14 India's Material Processing Capacity and Growth

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Abstract

India has emerged as a critical player in the global landscape of material consumption and processing. With one of the fastest-growing economies and a population surpassing 1.4 billion, India's demand for materials is expanding at unprecedented rates. Material processing refers to the extraction, transformation, and utilization of natural resources in manufacturing, mining, construction, textiles, food processing, and critical mineral sectors. This process forms the backbone of industrialisation, urbanisation, and economic growth in the country.

Keywords: Global Landscape, Fastest-Growing Economies, Natural Resources, Industrialisation, Economic Growth.

Introduction

The rise of India as a material-intensive economy can be attributed to multiple factors—rapid urban migration, expansion of infrastructure, rising incomes, and the global integration of supply chains. As India transitions from an agrarian base to an industrial and service-led economy, the intensity of resource use has increased significantly. At the same time, this growth raises concerns about long- term sustainability, resource efficiency, and the environmental implications of material processing.

India's transformation is not merely quantitative but also structural. The country has moved beyond being a low-value raw material supplier to becoming an important processor of complex materials such as steel, aluminum, plastics, and textiles. The construction sector has grown into one of the largest material consumers globally, while the automotive industry has doubled its material requirements in less than a decade. Alongside, demand for critical minerals like copper, cobalt, and rare earths has surged due to renewable energy transitions and technological advancements.

This paper examines India's material processing capacity and growth through a comprehensive framework that combines quantitative analysis, sectoral case studies, and policy perspectives. It integrates global and domestic contexts, evaluates key indicators such as Domestic Material Input (DMI), Domestic Material Consumption (DMC), and Physical Trade Balance (PTB), and assesses the implications of material use on the economy, society, and environment. By applying frameworks such as Economy-wide Material Flow Accounting (EW-MFA) and the System of Environmental-Economic Accounting (SEEA), the study highlights India's trajectory and identifies pathways for sustainable development.

The significance of this research lies in balancing three interconnected priorities: sustaining economic growth, enhancing social well-being, and ensuring environmental sustainability. India's choices in material management over the next decades will have global repercussions, influencing trade flows, climate commitments, and the broader transition to a circular economy.

Global Context

India's material processing capacity and growth cannot be studied in isolation; it must be contextualized within the broader global framework of resource use and consumption. The 21st century has witnessed an unprecedented rise in material demand worldwide, driven by population growth, urbanisation, and economic development. According to the United Nations International Resource Panel (IRP), global material use has more than tripled since 1970, increasing from 27 billion tonnes to over 92 billion tonnes in 2017. By 2050, global material demand is projected to reach 170– 190 billion tonnes, raising questions about planetary boundaries and ecological sustainability.

In this global narrative, India occupies a unique position. With its demographic dividend, rapid economic growth, and urban expansion, India's resource requirements are expected to rise sharply.

Comparative analysis indicates that India's per capita material consumption remains lower than that of developed economies, but the aggregate scale of demand places it among the largest consumers worldwide. For example, while per capita Domestic Material Consumption (DMC) in India was approximately 2.1 tonnes in 2020–21, this is still far below the global average of 12 tonnes and China's 17 tonnes. However, given India's population size, even modest per capita increases translate into enormous absolute growth.

Global Drivers and India's Rising Relevance

Several global drivers amplify India's significance in material processing:

- **Population growth and urbanisation:** India is projected to add nearly 400 million urban residents by 2050, requiring massive expansion in housing, transport, and infrastructure. This directly translates into exponential demand for construction materials such as steel, cement, and aggregates.
- **Industrial expansion:** The rapid growth of construction, automotive, textiles, and consumer goods sectors has positioned India as a major contributor to global material flows. India's automotive sector alone has witnessed an annual growth rate exceeding 14%, requiring vast amounts of steel, aluminium, copper, and plastics.
- **Global supply chain integration:** India is increasingly embedded within international production networks. From supplying raw materials like iron ore and bauxite to becoming a global centre for automobile and textile production, India's role in global supply chains amplifies its material footprint.
- **Strategic competition for critical minerals:** With the global transition towards clean energy and digital technologies, demand for rare earths, lithium, cobalt, and copper has soared. India's growing requirements for these resources tie it directly to international markets and geopolitical contests.

Comparative Perspective

Compared to advanced economies, India faces a dual challenge: sustaining economic growth while avoiding the unsustainable material footprints of industrialised nations. While per capita consumption in countries like the United States and European Union ranges between 15–25 tonnes annually, India's relatively low figure provides an opportunity to chart a more sustainable path.

However, replicating the high-consumption model of the West would place immense strain on both domestic ecosystems and global resource markets.

China offers a cautionary example. Its industrial boom, built on heavy material consumption, has generated economic prosperity but also severe environmental degradation, air pollution, and global resource market volatility. India, currently at a similar inflection point, can learn from China's trajectory by adopting resource efficiency and circular economy principles early in its industrialisation curve.

Global Environmental Implications

India's material growth carries global environmental consequences. Rising demand for steel, cement, plastics, and critical minerals will contribute to carbon emissions, biodiversity loss, and water stress unless managed sustainably. The International Energy Agency (IEA) estimates that materials-related industries account for nearly 25% of global CO_2 emissions. As India becomes a larger material processor, its policies and practices will directly impact global climate targets, especially the Paris Agreement's ambition of limiting warming to below 2°C.

Towards a Sustainable Global Role

In this context, India's material processing growth is not simply a domestic issue but part of a global challenge of resource governance. The world will closely watch how India balances its development imperatives with sustainability. By adopting efficiency-enhancing technologies, promoting secondary raw material use, and embracing circular economy models, India has the potential to emerge as a global leader in sustainable material processing.

Resource Efficiency: National Perspective

India's economic trajectory is characterised by rapid industrialisation, urbanisation, and rising material intensity. However, the availability of natural resources is not infinite, and the environmental and social costs of extraction are becoming increasingly visible. From groundwater depletion in agriculture to unsustainable sand mining in construction, the pressure on ecosystems is growing. This necessitates a national conversation around **resource efficiency**—the ability to generate more economic output with fewer natural inputs while minimising environmental damage.

- **Resource Supply Constraints**

India possesses abundant reserves of coal, iron ore, bauxite, and limestone but is increasingly dependent on imports of critical minerals such as copper, cobalt, lithium, and rare earth elements. With rising energy transition needs (solar panels, wind turbines, electric vehicles), the demand for these imported resources is set to multiply. Supply disruptions, global price volatility, and geopolitical risks add further uncertainty.

Domestic constraints are equally pressing. For example:

  - **Sand and aggregates:** Over-extraction for construction has led to riverbank erosion, groundwater decline, and loss of biodiversity.
  - **Water resources:** Industrial use competes with agricultural and domestic needs, leading to regional conflicts.
  - **Land availability:** Expansion of mining and construction encroaches on forests, agricultural land, and indigenous territories.

- **Environmental Impacts**

Resource extraction and processing are responsible for some of India's most severe environmental challenges:

  - **Land degradation:** Nearly 30% of India's land area is degraded due to mining, deforestation, and unsustainable agricultural practices.

- **Air pollution:** Cement, steel, and power plants contribute significantly to particulate matter and greenhouse gas emissions.
- **Biodiversity loss:** Quarrying and mining threaten fragile ecosystems, particularly in mineral- rich tribal belts.
- **Climate change impacts:** Resource-intensive industries contribute directly to CO_2 emissions, undermining India's commitments under the Paris Agreement.

- **Circular Economy and Climate Commitments**

To reconcile economic growth with environmental limits, India has begun embedding **circular economy principles** in its policy discourse. The **NITI Aayog's "Strategy for Resource Efficiency"** (2019) emphasises recycling, reuse, and reduction of material use. Circular practices are now being promoted in:

- **Automotive sector:** End-of-life vehicle recycling, Extended Producer Responsibility (EPR) for batteries and tyres.
- **Construction:** Promotion of recycled aggregates, fly ash in cement, and waste-to-building materials.
- **Plastics:** Ban on single-use plastics and EPR guidelines for packaging waste.

India's climate commitments under its **Nationally Determined Contributions (NDCs)** also depend heavily on resource efficiency. Achieving a 33–35% reduction in emissions intensity of GDP (compared to 2005 levels by 2030) requires material efficiency improvements in steel, cement, and transport sectors.

Analytical Framework

To analyse India's material processing trends systematically, this study employs a multi-layered analytical framework combining **Economy-wide Material Flow Accounting (EW-MFA)**, **System of Environmental-Economic Accounting (SEEA)**, and **Material Flow Analysis (MFA)**.

- **Economy-wide Material Flow Accounting (EW-MFA)**

EW-MFA tracks the physical flow of resources into, within, and out of the economy. It quantifies:

- **Domestic Extraction (DE):** Raw materials extracted domestically.
- **Imports & Exports:** Cross-border material trade.
- **Direct Material Input (DMI):** DE + Imports.
- **Domestic Material Consumption (DMC):** DMI – Exports.
- **Physical Trade Balance (PTB):** Imports – Exports.

This approach helps policymakers identify whether India's material demand is increasingly met through domestic extraction or imports, and what implications this has for sustainability.

- **System of Environmental-Economic Accounting (SEEA)**

SEEA, developed by the United Nations, integrates environmental data with economic accounts. It provides a framework to link material flows with economic indicators such as GDP, employment, and sectoral output. For India, SEEA offers insights into:

  - How resource efficiency affects economic productivity.
  - The environmental costs of material extraction and processing.
  - Trade-offs between growth, employment, and sustainability.

- **Material Flow Analysis (MFA)**

MFA applies a systems approach to trace material flows across production and consumption chains. For example, in the construction sector, MFA can map the journey of limestone from

Quarrying → cement plants → construction sites → demolition waste → recycling. This granular analysis supports the design of circular economy interventions.

- **Industrial Systems Thinking**

Industrial systems thinking views material processing as part of an interconnected socio-economic system. Rather than treating industries in isolation, it considers linkages—such as how steel demand in the automotive sector influences mining, energy consumption, and recycling streams. This approach is crucial for policy integration across sectors.

Key Indicators of Material Use in India

India's material processing capacity can be quantified using a set of internationally recognised indicators. These provide insights into the scale, efficiency, and sustainability of material flows.

- **Domestic Extraction (DE)**

Domestic Extraction refers to the total weight of natural resources extracted from within national territory for use in the economy. India has significant domestic extraction volumes in coal, iron ore, limestone, sand, and biomass.

  - Coal extraction exceeded **700 million tonnes** in 2020.
  - Limestone extraction, critical for cement, stood at **330 million tonnes**.
  - Sand and aggregate extraction are not fully documented but are estimated at **5–6 billion tonnes annually**, mostly for construction.

- **Imports and Exports**

India imports critical materials such as crude oil, copper, cobalt, and rare earth elements, while exporting iron ore, steel, textiles, and agricultural commodities. The **Physical Trade Balance (PTB)** has been widening, reflecting growing import dependency.

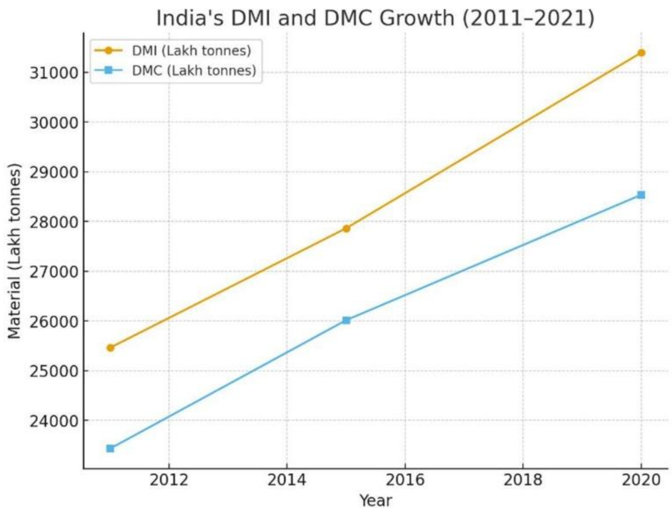
- **Direct Material Input (DMI) and Domestic Material Consumption (DMC)**
    - **DMI** = Domestic Extraction + Imports.
    - **DMC** = DMI – Exports.

Between 2011–12 and 2020–21:

- DMI rose from **25,459 lakh tonnes** to **31,393 lakh tonnes**.
- DMC rose from **23,430 lakh tonnes** to **28,534 lakh tonnes**.
- Per capita DMC increased modestly, from **1.92 tonnes to 2.10 tonnes**, reflecting incremental but significant growth.

Table 1: Material Use Indicators in India (2011–2021)

Indicator	2011–12	2015–16	2020–21
DMI (Lakh tonnes)	25,459	27,862	31,393
DMC (Lakh tonnes)	23,430	26,013	28,534
DMC per capita (t)	1.92	2.03	2.10
DMC/GDP (t per ₹ Lakh)	0.30	0.22	0.21



Line graph showing DMI, DMC, and per capita DMC over 2011–2021, highlighting steady growth.

- **Efficiency Trends**

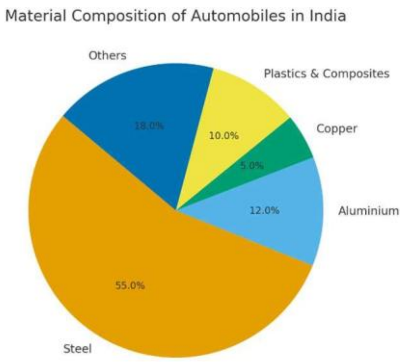
The decline of **DMC/GDP** from 0.30 in 2011–12 to 0.21 in 2020–21 signals gradual improvement in material efficiency. This means India is producing more economic value per tonne of material consumed. However, efficiency improvements remain slower compared to developed countries.

Sectoral Analysis

Material use is not evenly distributed across sectors. Two of the largest and fastest-growing sectors are **Automotive** and **Construction**. Together, they account for more than half of India's processed material demand.

- **Automotive Sector Growth and Scale**
  - India's automotive sector has grown at **14%+ annually** over the past decade.
  - India is now the **world's fourth-largest automobile market**, projected to become the third- largest by 2030.
  - Material requirements for the sector are expected to **double within a decade**. **Material Composition**
  - **Steel:** Dominant material, ~55% of a vehicle's weight.
  - **Aluminium:** Growing role in lightweight vehicles; per vehicle use projected to rise from 120 kg (2020) to 250 kg (2030).
  - **Copper:** Used in wiring and electric vehicles. EV adoption will push copper demand up to 1.5 million tonnes by 2030.
  - **Plastics & composites:** 8–10% of material share, rising in EVs.

  Recycling and Circularity
  - India has initiated **End-of-Life Vehicle (ELV)** regulations.
  - Informal sector dominates recycling but suffers from inefficiency and environmental risks.
  - Potential to recover **70–80% of metals** from scrapped vehicles through organised recycling.

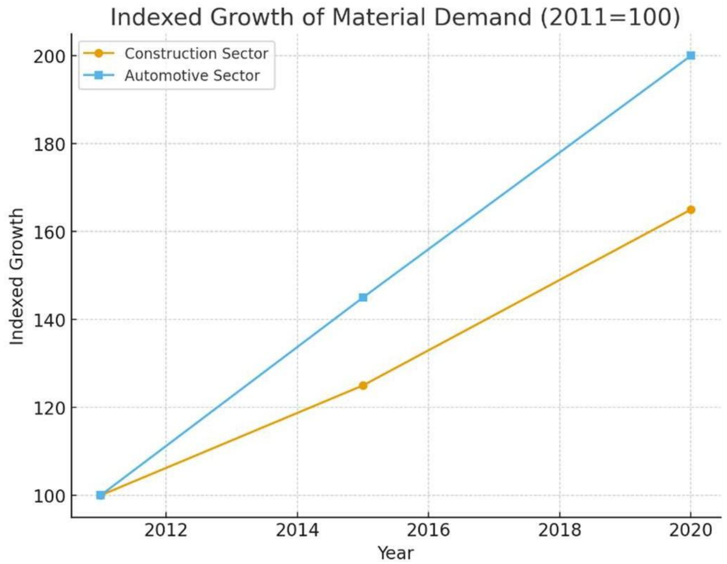


Pie chart of material composition of vehicles (steel, aluminium, copper, plastics).

- **Construction Sector Growth and Importance**
  - Construction is the **second-largest consumer of materials** after agriculture.
  - Annual growth **~10%**, driven by urbanisation, housing, and infrastructure expansion.
  - Accounts for nearly **40% of national material use**. **Key Materials**
  - **Sand and stone:** Largest volume, but poorly regulated extraction.
  - **Cement and limestone:** India is the **second-largest cement producer** globally (~340 million tonnes in 2020).
  - **Soil and clay:** Used in bricks; India consumes **250 billion bricks annually**. **Vulnerabilities**
  - Price volatility in sand, cement, and steel impacts construction costs.
  - Illegal sand mining creates ecological risks and social conflicts.
  - Dependence on energy-intensive cement poses climate challenges.

Circular Practices

  - Use of **fly ash** in cement (policy-driven by thermal power plants).
  - Recycled construction and demolition waste (~50 million tonnes annually), though still underutilised.
  - Government programmes (Smart Cities Mission, Housing for All) encourage material-efficient designs.



Bar chart comparing growth rates of material use in construction vs. automotive (2011–2021).

Quantitative Trends and Indicators

India's material processing trends over the past decade reveal both opportunities and challenges. The data indicates rising material demand but also modest improvements in efficiency.

- **Growth in DMI and DMC**

  From 2011–12 to 2020–21:

  - **Direct Material Input (DMI)** rose from **25,459 lakh tonnes** to **31,393 lakh tonnes** (+23%).
  - **Domestic Material Consumption (DMC)** increased from **23,430 lakh tonnes** to **28,534 lakh tonnes** (+22%).
  - This growth reflects industrial expansion, infrastructure projects, and rising household consumption.

Table 2: Material Flow Indicators, 2011–2021 Year

DMI (Lakh tonnes) DMC (Lakh tonnes) DMC per capita (t) DMC/GDP (t/₹ Lakh)

2011–12 25,459	23,430	1.92	0.30
2015–16 27,862	26,013	2.03	0.22
2020–21 31,393	28,534	2.10	0.21

- **Per Capita Consumption**

  Per capita DMC rose slightly from **1.92 tonnes in 2011–12** to **2.10 tonnes in 2020–21**. Although modest, this increase is significant given India's population size. The aggregate effect is a large rise in material throughput.

- **Material Efficiency**

  The decline in **DMC per unit of GDP** (from 0.30 to 0.21 tonnes per ₹ lakh GDP) suggests gradual improvements in resource efficiency. However, efficiency levels remain below those of developed economies like Japan or Germany, where circular economy measures are deeply embedded.

- **Trade Dependence**

  India's growing reliance on imported crude oil, copper, and critical minerals increases its vulnerability to global price shocks. A positive trend is the increase in exports of value-added steel and aluminium, indicating upward movement in the value chain.

Environmental and Social Impacts

Material extraction and processing carry profound environmental and social implications in India.

- **Environmental Impacts Land Degradation**

  - Nearly **30% of India's land area** is classified as degraded.

- Mining belts in Jharkhand, Odisha, Chhattisgarh, and Goa show significant soil erosion and forest loss.

Water Stress

- Industries like textiles, paper, cement, and chemicals are highly water-intensive.
- Over-extraction of groundwater for construction and agriculture reduces water availability for local communities.

Air Pollution

- Cement and steel industries are among the largest emitters of particulate matter and greenhouse gases.
- Dust from stone quarries and construction sites contributes to poor urban air quality.

Greenhouse Gas Emissions

- Resource-intensive industries contribute directly to India's CO_2 emissions (~25% of total).
- Cement production alone accounts for ~8% of global CO_2 emissions; India's cement industry is a major contributor.

Biodiversity Loss

- Illegal sand mining threatens river ecosystems, fish populations, and wetlands.
- Mining activities in ecologically sensitive zones affect wildlife habitats.

- **Social Impacts Employment and Livelihoods**
  - Mining and construction provide direct employment to millions of workers.
  - Informal recycling sectors sustain livelihoods for over 1.5 million people.

Urban Migration

- Material-intensive industries fuel rapid urbanisation.
- Cities face challenges of housing, infrastructure, and service provision.

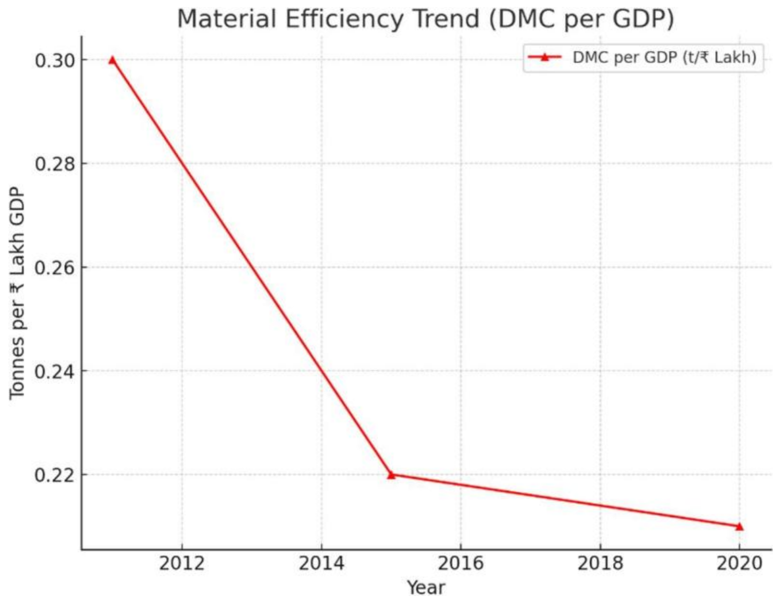
Social Conflicts

- Resource extraction often displaces indigenous and rural communities.
- Conflicts arise around land acquisition, environmental degradation, and inadequate compensation.

Health Impacts

- Mining regions report higher incidence of respiratory and water-borne diseases.
- Workers in unregulated recycling sectors are exposed to toxic chemicals

and unsafe practices.



Infographic showing the "triple burden" of material processing — **environmental (land, air, water)**, **economic (GDP, jobs)**, and **social (health, migration)** impacts.

Future Outlook

India's material demand trajectory is projected to accelerate dramatically.

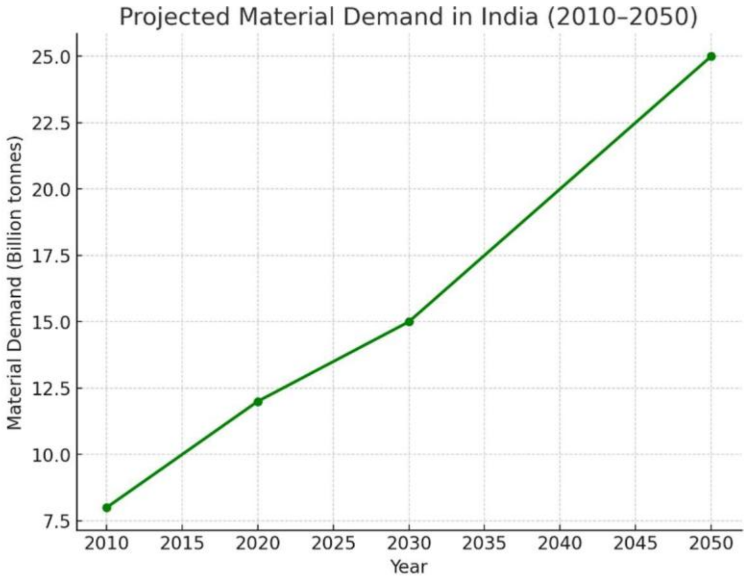
- **Material Projections**
  - By **2030**, material requirements could reach **15 billion tonnes**.
  - By **2050**, demand may rise to **25 billion tonnes**.
  - Key drivers: infrastructure expansion, urbanisation, energy transition (renewables, EVs), and rising consumption.
- **Potential Bottlenecks**
  - **Supply shortages:** Sand, rare earths, copper, and cobalt.
  - **Price volatility:** Global shocks affecting imports.
  - **Environmental constraints:** Climate change, water scarcity, and land degradation.
- **Sustainability Imperatives**

  To avoid unsustainable growth, India must:
  - **Invest in circular economy models** – scaling up recycling of steel, aluminium, plastics, and construction waste.
  - **Promote material substitution** – replacing sand with manufactured

aggregates, and plastics with biodegradable alternatives.

- **Strengthen regulations** – especially for mining and construction sectors.
- **Enhance international cooperation** – to secure critical minerals through strategic partnerships.

- **Opportunities for Innovation**
  - **Industry 4.0:** Use of AI, IoT, and blockchain to track material flows.
  - **Green construction:** Adoption of prefabricated, modular, and low-carbon building technologies.
  - **E-mobility:** Recycling of EV batteries to secure lithium and cobalt supplies.
  - **Renewables integration:** Using waste heat recovery and green hydrogen in steel and cement industries.



Conclusion and Recommendations

Conclusion

India's material processing landscape is undergoing a profound transformation. The steady rise in **Domestic Material Input (DMI)** and **Domestic Material Consumption (DMC)** reflects the country's rapid economic expansion, industrialisation, and urbanisation. With DMI rising from **25,459 lakh tonnes in 2011–12** to **31,393 lakh tonnes in 2020–21**, India is solidifying its position as one of the largest consumers of natural resources globally.

Yet, this growth comes at significant environmental and social costs. Mining-related land degradation, air and water pollution, biodiversity loss, and public health challenges underscore the urgent need for **sustainable material management strategies**. Social issues such as urban migration, employment vulnerability, and conflicts around resource extraction highlight the complexity of material-driven development.

Global comparisons suggest that while India's material efficiency (DMC/GDP) has improved marginally, it remains below international best practices. Unless new circular approaches are adopted, projections indicate that material demand could reach **15 billion tonnes by 2030** and **25 billion tonnes by 2050**, raising risks of shortages, price shocks, and ecological crises.

Therefore, India faces a pivotal moment: balancing the imperatives of economic growth, social well- being, and environmental stewardship. This calls for systemic interventions that combine resource efficiency, policy reform, and innovation.

Recommendations

1. **Strengthen Resource Efficiency Policies**
   - Expand the **National Resource Efficiency Policy (NREP)** into a binding framework with measurable targets.
   - Establish sector-specific material efficiency roadmaps for automotive, construction, and textiles.
   - Incentivise industries through tax benefits, subsidies, and green certification.
2. **Promote Circular Economy Models**
   - Scale up recycling infrastructure for **steel, aluminium, plastics, and construction waste**.
   - Formalise the informal recycling sector by integrating workers into structured systems with training and safety standards.
   - Encourage **product design for durability, repairability, and recyclability**.
3. **Advance Sustainable Mining Practices**
   - Strengthen monitoring of sand, stone, and coal extraction.
   - Deploy **remote sensing and digital tracking** to curb illegal mining.
   - Implement community-based rehabilitation programs in mining-affected regions.
4. **Foster Innovation and Industry 4.0**
   - Encourage use of **IoT, AI, and blockchain** to monitor supply chains.
   - Promote **green steel and cement technologies** using renewable energy and waste heat recovery.
   - Support R&D into **biodegradable materials** and alternatives to critical minerals.

5. **Integrate Climate Commitments**
   - Link material efficiency goals to India's **Nationally Determined Contributions (NDCs)** under the Paris Agreement.
   - Develop carbon accounting frameworks for major industries such as cement, steel, and construction.
   - Encourage use of **low-carbon building materials** in public infrastructure projects.
6. **Enhance International Cooperation**
   - Secure strategic partnerships for critical minerals (lithium, cobalt, rare earths).
   - Engage with international platforms such as the **International Resource Panel (IRP)** and the **G20 Resource Efficiency Dialogue**.
   - Align India's policies with global best practices to ensure competitiveness.
7. **Strengthen Data, Monitoring, and Research**
   - Expand the use of **Economy-wide Material Flow Accounting (EW-MFA)** and **System of Environmental-Economic Accounting (SEEA)** frameworks.
   - Publish annual **Material Flow Reports** with detailed sectoral data.
   - Encourage academic-industry collaborations to generate reliable datasets.

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