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REVIEW ARTICLE

Scope of Energy Harvesting from Agricultural Biomasses in India

Someshwar Chowdhury[1,2], Ashish Bhalchandra Deoghare[2], Rakesh Kumar Ghosh[1*] and Deb Prasad Ray[1]

[1]ICAR-National Institute of Natural Fibre Engineering and Technology, 12 Regent Park, Kolkata, West Bengal, India
[2]Department of Mechanical Engineering, National Institute of Technology Silchar, NIT Road, Fakiratilla, Cachar Silchar, Assam, India

*Corresponding author: iarirakesh@gmail.com (**ORCID ID:** 0000-0002-2937-7894)

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ABSTRACT

Agricultural residue constitutes an important part of the larger discussion about the environmental costs of development, covering a range of concerns from green energy harvesting to residual waste management. Research into the potential uses of agricultural waste is aimed at solving two problems at once, *viz.*, waste disposal and the need to create useful products from waste materials. As agricultural turnover increases with each passing year, so does the volume of agricultural residue generation. The use of biomass in recyclable format is the latest adapted method among all. Nutrient recyclability, biogas plants, multiple bioenergy forms are some of the needs of the hour in the sector of biomass energy. The government of India is taking initiatives to promote the use of biomass both in the fields of energy as well as for composite material production. From issuing low-interest loans to providing back-end subsidies, everything is being done at the moment to promote and empower clean-energy startups that aim to contribute to the process of utilizing residual agrowaste for real, tangible profit, both in environmental and monetary terms. The objective of our research has been to accelerate that process through the exploration of new and innovative solutions.

HIGHLIGHTS

- Management of residue–to–product residue (RPR).
- Cereals have the highest potential in the supply of bioenergy.
- Contribution of bioenergy to the global energy demand is increasing day by day.
- Efficacy of biomass in the supply of bioenergy also depends on the technology adapted for energy harnessing.

Keywords: Agricultural biomasses, Renewable energy, Energy harvesting, Bioenergy

In recent years, the boom of urbanization and industrialization has made clean energy a modern-day necessity. The quest for a cleaner and greener environment has gathered momentum in parallel with the increasing usage of electronic gadgets. As the demand for electrical power in our everyday lives has increased, so has our demand for cleaner, sustainable sources of electricity. Power requirement in India in the year 2000 was about 441 Mtoe (million tons of oil equivalent) and the present demand is about 880 Mtoe (IEA, 2021). Presently, India (1137 billion kWh) is the world's third highest consumer of electricity, China being the first (approximately about 5564 billion kWh) and the USA the second (approximately 3902 billion kWh for the year 2020) (INDEX, 2020) with average demand doubling every decade (INDEXMUNDI, 2020). To meet this rise in demand, there has been a marked increase

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in research and development concerning renewable energy. While major non-renewable sources like oil, coal, and natural gas still account for around 75% of the demand (2020), the rest (about 25%) has been met with the supply from biomass and other renewable sources.

Electrification of India is one of the main targets of GoI. One of the national objectives at this point is the total electrification of Indian Railways, ensuring "net zero" emissions by the year 2030. The aim is to draw the entire electrical load from renewable sources of energy. New ways have been proposed to harness renewable sources to the maximum extent possible. The beauty of renewable sources of energy lies in their renewability. Other than the existing renewable sources like solar energy, wind energy, tidal energy, etc., there are new sources that are being tapped these days and are much more useful for mankind. The usefulness of a renewable source of energy depends on the availability of the source, time of replenishment of the source, efficiency in harnessing the maximum output, and minimizing the least contribution to pollution.

Generation of Biomass

Agriculture began in earnest around 10-12,000 years ago. We have come a long way from that time. Post-Independence, in the late 1960s, with the implementation of the Green Revolution in India, crop production increased 2-3 folds. This inspires the fact that land addition to the agricultural community was the least (about 30%) in the past 50 years since Independence (Pingali, 2012). This increase in food production also leads to the rise in the year-old problem of higher generations of agricultural residue. Every year around 620 MT of agro residue is generated in India. Among various states, Uttar Pradesh (18.63%) followed by West Bengal (10.19%), Andhra Pradesh (9.25%), Punjab (9.14%) and Maharashtra (8.32%) remain the major residue-generating states (Fig. 1). Cereals contribute around 361.85 MT of residue annually and the five highest contributing states are Uttar Pradesh (19.90 %), Punjab (12.59 %), West Bengal (10.29%), Andhra Pradesh (9.13 %), Haryana (6.83 %) (Fig. 2a). Nearly 122.39 MT residues are generated annually from fibre cultivation systems and the

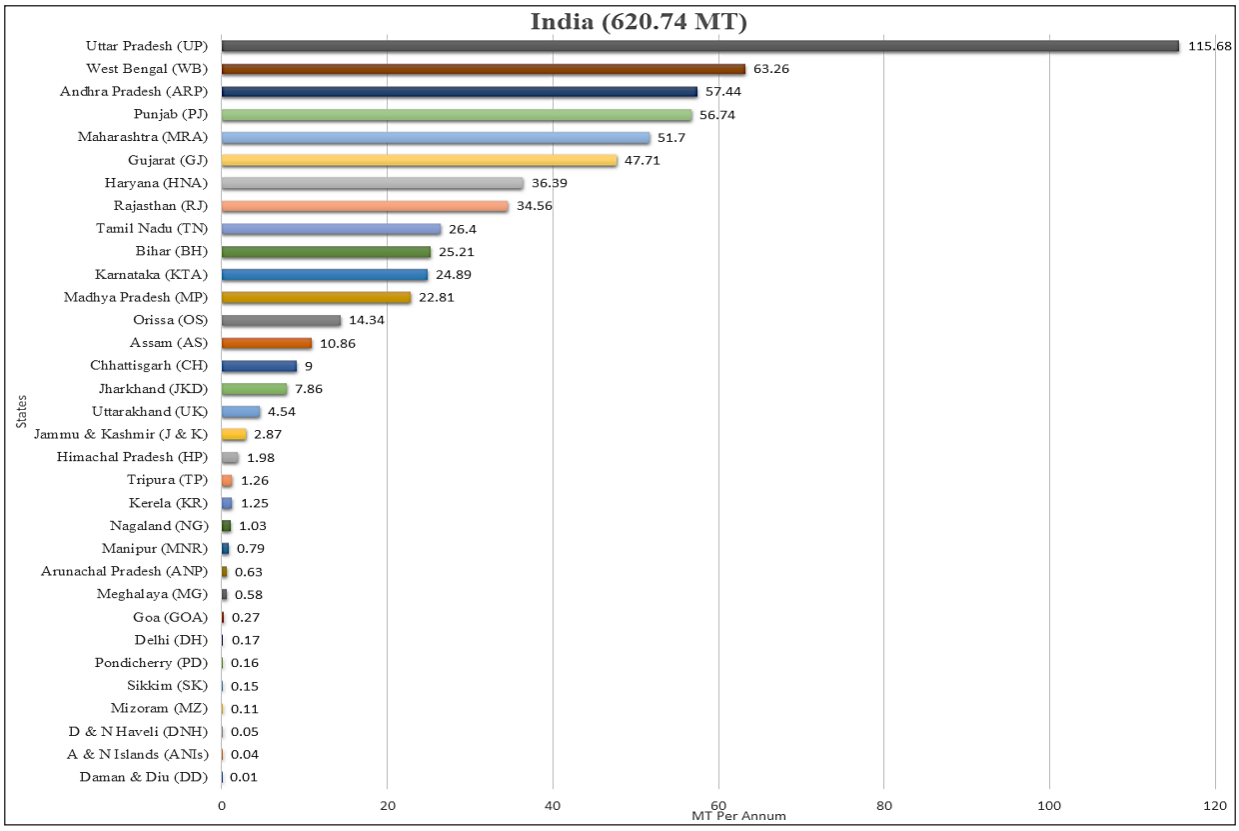

Fig. 1: Crop residue generation of various states of India

major five states are Gujrat (23.38 %), West Bengal (19.96 %), Maharashtra (15.94 %), Andhra Pradesh (13.13%), and Punjab (7.61 %) (Fig. 2b). Around 107.49 MT residues are generated from sugarcane and the top contributors are Uttar Pradesh (38.26%), Maharashtra (21.27 %), Tamil Nadu (12.37 %), Karnataka (8.8 %), and Gujrat (5.85%) (Fig. 2c). Out of 28.71 MT of oilseed crop residues, major contributors are Rajasthan (32.25%), Gujrat (17.62%), Andhra Pradesh (8.70%), Uttar Pradesh (8.67%), and Haryana (7.48%) (Fig. 2d). The issue of agricultural remnants dumped or burning persisted for decades. Management of agricultural residue is one of the major challenges to society these days. Biomass is an easy product to set on fire under any environmental condition. In India, stubble burning is one of the oldest practices still being continued today by farmers in villagers to get rid of these agricultural residues. One of the more serious environmental issues faced by GOI is the burning of agricultural residue on the farm which results in the reduction of nutrients and micronutrients level in the soil, thereby reducing soil fertility (GNM, 2021).

Hazards of biomass burning for energy purposes

Energy has been produced from biomass for ages. The energy produced was used exclusively in the form of fire. In turn, the direct, open-field burning of agro-waste results in the generation of large amounts of gases (ozone, carbon monoxide, methane, etc.) and ash which are extremely harmful to the human body (SANDEE, 2012). Researchers have proven that ozone generated from the burning of these biomasses results out to be 2 to 10 times more in volume than the yearlong pollution generated from an urban area of the Pacific (Bourgeois *et al.* 2021).

Techniques for energy harnessing

Animal husbandry, livestock farming, and agriculture are a couple of main sources of

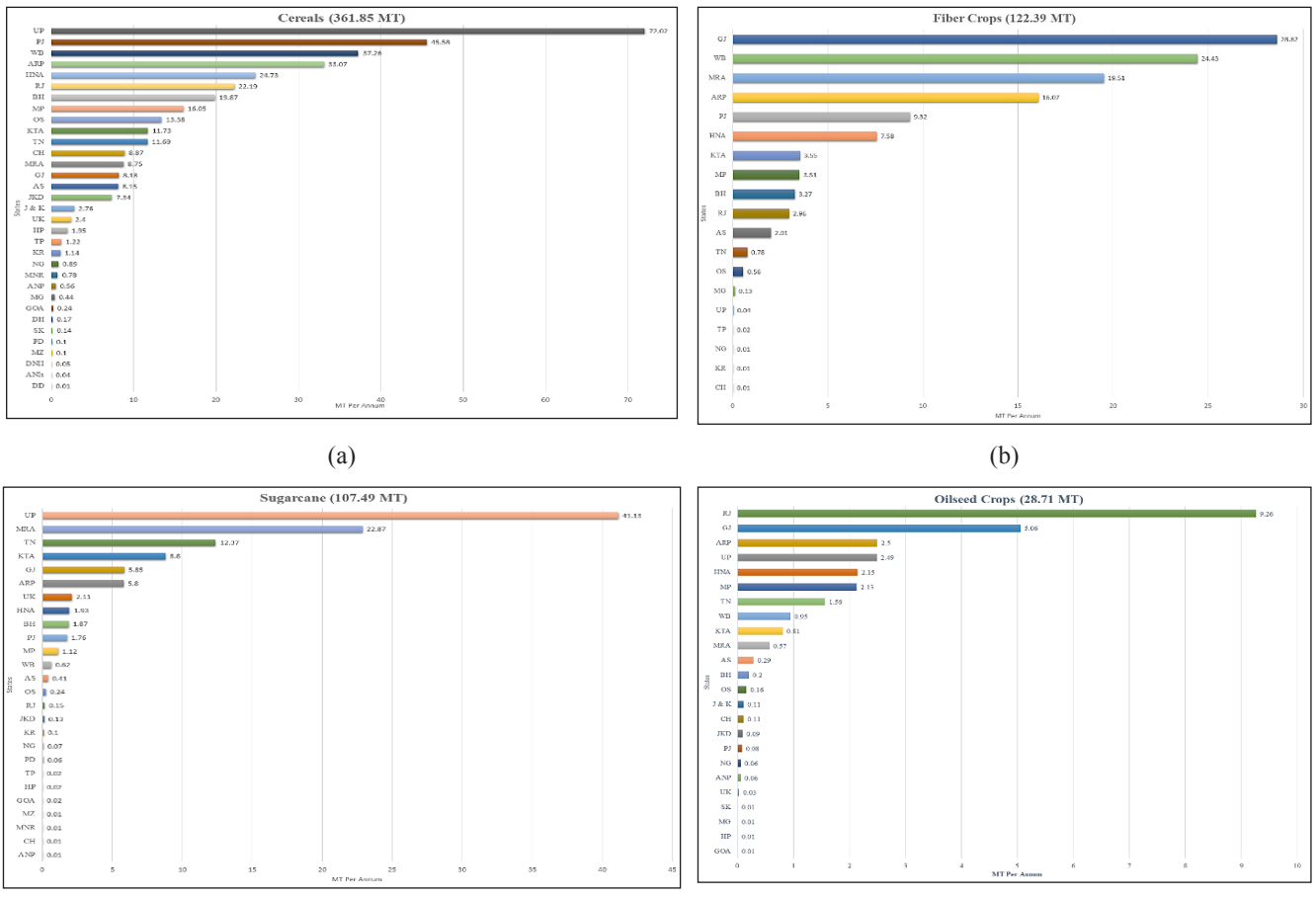

Fig. 2: Crop-wise production of different agro-residues **(a)** cereals, **(b)** fibre-crops, **(c)** sugarcane, and **(d)** oilseed crops in various states of the Indian subcontinent

income for the people of rural India. Biomass generated from these activities form the livelihood of a significant percentage of villagers. Collection, segregation, and accumulation of biomasses categorically based on calorific values are the major challenges. Multi-various processes like - direct combustion, thermochemical conversion, and biochemical conversion are being undertaken for the management of these residues for energy conversion techniques (Fig. 3). Out of the three processes, the first one is the most popular and has been in use for ages. But the technique of carrying out the process has changed a lot these days. Today it results in better power output for society and pollutes the environment to a lesser degree.

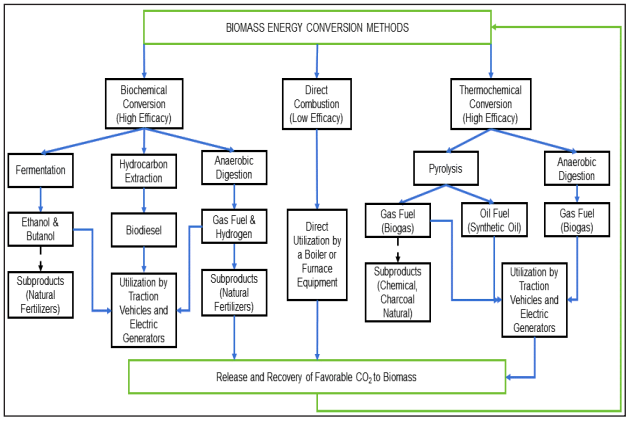

Fig. 3: Methods for energy harvesting from biomass

The conversion of biomasses to briquettes and pellets is an old technique practiced for ages. And these in turn are used for power generation in the form of heat or fire for many purposes. The more steps we have in the process of power generation from biomasses, the more pollution there is. Briquetting and pelleting exist these days only for the transport and movement of biomass from the place of production to the place of utilization. Nowadays, biomass as a fuel-based power plant is the latest technology in the field of power generation. India has its first biomass-based power plant - The Jabalpur Biomass Power Project at Madhya Pradesh with a capacity of 12MW. Nowadays, under schemes of Rural Electrification and Pradhan Manti Ujjawala Yojana almost 90% of all the villages in India and 8.05 million households of mostly rural India respectively have access to cleaner and greener fuels in the form of electricity and cooking gas.

Biomass Potentiality

Biomass management is one of the latest challenges these days in India, with available surplus biomass of 250 MT, and the potential for 28GW energy. Fig 4 represented various pathways for energy harvesting from biomass.

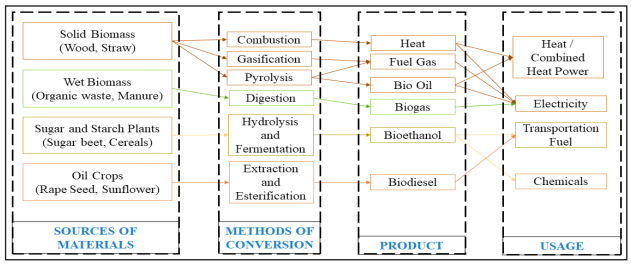

Fig. 4: Schematic pathway of power generation

India has installed 10170 MW capacity of power generation from the biomass sector, out of which 18.05% are biomass-dependent power plants, 74.36% from bagasse cogeneration technique, and 7.59% from non-bagasse cogeneration (BIO ENERGY, 2021). GoI is promoting several schemes and benefits in the form of subsidies, and low-interest loans for new entrepreneurs to grow up environment-friendly industries with the use of the remnants of the agriculture sector and existing industries for their modernization and expansion in the fields of cogeneration techniques for better use of the residual biomass wastes (WTE, 2022). Other than centralized methods of collecting and segregating the use of these biomasses pan India based, there are certain techniques in use for power generation for locally and short span of available use of biomasses. Biogas (which is a composition of methane, carbon dioxide, hydrogen sulphide, and some other gases), is one of the oldest techniques in the generation used for decades and is still prevalent in rural India for the disposition of biomasses in the form of agricultural waste, manure, municipal waste, plant materials, sewage, green waste, and food waste.

Current researches in energy harvesting from biomass

In the year 2008, out of the total fuel demand in the world, 13% is acknowledged by renewable sources which actually includes 10% of biomass (municipal waste – 3%, agricultural waste - 10%, other wood - 20%, fuelwood - 67%), 2% of hydro

sources and other sources around 1%, whereas, for the year 2011 this renewable sector contributed up to 40% more with a rise in supply from 13% to 21.8% in the total energy supply of the world (Popp *et al.* 2014). Tapping the highest residue-to-product ratio (RPR) is the need of the hour. Out of the most common crops (*viz.* rice, wheat, maize, coarse cereals, sugarcane, cotton) around us, cotton stalks have the highest RPR value of 3.8 Kg/Kg followed by rice straw at 1.5 kg/kg (Singh, 2016). Crop residues vary in their composition (Avcioglu *et al.* 2019; Singh *et al.* 2022).

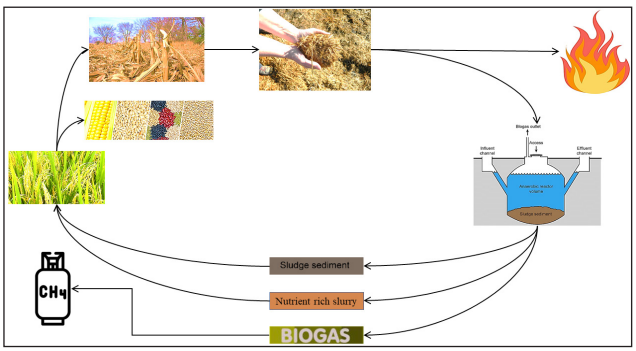

Fig. 5: Energy harvesting and nutrient recycling for a sustainable method

Researchers have stated bioenergy potential categorically for each crop type namely 133.67 MT of cereals residue estimated to about 2.26 * 10^{18} J of bioenergy, sugarcane residue of 51.12 MT estimated to 1.08 * 10^{18} J of energy, 22.10 MT of other types of residues generates 0.38 * 10^{18} J of bioenergy (Singh, 2016). Challenges have already been taken these days in a small-scale centralized collection of these residues over a particular area (block, panchayat, town, village, etc.) and generate some useful energy in the form of heat and electricity with the help of modern technologies (torrefaction, gasification, biogas, biofuel, etc.) (Hiloidhari *el al.* 2011; Singh, 2015; Ong *et al.* 2021) and use this form of heat energy for industrial purpose and paper industries (Farla *et al.* 1997).

CONCLUSION

Every bit of agricultural residue is a potential source of energy. Biomass technologies are the next generation power harvesting methods. This not only acts as source of energy but also helps in preservation of natural resources and restricts in addition of pollution to the environment. Reachability of biomass energy to a particular corner of the world is one of the easiest tasks these days with the help of new trending technological development in comparison to the supply of the traditional non-renewable energy sources. Though, biomasses have immense potential in energy harvesting but there are several issues that are concerning the use of these till date *viz.*, (i) crop residue availability; (ii) handling, storage and collection practices on regular basis; (iii) applicability of proper technologies with the correct form of residue available.

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