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ECONOMIC ASSESSMENT OF BIOMASS RESOURCE UTILIZATION IN THE CIRCULAR ECONOMY: EVIDENCE FROM UZBEKISTAN

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Abstract: The transition toward a circular economy has become one of the most important strategies for ensuring sustainable economic growth, efficient resource utilization, and environmental protection. Biomass resources, particularly agricultural residues, livestock waste, and organic municipal waste, represent an important renewable resource capable of contributing to energy security and sustainable development. Uzbekistan, as an agricultural country, generates substantial quantities of biomass every year through cotton production, wheat cultivation, horticulture, livestock farming, and food-processing industries. However, a considerable share of these resources remains underutilized or is disposed of through environmentally

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harmful practices, resulting in both environmental pollution and economic losses. This study assesses the economic potential of biomass resource utilization in Uzbekistan within the framework of the circular economy. The research applies descriptive analysis, comparative analysis, and economic evaluation methods using data from international organizations and national statistical sources. The study identifies the major biomass resources available in Uzbekistan and evaluates their contribution to renewable energy production, greenhouse gas emission reduction, rural employment, and resource efficiency. The findings indicate that Uzbekistan possesses considerable biomass potential that can be transformed into electricity, heat, biogas, biofertilizers, and other bio-based products. Effective utilization of these resources would reduce dependence on fossil fuels, improve waste management, create additional income for farmers, and support national green economy objectives. Nevertheless, several challenges—including limited investment, outdated technologies, insufficient infrastructure, and fragmented biomass supply chains—continue to constrain biomass commercialization. The study concludes that biomass utilization should become an integral component of Uzbekistan's circular economy strategy. Strengthening policy support, encouraging private investment, modernizing technologies, and improving biomass logistics would significantly enhance the country's renewable energy capacity while promoting sustainable economic development.

Keywords: Circular economy, biomass resources, renewable energy, economic assessment, agricultural residues, bioenergy, sustainable development, Uzbekistan.

1. Introduction

During the last two decades, sustainable development has become one of the principal priorities of economic policy worldwide. Rapid industrialization, population growth, increasing energy consumption, and environmental degradation have intensified the need for more efficient resource management systems. Traditional linear economic models based on the principle of "take–make–dispose" have led to excessive natural resource depletion, growing waste generation, and increased

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greenhouse gas emissions. Consequently, many countries are adopting the circular economy model, which emphasizes resource efficiency, waste minimization, recycling, and the continuous use of materials within production systems. The circular economy seeks to extend the life cycle of products and resources while minimizing environmental impacts. Within this framework, biomass represents one of the most valuable renewable resources because it can be continuously regenerated through agricultural and biological processes. Biomass includes agricultural residues, livestock manure, forestry by-products, food-processing waste, and municipal organic waste. Instead of being discarded, these materials can be converted into renewable energy, organic fertilizers, biofuels, and industrial raw materials, thereby creating additional economic value. Globally, biomass already plays an important role in renewable energy systems. Many developed countries have successfully integrated biomass into national energy policies through the construction of biogas plants, biomass power stations, and biofuel production facilities. These initiatives have contributed to reducing fossil fuel consumption, lowering carbon emissions, and promoting rural development. International organizations, including the Food and Agriculture Organization (FAO), the International Energy Agency (IEA), and the World Bank, emphasize that sustainable biomass utilization is essential for achieving the Sustainable Development Goals and fulfilling international climate commitments. Uzbekistan possesses favorable conditions for biomass development due to its large agricultural sector. Cotton, wheat, fruits, vegetables, vineyards, and livestock farming generate significant quantities of agricultural residues every year. However, much of this biomass is either burned in fields or left to decompose, leading to environmental pollution and inefficient resource use. Expanding biomass utilization could improve energy security, increase farmers' incomes, reduce waste, and support the transition toward a green economy. The purpose of this study is to evaluate the economic potential of biomass resource utilization within the circular economy framework in Uzbekistan. Specifically, the research aims to assess the availability of biomass resources, analyze their economic and environmental benefits, identify existing

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challenges, and propose policy recommendations for improving biomass management and promoting sustainable development.

2. Literature Review

The concept of the circular economy has attracted considerable attention in recent years as governments and researchers seek sustainable alternatives to the traditional linear economic model. According to the Ellen MacArthur Foundation, the circular economy is based on three main principles: eliminating waste and pollution, keeping products and materials in use for as long as possible, and regenerating natural systems. Biomass utilization fits well within these principles because biological resources can be continuously renewed and reused through efficient management practices. Previous studies indicate that biomass is one of the most important renewable energy sources worldwide. Scarlat et al. (2022) argue that agricultural residues should be viewed as valuable economic resources rather than waste. Biomass can be transformed into electricity, heat, biofuels, and organic fertilizers, thereby increasing resource efficiency and reducing environmental impacts. Similarly, the International Energy Agency reports that biomass accounts for a significant share of global renewable energy consumption and contributes to energy diversification and climate change mitigation.

Research on Uzbekistan highlights the country's substantial biomass potential due to its strong agricultural base. Cotton stalks, wheat straw, livestock manure, fruit tree pruning residues, and food-processing waste represent major biomass resources. However, previous studies also emphasize that biomass utilization remains limited because of insufficient investment, outdated technologies, and weak logistics infrastructure.

Although existing literature provides valuable information regarding biomass availability and renewable energy production, relatively few studies have comprehensively evaluated the economic potential of biomass utilization within the circular economy framework in Uzbekistan. This research seeks to address this gap by

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integrating economic, environmental, and resource-efficiency perspectives into a single analytical framework.

3. Research Methodology

This study employs a mixed-method research approach that combines quantitative and qualitative methods to assess the economic potential of biomass resource utilization in Uzbekistan within the framework of the circular economy. Such an approach enables a comprehensive evaluation of biomass resources by considering economic, environmental, and social dimensions simultaneously.The research is based primarily on secondary data obtained from international organizations, scientific publications, and national statistical reports. Information was collected from the Food and Agriculture Organization (FAO), the International Energy Agency (IEA), the World Bank, the State Statistics Agency of the Republic of Uzbekistan, and the Ministry of Energy of Uzbekistan. Additional data were gathered from peer-reviewed journal articles related to biomass utilization, renewable energy, and circular economy development.

Several analytical methods were applied in the study.

Descriptive statistical analysis was used to evaluate the availability of biomass resources, agricultural production, renewable energy potential, and regional distribution of biomass.

Comparative analysis was employed to compare Uzbekistan's experience with countries that have successfully developed biomass industries, including Germany, Sweden, China, and Turkey.

Economic assessment focused on evaluating the potential benefits of biomass utilization through indicators such as renewable energy production, additional income generation, reduced waste management costs, and environmental improvements.

The study also applies the principles of the circular economy to demonstrate how agricultural residues can be transformed into valuable economic resources instead

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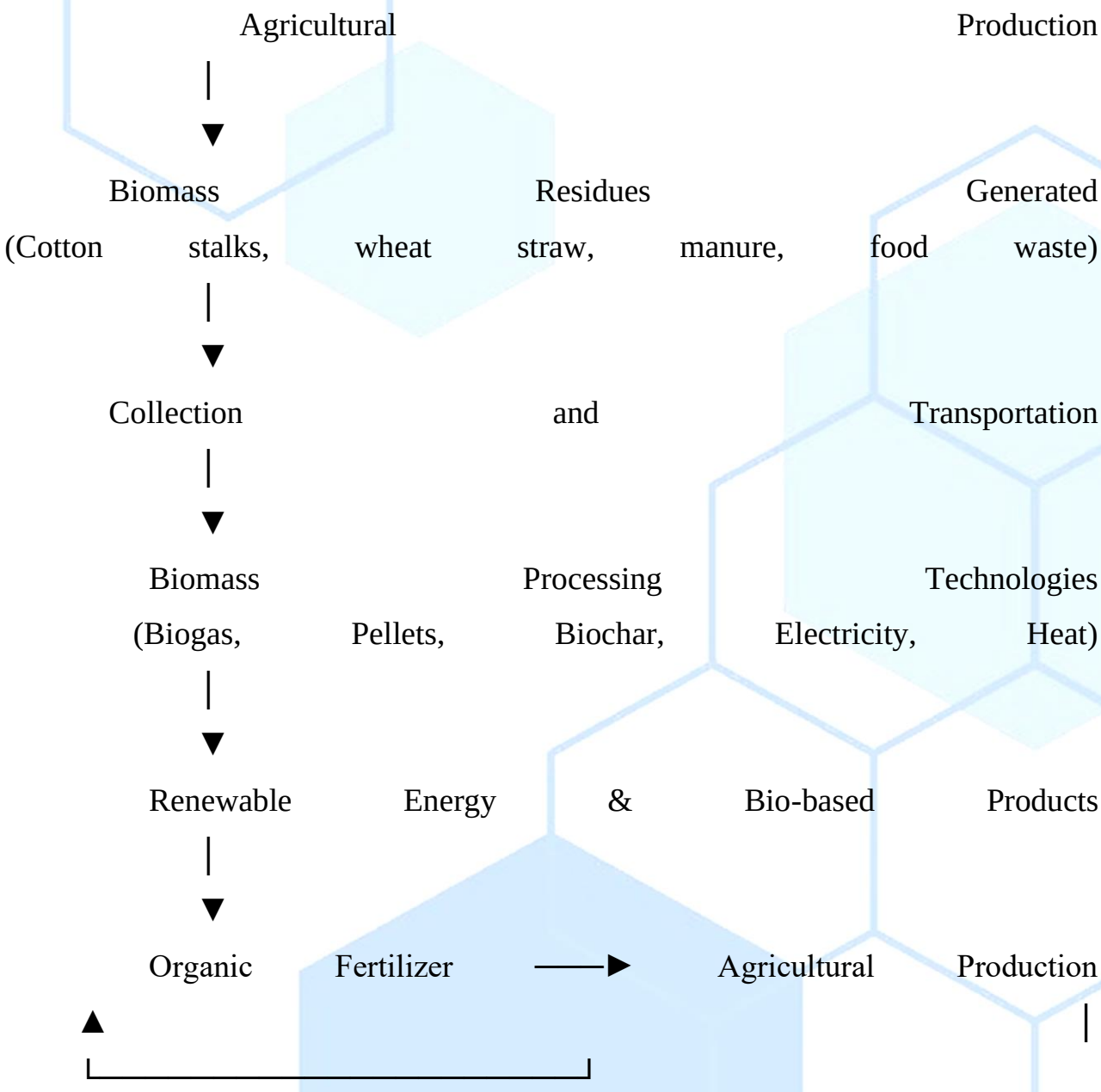
of being treated as waste. This integrated methodological framework provides a comprehensive basis for evaluating biomass commercialization in Uzbekistan.

Figure 1. Circular Economy Model of Biomass Resource Utilization in Uzbekistan



4. Biomass Resources in Uzbekistan

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Uzbekistan is one of the leading agricultural countries in Central Asia, where agriculture continues to play an important role in economic development. The sector contributes significantly to employment, food security, and export earnings while simultaneously generating large quantities of organic residues suitable for biomass utilization.

The principal biomass resources in Uzbekistan include:

I. cotton stalks;
II. wheat straw;
III. rice husks;
IV. fruit tree pruning residues;
V. vineyard residues;
VI. livestock manure;
VII. poultry litter;
VIII. food-processing waste;
IX. municipal organic waste.

Among these resources, agricultural residues represent the largest share because Uzbekistan annually cultivates extensive areas of cotton and wheat. These crops produce substantial amounts of by-products that can be converted into renewable energy or bio-based products.

According to available estimates from international organizations, Uzbekistan generates more than **30 million tonnes of biomass resources annually**, most of which originate from agricultural activities. Despite this significant potential, only a relatively small proportion is currently utilized for energy production or industrial purposes. Instead of being processed, a considerable amount of agricultural biomass is burned directly in fields or left to decompose naturally. Such practices contribute to greenhouse gas emissions, soil degradation, and inefficient resource utilization.

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Table 1. Major Biomass Resources in Uzbekistan

Biomass Source	Main Origin	Possible Utilization
Cotton stalks	Cotton production	Pellets, briquettes, electricity
Wheat straw	Wheat cultivation	Biofuel, heat generation
Livestock manure	Animal husbandry	Biogas production
Fruit pruning residues	Orchards	Biomass fuel
Vineyard residues	Vineyards	Pellets, biochar
Vegetable waste	Food processing	Compost, biogas
Municipal organic waste	Households	Waste-to-energy

The diversity of biomass resources provides opportunities for developing various renewable energy technologies and promoting circular resource management.

5. Economic Assessment of Biomass Utilization

From an economic perspective, biomass represents an underutilized renewable resource capable of creating additional value throughout the agricultural production chain.

The economic benefits of biomass utilization can be grouped into four major categories.

5.1 Energy Production. Biomass can be converted into electricity, heat, and biogas using modern conversion technologies such as anaerobic digestion,

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combustion, gasification, and pyrolysis. Renewable energy generated from biomass reduces dependence on fossil fuels and strengthens national energy security.

5.2 Additional Income for Farmers. Agricultural residues are traditionally regarded as waste with little or no market value. However, under the circular economy model, farmers may generate additional income by selling biomass to bioenergy plants or biomass processing companies. This creates an entirely new agricultural value chain.

5.3 Employment Creation. The biomass sector generates employment opportunities during:

I. biomass collection;
II. transportation;
III. processing;
IV. operation of biomass plants;
V. equipment maintenance;
VI. research and engineering.

Most of these jobs are created in rural areas, contributing to regional economic development.

5.4 Environmental Cost Reduction

Open-field burning of agricultural residues produces significant quantities of carbon dioxide, methane, and particulate matter. Utilizing biomass instead reduces environmental pollution and lowers waste management costs. Furthermore, biogas plants produce digestate that can be used as an organic fertilizer, reducing the demand for chemical fertilizers.

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Table 2. Main Economic Benefits of Biomass Utilization

Indicator	Expected Economic Effect
Renewable electricity	Increased energy security
Biogas production	Lower fossil fuel consumption
Organic fertilizer	Reduced agricultural costs
Rural employment	Increased household income
Waste recycling	Improved resource efficiency
Carbon emission reduction	Environmental benefits

Overall, biomass utilization contributes simultaneously to economic growth, environmental protection, and sustainable rural development.

6. Results and Discussion

The analysis indicates that Uzbekistan possesses favorable conditions for expanding biomass utilization because of its abundant agricultural resources and increasing demand for renewable energy. The country's agricultural sector generates millions of tonnes of biomass annually, yet only a small proportion is commercially utilized. This represents a significant opportunity for improving resource efficiency under the principles of the circular economy.

International experience demonstrates that biomass industries become economically successful when governments provide stable policy support, financial incentives, and technological modernization. Germany and Sweden have developed extensive biomass energy systems through investment subsidies and feed-in tariffs, while China has expanded biomass utilization by integrating agricultural waste into

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renewable energy production. Compared with these countries, Uzbekistan has considerable natural potential but remains at an early stage of biomass commercialization. The principal barriers include insufficient investment, limited technological capacity, fragmented biomass supply chains, and inadequate logistics infrastructure.

Despite these challenges, the findings suggest that biomass could become an important component of Uzbekistan's renewable energy strategy. Expanding biomass utilization would improve waste management, reduce greenhouse gas emissions, create additional employment opportunities, and increase rural incomes while supporting the country's transition toward a sustainable circular economy.

7. Policy Recommendations

The results of this study indicate that Uzbekistan has significant biomass resources that remain largely underutilized. Effective management of these resources could improve renewable energy production, reduce environmental pollution, strengthen energy security, and support sustainable economic development. To realize this potential, several policy measures should be implemented. First, it is essential to develop a **national biomass development strategy** that clearly defines long-term objectives, institutional responsibilities, investment priorities, and mechanisms for biomass collection and utilization. Such a strategy should be integrated into Uzbekistan's broader Green Economy Strategy and renewable energy development programs.

Second, the government should encourage private investment through financial incentives such as tax exemptions, low-interest loans, grants, and public-private partnerships. These measures would reduce investment risks and promote the establishment of biomass processing facilities, particularly in rural areas where agricultural residues are abundant. Third, improving biomass collection and transportation systems is necessary to ensure a stable supply of raw materials. Regional biomass collection centers, storage facilities, and logistics networks would reduce transportation costs and improve operational efficiency. Another important

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recommendation is the modernization of biomass conversion technologies. The introduction of advanced technologies such as anaerobic digestion, gasification, pellet production, and biomass-fired combined heat and power (CHP) systems would increase energy efficiency while reducing environmental impacts.

In addition, universities and research institutions should strengthen research on biomass utilization and circular economy practices. Cooperation between academic institutions, government agencies, and private companies can accelerate technology transfer and support innovation in renewable energy.

Finally, public awareness campaigns should be implemented to educate farmers and local communities about the economic and environmental benefits of biomass utilization. Farmers should be encouraged to consider agricultural residues as valuable economic resources rather than waste.

8. Conclusion

The transition toward a circular economy requires more efficient utilization of renewable biological resources capable of supporting sustainable economic development. Biomass has emerged as one of the most promising renewable resources because it contributes simultaneously to renewable energy production, waste management, greenhouse gas emission reduction, and rural development. This study examined the economic potential of biomass resource utilization in Uzbekistan within the framework of the circular economy. The analysis demonstrated that the country generates substantial quantities of biomass from agriculture, livestock farming, food-processing industries, and municipal organic waste. Despite this considerable resource base, a significant proportion of biomass remains underutilized due to technological, financial, and institutional constraints. The findings suggest that biomass utilization could provide multiple economic benefits, including increased renewable energy production, additional income for farmers, reduced dependence on fossil fuels, improved waste management, and new employment opportunities in rural areas. Furthermore, the adoption of circular economy principles would transform agricultural

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residues from low-value waste into economically valuable resources, thereby improving resource efficiency and environmental sustainability.

International experience also demonstrates that successful biomass development depends on supportive government policies, technological innovation, efficient logistics, and adequate financial incentives. Countries such as Germany, Sweden, and China have shown that biomass can become an important component of national renewable energy systems when appropriate institutional frameworks are established.

For Uzbekistan, expanding biomass utilization represents an opportunity to diversify the national energy mix, promote green economic growth, and contribute to climate change mitigation. Achieving these objectives will require coordinated action by government institutions, private investors, research organizations, and local communities.

Overall, biomass utilization should be recognized not only as an alternative energy source but also as a strategic instrument for implementing the principles of the circular economy and ensuring sustainable development in Uzbekistan.

9. Practical Implications

The results of this research have several practical implications for policymakers, investors, researchers, and agricultural producers.

For policymakers, the findings provide evidence that biomass should be integrated into national renewable energy and circular economy strategies. Appropriate regulatory frameworks, investment incentives, and institutional coordination are essential for developing a sustainable biomass sector. For investors, the study demonstrates that biomass projects have the potential to become economically viable, particularly when supported by modern technologies and favorable government policies. Investments in biogas plants, biomass power stations, and pellet production facilities could create long-term economic returns while contributing to environmental sustainability. For farmers, biomass commercialization offers an opportunity to generate additional income by selling agricultural residues that

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are currently discarded or burned. This would improve farm profitability and encourage more efficient resource utilization.

For researchers, the study provides a foundation for future investigations into biomass supply chains, life-cycle assessment, carbon emission reduction, and the application of digital technologies in biomass management.

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