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Post-mining land use selection using Land iQ and the battery energy and storage site suitability tool

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Abstract

Mine closure across Australia presents a portfolio-scale challenge: thousands of sites require transition plans, yet most post-mining land-use (PMLU) assessments are conducted on a site-by-site basis. Identifying land for development, such as renewable energy, residential and industrial sites, is also a profound challenge. By integrating these 2 challenges and investigating the potential of redeveloping brownfield sites rather than greenfield sites, we present a solution, albeit currently only at a high level, that could simultaneously yield development land and remediate brownfield sites. Examples of repurposed mining sites are uncommon, but there are innovative case studies both in Australia and globally. This paper presents a scalable, screening-level multi-criteria analysis (MCA) framework that evaluates the relative suitability of mining and mine-adjacent land parcels for 6 candidate PMLUs across New South Wales (NSW) and Queensland (QLD). Drawing on publicly available mine location data, the Land iQ platform and battery energy storage system (BESS) site selection feasibility attributes, the framework scores each parcel across 4 MCA dimensions: physical feasibility, planning and environmental constraints, infrastructure and access, and strategic alignment. Results are reported as portfolio-level distributions and aggregated patterns rather than site-specific recommendations, supporting early-stage strategic planning for governments and portfolio owners. The framework demonstrates that transparent, reproducible screening can reveal spatial patterns in re-use potential, identify dominant constraints and reveal multi-option sites suitable for diverse post-closure futures.

Keywords: *post-mining land use, renewable energy, site selection, development, site suitability*

1 Introduction

Mine closure is an increasingly pressing challenge for the Australian mining industry (Simpson et al. 2025). With thousands of active and legacy mine sites distributed across all states and territories, governments and mining companies face the complex task of planning productive post-mining land uses (PMLUs) at a portfolio scale. There are some 80,000 abandoned mines in the country (Yellishetty & Bach 2023). While detailed feasibility studies are essential for individual sites, the sheer number of sites requiring transition plans creates a need for scalable screening tools that can identify relative suitability and prioritise sites for deeper investigation.

Land development, with its concomitant challenges such as biodiversity offsetting and regulatory pathways, poses a profound challenge for Australia. The opportunity to repurpose brownfield sites, if contamination and other latent risks can be mitigated, presents a significant opportunity for the government, developers and civil society. While successful mine site relinquishment and repurposing examples are rare, there are excellent cases, both in Australia and globally, where this has been successfully implemented (Whitbread-Abrutat & Lowe 2024).

Existing PMLU assessment frameworks typically operate at the site level and require detailed geotechnical, environmental and socio-economic data. This creates a gap between the strategic, system-wide planning

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needs of governments and portfolio owners and the granular, site-specific data required by traditional assessment methods.

This paper addresses that gap by developing a multi-criteria analysis (MCA) framework that operates at a screening level across a portfolio of mining land parcels. The framework evaluates suitability for 6 candidate PMLUs, selected for their policy relevance and data availability:

1. battery energy storage systems (BESS) – energy transition infrastructure
2. utility-scale solar photovoltaic (PV) – renewable energy generation
3. industrial/logistics reuse – economic development
4. conservation/ecological restoration – biodiversity and ecosystem services
5. grazing/low-intensity agriculture – continuation of rural land use
6. recreation/tourism – community benefit and placemaking.

The framework aligns with Sustainable Development Goals (SDGs) 7 (Affordable and Clean Energy), 9 (Industry, Innovation and Infrastructure), 11 (Sustainable Cities and Communities) and 15 (Life on Land). Results indicate *relative suitability*, not economic viability or regulatory approval likelihood.

A framework for selecting PMLUs is presented in Figure 1. This framework proposes using 3 lenses to select PMLUs. The first of these is that sites should be made safe, stable and non-polluting; this is typically the foundational requirement for any mine closure or transition process. The second lens is understanding the site's knowledge base, which is where the work presented in this paper first makes contact. Understanding the site's suitability for various potential PMLUs helps identify alternative PMLUs to consider in the MCA process (in addition to the baseline PMLU). The third lens is a consideration of which SDGs the proposed PMLUs could contribute to and of the national, regional and local drivers/needs. The second point of relevance for the work presented in this paper is in the MCA process. In our paper, we conduct an MCA to assess the PMLUs based on various relevant criteria.

It is important to note that our assessment is a screening-level assessment. Once sites are investigated in more detail, key closure-specific constraints that are not explicitly represented in the screening framework (e.g. residual contamination, acid and metalliferous drainage, geotechnical stability, pit lake hazards and relinquishment requirements) may materially influence PMLU feasibility.

Stakeholder, cultural and social transition considerations are often central to PMLU selection and closure outcomes. These also need to be considered once a shortlist of sites has been selected from a screening-level assessment. The nearby and sometimes regional communities, Indigenous people (who may be rightsholders, not simply stakeholders) and their livelihoods are central concerns to mine closure transitions. There are increasing expectations on mining companies to participate in the repurposing of sites and in catalysing substitutive economies, which were once the domain of government agencies.

Screening-level assessments can occur at any stage in a mine's life cycle, but the earlier they occur, the better. Ideally, these assessments should occur during or before conceptual closure planning for sites, so they can be incorporated into the planning process, designs and cost estimates. But these assessments could be conducted across a portfolio of abandoned mines, aiding their rehabilitation, remediation and repurposing.

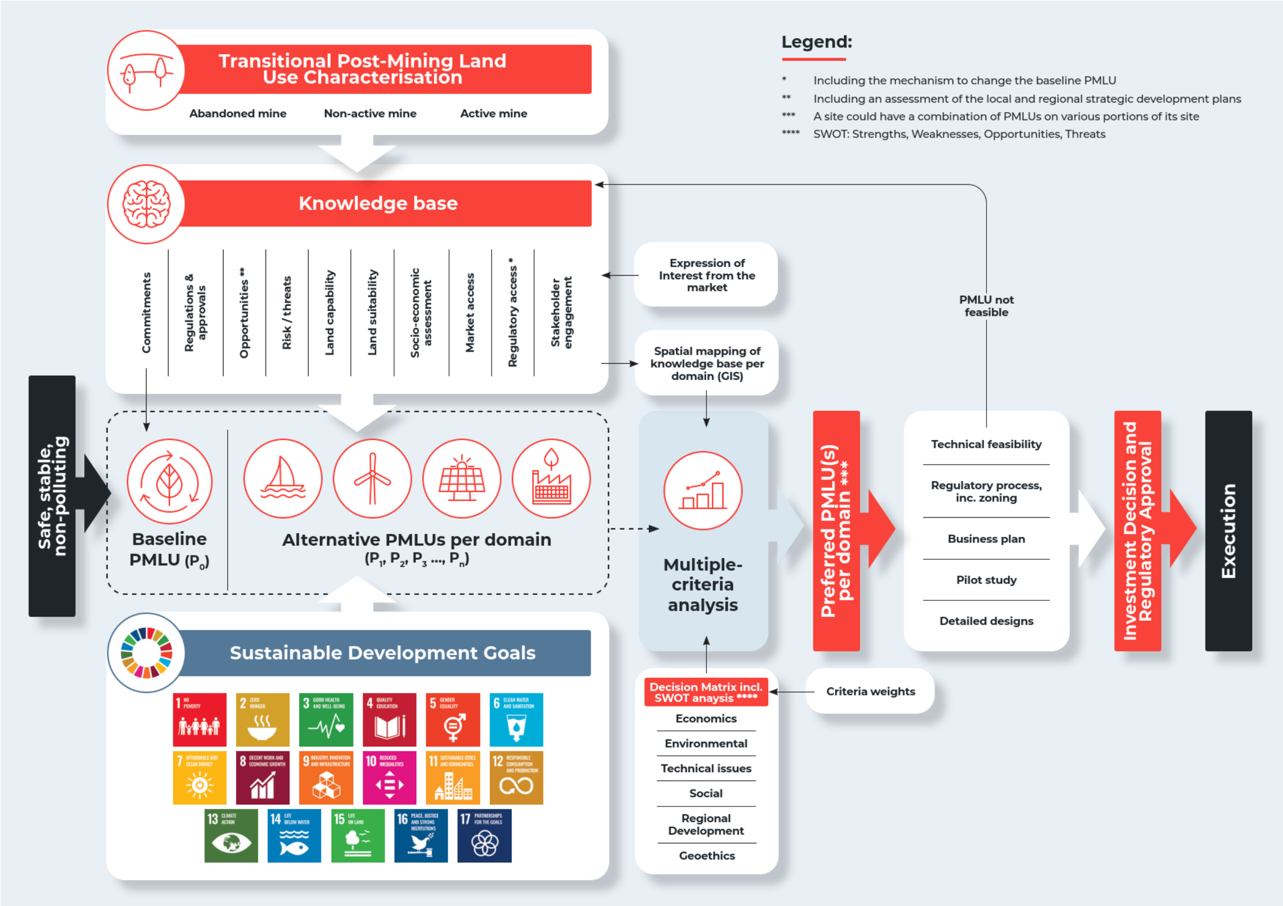


Figure 1 **Framework for selecting post-minig land uses with Sustainable Development Goals as a lens (Simpson et al. 2025)**

2 Data and study area

The analysis draws on 3 primary datasets, each contributing distinct attributes to the screening framework. Table 1 summarises the input datasets.

Table 1 **Summary of input datasets**

Dataset	Coverage	Records	Key attributes
Mine locations (NSW)	NSW	30,400 points	Location, commodity, operational status
Mine locations (QLD)	QLD	3,853 points	Location, commodity, operational status
Land iQ site suitability	NSW only	NSW parcels	Zoning, flood risk, biodiversity, heritage, population and employment
BESS feasibility attributes	NSW + QLD	NSW + QLD lot sample	Developable area, earthworks, grid distance, flood/heritage flags
Combined analysis parcels	NSW + QLD	3,046 lots	2,275 NSW + 771 QLD mine-adjacent lots

2.1 Mine locations

Point-based mine datasets were sourced for NSW (30,400 points) and QLD (3,853 points), capturing mine name, commodity class and operational status (Werner et al. 2020). These points serve as spatial anchors: each mine point identifies proximate land parcels for screening.

2.2 Land iQ

Land iQ is a state-of-the-art digital platform developed through a partnership between the New South Wales Government (Property and Development NSW) and WSP (with collaborators Giraffe and Aerometrex) to transform how land use planning and site assessment are conducted. Conceived as a 'world-first data platform for land use', Land iQ enables planning and property professionals to make faster, smarter decisions about land use by providing on-demand access to a rich library of spatial data and analytics. The tool serves as a one-stop, whole-of-government platform that integrates vast datasets and analysis modules for evaluating site suitability and scenario outcomes.

Land iQ aggregates over 200 curated and pre-processed spatial datasets covering a wide range of factors for every land parcel. This includes data on land capability and topography, environmental constraints (e.g. floodplains, bushfire zones, biodiversity values), land zoning and planning controls, climate change projections, infrastructure and service accessibility, ownership and tenure and more. The platform organises these into more than 40 standardised land use typologies for consistent analysis across the entire jurisdiction. The Land iQ data coves approximately 8 million land lots and properties across NSW, making it possible to evaluate essentially any site in the state within minutes. By creating a centralised, spatially enabled data repository, Land iQ ensures that all users are working from the same up-to-date information, breaking down data silos and supporting cross-agency collaboration.

The Land iQ platform provides parcel-level suitability attributes for NSW, including land zoning, flood susceptibility, biodiversity percentage, bushfire risk, heritage classification, contaminated land status, population proximity, employment accessibility and climate indicators (rainfall, fire weather days) (Property and Development NSW 2024). These attributes are, at this stage, unavailable for QLD, creating a jurisdictional asymmetry that is addressed through tiered analysis.

2.3 Battery energy and storage system site suitability tool

While Land iQ addresses broad land use planning needs, WSP's BESS Site Suitability Tool is a specialised platform focusing on the rapidly growing domain of energy storage and renewable power projects. BESS, often coupled with solar farms, represent a promising PMLU for former mine lands – especially as regions seek to leverage existing grid infrastructure and open spaces for renewable energy development. The BESS Site Suitability Tool was developed as a geospatial, data-driven platform to rapidly evaluate land for utility-scale battery and solar projects. It enables planners and developers to screen large areas for the most favourable locations to install battery energy storage systems, accounting for both grid connectivity and site-specific development constraints.

Similar to Land iQ's philosophy, the BESS tool integrates a wide range of datasets to compute a suitability score for each land parcel in a target region. The analysis is tailored to the needs of energy storage infrastructure. Key factors include physical characteristics (e.g. topography/slope and soil stability), environmental and heritage constraints (flood risk, bushfire hazard, ecological or cultural heritage overlays), land use and planning controls (zoning designations, noise sensitivity of neighbouring areas, development approval requirements) and infrastructure proximity (distance to electrical substations or transmission lines, access roads). Uniquely, the BESS tool also performs electrical network analyses – for example, load flow and capacity assessments of potential substation connection points – to determine where the grid can feasibly accommodate new BESS installations. By fusing these data layers, the tool can flag 'red light' conditions (such as an environmentally protected area or insufficient grid capacity) and elevate high-potential sites that meet all technical and regulatory criteria for a battery/solar project.

The BESS dataset provides energy infrastructure-specific attributes for both NSW and QLD, including developable area, required earthwork volumes, distances to substations and state-controlled roads, sensitive receptor proximity and binary feasibility flags for flood risk, cultural heritage and lot size adequacy.

2.4 Data integration and gaps

Mine points were spatially joined to BESS land parcels and Land iQ property records using intersection-based joins. Mine site geometries are latitude–longitude points and do not capture site boundaries. Mine sites that did not intersect a parcel were dropped. After removing duplication (retaining the nearest mine per lot and the largest-area Land iQ intersection per parcel), the combined dataset provides a consistent analytical unit for MCA scoring.

Land iQ is NSW-only, limiting 5 of 6 land uses to NSW parcels. Only the BESS scoring spans both states. As a result, portfolio-level results for 5 of the 6 PMLUs represent NSW-only suitability patterns. Comparisons across land uses should therefore be interpreted within the NSW subset, while cross-jurisdictional comparisons (NSW versus QLD) are valid only for BESS. The framework does not currently support direct comparison of aggregated suitability distributions across all land uses at a national (2 state) level.

The mine locations in NSW and QLD with land parcels included in the analysis are presented in Figure 1.

3 Methods

3.1 Land use selection

Six candidate PMLUs were selected using 3 filters: screenable with available attributes, relevant to governments and portfolio owners, and common enough to allow pattern detection. Residential development was excluded due to high regulatory and geotechnical uncertainty. Intensive agriculture was excluded due to missing soil and water chemistry data. Water-filled void uses were excluded due to missing lake morphology data.

3.2 Multi-criteria analysis design

Attributes were grouped into the following 4 MCA dimensions, consistent with established PMLU screening frameworks, as presented in Table 2:

1. Physical feasibility – site area, earthwork requirements, developable area
2. Planning and environmental constraints – flood risk, biodiversity, heritage, bushfire, contamination
3. Infrastructure and access – distance to roads, rail, substations, open space
4. Strategic alignment/co-benefits – land zoning compatibility, population catchment, employment proximity.

Table 2 MCA dimensions by land use

Land use	Coverage	Physical feasibility	Planning & environment	Infrastructure & access	Strategic alignment
BESS	NSW + QLD	Developable area, earthworks volume	Flood risk, cultural heritage, lot size	Road distance, substation distance	Sensitive receptor distance
Solar PV	NSW	Site area, earthworks volume	Flood prone, biodiversity percentage, bushfire risk, heritage	Substation distance	–

Land use	Coverage	Physical feasibility	Planning & environment	Infrastructure & access	Strategic alignment
Industrial	NSW	Site area	Flood prone	Road distance, rail station distance	Industrial zone compatibility, employment proximity
Conservation	NSW	Biodiversity percentage, vegetation cover	Contaminated land, severe fire weather	Public open space proximity	–
Grazing	NSW	Site area	Severe fire weather	–	Rural zone compatibility, annual rainfall
Recreation	NSW	–	Flood prone, bushfire risk	Public open space proximity	Nearby population, heritage (positive)

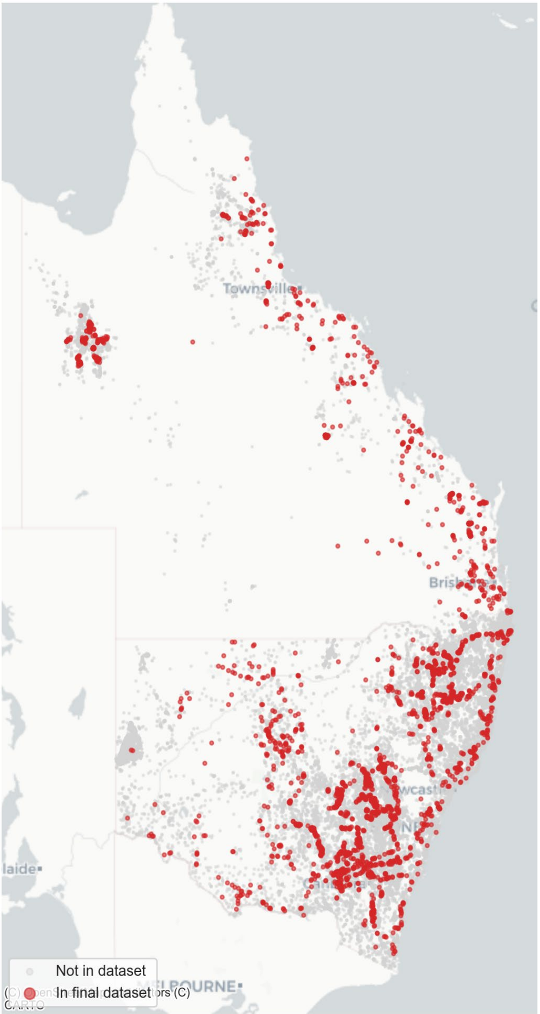


Figure 2 Mine locations across New South Wales and Queensland. Red points indicate mines with intersecting land parcels included in the analysis; grey points are mines excluded due to data availability or spatial join constraints

3.3 Scoring and weighting

Each continuous attribute was normalised to the 0–1 range using min-max scaling. Attributes where lower values indicate greater suitability (e.g. distance to road, earthworks volume) were inverted before normalisation. Binary attributes (e.g. heritage presence, zone compatibility) were scored as 0 or 1. Equal weights were applied within each MCA dimension and equal weights were applied across dimensions. This avoids false precision in a screening-level analysis where the relative importance of dimensions is dependent on context.

For BESS, 3 hard constraints were applied: lots that failed any of the constraints (flood risk, cultural heritage presence, or inadequate lot size for a 5 MW installation) were excluded from scoring and assigned a null suitability value. All other land uses applied soft constraints through normalised penalty scores rather than hard exclusion. To assess sensitivity to weighting assumptions, 3 scenarios were tested for BESS: equal weights (baseline), energy-led (physical feasibility and infrastructure weighted 2×, planning weighted 0.5×) and community-led (planning weighted 2×, physical and infrastructure weighted 0.5×). Rank stability was measured using Spearman correlation between scenario rankings and the baseline.

3.4 Uncertainty and exclusions

This analysis is explicitly a screening-level analysis. Results indicate relative suitability, not economic viability or likelihood of regulatory approval. All scoring thresholds and normalisation parameters are reported for transparency, but site-specific input values are withheld to protect data confidentiality.

4 Results

4.1 Portfolio-level suitability patterns

Table 3 presents summary statistics for all 6 land use MCA scores and Figure 3 visualises these score distributions. BESS suitability was scored across both NSW and QLD, while all other land uses were limited to NSW parcels due to Land iQ data availability. Only lots passing the feasibility thresholds were scored.

Table 3 Summary statistics of MCA suitability scores by land use

Land use	Feasible lots	Mean	Std	Min	Q1	Median	Q3	Max
BESS	2,337	0.466	0.102	0.28	0.378	0.48	0.504	0.864
Solar PV	2,275	0.468	0.062	0.2	0.442	0.492	0.5	1
Industrial	2,275	0.489	0.026	0.249	0.485	0.493	0.497	0.723
Conservation	2,275	0.627	0.076	0.17	0.605	0.631	0.651	1
Grazing	2,275	0.521	0.057	0	0.493	0.526	0.553	0.78
Recreation	2,275	0.512	0.056	0.222	0.481	0.522	0.54	0.784

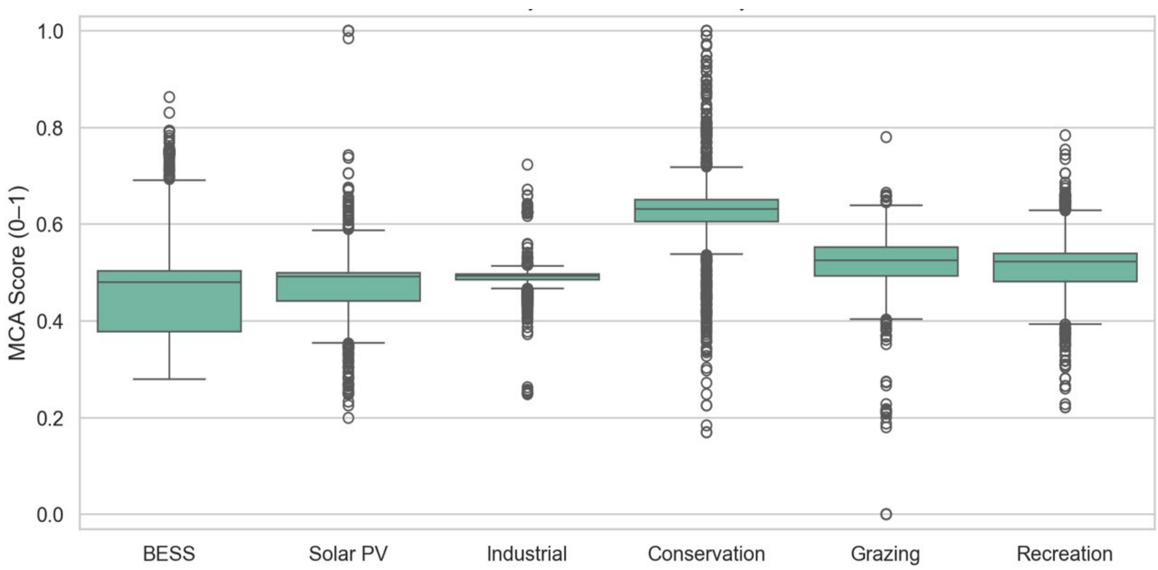


Figure 3 Multi-criteria analysis suitability score distributions by land use. Boxes show interquartile range; whiskers extend to 1.5× interquartile range

Figure 4 presents the distribution of BESS suitability scores by state, highlighting the cross-jurisdictional comparisons enabled by the BESS dataset.

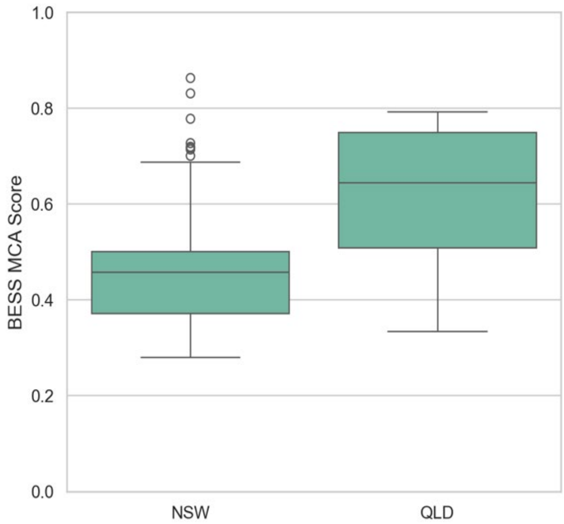


Figure 4 Battery energy storage system suitability score distribution by state, showing the cross-jurisdictional comparison enabled by the battery energy storage system dataset

4.2 Cross-use trade-offs and option diversity

An option diversity index was computed for each site by counting the number of land uses for which the site scored above the per land use median threshold. Sites with greater option diversity represent 'multi-option' parcels where multiple PMLUs are viable, providing portfolio owners with greater flexibility in transition planning (Figure 4).

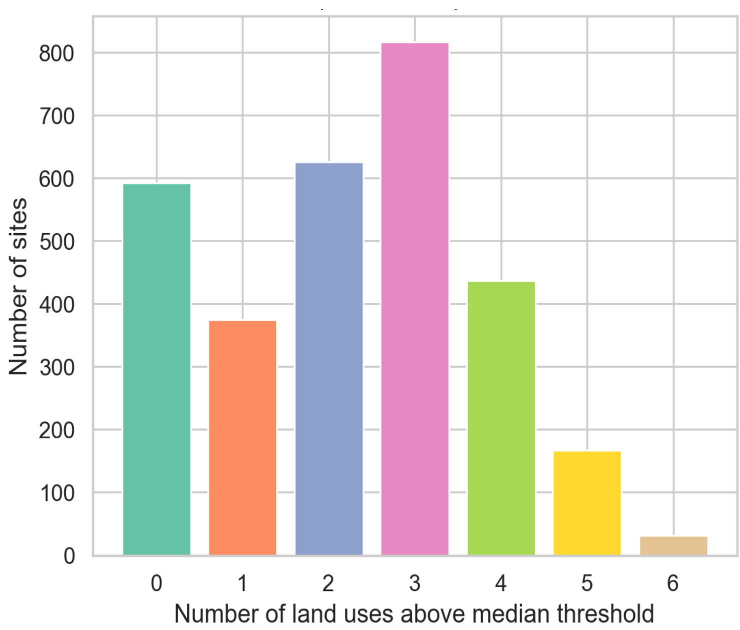
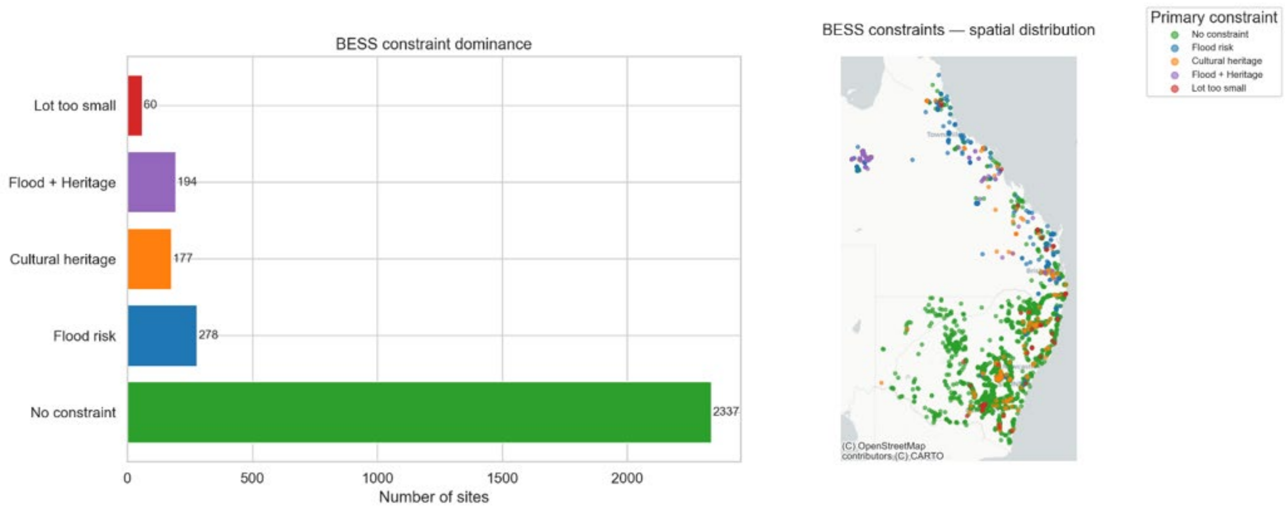


Figure 5 Option diversity index: number of land uses above median suitability threshold per site. Sites scoring highly across multiple uses represent flexible transition candidates

4.3 Dominant constraints

For the BESS assessments, a constraint analysis reveals that flood risk is the primary factor limiting site feasibility. Figure 6 shows the spatial distribution of primary constraints alongside their relative frequency.



(a) (b)

Figure 6 Battery energy storage system constraint dominance; (a) Primary limiting factor per site; (b) Spatial distribution of constraints across New South Wales and Queensland. Sites without binding constraints are scored for battery energy storage system suitability

4.4 Regional contrasts: commodity versus re-use suitability

Mean MCA scores were computed by commodity class to reveal relationships between mine type and PMLU suitability (Figure 7). Only commodity classes with 20 or more sites were included to avoid 'noise' from rare categories.

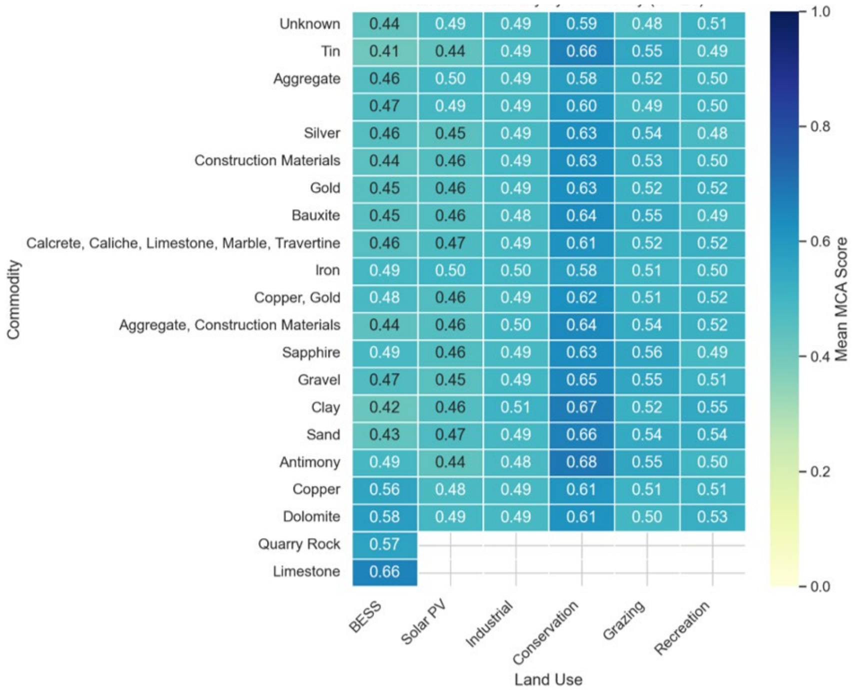
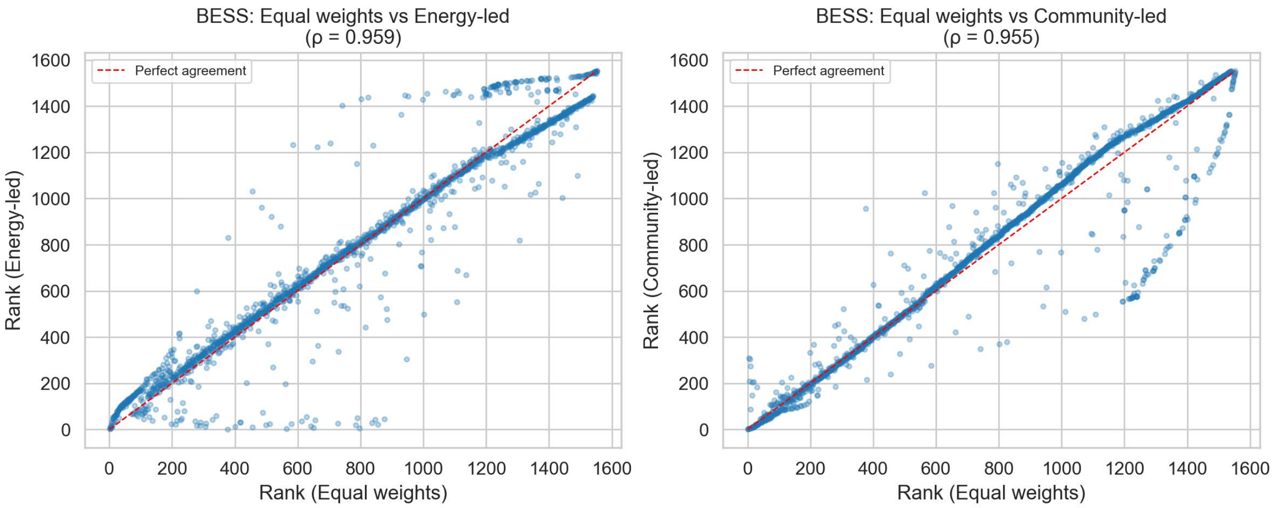


Figure 7 Mean multi-criteria analysis suitability score by commodity class and land use. Commodity classes with fewer than 20 sites are excluded. Colour intensity indicates relative suitability

The heatmap reveals that suitability patterns are not uniform across commodity types. Some commodity classes exhibit stronger suitability for specific uses but poor prospects for others. This information supports portfolio-level prioritisation by identifying which commodity-linked sites are most amenable to transition.

4.5 Scenario sensitivity

To assess the robustness of MCA rankings to weighting assumptions, BESS suitability was recomputed under 3 weighting scenarios. Figure 8 shows rank stability between the equal-weight baseline and each alternative scenario.



(a) (b)

Figure 8 Rank stability plots for battery energy storage system suitability; (a) Under equal-weight (baseline), energy-led weighting scenario; (b) Under community-led weighting scenario. Each point is one site; deviation from the diagonal indicates rank change. Spearman correlation (ρ) quantifies overall rank agreement

5 Discussion

5.1 Strategic implications for governments and operators

The portfolio-level screening presented here reveals several patterns relevant to strategic mine closure planning.

5.1.1 Multi-option sites exist and are identifiable

A meaningful proportion of parcels score above median suitability for 3 or more land uses, indicating that the post-mining transition need not be constrained to a single pathway. For portfolio owners managing diverse closure liabilities with different domains within their sites, identifying multi-option sites enables staged planning where early decisions preserve optionality. In this study, we have provided this suitability test at a screening level. Once a site is selected for further investigation, more detailed studies will be required. These include stakeholder, community and cultural considerations in PMLU selection. In practice, closure outcomes are often socially negotiated and influenced by community expectations, Indigenous values, landholder preferences and regional development priorities, beyond technical suitability alone.

5.1.2 Constraints, not opportunities, often dominate outcomes

The constraint dominance analysis demonstrates that for energy-oriented re-use (BESS), site feasibility is often limited by flood risk, cultural heritage, or inadequate lot size – factors unlikely to be addressed solely through remediation. This finding underscores the importance of constraint mapping as a first step in PMLU screening.

5.1.3 Commodity type is a potential predictor

The variation in MCA scores across commodity classes suggests that mine type may reflect underlying site characteristics relevant to PMLU suitability characteristics. However, the commodity class should be interpreted as a proxy for broader factors such as geology, disturbance extent and location, rather than a direct predictor of suitability. In future work, commodity type could potentially be used to infer likely contaminant types for soil contamination screening.

5.2 Where policy or data improvements would shift outcomes

Several data gaps constrain the current analysis and represent priorities for improvement:

- Extending Land iQ to QLD would enable cross-jurisdictional comparison across all 6 land uses, rather than only BESS.
- Site boundary polygons rather than point locations of mining sites would allow area-based suitability assessment and more accurate spatial joins.
- Soil and water quality data would unlock the assessment of intensive agriculture and aquaculture re-use pathways.
- Grid connection capacity data would strengthen energy-related screening beyond distance-based proxies.

5.3 Limits of screening-level inference

This framework is explicitly designed for strategic screening, not site-level planning. Several limitations apply:

- No field validation: scores reflect data attributes only and have not been validated against site inspections or stakeholder assessments.
- Uniform weighting: equal weights across MCA dimensions reflect an absence of stakeholder-derived preferences. The scenario sensitivity analysis partially addresses this by assessing robustness to

changes in weighting. While the rationale for equal weighting is reasonable for screening purposes, in future work, alternative stakeholder-informed or risk-based weighting approaches could support methodological defensibility.

- Static attributes: the analysis captures a snapshot in time and does not model dynamic factors such as changing land values, policy settings or remediation investment.
- Jurisdictional asymmetry: the NSW-only availability of Land iQ data means that 5 of 6 land uses can be assessed only for NSW parcels, limiting cross-state comparisons. However, this limitation may diminish in the future when Land iQ is extended to other states.
- Spatial extent: representing mine sites as single latitude–longitude points can significantly mischaracterise their true spatial extent, particularly for large open-cut mines, tailings storage facilities, or multi-domain sites. While mine points were matched to parcels, many mines span multiple parcels and are therefore their spatial extent is not fully represented in the dataset. This simplification may introduce spatial bias into the suitability analysis. In future work, we plan to expand our analysis to quantify the potential magnitude of this spatial error, review how it may influence MCA outcomes and outline possible mitigation approaches, such as commodity-specific footprint approximations or the use of publicly available mine boundary polygons where accessible. In future work, it would be beneficial to include a quantitative estimate of the potential spatial error, for example, the percentage of mines with an area greater than 'X' hectares for which a single-point representation may fall outside the actual site footprint.
- Regulatory and closure criteria not explicitly modelled: the framework does not incorporate jurisdiction-specific closure completion criteria, relinquishment requirements or regulatory acceptance thresholds. These factors can materially influence the feasibility and timing of PMLUs. Future iterations could integrate regulatory constraints as additional screening criteria or scoring dimensions, improving alignment with closure planning processes and practical implementation pathways.

6 Conclusion

This paper demonstrates that scalable, transparent PMLU screening is feasible and provides indicative insights at the portfolio scale. By combining publicly available mine location data with parcel-level suitability attributes from the Land iQ platform and BESS feasibility datasets, the framework evaluates relative suitability across 6 candidate land uses for over 3,000 mine-adjacent parcels in NSW and QLD.

The equal-weight MCA approach, structured around 4 interpretable dimensions, produces suitability distributions that indicate patterns of variation across land uses, commodity types and spatial constraints. The identification of multi-option sites, dominant constraints and commodity-linked suitability patterns provides preliminary insights that can inform early-stage decision-making for governments developing closure policies and mining companies managing portfolio-scale transition planning.

The framework's value lies not in replacing detailed feasibility studies but in systematically identifying where further investigation may be warranted. By operating at the screening level with transparent methods and reproducible scoring, the approach can support early-stage transition planning for policy and investment contexts.

Future work should extend the attribute base to include soil quality, grid capacity and stakeholder preference data, validate screening results against site-level assessments, and explore dynamic modelling of land-use transition pathways under changing policy and market conditions.

Use of artificial intelligence: disclosure statement

In the preparation of this work, the authors used Microsoft Copilot Chat and Github Copilot to draft the MCA methodology (including selecting site attributes relevant to each PMLU and suggesting high-value visualisations), write the code to implement the analysis (subject to testing and debugging) and draft the initial text of the paper (subject to rigorous manual editing). The authors have reviewed the content and edited it where required and take full responsibility for said content.

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