

Bamboo-based products

Bamboo is a fast-growing, woody grass known for its strength and rapid renewability, making it a valuable resource across various sectors, including furniture, construction, and power generation. India possesses the largest bamboo-bearing area globally (Bansal 2020). Despite its abundance, India imported 88 per cent of the raw material required for bamboo-based industries in 2021 (Mathur 2023). This is because much of India's bamboo resources are in protected areas, steep slopes, and remote regions, making harvesting and extraction undesirable and challenging. Additionally, low bamboo productivity in forested areas escalates raw material costs, making imported bamboo economically favourable for domestic industries (FMC 2022). Therefore, there is a pressing need for large-scale bamboo cultivation to unlock the potential of the bamboo-based economy. Establishing bamboo plantations and processing units has the potential to stimulate the local rural economy and increase farmers' incomes. Odisha can accelerate economic growth and contribute to India's self-reliance mission by scaling both bamboo demand and supply through commercial cultivation on wasteland and its utilisation in sectors like furniture, construction, agarbatti, charcoal, packaging, etc.

Opportunities for 2030

Jobs, market and investment opportunity

By cultivating bamboo across ~15,000 hectares (~3 per cent) of cultivable wasteland and integrating it into bamboo-based industries such as furniture, housing, agarbatti, packaging, activated charcoal, and ethanol, Odisha could generate ~29,000 jobs by 2030 (of which 3,000 jobs are created through cultivation). The endeavour requires a cumulative investment of ~USD 1,000 million, unlocking a market opportunity worth ~USD 800 million annually.

- **Bamboo-based furniture industry** - Maharashtra leads in modern bamboo furniture production, with Konbac's¹ Kudal facility capturing ~65 per cent of the Indian market². The rest of the market comprises many small, scattered players. With strategic policies and government support, Odisha can attract enterprises in the bamboo furniture industry, becoming a regional hub and capturing up to 35 per cent of the market by 2030. Consequently, establishing ~2,000 new bamboo furniture units would require a total investment of USD 37 million and generate 9,000 jobs, leading to a market opportunity worth USD 88 million.
- **Bamboo-based housing** - By 2030, Odisha plans to construct 204,340 rural and 353,182 urban houses under schemes like Housing for All and PMAY-G. If 30 per cent of these structures incorporate bamboo as their primary material, we can open up market opportunities for bamboo mat boards and treated bamboo poles at USD 9 million and USD

¹ Native Konbac Bamboo Product Private Limited is a national award-winning social enterprise based in Kudal, Maharashtra. Its aim is to build sustainable and eco-friendly bamboo structures, specialising in bamboo-based furniture.

² Stakeholder consultations

37 million, respectively³. This initiative is expected to create ~7,000 jobs with a total investment of USD 7 million.

- **Bamboo agarbatti market** - By 2030, India is expected to import ~150,000 MT of bamboo sticks annually to meet its incense stick demand. It opens up a huge opportunity for Indian states to displace these imports via local production. If Odisha captures about 30 per cent of forecasted imports by 2030 (mirroring Karnataka's current market share), it could create ~6,000 jobs across 590 new production units, needing an investment of USD 9 million. The projected market potential for Odisha's bamboo stick production is valued at USD 51 million annually by 2030.
- **Bamboo-based packaging** - India's packaging sector is expanding at an annual growth rate of 22-25 per cent CAGR (PIAI n.d.) and will require an additional production capacity of approximately 9 MMTPA⁴ by 2030 to meet rising demand. Currently, Gujarat has the leading market share at about 26.5 per cent. If Odisha were to capture a similar market share by 2030, it would need to set up an additional production capacity of ~6 MMTPA⁴. With about 10.5 per cent of this capacity expected to be bamboo-based, around 0.6 MMTPA⁴ capacity of bamboo packaging facilities would require an investment of USD 961 million. It would generate ~4,000 jobs while capturing a market opportunity valued at USD 512 million by 2030.
- **Bamboo-based activated charcoal** - About 40 per cent of the bamboo gets wasted in bamboo stick making, which can instead be effectively utilised to make bamboo charcoal for industrial applications. This approach aligns with NITI Aayog's recommendation to reduce costs and improve competitiveness (Goswami 2022). If Odisha captures around 30 per cent of India's bamboo stick market by 2030 (as noted in the previous section) and repurposes all bamboo waste from stick production for charcoal, it could establish approximately 100 bamboo charcoal production units. This would create ~200 jobs and a market opportunity worth USD 24 million, requiring a total investment of USD 2 million.
- **Bamboo-based ethanol** - India needs to expand its ethanol production to 14,540 thousand MT by 2030 to achieve 50 per cent ethanol blending in petrol (Policy Circle 2023). By 2030, if Odisha establishes bamboo ethanol facilities mirroring Assam's current capacity of 49,000 TPA, it will create ~150 jobs for plant operation and maintenance. Setting up such a production unit in Odisha would necessitate a capital investment of USD 114 million to seize the market opportunity valued at USD 49 million.

³ Stakeholder consultations

⁴ Million metric tonne per annum

Bamboo-based industry	Jobs	Market opportunity (in million USD)	Investment opportunity (in million USD)
Overall	~29,000	~800	~1,000
Furniture	~9,000	88	37
Housing	~7,000	46	7
Agarbatti	~6,000	51	9
Packaging	~4,000	512	961
Activated Charcoal	~200	24	2
Ethanol	~200	49	114
Odisha needs to cultivate suitable bamboo species in ~15,000 hectares on cultivable wasteland to produce sufficient raw bamboo to satisfy all the demand-based scenarios considered above			
Bamboo cultivation	~3,000		

Table 1- Employment, Market, and Investment Potential for Various Bamboo-Based Sectors in Odisha by 2030 under Ambitious Scenarios

Why should Odisha invest in bamboo-based products?

1. **Reduce import reliance:** India imports 88 per cent of the raw materials needed for bamboo-based industries from other countries (Mathur 2023). By investing in the bamboo value chain—expanding bamboo cultivation and strengthening processing capacity to produce finished products—Odisha can increase self-sufficiency and reduce import dependence.
2. **Achieve energy security:** Odisha can strengthen state and national energy security by investing in bamboo-based biofuel technology, as bamboo serves as a promising feedstock for biofuel production (Chin et al. 2017). This investment offers Odisha a valuable opportunity to develop its bamboo value chain.
3. **Enhanced income and quality of life for rural women and artisans:**
 - a. By engaging in various stages of the bamboo value chain—from harvesting to processing and marketing, women can secure better livelihood opportunities (Datta et al. 2017), which would not only boost their financial independence but also raise their status within their communities.

- b. Artisans often lack access to markets and technology, and their income fluctuates due to seasonal demand and agricultural cycles. Investing in bamboo value chains, particularly bamboo mat weaving for construction-grade mat boards, allows Odisha to support artisans with new market opportunities, better production technologies, and financial assistance (Patel et al. 2022).
4. **Reduces GHG emissions:** Bamboo reduces GHG emissions by acting as a carbon-negative plant, capturing more CO₂ than it emits throughout its life. It stores 30-120 mg of carbon per hectare and sequesters 6-13 mg annually (Manandhar 2019). The carbon stored in bamboo remains locked within its biomass, whether used in products or construction materials, preventing its release (Shukla & Joshi 2020). Bamboo also serves as an energy-efficient building material, requiring only 30 MJ/m₃ per N/mm₂ production, far less than concrete, steel, and lumber, which need 240, 500, and 80 MJ/m₃ per N/mm₂, respectively. Bamboo processing consumes just one-eighth of the energy needed for concrete, one-sixteenth for steel, and half for lumber (Gutiérrez 2000).
5. **Restore degraded ecosystems:** Promoting bamboo farming on wastelands⁵ could help reduce soil erosion, as a single bamboo plant can help bind soil up to six cubic metres. Bamboo also improves soil fertility by adding organic matter, which enriches the ecosystem and creates habitats for various primate species (Shukla & Joshi 2020).

Overall, strengthening bamboo value chains will directly contribute to seven of the seventeen sustainable development goals (SDGs), including poverty reduction (SDG 1), access to energy (SDG 7), economic growth (SDG 8), resilient cities (SDG 11), responsible production and consumption (SDG 12), climate action (SDG 13), and biodiversity conservation (SDG 15). This approach will also foster stronger implementation and partnerships (SDG 17) (INBAR 2015).

Inspiration from a success story

Bamboostan, a Guwahati-based startup, is building a robust bamboo supply chain in the Northeast by procuring raw bamboo from farmers and processing it into beams, sticks, slats, and other products for the construction and paper industry. Bamboostan procures nearly 24,000 MT of raw bamboo annually from local farmers to ensure a steady supply of



⁵ [National Bamboo Mission](#) promotes wasteland development through bamboo plantation. Although this analysis covers only a small percentage (3.1 per cent) of the total cultivable wasteland, prior baseline studies on the socio-ecological dimensions and the selection of native bamboo species suitable for Odisha are essential to ensure that the wasteland ecology is not disturbed.

standardised bamboo products to private players, thereby creating value for local communities by providing steady income and livelihood opportunities⁶.

Who could support in scaling bamboo-based products?

1. Role of departments:

- a. **Odisha Bamboo Development Agency (OBDA):** OBDA is responsible for promoting the overall growth and development of the bamboo sector in Odisha. Therefore, it would play a significant role in scaling up the bamboo value chains. It should promote integrated development, which involves coordinating on-farm and off-farm activities to ensure a seamless flow from bamboo cultivation to final product manufacturing. OBDA also provides technical support, market linkages, research, and innovation, encourages investment, and fosters collaboration between various departments.
- b. **Forest, Environment and Climate Change Department:** The department can facilitate coordination, support policy implementation, and ensure adherence to environmental regulations during the planning and scaling up of the bamboo value chain in Odisha.
- c. **Micro, Small, and Medium Enterprises Department (MSMED):** The MSME department can play a pivotal role in supporting OBDA by collaborating with incubators such as Sambalpur University and KIIT-TBI, as well as initiatives like StartUp-Odisha, to promote bamboo-based startups, providing financial support, facilitating market access, promoting research and development, and streamlining licensing procedures. The MSME department could collaborate closely with Mission Shakti to effectively engage women SHGs and their federations in bamboo product production in value chains such as bamboo mats, etc.
- d. **Housing and Urban Development Department:** The department can champion bamboo as a construction material by actively endorsing bamboo-based housing projects and collaborating closely with OBDA. Targeted policies and incentives, such as mandating that 30 per cent of government housing integrate bamboo as its primary raw material, can stimulate the adoption of bamboo-based construction techniques among builders and developers. Moreover, by organising capacity-building workshops and launching awareness campaigns, the department can raise awareness and generate demand for bamboo-based construction solutions across the state.
- e. **Odisha Rural Development and Marketing Society (ORMAS):** ORMAS is an

⁶ Stakeholder consultation

autonomous body under the Odisha Panchayati Raj Department that could help OBDA promote bamboo-based industry in rural areas by assisting in forming bamboo-based producer groups, and providing support in technology adoption, product diversification, packaging, branding, and sales. ORMAS should also facilitate market linkages by organising buyer-seller meets and creating an online marketplace for bamboo products.

- f. **Odisha State Pollution Control Board:** The Odisha State Pollution Control Board (OSPCB) should regulate bamboo-related ventures to ensure compliance with environmental standards and promote sustainable practices. This involves conducting Environmental Impact Assessments, advocating for the adoption of cleaner technologies, and organising training initiatives to raise awareness. By doing so, the OSPCB can actively promote the establishment and operation of environmentally responsible bamboo industries in Odisha.
- g. **Indian Council of Forestry Research and Education (ICFRE):** ICFRE can conduct advanced research on bamboo species, sustainable forestry practices, and perform ecological mapping to evaluate bamboo quantity, productivity, and area coverage.
- h. **Science and Technology Department (S&TD):** The department could work to improve the bamboo sector through technology promotion and its dissemination by including bamboo as a special area in the S&TD supported incubators, and other programmes. The department could also promote application-oriented research in the bamboo sector and support projects that are entrepreneurial in nature and can be commercialised.
- i. **Odisha Skill Development Authority (OSDA):** OSDA should integrate bamboo value chain-related skilling into coursework and offer specialised training programmes and workshops to enhance the skills of bamboo farmers, artisans, and entrepreneurs working in the bamboo sector. OSDA also has the potential to facilitate the adoption of modern technologies and offer entrepreneurship support services to aspiring bamboo entrepreneurs.

Odisha can establish a focused policy on the bamboo-based economy, assign specific mandates and roles to different line departments regarding bamboo and its products' promotion, and set targets for monitoring bamboo development in the state, similar to Assam, Tripura, and Nagaland.

2. Role of the private sector:

- a. **Corporate social responsibility (CSR):** Private players can help mobilise the CSR funds to raise bamboo plantations. They can also enable bulk procurements from the farmers to ensure long-term income security for cultivators.
 - i. Dalmia Cement, for instance, is attempting to make its cement greener by using bamboo instead of fossil fuels to make cement and collaborating

- directly with bamboo farmers to ensure backward linkage.
- ii. ITC is taking proactive measures to support bamboo farming in India's northeastern states, facilitating a stable supply of bamboo sticks for its agarbatti brand, Mangaldeep. This initiative not only promotes sustainable sourcing practices but also significantly uplifts the livelihoods of local communities.
 - iii. Financiers will play an important role in enabling finance for cultivation, processing, and downstream operations in the form of working capital and project financing.
- b. Collaborations:** The private sector should work closely with farmers, either through CSOs or directly, to share knowledge about bamboo species, quality, and cultivation practices. This collaboration will help farmers produce the high-quality bamboo needed for downstream processing. Private players should also partner with OSDA to align skilling initiatives with industry requirements and work with ORMAS to ensure that farmer producer organisations (FPOs) support industry-aligned objectives. Another important role that the private sector could play is by collaborating with SHG federations through initiatives like Mission Shakti. Such partnerships should focus on enabling more value addition to bamboo by farmers rather than viewing communities solely as suppliers of raw materials.
- c. Product design:** The private sector could play a crucial role in addressing functional gaps in scaling up the bamboo value chain by innovating in product designs and improving quality to better meet customer needs.

3. Role of local administration and civil society organisations (CSOs):

- a. Raising awareness:** CSOs can promote bamboo cultivation by engaging with communities to raise awareness about its benefits and encourage the formation of bamboo-based FPOs.
- b. Onground implementation and handholding:** CSOs can provide training, connect artisans with financial institutions, and offer guidance on production techniques to ensure the success of bamboo-based enterprises.
- c. Enabling market linkages:** CSOs can help artisans access markets for bamboo products through exhibitions, trade fairs, and online platforms, promoting quality standards and product innovation to enhance marketability.

Overcoming challenges to scale bamboo based products value chain

Shifting focus: Despite being the second-largest producer of bamboo globally, India has a negligible presence as a supplier in the world's bamboo market. This is primarily due to India's continued focus on low-value and slow-moving products, such as handicrafts and utility items made from

unprocessed bamboo. These products often require specific bamboo species that are hard to source, further limiting their scalability. Additionally, India's bamboo market is primarily driven by domestic demand, and we currently import significant amounts of bamboo to meet internal needs (INBAR 2018). While addressing this domestic shortfall is critical, there is also a distinct opportunity to capture global markets with high-value and industrial bamboo products, such as bamboo-based packaging and construction materials. Meeting domestic demand for products like agarbatti should remain a priority but simultaneously pursuing global opportunities for industrial products will help diversify the sector and tap into larger markets.

1. Sector-wide challenges

- a. **Limited awareness:** Currently, the general awareness about bamboo's use beyond the handicraft sector, such as in construction and packaging, is relatively limited among the masses, as well as with industry players.

Way forward: We can increase consumer awareness regarding different use cases of bamboo by incorporating bamboo as road dividers, ceilings in government buildings, and furniture in public parks, as well as by launching public awareness campaigns to encourage broader adoption of bamboo in non-traditional sectors.

- b. **Locational challenges:** Bamboo-based industries are often far from bamboo-bearing areas, leading to increased raw material procurement costs driven by historical industrial zoning and availability of infrastructure rather than proximity to raw materials (Awadh 2010).

Way forward: To ensure the year-round availability of cheap raw materials, manufacturers should situate their production units closer to bamboo cultivation areas. This needs to happen in parallel with CSOs encouraging more farmers to adopt bamboo cultivation through FPOs and linking them with bamboo-based manufacturers to provide assured markets to farmers. The private sector, through CSOs, can mainstream the use of hand-held mechanised equipment, allowing farmers to create bamboo splinters on the field before aggregating them to be sent to manufacturing units, which can increase a truck's loading capacity, saving further transportation costs.

- c. **Low price competitiveness:** Bamboo-based bioplastics and mats are taxed at 18 per cent GST, while bamboo flooring faces 12 per cent GST. Taxing bamboo-based products at a higher GST rate than conventional products makes them less appealing to consumers.

Way forward: Reducing GST to 5 per cent for the above-mentioned bamboo-based

products can make them more attractive to consumers and encourage greater adoption of these products among end-users⁷.

- d. **Lack of research and development:** Bamboo sector faces a significant challenge due to insufficient research and development (R&D) on effective raw material utilisation and product design limiting the ability to create a diverse range of standardised products to maximise economic potential of bamboo.

Way forward: To significantly reduce waste during the harvesting and primary processing of bamboo, we must encourage farmers to adopt simple hand-held tools that enable sustainable harvesting while reducing wastage. We need to mainstream cost-effective and innovative technologies that enable cultivators and bamboo-dependent communities to produce diverse industrial applications for bamboo, including charcoal production, packaging solutions, composite materials, and biofuels (Liese and Kohl 2015).

- e. **Financing needs:** Financing bamboo-related projects presents challenges, particularly for startups and entrepreneurs testing new technologies. The National Bamboo Mission (NBM) provides substantial financial support through a credit-linked back-ended subsidy⁸, but it requires entrepreneurs to contribute 10 per cent of the total project cost. The government covers 50 per cent through subsidies, and banks finance the remaining 40 per cent. This model works well for entrepreneurs with proven technologies in a mature market, but it poses challenges for small startups experimenting with newer technologies that need to overcome entry barriers.

Way Forward: Foster innovation by providing smaller grants similar to BIRAC BIG grant⁹ to support startups working on novel industrial applications of bamboo. These grants better suit entrepreneurs testing new technologies by reducing entry barriers.

- f. **Lack of perceived demand:** Several bamboo-based companies we consulted expressed concerns about the perceived lack of demand for non-traditional bamboo products like bamboo charcoal, bamboo based packaging, and construction materials. This lack of demand arises from customers being unaware of these products and high price points (Patel et al. 2022; APN-GCR 2020).

Way forward: The government of Odisha can drive initial demand for non-traditional bamboo products like bamboo-based construction products through public

⁷ Stakeholder consultation

⁸ The Indian government offers a **Credit-Linked Back-Ended Subsidy (CLBS)** under the National Bamboo Mission to encourage bamboo cultivation and processing. This subsidy reimburses a portion of project costs (25-35 per cent) after a project's completion.

⁹ **The Biotechnology Ignition Grant (BIG) scheme** launched by Biotechnology Industry Research Assistance Council (BIRAC) provides up to ₹50 lakh to early-stage Indian biotech startups to validate their ideas and develop prototypes.

procurement programmes, such as mandating that some percentage of all government housing projects utilise bamboo as the primary raw material by including these bamboo-based products in the rate schedule. Players manufacturing other non-traditional products, such as bamboo packaging, must also work closely with end-users to tailor their products per customer requirements. Securing long-term supply agreements with guaranteed buy-back provisions would offer manufacturers greater price stability, while end-users could benefit from emission reduction credits for adopting sustainable bamboo solutions.

2. Sector specific challenges:

a. Bamboo-based construction sector

- i. **Perception of durability:** Traditional construction materials such as steel and cement are perceived to be more durable than bamboo-based alternatives. The issue worsens further as architects and engineers do not know how to use bamboo in construction effectively, nor are they interested in learning about it as they require additional learning effort (UNDP 2023).

Way forward: The government should take the lead in mainstreaming the use of bamboo in construction by utilising bamboo to lay the foundation and interior decoration of important public buildings (Yadav and Mathur 2021). This can be done by encouraging states to include bamboo in the schedule of rates for construction and by developing these construction projects in PPP¹⁰ mode by incentivising the private players to use bamboo as a construction material through subsidies, tax break and other incentives. Innovations such as engineered bamboo products¹¹ have improved the performance and durability of bamboo. However, more innovation, research support, and widespread dissemination of existing technology and know-how among architects and construction workers are needed. To promote bamboo-based construction, we must integrate bamboo into coursework through specialised training programmes and workshops for architects and engineers supported by organisations like BMTPC¹² and the Construction Skill Development Council of India¹³.

¹⁰ Public-private partnerships

¹¹ Engineered bamboo products (EBPs) are bamboo-based construction materials made from breaking raw bamboo culms into smaller pieces. These pieces are then glued together using modern adhesives to form a composite panel or dimensioned lumber stock to enhance their properties and standardise their dimensions.

¹² The Government of India established the Building Materials & Technology Promotion Council (BMTPC) in 1990 as a non-profit autonomous body to promote innovative building materials and technologies.

¹³ Construction Skill Development Council of India (CSDCI) is a non-profit organisation established to address the skill gap in the construction sector.

- ii. **High entry barriers:** New entrants in Advanced Housing Construction Materials (AHCM)¹⁴ manufacturing faces significant challenges, such as high initial capital investment and limited access to technology, as many of these technologies are imported. Without government support, it is difficult for new players to gain market share.

Way forward: The government could offer fiscal incentives to establish manufacturing units and invest in R&D to develop low-cost indigenous technology, reducing import dependence and supporting local manufacturing. Reducing GST rates on bamboo-based construction products would lower costs and make them more attractive to manufacturers and builders¹⁵.

b. Bamboo-based furniture industry

i. Physiological barriers: Joining two pieces of bamboo together to make an aesthetically pleasing and durable modern furniture is difficult due to the natural physiology of bamboo (Pritchard 2023). The inter-nodal distance varies greatly depending on its species, age, and growing conditions of bamboo (Dessalegn et al. 2022). This irregularity results in misalignment, and inconsistent load-bearing capacity at joints impacts the durability of the product.

Way forward: The government must collaborate with the National Institute of Design to foster innovative design processes that use bamboo's natural characteristics to create modern, aesthetically appealing furniture (Susanth et al. 2023). These modern joinery techniques need to be documented in the form of process manuals and disseminated among artisans, designers, and manufacturers.

ii. Poor quality of products: Despite Indian artisans producing bamboo-based furniture for several years, the Indian bamboo furniture sector has struggled to scale up and capture market share. This stagnation results from the current approach to design and construction that relies heavily on hand-held tools and semi-mechanised processes, which limits efficiency and consistency in product quality (Susanth et al. 2023).

Way forward: Industry needs to adopt a component-based production system to facilitate easier production, transport, and assembly of bamboo furniture, making it more competitive in the market. By breaking down furniture into standardised components, manufacturers can streamline the production process, reduce labour costs, and improve quality control (Susanth et al. 2023). Implementing knockdown joints will not only enhance the structural integrity of the furniture but also make it easier for consumers to transport and assemble their purchases. This flexibility can

¹⁴ Advanced Housing Construction Materials (AHCM) are innovative materials like composite materials, prefabricated components, and sustainable materials (like bamboo). These materials enhance energy efficiency, reduce construction time, and improve building quality compared to traditional materials.

¹⁵ Stakeholder consultations

attract a broader customer base, particularly among urban dwellers who may prioritise space-saving solutions.

c. Bamboo cultivation:

i. Limited demand: Despite initiatives like the Atal Bamboo Samruddhi Yojana in Maharashtra, the farmers are still not motivated to grow bamboo and remain reluctant to cultivate bamboo due to a lack of visible demand from industry players (Gawande 2021). Moreover, even if farmers are interested in bamboo cultivation, funds allocated for bamboo cultivation under the National Bamboo Mission support only high-density bamboo plantations on wastelands suitable only for paper mills or biomass and not for any specialised end use such as construction that is highly valued by industry. However, farmers generally lack this technical knowledge along with which bamboo species best suits a particular industrial application, resulting in low-quality produce not utilised by industry.

Way forward: CSOs can disseminate useful technical knowledge regarding bamboo cultivation in a comprehensible manner to motivate formation of bamboo-based FPOs. CSOs can then help in linking these FPOs with industry players through long-term assured buy back contracts to facilitate transparent interactions between producers and bamboo-based product manufacturers.

d. Bamboo-based ethanol:

i. Increased production cost due to pretreatment steps: Bamboo requires additional pretreatment steps before it can be used as a feedstock for biofuel production due to its high lignocellulose content. This increases production costs and reduces the economic feasibility of bamboo based biofuel (Liang et al. 2023).

Way forward: Biofuel producers should use post-production bamboo waste generated by other sectors, such as agarbatti and furniture, for biofuel generation as it is already pretreated (NRL 2020-21) to reduce operational costs.

Risk-proofing the scale-up of bamboo-based products

1. Environmental risks associated with scaling up the bamboo value chain include:

- a. Harmful chemical use:** Harmful chemicals, such as Copper chrome boron (CCB)¹⁶, are used during secondary processing to extend the shelf life of bamboo, which can have adverse effects on biodiversity.

¹⁶ Copper Chrome Boron (CCB) is a common chemical used as a preservative during bamboo processing

Mitigation: To promote sustainability within the bamboo value chain, we need to transition to eco-friendly alternatives such as water leaching treatment and smoke treatment and use botanical extracts such as neem oil (Kaur et al. 2016).

- b. Large-scale monoculture:** The widespread adoption of large-scale bamboo monoculture raises social and environmental concerns such as habitat destruction, loss of biodiversity, and soil degradation (Bowyer 2014).

Mitigation: The state should promote bamboo cultivation primarily via mixed cropping, intercropping, or agroforestry settings.

- c. Risks associated with cultivable wasteland utilisation:** Utilising cultivable wasteland for bamboo cultivation poses ecological risks due to unclear classification of wastelands and lack of understanding about their ecological importance.

Mitigation: Wastelands may support unique ecosystems and serve as habitats for various species, including endangered grassland birds. Additionally, these areas might provide ecosystem services such as soil stabilisation and water regulation. Therefore, repurposing such areas for bamboo cultivation requires thorough ecological assessments to mitigate potential adverse impacts on biodiversity and other environmental functions (Kar et al. 2024).

- d. Increased emissions:** Processing bamboo stick waste to produce activated charcoal can lead to more emissions if not done in a controlled manner.

Mitigation: To prevent this, charcoal units must follow strict regulations and ensure that the Odisha State Pollution Control Board (OSPCB) regularly monitors these units.

- 2. Diverting land for bamboo cultivation to satisfy energy needs:** While bamboo has significant potential as a renewable energy source (bamboo-based ethanol), focusing solely on energy production could lead to the diversion of valuable land that could otherwise be used for more critical purposes, such as food security and the production of sustainable materials.

Mitigation: It is important to prioritise food, feed, and material applications of bamboo over energy usage, as this aligns with bioeconomy principles (Stegmann, Londo and Junginger 2020). This approach ensures that bamboo contributes to food security, provides raw materials for various industries, and supports rural livelihoods while balancing energy needs with sustainable land use.

Annexure

Scoping of bamboo-based products value chain

The bamboo value chain includes several key segments:

1. Raising bamboo plantations
2. Harvesting and primary processing of bamboo
3. Transporting and directing harvested bamboo to industries utilising it as raw material
4. Secondary processing of bamboo to create intermediate products
5. Utilising intermediate products to manufacture finished products
6. Distributing finished bamboo products to end consumers

For the scope of this study, we have limited the analysis to the direct employment generated from bamboo cultivation, harvesting, and the production of finished bamboo products. Jobs created in marketing, sales, and distribution of harvested bamboo to bamboo-based industries or finished bamboo products to end-users have not been included.

We estimated the future demand for select bamboo-based industries in Odisha for 2030. Using this demand mapping, we calculated the total annual bamboo requirement as raw material for these industries. Based on the raw materials required for select bamboo-based industries in 2030, we identified the cultivation area needed to meet the projected demand in Odisha by 2030.

Jobs and market estimation

Market selection:

1. To identify potential markets for Odisha's bamboo, we developed a qualitative framework informed by stakeholder consultations. This framework prioritises markets based on key factors such as scalability, availability of suitable bamboo species, existing market conditions, supply chain challenges, and alignment with national objectives. By leveraging industry insights and secondary literature review, the framework pinpoints markets with the highest growth potential in Odisha by 2030. It is important to clarify that the exclusion of certain markets does not imply a lack of future opportunities, but rather a focus on near-term scalability and alignment with policy goals.
2. Our analysis, supported by secondary research and stakeholder consultations, identified the following potential markets for bamboo in Odisha: activated charcoal, ethanol, sticks, furniture, construction (housing), and packaging. These markets were selected for their strong scaling potential due to the availability of suitable bamboo species and their alignment with emerging demand trends and national policy priorities. By concentrating on these promising sectors, we aim to maximise Odisha's economic returns from the bamboo industry by 2030.
 - a. We excluded bamboo for paper and handicrafts from this analysis. The paper industry has largely shifted to using agroforestry species, and current policy

frameworks do not strongly support bamboo as a raw material for paper production. Similarly, the bamboo handicraft sector, while important, faces limitations in scalability, making it less suitable for large-scale commercialisation.

- b. Bamboo pellets were also excluded from our analysis. Our methodology prioritised value chain activities with significant job creation potential. Odisha can meet its biomass pellet requirements for the 7 per cent co-firing mandate by 2030 using agricultural residues. This approach avoids diverting land from bamboo cultivation to energy production and adheres to bioeconomy principles that prioritise food and material needs over energy production.

Market sizing (in units):

- Step 1: Define your market based on your set parameters and scoping principles.
- Step 2: Identify potential market: Identify all possible markets for your product/service, then select a target market.
- Step 3: Deciding on the unit: Decide on the type of unit that will be considered for the estimation. The type of unit considered will vary depending on the value chain and market considered for the estimation.
- Step 4: Calculating the total number of units to be considered based on the scenario considered.

Table 1: Approach to estimate market potential (in units) of bamboo-based products is as follows:

S.No	Sector	Approach (to market estimation)	Assumptions
1.	Bamboo cultivation and harvesting	Currently on an average 366 hec of land is used for bamboo cultivation in Odisha (Source- analysis of data from OBDA website). To satisfy the harvested bamboo requirement for all the ambitious scenarios outlined across the above-mentioned industries, Odisha needs to cultivate bamboo across 15,000 hectares of cultivable wasteland. This area constitutes approximately 3.1 per cent of the total cultivable wasteland available in Odisha.	<p>1. Different bamboo species suit specific industrial uses. For instance, <i>Bambusa tulda</i> is ideal for sticks, while <i>Bambusa balcoa</i> excels in construction. However, some uses of bamboo are species-agnostic; for instance, bamboo ethanol and charcoal production can utilise any species of bamboo</p> <p>2. We selected <i>Bambusa balcoa</i> for our analysis due to its versatility and suitability for Odisha's climate. The National Bamboo Mission recommends it for commercial cultivation. It is widely used in construction, scaffolding, ladders, and bridges. Additionally, it finds applications in agarbatti sticks, bamboo wood chips, and pulp and paper.</p>
2.	Bamboo-based	Maharashtra leads in modern bamboo	1. Assuming favourable govt. support and

	furniture	<p>furniture production, with KONBAC's Kudal facility capturing 65 per cent of the Indian market (stakeholder consultation). The rest of the market comprises many small, scattered players. With strategic policies and government support, Odisha can attract enterprises in the bamboo furniture industry, becoming a regional hub and capturing up to 35 per cent of the market by 2030.</p>	<p>policy push as well as looking at the attention bamboo is receiving in the market, we are assuming that bamboo's market share in the overall Indian furniture market will increase from 0.5 per cent to 2 per cent by 2030¹⁵.</p> <p>2. In the absence of CAGR growth rate of India' furniture industry till 2030, we have taken the CAGR growth rate till 2029 for our calculation.</p> <p>3. Odisha has the raw materials and the artisan base required to materialise these numbers. However, the artisans need to be skilled in product innovation, design, and marketing, along with infrastructure and favourable policy support¹⁷</p> <p>4. One modern bamboo furniture unit produces 1500 units per annum at 75 per cent capacity utilisation</p>
3.	Bamboo-based housing	<p>By 2030, Odisha aims to construct 204,340 rural and 353,182 urban houses under schemes like Housing for All and Pradhan Mantri Awas Yojana - Gramin (PMAY-G). Assuming that 30 per cent of these government houses integrate bamboo as their primary raw material, there will be a need to establish new facilities dedicated to bamboo mat boards and treated bamboo pole production in Odisha.</p> <p>As per the UNDP report on affordable housing materials, treated bamboo poles are used for rural houses, and bamboo mat boards are used for urban houses.</p> <p>75 sq mt of bamboo mat is needed for one urban house and 500 ft of treated bamboo pole is needed for one rural housing (Source- lit review- UNDP, Udyogini report, KVIC)</p>	<p>Context- Bamboo is widely used for housing, bridges, temporary shelters, scaffolding, and several similar applications as it is a very user-friendly material, is naturally pre-finished and in ready-to-use form. However, without treatment and processing, its durability is low. Therefore, it is important to convert this material into bamboo-based panels that can be used as durable and sustainable construction material. Bamboo-based panels can be classified into many groups based on the technology used. We chose bamboo mat boards for our labour and market estimation due to their greater employment potential and current adoption rate in India. Bamboo mat-based products are more labour-intensive, provide employment opportunities for women weavers, and can be produced with less capital investment in decentralised rural units.</p> <p>Assumption: 1. Assuming all the housing shortage in Odisha is to be met by 2030 (the basis for this assumption is the SDG11 goal to</p>

¹⁷ Stakeholder consultation

			<p>provide safe housing for all), 204,340 rural and 353,182 urban houses will be constructed in Odisha based on schemes such as Housing for All and Pradhan Mantri Awas Yojana - Gramin (PMAY-G).</p> <p>2. We assume bamboo mat boards will be used for urban housing and treated bamboo poles for rural housing, based on the UNDP report on affordable housing construction materials where for Odisha, bamboo was identified as one of the materials.</p> <p>3. The calculation is based on a detailed project report (DPR) by KVIC for a bamboo mat board-making unit that operates for 300 days a year, 8 hours per day, with an installed capacity of 32,000 mat boards per annum. Each bamboo mat board is made of three layers of woven bamboo mats, each about 3mm thick. We assume a 65 per cent capacity utilisation for the bamboo mat board unit.</p> <p>4. Each weaver can produce 1,500 woven mats per annum, provided they have ready slivers and weave for 300 days a year. This number is derived from a primary study by the Udyogini bamboo mat weaving initiative in 2010.</p> <p>5. Each bamboo pole weighs 6 kg, as per the KVIC document</p>
4.	Bamboo agarbatti sticks	<p>Currently, Odisha captures 9.23 per cent of the market and Karnataka is the leader with 30 per cent domestic market capture. However, this is not sufficient as India's consumption of incense sticks far exceeds our production capacity and because of which we have to import bamboo sticks. (All data points for analysis taken from PIB and KVIC).</p> <p>Extra bamboo sticks that need to be produced in MT in 2030 to become self sufficient by meeting all of India's demand domestically was calculated using current production and consumption data of incense sticks (Data source- PIB) and the CAGR at which the</p>	<p>1. Out of the entire weight of the incense stick- 30 per cent is of the stick. Source- KVIC.</p> <p>2. One agarbatti unit at 80 per cent capacity utilisation produces 72MT bamboo sticks per annum (Source- Detailed project report and business plans from KVIC)</p>

		<p>incense sticks are expected to grow (5.58 per cent) grow by 2030 (based on market report by Markets and data).</p> <p>To meet this additional demand, India will need to increase the production capacity substantially, assuming that Odisha becomes a national leader and captures 30 per cent of the currently untapped stick market by scaling up the production units substantially. This can be achieved by leveraging the KAAM scheme and expanding and leveraging ORMAS's existing tie-ups with ITC and other agarbatti giants.</p>	
5.	Bamboo-based packaging	<p>India's packaging needs would grow substantially by 2030 and we would need to install additional production capacity of 8.9 MMTPA required to meet this demand (This is based on analysis of current production data and estimated CAGR from CPPRI). Currently, Gujarat has the leading market share at about 26.5 per cent (Based on statistics from IPPTA). Taking a leading state scenario, If Odisha were to capture a similar market share of the additional production capacity by 2030, it would need to set up an additional production capacity of 5.88 MMTPA. Assuming that 10.5 per cent of this additional capacity will be bamboo-based, we anticipate that 3,871 jobs will be dedicated to bamboo-related activities in these new facilities by 2030.</p> <p>(NOTE- Please note that we are here not considering the existing market but expanding the production capacity by installing new plants. The amount of raw bamboo required to meet this scenario has been accounted for and accommodated into the area of bamboo cultivation that we will need to take up)</p>	<p>1. Given the diverse raw material base available for paper mills and their material-agnostic nature, attributing employment directly to bamboo is challenging. To estimate the potential job creation from bamboo, we approximate that roughly 10.5 per cent of the total jobs created in new paper mills could be engaged in bamboo-related operations. This is based on Indian Paper Manufacturers Association (IPMA) data showcasing the breakdown of raw materials used in Indian paper production, where wood constitutes 21 per cent of the total. Due to a lack of data on specific bamboo utilisation, we assumed an equal proportion of bamboo and wood, resulting in a 10.5 per cent allocation for each material.</p> <p>2. Three metric tonnes of bamboo are required to produce one metric tonne of bamboo packaging paper¹⁸</p>
6.	Bamboo-based activated charcoal	<p>By 2030, India is expected to import approximately 150,000 metric tonnes of bamboo sticks to meet its incense stick demand, prompting an ambitious plan</p>	<p>1. Conversion ratio of bamboo to charcoal is 25 per cent (Source- Info sheet by National Mission on Bamboo applications + Stakeholder consultation)</p>

¹⁸ Stakeholder consultations

		<p>for self-sufficiency. Under this ambitious scenario, we assume that Odisha will become a national leader by capturing 30 per cent of the untapped stick market, mirroring Karnataka's success, and will use bamboo waste for charcoal production. We have assumed all the bamboo stick waste generated under the bamboo agarbatti scenario will be diverted for charcoal production. Then using the conversion ratio of 25 per cent, we calculated the total bamboo charcoal in tonnes that can be produced using all the stick waste in Odisha under an ambitious scenario by 2030. The amount of bamboo charcoal in MT/annum that can be produced in one unit is 60MT (Source- stakeholder consultation). Using this, we calculated the total number of bamboo charcoal units required as well as the total jobs created.</p>	<p>2. All bamboo waste produced during stick production is redirected towards bamboo-activated charcoal production. This assumption is based on the NITI Aayog recommendation to use waste from stick production for making charcoal to ensure effective waste utilisation, which would help decrease the cost of production and make our bamboo products more competitive.</p> <p>3. 40 per cent bamboo is wastage while producing incense stick (Source- KVIC)</p>
7.	Bamboo-based ethanol	<p>If Odisha establishes a bamboo ethanol plant with a capacity of 49,000 TPA, similar to Assam, by 2030</p>	<p>Context- The govt has approved Pradhan Mantri JI-VAN Yojana (Jaivindhan- Vatavaran Anukool Fasal Awashesh Nivaran) for providing financial support to integrated bio-ethanol projects using lignocellulosic biomass and other renewable feedstock. It can further boost the production of biofuel using bamboo. There is already a bamboo-based ethanol factory that started operations last year in Assam. Further boosting the bamboo economy, a memorandum of understanding (MOU) was signed on 27th June 2019 between Forest Development Corporation of Mah. Ltd., Maharashtra State Bamboo Development Board, and Vtara Energy Group Private Limited. The MOU was signed to supply the bamboo/wood-based biomass to Vtara Energy Group, an Australia-based company, for the 1st phase to produce 2G ethanol in the industrial biotechnology hub at Mul, Chandrapur district. Odisha can also explore such opportunities.</p> <p>Assumption:</p> <p>1. In the absence of a specific market price for bamboo-based ethanol, the government-fixed price of ethanol produced</p>

			<p>from sugarcane juice, at Rs. 65.61 per litre (PIB 2022), has been adopted as a benchmark. The calculation of ethanol yield from bamboo is based on the environmental impact assessment (EIA) report of the Numaligarh Refinery Limited (NRL) (PCBA 2020). All calculations are based on the NRL's EIA report.</p> <p>2. To produce 1 tonne of bamboo ethanol, 6.1 tonnes of air dried bamboo is required (Source- NRL- EIA report)</p>
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Job estimation:

1. Key informant interviews (KIIs) were conducted with nine players working in the bamboo value chain based on purposive and convenience sampling to capture the number of people employed in that facility, average capacity utilisation, production capacity, etc.
2. We also derived full-time equivalent (FTE) figures from secondary literature, including detailed project reports (DPRs) for some sub-value chains, such as bamboo agarbatti and bamboo ethanol. We further validated these DPRs through stakeholder consultations wherever possible.
3. To calculate the FTE/job multiplier, the total number of working days considered per annum was based on the average number of working days in the industry gathered through KIIs.
4. The formula used to calculate FTE for bamboo product-based VCs:

$$FTE/annum\ unit = \frac{\text{Total number of people employed in a facility on a full time basis}^{19}}{\text{annual capacity of bamboo production facility (MT/annum)}}$$

- a. In cases like bamboo cultivation, where job tenure is five years or less, we calculate job multipliers using the formula mentioned above. These job multipliers are referred to as 'Job years'. To convert them into FTE, we divide the total job years by five²⁰.

$$Total\ jobs^{21} = FTE/per\ MT\ of\ product\ X\ market\ potential\ (total\ product\ produced\ in\ MT\ in\ 2030)$$

Table 2: The sector-wise FTE considered are as follows:

S. No.	Phase	FTE/MT
1.	Bamboo-based furniture	0.004/one modern bamboo furniture item

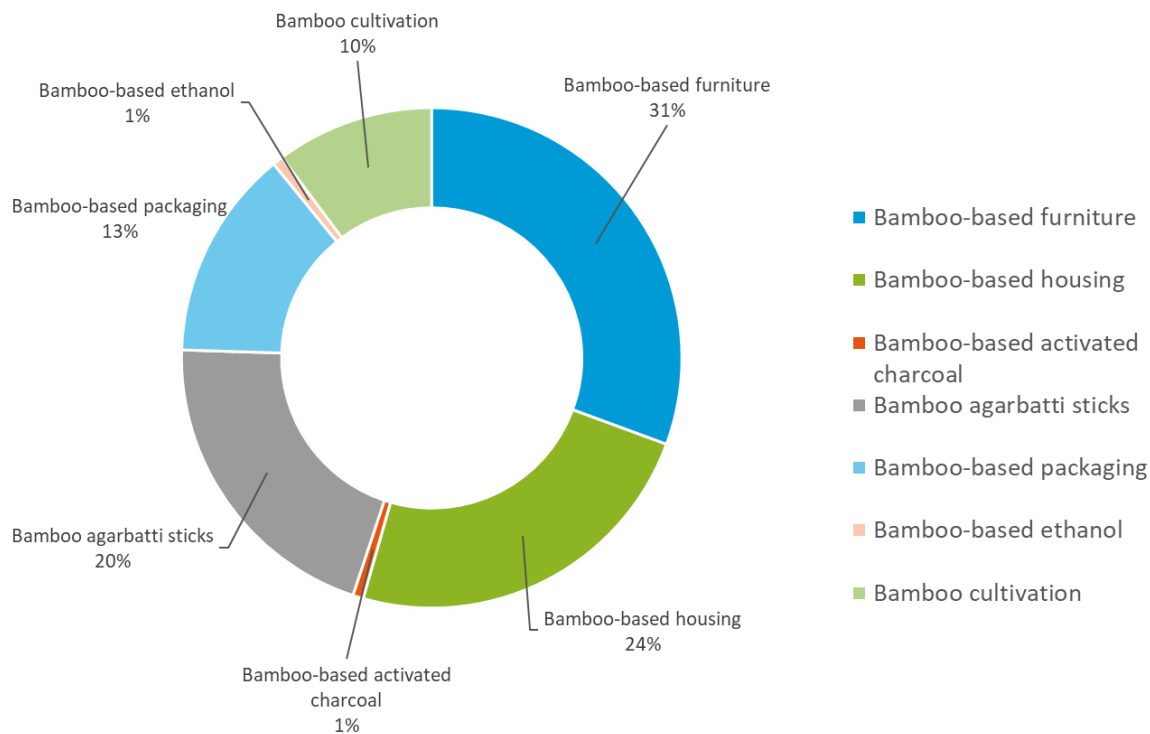
¹⁹ The total number of working days considered per annum for calculating the FTE/job multiplier was based on the average number of working days in that particular industry. This information was captured either through stakeholder interviews or from secondary sources.

²⁰ A median job tenure for an employee aged 25 and above has stayed approximately five years since the 1980s. This is based on an EBRI issue brief titled, '[Trends in Employee Tenure, 1983–2022.](#)'

²¹ We have not accounted for any job reduction due to automation.

2.	Bamboo-based housing	0.0009/one treated bamboo pole 0.0007/sq. mt.of bamboo mat board
3.	Bamboo agarbatti sticks	0.13/MT ²²
4.	Bamboo-based packaging	0.002/MT ²³
5.	Bamboo-based activated charcoal	0.04/MT
6.	Bamboo-based ethanol	0.003/MT

Figure 1: Sector-wise division of jobs



Market opportunity (in value) estimation

To estimate the potential market opportunity for bamboo-based products in Odisha, we multiplied the total number of products required in 2030 for each sector by the sale rate of bamboo products at B2B²⁴ either through stakeholder consultations or through rates mentioned on third party sites such as IndiaMART.

²² Based on detailed project report by KVIC on bamboo agarbatti stick production unit

²³ Based on stakeholder consultations with bio-based packaging production units producing 75,000 MT of packaging paper annually

²⁴ B2B (Business-to-Business) refers to transactions or interactions between two businesses rather than between a business and individual consumers

Table 3: The sector-wise per unit prices of bamboo-based products²⁵ are as follows:

S.No	Sector	Product considered	Per unit price
1.	Bamboo-based furniture	Modern bamboo furniture	USD 40/furniture
2.	Bamboo-based housing	Bamboo mat board (for urban housing) and treated bamboo pole (for rural housing)	USD 1.15/sq mt. of bamboo mat board ²⁶ USD 1.2/treated bamboo pole ¹⁷
3.	Bamboo agarbatti sticks	Round bamboo agarbatti sticks	INR 100/Kg of bamboo sticks ²⁷
4.	Bamboo-based packaging	Bamboo-based packaging paper	USD 0.85/Kg of packaging paper ²⁸
5.	Bamboo-based activated charcoal	Bamboo-based activated charcoal	USD 4/Kg ²⁹
6.	Bamboo-based ethanol	Bamboo-based ethanol	USD 0.79/litre of bamboo ethanol ³⁰

Investment opportunity estimation

We calculated the total investment needed to realise the projected market opportunity by focusing solely on capital expenditure (CAPEX). When determining the number of units or facilities required to meet 2030 demand, we rounded up any decimal values.

The total investment opportunity was calculated using the following formula:

$$\text{Total Investment opportunity} = (\text{Total number of units required to be set up by 2030}) \times (\text{CAPEX required to set up one unit})$$

Table 4: The sector-wise CAPEX considered are as follows:

S.No.	Value chain phase	Industries	CAPEX required ³¹
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²⁵ We have not estimated the market potential for raw bamboo by multiplying the total bamboo harvested in 2030 by the average selling rate of raw bamboo. This is because the raw bamboo is diverted to different industries for further processing into various finished products. Therefore, to avoid double counting, we have only considered the market value of these finished products, not the raw bamboo produced from bamboo cultivation.

²⁶ Udoygini and KVIC

²⁷ The price is based on median range of wholesale prices of bamboo sticks on indiamart

²⁸ Stakeholder consultation

²⁹ The price of activated bamboo charcoal in business-to-business (B2B) transactions is calculated by averaging the values from IndiaMart to determine the price per kilogram.

³⁰ The price of one litre of bamboo ethanol as set by the central government (Source- PIB)

³¹ Figures rounded off to nearest 1000s and nearest 100s in case the number is less than 1000

1.	Bamboo cultivation and harvesting	Primary production	USD 900/Hec ³²
2.	Bamboo-based furniture	Secondary processing	USD 25,000/unit ^{33,24}
3.	Bamboo-based housing	Secondary processing	USD 55,000/bamboo mat board production unit ³⁴ USD 241/treated bamboo pole unit ³⁵
4.	Bamboo agarbatti sticks	Secondary processing	USD 15,000/unit ³⁶
5.	Bamboo based packaging	Secondary processing	USD 120 million/300 TPD plant ²⁶
6.	Bamboo-based activated charcoal	Secondary processing	USD 21,600/unit ³⁷
7.	Bamboo-based ethanol	Secondary processing	USD 114 million/49,000MT plant capacity ³⁸

³² Figure is exclusive of labour cost

³³ One modern bamboo furniture unit produces 1500 bamboo furniture items per annum

³⁴ Based on DPR by advancing northeast

³⁵ Based on UNDP 2021 report on Understanding the Value Chain of Affordable Housing Construction

³⁶ Based on DPR by KVIC

³⁷ Stakeholder consultations

³⁸ If Odisha sets up a bamboo ethanol production unit with an annual capacity of 49,000 MT

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