



MOBILISING AGRI-RESIDUES FOR MODERN BIOENERGY

THE AGRICULTURAL RESIDUE RESOURCE

In the ambition for achieving net zero emissions, indigenous agri-residues offer benefits when used in bioenergy and can contribute to several UN Sustainable Development Goals (SDGs). Agri-residues are a diverse range of biomass types arising from the production of food and industrial crops. Primary residues are those left in the fields after harvest, and secondary residues result from processing of the agricultural commodity. Thus, agri-residues include straws, stalks, stems, tops, husks and shells, as well as residues from the brewing and sugar industries. As crop production depends on weather, climate and geography, harvest is variable and crops are frequently cultivated far from the point of potential use of their associated residues. Primary residues are generally widely dispersed, low energy density materials, often high in moisture and perishable. Thus, they require densification and/or other pretreatment prior to use, to extend their shelf life and improve the feasibility and economics of storage, transportation, and use.

The top ten agricultural crops include sugar cane, maize, wheat, rice, oil palm fruit, soya beans, and cassava and their total production was over 5.5 Gt in 2022; each gives rise to different tonnage and types of residues. The exploitable global agri-residue resource depends on three main factors:

- 1) Total global resource: assessed based on the annual production of the different food crops from an estimation of the residue-to-product ratio; the number varies with geography.
- 2) Total sustainable global resource: the fraction that can be removed without impacting soil health, and considering biodiversity, local economic and environmental benefits versus bioenergy. This is the sustainable recovery factor (SRF).
- 3) Technical potential: assessment of the amount of the sustainable resource that is economically feasible to be used for energy and consideration of the associated greenhouse gas (GHG) savings.

Secondary residues are usually already concentrated and often have a SRF near 100% and so represent some of the easiest agri-residues to exploit. They include husks, shells and sugar cane bagasse. Some of the primary resources that are widely underutilised include sugarcane trash, soya bean straw, rice straw, oil palm fronds and empty fruit bunches; many others should be assessed for country-specific availability.

THE ESTIMATED GLOBAL POTENTIAL (MEDIAN VALUES) OF RESIDUES INDICATES A SIGNIFICANT CONTRIBUTION TO PRIMARY ENERGY OF 3312 PJ/Y BY 2030, INCREASING TO 70,000 PJ/Y BY 2050. ACCESSING AND MOBILISING THIS RESOURCE BECOMES A KEY CHALLENGE FOR THE FUTURE.

THE NEED FOR PRETREATMENT

As crop production varies with geography, countries will have a different mix of residues to exploit. Thus, every energy project will require bespoke design in developing a supply chain. Generally, densification is

a prerequisite to residue utilisation, including baling, briquetting or pelleting. Experience in pelleting of agri-residues is growing: understanding of factors including particle size, moisture, lignin nature and quantity, process conditions, or the use of binders or additives, help in the production of durable pellets.

In addition to challenging physical properties, the residues are often high in ash and problematic elements such as chlorine, nitrogen, and potassium. This may dictate an additional/alternative pretreatment step to produce a fungible fuel supply. Water washing can remove some troublesome elements and could play an important role in valorising agri-residues. Thermal pretreatments such as torrefaction, hydrothermal carbonisation, or steam explosion have been developed for upgrading agri-residues and can deliver superior pelleted fuels. Properties such as bulk density, energy density, durability, and resistance to weathering are targeted, and in some cases ash, chlorine and potassium levels are decreased also. Each added complexity in developing the supply chain affects the economics and GHG savings realised. Thus, each project needs to be considered on a case-by-case basis via technoeconomic assessment. Some of the best examples in the exploitation of agri-resources globally consider all these factors and also meet some key social development targets of the SDGs.

COMBUSTION SYSTEMS

Agri-residues have a role to play in the decarbonisation of the energy sector due to their availability, lower cost, higher carbon savings, and sustainability compared to woody biomass. Their use has been incentivised through various energy policies. The ash chemistry and high ash content of straws and other residues remains a challenge but may be overcome through boiler design. Fluidised bed boilers and grate systems are often more tolerant to deposition problems than pulverised fuel combustion systems. Many projects use agri-forestry fuels where the residue is blended with wood fuels. This assists supply-chain logistics and the blend with wood dilutes the problematic components in the agri-residue, which has enabled levels of 20–30% agri-residue in some cases. For projects that are seeking to displace coal via inclusion of agri-residues, the use of additives has proved effective in mitigating corrosion or ash deposition issues.

THE AGRI-RESIDUE PELLET MARKET

The wood pellet market has increased substantially this century to over 40 Mt in 2023 to meet growing demand in Europe and Asia. The most established markets for agri-residue pellets are for straws (wheat, rice, barley and oat straws) and husks (rice, coconut, peanut, wheat, sunflower and soya bean) and their 2023 market size was 6–8 Mt each. Agri-pellets are traded internationally, and the total agri-residue pellet market is over 22 Mt, with a value approaching \$4 billion. Traded pellets and briquettes are categorised under the ISO, but agricultural residues are not just traded in pelleted form. Two of the largest markets are for distiller's grains and solubles (DDGS), and soya bean processing residues; both are residues from integrated food and biofuel production industries. Their total market size in 2023 was 34.8 Mt and nearly \$15 billion; main exporters are the USA (for DDGS) and Brazil and Argentina (soya bean residues). Many agricultural and food processing residues are sold for animal fodder or feed; other markets include animal bedding, bioenergy, and horticulture.

The EU and the UK are the largest importers of biomass globally, mainly industrial wood pellets, but there is also an important role for agri-residues, such as straw. The agricultural residue market in Asia is growing rapidly, including for energy use. Japan and South Korea are the second and third largest global importers of biomass. Residues from the palm oil industry represent an important indigenous resource for Malaysia and Indonesia and these residues are also exported for bioenergy projects in Japan and Europe. China is mobilising its agri-residues in over 1000 agri-forestry-fuelled power projects, mainly in circulating fluidised bed and grate furnaces. This is being incentivised for dual benefits of straw management and decarbonisation of power. The Indian Government has mandated cofiring 5–7% residues in their fossil-fuelled electricity plant. Massive development of supply chains is required to achieve this goal.

Bioenergy from agri-residues is gaining traction as many nations are formulating incentives and policies for their use. Expansion of the international trade and markets in agri-residues for bioenergy will depend on many issues, some are captured in Figure 1.

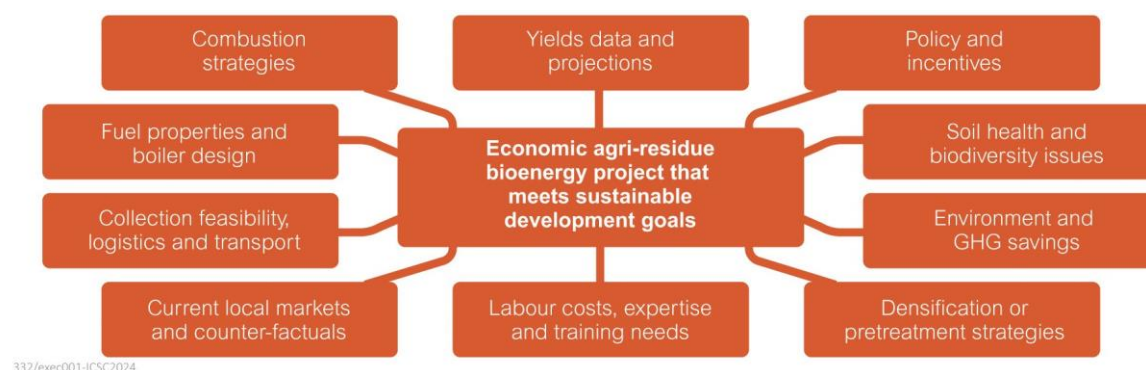


Figure 1 Some factors that govern the development of agri-residue supply chains and successful deployment for bioenergy

AGRI-RESIDUE ENTERPRISES WILL NEED TO IDENTIFY THE BEST RESIDUES AND THEIR GEOGRAPHICAL LOCATIONS FOR EXPLOITATION; THE ECONOMICS AND ASSOCIATED GHGS DEPEND ON LOCAL SITUATIONS AND ARE COUNTRY-AND RESOURCE-SPECIFIC. IN THE FUTURE, AI MODELLING AND DIGITAL PROCESSING MAY HELP TO ACHIEVE THIS AND SO MOBILISE UNTAPPED RESOURCES.

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Each executive summary is based on a detailed study which is available separately from: www.sustainable-carbon.org. This is a summary of the report: Mobilising agri-residues for modern bioenergy by Prof Jenny Jones, Dr Leilani Darvell, Dr Bijal Gudka, ICSC/332, ISBN 978-92-9029-655-3, 128 pp, July 2024.