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CIRCULAR ECONOMY IN ACTION: TRANSFORMING WASTE BIOMASS INTO ENERGY – A PLAN FOR NIGERIA'S ECONOMY

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ABSTRACT

The circular economy paradigm offers Nigeria a sustainable path to economic diversification, resource efficiency, and energy security. This study focuses on transforming agricultural residues and other waste biomass into bio coal through torrefaction. It highlights the untapped potential of agricultural residues, such as rice husks, cassava peels, and palm kernel shells, alongside municipal solid waste. The paper presents a comprehensive plan for integrating bio coal production into Nigeria's energy landscape, detailing its economic, environmental, and social benefits. Data collection, methodology, results, and recommendations are outlined to underscore the feasibility and impact of this approach.

Keywords: Bio coal, Biomass energy, Circular economy, Renewable energy, Torrefaction, Waste biomass.

INTRODUCTION

Nigeria, Africa's largest economy faces significant economic and environmental challenges. Its economy relies heavily on fossil fuels, accounting for over 90% of export earnings. This dependency exacerbates vulnerability to fluctuating global oil prices and environmental degradation. However, Nigeria's agricultural and municipal sectors generate substantial biomass waste because of rapid urbanization, population, and industrialization, representing an underutilized resource with the potential to transform the energy landscape. This waste can have severe environmental and health implications if not properly managed. With the adoption of a circular economy, waste can be converted into energy, providing a sustainable solution for Nigeria's economy.

This article examines the viability of biocoal production in Nigeria, focusing on agricultural residues and municipal waste. It explores the process of torrefaction, its advantages, and its potential to create economic opportunities while addressing environmental challenges.

The Problem: Waste Biomass in Nigeria

Nigeria produces large amounts of biomass as waste, including agricultural waste, municipal solid waste, and food waste. According to the World Bank, Nigeria generates approximately 32 million tons of MSW annually, a significant portion being organic waste (World Bank, 2019). If this waste is not managed properly, it can lead to environmental pollution health issues and economic losses. The fossil energy crisis and global environmental pollution have led to a high demand for renewable and sustainable energy (Zhang and Song, 2018).

The Solution: Torrefaction of Waste Biomass

Torrefaction is a thermal process that converts biomass into high-energy bio coal. This process involves heating the biomass without oxygen to a temperature of 200-300^{0}C.This process can greatly improve the properties of solid biomass fuel, raising the energy density and enabling the pretreated fuel to be stored, ground, and easily transported. It makes the biomass like coal (Wei-Hsin, 2015). It can play a pivotal role in achieving a circular economy by promoting resource efficiency, reducing greenhouse gas emissions, and providing a sustainable solution for Nigeria's economy. These improvements make torrefied biomass a promising alternative to fossil fuel, offering both environmental and economic advantages.

BENEFITS OF TORREFACTION

1. **Reduced moisture content:** Torrefaction reduces the moisture content of biomass, making it easier to transport and store (Kumar *et al.,* 2017). Significant loss of energy due to re-absorption of moisture in biomass is saved (Kumar *et al.,* 2017)
2. **Improved energy density:** Torrefaction increases the energy density of biomass by 30% compared to raw biomass (Tumuluru *et al.,* 2021). The calorific value rises thereby making it a more efficient fuel for energy production (Wannapeera *et al.,* 2017).
3. **Increased shell life:** The shell life of the biomass increases using torrefaction making it a more reliable fuel source (Wannapeera *et al.,* 2017).
4. **Homogenous composition**: Whatever the original feedstock, torrefaction produces a more uniform product. This uniformity simplifies handling, combustion, and processing, leading to a more predictable and efficient energy production (Zhang and Song, 2018).
5. **Enhanced grindability**: The process of torrefaction makes the biomass more brittle, reducing the energy required for grinding by 85%. This enhanced grindability facilitates its use in various applications such as co-firing in coal-fired power plants and gasification without significant modifications, facilitating a conversion to renewable energy sources (Tumuluru *et al.,* 2021).
6. **Environmental benefits**: Using torrefied biomass as a renewable energy source contributes to reducing greenhouse gas emissions. Its improved properties make it a fossil fuels, supporting global efforts to fight climate change (Tumuluru *et al.,* 2021).

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METHODOLOGY

The study employs a mixed-methods approach, combining quantitative and qualitative data:

1. **Data Collection**:
   - **Agricultural Residue Data**: Information on crop yields and waste generation was sourced from the Nigerian Bureau of Statistics (NBS).
   - **Energy Demand Analysis**: Data on Nigeria's energy consumption and rural electrification rates were analyzed.
   - **Emissions Data**: Greenhouse gas emissions from agricultural waste burning and fossil fuel consumption were assessed.
2. **Experimental Process**:
   - Biomass samples (e.g., rice husks, cassava peels, palm kernel shells) were torrefied at temperatures between 200°C and 300°C for varying residence times.
   - The resulting bio coal's energy content, proximate analysis, and bulk density were measured.
3. **Economic Analysis**:
   - Cost-benefit analysis of biocoal production versus traditional fossil fuels.
   - Assessment of job creation potential and investment requirements.

RESULTS

1. **Resource Availability**:
   - **Agricultural Residues**: Nigeria generates approximately 50 million metric tons of agricultural residues annually, including:
     - Rice husks: 5 million tons
     - Cassava peels: 3 million tons
     - Palm kernel shells: 8 million tons
   - **Municipal Waste**: 32 million tons of municipal solid waste annually, with 60% being organic.
2. **Biocoal Production Metrics**:
   - Energy content of torrefied biomass: 18-22 MJ/kg.
   - Reduction in moisture content: Up to 70%.
   - Increase in energy density: Approximately 30% compared to raw biomass.
3. **Environmental Benefits**:
   - Annual CO_2 emissions reduction potential: 8.5 million tons.
   - Diversion of waste from landfills: 15 million tons annually.
4. **Economic Impact**:
   - Projected annual revenue from biocoal sales: $2 billion.
   - Job creation potential: 50,000 direct and 200,000 indirect jobs.

TABLES AND CHARTS

Table 1: Biomass Feedstock Availability in Nigeria

Feedstock	Annual Availability (Million Tons)	Energy Potential (PJ)
Rice Husks	5	90
Cassava Peels	3	54
Palm Kernel Shells	8	144
Municipal Waste	32	576

As shown in Figure 1 below the chart compares the energy content (MJ/Kg) of raw biomass, torrefied biomass, and traditional biomass. As seen, torrefied biomass has a higher energy content than raw biomass but slightly less than traditional coal, showing its potential as an efficient and sustainable energy source.

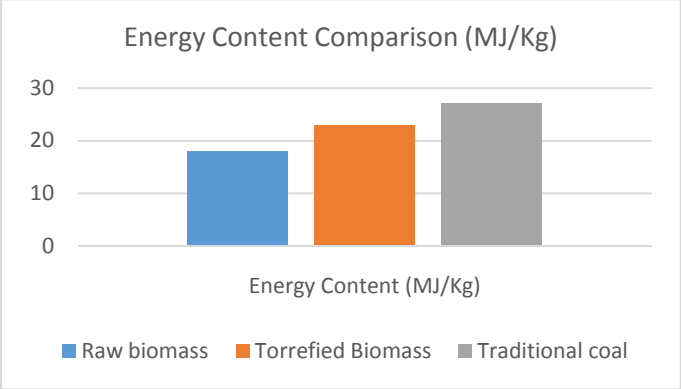

Figure 1: A bar chart comparing energy content (MJ/kg) of raw biomass, torrefied biomass, and traditional coal.

Figure 2 below shows **a** schematic torrefaction process flow showing key steps: feedstock preparation, torrefaction reactor, cooling and discharge, and product recovery.

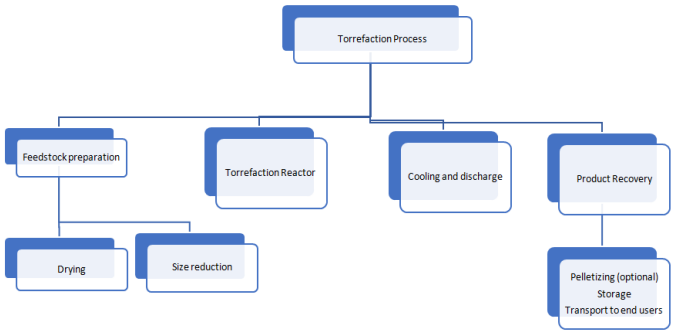

Figure 2: Torrefaction process flowchart (Tumuluru*et al*., 2021)

Table 2: Economic and Environmental Impact of Biocoal Production

Impact Area	Metric	Estimated Value
Revenue	Annual Sales	$2 billion
Employment	Direct Jobs	50,000
Employment	Indirect Jobs	200,000
CO_2 Emissions	Reduction Potential	8.5 million tons annually
Waste Diversion	Landfill Waste Reduction	15 million tons annually

CONCLUSION

Transforming waste biomass into energy is a circular economy approach that can provide a sustainable solution for Nigeria's economy. Bio coal production through torrefaction represents a transformative opportunity for Nigeria's energy and economic sectors. These advances make torrefied biomass a promising substitute for traditional fossil fuels. By harnessing agricultural residues and

municipal waste, Nigeria can reduce reliance on fossil fuels, lower greenhouse gas emissions, reduce waste, create sustainable jobs, and generate revenue. Moreover, biocoal aligns with global clean energy goals and enhances rural electrification efforts. With the implementation of a policy framework, infrastructure development, private sector, public awareness, and research and development, Nigeria can unlock the potential of waste biomass and create a more sustainable economy.

RECOMMENDATIONS

1. **Policy Framework**:
   - Develop policies to incentivize biocoal production, including tax breaks and subsidies for both companies and investors respectively.
   - Establish a regulatory framework to ensure quality standards and market stability.
2. **Infrastructure Investment**:
   - Build decentralized torrefaction plants in agricultural hubs for collection, processing, and conversion of waste biomass into bio coal. This includes torrefaction plants, bio digester plants and fermentation plants.
   - Enhance transportation networks for biomass collection and distribution.
3. **Capacity Building**:
   - Implement training programs for biomass processing and torrefaction technologies.
   - Foster partnerships with international experts and organizations.
4. **Public Awareness Campaigns**:
   - Educate farmers and waste producers about the economic benefits of biocoal.
   - Promote the environmental advantages of biocoal to garner public support.
   - Create the awareness about biomass conversion including waste management, job creation and renewable energy.
5. **Research and Development**:
   - Support R&D to optimize torrefaction technologies for local feedstocks.
   - Develop pilot projects to demonstrate the feasibility of biocoal production.
   - Improving on existing projects.

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