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"Reconcile land system changes
with planetary health"

Catalyst-enhanced biomass gasification for agroecological energy transitions in Africa

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Abstract

Sub-Saharan Africa, where most economies are agrarian, faces profound energy access challenges that directly undermine agricultural productivity, food security, and rural livelihoods. Small-scale farmers in countries like Kenya, and especially within the Mwea Tebere Irrigation Scheme, the country's largest rice-growing region, rely on water-intensive farming while contending with high irrigation costs due to fossil fuel dependence. Simultaneously, open burning of rice husk waste pollutes the air and exacerbates environmental degradation. Growing up in Mwea, I witnessed firsthand how these intertwined economic, environmental, and energy burdens impacted my mother, a smallholder rice farmer, and our wider community. This experience fueled a lifelong commitment to developing clean, affordable, and livelihood-transforming energy innovations for rural areas. This study explores a cost-effective and environmentally friendly energy solution by converting rice husk waste into hydrogen-rich syngas through downdraft gasification. The research integrates two core innovations:

i. Densifying rice husks into pellets with sawdust to improve handling and combustion, and,

ii. Catalytically enhancing gasification using iron (III) oxide (Fe O) derived from local laterite soil to reduce tar formation and boost hydrogen production, specifically targeting energy generation through internal combustion engines and decentralised rural electrification.

Tests were done on a 20 kW Power Pallet downdraft gasifier to see how raw husk, binder-only pellets, and Fe_2O_3-doped pellets affect the syngas composition, cold gas efficiency, tar production, and ash behaviour. Preliminary results show that Fe_2O_3-doped pellets greatly increase hydrogen production, reduce tar output, and make the gasifier run more smoothly. A complementary techno-economic analysis affirms the affordability and viability of decentralised deployment using locally sourced materials. The produced hydrogen-rich syngas provides a sustainable, low-cost alternative to diesel and other fossil fuels for irrigation pumping, agro-processing, and rural electrification. By replacing expensive and polluting energy sources, this solution directly addresses the intertwined challenges of food security, environmental degradation, and rural economic development. It contributes to SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Future work will focus on piloting the system through rural energy cooperatives, enabling widespread adoption that empowers smallholder farmers, strengthens agroecological resilience, and supports inclusive, sustainable rural development.

Keywords: Agroecology, biomass gasification, circular economy

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