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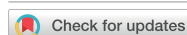
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Making coal mine repurposing ‘fit for purpose’ in the Global South: why methodological flexibility is paramount

Aishwarya Ramachandran^{1,*} , Stephen M Chignell² and Vaibhav Chowdhary¹¹ Ashoka Centre for a People-centric Energy Transition, Ashoka University, New Delhi, India² Department of History, School of Humanities, University of Bristol, Bristol, United Kingdom

* Author to whom any correspondence should be addressed.

E-mail: aishwarya.ramachandran@ashoka.edu.in**Keywords:** energy transition, mining, repurposing, post mining land use, coal

1. Introduction

Myriad challenges complicate pathways to a just transition away from coal. Among the top coal producing and consuming economies are several lower- and middle-income countries (LMICs), including India, Indonesia, and South Africa, that are balancing energy transition efforts with the need for energy security and accessibility. In many coal producing regions, decades of coal mining have supported local economic growth, and coal companies have provided much needed schools, healthcare, and community centers. However, many have become ‘monoculture societies’, where fossil fuel retirement will not only cause unemployment among formal and informal mine workers but also reduce local business income, force outmigration, and drive sociocultural upheaval (Kime *et al* 2023).

Repurposing closed and abandoned mine sites offers a transformative opportunity to mitigate the socioeconomic and environmental impacts of mining. Repurposing occurs after or alongside mine closure activities (e.g. remediation and rehabilitation), and involves converting mine land and infrastructure into new, productive uses (e.g. reservoirs, renewable energy sites, wildlife habitats, or recreational areas), often with the goal of mitigating employment loss while supporting economic diversification and sustainable development (Ronyastra *et al* 2023, Pagouni *et al* 2024, Matanzima *et al* 2026).

The selection of specific post-mining land uses (PMLUs) impacts several stakeholder groups (e.g. workers, governments, and local communities), and thus a variety of policies, decision-making frameworks, and methods for PMLU planning have been recently developed (see Pagouni *et al* 2024 for a global review). These resources and practices overwhelmingly come from high-income contexts such as the United States, Canada, Germany, Poland,

and Australia (Matanzima *et al* 2026), paralleling the academic literature on just transitions more broadly (Diluiso *et al* 2021, Gather *et al* 2025, Mbeva *et al* 2025).

Although such examples can offer guidance, they may have limited applicability to LMICs, which are often dealing with limited resources, lack of data, misaligned incentives, unclear land tenure, institutional fragility, and limited alternative employment and business opportunities (Bainton and Holcombe 2018, Measham *et al* 2024, Gather *et al* 2025). These challenges are often compounded by legacies of (neo)colonialism and unequal global resource governance structures. Moreover, mine closure practices were codified in mature mining economies, where the emphasis was on restoring the ‘natural’ pre-mining landscape (Limpitlaw and Briel 2014). Yet the cost of restoration alone may be far greater to rural communities in LMICs where social infrastructure is more urgently needed and was previously provided by mining companies.

In addition to its Global North focus, mine closure has historically been perceived and approached as a technical process focused on meeting safety and regulatory requirements (Huang *et al* 2022). Researchers and policymakers increasingly call for a move away from ad-hoc, highly technical, site-specific strategies toward approaches that integrate biophysical and engineering aspects with regional cultural, social, and economic dimensions (Ronyastra *et al* 2023, Measham *et al* 2024, Worden *et al* 2024, Matanzima *et al* 2026). This shift emphasizes transdisciplinarity—integrating methods and perspectives from multiple academic disciplines and non-academic stakeholders—to incorporate the range of social and environmental values held by local communities, former mine workers, and other stakeholders (Matanzima *et al* 2026).

Despite these developments, the academic literature on mine repurposing remains largely siloed. Engineering and geosciences approaches prioritize structured decision making based on quantitative multi-criteria decision analysis (MCDA), often combining expert-driven criteria weighting with geographic information systems (GIS) (Pagouni *et al* 2024). This emphasis on technical rigor often comes at the expense of meaningful stakeholder engagement. Arratia-Solar *et al* (2022) found that of 22 studies applying MCDA techniques to PMLU planning, only two involved community stakeholders. Moreover, technical approaches that do include stakeholder perspectives in the PMLU selection process often consider their views last (e.g. Amaro *et al* 2022, Arratia-Solar *et al* 2022), reducing stakeholders to endorsers of expert-driven plans with little ability to shape project design.

In response to this imbalance, a growing body of social science literature is focused on understanding community perceptions, local knowledge, and power dynamics of mine closure and repurposing. These approaches use qualitative methods like interviews, focus groups, stakeholder panels, and participatory mapping (Everingham *et al* 2018), but rarely integrate biophysical or technical analyses into their analysis (an exception is Worden *et al* 2024). This disciplinary disconnect between ‘bottom-up’ and ‘top-down’ approaches often results in one side of the repurposing equation left unaddressed. The result is a proliferation of increasingly nuanced case studies and frameworks, but little guidance on how to integrate them.

There is also a disconnect between academia and practice, as governments and the mining industry rarely bring insights from academics into decision-making processes (Matanzima *et al* 2026). A key factor, particularly in LMICs, is that existing frameworks are not designed for contexts where data, time, and resources are limited. As a result, technical approaches based on highly structured GIS-based MCDA that require collecting, processing, and weighting numerous GIS layers are unlikely to get the necessary support from decision-makers. Similarly, running multiple rounds of interviews and focus groups with communities to gain detailed understanding of their knowledge, needs, and priorities may be ideal from a social science perspective, but our experience in Ethiopia and India suggests these demands can be onerous for local officials in LMICs. Such engagement is costly—demanding travel, facilitation, and repeated visits—and can be politically sensitive, as inviting stakeholder input may unsettle existing power dynamics.

In addition, feelings of suspicion and distrust of researchers by stakeholders, along with unrealistic expectations about project outcomes, can necessitate on-the-fly revisions to the methods being offered to or co-developed with stakeholders (Thomas

et al 2018). Again, these issues are likely to be more pronounced in LMICs, where governance and institutional capacity is often limited. Consequently, methods which appear highly technical, expensive, or time consuming at the outset are unlikely to be adopted (figure 1). Flexibility is thus key for transdisciplinarity in development contexts, particularly for researchers or consultants working with an array of stakeholders in different sectors (Thomas *et al* 2018, Bursztyn and Purushothaman 2022).

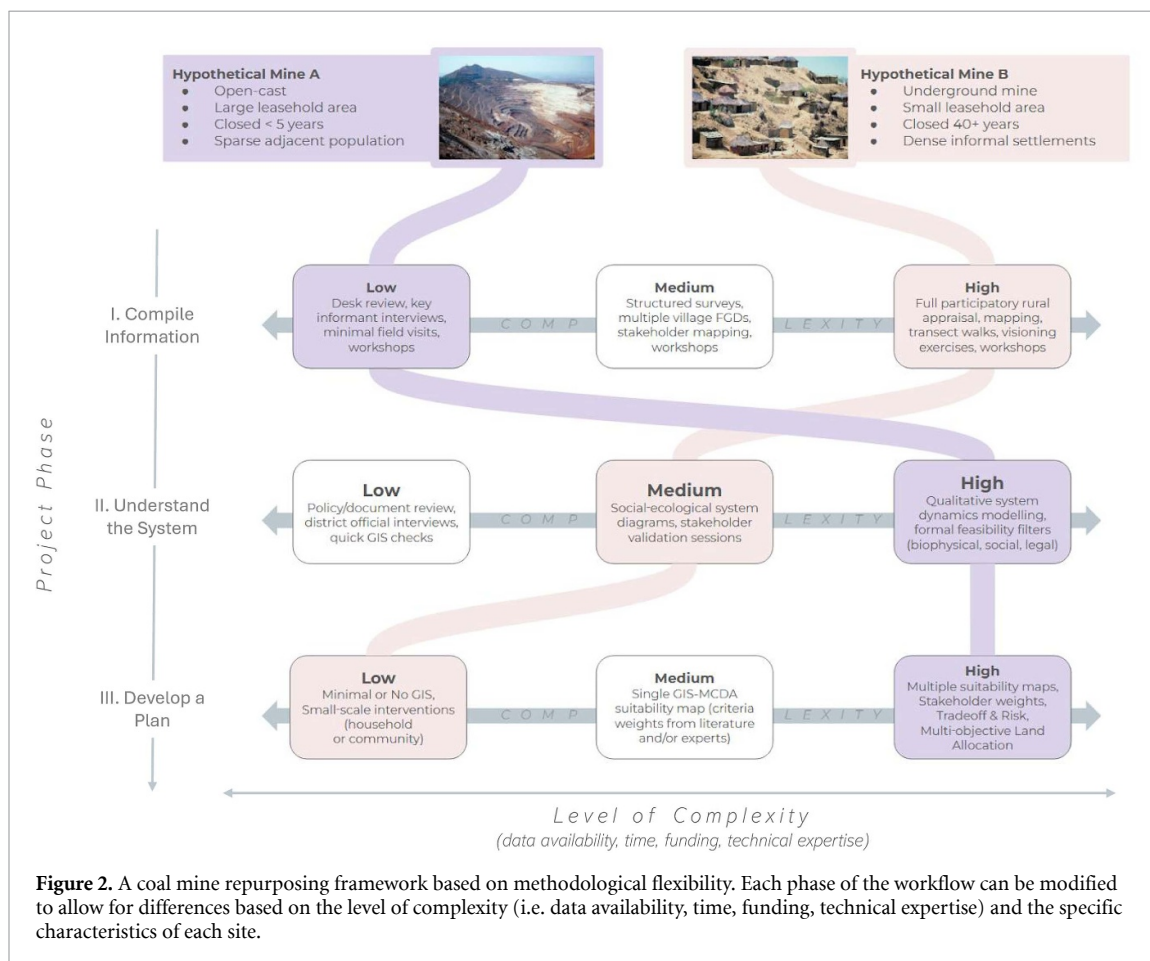
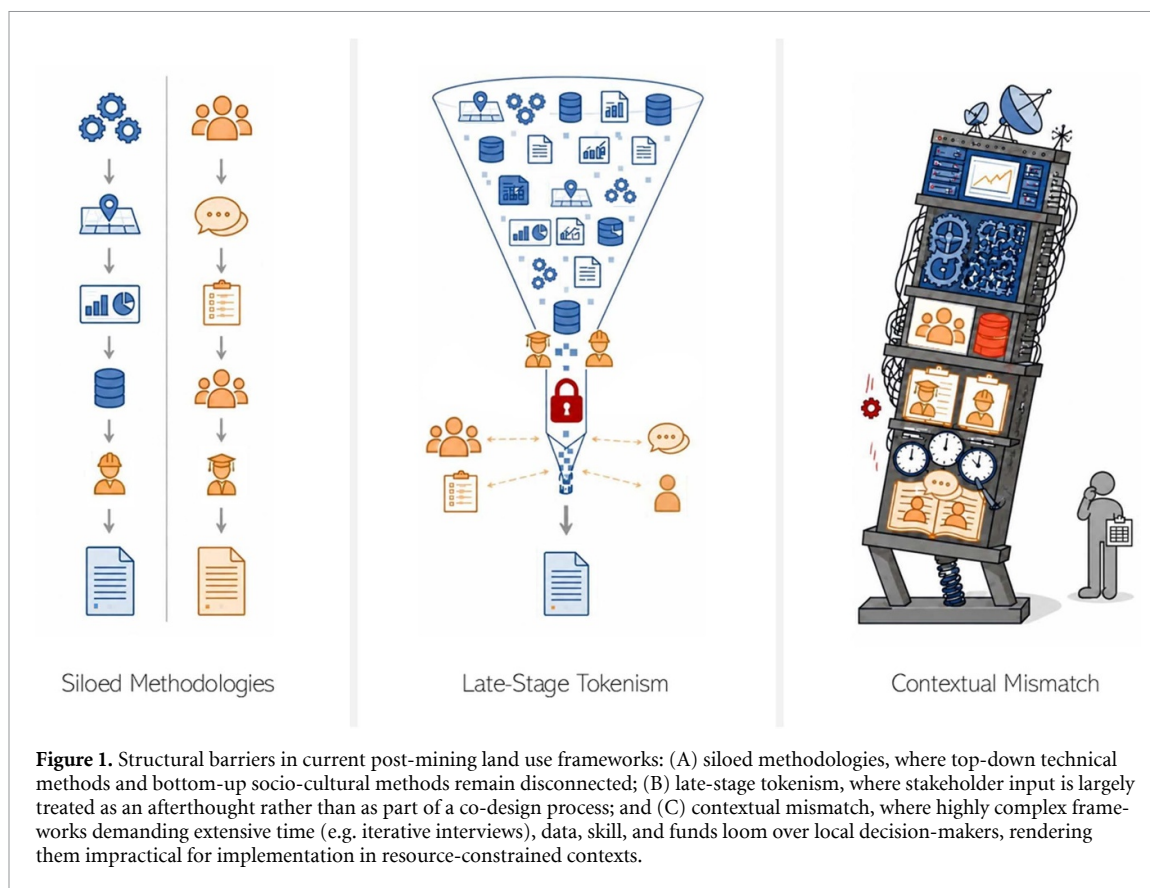
2. A flexible approach to repurposing mine sites in LMICs

There is no ‘one-size-fits-all’ process for transitioning away from coal (Xie *et al* 2025). If researchers expect decision-makers in LMICs to implement structured approaches to coal mine repurposing, they need to design their frameworks with pragmatism and foresight. Just as architects build flexible structures with loose joints so buildings move with seismic forces instead of collapsing, coal-mine repurposing frameworks should be designed to shift with sudden changes in context.

Here, we demonstrate what adding flexibility to each phase of a repurposing framework might look like (figure 2). We suggest three overarching phases: (I) compiling relevant information about the mine site, stakeholders, and regional context; (II) understanding the surrounding social-ecological system (SES) and considering how potential PMLUs may affect its dynamics, and; (III) developing a repurposing plan that is both technically suitable for the site and matches stakeholder priorities. In practice, each phase will consist of several steps, but to retain flexibility, we do not prescribe what exactly those steps should be. Rather, we place each step along a spectrum of low-medium-high complexity, allowing for differences in data availability, time, and resources.

I: Compile information & identify stakeholder priorities

Phase I involves compiling information about the mine site, its history, and the priorities of local and regional stakeholders. This phase begins with mapping the diverse actors (e.g. state entities, domestic firms, and multinational corporations) that own and operate the mine, a task typically carried out by contracted researchers or consultants. Including social context and stakeholder input up front mitigates the risk of it being tacked on tokenistically or left out entirely; this ensures proposed solutions are appropriate and accepted, supporting transdisciplinary co-design and long-term sustainability. Low-complexity activities in this phase might include reviewing mine closure plans and reports on mine-affected communities, and interviewing mine staff,



government officials, and/or community leaders. A medium-complexity approach might add structured stakeholder engagements such as focus group discussions, visioning exercises, or participatory mapping. A high-complexity approach could involve iterative multi-stakeholder engagement and time-intensive methods such as transect walks and cost-benefit analysis.

II: Understand the system & match priorities to PMLUs

The longer-term social-ecological resilience of post-mining areas depends on forming positive feedback loops that reinforce environmental benefits and human well-being in not just the mine site, but the surrounding region. This expanded scope requires understanding the mine site as an interconnected SES comprising human (social, economic, cultural, institutional) and ecological (biophysical, species, ecosystem processes) components and the interactions between them (Cao and Tang 2025).

Phase II seeks to develop this SES understanding of the mine site and use it to match stakeholder priorities identified in Phase I with a shortlist of PMLUs. Low-complexity activities might involve reviewing policy documents, reports, interviews with district officials, and quick checks of GIS data for the region. A more complex option would be to represent the current SES of the mine site visually, such as by constructing causal loop diagrams (CLDs) documenting relevant variables, their relationships, and feedback loops (e.g. Dissanayake *et al* 2025). If significant time and expertise are available, this step could include in-depth workshops with community representatives, closure planners, local government, NGOs, and scientific experts.

Once a baseline understanding of the SES has been achieved, the next step is to use this understanding to screen each potential PMLU. This screening might involve consulting summaries of stakeholder priorities collected in Phase I, revisiting and revising the CLD to incorporate each potential PMLU, or using qualitative system dynamics modeling software to simulate short and long-term changes to the SES (e.g. what might employment levels look like in 5–10 years). The goal is to produce a shortlist of PMLUs and validate it with communities and regional stakeholders, explaining how Phase I consultations informed selections, updating the SES representation as needed, and reaffirming consent.

III: Assess suitability & develop a plan

Phase III identifies the most suitable areas of the mine site for each PMLU on the stakeholder-approved shortlist, and it uses this information to develop a

site-specific repurposing plan. The first step involves conducting a suitability analysis of each shortlisted PMLU based on multiple biophysical and social criteria. As with the previous phases, the level of complexity should match the site's context and available resources (data, time, funding). For example, mines in densely populated settings may be better suited to small-scale, iterative repurposing projects, as large-scale plans risk exceeding community tolerance and generating conflict without ongoing dialogue (Krzemień *et al* 2026). Here, a low-complexity analysis based on continued interviews and focus groups might be most appropriate. Larger areas with limited human settlements could use GIS-MCDA to produce suitability maps for each PMLU on the shortlist, and develop repurposing plans based on patches of highly suitable areas.

A more complex approach could involve incorporating additional expert- and/or stakeholder-derived weights into the GIS-MCDA, accommodating varying levels of decision risk tolerance and inter-criteria tradeoff, or employing land allocation algorithms. These algorithms assign land parcels to different uses by iteratively optimizing across competing objectives (e.g. maximizing green space versus maximizing residential or industrial development). The resulting draft maps and plans should be validated with stakeholders to confirm that siting, management rules, and expected benefits meet expectations, and that impacts (positive and negative) are understood.

3. Moving forward

Rather than imposing complex methodological demands up front, focusing on small-scale wins (e.g. demonstrating tangible results and maintaining continuity) may be more effective in the initial stages of stakeholder consultation. Methodological flexibility in mine repurposing contributes to a just transition by allowing Global South stakeholders to selectively adopt Global North practices where useful while rejecting or adapting others. Crucially, social insights have been not only siloed from technical analyses but applied too late to shape decisions. The flexibility we advocate front-loads social engagement and returns to it throughout—implying a shift in resources away from costly, abstract analyses and toward giving local stakeholders a genuine voice in their post-mining futures.

Data availability statement

No new data were created or analysed in this study.

ORCID iDs

Aishwarya Ramachandran  0000-0002-1590-741X

Stephen M Chignell  0000-0002-8277-4338

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