

3. Biomaterials – S & T

Biomaterials are becoming a central focus in the development of materials for products as nations transition to more sustainable manufacturing methods

Biomaterials- Concept and Scope

Biomaterials are materials derived wholly or partly from biological sources or produced using biological processes, designed either to replace or complement conventional fossil-based materials. Unlike traditional materials, biomaterials are embedded in renewable feedstocks, circular economy principles, and low-carbon production pathways. They are increasingly used across-

1. Packaging (bioplastics, compostable films)
2. Textiles (bio-based fibres)
3. Construction (bio-composites, bio-resins)
4. Healthcare (biodegradable sutures, implants, tissue scaffolds)

Typical examples include

1. Bioplastics derived from plant sugars or starch
2. Bio-based fibres replacing petroleum-based synthetics
3. Medical biomaterials designed for biodegradability and biocompatibility

Categories of Biomaterials – Biomaterials are broadly classified into three functional categories-

Drop-in Biomaterials

1. Chemically identical to petroleum-based materials
2. Can be used within existing manufacturing, recycling, and disposal systems
3. Offer easier market adoption due to low transition costs
4. Examples- bio-based polyethylene, bio-PET

Drop-out Biomaterials

1. Require new processing, handling, or disposal infrastructure
2. Often biodegradable or compostable under controlled conditions
3. Environmental benefits depend on end-of-life systems
4. Examples- PLA-based compostable packaging

Novel Biomaterials

Provide entirely new properties or functions Enable innovation beyond simple substitution. Examples-

1. Advanced bio-composites
2. Smart biomaterials in healthcare
3. Engineered tissue scaffolds

Importance and Strategic Rationale for India

Biomaterials align multiple national objectives simultaneously

1. Environmental sustainability
2. Industrial growth
3. Farmer income diversification
4. Import substitution

Indigenous biomaterials manufacturing can

1. Reduce dependence on fossil-based imports for plastics, chemicals, and materials
2. Strengthen supply-chain resilience

Agricultural feedstocks and residues

1. Create **value-added markets** beyond food
2. Offer new income streams for farmers, especially from crop residues and waste

As global markets shift toward low-carbon and circular products, biomaterials-

1. Enhance India's export competitiveness
2. Reduce exposure to future carbon border measures

Biomaterials directly support domestic policy goals

1. Waste reduction and circular economy
2. Single-use plastic bans
3. Climate mitigation and bioeconomy expansion

Global Scenario and Comparative Developments

European Union - The EU has adopted a single, binding Packaging and Packaging Waste Regulation (EU) 2025/40, which

1. Recognises that compostable packaging has demonstrable environmental benefits in specific use cases
2. Creates regulatory clarity for biomaterials adoption

This has accelerated

1. Private investment
2. Infrastructure development
3. Standardisation across member states

United Arab Emirates - The UAE is positioning itself as a global biomaterial manufacturing hub. Emirates Biotech is developing a large-scale PLA facility

1. Two phases of 80,000 tonnes per year each
2. Commercial operations targeted from 2028

Once fully operational, it will be the world's largest PLA plant, highlighting aggressive industrial strategy.

United States - The U.S. leads in transformative biomaterials technologies. A key driver is federal demand aggregation through USDA BioPreferred Program
Government procurement acts as

1. A market creator
2. A risk mitigator for early-stage technologies
3. A credibility signal for private investment

Present Status of Biomaterials in India - India's biomaterials sector—covering bioplastics, biopolymers, and bio-derived materials—is rapidly emerging.

The bioplastics market alone

1. Valued at approximately USD 500 million in 2024
2. Expected to grow strongly through the decade

Major industrial developments include- Balrampur Chini Mills planned PLA plant in Uttar Pradesh, among India's largest biomaterials investments

Domestic innovation ecosystem includes

1. Phool.co, converting temple flower waste into high-value biomaterials
2. Praj Industries, developing demonstration-scale bioplastics facilities

These initiatives indicate

1. Growing private-sector interest
2. Early-stage industrial capability
3. Strong linkage with India's broader bioeconomy ambitions

Issues and Concerns - Despite strong potential, several challenges must be addressed-

Feedstock Constraints

1. Scaling biomass feedstocks may create competition with food crops

2. Risk of land-use conflicts if not managed through productivity gains and residues

Environmental Externalities – Intensive feedstock cultivation could increase

1. Water stress
2. Soil degradation

Infrastructure Gaps

1. Inadequate waste management and composting infrastructure
2. Risk of biomaterials ending up in landfills, reducing environmental benefits

Policy Fragmentation – Disconnected policies across

1. Agriculture
2. Environment
3. Industry
4. Urban development

Strategic Lag

1. Delayed action could lock India into import dependence
2. Other countries may capture technology leadership and export markets first

Conclusion and Way Forward

To fully capitalise on biomaterials, India must

1. Expand biomanufacturing infrastructure
2. Improve feedstock productivity using biotechnology and precision agriculture
3. Invest in R&D across
 - a. Drop-in biomaterials
 - b. Novel, high-value biomaterials

Clear regulatory frameworks are essential

1. Standardised definitions
2. Labelling norms
3. Well-defined end-of-life pathways

Policy instruments that can accelerate adoption include

1. Government procurement mandates
2. Targeted fiscal incentives
3. Support for pilot plants and shared testing facilities

With coordinated action, biomaterials can become a pillar of India's bioeconomy, simultaneously delivering

1. Climate benefits
2. Industrial competitiveness
3. Rural income enhancement
4. Long-term sustainability gains

Source- <https://www.thehindu.com/sci-tech/energy-and-environment/what-are-biomaterials-and-how-do-they-work-explained/article70477939.ece>