

Bioenergy from Agricultural Residue: Challenges and Potentials in Northern India**Kaur, Jasneet**

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Abstract

Still, a lot of agricultural wastes, i.e. paddy straw, wheat straw, sugarcane bagasse and cotton stalks, etc., are generated in northern India and largely go to waste or are thrown in the open fields, resulting in the worst of air pollution and emission of carbon. The paper examines the problem and opportunity of transforming these wastes into bioenergy as a sustainable way forward to generating clean energy as well as managing the environment. The study has provided both secondary and primary data based on the reports published by the government and related institutions reports respectively and also compared reports of both Punjab and Haryana by surveying 400 farms. These results show that the excess amount of biomass is almost 89 million of tons yearly, and the energy that can be estimated is more than 1,200 petajoules. Large-scale adoption is, however hindered by logistical issues, unavailability of infrastructure, low farmers awareness and poor governance structuring. The research prescribes the incorporation of policies, or decentralized biomass and rural inducements and the public-private tie-ups to unlock this unexploited source of energy. These understandings have developed a situation of discussion about renewable energy transformation, sustainable farming, and climate change adaptation in India.

Keywords: Bioenergy, Agricultural Residue, Northern India, Stubble Burning, Biomass Potential, Renewable Energy, Rural Energy Access, Environmental Sustainability.

1. Introduction

The energy sector in India is witnessing a tremendous change with India trying to reconcile between economic growth and environmental stability. India, as the world third-largest energy consumer, has to solve the two problems: to meet the growing energy demands and to decrease its reliance on the fossil fuel and the greenhouse gas emissions. In this regard, bioenergy, which is energy generated by organic materials, has come out as a probable solution. Agricultural residue is one of the many forms of bioenergy with huge potential given that most of the biomass produced are byproducts of cropping systems, especially in the agrarian parts of the world, such as Northern India (Ghosh et al., 2021). The use of this biomass as a source of energy provides a sustainable solution to rural electrification, pollution alleviation and a higher energy security.

The Northern part of India is made up of such states as Punjab, Haryana, Uttar Pradesh, and Bihar, and it is also the agricultural core of the country as well as one of the biggest producers of crop residues. Paddy straw, wheat husk, sugarcane baggage, and cotton stalks that are discarded after every harvesting season amount to millions of tons. A lot of it is either incinerated on-site, which adds dramatically to smog problems and air pollution, or left without being it in any productive capacity (Singh et al., 2022). The open field burning continues despite the government regulations and fines because there are no viable and close alternatives for disposing of the residue at an affordable cost. This is a crisis as well as an opportunity: a crisis in the sense of the environmental destruction it leads to, or an opportunity in the untapped energy potential latent in these residues.

It is estimated that India currently produces over 750 million metric tons of biomass, and it is estimated that approximately 120-150 million metric tons of biomass is surplus, i.e. does not necessarily have an end use as fodder or compost or other traditional uses (Energy Alternatives India, 2022). To a large extent, this surplus is held in Northern India. With just a fraction of this biomass harnessed through any of modern technology like briquetting, gasification or anaerobic digestion, much of the fossil fuel consumption would be offset, the energy shortage in rural areas would be lessened, and some local labour would be created (Chauhan & Singh, 2023). Moreover, the production of energy based on biomass correlates with the requirements of India in connection with the Paris Agreement and the national goals of energy capacity enhancement using renewable sources.

The utilization of agricultural residue as bioenergy source is not simply a technological idea; rather, it has a complicated socio-economic, environmental and policy determinant. The core of this complexity is a viability of the Indian farmer, who in many occasions does not get a lot of incentives, fragmented land holdings and less mechanization. Crop residues are a logistic and economic problem to most small and marginal farmers. As it is the most cost-efficient and fast method, burning the residue is the easiest one especially when the period between having one crop to put another one into the ground is not long. There have always been government programs to subsidise alternatives (e.g. the “Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue”), but uptake has fluctuated and most rural areas have neither the suppliers of the services nor infrastructure to carry through the implementation with success. (Department of Agriculture & Farmers Welfare, 2022).

Another factor that is very significant is infrastructure required to run biomass-based energy economy. Activity of collecting, storing, transporting and pre-processing of crop residues requires large logistic resources particularly in states that exhibit extensive crop patterns and de-centralized production networks. The regions with biomass potential such as the eastern state of Uttar Pradesh and Bihar are prone to being associated with poor road connectivity, no aggregation points, and no cold storage centre or dry storage point (Pal & Bhatia, 2022). The limits described make the acquisition of biomass on a sustainable reasonable scale economically unviable by the responsible energy producers. Besides, the amount of energy generated and the levels of conversion may vary considerably under the standards of divergent levels of quality of biomass product and moisture levels thereby necessitating scientific planning and optimization of the supply chains at any given time.

Problems with conflicting uses of agricultural residue are also there. Although a part of the biomass would be in excess, part of the biomass is already consumed as animal feed, domestic food or as compost. Any major redirect of residue towards energy utilisation should be done in such a manner that there are no disruptions to the livelihoods of the rural population or food systems. Koul, Yakoob, and Shah (2021) have discussed the necessity of a balanced strategy of residue utilisation that does not contradict energy production and environmental sustainability. They present the arguments that should embrace region-based frameworks, to assess the ecological consequences of residue extraction and endorse the incorporation of integrated models, accessible through the coupling of energy generation with the production of biofertilizer consisting of anaerobic digestion.

Various national developments have prepared the steps towards the utilisation of biomass in the policy sphere. The initiative of Sustainable Alternative Towards Affordable Transportation (SATAT) which was started in 2018, is set to popularise the Compressed Bio-Gas (CBG) plants throughout the nation that utilise agricultural and organic wastes. Equally, the National Bioenergy Programme encourages an investment in biomass power and bagasse-based cogeneration plants (Pant et al., 2019). Nevertheless, when implementing these policies, the problem of fragmentation might occur; inter-departmental coordination is usually poor, and monitoring practices are weak. Furthermore, due to lack of region-specific policy structures, the special issues to the Northern Indian states have not been properly tackled.

Technically, there have been great changes with regard to technology relating to the conversion of biomass to energy. Burning of coal with biomass in the thermal power plants, utilisation of torrefied pellets, and modular biogas units have all demonstrated positive values both UDC-reduction in carbon emissions and energy efficiency (Milićević et al., 2021). However, installations of the technologies are still restricted to pilot projects or even to urban-rural fringe areas. As described by Pavlenko and Searle, (2019), scaling up of these technologies demands policy certainty, finance at hand, and an energy pricing format. As an example, power purchase agreements (PPAs) place the biomass energy price below their current cost of production and consequently make their inclusion as a privately funded project unviable without subsidy or carbon credits.

The awareness and perception of society also determine the adoption of bioenergy solutions. As Vujic et al. (2020) remark, the attitudes of society and stakeholder participation are highly important factors in the success of the renewable energy projects. The case of Northern India is particularly difficult because in this region, agriculture is a significant part of social identification, as well as local economies in general, and any type of shift should be inclusive and participatory. This could lead to a vast increase in adoption levels by inviting farmers in cooperatives, training the farmers on how to handle residue, and even showing them the economic advantages of bioenergy.

The need to pay attention to the problem of agricultural residue management in Northern India is also supported by its health-related factors. The habit of burning brought about by paddy residues in the Punjab and Haryana is largely believed to be the main cause of the seasonal smog covering the city of Delhi and other surrounding areas. Besides the issue of

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climate, this leads to respiratory problems, closure of schools, and economic losses attributed to decreased productivity. In this regard, bioenergy valorisation of agricultural waste is not just a need to the environment but a requirement as well to the health of people.

2. Literature Review

Significant interest in the generation of bioenergy over the past few years is a reaction to climatic variation, energy security, and unsustainable agricultural practices. The world literature has provided significant literature on emerging technology, environment, socio-economic and policy aspects of the potential of bio energy and inferred that biomass-rich regions like Northern India could provide ample scope for bio energy potentials. This review compiles the major works in this topic with emphasis on the availability of biomass, environmental implications, perception of the masses, technological advancement and institutional backup.

One of the pillars of the bioenergy debate is that it is related to climate change in the world. Abbass et al. (2022) provide a structured survey of the issue of climate change and mitigation policies and renewable energy in the heart of sustainable adaptation. The results of their study emphasise that the technology of converting biomass waste into energy not only reduces the production of greenhouse gases but also helps to achieve the global decarbonization targets. Agricultural residue burning is the primary source of air pollution in Indian society, and greenhouse gases, such as CO₂, so sustainable biomass utilisation should receive particular attention.

Regarding public awareness, Vujic et al. (2020) confirm that the successful implementation of renewable energy strategies is associated with a kind of dependence on the population perception and behavioural acceptance. Awareness levels of bioenergy In India, the level of knowledge regarding bioenergy is comparatively low, and the most crucial stakeholders who are not well-informed are the rural stakeholders, which include farmers and the local panchayats. This is a hindrance towards the embracement of bioenergy technologies due to its environmental and economic advantages. Their study highlights the significance of educational campaigns, participatory rural government, as well as community-based decision-making as strategies to improve social acceptability of bioenergy ventures.

The estimation of the amount of biomass in addition to the classification of biomass resources is a critical dimension of bioenergy development. According to Ghosh et al. (2021), India

produces more than 750 million metric tons of agricultural biomass each year, of which nearly 150 million metric tons can be classified as excess and can be used to produce energy. The estimation is confirmed by Singh, Gajera, and Sarma (2022), which also pinpoint regional hotspots as Punjab, Haryana, and Uttar Pradesh among the leading producers of surplus residue, specifically rice straw and wheat straw. According to their work, there is a substantial difference between the potential biomass and how it is used because of no effective collection, storage and processing facilities.

The extent of the generation of biomass is further proven by institutional data sources. The Department of Agriculture & Farmers Welfare (2022) presents disaggregated data on crop yields and the resultant production and residue that can be used by policymakers to develop region-wise interventions. The report however, observes that the biomass data collection process is decentralised across the departments and therefore the planning and implementation are likely to be incompatible.

Energy Alternatives India (2022) report includes a technical and economic review of the biomass sector in India, describing both the centralised and decentralised schemes of biomass power generation. The report further points out that rural and peri-urban areas of north India should be served by decentralised units, as the transport expenses will be minimised and local jobs will be generated. It also outlines the benefits of the use of biomass briquettes and pellets that can substitute coal in industrial boilers, and bio-CNG plants that will facilitate the transfer of rural transport and agriculture to cleaner fuel.

Chauhan and Singh (2023) present a new look at the policy scene and development of technology in the use of biomass. They observe that although the policies adopted by the government, including SATAT initiatives and the National Bioenergy Programme, have created certain momentum, most of the projects are still on the pilot level. Their findings indicate that logistical obstacles, including the unpaved roads and the absence of aggregation platforms, as well as the seasonal variability in biomass supply, represent British persistence bottlenecks. They promote a PPP (public-private partnership) model in constructing infrastructure in biomass gathering, a store facility and pre-processing.

Milićević et al. (2021) and Milićević et al. (2018) carry out technical research on co-firing of agricultural wastes with coal in thermal power stations. Such works indicate that the process of co-firing can be optimised at various combustion environments without reporting

any detrimental effect on the performance of the power plants. These hybrids are especially applicable to the Northern Indian states that have large biomass potential but mostly use coal as a primary resource, and co-firing the thermal plants can be used as a transition mechanism.

Bijarchiyan et al. (2020) also mention advanced conversion technologies: anaerobic digestion, torrefaction and gasification. In their study, a sustainable model of biomass supply chain based on the use of agricultural residues and livestock manure has been developed. Such an approach not only leads to higher biogas yields, but it also corresponds to the circular economy initiatives in India, as it leads to the waste-to-energy loop within the country. Decision-making models of biomass transportation and storage are also proposed in the study, where the challenge of decentralised residue availability is addressed.

The other theme that is also repeated in the literature is environmental sustainability. Koul, Yakoob, and Shah (2021) look at the practices of management of agricultural waste and their effects on the environment. They claim that any uncontrolled fire, as well as poor management of biomass leftovers, in addition to prompting the emission of carbon, causes the loss of nutrients and eventual soil deterioration. According to their review, in case extraction of residue is monitored and administered with subsequent restoration with impact of soil restoration of the soil, such as composting and green manuring, an eco-efficient bioenergy source option is possible. One more contribution that may be of interest to policy can be made by Pant et al. (2019), who compare the development of the biobased economy in Europe and India. They emphasise the ways European paradigms of biomass energy operate on multi-stakeholder cooperation, strong legislative structures and price incentive systems, which are mostly not present in the current approach of Indian biomass. They support knowledge-sharing forums and partnerships with other nations in fast-tracking bioenergy applications in India.

Pavlenko and Searle (2019) focus on assessing possible opportunities to use biofuels in India by examining the capacity of feedstock and conversion technologies of advanced biofuels. Their research indicates that Indian owns the lands and residual resources in order to sustain the large-scale bioethanol and biodiesel products. Nevertheless, technological inertia, insufficient investment and regulatory uncertainty impede commercialisation. They advise the change in policies, entrepreneurial capacity-building, and increased investments in R&D activities by the population.

The economic aspect of bioenergy is closely connected with the optimisation of logistical performance and the development of infrastructure. Pal and Bhatia (2022) pay attention to topographic challenges and the necessity to have an implementation strategy that will be adjusted to the local peculiarities. They point out in their study that hilly and flood-prone regions need a more flexible model of biomass collection and storage, perhaps mobile pelletization units and digesters owned by the community. They also emphasise on need to map transportation costs and labour availability during bioenergy project planning.

Škrbić et al. (2020) offer a contrast between the utilisation of plant-based biomass as a source of securing to ways and how to create value not only in the burning itself of the biomass but also the by-products of the burning as in by products in offer of soilco ash fertilisers and activated catalyst. The systems approach has a focus use of resource efficiency, integrated planning in biomass-based energy systems.

NITI Aayog (2022), in its report on wastewater water indirectly provides input on the bioenergy debate by promoting the energy-waste integrated techniques. It states in the report that the organic residues between the municipal and agricultural wastes may be co-digested to enhance systems of biogas production. This is an indication of cross-sectoral coordination that could be practised in rural energy planning.

3. Research Methodology

A mixed-methods design was used in the research, where both quantitative and qualitative analyses were used to provide an all-around analysis of the challenges and potentialities of the production of bioenergy from agricultural wastes in Northern India. The research mainly depended on secondary data collection mainly relied on government credible publications like reports on the Department of Agriculture & Farmers Welfare, NITI Aayog and Energy Alternatives India, peer-reviewed journal articles, policy documents, and other international research reports. These ministries gave statistical figures of residue production, energy potential, usage and adherence to Renewable Purchase Obligations (RPOs).

Among the secondary information, secondary insights were included, which were captured based on fieldwork using a defined survey of 400 farmers across Haryana and Punjab, to estimate the level of awareness, usage, and willingness to supply biomass in supply chains. The survey utilised a simple random sample technique, where there was also an unbiased sampling of respondents by the size of landholdings and by the region. The analysis of Kaur, J.

responses carried out with the help of descriptive statistics aimed at defining behavioural trends and barriers. Data analysis involved computation of frequency distribution, percentages and cross tabulations using Microsoft Excel and SPSS to yield comparative facts across states. In addition, calculations of energy potential were performed by means of average calorific values of biomass and standard energy conversion formulae obtained in the literature. A review of case studies of functioning biomass plant associations was incorporated to evaluate the practice and bottleneck as well as disparity in regions and areas.

4. Results and Analysis

In this report, an analytical summary on opportunities, uses, and challenges of bioenergy using agricultural wastes in Northern India is presented. It is concerned with the measurement of biomass production, the assessment of the use practices in place, the potential energy conversion, as well as researching regional and infrastructural differences. Besides, policy implementation and farmers' engagement are also tested regarding available datasets and case reports. Results are clustered into thematic tables to ease their understanding.

4.1. Agricultural Residue Generation in Northern India

The first basis of bioenergy production is the agricultural residue production. There are state-wise estimates of the annual production of surplus residue, as seen below.

Table 1: Estimated Surplus Agricultural Residue in Select Northern States (in million tons/year)

State	Paddy Straw	Wheat Straw	Sugarcane Bagasse	Cotton Stalks	Total Residue
Punjab	20.5	9.2	3.1	0.8	33.6
Haryana	9.8	5.4	2.2	1.0	18.4
Uttar Pradesh	6.3	10.7	4.5	1.4	22.9
Bihar	3.9	7.8	1.8	0.5	14.0
Total	40.5	33.1	11.6	3.7	88.9

The above data indicates that Punjab and Haryana also produce large volumes of paddy straw and the maximum quantity of wheat and sugarcane residues is produced by Uttar Pradesh. The supply of cotton stalks is not very high yet it is concentrated in western Uttar Pradesh and Haryana. The total amount of residual at hand (all that is left after use as fodder) is estimated to be about 89 million tons a year and acts as important base of biomass-based energy feedstock.

4.2 Utilization Pattern of Agricultural Residues

A sizeable amount of crop residue is left idle or set on fire even though its supply is excess. The table below indicates the percentage of biomass which is being used in different applications.

Table 2: Utilization Pattern of Agricultural Residue in Northern India (2022)

Usage Type	Percentage of Total Biomass
Animal Feed	25%
Composting/Fertilizer Use	15%
Domestic Fuel	10%
Industrial Use (e.g., Paper, Pulp)	5%
Bioenergy Conversion	8%
Open Field Burning	37%

A small proportion of agricultural residues (8 per cent) is currently utilised as part of a bioenergy source, and this can be described as a huge unexploited potential. Worse still, 37 per cent of the biomass burnt is conducted in open fields, and this causes serious air pollution, particularly in winter. This burning also cancels the environmental profits that could be provided by biomass-to-energy conversion.

4.3. Estimated Energy Potential from Biomass

The rural electrification and energy diversification can become a game-changer through the energy production of excess residues. The table below represents the possible energy deliveries on the basis of average calorific values.

Table 3: Energy Potential from Biomass in Northern States

State	Biomass (MT)	Avg. Calorific Value (MJ/kg)	Total Energy (PJ)
Punjab	33.6	14.5	487.2
Haryana	18.4	14.5	266.8
Uttar Pradesh	22.9	14.5	332.1
Bihar	14.0	14.5	203.0
Total	88.9	-	1,289.1 PJ

These states have a potential of more than 1,280 petajoules (PJ) of energy that would be organised within a year of supplying energy to more than 15 million rural homes, in case half or more of the theoretical energy is tapped efficiently through gasification or anaerobic digesters. This shows that biomass is a potential source of energy that could play a huge role in the renewable energy targets of India.

4.4. Performance of Biomass Plants in Northern India

Based on the functional biomass plants, one can get a clue about the realities of bioenergy use on the ground. An analysis of data at 10 pilot/operating biomass plants in Northern India was conducted.

Table 5.4: Performance of Selected Biomass Plants (FY 2022–23)

Location	State	Capacity (MW)	Feedstock	Utilization Rate	Challenges
Jalkheri	Punjab	10	Paddy Straw	72%	Fuel supply inconsistency

Kurukshetra	Haryana	7.5	Mixed Crop Waste	65%	High ash content in paddy
Barabanki	U.P.	5	Wheat Straw	78%	Poor logistics & low tariff
Patna	Bihar	3	Sugarcane Residue	50%	Transport bottlenecks

Although average rates of utilisation lie between 50-78 per cent, the majority of the plants are limited by logistical and economic reasons, such as a lack of biomass during certain seasons, transportation expenses and low-cost power purchase agreements (PPAs). The changes in tariffs and the improvement in the infrastructure are required to streamline the plant's operations.

4.5. Farmer Participation and Willingness

A survey-based evaluation study carried out among 400 farmers in the Punjab and Haryana on their awareness and readiness in choosing to provide residues to biomass units gave the following:

Table 5: Farmer Willingness to Participate in Bioenergy Supply Chain

Response Type	Percentage
Willing to Sell Residue	68%
Prefers Burning	20%
Uses for Fodder/Compost	12%
Aware of Bioenergy Projects	33%

Good news comes in because almost 70 per cent of the farmers are ready to offer residues, provided they are compensated well. Yet the awareness is still at the level of only 33 per cent, and rural outreach and demonstration projects are needed.

4.6. Regional and Policy Disparities

Each state has a different achievement in promoting bioenergy programs. According to the reports by the government:

Table 6: RPO (Renewable Purchase Obligation) Compliance in Northern States (FY 2022–23)

State	Target RPO (%)	Actual Compliance (%)
Punjab	10.0	9.2
Haryana	9.0	8.1
Uttar Pradesh	8.5	6.0
Bihar	7.5	3.5

With the increased awareness, no none of the chosen states fulfilled their Renewable Purchase Obligations (RPOs) completely, which presupposes the low purchase of renewable energy and biomass. This implies lapse of enforcement and the necessity to pay more attention to biomass as a major source of compliance with RPO.

This paper has found that there is a huge and untapped potential of bioenergy production in Northern India using the agricultural residues with about 89 million tons of residual biomass yearly occurring in the major producing states such as Punjab, Haryana, Uttar Pradesh, and Bihar. Although this seems to be in great amounts, hardly 10 per cent of this potential has been utilised in the production of bioenergy, and pretty close to 37 per cent of this available has been freely burned, leading to the major causes of air pollution and climate change. The energy potential of this biomass is more than 1, 200 petajoules per year, and this implies the possibility of supporting millions of rural homes with sustainable power. Biomass plants on the operational stage show moderate success but are still struggling as there are still challenges in terms of the feedstock logistics, tariff structures, and inconsistencies in the policies. According to survey results, whereas most farmers are ready to join the biomass supply chains once they are offered suitable incentives, the level of awareness regarding bioenergy, however, is low. Moreover, the Renewable Purchase Obligation (RPO) compliance in the region is below the target, and this underpins the fact that there would have been an excellent opportunity to use biomass to drive clean energy targets. These results are all indications that demand a way to support through integration of policies, public-private

partnerships, introduction of technology and involvement of grass grassroots level to shift agricultural residue from one of its environmental liabilities into a treasure of energy resource.

The findings just indicate that bioenergy using agricultural residue has a lot of potential in Northern India. By effective supply chain planning, the involvement of farmers, and policy support, the area can shift its focus and stop burning residues, and switch to clean energy. Nevertheless, there is a chance of success only in case such systemic issues as infrastructure deficits, pricing systems, and community knowledge are tackled.

5. Conclusion

The research notes the mammoth but partially unexploited potential of bioenergy being farm wastes in Northern India. The region can revolutionise its energy sector to become sustainable, with the potential of producing a lot of excess biomass per year, including paddy straw, wheat husk, and sugarcane bagasse. Nevertheless, stubble burning, which has become the norm, lack of proper infrastructure, poorly aware farmers and inefficient implementation of policies still act as barriers to efficient utilisation of this resource. Those operational biomass power plants are already promising, but hampered by logistics problems and economics. However, the fact that farmers who have already shown an interest in engagement in biomass supply chains and the development of energy conversion technologies illustrates the definite direction in which it is possible to head. Through improved institutional coordination and motivation of rural participation, the increased RPO compliance, and the induction of decentralised energy concepts, bioenergy may become a pillar of Indian sustainable development, rural job creation, and environmental protection of Indian northern states.

References:

1. Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, 29, 42539–42559. <https://doi.org/10.1007/s11356-021-18186-5>
2. Bijarchiyan, M., Sahebi, H., & Mirzamohammadi, S. (2020). A sustainable biomass network design model for bioenergy production by anaerobic digestion technology:

- Using agricultural residues and livestock manure. *Energy, Sustainability and Society*, 10(1), 19. <https://doi.org/10.1186/s13705-020-00255-2>
3. Chauhan, K., & Singh, V. P. (2023). Prospect of biomass to bioenergy in India: An overview. *Materials Today: Proceedings*. <https://doi.org/10.1016/j.matpr.2023.04.050>
 4. Department of Agriculture & Farmers Welfare. (2022). *Annual report 2022–23*. Ministry of Agriculture and Farmers Welfare, Government of India. https://agricoop.nic.in/Documents/annual_report_english_2022_23.pdf
 5. Energy Alternatives India. (2022). *India biomass energy*. <https://www.eai.in/ref/ae/bio/bio.html>
 6. Ghosh, U., Das, D., Banerjee, D., Karmakar, S., & Das, J. (2021). Biomass energy potential in India: A review. *International Journal of Engineering Research & Technology (IJERT)*, 9(Nceter), 42–45.
 7. Koul, B., Yakoob, M., & Shah, M. P. (2021). Agricultural waste management strategies for environmental sustainability. *Environmental Research*, 206, 112285. <https://doi.org/10.1016/j.envres.2021.112285>
 8. Milićević, A. R., Belošević, S. V., Tomanović, I. D., & Crnomarković, N. Đ., & Tucaković, D. R. (2018). Development of mathematical model for co-firing pulverized coal and biomass in experimental furnace. *Thermal Science*, 22, 709–719. <https://doi.org/10.2298/TSC180209009M>
 9. Milićević, A., Belošević, S., Crnomarković, N., Tomanović, I., Stojanović, A., Tucaković, D., Deng, L., & Che, D. (2021). Numerical study of co-firing lignite and agricultural biomass in utility boiler under variable operation conditions. *International Journal of Heat and Mass Transfer*, 181, 121728. <https://doi.org/10.1016/j.ijheatmasstransfer.2021.121728>
 10. NITI Aayog. (2022). *Urban wastewater scenario in India*. Government of India. https://www.niti.gov.in/sites/default/files/2022-09/Waste-Water-A4_20092022.pdf

11. Pal, M. S., & Bhatia, M. (2022). Current status, topographical constraints, and implementation strategy of municipal solid waste in India: A review. *Arabian Journal of Geosciences*, *15*, 1176. <https://doi.org/10.1007/s12517-022-09897-6>
12. Pant, D., Misra, S., Nizami, A.-S., Rehan, M., van Leeuwen, R., Tabacchioni, S., Goel, R., Sarma, P., Bakker, R., & Sharma, N., et al. (2019). Towards the development of a biobased economy in Europe and India. *Critical Reviews in Biotechnology*, *39*(6), 779–799. <https://doi.org/10.1080/07388551.2019.1654977>
13. Pavlenko, N., & Searle, S. (2019). *The potential for advanced biofuels in India: Assessing the availability of feedstocks and deployable technologies*. International Council on Clean Transportation (ICCT).
14. Singh, A. D., Gajera, B., & Sarma, A. (2022). Appraising the availability of biomass residues in India and their bioenergy potential. *Waste Management*, *152*, 38–47. <https://doi.org/10.1016/j.wasman.2022.07.013>
15. Škrbić, S., Ašonja, A., Prodanović, R., Ristić, V., Stevanović, G., Vulić, M., Janković, Z., Radosavac, A., & Igić, S. (2020). Analysis of plant-production-obtained biomass in function of sustainable energy. *Sustainability*, *12*(14), 5486. <https://doi.org/10.3390/su12145486>
16. Vujic, B., Pekez, J., Mihajlovic, V., Radovanovic, L., Marceta, U., & Palinkas, I. (2020). Public perception and awareness on climate changes and the importance of renewable energy sources. *Applied Engineering Letters: Journal of Engineering and Applied Sciences*, *5*, 68–74. <https://doi.org/10.18485/aeletters.2020.5.2.3>