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Policy Brief

A Blueprint for Pakistan's Bioeconomy: Turning Resources into Resilience

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Executive Summary

Overview

Agriculture contributes 24 percent to Pakistan's national economy and employs 37.4 percent of the workforce. Despite this strong agricultural base, the bioeconomy's share in national output remains among the lowest globally. This shows a wide gap between the available bioeconomy resources and their effective utilisation. Based on national statistics, sectoral reports, and existing bioeconomy literature, this Policy Brief examines the systemic challenges constraining Pakistan's bioeconomy and outlines actionable solutions to unlock its potential.

The Brief highlights that annually an estimated PKR 500 billion worth of agriculture produce is lost at post-harvest stage. Agricultural inefficiencies, such as water insecurity and outdated seeds, continue to hinder productivity. Weak regulatory systems, moreover, prevent biotechnology from reaching farmers and industry. In Pakistan, energy tariffs are also among the highest in the region, undermining competitiveness of its biomass-processing industries.

The findings suggest that, by aligning Pakistan's bioeconomy strategy with global best practices and leveraging its natural comparative advantages, the country can transform agricultural residues and biological resources into value-added products such as biofuels and biopharmaceuticals. This may strengthen Pakistan's food security and rural employment and reduce fossil fuel dependence, increase exports while building resilience against economic shocks.

Policy Recommendations

- Establishing a National Bioeconomy Council within one year with a digital one-window portal for biosafety, seed registration, and export certification.
- An investment plan for modern packhouses, cold storage hubs, and processing facilities in major producing districts.
- Launching waste-to-value pilot projects for crop residues and livestock waste in Punjab and Sindh.
- Strengthening export competitiveness by implementing traceability and certification systems aligned with EU and GCC requirements.

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Introduction

Bioeconomy refers to economic activities that make use of biological resources to produce bio-based goods and services[1]. It is considered a pathway toward sustainable development as it drives innovation in agriculture, industry, and health sector through the application of biotechnology and modern life sciences, as well as promotes resource efficiency through recycling and residue valorisation. In parallel, it reduces dependence on fossil fuel-based inputs by offering renewable alternatives such as bioenergy, bioplastics, and biofertilisers.

Agriculture, in particular, forms a critical pillar of the bioeconomy as it supplies the bulk of biological resources on which bio-based production depends. Pakistan also has strong bioeconomy potential due to its large arable area. Currently, agriculture contributes 24% to the national economy. 37.4% of the workforce is engaged in the agriculture sector[2]. Despite this strong agriculture base, the contribution of the bioeconomy to national output remains among the lowest in the world, highlighting a significant gap between available resources and their effective utilisation.

Issue to be Analysed

- Identify the systemic challenges constraining Pakistan's bioeconomy.
- Propose actionable solutions to unlock Pakistan's bioeconomy potential.

Analysis

Pakistan is unable to tap its bioeconomy resources. Developed countries, however, are tapping into the potential of the bioeconomy and ensuring a balance between bioeconomy and traditional economy. Sweden, for instance, is replacing fossil-based resources with bio-based renewable alternatives. Major challenges behind bioeconomy integration are discussed hereunder.

Value Addition and Biofuels

Pakistan incurs an estimated PKR 500 billion in annual losses at the post-harvest stage. The losses ranges from 25 to 50 % in fruits and vegetables, which contribute to the country's food security challenges (see Table 1). This occurs primarily due to

[1] Bugge, M. M., Hansen, T., & Klitkou, A. (2016). What is the bioeconomy? A review of the literature. *Sustainability*.
[2] Dawn (2025). https://www.dawn.com/news/1917950

inadequate cold chains, limited grading facilities, and insufficient storage systems.[3]

Table 1: Post-Harvest Losses by Province	
Province	**Fruits & Vegetables**
Punjab	~40%
Sindh	~45%
Khyber Pakhtunkhwa	~35%
Balochistan	~40%
Dawn (2025)	

With Pakistan's population growing at approximately 2% annually, it is imperative to ensure that agricultural produce reaches consumers in safe condition, retaining the nutritional value present at the time of harvest. Some traditional methods to prevent these losses (such as chemical pesticides), diminish the nutritional value of crops and harm soil's health.[4]

Energy

Pakistan's agricultural biomass processing industries, which could otherwise absorb a portion of the agriculture produce, remain uncompetitive due to high energy and production costs compared to regional peers. Consequently, much of the country's agricultural biomass is wasted instead of being converted into higher-value products such as biofuels, biochemicals, or bioplastics, representing a major missed opportunity for value addition within Pakistan's bioeconomy.

Bioeconomists report that electricity and fuel account for up to 30-40% of their industry's total operating expenses. However, the industrial energy tariffs in Pakistan are at $0.15 per kWh, almost double that in Vietnam. In Gas and LNG, Pakistan's industry is paying around $ 9 per MMBtu energy tariffs. This rate is almost 1.5 times higher than Bangladesh. At such tariffs, the cost of electricity remains higher than all major competitors. Recently, following the disconnection of industrial captive power plants, the government approved a 6.6% increase in prescribed natural gas prices to meet about Rs 890 billion in revenue requirements for the companies during 2025-26.

Agriculture

Agriculture is the backbone of Pakistan's bioeconomy. However, it suffers from systemic challenges. Water insecurity remains the most pressing issue, with inefficient irrigation practices and lack of water pricing reforms leading to wastage and poor yields. Farm sizes are shrinking due to land fragmentation, making mechanisation and

[3] Qureshi, S. (2020). Challenges and opportunities for agriculture in Pakistan: towards food security. *Asian Journal of Agriculture and Development*.
[4] Ibid.

modern farming unviable[5].

Productivity is stagnating because of outdated seeds, limited extension services, and minimal adoption of best agronomic practices. Certified seed availability is low, and private investment in seed development is held back by unpredictable policies. Deforestation, particularly in Pakistan's KP province continues unchecked. In rural regions, crop residues are routinely burnt rather than converted into valuable inputs, further degrading soil health and air quality.

International Trade

Pakistan's bio-based exports suffer from recurring quality lapses and lack of traceability systems, which frequently lead to rejection in foreign markets. In 2024, Pakistan's fish exports, especially to the US and EU, faced frequent cancellations due to environmental non-compliance and poor storage conditions. International buyers often perceive Pakistani products as inconsistent, resulting in a trust deficit that limits long-term contracts.

The trade structure also favours raw material exports such as lint cotton, molasses, or oilseed cake rather than processed goods with higher margins. In addition, weak product development capacity means Pakistan rarely introduces new bio-based products tailored to global consumer trends.

Biotechnology

Biotechnology is the growth engine of the bioeconomy. However, in Pakistan, it ia constrained by lack of skilled manpower and fragmented institutional efforts. There are too few trained bioeconomists. Efforts are scattered across ministries and councils without coordination, leading to duplication and wasted resources. Regulatory approvals for biosafety, trials, and product registration are slow and unclear, discouraging private investment. Moreover, commercialisation remains weak as research often remains confined to labs without mechanisms for spinouts, patents, or industry adoption.

Proposed solutions for Pakistan

Pakistan's bioeconomy barriers can be addressed through a transition toward modern sustainable production systems. Based on the literature, the following solutions are proposed to unlock Pakistan's bioeconomy potential.

Cold Chain and Processing Infrastructure

[5] FAO. (2019). *The State of Food and Agriculture 2019: Moving forward on food loss and waste reduction*. Food and Agriculture Organization of the United Nations.

Post-harvest inefficiencies in Pakistan's horticulture sector undermine domestic food security and weaken export competitiveness. In the horticulture sector (as stated in the challenges section), post-harvest losses reach an estimated 35-40% in perishable commodities such as mangoes, citrus, potatoes, and onions.[6] The consequences are not limited to local markets. For instance, mango exports frequently face rejection in the EU due to poor handling, lack of cold chain facilities, and inconsistent quality, costing Pakistan millions of dollars in lost earnings.

Comparable challenges have been successfully addressed elsewhere, globally. India's National Horticulture Board, for example, financed large-scale investments in pre-cooling units and packhouses for grapes and pomegranates. These facilities allowed farmers to meet strict international quality standards, reduce wastage, and establish a consistent presence in European supermarkets.

Global lessons suggest that Pakistan could follow a similar pathway by developing packhouses and pre-cooling facilities in its major fruit and vegetable clusters. Financing could be structured through matching grants for farmer cooperatives and concessional credit for private investors, while provincial governments scale up models like Punjab's "value-chain cluster" pilot. In that initiative, onion and potato packhouses helped farmers extend shelf life, reduce wastage, and capture higher margins. If scaled nationally, such interventions could cut annual horticultural losses by as much as $1 billion, while substantially boosting export competitiveness.

Beyond horticulture, resource valorisation offers additional opportunities. Brazil's sugarcane ethanol industry illustrates how agricultural residues can underpin energy security and rural employment. Pakistan, with abundant rice straw, wheat straw, and dairy waste, could replicate this model by investing in biorefineries for second-generation ethanol, biogas, and bioplastics. Instead of burning residues, a practice that worsens smog and climate impacts, these by-products could be monetised through waste-to-value industries, generating both economic and environmental returns.

Energy Cost Relief for Processors

In Pakistan, high energy costs remain one of the most binding constraints on agro-processing and bio-based industries. This significantly reduces competitiveness in regional markets.

[6] https://doi.org/10.71016/hnjss/x51w2w80

Energy-intensive products such as kinnow juice concentrate or rice-based starch derivatives often fail to reach export scale because processors cannot offer consistent prices in global markets. Inefficient machinery and outdated irrigation pumps add to the burden, with diesel waste from old tractors alone costing Pakistan's agriculture over PKR 38 billion annually.

Comparable challenges have been tackled successfully elsewhere. Mexico, for instance, integrated its industry with co-generation from sugar mills, enabling plants to produce both fuel and electricity while lowering energy costs. In India, the government's renewable energy programs allowed rice mills and cold storages to install rooftop solar with net-metering, cutting power costs by up to 25%. These measures can make agro-processing more competitive while reducing reliance on volatile grid tariffs.

For Pakistan, a similar pathway could be charted by enabling agro-processors to directly source renewable power through wheeling and net-metering agreements. This would allow processors in clusters such as Faisalabad's textile parks or Multan's mango pulp units to run operations on cheaper solar or wind power. Financing mechanisms could be designed around concessional credit lines, supported by development banks, for investments in efficient boilers, waste-heat recovery systems, and renewable integration.

Provincial governments could replicate models like Punjab's recent pilot, where solar tube wells and energy-efficient pumps reduced farmers' input costs and improved reliability of water supply. Scaling such initiatives across agro-processing clusters could save billions annually in wasted energy while creating a competitive edge for Pakistan's bio-based exports.

Residue Management and Waste-to-Value Projects

Crop residue burning is one of Pakistan's most visible environmental challenges. Each winter, rice stubble burning in Punjab and Sindh contributes significantly to smog episodes, worsening health costs and reducing agricultural productivity. Yet these residues, rice straw, wheat straw, and maize cobs, represent valuable raw materials that remain untapped. For instance, Punjab alone generates over 20 million tonnes of crop residues annually, much of which is either burned or left to decompose without economic use.

Other countries have successfully turned this problem into an opportunity. In India, government-backed programs support small enterprises that collect residues then

supply biomass fuel to brick kilns and power plants. Such models show how agricultural waste can be transformed into value-added energy and industrial inputs.

For Pakistan, provinces could design residue supply chains by contracting village-level enterprises to collect crop residues and channel them into biogas plants, briquetting units, or second-generation ethanol refineries. Financial support, such as subsidies for balers and transportation, would make residue collection viable for small players. A national program could link residue markets to industrial buyers (cement, power, or ethanol firms), creating both rural employment and cleaner air. If scaled, such interventions could simultaneously reduce smog, lower fossil fuel dependence, and generate thousands of green jobs.

Strengthening Export Quality and Traceability

Pakistan's agricultural exports face chronic setbacks due to quality lapses and weak certification systems. Mangoes, kinnows, and rice consignments are frequently rejected in high-value markets like the EU and Gulf states because of pesticide residues, inconsistent grading, or lack of traceability. These rejections not only cost millions in lost foreign exchange but also erode Pakistan's credibility as a reliable supplier.

Comparable challenges have been overcome elsewhere through strong quality infrastructure. Thailand's fruit exporters, for example, benefitted from internationally qualified labs and digital traceability systems that track produce from farm to shelf.

For Pakistan, the solution lies in establishing internationally accredited testing labs and farm-to-export digital traceability systems. Exporters could be certified under a Trusted Facility program, signalling compliance with international residue and safety benchmarks. Beyond food exports, biotechnology applications, such as improved seed varieties, biofertilisers, fish and algae strains, and industrial microbes, could further raise competitiveness by diversifying bio-based exports. Genetic engineering of stress-tolerant crops and livestock would strengthen resilience against climate stressors. Together, these measures would restore buyer confidence, reduce rejection rates, and unlock premium markets.

Regulatory Reforms in Biotechnology

In Pakistan, the current biosafety and biotechnology approval framework is notorious for its delays, seed trials can take years, and approvals for food and feed safety often remain stuck in bureaucratic pipelines. This regulatory bottleneck has discouraged both local researchers and foreign investors from commercialising biotech solutions.

Global experience highlights the opposite approach. In the Philippines, biotech approvals operate on guaranteed timelines, allowing field trials and commercial releases to proceed within a year. Argentina, one of the pioneers in GM crop adoption, implemented transparent digital tracking systems for applications, which built investor confidence and also enabled the country to rapidly expand biotech cultivation.

Pakistan could follow these lessons by committing to service timelines thirty days for contained use approvals, ninety days for field trials, and six months for food and feed safety assessments. Introducing digital tracking of applications would improve transparency, reduce corruption, and allow researchers to monitor progress in real time. By halving approval times, Pakistan could enable at least twenty biotech field trials annually, ensuring that locally developed or imported technologies reach farmers and industries much faster. This would accelerate the translation of research into commercial products, energizing Pakistan's bioeconomy with innovation-driven growth. Moreover, the approval duration may be reduced through e-certification and action against counterfeit seeds.

Bioenergy and Waste Management Systems

Pakistan holds significant potential in biofuel production. Waste-to-energy technologies and biowaste recycling can also turn agricultural residues into value-added products. With abundant biomass resources and local engineering development, Pakistan can build bio-based industries that support food security, rural employment, water conservation, and sustainable economic growth.

For Pakistan's bioeconomy transition, financing mechanisms will be critical to transform ideas into investable projects. Traditional budgetary allocations are insufficient given fiscal constraints, making it necessary to adopt innovative approaches such as green bonds, blended finance, and public–private partnership (PPP) models.

Green bonds floated by federal and provincial governments could fund bio-based infrastructure including packhouses, biorefineries, and waste-to-energy plants. By combining concessional public funds with private capital, the government can help de-risk high-potential ventures. Early-stage investments may target initiatives like biogas projects and precision agriculture startups. PPP models could also support cold chain facilities and residue collection systems, with the state covering viability gaps and private operators ensuring efficiency and technological advancement.

Together, these instruments can establish a financing ecosystem that attracts both

domestic and international investors, making the bioeconomy agenda scalable and sustainable.

In parallel, Pakistan may promote precision agriculture through sensors, drones, and data analytics to improve yields, pest control, and water-use efficiency, while ensuring affordable machinery for small and mid-sized farmers. Diversifying financing instruments, de-risking innovation, and advancing precision agriculture are can accelerate Pakistan's bioeconomy transition.

Policy Recommendations

- Establishing a National Bioeconomy Council within one year with a digital one-window portal for biosafety, seed registration, and export certification.
- An investment plan for modern packhouses, cold storage hubs, and processing facilities in major producing districts.
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- Strengthening export competitiveness by implementing traceability and certification systems aligned with EU and GCC requirements.

Conclusion

The bioeconomy offers Pakistan a strategic pathway toward sustainable growth and economic security. The country's agriculture sector provides a strong foundation for the bioeconomy. However, persistent inefficiencies and fragmented policies limit the sector's potential. Lessons from EU, Brazil, and India suggest that coordinated governance, investment in infrastructure, and adoption of biotechnology can turn biological resources into engines of innovation and competitiveness.

Action Matrix

Action Area	Pathways to Solution	How to Implement Each Solution	Actors Responsible	Timelines
National Bioeconomy Council & One-Window System	Establish a centralised governance body with digital one-window approval system.	Develop online platform with guaranteed approval timelines (30–180 days depending on process).	Ministry of Commerce, Ministry of Science & Tech, Ministry of National Food Security	**Short-term:** Establish council & platform. **Long-term:** Institutionalise Council with expanded mandate.
Cold Chain & Processing Infrastructure	Reduce 35–40% post-harvest losses through modern cold storage, packhouses, and handling technology.	Scale Punjab's packhouse pilot to mango, citrus, potato, onion clusters. Provide concessional credit/matching grants for water treatment, pruning, etc.	MNFSR, Provincial Govts, Ministry of Industries, TDAP, Farmer Cooperatives, Private Sector.	**Short-term:** Scale 2-3 clusters, introduce mechanical harvesting. **Long-term:** Establish hundreds of packhouses nationally; reduce $1bn in annual losses.
Energy Cost Relief for Processors	Lower processing costs through renewable integration, efficiency upgrades, and co-generation.	Concessional credit for efficient boilers, and waste-heat. Enable agro-processors to source renewable power via wheeling & net-metering.	Ministry of Energy, Provincial Energy Depts, Private Sector, Development Banks.	**Short-term:** Finance solar tube wells, rooftop solar, efficient pumps. **Long-term:** Large-scale renewable integration and biomass cogeneration.
Residue Management & Waste-to-Value	Convert crop residues into biogas, ethanol, briquettes to reduce smog & fossil fuel imports.	Contract rural enterprises for residue collection. Provide subsided credit for balers and transportation.	Provincial Govts, Ministry of Climate Change, MNFSR, Private	**Short-term:** Launch collection pilots in Punjab & Sindh. **Long-term:** National

		Create residue markets linked to power plants.	Sector, SMEs.	residue markets and large-scale biorefineries.
Export Quality & Traceability Systems	Improve global competitiveness by reducing rejections and ensuring compliance.	Establish 2-3 accredited residue testing labs. Pilot digital traceability for mango and kinnow supply chains.	TDAP, MNFSR, Ministry of Commerce, Chambers of Commerce, Private Exporters.	**Short-term:** Accredited labs, traceability pilots. **Long-term:** Trusted Facility program nationwide, biotech exports scaled.
Financing Mechanisms for Bioeconomy	Mobilise innovative finance to fund bio-based infrastructure.	Green bonds for bioeconomy/biorefinery Involve commercial banks/DFIs in bioeconomy financing.	Ministry of Finance, SBP, SECP, Development Banks, Private Investors.	**Short-term:** Design green bond & blended finance pilots. **Long-term:** Scalable financing ecosystem attracting global investors.
Education, Skills & Precision Agriculture	Build skilled workforce & adopt modern technologies.	Launch vocational training programs in bioeconomy-related fields (processing, renewable energy, biotech, precision agriculture).	Ministry of Education, NAVTTC, MNFSR, Provincial Agri Depts, Private Sector	**Short-term:** Pilot training in IT, biotech, and agri-tech. **Long-term:** Nationwide adoption of precision agriculture and skilled workforce base.