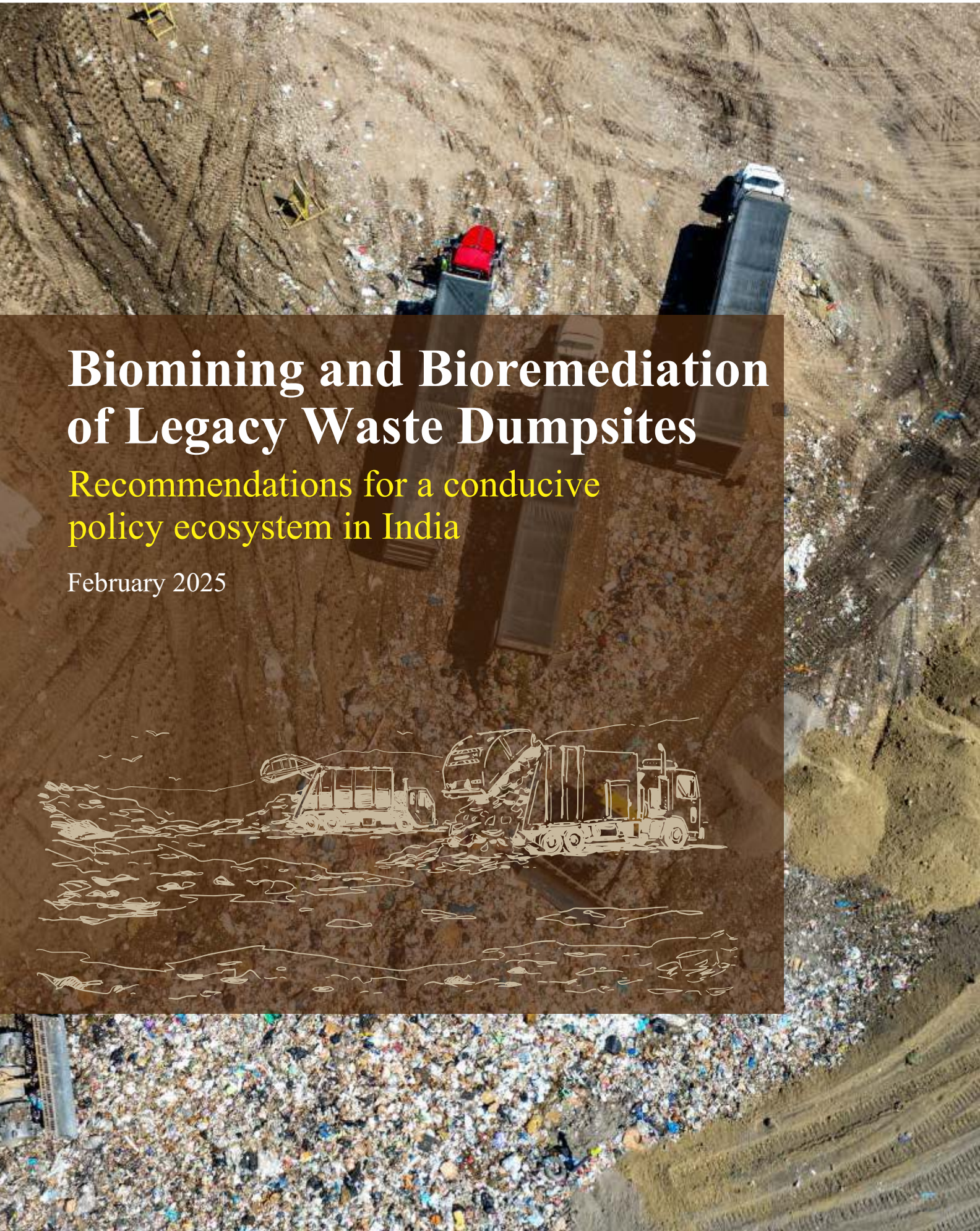
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Biomining and Bioremediation of Legacy Waste Dumpsites

Recommendations for a conducive policy ecosystem in India

February 2025

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PREFACE



India is at a pivotal point in its urban development journey, where sustainable waste management is both an urgent need and a collective responsibility. Federation of Indian Chambers of Commerce & Industry (FICCI) is delighted to be associated with the development of this critical report.

Legacy waste dumpsites pose significant environmental and public health challenges, serving as persistent sources of pollution and resource loss. Addressing these issues demands innovative, sustainable solutions. This report explores cutting-edge biological approaches to transform waste liabilities into opportunities for recovery and renewal. By adopting the recommendations laid out in this study, businesses can unlock new pathways for innovation, resource recovery, and economic growth, aligning with the principles of a circular economy.

Industries stand to benefit immensely from the insights provided here, particularly in exploring avenues for value addition through refuse-derived fuel (RDF) processing, biosoil applications, and the integration of advanced technologies for waste management. The report highlights opportunities for partnerships, financing, and policy convergence, enabling businesses to contribute meaningfully to India's goal of achieving a dumpsite-free urban landscape by 2026 under the Swachh Bharat Mission-Urban (SBM-U) 2.0.

As nations seek sustainable solutions to legacy waste management, the integration of biomining and bioremediation represents a transformative step toward a cleaner, more resource-efficient future. We hope this report serves as a valuable resource for policymakers, researchers, and industry leaders, inspiring collective action to reclaim and restore our shared environment.

FICCI is honoured to support such initiatives, fostering dialogue and collaboration to address the critical challenges of our time. Together, we can catalyse impactful change and set benchmarks for sustainable urban development.

Jyoti Vij
Director General
FICCI



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FOREWORD



India's rapid urbanization, while a testament to its progress, has brought significant challenges in the management of municipal solid waste. Among these challenges, the presence of legacy waste in overburdened municipal solid waste value systems across the country poses critical environmental and health hazards, while as well occupying valuable land resources. According to the Swachh Bharat Mission, as on date, India is home to over 2400 major dump sites, with legacy waste covering more than 14,000 acres of valuable land resources. Addressing this issue is not only an environmental imperative but also a vital step towards creating sustainable cities. To manage these legacy dumpsites effectively, mitigate their environmental, health, and societal impacts, as well as reclaim the urban land parcels, 'Biomining', has rapidly emerged as a preferred solution with it's proven environmental and socio-economic benefits. The sector has supportive policy ecosystem, however, effective planning and implementation of biomining projects faces several challenges.

Neev Funds are managed by SBI Ventures Limited, wholly owned subsidiary and alternative investment arm of State Bank of India (SBI). We are a climate-focused private equity fund backed by global and domestic institutional investors such as Government of United Kingdom, European Investment Bank (EIB), Japan International Cooperation Agency (JICA), Government of India (through Fund of Funds for Startups and Self Reliant India Fund) and SBI Group. It's mission is to foster growth and capital expansion in India's MSMEs, focusing on sectors with multiplier effects such as the circular economy, clean energy, electric vehicles, and efficient utilization of raw materials and water. Our study on biomining and bioremediation of legacy waste underscores our commitment to enabling solutions that align with India's effort to improved waste management and circular economy and Swachh Bharat Abhiyan goals.

The findings of this study aim to bridge knowledge gaps, highlight crucial linkages through case studies, and offer scalable recommendations that can be adopted to ensure sustained outcome from the biomining process overcoming execution challenges. Along with adequate financing being a crucial factor for effective biomining, elements such as management of aggregate (RDF, bio-soil) and their traceability, identifying suitable contractors, EHS, and risk aspects, etc., have been found to influence the lifecycle and timeline of biomining projects. By uncovering recommendations such as planning in convergence and clusters, involvement of academia, centralized monitoring systems, capacity building, documenting best practices, etc. such initiatives seek to provide actionable insights for policymakers, urban planners, and waste management practitioners

At Neev Fund, we are proud to support initiatives that converge at the intersection of environmental sustainability, social impact, and economic viability. We are confident that this study will catalyze meaningful action and inspire stakeholders to adopt sustainable waste management practices, thereby contributing to a cleaner, healthier, and more resilient India.

We extend our gratitude to all partners, experts, and organizations that have contributed to this comprehensive study. Together, let us drive the change toward a future where legacy waste is no longer a burden but a resource for renewal.

Sincerely,

Neev Fund

SBI Ventures Limited

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Table of Contents

1. Introduction 1

1.1. Status of legacy waste dumpsites in India 1

1.2. Evolution of the policy ecosystem 1

1.3. Background to this study 2

2. Ecosystem of legacy waste dumpsites in India 5

2.1. Each legacy waste dumpsite is unique and needs localized approaches 5

2.2. Biomining offers several advantages and opportunities 6

2.3. Challenges to scientific biomining 7

3. Biomining project lifecycle 9

3.1. Key aspects of a successful biomining project 9

4. Recommendations: Key enablers for effective biomining 13

4.1. Identified areas of recommendations for conducive policy instruments 13

4.2. It is important to encourage holistic project planning, focusing on critical factors like engaging of competent contractors 15

4.3. Stakeholders stressed the need for capacity building across the biomining ecosystem 16

4.4. Monitoring and traceability are important across the project lifecycle 18

4.5. Scientific management of aggregates, with focus on utilization as part of a circular economy 19

4.6. Convergence of funding is key to ensuring an integrated approach to dumpsite biomining and bioremediation 21

4.7. Scientific closure of dumpsites along with productive usage of recovered land 24

5. Way forward 27

5.1. Facilitating a conducive ecosystem through convergence and collaborations 27

Appendices

Appendix A. - Important considerations in planning of biomining projects 33

Appendix B. - Suggestive qualification criteria and scope of work for contractors 37

Appendix C. - A framework of ESG and EHS safeguard principles 41

Appendix D. - Frameworks for impact and cost benefit analysis 43

Appendix E. - Consent to Establish and Operate as regulatory instruments for effective monitoring 49

Appendix F. - Centralized certification and traceability mechanism for RDF and Biosoil 51

Appendix G. - Plastic EPR credits from RDF processing 55

Appendix H. - A discussion on regulatory ecosystem on disposal of aggregates 57

Appendix I. - Key References 61

ABBREVIATIONS

BRAIN	Biotechnology Research and Information Network
C&D	Construction and Demolition
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
CTE	Consent to Establish
CTO	Consent to Operate
CSR	Corporate Social Responsibility
DMF	District Mineral Foundation
DPR	Detailed Project Report
EHS	Environment, Health, and Safety
EPR	Extended Producer Responsibility
ERP	Enterprise Resource Planning
ESG	Environmental, Social and Governance
FC	Finance Commission
FCDO	The Foreign, Commonwealth and Development Office (FCDO)
GCF	Green Climate Fund
GHG	Green House Gas
GPS	Global Positioning System
Gt	Giga Tonne
INR	Indian Rupee
ISRO	Indian Space Research Organization
ISS	he International Space Station
KPI	Key Performance Indicator
MIS	Management Information System
MOEFCC	Ministry of Environment, Forest, and Climate Change
MOHUA	Ministry of Housing and Urban Affairs
MOU	Memorandum of Understanding
MLP	Multi-Layered Plastic
MRF	Material Recovery Facility
MT	Metric Tonne

NABL	National Accreditation Board for testing and calibration Laboratories
NGT	National Green Tribunal
NIUA	National Institute of Urban Affairs
NOC	No Objection Certificate
PIBO	Producers, Importers or Brand owner
PPP	Public Private Partnership
QCBS	Quality and Cost-based Selection
RDF	Refuse-Derived Fuel
RFP	Request for Proposal
SBM	Swachh Bharat Mission
SIDBI	Small Industries Development Bank of India
SLM	Soil Like Material
SPCB	State Pollution Control Board
SWM	Solid Waste Management
TOR	Terms of Reference
ToT	Training of Trainers
ULB	Urban Local Body
USEPA	United States Environmental Protection Agency

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EXECUTIVE SUMMARY

India, being a rapidly urbanizing nation, faces the annual loss of hundreds of hectares of land to dumpsites due to escalating generation of poorly managed municipal solid waste. The management of these dumpsites, mitigation of their environmental, health, and societal impacts and the recovery of valuable urban land parcels face significant challenges. However, in recent years, technology enablement, extensive private sector involvement, and decentralized governance are emerging as the main guiding principles of Solid Waste Management (SWM) in India. Moreover, the principles of the circular economy are being increasingly employed for efficient resource recovery and reuse of such waste.

Various sources estimate the number of legacy-waste[1] dumpsites in India to be around 3,000-4,000. According to the Swachh Bharat Mission (SBM) Urban program, the country has 2,429 reported dumpsites (each with a minimum of over 1,000 tonnes of legacy waste), of which only about 660 (~25%) have been remediated[2] to date. These dumpsites reportedly cover an area of over 14,000 acres and contain at least 235 million MT of legacy waste. Many socio-economic studies consider a 5 km radius as the impact periphery of any given project, implying that these 2,429 sites would be affecting over 1,80,000 sq.km. across the country, i.e., nearly 5% of India's total area. While the environmental impacts of dumpsites vary based on their size and geographical location, these legacy dumpsites have continued to pollute localities for decades.

Biomining, with its proven environmental and socio-economic benefits and an evolving policy environment, is quickly becoming a solution for bioremediating and reclaiming legacy dumpsites across India. Under SBM, Urban Local Bodies (ULBs) are expected to focus on remediating their dumpsites through biomining within the brief program period and complete remediation activities by 2026. While there are some well-documented and highlighted success stories in India, the fact that only about 25% of the legacy waste dumpsites have been remediated till date indicates that many cities may be lagging in choosing the correct approach to bioremediation and biomining. This could be due to the challenges that persist in the effective planning and execution of biomining projects, arising from gaps in understanding, insufficient data, the need for effective Environmental, Health, and Safety (EHS) risk mitigation, or inadequate technical capacity for scientific implementation and strict compliance with statutory requirements. Furthermore, many of these projects may be delayed or implemented with less efficacy due to budget constraints or local factors like regional weather variations.

To this end, SBI Ventures Limited along with its partners and the Foreign, Commonwealth and Development Office (FCDO), Government of United Kingdom and Small Industries Development Bank of India (SIDBI), have supported a "Study of Biomining and Bioremediation". The key objective of this study is to comprehend optimal approaches and possible policy inputs to strengthen the biomining and bioremediation ecosystem in India.

This report summarizes key findings and recommendations from the "Study of Biomining and Bioremediation". The study indicates that the success of biomining is entirely contingent on the specific circumstances of the city in question. While there are general guiding documents from

[1] Aged municipal solid waste lying in dumpsites is called legacy waste

[2] Remediation means the process of cleaning up contaminated areas by removing or treating the waste material

anchor institutions and programs, including SBM, Central Pollution Control Board (CPCB) and Central Public Health and Environmental Engineering Organisation (CPHEEO); local factors necessitate tailored planning and implementation by the ULBs. While these guidance documents prescribe what could be done, there is a need to have these institutions recommend some 'must-haves' for any biomining project. This would be important so that the projects don't themselves become sources of pollution.

Most cities have delegated their biomining activities to private contractors, while some have adopted models where they lead the biomining execution efforts. Several factors such as division of scope between ULB and contractor, linkage to co-processing unit, age of waste, quality of aggregates, capacity of stakeholders, budget availability beyond SBM, monitoring efficiency, and traceability of aggregates, are understood to have influence upon the project dynamics, economics, and ease of implementation.

It is crucial to recognize the multifaceted requirements for successful biomining project execution and plan accordingly before initiating any such project. This study, as detailed in chapter four, highlights the importance of multidimensional planning in biomining projects and emphasizes the importance of taking an integrated approach to effective biomining implementation and its monitoring. The study recommends that ULBs could conduct detailed studies and site-specific assessments prior to budgeting the project or hiring contractors for biomining. The findings from these assessments could be adequately considered as the basis for preparing bid documents and allocating the contractual obligations for the contractor. Comprehensive prefeasibility assessment and understanding market linkages before initiating the tendering for biomining projects are key success factors for such projects. Also, the prior experience and expertise of biomining contractors in undertaking compressive biomining projects is an important criterion affecting the efficiency of the biomining project implementation.

The study identifies that sufficient budgetary provisions are necessary to implement aspects like a comprehensive prefeasibility study, realizing the market linkages and conducting rigorous monitoring, failing which the success of the project may get compromised. Towards this goal, SBM budget could be utilized in convergence with other funds like Finance Commission (FC) Grants, Corporate Social Responsibility (CSR) funds and multilateral financing.

Capacity building of key stakeholders is important for effective planning, execution, and monitoring of biomining projects in the country. This could include stakeholders such as: i) ULBs on understanding of processes - planning, budgeting, executing, monitoring, and disposal of aggregates; ii) Contractors as there are only a limited number of experienced biomining contractors in India capable of undertaking scientific biomining; and iii) Academia who must be encouraged and trained on aspects of project monitoring, to support ULBs in effective implementation of biomining projects. It is important that an ecosystem is developed for cross learning and knowledge transfer among these stakeholders.

Monitoring of biomining projects and traceability of aggregates is important to ensure scientific management of legacy dumpsite biomining. Towards this, there would be need for a centralized mechanism for RDF traceability and usage of technology and concepts like Enterprise Resource Planning (ERP), Global Positioning System (GPS) and Extended Producer Responsibility (EPR). Additionally, the mandatory introduction of Consent to Establish (CTE) as a regulatory instrument to monitor biomining projects could be explored.

With a focus on disposal of aggregates, Refuse-Derived Fuel (RDF) and Biosoil in particular, it was found that transportation to distant co-processing units is a key cost component for biomining projects, which needs to be suitably addressed. Further, inferior quality of RDF discourages market linkage, hence increasing processing cost. Identifying these issues, the study emphasizes the need for innovation in value addition through aggregates and their scientific management. Finally, the study highlights the importance of effective dumpsite closure and encourages planning of productive usage of remediated dumpsites. Designing biomining projects with a clear vision for the closure and usage of the remediated land parcel would encourage quality implementation of the biomining process, while facilitating recovery of valuable land.

In conclusion, this report provides an overview of the current state of biomining in India and offers insights and recommendations for policymakers, practitioners, and other stakeholders involved in biomining and management of legacy waste dumpsites in the country.



01 INTRODUCTION

1.1. Status of legacy waste dumpsites in India

Biomining refers to the "scientific process of excavation, treatment, segregation and gainful utilization of aged municipal solid waste lying in dumpsites, typically referred to as legacy waste." Various sources estimate the number of legacy waste dumpsites in India to be around 3,000-4,000. According to the Swachh Bharat Mission (SBM) program, the country has 2,429 reported dumpsites (each with a minimum of over 1,000 tonnes of legacy waste), of which only about 660 (25%) have been remediated to date. These dumpsites reportedly cover an area of over 14,000 acres and contain at least 235 million MT of legacy waste. Many socio-economic studies consider a 5 km radius as the impact periphery of any given project, implying that these 2,429 sites correspond to a periphery of over 1,80,000 sq.km. across the country, i.e., nearly 5% of India's total area. While the environmental impacts of dumpsites vary based on their size and geographical location, these legacy dumpsites have continued to pollute for decades. In the recent years, biomining is being effectively used for management and reclamation of these legacy waste dumpsites in the country. Table 1 highlights the status of legacy waste dumpsites and biomining in India.

Table 1: Status of legacy waste dumpsites and biomining in India

National Status	Average size of dumpsites	52 Million plus cities	Status of remediation
• 2,429 Dumpsites • More than 14,000 acres under dumpsites • 235 Mn MT of legacy waste	• 0.11 Mn MT of legacy waste, • 15.6 acres, • 7,000 MT per acre	• 3% of dumpsites with 58% of waste, • 77 dumpsites, • Avg. 1.9 Mn MT of waste per site, • Avg site area is 46 acre	• 660 dumpsites remediated • ~48% of the legacy waste remediated • 40% of area has been reclaimed

Source: *Swachh Bharat Mission Urban MIS, as extracted on January 15, 2025*

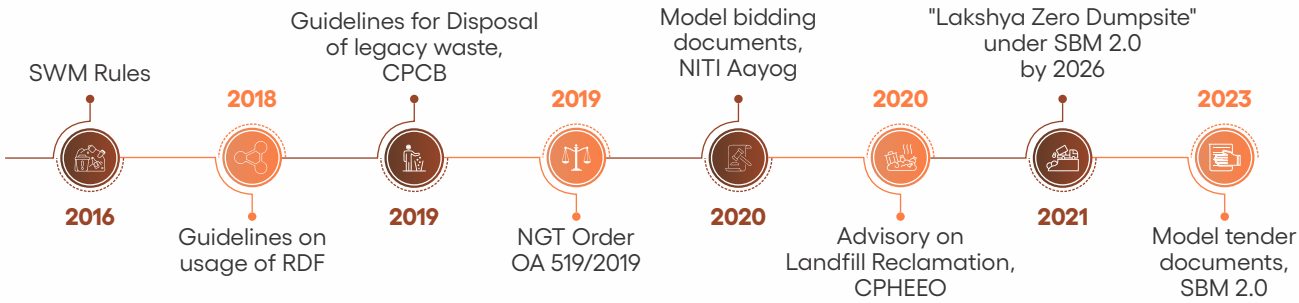
Note: *Million-plus cities is a nomenclature used by the Government of India for cities with a population of a million (1 million = 10 lakh).*

1.2. Evolution of the policy ecosystem

The biomining ecosystem in India has evolved over the past decade through a series of policy interventions and guidance documents published by the central government entities. The Government of India notified the Solid Waste Management Rules, 2016 directing ULBs to undertake biomining, bioremediation or capping of dumpsites within a five-year period. In July 2019, the National Green Tribunal (NGT) identified that the SWM Rules 2016 relating to dumpsite management was not being adhered to, and it provided stringent orders on management of legacy waste dumpsites in India, with focus on biomining and bioremediation. The NGT directed that capping of legacy waste would lead to huge environmental and health

consequences, and hence suggested biomining and bioremediation as the environmentally safe and the most preferable approaches to dumpsite remediation. Figure 1 depicts the evolution of policy ecosystem on biomining of legacy waste dumpsites in India.

Figure 1: Evolution of policy ecosystem on biomining of legacy waste dumpsites in India



The NGT's order has facilitated the policy ecosystem for biomining of dumpsites in India. While 'Guidelines for Disposal of legacy waste' were published by the CPCB in 2019, the NITI Aayog introduced 'model bidding documents for legacy waste remediation projects' in 2020. 'An advisory on landfill reclamation' was published by CPHEEO in 2020 with technical guidance. The "Lakshya Zero Dumpsite" under SBM 2.0 was declared in 2021, which targets remediation of all legacy dumpsites by 2026. A guideline on 'Usage of Refuse Derived Fuel in Various Industries' was introduced by the Ministry of Housing and Urban Affairs (MoHUA) in 2018. Further, Extended Producer Responsibility (EPR) has been introduced in the amendments to the Plastic Waste Management (PWM) Rules 2016, but there are no formal regulations facilitating EPR with respect to biomining aggregates. While such policy instruments and initiatives have been taken by the Government, as per the SBM Management Information Systems (MIS), more than 2,000 sites still remain to be remediated and reclaimed during the next two years. This study was designed and taken up to understand the challenges and enablers to realise this target of a legacy waste dumpsite free India by 2026.

Landmark NGT Order on legacy waste dumpsites remediation 'order-519/2019'

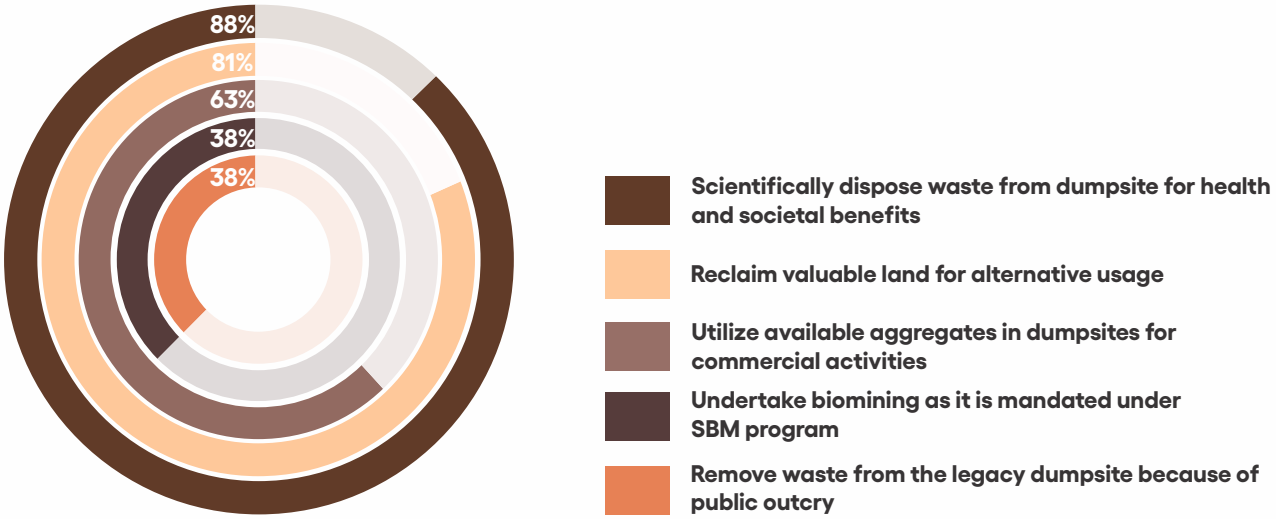
- The NGT while deciding on legacy waste dumps in Delhi directed the State Government to allocate INR 250 Cr for bioremediation and biomining project for Okhla, Ghazipur and Bhalswa dumpsites
- The Court recognized that its earlier directions for compliance to SWM Rules 2016 had largely not been implemented by ULBs across India.
- Mandated remediation work in legacy waste dumpsites across India, with a statutory timeline for completion
- Introduced liability on ULBs that had not commenced remediation of legacy waste sites

1.3. Background to this study

This study on biomining and bioremediation of legacy waste dumpsites in India was conducted through extensive secondary research supported by inputs from primary consultations. With limited published information on the subject available in India, inputs were collated from stakeholders representing ULBs, contractors, academia and government departments. In order to ensure insights from stakeholders consultations, a webinar and a survey were also conducted to discuss and solicit inputs on possible policy instruments to strengthen the legacy dumpsite

biomining ecosystem. Learnings from the survey outcomes have been included suitably to support the perspective presented in the report. For example, Figure 2 provides the key reasons for undertaking biomining, as mentioned by stakeholders during this survey, and it is hence understood that the purpose of undertaking biomining, apart from the compliance perspective is the array of benefits that the process opens up leading to public welfare. Figure 3 depicts the methodology followed for this study. It details the parameters of the study, along with the areas of focus and analysis, and the policy inputs developed.

Figure 2: Reasons to undertake biomining as per survey respondents



Response to a survey question on reasons to undertake biomining (multiple choice)



Figure 3: Methodology for this study

1. Secondary Research

Literature review on current legacy waste management practices, best practices, analysis and synthesis of available secondary data, referred to 20+ sites on different aspects

Parameters of study

- Models of operations
- Selection of contractors
- Baseline
- Contract scope
- Processes involved
- Supply chain of aggregates
- Project economics
- Impact & benefit assessment
- Monitoring and KPIs,
- Project and EHS Risks

2. Primary Research

Areas of focus

- Four sites explored for available information (project sizes of 1 lakh MT to 125 lakh MT, and 4 acres to 225 acres)
- Project background, budget, timelines
- Operational models, stakeholders involved
- Planning, process flow
- Monitoring mechanisms, EHS aspects
- Market linkages, Recovery of land
- Best practices, challenges and learning

Array of stakeholders consulted (30+ interactions)	
Urban Local Bodies	Govt. Departments
Pollution Control Boards	Think Thanks
O&M Contractors	Academics
Project Consultants	Industry experts

Key learnings and recommendations

3. Analysis & Evaluation

Checklist for biomining
Minimum considerations and aspects for biomining projects including prefeasibility, contractor scope identification, budgetary planning, monitoring and market linkage

Aggregates disposal and monitoring
Disposal of aggregates and monitoring mechanisms at site and offsite

Project economics
What is the importance of facilitating convergence?

Impacts, Benefits, EHS
What are the aspects to consider for such biomining projects?

Capacity building
Role of capacity building of key stakeholders in facilitating a conducive ecosystem

4. Consultations & Policy Inputs

Key policy inputs

- Capacity building of stakeholders
- Biomining process checklist
- Convergence for financing
- Centralized monitoring, traceability and EPR,
- CTE as a requirement
- Effective closure & land use of remediated projects

A webinar for inputs, attended by 40+ stakeholders

A workshop to disseminate findings

02 ECOSYSTEM OF LEGACY WASTE DUMPSITES IN INDIA

2.1. Each legacy waste dumpsite is unique and needs localized approaches

While there are several guidelines and frameworks to develop and manage legacy waste dumpsites in India, this study highlighted that each dumpsite is different with its own local advantages and challenges. It is important to acknowledge this difference and build capacity for localized planning and implementation of biomining projects. For example, Table 2 lists four randomly selected legacy waste dumpsites from various parts of the country, which highlight these differences.

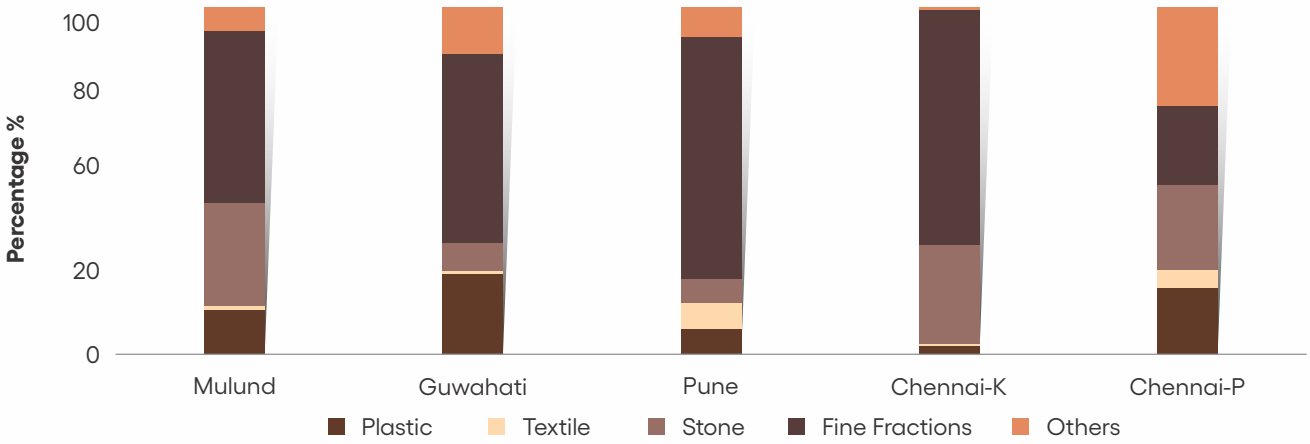
Table 2: Variation in dumpsite characteristics

Legacy waste dumpsite	Legacy Waste in Mn MT	Area in acres	million MT of legacy waste per acre
Bombgarh, Leh	0.1	28	0.004
Sector 54 Noida	0.1	4	0.025
Deonar, Mumbai	12	326	0.037
Pirana, Ahmedabad	12.5	84	0.149

Similarly, Figure 4 shows how waste composition varies across different sites, with different age of legacy waste and characteristics of the respective ULB. Within the same city, Chennai, the waste composition of Kodungaiyur and Perungudi dumpsites differed.

Figure 4: Difference in age and composition of waste

	(Mulund, Mumbai)	(Boragaon, Guwahati)	(Urali Devachi, Pune)	(Kodungaiyur, Chennai)	(Perungudi, Chennai)
Age	~ 10 years	~ 15 years	~ 40 years	~ 10 years	~ 40 years



The approach for biomining in each site would need to be customized, taking into account the size of dumpsite, quantity of waste, age of dumpsite, geographical location, quality and characteristics of waste, composition of different aggregates, availability of local contractors to undertake biomining activity, availability of local coprocessors to utilize the RDF, and scope of usage of the biosoil or fine fractions.

2.2. Biomining offers several advantages and opportunities

Biomining of legacy waste dumpsites has several advantages and provides several opportunities for further improvement of urban waste management ecosystem. Biomining of a dumpsite leads to reduction in pollution and emission from dumpsites, along with alleviating the affected biodiversity in the region. The most important advantage of biomining process is that it results in sites free from any waste dump, which were sources of pollution in term of leachate and gaseous emissions. Leachate migration[3] has been found to contaminate surface water and groundwater. While fugitive gas emission[4] from the landfill surface to atmosphere is a contributor to global warming and can give rise to odour issues and dense gases can accumulate in low ground giving rise to risk to human, flora, and fauna health. Hence, biomining is encouraged over bio-capping[5] of legacy dumpsites.

Reclaiming the land remains a key objective of dumpsite bioremediation, and in several places, it was observed that the rate of property in the periphery of legacy waste dumpsites is up to 50% lower than similar property in areas further away[6]. An example can be cited for the Pirana dumpsite biomining project in Ahmedabad, where the city estimates real estate potential of worth INR 2,200 crore recoverable through biomining[7].

Figure 5: Advantages and advances in biomining of legacy waste dumpsites in India

Reclamation of valuable land

- **14,000+** acres of land for reclamation
- In many cases, property rates in periphery of active dumpsites are seen to be lower by **upto 50%**
- E.x, Pirana dumpsite in Ahmedabad is estimated to reclaim land worth INR **2,200 Cr.** In value

Socio-environmental impact

- Reduction in air pollution, GHG emissions, soil contamination, ground water contamination, dust emission, foul odour elimination
- Landscape aesthetics: For ex, cost to aesthetic damage was estimated to be INR 49 Crore due to Bandhwari dumpsite, Gurugram
- Biodiversity loss of between 30-300 species per 100 acres due to the dumpsite exposure that affects surrounding wildlife as per US EPA

[3] Leachate migration refers to percolation of contaminated water (leachate) into the soil and onto sources of water, carrying pollutants such as heavy metals, organic chemicals and pathogens.

[4] Fugitive gas emission refers to leaks and irregular releases of gases or vapors from a pressurized containment, like a legacy dumpsite in this case

[5] Bio-capping refers to a scientific process of covering a dumpsite with barrier layers consisting of high density polyethylene (HDPE) liner, clay liner and a vegetative cover to minimize the percolation of rainwater into the legacy waste underneath

[6] Source: Research Team's analysis based on discussions and secondary research

[7] Source: Waste segregated at Pirana dumpsite to be used in highway, as accessed from The Indian Express

Potential for Circular Economy

- **Co-processing of RDF** recovered as a substitute fuel
- **Biosoil** for agriculture and civil works
- At the national level, potential for recovery RDF **(432 Lakh MT) and Biosoil (1,168 Lakh MT)**
- E.x. Uttar Pradesh deployed the EPR framework for nonrecyclable plastic waste
- E.x. Greater Chennai Corporation is identifying biomining projects, for global Carbon Credit market
- Ex. Anna University has developed solutions to increase usability of biosoil in agriculture

Scientific Process: Benefit over Bio-capping

- Land reclamation yielding economic value from project
- Requirement of several years of **post-closure maintenance** and monitoring with bio-capping
- Risks such as **fire accidents** due to gas leak in bio-capping

Note: *Research Team's analysis on reclaimable land, potential for RDF and Biosoil, other sources include secondary literature and primary consultations*

Along with these positive socio-environmental impacts, biomining as a process could facilitate the benefits of a circular economy through coprocessing of RDF as a fuel substitute, Construction and Demolition (C&D) waste reusage for construction material and biosoil[8] for agriculture or civil works. The utilization of segregated and processed aggregated would depend on the quality of aggregate and efficiency of the undertaken biomining project. The reclaimed land, if put to innovative alternative usages, could facilitate economic growth in the locality. Figure 5 lists such advantages and opportunities in biomining of legacy waste dumpsites in India.

2.3. Challenges to scientific biomining

Biomining is an emerging technology for scientific legacy waste dumpsite management in India. Though the process itself is simple, the challenges lie in the effective implementation of the process as prescribed and efficient collaborations between all the concerned stakeholders. Some of the key challenges in legacy waste dumpsite biomining and bioremediation, as identified through this study, are detailed below.

Need for updated guidance documents – Biomining is a developing area, with several biomining projects having been taken up during the past two years. There is a need for updated guidance documents and standard operating procedures for the ULBs and contractors. The key guidance documents currently available were drafted 4-5 years back by CPCB and CPHEEO, and may need updating based on feedback and experiences of the ULBs.
Utilization of RDF – Linkage with coprocessors has been identified as a key challenge, where in, the ULB and contractors are finding it difficult to establish market linkage with cement plants or waste to energy plants for coprocessing the RDF. In many cases, the ULB and contractors are paying the coprocessors to dispose the RDF. The ULB and contractors are also having to spend a substantial portion of their budget in transportation of RDF to coprocessing sites. This has led to RDF lying unutilized in the dumpsites across India leading to fire and contamination hazards. Further, exposure to soil and moisture renders RDF unusable for coprocessors.
Quality of RDF and biosoil – The low quality of RDF in terms of moisture and energy content has been seen as a major deterrent for usage of RDF by coprocessors. Similarly, several stakeholders identified that biosoil may not be suitable for usage as a compost for growing of food materials. Such usage of biosoil needs close monitoring for toxicity or contamination.

[8] Biosoil refers to the organic material rich aggregate separated through the biomining process

Technical capacity of stakeholders – The study identifies that there is need for technical capacity with the ULBs to effectively plan and implement biomining projects. Similarly, there seems to be inadequate capacity of local contractors to take up scientific biomining. Further, there are only a few local academia with capacity to take up project monitoring roles.

Inadequate data and protocols for planning, execution and monitoring – While undertaking the study, it was observed that data inadequacy (e.g. quality of waste, available market linkages, ground level for the site, etc.) remains a challenge. Because of this, ULBs may not be able to calculate an accurate project cost, identify potential impact and benefits, undertake waste quantification, identify and use appropriate equipment (beyond trommels), undertake sampling during processing, plan post-reclamation utilization, or establish protocols for EHS and risk management. In the absence of regulatory requirements like CTE, most ULBs are not taking up exhaustive monitoring. All these activities require dedicated guidelines, capacity building and handholding support, particularly to the non-million-plus ULBs.

Financing – Many stakeholders highlighted that available funds are inadequate for scientific biomining. For example, sufficient funds may not be available for a detailed pre-feasibility study or for scientific disposal of aggregates. Therefore, ULBs are prioritizing the processing and cleaning of dumpsite areas and may miss some of the steps necessary for a holistic biomining process. This may particularly be the case in the ULBs with population of less than one million.

Revenue generation from biomining operations – While several stakeholders advocate for biomining as a revenue generating activity, during this study there were only a few cases where biomining activity was generating some amount of revenue from its operations (primarily through sale of RDF).

Externalities – There are many localized externalities which are seen to pose challenges in taking up biomining projects. For example, for a site located in high rainfall area, like in the Western Ghats, it requires additional infrastructure and time to take up an effective biomining project. Such externalities have in some cases led to delays in project timelines by 2-3 years. Similarly, for sites located in areas which are not in the vicinity of a cement coprocessing unit or a waste-to-energy plant, a large component of the project budget is needed to be allocated for transportation of aggregates. Further, dumping of fresh waste in legacy dumpsites, due to absence of alternative dumping infrastructure for fresh waste, is seen as a challenge in most cases.

Unscientific disposal and pollution – In case the biomining activity is not done scientifically and waste processing is not effectively achieved, it may lead to disposal of the aggregates in areas outside the dumpsite which in turn may lead to creation of multiple sources of soil and water contamination.

Stakeholders were asked during a survey on what they thought were some of the key challenges for biomining in India. The results are presented in **Figure 6**.



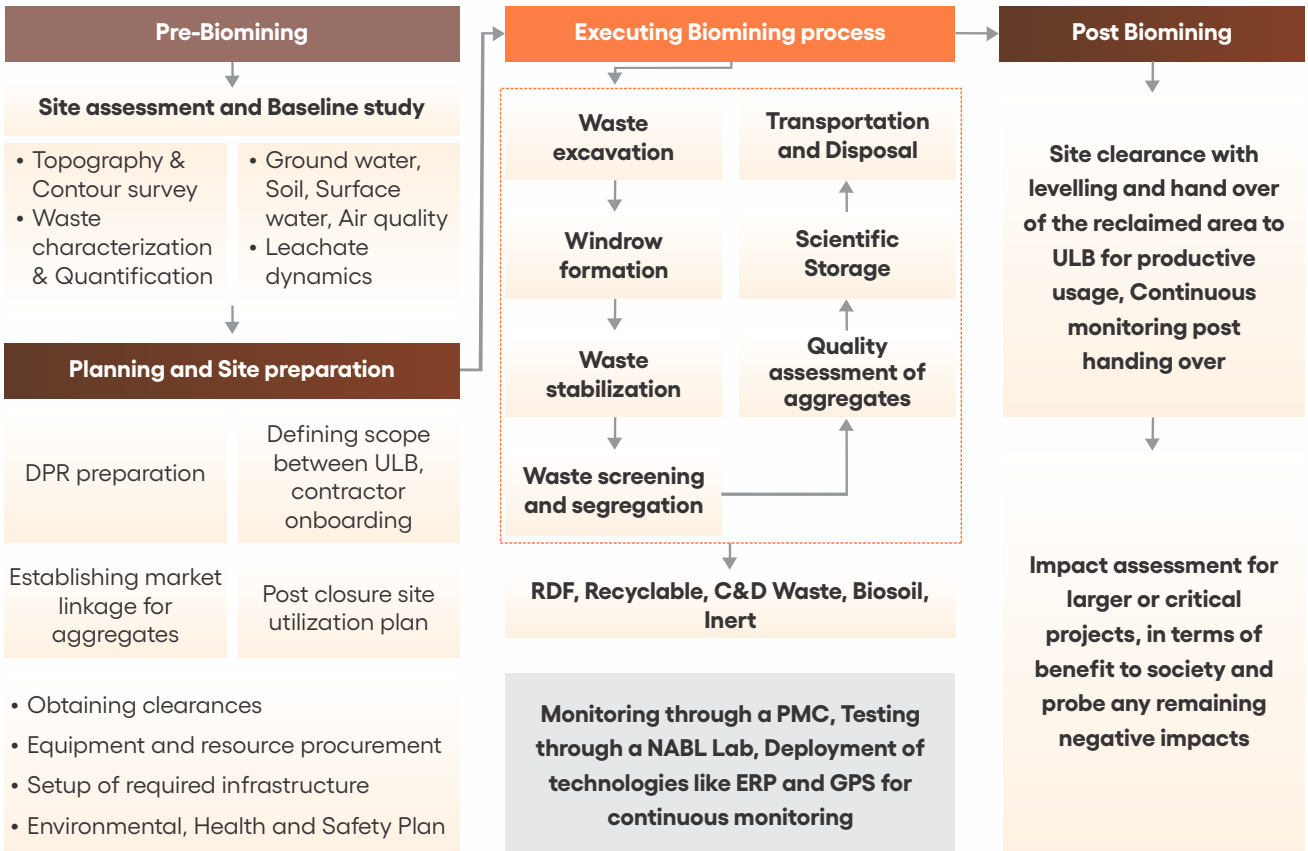
As part of the survey, respondents were asked the key challenges for biomining in India.
In this multiple- choice question, they were allowed to choose more than one challenge as well.

03 BIOMINING PROJECT LIFECYCLE

3.1. Key aspects of a successful biomining project

Secondary research and consultations indicate that biomining as a technical concept is a straightforward and uncomplicated process, provided the steps in the project lifecycle are appropriately followed. It was observed that in several cases, many of the steps were ignored, focussing only on the excavation and screening using limited equipment like trommels and blowers. Based on the understanding gained from the study, key steps that should be followed for scientific biomining were identified and are presented in Figure 7. From primary consultations, it is observed that some of these key steps indicated below got skipped, or may not have been scientifically undertaken while implementing biomining projects. The same was also corroborated through the survey of key stakeholders done during the study using a multiple-choice questionnaire on the steps in biomining that they considered as critical; and 81% of those who responded identified i) Having a Detailed Project Reports (DPR); and ii) Safe storage and disposal of RDF as critical steps. Several stakeholders highlighted the need for effective planning, and aspects related to management of environment health and safety (EHS) during the commence of the projects.

Figure 7: Highlights of some of the key steps that should be followed for scientific biomining



A checklist of key steps across four phases for effective biomining and bioremediation of a legacy waste dumpsite is provided in Table 3. Further, some of the key aspects of the biomining lifecycle are identified as key enablers and elaborated in Chapter 5 - Way forward.

Table 3: Checklist of key steps in a legacy waste dumpsite biomining and bioremediation project lifecycle

S. N.	Key steps as per phase of project development
Phase 1	**Pre-Biomining**
1	Preliminary site assessment including survey of the topography and contour of the site
2	Waste characterization and quantification to aid in further planning the project in terms of project urgency and approach
3	Baseline study to assess existing status of pollution, if any, of ground water, surface water, soil quality, air quality, leachate dynamics, ecological baseline (if necessary), socio-economic assessment (e.g. informal sector dependent on the site), etc.
4	Assessing the technical, financial, and regulatory feasibility of the project
Phase 2	**Planning and Site preparation**
1	Preparing a detailed project report considering the assessments in the preliminary stage, including detailed environmental assessment like air, water, soil germination; landfill gas testing, site analysis (through drilling the waste, drone analysis, etc), detailed waste characterization, regulatory analysis, budget analysis, etc.
2	Identification of sources for financing the project
3	Quantifying each aggregate and their quality, like the RDF, biosoil, C&D waste, etc. Establishing market linkage for these aggregates.
4	Clearly defining the scope between ULB and contractor
5	Onboarding of contractor through competitive Quality and Cost-based Selection (QCBS) processes
6	Obtaining statutory clearances and authorizations
7	Identifying alternative sites for waste disposal, if necessary
8	Drafting a detailed project implementation schedule and timeline
9	Preparing a post-closure site utilization plan, so that there is clarity on productive usage of the site post reclamation
10	Procurement of necessary equipment and resources
11	Setting up of required infrastructure including the power, energy, electricity, transportation, and connectivity etc., as required
12	Drafting a robust Environmental, Health and Safety Plan, and provisioning of protective equipment
Phase 3	**Biomining execution**
1	Execute excavation and stabilisation of waste in windrows. This will vary based on age of waste, organic contents and microorganism solution used
2	Waste screening and segregation through scientific process and use of machinery

3	Recovery of materials, appropriate handling and storage
4	Monitoring and record keeping of recovered materials
5	Quality assessment of recovered materials through laboratory testing, and record keeping of test results of recovered materials
6	Transportation of recovered materials for utilization or for disposal, as per project plan, and record keeping of material utilization or disposal
Phase 4	**Post-Biomining**
1	Site clearance with levelling and hand over of the reclaimed area to ULB for productive usage
2	Impact assessment for larger or critical projects, in terms of benefit to society and probe any remaining negative impacts through post-remediation monitoring plan

In order to ensure the steps of biomining are undertaken scientifically, a Project Management Consultant (PMC); an organization or an academic institution of repute, may be engaged by the ULB to facilitate and monitor the biomining process.

It is also seen that effective planning and execution of the above steps become cumbersome for smaller ULBs to follow. In such cases, the state government may create clusters of dumpsite remediation projects and plan the procurement of contractors for biomining of all these sites as a clustered project. Further, the budgetary allocation, monitoring provisions and disposal of aggregates for the clusters may be planned accordingly in convergence and collaboration of concerned ULBs. It is advisable to first identify all dumpsites where biomining is required. Then governments should prepare a comprehensive action plan at the state level. It is critical to select the appropriate contractor by a tendering process based on their technical and financial competence in the domain of legacy waste treatment and disposal. The cluster-based approach could be a good option to encourage successful players in this field, while it remains critical to ensure that the projects are monitored at the state level through a competent authority. For e.g., the Directorate of Urban Local Bodies, Jammu and Kashmir planned a cluster-based approach, wherein six dumpsites (with a cumulative quantity of nearly 80,000 tonne of waste) were identified by the state for remediation of legacy waste, and the tender was accordingly prepared for the selection of an agency to execute the work. In a similar manner, clustering the monitoring requirements, the Government of Tamil Nadu has appointed Anna University as Project Monitoring Unit (PMU) for all biomining activities in the state.

The subsequent chapter discusses key areas from within this biomining process lifecycle, which have been identified as important enablers that could be facilitated through conducive policy ecosystem.




RECOMMENDATION

04 RECOMMENDATIONS: KEY ENABLERS FOR EFFECTIVE BIOMINING

4.1. Identified areas of recommendations for conducive policy instruments

Based on the study, six key areas of recommendations were identified where conducive policy instruments could be explored to facilitate an effective biomining ecosystem.

1. It has been found that project planning, including engaging of the right contractor with proper division of scope on biomining is important for effective implementation. The project should be planned effectively through detailed prefeasibility assessment, while market linkages for RDF and biosoil should be arranged prior to starting the project.
2. Capacity building of contractors, ULBs and academia, is important in building a collaborative ecosystem for undertaking comprehensive biomining projects in India which ensure clearing dumpsites, along with safe management and disposal of by-products generated.
3. Monitoring and traceability has been emphasized as a key enabler to ensure that the objectives of biomining are scientifically met.
4. Several factors like distance from coprocessing units or disposal sites affect utilization of aggregates, necessitating policy facilitation for alternative methods of disposal of the aggregates (like biosoil as construction material or as a soil enricher).
5. It is important for the union government and state governments to work with stakeholders including multilaterals and private sector to converge on finance, to ensure that adequate financing is available for biomining projects.
6. Scientific dumpsite closures and productive usage of reclaimed land need regulatory clarity. The Figure 8 lists these six key areas for conducive policy instruments.

Figure 8: Six key areas of recommendations for conducive policy instruments

Factors and their magnitude may be unique or different for each biomining project

Project planning & engaging Contactors

- Prefeasibility & market linkage before initiating tendering for biomining project
- **Previous experience & knowledge on scientific implementation** by contractors
- Role of continuous **project monitoring**

Capacity of key stakeholders

- ULBS - **Understanding** of processes: planning, budgeting, executing, monitoring, disposal
- **Capacity** of contractors to undertake scientific biomining
- **Effective project monitoring** preferably by academia
- **Cross learning, knowledge transfer and sector mentors**

Monitoring & Traceability

- Need for **centralized mechanism for RDF traceability**
- Use of **technology & concepts** of ERP, GPS, etc. to improve monitoring & traceability
- **CTE requirements for project**

Convergence of finances

- SBM Budget **in convergence with other funds like FC, CSR, DMF**
- **Sufficient funds for tasks like monitoring, transport, prefeasibility, quality testing needed**-else overall biomining process may be compromised

Aggregate - RDF, Bio-soil disposal

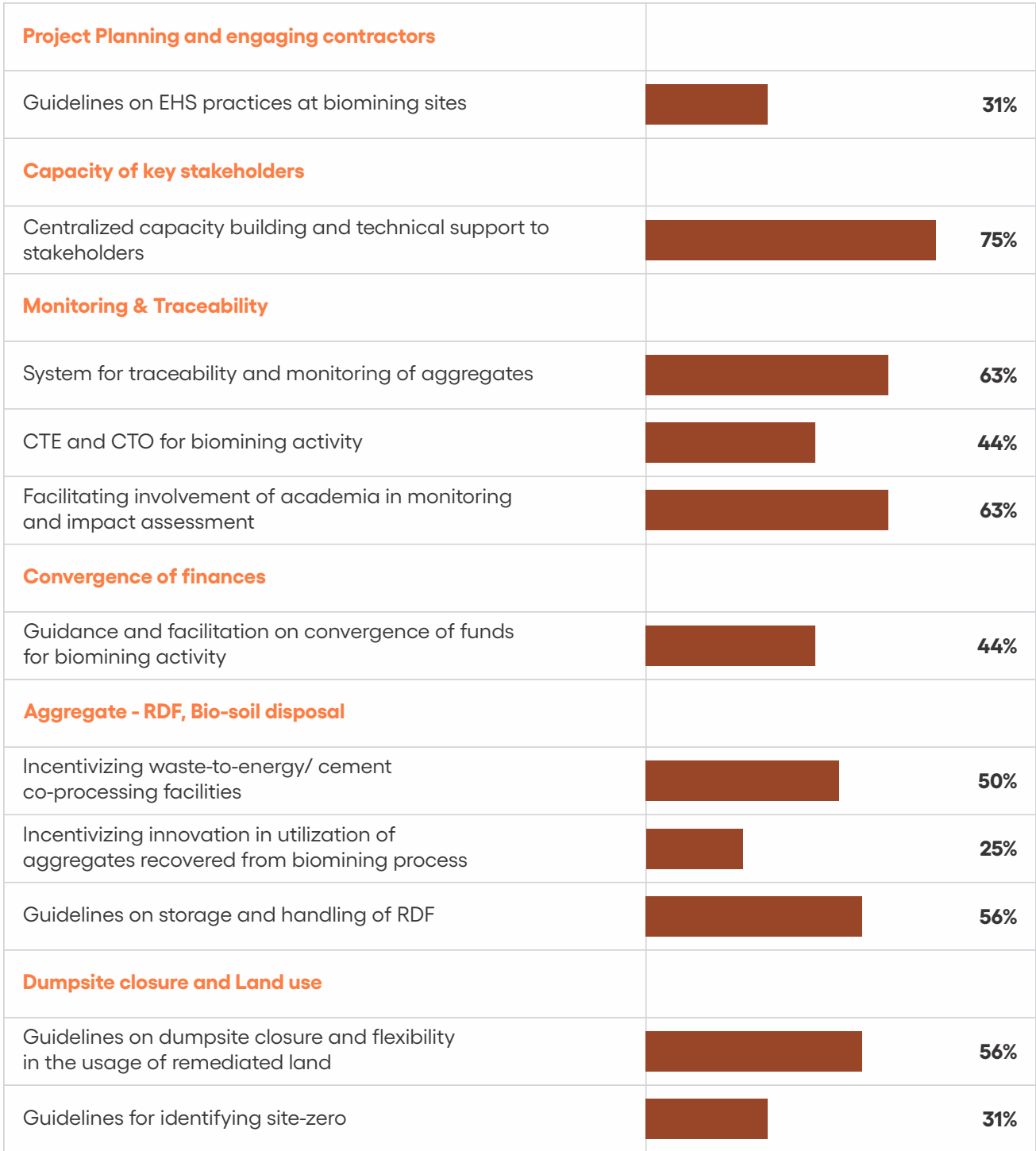
- **Distance** from Co-processing unit is a key cost component
- Poor **quality** of RDF discourages market linkage, increases **processing cost**
- **Use of concepts like EPR and carbon credit**
- Need for **innovation**

Dumpsite closure and Land use

- **No clear guideline** of site zero and closure
- **Contamination prevails** post removal of surface waste

As part of the survey undertaken during the study, stakeholders were asked to identify key areas of policy interventions for biomining of dumpsites. The findings from the survey are provided in the Figure 9.

Figure 9: Key areas of policy interventions for biomining of dumpsites as per survey respondents



In this multiple-choice question, the top choices for key policy areas for biomining were mapped based on the number of respondents choosing that particular option.

4.2. It is important to encourage holistic project planning, focusing on critical factors like engaging of competent contractors

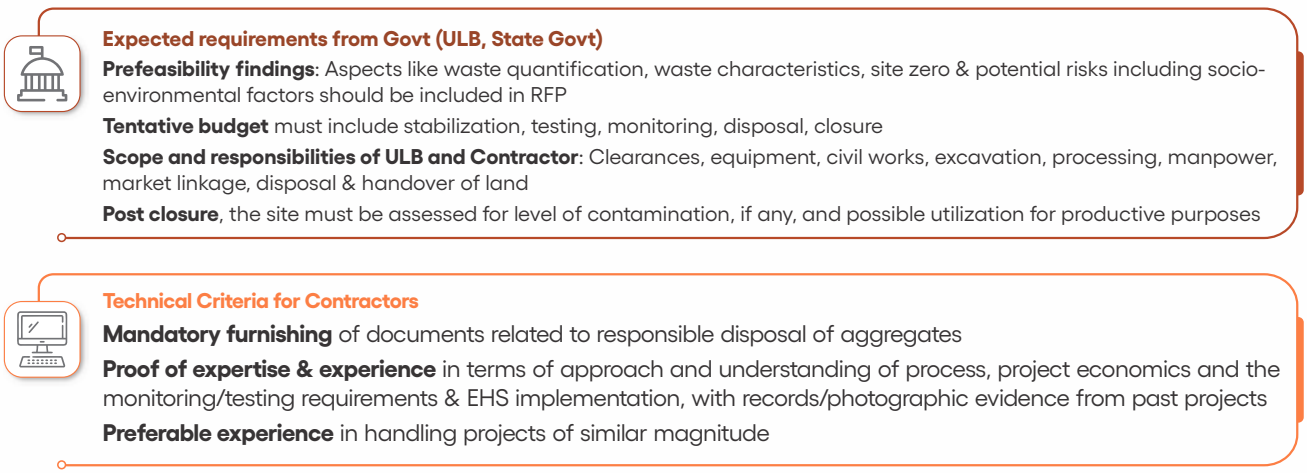
A. Holistic project planning

It is important that the legacy dumpsite biomining projects are planned in such a way that the target is set at recovering the land for more usable purposes, instead of only cleaning-off the land. Further, the recovery should not end up creating multiple sources of contamination by dumping unprocessed recovered waste at multiple locations. Hence, project planning is important, particularly undertaking of a detailed pre-feasibility assessment ensuring that the portion of dumpsite which is taken for recovery is not being used for disposal of any fresh waste, and other similar aspects into account. For example, it has been observed that at times due to improper prefeasibility assessments, there have been errors in the amount of waste quantified, leading to miscalculations in the budget and in the tender requirements. Such mistakes could be avoided through efficient project planning. Further, project planning needs to consider all necessary budget heads and allocate appropriate budget towards aspects such as stabilization, monitoring, and testing. It has been observed that many biomining projects avoid taking these heads into consideration and only focus on the capital expenditure and on the disposal of the processed aggregates. Similarly, it is found that ULBs, who during the planning phase itself have identified the targeted utilization of the reclaimed land, are expected to stay committed to systematically completing the biomining process. Figure 10 lists some of the aspects which need to be considered at the planning stage.

B. Engaging competent contractors

The ULB needs to identify all the necessary steps to be implemented for the biomining process, along with allocation of scope between the ULB and the contractor. Critical responsibilities like obtaining clearances, equipment, civil works, excavation, processing, workforce, RDF processing, market linkage, disposal and handover of land should be clearly defined and detailed in the RFP while onboarding of contractors. The technical criteria for selection of contractor have improved through a set of guidance documents coming from the Government of India in 2023. But there is a need to focus on the technical expertise of the contractors, and quality of work delivered rather than focusing on the least price quoted by the bidders. Appendix A provides few important considerations in planning of biomining projects, which are expected to be taken up by the government. Similarly, Appendix B suggests a scope of work and selection criteria for contractors. It is important that the concession agreements clearly define the scope of the contractor and ensure that the contractual stipulations adhere to the guidelines issued by the various statutory authorities.

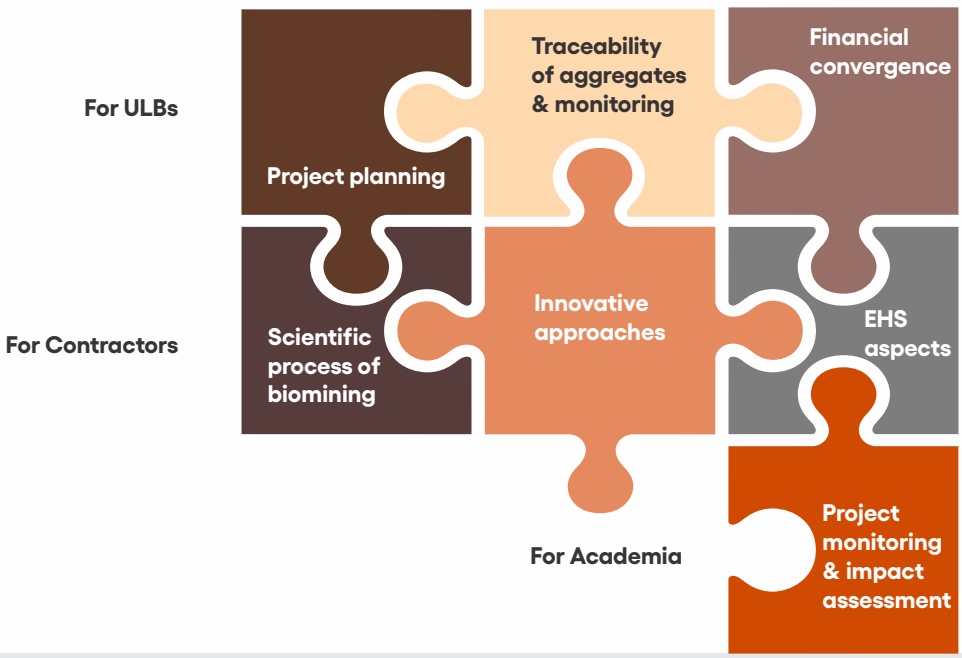
Figure 10: Encouraging proper planning: aspects like defining role of the government and selection of contractor



4.3. Stakeholders stressed the need for capacity building across the biomining ecosystem

The role of capacity building has been identified as a critical factor to create a conducive ecosystem for biomining in India. The key stakeholders, i.e., the Government (ULB/state), the contractors and the academic institutions may need capacity building and handholding support to enable effective planning, execution, and monitoring of biomining projects. While there are guidelines, the study concludes, that comprehensive directives may be necessary on aspects related to appointment of implementation partners, project planning, convergence of funds, and on project management aspects at pre, post, and during the project execution phases, with step-by-step guidebooks for executioners and clear Do's/Don't documents from the Central Ministry. Further, guidance is necessary related to dealing with disposal of RDF, inert and biosoil, and various quality control aspects which may help implementation agencies during their implementation journey.

Currently in India, there does not seem to be any go-to training module for learning these aspects. Though the Government of India has empanelled several knowledge partners, availability of master trainers to train ULBs and contractors remains a challenge. Development of such training modules (with audio visual training kits), and capacity building of master trainers may be focussed upon. During consultations, stakeholders conveyed that there is a need to work with smaller contractors and smaller ULBs as they may not be able to get a grip on the situation on their own. To mitigate the risk from the absence of technical workforce and understanding, projects in smaller ULBs may be clustered and support may be provided by knowledge partners collectively for effective biomining projects in the cluster, which could bring in the scale required for such knowledge partners. Similarly, small contractors may be encouraged to form consortiums to enhance their capacity. Figure 11 suggests the key areas for focus on capacity building as per responses received from a survey during this study.



In this multiple-choice question, more than half of the respondents felt that project planning for ULBS, scientific process of biomining for contractors and project monitoring & impact assessment for academic institutions are key areas that need prioritization for capacity building

The Figure 12: Suggested areas of capacity building of different stakeholders. The ULBs, in particular, need to build capacity on planning, implementation and monitoring of biomining work, ensuring the EHS practices on site, safe closure, and any post closure monitoring of site. Similarly, contractors need to be equipped with the knowledge of stabilization, monitoring methods, testing, worker safety, Environmental, Social and Governance (ESG) and EHS management, and fulfilling transparency requirement. It is necessary that such socio-environmental impacts are identified for scenarios before, during and post operations.

Accordingly, the ULB along with the contractor, should identify adequate impact management plans, as necessary. Academic institutions need to be encouraged and funded through research studies to effectively perform impact assessment, and benefit analysis. It was found that there are very few literature or detailed studies done on impact and benefits of successfully completed biomining project in India. Appendix C provides a framework with key considerations for ESG and EHS safeguard principles, which need to be sensitized, emphasised to the stakeholders, and ensure adoption during project execution. Adhering to these practices may also prove beneficial for bankability of such projects and attract multilateral or private sector financing for the project.

Further, Appendix D provides a brief on the process of undertaking cost benefit and impact analysis for such projects on biomining and bioremediation of legacy waste dumpsites. These are identified as major areas of capacity building, and the union or state government institutions may facilitate such training exercises. Various methods/tools or a combination of several methods/tools may be utilized for capacity building activities, which may include modules created through audio-video clips, classroom courses by centres of excellences, visit of ULBs which have successfully undertaken biomining projects, Training of Trainers (ToT), etc.

Figure 12: Suggested areas of capacity building of different stakeholders

Stakeholder	Areas of capacity building
Urban Local Bodies	**Selection** of qualified **contractors**, division of **scope** **Assessment** of site, waste **quantification**, planning and **budgeting** for projects **Monitoring** of project and **disposal** of aggregates **Execution** in compliance to desirable **EHS practices** Working with SPCB to ensure environmentally **safe closure of site**
Contractors	**Scientific processes** of biomining including stabilization, testing, monitoring **EHS requirements** for workers **Reporting** of progress and use of ERP in progress **monitoring** **Transparency** in **disposal** Closure of site and **handing over** to the ULB
Academic Institutions	Biomining project **monitoring support to ULB and identifying key KPIs** **Measuring & reporting** of KPIs for projects **Impact assessment** and **benefit analysis** from project Understanding of **contractual obligations and monitoring** of the contractors

4.4. Monitoring and traceability are important across the project lifecycle

A. Monitoring through CTE and CTO

Figure 13: Proper monitoring is critical for success of biomining projects



a. A CTE/CTO not mandatory for biomining projects
- **Ensure aggregates do not become source of pollution**
- **Traceability is ensured, single sources avoided in becoming multiple sources of contamination**

b. Identified KPIs to monitor may include
- **Waste processed, Weight of recovered and disposed aggregates, Mode of disposal**
- **Bills, Manpower usage, Vehicles operational**
- **Lab assessments on quality**

One of the important aspects affecting the quality of biomining projects is lack of continuous monitoring and traceability of aggregate. During this study, several stakeholders highlighted that in many dumpsites, RDF is seen lying for months. This is due to limited market linkages or the quality of RDF not meeting the co-processors' quality requirements. When the RDF is left in the open for months post screening, it becomes non-usable due to the mixing of moisture and soil. Further, it is understood that due to budget limitations, continuous environmental monitoring of the project is sometimes not taken up. Also, there is no mandatory Consent to Establish (CTE) requirements for biomining projects, hence the State Pollution Control Boards (SPCB) are usually not monitoring these projects, and they leave it to the ULBs to monitor. It is to note that most ULBs lack proper technical expertise to monitor these projects, while SPCBs are well equipped to monitor and identify issues during the project life cycle. Due to lack of proper monitoring, for example, in several cases materials like biosoil or inert are used for levelling of low-lying areas, without adequate laboratory testing on toxicity. Only if traceability is ensured, such single sources of pollution i.e., the dumpsites, could be prevented from becoming multiple sources of contamination, as in this example. The role of CTE-led monitoring of biomining projects is explained in Appendix E.

B. KPI based monitoring of biomining activities

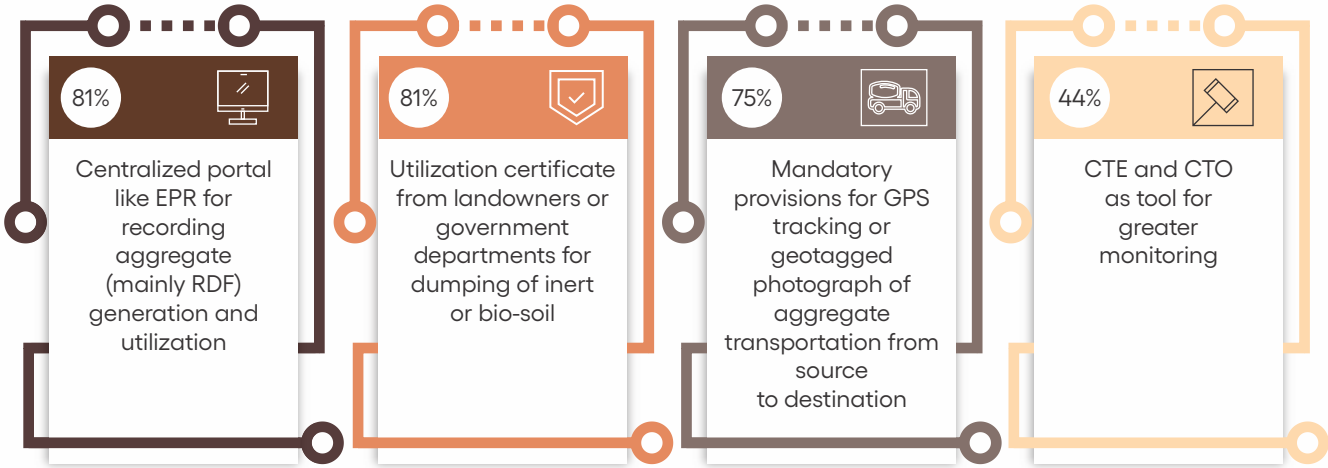
Continuous monitoring may be undertaken through establishing of Enterprise Resource Management (ERP) systems and maintenance of records. Key Performance Indicators (KPI) could be identified for monitoring of the project. A proper mechanism to monitor the progress of the project and its effectiveness could be established covering frequency of monitoring, record keeping, concerned stakeholder responsibilities for monitoring, quality of monitoring, etc. A third-party monitoring agency may be appointed for monitoring of the project as a Project Monitoring Unit. Also, a National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited laboratory may be appointed to monitor the environmental parameters. IT-based tools for compliance management like SAP enterprise resource platform-based solutions may be introduced at pivotal level, like at the level of the State government department. Further, a framework for a government-facilitated centralized portal for certifying and monitoring of aggregates (RDF) is also suggested in Appendix F.

The following are the major phases of monitoring of a biomining project-

- Baseline stage (before to the biomining); which comprises of baselining of environmental parameters to capture 'As-Is' before the commence of bio-mining project;

- Implementation stage; for compliance and assessment during the biomining process to ensure that there are no negative impacts on the environment;
- Post closure stage, for compliance and assessment, the monitoring shall ensure that the closure has been done scientifically with no environmental hazards;

Figure 14: Which mechanisms would be effective in ensuring better traceability and management of aggregates as per survey respondents

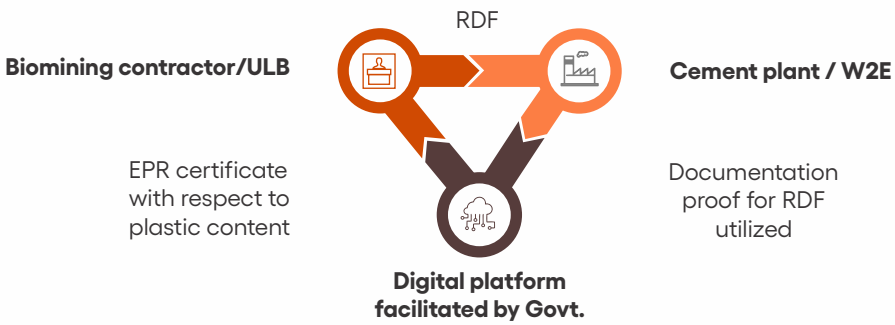


In this multiple-choice question, stakeholders responded on mechanisms that they felt would be effective in ensuring traceability of aggregates, However, one respondent provided an open ended response to this question, raising concern as to how the credibility of the RDF/Bio-soil disposal certificate provided by the contractor can be ensured.

4.5. Scientific management of aggregates, with focus on utilization as part of a circular economy

While traceability of aggregates is important, it is also important that the aggregates like RDF, biosoil, recyclables and C&D waste are utilized in alternative industries, facilitating a circular economy. For example, EPR has been tried to facilitate RDF management in India. But it was found that a substantial portion of the stakeholders are not aware of the possibility or process of utilizing EPR. As part of this study, when asked during a survey, 79% of respondents who are aware of EPR as an option for proper RDF management, stated that it would be an effective mechanism and hence should be facilitated.

Figure 15: EPR as a mechanism for RDF management



In many cases it has been observed that ULBs undertaking biomining are required to add additional machinery to process the RDF and convert into briquettes or oil, for better market acceptance. The Government may incentivize such processing/value-addition of RDF so that ULBs may recover parts of the invest which they make on setting up the facilities. The Government may facilitate Processing-Linked Incentives or waste-to-fuels and RDF plants at strategic locations. The co-processors may be incentivised for processing RDF, which could encourage these units to take-up more RDF as fuel. Similarly, for setting up plants at strategic locations, industries may be incentivised through capital incentives towards the plant and machinery, providing land at subsidized cost, providing tax rebates, etc.

It is observed that biosoil is being dumped at several locations surrounding the legacy dumpsite, with limited monitoring. There has been recent research on application of biosoil as construction material. There is also research about enhancing the nutrient content of biosoil for agricultural application. As biosoil is the majority component of the legacy waste dumpsite, innovation in this regard needs to be facilitated. This may lead to generation of revenue streams for the biomining process.

It is hence recommended that policy instruments may be introduced to facilitate circular economy and enhance scopes for monetization of aggregates from biomining projects. Some examples of policy instruments are;

a. Incentivizing innovation: Quality and value addition in RDF may be encouraged through subsidizing supporting processes and technologies. This may ensure that there is greater acceptability of bio-mined RDF by the coprocessors.

b. EPR for use of RDF: Guidelines on use of EPR mechanism for RDF and recyclate may be introduced, to encourage ULBs to go for EPR certification of the plastic recovered through segregation or biomining. A centralized system or a marketplace may be encouraged, anchored by the CPCB, which may regulate and establish competitive pricing for the aggregates.

c. Popularizing biosoil & aggregates: States may put up directives allowing sell of biosoil for landfilling purpose in government funded infrastructure projects. Similarly, usage of C&D waste may be encouraged in government projects.

d. Capacity building of stakeholders like ULBs and Contractors is necessary in innovative business models on monetizing aggregates from biomining projects.

A discussion on the current regulatory ecosystem on disposal of aggregates is provided in Appendix G.

Case: EPR as a tool for RDF management piloted in Prayagraj, Uttar Pradesh
As one of the first cases in the country, the ULB of Prayagraj tried utilizing EPR as a tool for RDF management. The entire dumpsite was sampled, which is about 1 Mn MT and the constituents were identified. The study was conducted to understand the processing technique for the materials, and come up with appropriate EPR business model to ensure economically positive yield for all the concerned stakeholders i.e., waste management agency, cement industry, brands, etc. Today, it is understood that more than 50,000 tonnes of RDF have been utilized by the cement plants with whom there was an initial understanding as the MoU (as a pilot). Now there are more cement plants who have come forward and are part of the whole process. Municipalities can, tender the remediation process by also asking the brands and cement industries to bid for it, giving scope for revenue generation.

Source: *Primary consultations*

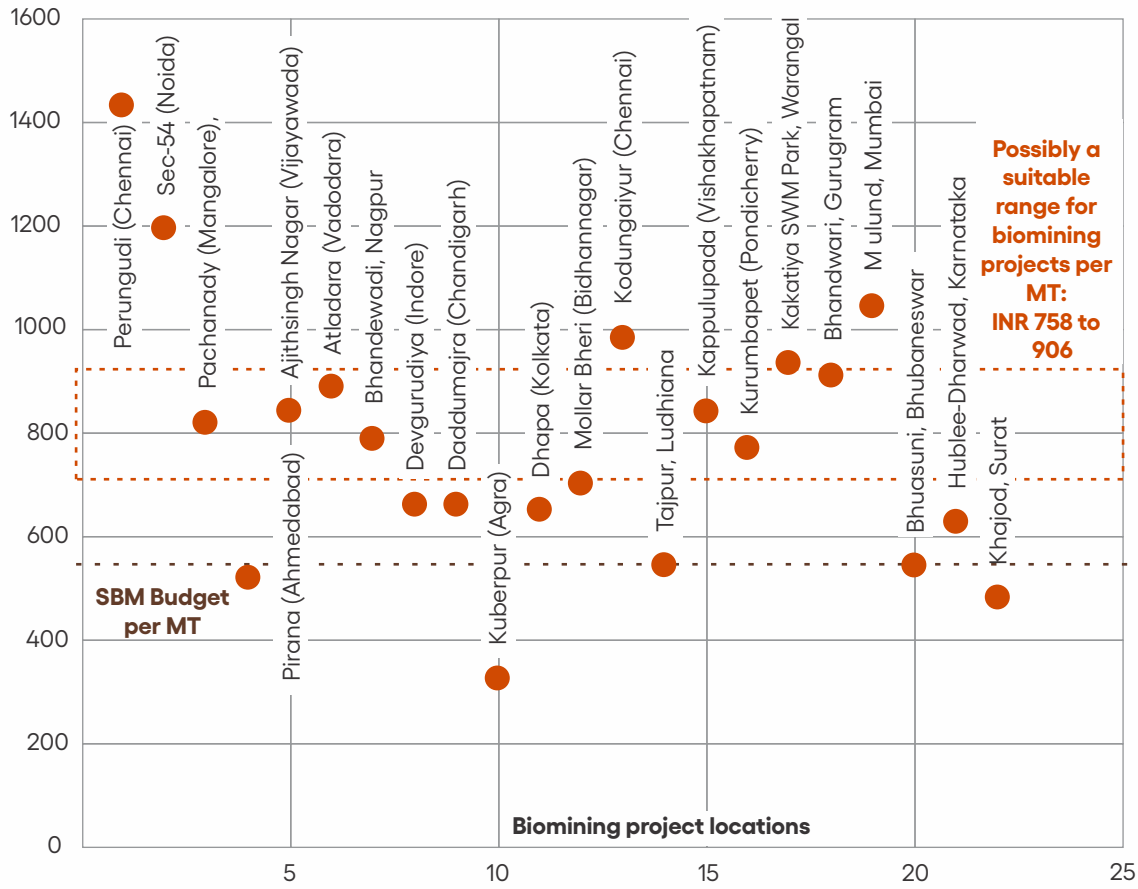
4.6. Convergence of funding is key to ensuring an integrated approach to dumpsite biomining and bioremediation

The Swachh Bharat Mission Urban 2.0 has given priority to biomining of dumpsites, and a budgetary allocation of INR 550 per tonne of processed waste is provided as part of this mission. As part of this study, it is understood that several ULBs are able to undertake biomining projects within this budget. But there is little clarity on the quality of biomining taken up in these ULBs, due to lack of post-project implementation studies on the completed/ongoing projects. However, by studying available case studies (which are highlighted as success stories published by the government and other credible institutions), it is found that the budget spent by these ULBs per tonne is relatively higher.

A. Project economics

Through an analysis of different scenarios of project economics undertaken as part of this study, it was estimated that for undertaking a successful biomining project, a suitable budget may range between INR 758 to 906 per tonne. These costs and investments calculated for the end-to-end process includes the Capital Cost, Operational Cost, Disposal Cost and Contingency, as per referred literature and inputs from primary consultations. This includes EHS and risk management aspects as part of capital and operational costs. This range may be further added up with a contractor profit of approximately 10% of the per tonne cost. It is understood from the study that revenue from recovered materials and cash flows, if any, are usually negligible in comparison to the budgeted expenses. This is represented in **Figure 16.**

Figure 16: A chart showing per MT cost of biomining for several cases



It is observed that most of these sites spent more than INR 550 per tonne on processing of waste. Study of these published references indicate that projects have been delivered at as low as around INR 480 per tonne in Khajod, Surat, while for Perungudi, Chennai, this is as high as INR 1,400 per tonne. So, it can be inferred that these cities and have been able to perform biomining and arrive at desired results in such range of budgets, which indicates that the project economics and Value For Money (VFM) are subjective and are based on local conditions. Factors like quality of waste, availability of contractors, availability and distance of processors, etc. would impact the cost and quality of project implementation, and ultimately could impact the cost-to-benefit and the VFM.

B. Converging on funds and sources of financing

It is observed that convergence of funds would be key to enabling scientific biomining of dumpsites. The financial requirements may be converged from different government, private sector, and multilateral sources. While the Government of India's SBM Urban 2.0 program is leading the financing ecosystem, other union government programs like District Mineral Foundation (DMF) Fund and Finance Commission (FC) grants may be explored for scope of convergence on particular aspects of a biomining project development. Further, the state or the ULB may allocate their own fund, from taxes, user fees or tipping fees. In case of smaller ULBs, the state could fund through a cluster approach. It is important that for such projects, scope for Public Private Partnerships (PPP) is explored. This is particularly important in developing the coprocessing and recycling requirements. Further, Corporate Social Responsibility (CSR) collaborations may be encouraged for biomining projects.

C. Grants and loans for biomining

In addition to domestic sources, funding from International Support Mechanisms (Grants and Loans) could also be explored. Loans from banks may also be encouraged for such projects, and the government may facilitate this sector through priority sector lending. For bankability of biomining projects, it is necessary that in addition to having techno-economic-financial feasibility, the project adequately addresses EHS and ESG aspects.

Figure 17: Case: Financial convergence in Chennai's Kodungaiyur dumpyard biomining projects

Area 252 acres	**Legacy waste - 6.6 Mn MT**
Project cost - INR 641 crore	**Processing cost - INR 963 per tonne**

An innovative model of convergence was adopted by the Greater Chennai Corporation (GCC), where the Centre's share is INR 160 Cr, state's share is INR 103 Cr, and Other's share (59%) is INR 378 cr (which includes KfW fund, GCC own revenue, User Charges, FC grant)

The GCC is also planning to start earning revenue from trading of carbon credits in the international market by identifying projects including biomining. GCC has planned to plant trees in the outer periphery of the Perungudi dump yard once the bioremediation is completed for adding green cover. The same has been planned for Kodungaiyur dumpsite as well. With the existing green cover projects, GCC is expected to earn INR 1.8 Crore annually through carbon credits for the next ten years.

D. EPR and Carbon credits

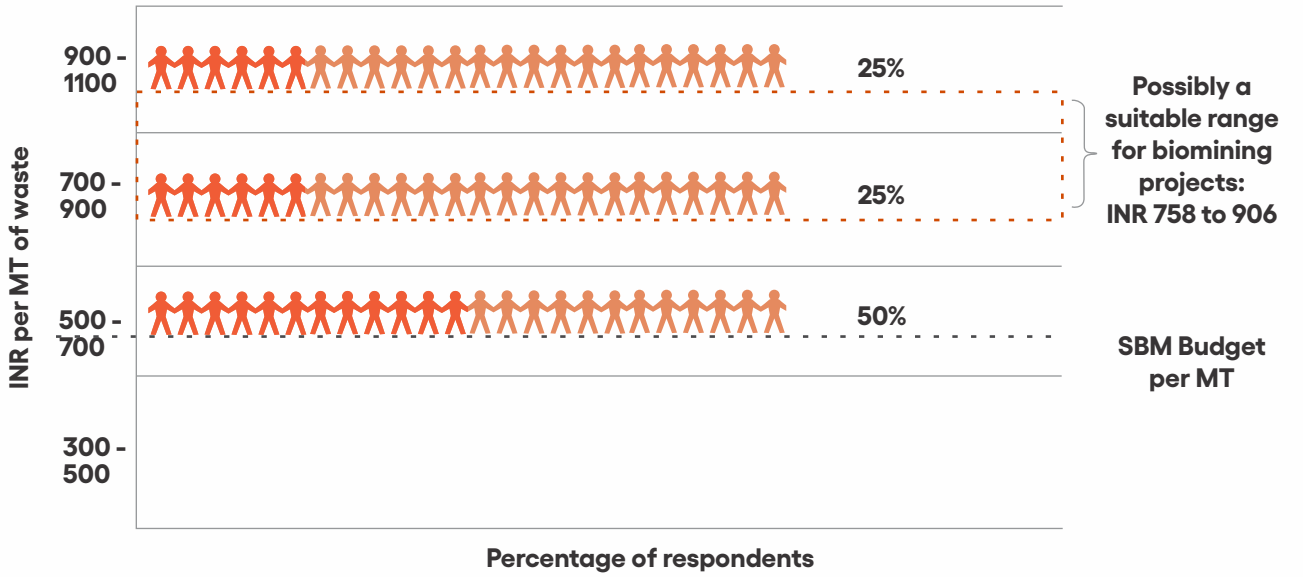
Innovative models like EPR and Carbon Credits could be explored as well, based on feasibility. The concept of EPR has been explained in the earlier sections. A carbon credit is a financial instrument that represents a reduction in GHG (Green House Gas) emissions, where the buyer pays another company to take some action to reduce its greenhouse gas emissions, and the buyer gets credit for the reduction. As per the Carbon Trading Scheme 2023, published in 2023 by Ministry of Power; "carbon credit" means a value assigned to a reduction or removal or avoidance of greenhouse gas emissions achieved and is equivalent to one ton of carbon dioxide equivalent (tCO2e).

Though it must be highlighted that biomining needs to be considered as an economic project for social good, and this should not be considered as a revenue generating avenue. In interaction with several stakeholders, it was observed that there are several cases where DPRs (Detailed Project Report) were prepared targeting a large amount of revenue generation from biomining projects and have failed to generate revenue during implementation. The Table 4 lists the options and provisions for convergence and revenue generation for biomining projects.

Table 4: Options and provisions for convergence and revenue generation for biomining projects

S.N.	Possible sources for convergence or revenue	Available provisions
1	**SBM 2.0**	Budgetary provision of **INR 550 per tonne** of waste
2	**Finance Commission Grants**	**50% of the tied funds for non-million plus cities** is reserved for sanitation & waste management
3	**District Mineral Foundation (DMF) Fund**	DMF can be utilized for **environment preservation and pollution control measures**
4	**Corporate Social Responsibility**	Support (e.g. equipment or project monitoring expenses) may be procured through CSR under **Environment & Conservation of Resources Category**
5	**ULBs or State's own fund**	ULBs, with higher **cost to benefit** assessed may prioritize, and fund such projects through own taxes, user fees or tipping fees
6	**Lending / Grants**	**Bank or multilateral** lending to ULBs
7	**Sale of aggregates**	Depending on the quality and demand, **revenue from RDF, Biosoil, recyclables,** etc.
8	**Innovative approaches**	Initiatives like **EPR credit, Carbon credit,** etc.

Figure 18: 'Manageable budget' for undertaking booming (including safe disposal of rejects) as per survey respondents.



The prescribed budget as per SBM Urban 2.0 is INR 550 per tonne, while the possible range for biomining projects as per this study, i.e. INR 758-906 is marked in dotted box. Half of the stakeholders felt that a budget of more than INR 700 per tonne would be ideal for taking up biomining projects.

More than half of the respondents felt that project planning for ULBs, scientific process of biomining for contractors and project monitoring & impact assessment for academic institutions are key areas that need prioritization for capacity building.

4.7. Scientific closure of dumpsites along with productive usage of recovered land

Figure 19: A case-to-case approach may be taken for remediated sites

Usage of recovered land

a. After bioremediation, land remains contaminated. Hence current guidelines require not using it for habitation purposes for **15 years**

b. May be taken up case to case basis, **based on toxicity and fit for usage**

c. Use cases like Sports Ground, Industrial usage, Recreation, etc. may be facilitated on a case-to-case basis

SWM rules and CPCB guidelines for disposal of legacy waste 2019 provide some guidance on usage of reclaimed land. CPCB guidelines for disposal of legacy waste 2019 prescribe that the ULB should demarcate and declare a buffer zone of no new habitation for up to 500 meters around the cleared site to prevent real-estate activity from encroaching the buffer as soon as the dump is removed. If a dump is engulfed within a growing city and its continued use for waste management is unsuitable, it is suggested to identify in advance the planned future use of that site. As per the SWM Rules 2016, cleared dumps are not permitted for habitation for at least 15 years. This is because of unhealthy leachate below the site and formation of flammable and offensive landfill gases from waste pockets that may remain unexcavated. CPCB guidelines provide permissible options for reclaimed dumpsite sites as reuse for SWM, open stadia, sports grounds, parks and gardens,

parking lots, container yards, warehouses of non-flammables and similar facilities where people are not living or working all day and night.

India is a fast-developing country, and many of these dumpsites lie inside a city, and hence its value must be realized in innovative ways. It is suggested that regulations could be relooked, to facilitate optimal end usage of reclaimed land for socio-commercial purposes, after ensuring necessary geotechnical and chemical analysis have been done; and the land is fit for use. This would motivate ULBs to improve their biomining, targeting remediating the land to its near original condition. Based on a fit-to-usage assessment, some case-to-case basis approach may be taken, and CPCB may provide guidelines regarding the same. In the absence of clear and separate provisions for end use of land reclaimed after biomining, it is seen that ULBs are mostly converting remediated sites into greenspaces or use it for solid waste management purposes.

Figure 20: Case of Turning a Dumpsite into a World Cup Eco Park

Nanjido is a small island near Seoul, South Korea. In 1978, it was converted into a garbage dumpsite for the city of Seoul. In 1993, the Seoul city government decided to close the dumpsite and conduct landfill stabilization work. To commemorate the 2002 Korea-Japan FIFA World Cup, the government in 1997 started work to build an ecological park 'the World Cup Park' at the dumpsite.

Steps of converting the site into the World Cup Park, with community participation

a. **stabilization** was done through (i) installation of an impermeable wall to prevent leakage of leachate from the dumpsite; (ii) treatment of leachate; (iii) collection and treatment of landfill gas; (iv) slope stabilization to manage the side of waste heaps; (v) construction of grassland after covering the top of the landfill with soil.

b. **Ecological restoration** was done through planting of oak trees, wild pear trees, and other plants that could be used as food by animals. It built an artificial wetland to promote biodiversity in the park. Corridors for wild animals-such as the narrow-mouth frog, which is one of the flagship species of the World Cup Park-were also installed.

Results of this transformation

a. **Increase in tourists,** for e.g.in 2018, more than 90 lakh people visited the park, which is about the same number of people living in Seoul.

b. **Improved habitats for plants and animals,** with the Seoul city government managing the ecological park as a conservation area where animals and plants are protected.

c. **Use of landfill gas as fuel,** with 23.2 crore cubic meters of landfill gas recovered between 2002 to 2013, was valued at about USD 70 lakh

d. **Recognition for environmental education,** The World Cup Park is recognized as a place for international environmental education. About 3,000 domestic and foreign public officials visit the World Cup Park annually.





05 WAY FORWARD

5.1. Facilitating a conducive ecosystem through convergence and collaborations

While the Government of India is currently focusing on remediation and reclamation of legacy waste dumpsites by 2026, as seen in other developed nations, biomining sector has significant scope in the future of an economy in many ways. It enables the extraction of value from low-grade resources that were previously not considered useful. Biomining is already being used for extraction of high value resources from e-waste and waste from mining. Further biomining can tap into unconventional mineral resources that were previously unexploited. These include deep subsurface deposits, deep sea minerals, and even extraterrestrial minerals, and several research in this regard are being taken up. For e.g., a firm Biotechnology Research and Information Network (BRAIN), is mining precious metals from e-waste through microbes in Germany. Similarly, an experiment on the International Space Station (ISS) has shown that microbes can extract valuable or useful elements from rocks in microgravity, suggesting "biomining" might be key to extracting minerals from asteroids.

With an aim of a dumpsite-free India, along with ensuring that value is created out of reclaimed land, the vision for biomining and bioremediation of legacy waste dumpsites in India could be-

> *"Biomining: Unearthing value from legacy waste, reclaiming land parcels for productive usage, and nurturing a sustainable future for India's urban landscapes."*

This vision would require biomining of dumpsites to be facilitated in a scientific manner, and a holistic way such that a) value is extracted from the segregated fractions (RDF, biosoil, etc.), b) land is reclaimed in close to original condition, and c) India's urban landscapes are made free from these decades-old sources of contamination and pollution.

Five action points could be considered for further deliberations and engagement by all stakeholders of the biomining ecosystem in India.

1. Awareness and regulatory revisions

Stakeholders including the Government bodies and think tanks may raise awareness among local bodies, policymakers, contractors, citizens, etc. about the benefits of biomining and the processes involved in scientific biomining. There is a need for these stakeholders to advocate for strong policies that prioritize biomining over open dumping and capping methods. For example, the SWM Rules 2016 would need to be updated, and biomining may need to be suggested as the only method to manage legacy waste dumpsites in India (while disallowing any bio-capping activities). Similarly, the guidance documents from CPHEEO, CPCB, etc. need to be updated. Most of these documents were published before SBM Urban 2.0, when biomining was not prevalent in India. Today, there is a need to revisit the guidance documents, and create clear directives on certain aspects of biomining, as the country moves ahead towards

achieving its targeted biomining sites by 2026.. Additional guidance documents could be developed on:

a. Standards for co-processing of RDF from biomining projects

b. Biosoil standards for gainful utilization

c. EHS aspects of biomining projects

d. Updating of the SWM Rules, detailing clauses related to biomining

e. Project economics and process of budgeting such projects

f. Monitoring and productive usage of reclaimed land

The Appendix H discusses the regulatory ecosystem on disposal of aggregates, and possible policy aspects and revisions to facilitate the ecosystem.

Planning in convergence and clusters

Biomining projects may face inadequate financing which may lead to incomplete execution of several aspects of the project. Similarly, smaller ULBs find it difficult to undertake scientific biomining. There could be challenges in converging of different funds and sources of financing, given the implementing agencies may be different ministries/departments/institutions. Further, each fund may have different guidelines for disbursement and implementation. The Union Government could hence establish clear guidelines of usage of government funds like Finance Commission Grants and DMF fund for biomining activities.

Further at the Union or state level, corporates could be encouraged to support biomining projects through their CSR funds. A list of projects available for CSR funding could be maintained by MoHUA. Further, a list of bankable projects could be collated by MoHUA, for consideration of banks and multilaterals. MoHUA or the state urban development departments could facilitate planning of biomining projects in clusters. This could encourage contractors to participate in the procurement for the cluster as it would offer economies of scale to the contractor. Similarly, at larger biomining projects, MRFs (Material Recovery Facilities), composting centres, C&D processing units, RDF processing units, etc could be planned as an integrated part of the biomining project. This could help in maximizing available budgets, while also making it easier for the department or ULB to monitor the progress.

Role of Academia

Academia needs to play a larger role in the development of a robust ecosystem for biomining. MOHUA could partner with academic institutions like Anna University, who are already working as Project Monitoring consultants for biomining projects. Such institutions could act as mentors to other institutions from across India. MOHUA, MOEFCC (Ministry of Environment, Forest, and Climate Change) and other ministries could allocate dedicated funds for investing in research to develop innovative technologies or approaches tailored to Indian conditions. This would be necessary for management of aggregates, in particular. For example, innovative solutions may be explored for processing of lower quality RDF or enriching biosoil to be used as construction material, etc. Academia could also play a significant role in undertaking benefit and impact studies of dumpsites and biomining projects as there are very few scientific studies or published reports in India for this sector. Appendix D. provides a framework for impact and cost benefit analysis, which could be

referred by Academia in undertaking assessment of biomining projects.

Centralised monitoring system and database

To improve traceability and for effective monitoring of biomining activities, a centralized monitoring and database system could be developed, which may be anchored by CPCB, CPHEEO or MOHUA. This database and monitoring system could include several aspects such as:

a. Centralized system for generation of certificates for utilization of aggregates (RDF and biosoil)

b. Database of equipment providers, contractors, etc.

c. Integration with the plastics EPR portal, with scope for EPR credit trading

d. Integration with carbon credit scheme

e. Research reports, impact studies, model DPRs

The Appendix E. discusses the Consent to Establish and Operate as regulatory instruments for effective monitoring. Similarly, Appendix F. proposes a centralized certification and traceability mechanism for RDF and Biosoil.

Capacity building and handholding of stakeholders

It is understood that currently there is no single go-to document providing comprehensive guidelines and good practices for biomining. Further, there is a risk of compromises in the quality of execution due to lack of nuanced expertise in biomining amongst stakeholders involved in the activity. Hence, there is a need for a one-stop facilitation and knowledge support to, especially to smaller ULBs and contractors, particularly on aspects like planning EHS and mitigating project risks. Think tanks or research institutions of repute, like the National Institute of Urban Affairs (NIUA), along with experts from the industry and academia could anchor such initiatives and support the ecosystem in knowledge transfer and handholding.

The Appendix A. discusses the important considerations in planning of biomining projects. Further, the Appendix B. provides a suggestive scope of work and qualification criteria for contractors. The Appendix C. provides a framework of ESG and EHS safeguard principles. The Appendix G. proposes a mechanism for Plastic EPR credits from RDF processing. These Appendixes provide a blueprint and framework of key areas of focus which could be taken up for capacity and handholding of stakeholders.

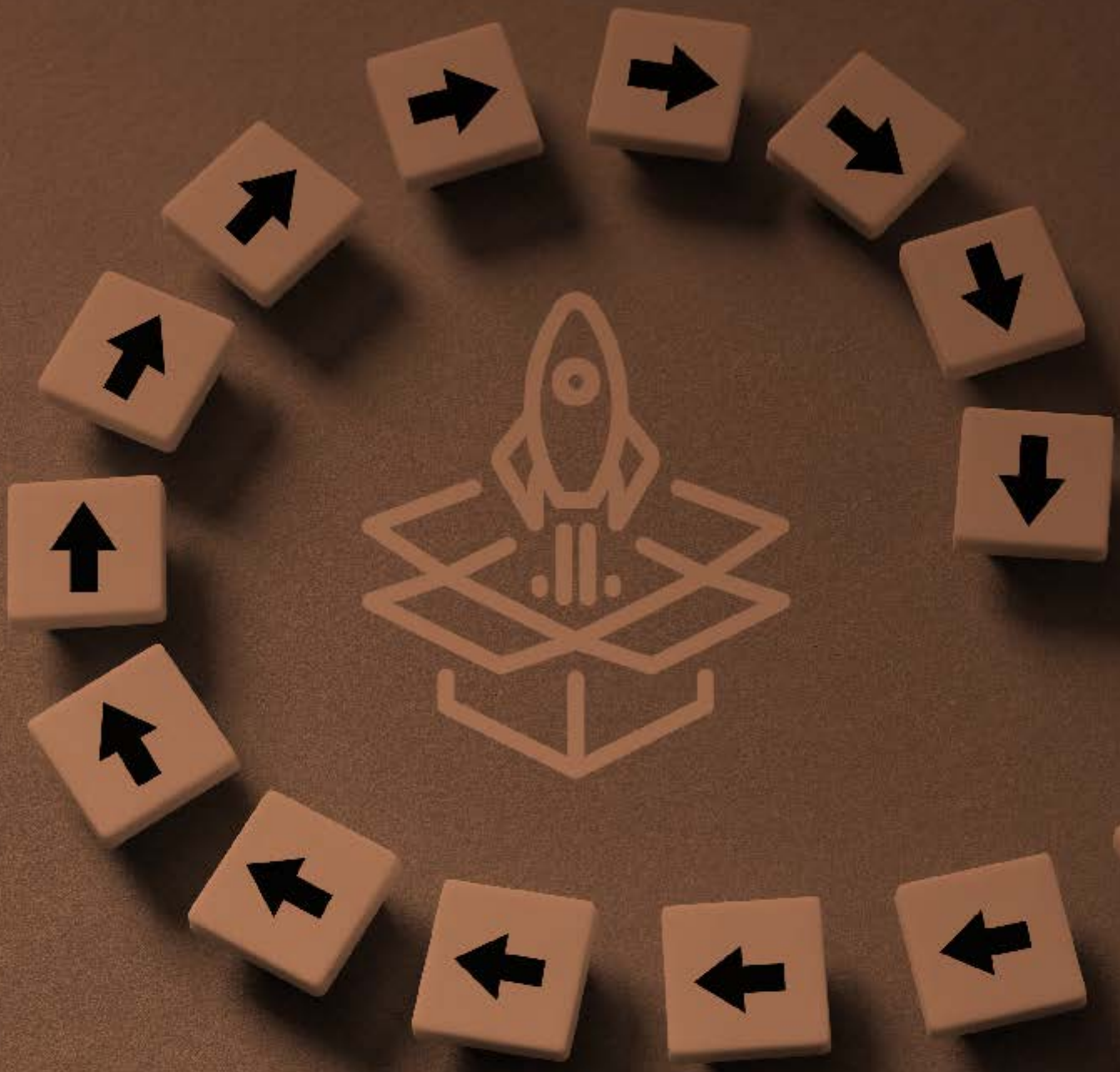
Table 5: STAR: Situation, Task, Action and Result on the proposed way forward

SN	Situation	Task	Action	Result
1	As per this study, it is observed that there is a need for awareness generation among the stakeholders on the prevailing regulatory ecosystem and benefits of scientific biomining. Further, there is need to	• Stakeholders including the Government bodies and think tanks may raise awareness among local bodies, policymakers, contractors, citizens, etc. about the	• Nodal Capacity building and research institutions like NIUA, IIHS, CEPT, etc. can be entrusted for awareness generation among the different stakeholders	• The ecosystem would be aware of the biomining process, prevailing regulations, and would be able to play a more productive role.

SN	Situation	Task	Action	Result
	regulatory revisions, taking into account the requirements for a strengthened ecosystem.	benefits of biomining and the processes involved in scientific delivery of biomining projects. • Also, regulatory revisions needs to be relooked and discussed.	• Biomining & Bioremediation toolkit with audio visual platforms • Classroom training of trainers • Peer learning programs • Deliberations on regulatory revisions	• Further, regulatory revisions would cater to needs to of the ecosystem in standards, motoring, traceability, budgeting, etc.
2	It was found that Biomining projects may face inadequate financing which may lead to incomplete execution of several aspects of the project. Smaller ULBs find it difficult to undertake scientific biomining.	• It is important to deal with challenges in converging of different funds and sources of financing, given the implementing agencies may be different entities. • Further, smaller projects may be planned as clusters to attract better contractors and funding.	• The Union Government could establish clear guidelines of usage of government funds for biomining • A list of projects available for CSR funding or bankable projects may be maintained by MOHUA	• his would facilitate convergence of funds, along with opening up funding opportunities from CSR and banking institutions.
3	In India there is lack of research, innovation, monitoring, impact assessment, cost benefit assessments of biomining projects, where academia can play an active role.	• It is necessary that reputed academic institutions could be identified for handholding and mentoring the ecosystem on biomining. • Further the government could facilitate funding academia in critical areas pertaining to the biomining ecosystem.	• Identify key academic institutions who could handhold and mentor ULBs/Contractors/ Other institutions • Constitute a dedicated fund to encourage research and development in the sector • Mandate stringent monitoring and impact assessment of biomining projects, ideally through the academia	• With the academia being encouraged, localized innovation and solutions would be available. Impact of biomining projects would be recorded and assessed. • Further, there would be ease of knowledge transfer within stakeholders.
4	It is observed that monitoring of biomining projects is mostly limited to the ULBs, while aggregates from	• To improve traceability and for effective monitoring of biomining activities, it is	• A centralized databased may be anchored within one the Union Government institutions	• With a centralized system, there would be enhanced transparency in the biomining sector.

SN	Situation	Task	Action	Result
	biomining may be transported across India for use or disposal. Further, there is no system to check credentials of biomining contractors with respect to disposal of aggregates. There is need for a centralized monitoring system and database.	important that a centralized monitoring and database system be developed and mandated for all biomining projects. This could be a repository of all biomining activities, EPR, contractors, research reports, CTE clearances, etc.	• Databased and monitoring systems like CTE clearances, certificates for utilization of aggregates (RDF and biosoil), EPR certificates, Contractor performance, research reports, etc. may be integrated into this system	• The interlinked database and monitoring system would facilitate quality implementation of biomining projects.
5	During the stakeholder interactions throughout this project, most stakeholders emphasized the need for capacity building in the sector. It is understood that currently there is no single comprehensive guidelines and there is a risk of compromises in the quality of execution due to lack of nuanced expertise in biomining amongst stakeholders involved in the activity.	• It is an immediate requirement that in priority, capacity of all the key stakeholders i.e. the ULBs/ State governments, Contractors and Academia be enhanced in critical areas of biomining. Capacity enhancement is necessary in planning, execution, monitoring, aggregate disposal, etc.	• Identify gaps in capacity of the key stakeholders and locate institutions which could build modules on these areas and facilitate knowledge transfer • Dedicated funds could be allocated for capacity building in the sector	• With improved capacity building, the ecosystem would facilitate scientific biomining leading to effective management of all legacy dumpsites in the country. With proper knowledge transfer aggregates from biomining may be put to commercial use, further facilitating a circular economy.





Appendix A
Important considerations in planning of biomining projects

To enable effective implementation of a biomining project, it is important that the project is backed by a detailed prefeasibility assessment, led by detailed planning of each aspect prior to implementation. Figure 21 and Figure 22 detail the important components of this prefeasibility assessment and how these assessments are to be utilized in planning for a scientific biomining project.

Further, it has been observed that several biomining projects are limiting to use of rental trommels and blowers for processing of waste. It is important that the ULB assess its dumpsite characteristics and accordingly encourage the contractor to use an appropriate mix of equipment for biomining purpose. The Table 6 gives a list of equipment which should be explored, based on specific case requirements and techno-financial feasibility to ensure that the quality of biomining process ensures quality by-products in the forms of RDF, and bio-soil. Available CPHEEO manual, and other guiding documents may be used in this regard.

Table 6: List of suggestive equipment that are usually used in biomining projects

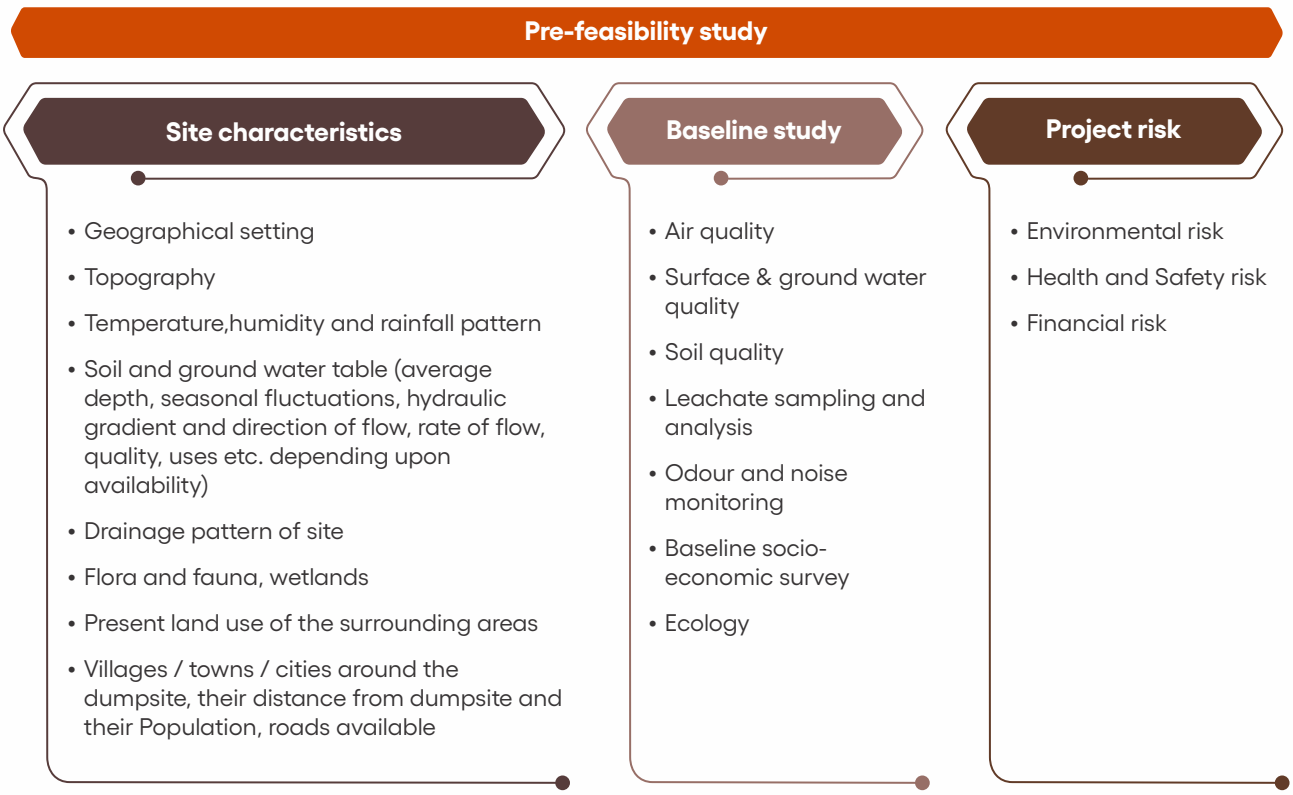
Excavation • Trackhoe and backhoe excavators • Bulldozers • Grappling Hoes	**Screens** • Trommel • Vibrating • Disc/star
Size Reduction/Shredding • Hammermills - vertical and horizontal shaft • Shear shredder • Rotary, guillotine, and scissors-type shears • Grinders - roller, disc-mill, ball mill • Flail mill • Wet pulper • Knife mill	**Ferrous Metal Separators** • Over-band magnets • Drum magnets • Head pulley magnets **Non-Ferrous Metal Separators** • Eddy current separators
Air Technologies • Wind shifter • Drum separators • Air classifiers • Air knife	**Handling Equipment** • Front-end loaders • Grapples • Conveyors • Forklifts

Similarly, typical infrastructural considerations which should be planned for a biomining project, taking into consideration aspects like monitoring, EHS, etc. are provided in the Table 7. cure entrance gate

Table 7: Suggestive Infrastructural considerations at a biomining project

1.	Security and reception office
2.	Weighing bridge
3.	Records room, Laboratory
4.	Medical room, workers area
5.	Parking for vehicles (heavy earth equipment, trucks etc.) with tyre washing facility
6.	Administrative building
7.	Temporary storage area for rejects, domestic hazardous waste, sanitary waste
8.	Material Storage Area
9.	Fugitive dust suppression mechanism at the waste handline areas
10.	Environmental Monitoring Unit
11.	Leachate collection and treatment unit
12.	Fire control unit
13.	Waste drying and windrow area
14.	Toilet-Bath complex with Personal Protect Equipment (PPE) storage room
15.	Overhead Water Tank

Figure 21: Key points to be considered under the pre-feasibility study



Potential impact

- Environmental impact
- Social impact
- Monetary impact such as recovered land value, increase in working days, increase in agriculture, clean water availabilityetc.
- Climate change impact

Project economics

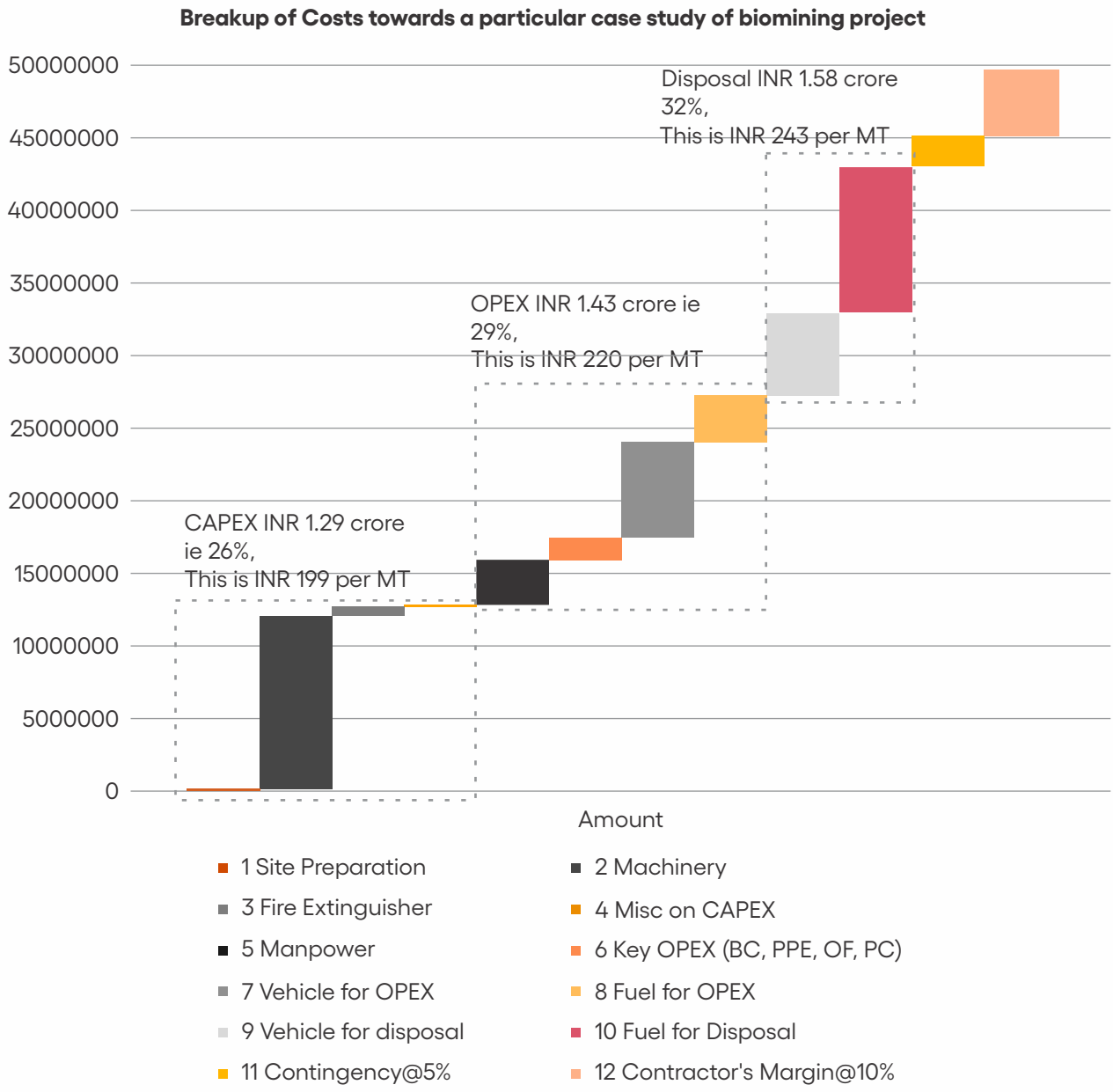
- Planning and capital cost
  - Prefeasibility study, Surveys, permissions and compliances
  - Machinery & Equipment
  - Electrical and civil items, Water supply
  - Fire & safety, Machinery repair, risk abatement infrastructure, etc.
- Operational cost
  - Vehicles rental cost, Fuel cost, Man-power costs
  - Safety equipment, utilities, bio-culture
  - Environment and health monitoring cost and other maintenance costs
- Other contingency cost
  - Contractor Margin
  - Contingency includes additional manpower cost due to rain, transaction advisory cost, project monitoring consultant cost
- Project revenue
  - Potential revenue from sale of RDF, recyclables, C&D waste and SLM

Figure 22: Using the prefeasibility findings in planning for dumpsite biomining project

	Pre-feasibility study	Planning
1	Contour survey	Selection of model of operation
2	Waste characterization	Identification of appropriate linkages for possible recovered materials
3	Waste quantification	Identification of alternate site for fresh waste disposal
4	Site characteristics	Space availability for equipment set up
5	Baseline study	Identification of required infrastructure
6	Project risk	Planning for alternate usage of the reclaimed land
7	Project economics	Preparation of remediation strategy and monitoring plan
8	Cost benefit analysis	Other plannings including EHS plan, Environmental and Social MP, Emergency Response Plan etc
9	Potential impact assessment	Preparation of DPR incorporating key points

Budgeting the project with detailed assessment and considering all key components is critical for the success of the project. As detailed in the project estimation for a particular biomining project (which is a 0.065 million MT waste remediation project in India) in Figure 23, based on available secondary literature, it is seen that Operational expenditure (OPEX), Capital expenditure (CAPEX) and Disposal costs, account for almost a third of the project expenses each. Further 10% of the budget was accounted for contractor margin. In such a case detailed assessment and adequate budget allocation is important during the planning stage, with due consideration of the disposal of waste in an environmentally suitable manner.

Figure 23: Breakup of costs towards a particular case study of biomining project



Source: *Rannebenur municipality (ranebennurcity.mrc.gov.in), Research Team's preliminary analysis*

Appendix B
Suggestive qualification criteria and scope of work for contractors

Suggested qualification criteria for the contractor

To enable scientific biomining, selection of a competent contractor becomes important. The suggested qualification criteria for the contractor may be as follows -

- To encourage adequate capacity of contractors, joint ventures may be encouraged
- Contractors should have worked on similar projects in terms of quantity of waste to be processed or value of the biomining project
- Contractor should have a defined plan for execution and disposal of waste from the site
- The contractor should have adequate documentary proof of scientific disposal of aggregates in earlier projects. The Figure 244 provides a list of documentary evidence that may be requested from the contractor.
- The turnover and technical experience requirements for the contractor may vary depending on the size and location of the dumpsite being planned for.

Figure 24: Documentary evidence for effective management of aggregates by contractor



Suggested scope of work for contractors

In most cases it is seen that the ULBs are delegating most of responsibilities to contractors, while they are supporting on coordination and managing externalities. For such contractor led models, the following outline of a scope of work may be suggested. It is to note that the ULB may undertake these activities through the biomining contractor or through an external expert agency (for scopes like geotechnical surveys, where the contractor may not necessarily have the competency). These may be covered as part of the key steps that should be followed for scientific biomining as represented in Figure 7 on this report.

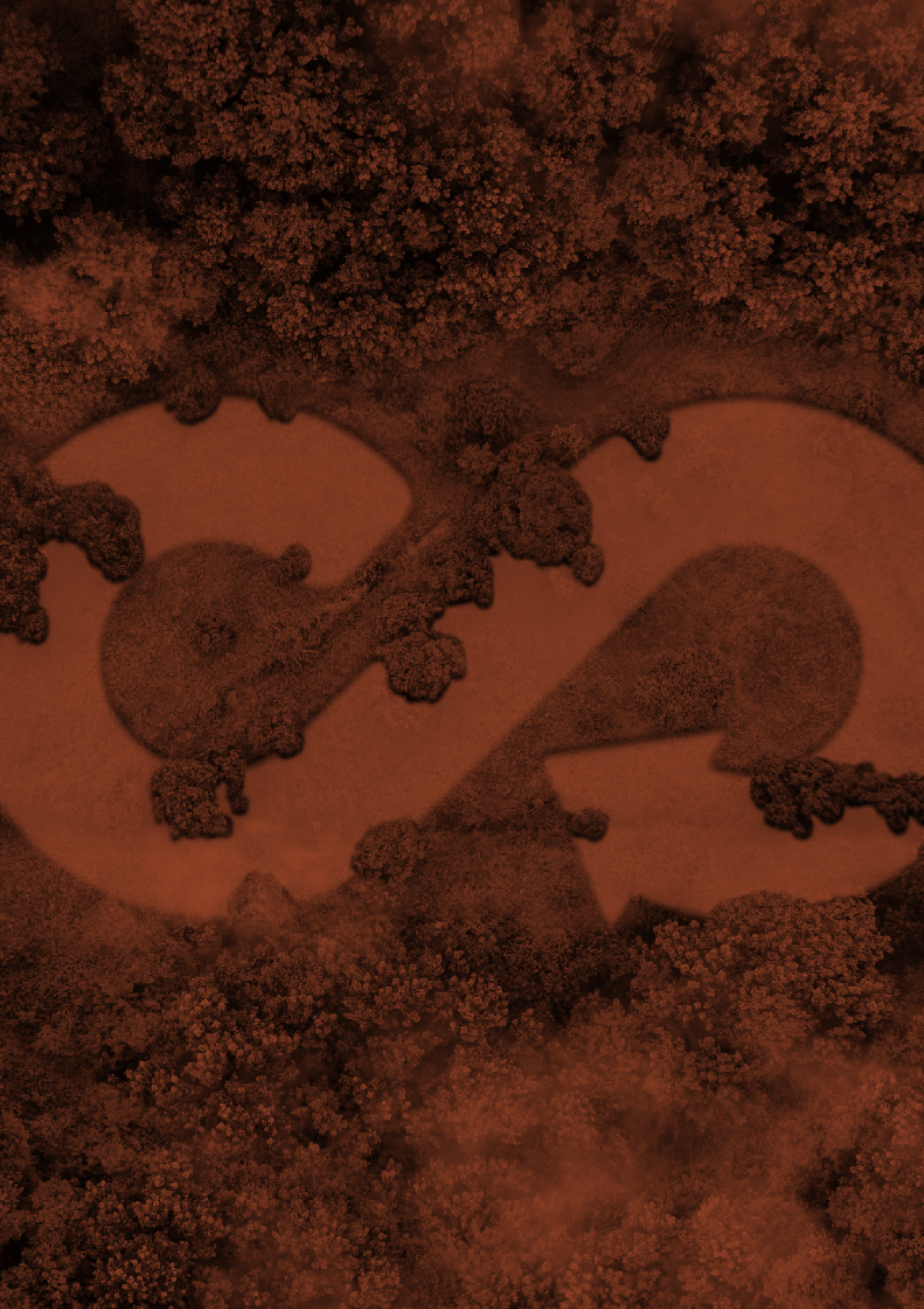
- Take necessary permissions and adhere to regulatory requirements.
- If necessary, take up studies to assess the quantity and quality of legacy waste at the site.
- Carry out necessary geotechnical surveys for considering the hydrological and flooding potential at site, to mitigate any effect on the activities during Bioremediation.
- Carry out soil, air, ground water and noise baseline studies so that the same will be available to evaluate post remediation of the dumpsite from authorized laboratories.
- Deploy the necessary workforce, materials, equipment, tools and construction of plants and sheds and creation of facilities for handling, separating, segregating, and storing for the operation of the plant.
- Excavate the existing mixed compacted garbage and bioremediate the waste through mechanical sieving/ segregation/ other machines like shredders, separators, etc.
- Ensure processing of the Legacy Waste in accordance with CPCB and CPHEEO guidelines, along with the SWM Rules 2016, NGT orders, etc.
- Ensure stabilization of the waste dump so that it releases no offensive odours and generates no leachate.
- Take necessary steps and processes to minimize environmental pollution while carrying out remediation of legacy waste at the dumpsite.
- Take all reasonable steps to ensure that there is control of odour, dust and treatment generated leachate, bird menace, fire hazards, etc. in and around the dumpsite during the period of remediation work.
- Segregate the excavated garbage into as many categories as possible, and maximize the separation of recyclables, RDF, biosoil, etc.
- Provide on-site storage facility for various fractions of processed waste.
- Manage and dispose the processed outputs such as RDF, biosoil, C&D waste, recyclables and inert from the processed aggregates
- Monitor and measure environmental parameters like air quality, soil quality, etc. during the biomining process
- Provide mitigation measures for the workers with respect to exposure to hazardous material, leachate, gases, odour, fire risks, landslide risks, etc.

- Monitor the quality of aggregates like RDF, biosoil and maintain records of their disposal
- Encourage utilization of processes like ERP and use of technologies like GPS for monitoring
- Set up a processing system flexible enough and convenient for segregation of legacy waste material, considering the microclimate and externalities like rainfall, cyclones, dry storms, etc.

While there is a set of responsibilities on the contractor, it is imperative that the project proponent (the ULBs in most cases, a cantonment board, or a township board) are responsible for the successful delivery of the bio-mining activity.

The proponent needs to ensure that there is a fair estimation of the quantum of waste using scientific methods, have a clear access to the site, facilities to avail power and water supply by the contractor, and facilitate/support the contractor for safe disposal of RDF and biosoil. The proponent needs to ensure close supervision and continuous monitoring of the project to its completion.





Appendix C
A framework of ESG and EHS safeguard principles

Adhering to ESG and EHS safeguard principles are necessary, not only to mitigate associate risks, but also to ensure that the biomining project is undertaken without any adverse effect on the environment, economy, or the society. Further, adopting these principles in the project may help in enhancing the bankability of the project for convergence financing. The SBM program also highlights health and safety requirements through a guidance RFP document.

Multilaterals like the International Financial Corporation, World Bank Group have prescribed Environmental, Health, and Safety (EHS) Guidelines, which are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP) and are referred to in the World Bank's Environmental and Social Framework and IFC's Performance Standards. The following table provides a framework of key safeguarding principles that may be taken up for biomining projects.

Table 8: A framework of ESG and EHS safeguard principles

Principle	Description of the principle in the context of biomining of dumpsites
Principle 1 Human Rights	• Recognizes the centrality of human rights to sustainable development and ensuring fair distribution of development opportunities and benefits; for all, without distinction. • In this case, it should be ensured that informal sector, ragpickers, etc. who are dependent on the dumpsite are not adversely affected and are suitably compensated.
Principle 2 Gender Equality and Women's Empowerment	• Recognizes and seeks to contribute to achieving gender equality. • In a biomining project, where many female workers may be employed, the ULB and contractor shall apply the principles of non-discrimination, equal treatment, and equal pay for equal work. • There should not be any short of inequality in terms of pay or rewards. The female workers should be provided with separate resting facilities.
Principle 3 Community Health and Safety	• Ensures that projects anticipate and avoid adverse impacts on the health and safety of communities in the vicinity from both routine and non-routine circumstances during the project's life cycle. • Ensures that projects provide workers with safe and healthy working conditions and prevents accidents, injuries, and disease. • The community should be made aware of adverse effects from project, if any. • The contractor should a. undertake appropriate health and safety assessments b. provide adequate personal protection equipment c. adopt appropriate avoidance, minimization, and mitigation measures d. adhere to regulatory requirements and international best practices e. record and address any incidents at the site f. provide measures to protect workers from risks of fire, landslide, hazardous waste, etc.

Principle	Description of the principle in the context of biomining of dumpsites
Principle 4 Economic Impacts	• Promotes equitable and sustainable economic growth. • The cost benefit of the project may be taken up, and economic impacts may be studied. As part of the project, it must be ensured that local population gets employment, based on requirements.
Principle 5 Climate and Energy	• The project should promote climate security (mitigation and adaption) and sustainable development. • Biomining helps mitigate GHG emissions from the dumpsite, and with generation of RDF provides scope for further mitigation (from impact due to traditional fuel sources). • Where feasible, alternative energy usage like waste to energy or solar energy may be utilized in larger biomining project sites.
Principle 6 Water	• The project should promote sustainable and efficient use of waste resources to avoid adverse impacts on water resources and water-related ecosystems. • For a biomining project, it is important that it does not pollute water sources (surface or ground) due to the biomining activity or from leachate or runoff from the site.
Principle 7 Environment, Ecology and Land Use	• The Project shall avoid or minimize impacts caused by natural or human-caused hazards, such as landslides or fires, or release of gas, dust, or leachates, that could result from the project. • Adequate emergency preparedness plans should be available at the site. Further if the biomining activity involves handling or usage of genetically modified organisms, then suitable permissions and necessary caution should be implemented.
Principle 8 Storage, Transportation and Disposal	Adequate measures must be taken during the storage, transportation and disposal of waste or aggregates. Waste should be stored scientifically so as to prevent or control accidental releases to air, soil, and water resources. On-site and Off-site transportation of waste should be conducted so as to prevent or minimize spills, releases, and exposures to employees and the public. All waste containers designated for off-site shipment should be secured and labelled with the contents and associated hazards, be properly loaded on the transport vehicles before leaving the biomining site.

Appendix D

Frameworks for impact and cost benefit analysis

While doing a cost benefit analysis for a biomining project, it is important to identify the potential costs and financial benefits arising from the project. It is to note that it was found during the study that calculating possible financial benefits requires a large amount of primary data through detailed surveys, and such data is not available in secondary sources in the Indian context

Table 9: A list of possible costs and financial benefits from a biomining project for cost benefit analysis considerations

Possible Costs	Possible Financial Benefits
Project Planning	**Revenues**
• Investigative studies • Obtaining permits and planning consent • Consultancy and design costs	• Sale of recyclable materials • Sale of RDF • Utilization of reclaimed biosoil and inert (either reused on-site or sold as construction fill materials)
Capital Costs	**Avoided costs**
• Site preparation • Equipment and plant	• Post closure care and monitoring • Purchase or development of new landfill • Liability for future remediation • Utilization of free biosoil and inert for low land filling
Operational Costs	**Other benefits**
• Labour • Fuel/energy • Maintenance of equipment • Rental of equipment • Transport and haulage costs • Landfilling of residual materials • Administration and regulatory compliance • Staff training • Gate fees for combustible materials • Monitoring fees	• Potential value of reclaimed land • Potential value of recovered void space

As an example, the Table 10 lists the possible benefit to cost ratio for four legacy waste dumpsites. The benefit has been calculated as the average potential value of the land parcel, taking market value in vicinity areas, as per property buying sites, as reference. The cost of biomining is taken from secondary sources. The possible sale value of recyclables is taken as INR 6 per kg, based on literature review and input from stakeholders. It has been assumed that at an average a site may have upto 1% recyclables recovered from the aggregates. This has been concluded from various consultations that the project team had with experts and biomining practitioners.

The Value for Money in taking up the Noida Sector 54 project seems higher than that for Pirana, based on simple benefit to cost analysis. But, such analysis should include detailed primary survey, including socio-economic-environmental impact analysis, to give an accurate assessment of the value that a particular biomining project delivers to the society.

Table 10: Benefit to Cost ratio in terms of value of land and possible revenue from recyclables for few biomining sites[5]

Sites	Perungudi, Chennai	Pachanady, Mangaluru	Pirana, Ahmedabad	Noida Sector-54
Benefit to cost ratio in terms of possible value of land *	9.4	10.6	12.2	19.2
Benefit to cost ratio in terms of possible revenue from recyclables**	0.06	0.1	0.25	0.03

Note: ** Benefit is calculated as the average value of the residential land parcel taking market value in vicinity areas as reference, cost is taken from secondary sources*

*** Based on primary consultations, Recyclables in waste is assumed to be maximum 1% by weight and its price at the market is assumed to be around INR 6000 per tonne*

Impacts on physical environment

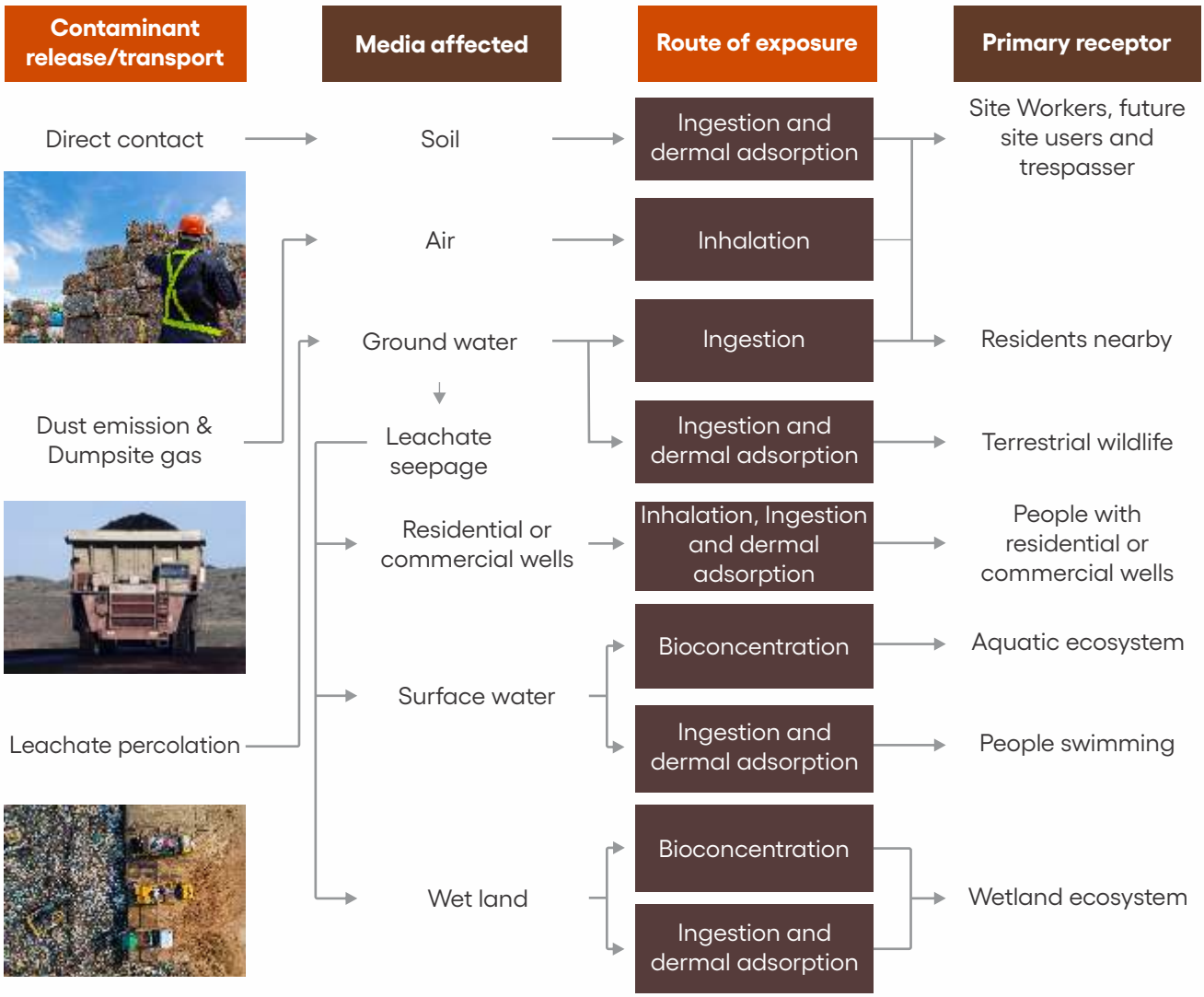
Identification of impacts from a legacy waste dumpsite is an important exercise, to understand the severity of contamination in the area, and plan accordingly. The impact assessment may include the following steps:

- Consultation to ensure the widest possible input to the definition of its scope, which should be iterative throughout the impact assessment process
- Identification of the probable zone of influence from the dumpsite
- Identification contaminants, route of exposure and primary receptors
- Identification and evaluation of human or ecological resources likely to be affected
- Assessment and definition of the significance of the dumpsites impacts
- Quantifying impacts, if possible or else recording impacts in qualitative terms
- Addressing the mitigation of these impacts as a key objective of the biomining project

The provides a framework for identifying potential sources and receptors for socio-environmental impact from a legacy waste dumpsite. These are remediated through scientific biomining of the site.

[9] Source: Research team's analysis based on secondary data.

Figure 25: Potential impact sources and receptors from a legacy waste dumpsite



Impact assessments are detailed long-term activities. As per the SWM Rules 2016, cleared dumps are not permitted for habitation for at least 15 years. This is because of unhealthy leachate below the site and formation of flammable and harmful landfill gases from waste pockets that may remain unexcavated. A study suggests that over a period, between 30-300 species per 100 acres may be affected due to exposure to landfills[10].

In India, there are not many research publications and assessment of impact of legacy dumpsites on the socio-economic-environmental parameters in the surrounding regions. However, some of the research work done around dumpsites in Chennai have explored the environmental impact from the legacy waste sites. One of the studies around Perungudi dumpsite undertaken in 2016 (K Prasanna et al, Rasayan J Chem) concluded that the concentration of the heavy metals Cr, Cd, Cu and Iron in the ground water samples were found to be beyond the permissible limit. While long-term exposure of excessive amount of Copper and Cadmium causes kidney damage and lung cancer, Chromium is also said to cause cancer if exposed for long time. The study also showed that the leachate was

[10] Source: Landfill Pollution Exposure, as accessed from PartnerOne Environmental

percolating from the landfill site to the ground water and was affecting the other subsurface water sources in the region. The findings of this study indicated that the contamination was severe in localities around the dumpsite. A GIS based study of the dumpsite undertaken in 2017 (S Mageswari et al, International Research Journal of Engineering and Technology) concluded that Dissolved oxygen in ground water was found to be far too lower than the stipulated limits given by the Indian Standards of Drinking Water (BIS 1500:991) and World Health Organization. Also, parameters like Sulphates, Iron, Phosphates and Specific conductance is present in higher concentration and exceeded the limits of standards. So, the ground water was not recommended for drinking purpose. Another study on the impact of Perungudi dumpsite on the Pallikaranai wetland in 2019 (Juniet Maria Jose et al, Nature Environment and Pollution Technology) suggest that water resources of the wetland posed ecological hazards. These toxic chemicals present in the leachate and sewage channels may cause toxic effects to biological organisms by potentially altering the genotype and phenotype of organisms inducing tumours, malformation, endocrine disruption and immune deficiency.

There are studies carried out by organizations like Tearfund[11] in association with Fauna & Flora International, Institute of Development Studies, & Wasteaid, which indicates that unmanaged waste contribute to human deaths between 400,000 and 1 million people each year in developing countries from diseases which are related to mismanaged waste. In addition to this, it is estimated that landslides in dumpsites have accounted for the death of150 people in the year 2017. Tearfund1 study also indicate that around 8-12.7 million tonnes of mismanaged post-consumer plastic waste ends up in the oceans every year.

Impact on climate change, potential for mitigation and adaptation

A. Impact on Climate Change due to GHG Emissions

Climate change Impacts life expectancy
Research indicates that if the annual average temperature increases by 1°C, the life expectancy at birth will decline by approximately 0.44 years. Additionally, a composite climate change index (combining temperature and rainfall) increasing by 10 points could lead to a decline of six months (0.50 years) in life expectancy. – The PLOS Climate Editors (2024)

As per India's National Communication to UNFCCC, the waste sector (solid waste and wastewater) emissions in 2019, accounted for nearly 2.34% of total national GHG emissions. Solid waste disposal itself contributed to nearly 22% of these GHG emissions. Indian cities have struggled to manage their waste and relied on linear methods of handling waste, leading to creation of legacy waste dumpsites. Bio-remediating dumpsites is solution for mitigating sources of green house gases. Further, segregation of waste and integrated waste management processes using concepts of circular economy, will lead to zero landfills or dumpsites, and is an adaptative solution to climate change impact from municipal solid waste.

There is disparity in methane emission estimates from Indian legacy waste dumpsites, which is mainly attributed to factors such as inconsistent data collection, variable landfill practices, informal waste disposal, methodological differences, changes over time, and regulatory variations. The total methane emissions from Indian landfills, calculated by CSIR-National Environmental Engineering Research Institute (NEERI) had been calculated to be 0.334 Gt per year or approximately 334 million MT per year. Literature review suggests that there are no studies conducted on the quantities of methane generated from individual dumpsites in cities all over the country.

[11] Tearfund@2019 : No Time to Waste-Tackling the Plastic Pollution before it is too late

The Table 11 presents the calculated average Methane emission in these four sites, based on LandGeM Landfill Gas Emission Model Version 3.03. This table also provides the calculated average annual global warming potential from Methane emission, in CO2e. The use of biomining in these sites, provides an opportunity to mitigate annual emissions, which would vary depending on the quantum of legacy waste dumped at the site, and the age of the waste. According to a study conducted by the Indian Space Research Organization, agriculture and waste sites contribute to about 14.43% of methane emissions in India. ISRO identified that Ahmedabad's Pirana dumpsite and Surat's Khajod dumpsites emit around 4,727 kg/hr and 4,705 kg/hr of methane, respectively.

Through this study, the LandGeM Landfill Gas Emission Model was used to predict the Average Methane emission at four sites. The data for these sites were taken from secondary sources and with relevant assumptions. For Pirana, Ahmedabad, the average Methane emission was found to be 4,658 kg/hr, as given below.

Table 11: Potential methane emission and global warming potential[12]

Sites	Perungudi, Chennai (2023)	Pachanady, Mangaluru (2023)	Pirana, Ahmedabad (2023)	Noida Sector-54 (2019)
Average Methane emission in kg/hr during the last year of dumpsite operations	1,532	307	4,658	75
Average annual global warming potential from Methane emission, in CO_2e which is saved from biomining	0.4 million MT	0.07 million MT	1.1 million MT	0.02 million MT

Source: *Research team's Analysis from secondary data*

Note: *The year in bracket represents the year taken into account for calculation*

Note 1 million = 10 lakhs (CO2e is usually represented as million MT)

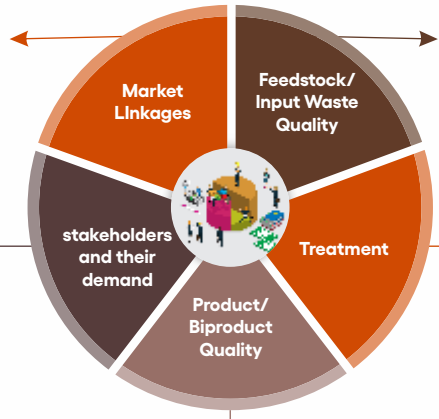
B. Potential for mitigation and adaptation

Bio-remediating dumpsites is a solution for mitigating sources of green house gases, when there is availability of organic fraction in waste. With organic waste stabilization, using micro-organisms, the fraction of waste, which would have decomposed (in aneorobic condition producing methane), is stabilized into carbon di oxide, and compounds of nitrogen. Carbon-di-oxide having GHG potential 21 times lesser than Methane, makes it a stabler gas and hence helps sequester. However as indicated the organic percentage in Indian legacy waste is limited, due to which mere biomining will not help mitigate green house gas mitigation, which necessitates looking into a holistic approach of looking into municipal solid waste management.

Approach to municipal solid waste management needs to change its perspective from linear to circular models, leading to climate change adaptation. This will result in a) waste being reused and recycled, thereby increasing the shelf-life of material, b) better management and handling of waste at the source, leading to source segregated waste stream c) waste is treated, using a set of methods comprising of physical treatment, biological treatment or thermal treatment, and d) minimum waste for disposal leading lower GHG emissions at the disposal facility. For effective waste management system, interdependencies are also to be addressed, as highlighted in Figure 26 .

[12] Source: Research Team's analysis based on secondary data

Figure 26: Circular Waste Management



- Collaborative participation of key Players and Stakeholders
- Established rates and quality of products
- Platforms to interact (technology integration for Demand and Supply)

- Planning Efficacy
- Awareness building (Citizens, Waste Workers)
- Segregation at Source
- Effective handling/ Infra/ Manpower

- Consumer Demand Assessment
- Awareness on roles for stakeholders
- Implementation of Policies to induce demand

- Policy and guidelines on QA/QC
- Testing and quality assurance supply chain
- Improved Governance
- Tried and Tested QA/QC methods

- Decentralized treatment leading to lower waste for end of pipe treatment
- Treatment Process considering back and front integration (Quality of waste/ Market Linkages)
- Replicability
- Supply Chain of Technology

Encouraging community engagement is also a favourable intervention to activate and promote environment stewardship towards mitigating and adapting to climate change effects from legacy dumpsites. Driving decentralised waste handling and processing systems at community and ward level help in converging salvageable waste while creating jobs within the community and supporting local economies. For Bulk waste generators in the community such as vegetable markets, large housing complexes, institutions etc. encouraging a proactive attitude towards waste management and encouraging segregating and recycling efforts at the source will instil a sense of responsibility and inclusivity at the grassroot itself. This will also go in line with the Government's approach undertake decentralized waste management, by treating decomposable waste at source, by the Bulk Waste Generators. Thus, this will ultimately lead to lesser organic waste at dumpsite, hence mitigating potential risks of GHG emissions.

Waste management systems need to be planned well in advance with mitigation and adaption methods which are forward looking, resilient with low carbon measures across its value chain;

Figure 27: Circular Waste Management

Value Chain	Mitigation Measures	Adaptation Measures
Waste Collection and Storage	• Source Segregation and Sorting • Demand and timelines driven waste collection to avoid GHG emissions • Real time monitoring to address spillage issues, prevent soil and water contamination • Selection of renewable energy & equipment	• Conduct climate vulnerability for existing infrastructure • Resource optimization through long term and short term projections ensuring adequate facilities for waste handling without resorting to environmental contamination • Waste collection coverage
Waste Transportation	• Transition to low emission vehicles • Route optimization through GPS enabled vehicles • Decentralized waste handling and processing systems to promote • environmental stewardship Energy management at Transfer Stations and storage facilities	• Design waste transportation system, with robust vehicle fleet management operations and maintenance plans • Climate risk assessments and Emergency Response Protocols for waste transportation infrastructure • Vehicle fleet management
Waste Treatment and Disposal	• Recycling rate enhancement with a robust supply chain for recovered material • Technology selection based on quality and characteristics of waste, availability of land, local climatic conditions and public consultations • Landfill should be scientifically capped and should be located away from human settlements • Landfill gas capture and utilization system	• Design an integrated waste management facility with appropriate plans for environmental controls • Enhance the resilience of infrastructure for composting and anaerobic digestion to ensure uninterrupted services during extreme weather events • Investigate and analyse all open and existing dumpsites

Appendix E

Consent to Establish and Operate as regulatory instruments for effective monitoring

1. Background

As per the existing regulatory requirements, Consent to Establish (CTE) and Consent to Operate (CTO) are not required for taking up biomining of legacy waste dumpsites. With the need for CTE and CTO, the State Pollution Control Boards (SPCB) do not directly monitor these biomining projects, hence there is limited traceability or accountability in such projects. Through stakeholder consultations it is understood that policy makers realise the importance of mandating CTE and CTO, while many stakeholders feel that these shall be additional regulatory burden on the ULBs.

As part of this study, it has been observed that without any such regulatory requirements for monitoring by the SPCBs, there may be several cases where ULBs are not following due process of undertaking scientific biomining. For example, several stakeholders identified cases where ULBs are not doing proper stabilization of waste, not adhering to EHS requirements such as proper fire safety measures, air, and water quality monitoring, etc. Further RDF is found to be lying at dumpsites for several months, posing severe fire hazards. Mandating CTE and CTO for would enable SPCBs to conduct periodic inspection of the projects to ensure the compliance of various provisions of environmental regulations, and conditions stipulated in respective CTOs (Consent to Operate).

It is suggested that the ULBs become the applicant for CTE and CTO, while the contractors adhere to the CTE and CTO requirements for the ULB. This shall encourage collaboration and coherence between the different stakeholders involved.

2. Benefits of mandating CTE and CTO

2.1. Improving Traceability

- Mandating CTE and CTO ensures that biomining projects adhere to established environmental regulations. Complying to these consent requirements through necessary documentation aids in creating a transparent trail, making it easier to trace the origin, methods, and impacts of the biomining operations.
- CTO requirements necessitate continuous monitoring of the biomining processes. This real-time data facilitates accountability, enabling authorities to identify and rectify any deviations from the approved environmental standards.
- CTE is required before establishing the biomining unit. CTO is necessary to be obtained after equipment are established, but before undertaking biomining operations.

2.2. Environmental Benefits:

- CTE and CTO mandates enforce rigorous standards for air, water, and soil quality. By

adhering to these standards, biomining projects can effectively control emissions, minimizing the environmental impact and safeguarding respective ecosystems.

- With CTE and CTO requirements, biomining projects are compelled to implement efficient waste management practices. This includes responsible disposal of by-products, preventing soil and water contamination.
- Stringent environmental clearances like these consents help protect biodiversity by preventing the degradation of surrounding ecosystems. This is crucial in regions with rich biodiversity, ensuring the long-term ecological balance.

2.3. Other Benefits of CTE and CTO Mandates:

- Companies involved in biomining could obtain CTE and CTO, demonstrating their commitment to the processes and environmental performance. This not only safeguards the environment but also reduces the risk of legal complications and financial penalties.
- Mandating CTE and CTO fosters public trust by assuring communities that biomining projects are conducted responsibly. This confidence is essential for the sustainable growth of the biomining industry in India.

3. Suggestive documentary requirements for obtaining CTE and CTO

3.1. Requirements for CTE

- Detailed Project Report (DPR) with details of the proposed processes, workforce, budget, etc.
- Environment baseline for air, noise, soil, surface water, ground water
- Land Documents, including contour details
- Site Plan for the project
- NOC (No Objection Certificate) from local body
- Process flow chart with technologies, and proposed capacity of operations
- Google map images identifying vulnerable locations within 1 km radius (or 5 km radius for larger projects)
- Photograph or video of the site before initiating biomining activities
- Environment and Risk Management plans
- Plan for disposal of aggregates (RDF, biosoil, inert, C&D waste)

3.2. Requirements for CTO

- Adherence report to CTE requirements
- Environment and Risk Management plans execution details and EHS provisions
- Details of established processes
- Other necessary permission, if any, e.g. water supply, energy supply, etc.
- Permission letters from receivers for aggregates (RDF, biosoil, inert, C&D waste)
- Photograph or video of the site after establishing biomining activities

Appendix F

Centralized Certification and Traceability Mechanism for RDF and Biosoil

1. Background

- During the process of biomining of legacy waste, Refuse Derived Fuel (RDF) and Biosoil are recovered aggregates. Historically, biomining contractors have been tasked with the responsibility of their disposal, typically diverting RDF to cement plants or waste-to-energy facilities for co-processing and Biosoil for landfilling.
- But stakeholder consultations as part of this study indicated that at times contractors are sidestepping proper disposal practices. Instead of adhering to environmentally sound methods, they resort to capping RDF beneath the dumpsite's surface or even resort to burning it. This alarming pattern poses a significant threat to our environment and demands a proactive approach. Similarly, biosoil is seen being utilized for agriculture purposes without proper toxicity assessments.
- To address this issue and ensure the responsible disposal of RDF and biosoil, the implementation of a Traceability Portal could be facilitated at the level of some anchor institution like the CPCB.

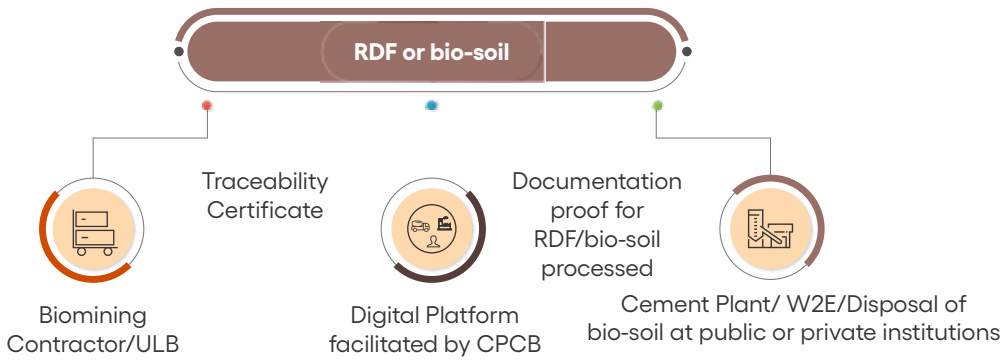
2. Objective

- The primary goal of this portal would be to establish transparency and accountability in the RDF and biosoil disposal process. Through this online platform, authorities could closely monitor and regulate the actions of biomining contractors, ensuring compliance with environmentally sustainable practices. Further certificates generated from this platform could be used as a proof of experience of the contractors, while bidding for new projects. This would facilitate credibility and would encourage co-processors to utilize RDF from biomining projects. This may encourage a market led valuation of the RDF, which would also depend on the quality of waste and effectiveness of biomining project.

3. Process Flow

- The process flow for operation of this proposed portal is described in , followed by detailed description of the proposed process.

Figure 28: Process flow for generation of traceability certificate



3.1. Stakeholders

- Entities Involved include Cement plants, Waste to energy plants, Any receivers of biosoil, Urban Local Bodies (ULBs), Biomining contractors

3.2. User Registration

- Stakeholders register on the portal submitting detailed information including legal details (if company) or pan details (if private individuals), capacity or demand of biosoil/RDF, geo-referenced location of the entity, etc.
- The entities shall be auto verified through their PAN/TAN numbers

3.1.2. Dashboard Access

- Verified entities gain access to personalized dashboards highlighting their transaction details, with a repository of issued certificates in their name

3.1.3. Certificate Request

- Cement plants and waste to energy plants initiate a certificate request for RDF
- In case of biosoil being taken by a private individual, the request may be initiated by the contractor or the ULB
- Provide necessary details such as date of receipt of RDF/Biosoil, utilization purpose, quantity, etc.
- Both the contractor/ULB and the receiver would need to validate details

3.1.4. Data Entry for Certificate

- Enter data and upload documents using standardized forms, including Weighbridge tickets, Processing logs, Quality analysis reports
- 3.1.5. Approval Process
- CPCB would review the certificate request and associated data
- Checks accuracy of data against industry standards, if necessary
- Verifies compliance with biomining guidelines such as quality requirement
- Approval criteria would include accurate data, proper documentation, and adherence to processing regulations

3.1.6. Certificate Generation

- The system generates a unique co-processing certificate upon CPCB approval
- Certificate details include Unique Certificate ID, Processing date, Quantity processed, Name of Issuer, Name of the entity the certificate is issued to, Digital signature for authenticity, etc.

3.8. Certificate Issuance

- Notification would be sent to the requesting plant about the approved certificate
- Copies of certificates would be sent to the relevant ULBs associated with the biomining project

3.9. ULB Verification

- ULBs verify the received certificates against actual RDF processing at biomining sites
- Cross-check data with their own records and conduct site inspections, if needed

3.10. Record Keeping

- The portal maintains a secure database of all certificates, approvals, and transaction records

3.11. Reporting and Analytics

- Reporting and analytics tools for CPCB, ULBs, and contractors may be provided in the portal
- CPCB can generate reports on monthly processing volumes, biosoil utilization, ULB-wise contributions, and contractor performance, etc.

3.12. Periodic Reviews

- CPCB would conduct periodic reviews of the portal's functionality, security, and overall performance
- Implement updates and improvements based on feedback and evolving biomining and SWM rules





Appendix G
Plastic EPR Credits from RDF Processing

1. Background

In the biomining of legacy waste, the recovery of Refuse Derived Fuel (RDF) is a crucial component for successful project execution. However, Urban Local Bodies (ULBs) and Biomining contractors find it increasingly difficult to dispose of RDF with cement plants and waste-to-energy facilities. Most of these plants are not compensating for the received RDF, making it economically challenging for ULBs and contractors to transport the material to distant co-processing facilities.

Amidst this challenge, Extended Producer Responsibility (EPR) of plastics may be utilized as an alternative method for RDF utilization and revenue generation, The majority of RDF contains plastic waste, and by strategically segregating this plastic component, EPR could be achieved with co-processing. This opens an avenue for ULBs and Biomining contractors to gain revenue by leveraging the Plastic Waste Extended Producer Responsibility (EPR) credit system.

The Plastic Waste Amendment Rules 2024 mention that the Central Pollution Control Board shall issue guidelines for authorisation of agencies for establishment of electronic platform for trade of Extended Producer Responsibility certificates between obligated entities. The Central Pollution Control Board shall develop the guidelines and shall fix the highest and the lowest price for extended producer responsibility certificates which shall be equal to 100 % and 30 %, respectively, of the Environment Compensation leviable on the obligated entities for non-fulfilment of Extended Producer Responsibility obligations, these rules. The exchange price of Extended Producer Responsibility certificate between registered entities through the portal shall be between the highest and the lowest prices as fixed above. Such a platform could be utilized for trading certificates generated from plastic waste processed from biomining projects.

The main challenge in ensuring EPR system for bio-mined RDF would be to assess the quality of RDF, the type and percentage of different category of plastic content for EPR eligibility.

2. Steps in line with currently executed EPR to generate plastic EPR credits from RDF

- Plastic content would be separated out of RDF which contains plastic, cloth, rubber, and other flammable materials
- The separated plastic content would be further segregated into three categories namely: Rigid, Flexible and Multi-Layer Plastic (MLP)
- These segregated plastic categories would be sent to respective partnered processors such as recyclers, waste to energy plants, cement plants, etc. for processing
- The processor would generate EPR credits after processing the plastic waste and would generate revenue by selling the credits to Producers, Importers or Brand owners (PIBOs)

- EPR revenue could be shared between plastic waste processors (recyclers) and biomining contractors or ULBs

3. Limitations

- It is difficult to segregate the plastic content category wise from the RDF
- Cost of segregation would be substantially higher which may make the process financially unviable, and would necessitate innovations in this regard

Appendix H

A discussion on regulatory ecosystem on disposal of aggregates

1. Market linkage and tripartite Memorandums of Understandings (MOU) for collaborative disposal of segregated aggregates

The SBM Urban 2.0 model RFP for legacy waste remediation suggests that the disposal linkages for the segregated factions like RDF or biosoil be identified jointly by the ULB and the contractor. The process and timelines for the same should be identified in the work plan prepared by the contractor and agreed with the ULB. As per this study, it is understood that while the large contractors may have appropriate contacts with co-processing cement plants or waste to energy plants, the local contractors shall be better placed at identifying locations for disposal of the biosoil or the C&D waste. In this case, it is important that the ULB plays an active role, and preferably identify these linkages prior to onboarding of the contractor. Further, tripartite MoUs may be encouraged between the ULB, the contractor and the coprocessor/receiver of aggregates.

2. Disposal of RDF

The SWM Rules 2016, through its Clause 15 recommends that preference should be given to decentralised processing to minimize transportation cost and environmental impacts such as waste to energy processes including refused derived fuel for combustible fraction of waste or supply as feedstock to solid waste-based power plants or cement kiln. Further, clause 18 of the Rules direct that all industrial units using fuel and located within 100 km from a solid waste-based RDF plant shall make arrangements to replace at least 5 % of their fuel requirement by RDF so produced.

Further, clause 21 of the SWM Rules 2016 provides guidance on the waste to energy processing. It suggests that non-recyclable waste having calorific value of 1500 K/cal/kg or more shall not be disposed of on landfills and shall only be utilised for generating energy either or through RDF or by giving away as feed stock for preparing RDF. High calorific wastes is suggested to be used for co-processing in cement or thermal power plants. The ULB or the contractor or any agency appointed by the government may setup waste to energy plant, with due approval from the SPCB.

As per this study, it has been observed that there are only few coprocessing units in India, and only about 50 cement plants and very few waste to energy plants are currently equipped with such coprocessing arrangements. Further, it is understood that very few industries may have replaced 5% of their solid fuel with RDF, while the Rules had suggested that this should be done withing 6 months of introduction of SWM Rules 2016.

The 'Guidelines for Disposal of Legacy Waste' issued by CPCB in 2019, suggested that non-recyclable plastic material should be sent for road making or to RDF units or cement plants. The coarsest fraction may have a lot of combustibles which can be baled and supplied as Alternate Fuel Resources in cement kilns or boilers. But it is understood in consultation with stakeholders

that non-recyclable plastic being inflammable in nature, along with having potential for being used as RDF, should not be used in road making. Rather, efforts should be taken in ensuring that such plastic is converted into RDF.

The 'Guideline on usage of RDF in various industries' issued by CPHEEO in 2019 suggests that the clause 18 of the SWM Rules 2016 may be modified, directly cement plants located within 400 km from a solid waste-based RDF plant to make necessary arrangements to utilise RDF following a phase wise manner at price fixed by State Government: It suggests that at least 15% of the fuel should be replaced by RDF, subject to availability of RDF. It is to note that, the study identified transportation of RDF to coprocessing units as a key cost for most biomining projects. Further, replacement of up to 15% of solid fuel with RDF may not be practical for most coprocessors given lack of continuous source of RDF or due to lack of proper quality of RDF from biomining operations. Here it is important that the RDF of biomining operations be used as a dovetail for the RDF from MSW and Agri-waste, which have scope for much reliable and continuous supply.

Wherever RDF is being supplied to coprocessors, guidelines must be issued on pricing of RDF, wherein, some cost sharing mechanism may be planned between the coprocessor, the contractor and the ULB. The cost sharing is built upon the fact that while the ULB is disposing its waste, the contractor needs to make some business sense out of this disposal and the coprocessor is being made available a cheaper fuel alternative for its operations.

To reduce the dependence on cement plants, the government of India may consider supporting applied Research and Development for conversion of RDF to liquid/solid/ gas fuel or other innovative options with potential replication in the form of pilot plants. If successful, this will open additional avenues for RDF utilization. For example, a commercial plant for alternative fuel from RDF is being operated in Ahmedabad, taking feed from the Pirana legacy waste dumpsite.

While some reports have suggested that ULB should themselves invest and built waste to energy plants, this study suggest that ULB should not invest in such activities. A market led mechanism should be encouraged, where the private gauges the value in building such plants at a particular ULB and may accordingly invest in such a project. Further, to provide an impetus for RDF standardisation mechanism and its utilization, collaborative measures on research and development needs to be facilitated with collaboration of different stakeholders, including the government departments, academia, cement organizations, biomining contractors, etc.

3. Disposal of Biosoil

The 'Guidelines for Disposal of Legacy Waste' issued by CPCB in 2019 suggest that the finest fraction in segregated aggregates will be organic matter plus fine soil, called 'bio-earth' which is also referred to as biosoil. The guidelines suggest that this can be used as soil improver, especially for restoring alkaline or saline soils to fertility, or to grow some vegetation for erosion control. This could be used in mined areas for controlling deforestation. It may also be used as landscaping or gardening or road medians within the ULB or the site, or as organic manure in tree pits. As specified in the CPCB guidelines for the disposal of legacy waste (2019), fine materials in the size range of 4-6 millimetres are referred to as 'bio-earth' or 'good earth' material, which can be utilised by farmers as a soil enricher, provided they comply with the Fertilizer Control Order standards. The fine soil-like material can also be used as a filler material for low-lying areas. However, in most of the cases, the fine-soil like material excavated from the legacy waste dumpsites do not comply with the standards. These guidelines also suggests that the biosoil should be periodically for heavy metals. Hence it is important to check for a user's

willingness and consent of using it. Through this study it is understood that while biosoil mostly is not found to have any toxicity, still it should not be used for food grade purposes without stringent testing and monitoring.

Given the fact that biosoil is recovered from historically contaminated sites having mixed garbage, scientific testing and assessment are critical prior to its usage in gainful applications. This includes testing for physical and chemical properties, identifying potential contaminants and ensuring compliance with environmental regulations. However, the CPCB guidelines do not provide specific information regarding the parameters that should be tested or the threshold limits, particularly for the presence of toxic metals. It is necessary that dedicated guidelines are published by the Government of India towards management and utilization of this biosoil/bio-earth or good earth material.

4. Disposal of recyclables

It has been observed that usually the quantum of recyclables recovered from biomining activities are low. Such recyclables may be sent to Material Recovery Facilities (MRF) for further processing and disposal with recycling contractors. As per the 'Guidelines for Disposal of Legacy Waste' issued by CPCB in 2019, the recyclables recovered from the bio-mining process should be sent for recycling as per the quality of the material. The recyclables like plastic, glass, metals, rags, and cloth recovered from the waste during screening should be sorted out and preferably cleaned before sending to recycling industries. These recyclables should also be randomly sampled by a NABL laboratory and tested for heavy metals, salinity/electrical conductivity, and leachability to ensure no environmental harm during use. In some cases, like in Pachanady dumpsite in Mangaluru, the ULB's MRF facility is provided in the vicinity. Such integrated arrangements encourage value addition and streamline the segregation process.

5. Disposal of Construction and Demolition (C&D) Waste

As per this study, it is observed that there is good demand for C&D waste, which is recycled or used back as construction material. The clause 15 of the SWM Rules 2016 suggest that the recovered construction and demolition waste recovered from the bio-mining process may be sent to a C&D processing facility if suitable for production of building materials. The heavy fractions may be used for road shoulders or for plinth filling. Stones and concrete, if any, can be used for road sub-grade, or for crushing. recycling and reuse in the construction industry

It is important that C&D waste is management in accordance with the C&D waste management rules 2016. To avoid need for longer transportation, C&D waste processing units could be built in vicinity to the dumpsite. An example of such an integrated planning is seen at the Perungudi dumpsite in Chennai.

6. Disposal of Inert

Inert are a key constituent of the segregated aggregates. As per the SWM Rules 2016, only the non-usable, non-recyclable, non-biodegradable, non-combustible and non-reactive inert waste and pre-processing rejects and residues from waste processing facilities may be allowed to go to sanitary landfill sites. It is important that in the absence of appropriate linkages for disposal of inert, a designated site is identified by the ULB for dispose of inert by the contractor.

Figure 29 Case: Use of inert from biomining in highway construction

Government of India has linked road construction with the Swachh Bharat Mission 2.0 by using inert material from solid waste in the building of embankments across National Highways, the major component of which is generated by bioremediation and bio-mining of this legacy waste. Through his initiative, the soil requirement for road construction can be met efficiently eliminating the requirement of procurement of soil from agricultural field. Ministry of Road Transport, in collaboration with the National Highways Authority of India has taken two pilot projects for utilization of inert material in road construction. The initial pilot project took place in Delhi-NCR, specifically on the urban extension road and the DND-Sohnaspur of the Delhi-Mumbai Expressway. The second project involved the use of inert solid waste material on the Ahmedabad-Dholera Expressway.



Appendix I
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