported by government initiatives, creating significant demand for large supplies and quantities of such solutions. Opportunities in providing higher efficiency outputs and improved refining exist in a space that is relatively nascent but poised to become significant as India mandates 20% of fuels to be from ethanol and non-fossil fuel sources.[36] Using agricultural wastes is preferred to directly extracting from cultivated crops to avoid food pressure and shortages.

EXAMPLES OF STARTUPS IN THIS BUSINESS MODEL

Early stage	AVINDIA; ALCHEMY ENERSOL INTERNATIONAL PVT LTD – Waste to Wealth
Growth stage	GREENJOULES

36. Press Information Bureau, Government of India. Ministry of Petroleum and Natural Gas. India's Ethanol Push: A Path to Energy Security. Retrieved from: https://pib.gov.in/PressNoteDetails.aspx?NoteId=153363&ModuleId=3&reg=3&lang=1

GREEN JOULES – CASE STUDY

ORGANISATION SUMMARY

Year of foundation: 2016
Number of employees: 82
Current biofuel generation: 350 kL a month

Green Joules is capitalising on India's abundant biomass waste to produce second-generation (2G) biofuels, positioning itself as a leader in the sustainable energy space. The company's technology enables the conversion of agro-waste into high-density energy fuels, such as diesel and aviation fuel, providing a valuable and environmentally friendly alternative to traditional fossil fuels without competing with food supply chains. Despite challenges related to policy frameworks and funding, Green Joules is focused on expanding its operations, optimising production capacity and forming strategic partnerships with key players in the energy sector, including major oil companies such as IndianOil (IOCL), Reliance Industries Limited (RIL) and Sabic.

The company's core value proposition lies in its innovative technology, which enables the production of economically viable and scalable drop-in crude oil, marketed under the brand name Abhilasha biofuel. This bio-crude is further refined into bio-naphtha (used as feedstock for biofuels and bioplastics), diesel and sustainable aviation fuels (SAF), among other products. Green Joules' approach addresses the growing demand for cleaner, renewable energy sources while remaining competitive in terms of cost and scalability.

Green Joules' biorefinery, located in Maharashtra, currently has a production capacity of 350 kilolitres per month. With a dedicated team of approximately 82 employees, Green Joules serves high-profile customers such as Unilever, Tata, L'Oréal, Amazon, L&T and Cisco, reflecting the growing demand for its sustainable fuels.

The company's founders bring extensive experience in research and development, particularly in creating high-performance drop-in fuel technologies. Despite not benefiting significantly from India's bioethanol policies, Green Joules' advanced fuel capabilities and competitive pricing have garnered considerable interest from the country's leading oil refiners, positioning the company as a potential front-runner in the emerging drop-in biofuel market.

SCALE

- **Existing revenue (FY23–24):** US$1 million
- **Break-even:** Not realised yet

IMPACT (numbers not quantified due to the nascence of the organisation)

Supporting farmers with additional income

Biomass converted into drop-in biofuels

CO2 emissions saved through drop-in biofuels

FUNDING RAISED

Type of Funding	Year	Purpose	Funders / Investors
Grant	2019	Product development	Government
Equity and debt	2023	Growth capital	Blue Ashva

INVESTMENT OPPORTUNITY

Total funding raised to date	US$ 5 million debt and equity mix

Green Joules plans to significantly expand its current production capacity of 350 kilolitres per month over the coming years as it looks to capitalise on its first-mover advantage in offering drop-in fuel solutions. This will require the establishment of new biorefineries, strategic joint ventures with established players and the expansion of existing facilities. Achieving that will necessitate substantial external capital, which the company plans to raise by blending private equity capital with low-cost debt from existing government schemes.

Green Joules is currently navigating its growth trajectory, with an increasing focus on scaling revenue both domestically and internationally. Given India's surplus of agricultural and biomass feedstock, Green Joules is well positioned to produce biofuels and drop-in fuels at competitive prices, particularly for export markets. This enables the company to tap into global demand for renewable fuels, further solidifying its potential as a key player in the sustainable energy sector.

SUCCESS FACTORS

Green Joules is well positioned to become a market leader in the emerging sector of second-generation (2G) biofuels. The company's proprietary technology, coupled with the economic viability of its biofuels, gives it a distinct competitive advantage. By focusing on non-food agro-waste as a feedstock, Green Joules not only contributes to sustainable energy production but also promotes circularity within the biofuel market. This approach addresses two critical issues: reducing waste and providing an alternative to fossil fuels.

The company's ability to convert low-cost agro-waste into high-value fuels enhances Green Joules' attractiveness to investors and potential partners, particularly those in industries seeking sustainable energy solutions. Additionally, its collaborations with established players such as IOCL serve to bolster the company's credibility in the market, while simultaneously creating pathways for scaling operations. These strategic alliances underscore the importance of forging partnerships in the energy sector to accelerate growth and ensure long-term success.

4 BIOCHAR TECHNOLOGY PROVIDERS

Context and opportunity

Biochar is an opportunity due to its high-value potential solution to the problem of crop waste, which is usually burned, leading to significant air pollution issues in India. Additionally, its ability to sequester high amounts of carbon makes it a high-value carbon mitigation solution. Biochar technology providers are emerging as pyrolysis solutions focus on more efficient products. However, the constraints are similar to biogas in the sense that the fragmented nature of farms presents an additional problem that needs to be solved to achieve scale.

EXAMPLES OF STARTUPS IN THIS BUSINESS MODEL

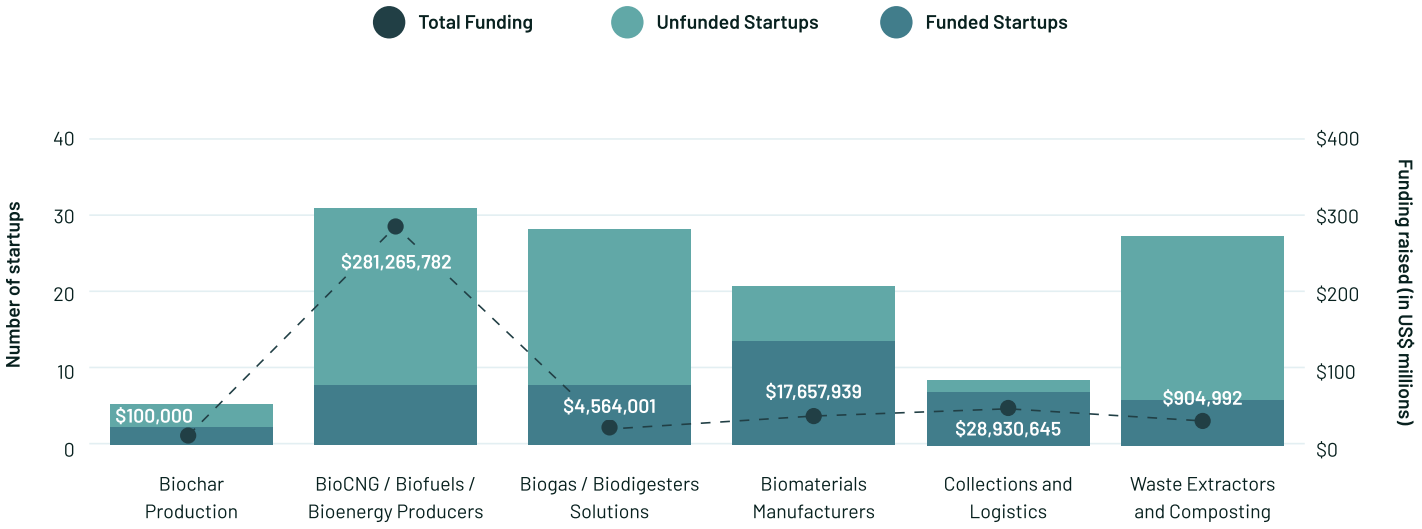
Early stage	TAKACHAR, Eco Char, ArSta eco

CHAPTER 3: INVESTMENT LANDSCAPE

Equity Investment Trends in Agricultural, Biomass and Food Waste Recycling and Circularity

Identified Companies	Funded Startups	Total Equity Funding Raised (US$)
117	41	333.4 million

Figure 4: Startups across the six main business models in the agricultural, food and biomass waste recycling and circularity value chain (Climake analysis)



The **117 startups** identified in Figure 4 are formal entities that operate across the agricultural, biomass and food waste circularity value chain (henceforth referred to as the agricultural waste value chain) in fields ranging from collection systems, on-farm conversion of waste for energy and fertiliser use to large-scale bioenergy setups. The agricultural waste value chain offers scope for more business models compared to other segments of the waste and circularity sector due to the diverse output potential of such waste and the potential for both localised, on-farm processing of solutions and large-scale processing in other settings to produce bioenergy or biomaterials.

The bioenergy space, which includes biofuels, drop-in fuels, bio-CNG and electricity from agri-waste, accounts for the highest number of startups and the largest funding in this segment. These are emerging and highly investable business models due to the high-value potential of energy outputs. However, the collection and logistics of aggregating agriculture waste and transporting it to centralised bioenergy facilities remain complex. That has led to the emergence of collection and logistics companies, such as PRESPL for biomass briquettes and Biofuels Junction for biofuels, which aggregate such wastes for centralised, larger-scale activities.

Biogas and biodigester solutions are the second-most prominent business model in this segment. This emerging field mainly focuses on processing agricultural waste from farms into biogas or biomethane for cooking or other use cases related to farming. Composting solutions have traditionally been a common way to handle agricultural and food wastes, but these have limited investment opportunities due to the relatively low-value output and the wide range of composting approaches. Solutions here that have received investment are ones focused on composting for large-scale facilities. All investments in this segment have been early stage and for less than US$ 500,000.

Two more emergent business models are the production of biochar and biomaterials from agricultural waste. Biochar is a carbon-rich material that can be used as an input in various activities, such as soil improvement, carbon sequestration to help mitigate climate change and water filtration to remove contaminants; it is also used as a livestock feed additive. Biochar is a nascent high-value product that offers significant investment potential, mainly for its role in carbon sequestration and as an agricultural input. The biomaterials business model focuses on making new materials (other than energy and fertilisers) from agricultural and biomass wastes. These include crop nutrition solutions, textiles and other natural materials.

Figure 5: Stage of investments of startups across the six business models in the agricultural, food and biomass waste recycling and circularity value chain by funding raised (Source: Climake analysis)

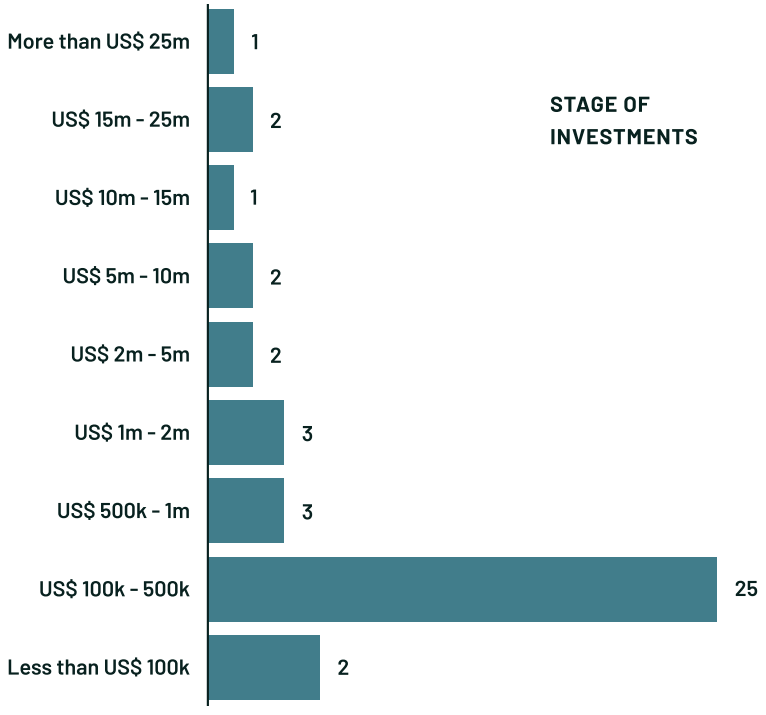
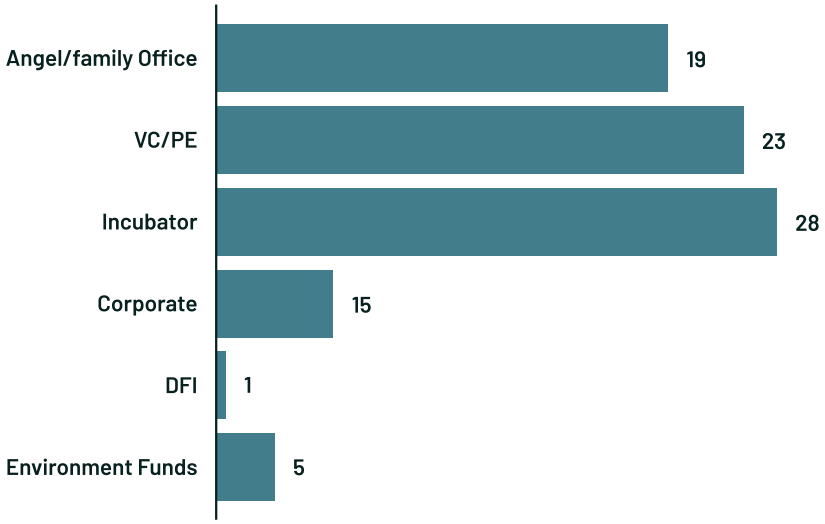


Figure 5 outlines the total funding raised by agricultural waste and circularity startups in India. 65% of that funding was below US$ 500,000 – a stage that goes from the pilot development of technologies to early traction. Agricultural waste circularity is a nascent and emerging sector that will steadily see more growth-funding deals. The presence of larger ticket sizes indicates investment pathways for the different business models in this sector. The larger ticket sizes have been received by enterprises working in the production of bioenergy or dealing with the collection and logistics of agricultural waste for bioenergy. Biogas and biodigester solutions are increasingly emerging and starting to receive investment interest, mainly in the US$ 500,000 range, although two companies have raised close to US$ 2 million.

Investor and Funding Landscape

Figure 6: Number of investors who have funded agricultural, biomass and food waste management and circularity startups by type (Source: Climake analysis)



The equity universe for agricultural waste circularity reflects the nascency of the sector, with incubators, early-stage venture capitalists and angel investors accounting for the majority of investors. Large-scale investors such as development finance institutions (DFIs) and growth-stage funds are only emerging as the pipeline of companies in this segment is still nascent. Greater participation of more investors, especially growth-stage investors, can be expected as the sector evolves. This waste segment has the advantage that most of its technologies are established and mature, except in certain emerging segments, such as biomaterials and drop-in fuels. Therefore, technological risks have been addressed for most of the other business segments, leaving investors free to focus on commercialisation and traction opportunities for startups in those segments. Despite that advantage, the lack of effective supply chains and the fragmented nature of agriculture (and waste collection) in India often prove to be significant barriers that enterprises must overcome.

The roles played by each investor in supporting enterprises are summarised below:

- Incubators are often the first backers of agricultural circularity startups with a tech-focused application, helping to fund product creation and proofs-of-concepts. In India, the majority of incubators are tied to academic institutions, but the presence of private platforms is growing and promises to provide more context-specific support.

- Angel funds and family offices are entering as the first institutional investors to enable early-stage proofs-of-concepts to transition to initial go-to-market, with environmental-focused family offices emerging to mainstream sustainability in corporate settings. Angel fund networks have participated significantly in the agricultural waste value chain segment.

- Venture capital (VC) and private equity (PE) funds operate in a wide space from funding initial go-to-market (seed-stage investments up to growth investments, based on the nature or focus of such funds). In the agricultural waste value chain, early-stage VC funds have been the main investors, focused on scaling solutions with early-stage traction for growth. VC and PE funds often lack a clear thesis on asset-heavy investments which are needed in climate action and circularity. VC funds, in particular, operate in the current biggest funding gap in plastic circularity: providing Series A/B ticket sizes for enterprises to fund go-to-market and initial growth.

- Environment-focused funds are ones that have a clear thesis aligned with the needs of agricultural waste and circularity enterprises. Such funds are potentially better equipped to fund and back these high-potential, often technologically complex, bets. However, such funds are limited and few, this study only identified five with at least one investment in this waste segment. However, agritech funds, which constitute a more numerous and mature investor group, are expected to increase their participation in this segment.

- DFIs fund growth, but the scale of capital they can deploy means that they can have an influence on the direction and bets of earlier-stage funds, making such funds more likely to align with the DFIs' stated priorities. DFIs play a catalytic role, bringing more private finance into the sector. They often do that by offering debt or equity on concessional terms to an enterprise, which allows it to grow to a level at which it can meet the expectations of more commercial investors. However, DFI participation has been limited in the agriculture waste segment; this study only identified one DFI investor. This is likely due to most deals in the space being nascent and limited.

Figure 7: Active equity investors in agricultural, biomass and food waste circularity (Source: Climake analysis)

Agricultural, Food and Biomass Waste Circularity Businesses Also Have Significant Debt Potential

Agricultural, food and biomass waste circularity businesses in India, particularly those in the growth stage, have demonstrated an ability to fund part of their capital needs with debt. These companies are raising three kinds of debt:

Project Finance

Bioenergy enterprises, in particular, require the setting up of capital-intensive, asset-heavy plants to produce drop-in fuels, biofuels or other bioenergy forms from agricultural waste. For companies that have raised equity and built a profitable business model, such debt financing is widely available from banks in India.

Banks, however, need companies to provide three years of profitable track record and offer collateral security beyond the project's assets. Recent examples of such funding include the expansion capital provided to GPS Renewables from mainstream banks in India, such as HSBC, HDFC Bank and Yes Bank. However, there are few companies with the scale and ability to attract capital from commercial banks in this waste segment. For companies who do not meet such banks' criteria, available options include specialised lenders such as Tata Cleantech. DFIs that provide more concessional interest rates are present if enterprises raise at a particular scale, something that has been limited in the sector. However, conversations with DFIs for this research revealed that they do have interest and intent to lend to firms operating in this segment.

Working Capital

As with project finance, profitable companies that can offer collateral security and personal guarantees from their founders are able to raise credit lines from local banks to meet their working capital needs. There are several other options for those who do not qualify for bank loans:

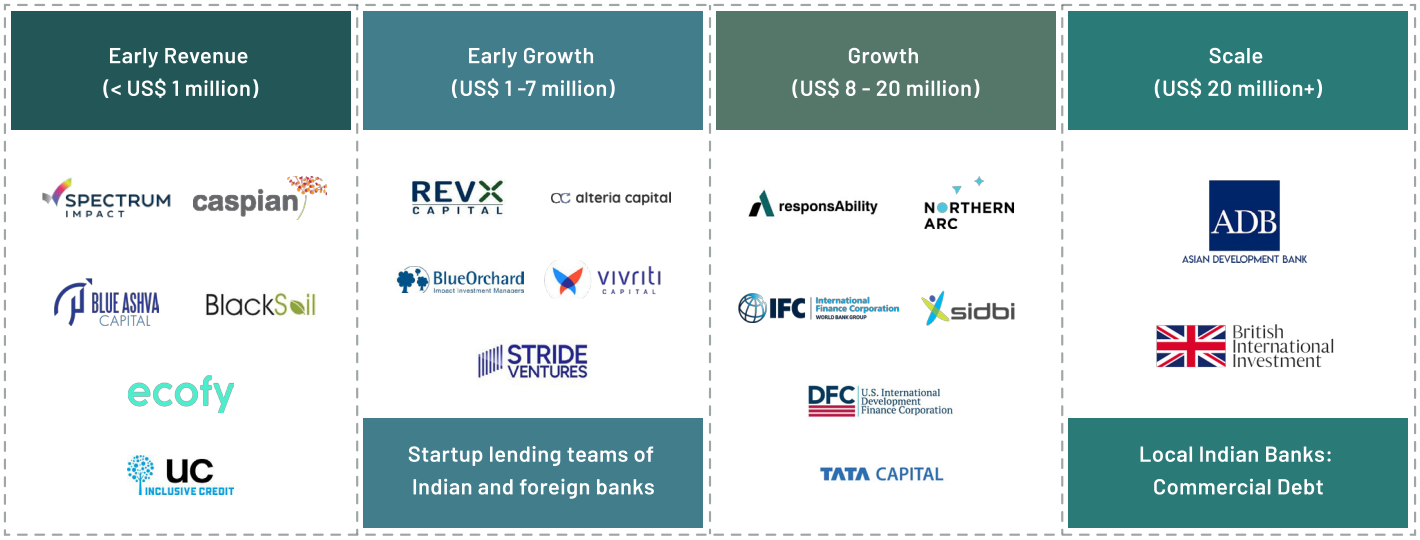
- NBFCs offering unsecured business loans to meet the working capital requirements of young startups
- Invoice discounting offered by banks, NBFCs and multiple trade receivables electronic discounting system (TReDS) platforms
- Financing linked to orders that provides working capital to purchase raw materials and pay vendors with repayments linked to the revenue received from such orders
- Revenue-based financing for companies that have fixed monthly revenue or standard offtake contracts.

Venture Debt

While more popular with technology startups, venture debt is increasingly gaining traction in environment and circularity sectors as well. Venture debt providers are able to complement the equity raised with a small debt component, thus increasing the runway for early-stage startups and providing an option for lower dilution in the early rounds of fundraising.

The universe of active debt investors in India's agricultural, biomass and food waste circularity segment is shown below.

Figure 8: Active debt lenders in agricultural, biomass and food waste circularity (Source: Climake analysis)



Blended Finance Options for Agricultural, Biomass and Food Waste and Circularity

Early-stage startups in the agricultural waste and circularity segment have access to grant capital in their early product development and pilot stages, mainly through incubator-led and corporate social responsibility (CSR) programmes. Bioenergy solutions can also access renewable and clean-energy-focused grants, such as USAID's South Asia Regional Energy Partnership (SAREP). The SAREP programme focuses on providing grants for enterprises to develop innovative pilots and business models, conduct market assessments and policy advocacy, and deploy decision-making tools in areas ranging from accelerating the deployment of clean energy technologies to enhancing private sector investments.

Blended capital at larger stages, however, has not yet been extensively adopted in this segment. There can be opportunities for this, especially in scaling promising entities at early stages, but there is no evidence yet of the sort of tailored concessional or catalytic vehicles that already exist in other segments such as plastic waste circularity.

CHAPTER 4: CONCLUSION

Agricultural, biomass and food waste is India's largest source of waste, with an estimated 350 million tonnes being generated annually. Biomass accounts for 80% of India's rural energy, which offers significant opportunities for agricultural and food waste to be leveraged to cater for this segment. Due to the significant volumes of waste and the diverse outputs they can generate, circularity in agricultural, biomass and food waste can provide significant opportunities and the number of business segments and outputs that can be supported is extensive. This report identifies three prevailing trends that will incentivise the adoption of agricultural, biomass and food waste circularity solutions and enterprises:

- High-value applications and opportunities in new bioenergy and biofuels are creating a greater focus on recycling.
- The burning of crop residue is being curbed at the source in line with new policy directions.
- New technology has been established that offers the chance to unlock novel, high-value outputs and deliver scale.

This study has identified 117 formal enterprises operating across six main business models in agricultural, biomass and food circularity: bioenergy solutions (26% of all enterprises in this field), biogas and biodigester solutions (24%), extraction and composting (23%), biomaterials solutions (17%), collection and logistics (7%), and biochar solutions (3%). Each segment offers differing levels of investment opportunity and potential based on the nature of the business and the operating context. Across most segments, only around 25% of enterprises were able to access equity financing, although 75% of collection and logistics companies and 60% of biomaterials startups were. The former can primarily because they have a clear business model with evident growth opportunities; whereas the latter can due to their high-value output potential. Businesses that can deliver and demonstrate high-value outputs are being recognised as investment opportunities.

The sector is nascent from an investment opportunity perspective: 65% of equity investments have been at less than US$ 500,000. Therefore, the equity universe in the sector is dominated by incubators, early-stage VC funds and angel investors. There have, however, been some investments at a significant scale, for example, Sukhbir Agro, a bioenergy enterprise that focuses on generating electricity from agricultural waste, has raised over US$ 1 billion in debt and equity capital, which shows the opportunity for investment pathways at scale in the sector. However, the bulk of the equity financing needed is at the early growth and traction stages, especially at the Series A stage.

Debt financing is an important and necessary financing tool. The participation of commercial banks in growth deals is a welcome sign of lenders' interest in participating in the segment. However, given the asset-heavy nature of establishing plants for bioenergy applications or supplying equipment and assets for applications such as composting and biogas generation, more capital is needed through project finance and working capital. Although grants are available for early-stage companies, blended finance is limited in most segments. At large scales, both blended finance and concessional capital are limited.

RESEARCH METHODOLOGY

The insights and conclusions of this guide were informed by data gathered from primary and secondary sources. The insights also leveraged the extensive work that Climake has already undertaken in the waste management and circularity sector.

DATA COLLECTION

1 Secondary Public Source Analysis

The first phase involved a thorough review of publicly available secondary sources: academic literature, industry publications and reports, government reports and statistics, news articles and press releases, and open-access databases and repositories.

2 Access to Proprietary Databases

We also accessed proprietary databases containing specialised and detailed information relating to startups, funding and investors, The main database leveraged for this was Tracxn. Access to these databases allowed us to obtain up-to-date market data and gather detailed company and investor-specific information.

3 Primary Research

To gather sector-specific feedback, we engaged in primary research with key stakeholders: startup founders, investors and experts in waste management and circularity. This primary research was undertaken as part of targeted and ongoing engagements with stakeholders. A total of five interviews were conducted with the following:

- Three founders of funded entities in the following core business models:
  - Collection systems and processing
  - Drop-in fuels
  - Compressed bio-CNG
- Two funds with a defined thesis in agricultural waste and circularity.

DATA ANALYSIS AND SYNTHESIS

The data collected from all sources were systematically analysed and synthesised. This process involved:

- Conducting content analysis to identify insights, conclusions, trends and forecasts
- Using data visualisation approaches to represent quantitative findings
- Validating assumptions and identifying discrepancies by cross-referencing information from different sources.

LIMITATIONS

While efforts were made to ensure comprehensive and accurate data collection, some limitations should be noted:

- Accurate data on key metrics such as waste quantities and recycling rates are poorly documented in India and vary significantly across waste streams. Our research aimed to validate all data points identified by identifying multiple sources, if available, validating with primary interviewees and leveraging our extant knowledge of the sector.

ASPEN NETWORK OF DEVELOPMENT ENTREPRENEURS

aspen institute

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