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INTERNATIONAL ERZINCAN
ENERGY SYMPOSIUM
— EES'26**

**APRIL 01-03, 2026
ERZINCAN, TURKIYE**

EDITOR: Dr. Hamza AYDOĞDU

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PESTLE Analysis of the Critical Raw Materials Industry development in North Macedonia

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Abstract

This paper evaluates the development trajectory and policy environment for the critical raw materials (CRM) industry in North Macedonia, using a PESTLE (Political, Economic, Social, Technological, Legal, Environmental) framework grounded in (i) peer-reviewed scientific and technical documents as primary evidence and (ii) complementary authoritative sources from EU institutions, North Macedonia's ministries, official statistics, and international datasets. The analysis is anchored to the EU Critical Raw Materials Act (CRMA), which defines 17 strategic raw materials and 34 critical raw materials and sets 2030 benchmarks for EU extraction (10%), processing (40%), and recycling (25%), while limiting over-dependence on any single third-country supplier (65%).

Evidence indicates that North Macedonia already functions as an upstream supplier to European value chains through exports of metal concentrates – especially lead, zinc, and copper – as well as historically significant ferro-nickel exports, though recorded ferro-nickel exports collapse sharply in 2024. Technological and environmental dimensions are strongly shaped by legacy and active extractive waste: published tailings characterizations identify large tailings volumes (e.g., Bučim tailings reported at ~125 Mt) and elevated concentrations of CRM-relevant elements in certain tailings (notably antimony/arsenic at Lojane; indium in Pb–Zn tailings at Sasa and Toranica), alongside significant pollution cases and governance challenges around prevention, monitoring, and emergency response.

Overall, the country's opportunity lies less in “new greenfield CRM mines” in the short term and more in upgrading permitting integrity, environmental enforcement, creating a national secondary resource (tailings) inventory and risk-based remediation program, and targeted investment in technology capabilities to (a) responsibly expand/modernize existing mining, (b) recover value from secondary resources (tailings, fly ash, waste rock), and (c) integrate with EU-compliant processing and ESG-driven contracting. Constraints are dominated by weak rule-of-law performance in anti-corruption, insufficient environmental administrative capacity, recent incident history (including a major 2025 mining-related pollution incident) affecting social license, limited downstream processing and circularity infrastructure, and data transparency deficits (notably mine-level production/reserve reporting to international standards and publicly accessible inventories of extractive waste).

Keywords: Critical Raw Materials (CRM); PESTLE analysis; mining policy; EU supply chains; regulatory risk.

1. INTRODUCTION

The European Union's green and digital transition creates structural demand for a diverse portfolio of critical raw materials whose supply is currently concentrated in a small number of

third-country producers. The EU Critical Raw Materials Act (CRMA; Regulation (EU) 2024/1252) responds to this strategic vulnerability by establishing 34 critical and 17 strategic raw material designations and binding 2030 benchmarks: at least 10% of EU annual demand met by domestic extraction, 40% by domestic processing, 25% by recycled materials, and a maximum 65% reliance on any single third-country supplier for each strategic raw material (European Union, 2024). These benchmarks represent a deliberate market-design intervention with direct implications for candidate countries that host relevant mineral resources.

North Macedonia occupies a geologically favourable position within the mineral-rich Western Balkans. The country produces lead–zinc–silver concentrates (principally at Sasa), copper concentrate (at Bučim), and hosts additional occurrences of antimony, gold, and barite (Renaud, 2020; Kiselicki et al., 2025). Mining and quarrying contribute approximately 2–3% of GDP, a modest share relative to neighbouring Serbia (Bor copper complex), but the sector's strategic significance extends beyond its macroeconomic weight: in 2023, lead–zinc concentrate exports were of the order of EUR 100–130 million, directed primarily to EU processing nodes (Kiselicki et al., 2025; UN Comtrade). Despite this existing integration, the country retains no domestic smelting or refining capacity, meaning that the majority of CRM value is captured by downstream EU processors.

As a candidate country with EU accession screening completed across all six negotiating clusters as of December 2023 (European Commission, 2025), North Macedonia faces a dual imperative: alignment with EU *acquis* requirements is both a legal accession obligation and a commercial precondition for participation in CRMA-compliant supply chains. However, the country's capacity to meet these requirements is contested. Published analyses of Western Balkans mining sectors have identified geological potential (Rokavec et al., 2021) and secondary resource opportunities (Steiner et al., 2022; Šajn et al., 2022), but country-level, multi-dimensional assessments that systematically link governance gaps to CRM supply chain feasibility remain absent from the peer-reviewed literature.

This paper addresses that gap through a structured PESTLE analysis of North Macedonia's CRM sector. The analytical objectives are: (i) to identify enabling conditions and binding constraints across political, economic, social, technological, legal, and environmental dimensions; (ii) to benchmark documented conditions against CRMA targets and EU accession requirements; and (iii) to derive policy recommendations that are explicitly grounded in quantitative or documentable evidence.

2. LITERATURE OVERVIEW

The Western Balkans mining literature provides a useful but incomplete foundation for country-level CRM analysis. A structured review reveals four principal strands of relevant scholarship, each with identifiable analytical limits.

2.1 Geological potential and regional resource registers

Rokavec et al. (2021) developed the West Balkan Mineral Register of Primary Raw Materials under the RESEERVE project, providing a systematic spatial inventory of copper, lead, zinc, chromium, nickel, and iron occurrences across the region. The Register's primary contribution is data transparency: by aggregating national geological survey data into a harmonised, EU-accessible format, it reduces exploration risk and supports investment targeting. However, the authors acknowledge significant heterogeneity in underlying data quality across countries and deposit types, and note that classification alignment with standards such as JORC and INSPIRE is incomplete. For North Macedonia specifically, the Register confirms the presence of lead–zinc and copper mineralisation but does not provide country-level resource estimates of the quality required for CRMA benchmark assessment.

Renaud (2020), drawing on USGS Minerals Yearbook data for 2019, provides the most systematic publicly available production statistics for North Macedonia's mineral sector, documenting lead and zinc concentrate outputs and noting the absence of domestic smelting capacity. This upstream-only structure is a recurrent finding in the country-level literature.

2.2 Secondary raw materials and circular economy potential

Steiner et al. (2022) provide the most detailed published geochemical and mineralogical characterization of tailings from North Macedonian and Serbian base-metal sulfide deposits, covering Sasa (Pb–Zn–Ag), Probištip (Pb–Zn), Bučim (Cu porphyry), and Lojane (As–Sb fault-bound vein-type). Their multi-element dataset, generated by XRF, LA-ICP-MS, and SEM analysis, documents significant geochemical heterogeneity across sites: Lojane tailings exhibit elevated As and Sb concentrations of potential environmental and recovery concern; Probištip tailings show the highest commodity metal concentrations (reported at >5,000 ppm Pb and approximately 4,020 ppm Zn in the most metal-rich sample), and also contain trace CRM-relevant elements including Sb, Ga, Ge, and In. The authors emphasise that additional milling would be required to separate ore from gangue at all characterized sites, and that quantitative reserve estimation – necessary for feasibility assessment – is not yet available in the public domain. This study establishes the primary quantitative basis for secondary CRM recovery assessment at North Macedonian sites.

Ramani et al. (2014) document the downstream environmental impact of active Pb–Zn mining operations in northeastern North Macedonia, characterising the water quality of the Bregalnica, Zletovska, and Kriva rivers in relation to the Zletovo and Toranica mines. Their data confirm that mining operations exert measurable influence on river chemistry, with elevated metal concentrations recorded downstream of active operations. This work establishes the evidential basis for the environmental liability dimension of North Macedonia's tailings and processing sites.

Šajin et al. (2022) extend the secondary resource analysis to the West Balkan region more broadly, estimating that mining and metallurgical waste constitutes a significant potential secondary source of metals for EU supply chains. Their study identifies the Western Balkans as a region where legacy mine waste could contribute meaningfully to EU CRM supply security, with implications for both circular economy policy and environmental remediation programming.

2.3 Value chain structure and economic upgrading

Kiselicki et al. (2025) provide the most recent and comprehensive analysis of North Macedonia's CRM sector, combining value chain analysis with a strategic framework for economic upgrading. Their central finding – that converting even a portion of Sasa's concentrate output into refined metal could increase sectoral revenues by approximately 50% – quantifies the opportunity cost of the current upstream-only model and provides an economic rationale for processing investment. The authors also document the country's EU-oriented trade patterns and identify governance as the primary constraint on value chain advancement. This paper's analysis builds directly on these findings.

2.4 Governance, institutional reform, and EU alignment

Armakolas and Krstinovska (2025) argue that the EU's enlargement strategy must be explicitly linked to its raw materials supply chain objectives, and identify a structural trust deficit between communities, mining operators, and regulatory authorities in the Western Balkans as a binding constraint on CRM development. Their analysis is consistent with the European Commission's 2025 monitoring report (European Commission, 2025), which documents anti-corruption failures, insufficient environmental administration capacity, and EIA/SEA misalignment in

North Macedonia specifically. Karanovic and Partners (2025) provide legal analysis of North Macedonia's recently adopted Mineral Resources Act, documenting the introduction of strategic project fast-tracking and updated royalty structures, but also noting the gap between legislative text and implementation capacity.

2.5 Summary of analytical gaps

Across these four strands, three analytical gaps motivate the present paper: (i) no published analysis applies a structured multi-dimensional diagnostic framework at the North Macedonia country level; (ii) governance and environmental enforcement dimensions are treated qualitatively or subordinated to geological and economic analysis; and (iii) quantitative benchmarking against CRMA 2030 targets is absent. This paper addresses all three.

3. MATERIALS AND METHODS

3.1 Methodological framework

This paper employs PESTLE analysis as a structured strategic diagnostics framework to assess the enabling conditions and binding constraints for CRM sector development in North Macedonia. PESTLE was selected over alternatives for three reasons. First, it provides domain-neutral coverage of six interdependent institutional and market dimensions (Political, Economic, Social, Technological, Legal, Environmental), which is particularly appropriate in a candidate-country context where EU *acquis* alignment simultaneously affects multiple regulatory chapters. Second, it facilitates direct mapping of analytical findings onto policy recommendations organised by jurisdictional actor – a necessary feature when outputs are intended to inform both national policy and EU-level CRM strategy. Third, PESTLE has documented precedent in minerals and transition planning contexts (Kiselicki et al., 2025), providing methodological continuity with the existing regional literature.

The framework is applied diagnostically rather than mechanically: each PESTLE dimension is analysed using a consistent internal structure comprising (i) primary evidence identification, (ii) characterisation of enabling conditions and binding constraints, (iii) comparative benchmarking against EU or CRMA standards where available, and (iv) derivation of policy implications linked to specific institutional actors. This structure ensures that no analytical conclusion rests on qualitative assertion alone.

3.2 Data sources

The analysis relies exclusively on publicly accessible, traceable sources. No primary data collection was conducted. Sources are organised by category:

- **EU regulatory and legal texts:** Regulation (EU) 2024/1252 (CRMA) (European Union, 2024); European Commission CRM list documentation (European Commission, 2023).
- **EU accession monitoring:** European Commission North Macedonia Report 2025 (COM(2025)530 final) (European Commission, 2025). This is the authoritative basis for governance, legal, and environmental assessments.
- **National legal framework:** North Macedonia Mineral Resources Act (2025) as analysed in Karanovic and Partners (2025). Ministry-level communications on concession fees and enforcement (Ministry of Energy, Mining and Mineral Resources, 2025, 2026).
- **Production and trade statistics:** USGS Minerals Yearbook 2019 (Renaud, 2020) for historical production baselines. Company operational reports: Central Asia Metals 2024 Operations Update (Central Asia Metals, 2024) for Sasa mine output. UN Comtrade

bilateral trade data for concentrate export values (HS codes 260300, 260700, 260800), as synthesised in Kiselicki et al. (2025).

- **Peer-reviewed geochemical and environmental literature:** Steiner et al. (2022) for geochemical and mineralogical characterisation of tailings from base-metal sulfide deposits at Sasa, Probištip, Bučim, and Lojane. Ramani et al. (2014) for documented water quality impacts of active Pb–Zn mining operations in northeastern North Macedonia. Šajn et al. (2022) for West Balkans-wide secondary raw material assessment.
- **Value chain and sector analysis:** Kiselicki et al. (2025) for value chain analysis, economic upgrading framework, and export data. Armakolas and Krstinovska (2025) for governance and social licence analysis.
- **Macroeconomic indicators:** FDI data from Djonovic (2025) and National Bank of North Macedonia. Corporate tax and royalty rates from Karanovic and Partners (2025).

All sources are peer-reviewed publications, official EU or national government documents, intergovernmental statistics platforms, or professional legal analyses with traceable institutional provenance. Press releases and unverified secondary sources are not used as primary evidence.

3.3 Analytical procedure

The analytical procedure follows five sequential steps:

Step 1 – Dimension-source mapping: Each PESTLE dimension was assigned a primary evidence category before evidence extraction, to prevent post-hoc source selection.

Step 2 – Structured evidence extraction: Quantitative and qualitative evidence was extracted using a template: source, indicator or finding, direction (enabling/constraining), magnitude (where quantifiable). All evidence is retained in Section 4 with explicit citations.

Step 3 – Comparative benchmarking: Where EU comparators are available (CRMA 2030 targets; EC accession performance ratings; EU-average indicators), North Macedonia's documented performance is compared and summarised in comparative tables (Tables 1–3).

Step 4 – Cross-dimensional synthesis: Evidence across dimensions is analysed for coupling effects – cases where weaknesses in one dimension amplify constraints in another. This produces the Discussion section's analytical narrative.

Step 5 – Evidence-grounded recommendations: Each recommendation is linked to a specific dataset and CRMA benchmark, ensuring no recommendation rests solely on qualitative judgment.

4. RESULTS

Table 1. North Macedonia CRM sector: PESTLE summary with EU/CRMA benchmark comparison

Dimension	Key Evidence (North Macedonia)	EU / CRMA Benchmark	Assessment
Political	Mining law reformed 2025 (Karanovic & Partners, 2025); anti-corruption: no progress (EC, 2025); concession registry incomplete (EC, 2025)	CRMA requires trusted-supplier governance; EC accession conditionality on rule-of-law	Significant gap: legislative reform outpaces enforcement capacity
Economic	Lead+Zn+Cu exports ~EUR 127M (2023) (Kiselicki et al., 2025); no domestic smelting; mining ~2-3% of GDP; Sasa ~25,000 t Pb + 18,000 t Zn (2024) (Central Asia Metals, 2024)	CRMA: 40% domestic EU processing by 2030; 10% domestic extraction (EU, 2024)	Upstream-only: value chain gap documented; concentrate export model dominant
Social	Toranica spill March 2025 (EC, 2025); Kazandol concession terminated 2018 on environmental grounds; 'profound lack of public trust' (Armakolas & Krstinovska, 2025)	EU acquis: meaningful public participation in EIA/SEA; CRMA ESG expectations	Elevated social-licence risk; two major adverse incidents 2018-2025
Technological	Tailings geochemically characterised at Sasa, Probištip, Bučim, Lojane (Steiner et al., 2022); paste backfill at Sasa (Central Asia Metals, 2024); SX/EW at Bučim; no domestic R&D centre	CRMA recycling benchmark: 25% of annual EU demand by 2030 (EU, 2024)	Active mines modernising incrementally; secondary recovery pipeline absent
Legal	Mineral Resources Act 2025: 30-yr concessions, 4% royalty (base metals), 4% (Au/Pt) (Karanovic & Partners, 2025); EIA law not aligned with EU acquis (EC, 2025)	Full EIA/SEA acquis alignment required; EU Environmental Liability Directive; CRMA due-diligence obligations	Partial alignment: concession structure modernised; EIA/SEA and liability frameworks require overhaul
Environmental	Toranica spill: enforcement gap and lack of protocols (EC, 2025); legacy Cr ⁶⁺ contamination at Jugohrom; elevated As/Sb at Lojane tailings (Steiner et al., 2022); river impacts downstream of Pb-Zn mines (Ramani et al., 2014); insufficient inspection staffing (EC, 2025)	EU Water Framework Directive; Mining Waste Directive; Environmental Liability Directive alignment	Material non-compliance: active incident response failures at operating mine in 2025; documented legacy contamination

4.1 Political Factors

North Macedonia's EU accession trajectory is the primary political determinant of CRM sector development prospects. The European Commission's 2025 monitoring report (European Commission, 2025) confirms completion of screening across all six negotiating clusters by December 2023 and adoption of a Reform Agenda under the EU Growth Plan's Reform and Growth Facility, covering governance, green and digital transition, human capital, and business environment. These structural conditions create institutional incentives for regulatory convergence with CRMA expectations and represent the principal enabling political condition.

Against this, governance weaknesses constitute a binding constraint. The Commission (European Commission, 2025) reports no progress in prevention and fight against corruption, describes corruption as prevalent and a serious concern, and identifies specific credibility failures in the anti-corruption commission alongside structural delays in high-level proceedings. In extractive sectors, documented conditions of this type elevate risks around concession allocation integrity and inspection discretion.

The 2025 Mineral Resources Act (Karanovic & Partners, 2025) introduces a Strategic Project designation allowing accelerated environmental permitting for deposits meeting EU CRM criteria – a relevant enabling reform. Concurrently, the Ministry of Energy, Mining and Mineral Resources reports intensified concession inspections and unilateral termination of contracts for non-performance, alongside a concession fee increase of up to 100% effective January 2025 (Ministry of Energy, 2026). However, Parliament's hearings following the 2025 Toranica tailings accident (European Commission, 2025) illustrate that reactive rather than anticipatory governance remains the dominant mode.

Implication: Legislative modernisation is insufficient without commensurate enforcement capacity. Publishing concession agreements, beneficial ownership data, environmental permits, and inspection outcomes as open, machine-readable datasets is the minimum governance standard implied by CRMA trusted-supplier expectations.

4.2 Economic Factors

North Macedonia's CRM export profile demonstrates material integration into European value chains at the upstream (concentrate) stage. Table 2 presents the documented production and trade profile:

Table 2. North Macedonia: CRM sector production and trade indicators, 2023–2024

Metric	Value	Year	Source / Notes
Mining & quarrying / GDP	~2–3%	2023	Kiselicki et al. (2025); sector estimates
Sasa mine: Pb concentrate output	~25,000 t Pb	2024	Central Asia Metals (2024)
Sasa mine: Zn concentrate output	~18,000 t Zn	2024	Central Asia Metals (2024)
Bučim mine: Cu concentrate output	~80,000 t conc. (~7,000 t Cu)	2024	Solway Group operational data
Lead concentrate exports	~EUR 60M	2023	Kiselicki et al. (2025); UN Comtrade
Zinc concentrate exports	~EUR 55M	2023	Kiselicki et al. (2025); UN Comtrade
Copper concentrate exports	~EUR 12M	2023	Company data; Kiselicki et al. (2025)
Total mineral export value	~EUR 127–130M	2023	Kiselicki et al. (2025); aggregate
Primary export destination	EU (~80%)	2023	Kiselicki et al. (2025); observations
Corporate income tax rate	10%	2025	Statutory; Karanovic & Partners (2025)
Mining royalty rate (base metals)	4% on gross metal content	2025	Karanovic & Partners (2025)
Mining royalty rate (gold, platinum)	4% on gross metal content	2025	Karanovic & Partners (2025)
Estimated mining labour force	2,000–3,000 workers	2024	Company and union estimates
Revenue uplift from partial refining	~50% (estimated)	2023	Kiselicki et al. (2025); value chain model

The upstream-only structure documented in Table 2 – all concentrates exported without domestic refining – has two economic implications. First, it confirms that North Macedonia already participates in EU value chains but at the lowest value-added stage. Second, it quantifies a structural opportunity: Kiselicki et al. (2025) estimate that partial domestic refining could increase sectoral revenues by approximately 50%, a margin that constitutes both a financial case for processing investment and an indicator of the current value-capture deficit.

North Macedonia's corporate tax rate of 10% and the new Mineral Resources Act's EU-aligned incentive structure (Karanovic & Partners, 2025) are enabling economic conditions. However, project finance for mining remains structurally constrained: long development lead times, high capital requirements for smelting and refining infrastructure, and the absence of domestic venture capital or mining-specialist lending create a gap between policy intent and investable projects. EU cohesion instrument (IPA III) financing represents the principal near-term mechanism for bridging this gap.

Implication: The economic case for CRM integration rests on upgrading existing concentrate operations – improving ESG compliance, traceability, and concentrate quality – rather than attracting greenfield primary investment in the short term. Processing investment requires EU co-financing and de-risking instruments; unilateral commercial investment is unlikely given current governance risk premia.

4.3 Social Factors

Social licence to operate is a binding constraint documented through two distinct categories of adverse outcomes.

First, project-level opposition has repeatedly translated into permitting failure or operational disruption. The Ilovica–Stuka copper-gold project experienced extended procedural contestation that precluded development despite documented mineral resources. The Kazandol copper mining concession was terminated in 2018 in response to environmental community opposition – a case that demonstrates the conversion of social-environmental conflict into sovereign risk and potential arbitration exposure (Armakolas & Krstinovska, 2025).

Second, operational incidents have materially damaged public trust. The Toranica tailings accident of March 2025 polluted a local waterway and, as documented by the European Commission (2025), revealed serious enforcement gaps and a lack of emergency preparedness. Parliamentary hearings followed, generating legislative pressure for revised dam safety regulations. State-level reporting described sharp post-incident increases in heavy metal concentrations, though the contested nature of specific quantitative claims in public discourse underscores the importance of independent, publicly accessible monitoring data.

Armakolas and Krstinovska (2025) characterise the social landscape as one of profound public distrust in mining contract arrangements, reflecting community perceptions that deals favour outside investors over local populations. This finding is structurally consistent with the EC's (2025) identification of weak public participation mechanisms in EIA processes and limited access-to-justice for environmental matters.

The workforce dimension presents a secondary constraint: the mining labour force is small (estimated 2,000–3,000 workers), aging, and subject to emigration pressure as technically qualified geologists and engineers seek higher-salary positions in EU member states. This skills gap is most acute in hydrometallurgy, geometallurgy, and environmental monitoring – precisely the technical domains required for a secondary CRM recovery programme.

Implication: The social risk profile implies that any new CRM initiative requires front-loaded community engagement, legally binding benefit-sharing arrangements, and independently verified environmental monitoring, not merely procedural EIA compliance. The fiscal mechanism already exists: municipal royalty allocations (78% of royalties directed to host municipalities under the Mineral Resources Act (Karanovic & Partners, 2025)) provide a foundation, but transparency of allocation and linkage to measurable local outcomes are absent.

4.4 Technological Factors

Technological readiness for CRM integration in North Macedonia operates on two tracks with distinct feasibility profiles.

The primary extraction and beneficiation track is operationally established. Sasa mine employs underground drill-and-blast methods with flotation concentration and is transitioning from top-down caving to cut-and-fill mining with paste backfill, improving both ore recovery and safety (Central Asia Metals, 2024). Bučim mine employs solvent extraction–electrowinning (SX/EW) to produce copper cathode – the one instance of in-country hydrometallurgical processing in the documented evidence base (Solway Group, n.d.). Both operations continue to depend substantially on legacy equipment and manual processes; automation is minimal.

The secondary resource recovery track represents the comparatively larger opportunity, and the one most directly aligned with the CRMA's 25% recycling benchmark. Steiner et al. (2022) provide multi-element geochemical and mineralogical characterisation of tailings at four North Macedonian sites (Sasa, Probištip, Bučim, and Lojane), establishing the primary published basis for secondary recovery assessment. Their dataset documents commodity metal concentrations (Cu, Pb, Zn) and CRM-relevant trace elements (Sb, Ga, Ge, In) in North Macedonian tailings, with Probištip returning the highest commodity metal concentrations in the characterised samples. Lojane tailings exhibit elevated As and Sb, creating both an environmental liability and a potential Sb recovery opportunity, noting that antimony is listed as a critical raw material under the CRMA. The authors caution that additional milling would be required to achieve mineral liberation at all sites, and that quantitative resource estimation is not yet available. Šajn et al. (2022) place these findings in a West Balkans regional context, characterising mining and metallurgical waste as a significant potential secondary metal source for EU supply chains. Ramani et al. (2014) document the downstream river water quality impacts of the Toranica and Zletovo Pb–Zn operations in northeastern North Macedonia, providing independent evidence of the environmental liability dimension of the tailings complex. Table 3 summarises the documented secondary resource profile for key North Macedonian sites:

Table 3. Documented secondary resource profile: selected North Macedonian tailings facilities

Facility	Primary Deposit Type	Key Geochemical Data	CRM Recovery Relevance
Bučim	Cu porphyry	Large tailings volume; Cu-bearing mineralogy; detailed public geochemistry limited (Steiner et al., 2022)	Secondary Cu potential; possible critical co-product traces; full characterisation required
Sasa	Pb-Zn-Ag massive sulphide	Active operation; paste backfill reduces new tailings generation; legacy volumes present; Sb noted in tailings (Steiner et al., 2022)	By-product Ag and Sb recovery potential; hydromet feasibility under study
Probištip	Pb-Zn	Highest commodity metal concentrations in characterised samples: >5,000 ppm Pb, ~4,020 ppm Zn; trace Ga, Ge, In present (Steiner et al., 2022)	Pb-Zn re-processing with CRM trace element by-product potential; additional milling required
Lojane	As-Sb fault-vein-type	Elevated As and Sb concentrations in tailings; high environmental hazard; river impacts from Pb-Zn operations in region (Steiner et al., 2022; Ramani et al., 2014)	Sb is a CRMA critical raw material: recovery interest high but hazard profile demands remediation-first approach

The absence of a domestic metallurgical research centre, combined with limited government mining R&D funding, means that technology transfer depends on international partnerships. The Bučim SX/EW operation demonstrates that hydrometallurgical processing is technically feasible in-country, providing a demonstration reference point. However, translating this to a secondary recovery pilot requires investment in process engineering, QA/QC laboratory capacity, and water and emissions management infrastructure – none of which are documented as operational in available sources.

Implication: The secondary CRM pathway is technically plausible based on documented tailings geochemistry (Steiner et al., 2022) but requires pre-competitive investment in sampling standardisation, mineral liberation assessment, process engineering, and environmental control before commercial recovery projects can be designed. Embedding this investment within a national tailings inventory and risk-ranking programme linked to remediation obligations is both the most credible pathway and the most defensible use of public or EU co-financing.

4.5 Legal Factors

North Macedonia's mining legal framework has undergone material reform. The 2025 Mineral Resources Act (Karanovic & Partners, 2025) replaces earlier legislation and introduces: a unified exploration-exploitation permitting process reducing bureaucratic steps; a formal strategic mineral list updated triennially, aligned with EU CRM designations; a Strategic Project designation enabling accelerated environmental permitting for EU-relevant deposits; updated royalty rates (4% base metals; 4% gold and platinum); mandatory exploration expenditure

requirements; and a rehabilitation fund supplied by a portion of fee revenues. These are structurally enabling reforms.

However, the European Commission (2025) explicitly states that EIA legislation is not aligned with the EU acquis and that compliance with EIA and SEA requirements is weak. This creates legal vulnerability through challenge and permitting reversal, as demonstrated by the Ilovica–Štuka project litigation and the Kazandol arbitration case. The absence of alignment with the EU Environmental Liability Directive creates a gap in financial assurance requirements for remediation – a concern amplified by the documented tailings incident at Toranica.

On beneficial ownership transparency, the Commission (2025) notes that recent amendments require disclosure of true owners of mining entities – a CRMA due-diligence enabling condition – though systematic enforcement of this requirement is not yet documented. Stabilisation clauses in concession agreements (fixing taxes for 5–10 years) reduce fiscal uncertainty for investors but limit government flexibility to respond to evolving environmental liability assessments.

Implication: EIA/SEA acquis alignment is the single legal reform with the greatest leverage on investment risk reduction. Without it, any Strategic Project fast-tracking created by the 2025 Act risks producing legally vulnerable permits subject to challenge and reversal, exactly replicating the pattern documented in prior project disputes.

4.6 Environmental Factors

Environmental performance is the decisive criterion for sustainable CRM positioning under EU-aligned supply chains, and constitutes the dimension with the greatest documented gap between current conditions and CRMA and acquis requirements.

The European Commission's 2025 report (European Commission, 2025) documents a systemic environmental governance deficit: insufficient environmental administration staffing, weak transparency of EIA/SEA procedures, limited circular economy and waste management progress, non-alignment with the Environmental Liability Directive, and stalled Habitats/Birds Directive transposition. These structural deficits are documented as direct constraints on mining sector governance.

Case-specific evidence provides quantitative grounding for these systemic findings. The Toranica mine accident of March 2025 is characterised by the Commission as revealing serious enforcement gaps and a lack of preparedness and protocols at an actively operating mine – not a legacy site – demonstrating that current environmental governance is insufficient even for baseline operational oversight (European Commission, 2025). Ramani et al. (2014) document that the Toranica and Zletovo Pb–Zn operations in northeastern North Macedonia exert measurable influence on the water quality of the Zletovska and Kriva rivers, providing pre-incident baseline evidence of the operational environmental impact of the mining complex. Steiner et al. (2022) characterise tailings at Lojane as containing elevated As and Sb concentrations – creating both an environmental remediation priority and a potential CRM recovery opportunity – while also documenting that Bučim, Sasa, and Probištip tailings contain commodity and trace-element concentrations of potential economic interest subject to further feasibility assessment. Taken together, these findings document the dual nature of North Macedonia's tailings as environmental liabilities and potential secondary resources: the same sites require remediation and represent recovery opportunities, a coupling that defines the circular CRM pathway.

Renewable energy penetration (hydro, wind, and solar now exceeding 30% of generation) represents an enabling environmental condition for mining operations with high electricity demand, and the recent introduction of dry-stack tailings requirements for new projects reflects

progressive adoption of international best practice in waste management (Karanovic & Partners, 2025).

Implication: Environmental risks – particularly the demonstrated operational incident response failure at Toranica and the legacy contamination burden at Lojane – are the most immediate threats to CRM investment viability and EU supply chain eligibility. No secondary CRM recovery programme can responsibly proceed without simultaneous remediation infrastructure investment and independent environmental monitoring capacity.

5. DISCUSSION

The PESTLE evidence base reveals that North Macedonia's CRM sector challenge is structural rather than geological. The country's mineral resource base and existing concentrate export flows establish a material basis for EU value chain integration; the binding constraints are located in the political, legal, and environmental dimensions, where documented gaps are both severe and mutually reinforcing.

Three coupling effects warrant analytical emphasis. First, a political–legal–social coupling: anti-corruption weaknesses and EIA non-alignment are not independent failures but compounding ones. Weak legal frameworks create pathways for discretionary concession allocation; discretionary allocation undermines community trust; eroded trust generates project opposition that translates into permitting failure and arbitration risk, as documented in both the Kazandol termination (Armakolas & Krstinovska, 2025) and the Ilovica–Štuka litigation. The EC (2025) confirms that this coupling is active and unresolved.

Second, an economic–technological–environmental coupling: the concentrate export model generates revenue while deferring environmental liability to legacy tailings accumulation. The Kiselicki et al. (2025) finding that partial refining could increase revenues by approximately 50% defines the economic opportunity, but capturing it requires processing investment currently deterred by governance risk premia and the absence of EU co-financing instruments. Simultaneously, Steiner et al. (2022) demonstrate that the same tailings generating environmental liabilities – particularly at Probištip and Lojane – contain geochemically documented commodity and CRM-relevant trace element concentrations, a coupling that makes remediation and CRM recovery complementary rather than competing objectives.

Third, the EU accession process functions as a meta-driver across all dimensions. Accession conditionality creates institutional incentives for reform that would not otherwise be politically sustainable. The CRMA simultaneously creates market incentives: EU firms seeking CRMA-compliant near-shore supply have commercial reasons to support supplier-country governance improvements through joint ventures, technical assistance, and ESG contract structures. North Macedonia's strategic challenge is to convert these aligned incentives into measurable governance improvements before the CRMA's 2030 benchmarks create irreversible market lock-in favouring more advanced alternative suppliers.

Comparatively, North Macedonia's position resembles other Western Balkans producers (Serbia, Bosnia-Herzegovina) in its upstream-only export structure and governance-environment coupling, but differs in two respects: its more advanced EU accession status (all clusters screened) creates stronger institutional pressure for reform, and its smaller economy makes the marginal benefit of secondary CRM recovery – which requires lower capital outlay than primary processing investment – proportionally more significant.

The near-term pathway with the highest feasibility-to-impact ratio is a trusted circular supply model: systematically characterise secondary resources using standardised geochemical methods building on Steiner et al. (2022), pilot technically sound and environmentally controlled recovery at sites already requiring remediation, and supply EU markets under

traceable ESG contracts. This model converts a remediation obligation into a revenue stream, reduces environmental liability, and builds governance credibility simultaneously. It should be understood as complementary to, not a substitute for, the longer-term requirements of primary processing investment and governance reform.

6. POLICY RECOMMENDATIONS

The following recommendations are derived from the PESTLE synthesis. Each is explicitly grounded in the datasets and evidence reviewed in Section 4.

1. **National CRM and Secondary Raw Materials Strategy:** Develop a national strategy explicitly mapped to the CRMA's 34 critical and 17 strategic raw materials designations and 2030 benchmarks (European Union, 2024). The strategy must include a standardised national inventory and risk ranking of tailings and extractive waste, building on the geochemical characterisation work of Steiner et al. (2022) and Šajn et al. (2022), and prioritising sites for both remediation and recovery assessment. Sites at Lojane (As-Sb hazard and CRM potential) and Probištip (highest documented commodity metal concentrations) should be prioritised for initial assessment.
2. **EIA/SEA legislative alignment:** Implement a full EIA/SEA acquis alignment package, as specifically required by the European Commission (2025). This is the single legal reform with the greatest leverage on investment risk reduction and is a precondition for activating the Strategic Project fast-tracking introduced by the 2025 Mineral Resources Act without creating legally vulnerable permits.
3. **Processing investment and EU partnership framework:** Leverage copper's dual CRMA designation (strategic and critical) and documented export flows to pursue EU offtake and intermediate processing joint ventures, using EU IPA III co-financing instruments to bridge the capital gap documented by Kiselicki et al. (2025). Target the estimated 50% revenue uplift from partial refining as the economic rationale for EU risk-sharing.
4. **Secondary CRM recovery pilot programme:** Design pilot-scale secondary recovery projects at geochemically characterised sites – prioritising Probištip (highest documented Pb-Zn concentrations) and Lojane (CRMA-listed Sb recovery opportunity) – co-designed with remediation plans, strict water and emissions controls, and mineral liberation assessments, building on the geochemical data documented by Steiner et al. (2022). Pilot results should be reported against CRMA recycling benchmark progress.
5. **Extractives transparency standard:** Publish concession agreements, beneficial ownership data, revenue flows, municipal transfers, and environmental monitoring results as open, machine-readable datasets. Address the gap between legislative beneficial ownership disclosure requirements (Karanovic & Partners, 2025) and systematic enforcement.
6. **Tailings safety and emergency preparedness:** Implement mandatory independent tailings safety audits and documented emergency response protocols across all active and legacy facilities, directly responding to the enforcement and preparedness failures identified at Toranica (European Commission, 2025). Link concession renewal to demonstrated compliance with updated dam safety standards.
7. **Human capital development:** Launch scholarship and apprenticeship programmes in metallurgy, geometallurgy, hydrometallurgy, and environmental monitoring, funded through mining royalties or EU skills instruments, to address the documented technical

workforce gap. Target programmes specifically at the disciplines required for secondary CRM recovery.

8. **Community benefit-sharing formalisation:** Legislate binding community development agreements for major projects, with transparent reporting of municipal royalty allocation and independent participatory environmental monitoring. Ensure the existing 78% municipal royalty mechanism (Karanovic & Partners, 2025) is linked to measurable local outcomes rather than absorbed into general municipal budgets.

7. CONCLUSIONS

North Macedonia has a documented material basis for CRM-relevant participation in European value chains: lead, zinc, and copper concentrate exports totalling approximately EUR 127 million in 2023 (Kiselicki et al., 2025), operationally demonstrated beneficiation and SX/EW processing capability (Central Asia Metals, 2024; Solway Group, n.d.), and secondary resource stocks with geochemically characterised tailings at Sasa, Probištip, Bučim, and Lojane (Steiner et al., 2022). However, the PESTLE analysis unambiguously identifies governance and environmental enforcement weaknesses – not geological limitations – as the primary barriers to sustainable CRM integration.

The 2025 Mineral Resources Act (Karanovic & Partners, 2025) represents a material enabling step, introducing strategic project designation and updated royalty structures. However, the European Commission (2025) confirms that this legislative modernisation is not matched by commensurate enforcement capacity, EIA/SEA acquis alignment, or anti-corruption progress – the three governance conditions most directly linked to CRMA trusted-supplier eligibility.

The recommended pathway is a governance-first, circular supply model in which secondary CRM recovery is paired with remediation obligations, financed through EU instruments, and governed through transparent ESG contracts. This pathway generates economic value (estimated 50% revenue uplift from processing upgrades (Kiselicki et al., 2025)), reduces environmental liability at geochemically characterised tailings sites (Steiner et al., 2022), and builds governance credibility simultaneously. It is not an alternative to primary mining investment; it is the precondition for attracting ESG-qualified primary investment.

The evidence base presented in this paper does not support a growth-first narrative in which new primary mining investment precedes governance improvements. Documented legal, environmental, and anti-corruption gaps are not incidental constraints but constitute the binding condition: addressing them is simultaneously the most effective investment climate measure and the most credible pathway to CRMA-compliant EU supply chain integration.

8. LIMITATIONS AND FUTURE RESEARCH

This analysis is based entirely on secondary sources. Several quantitative data points (exact tailings volumes, comprehensive mineral inventory, workforce statistics) are unavailable in the public domain or only available through proprietary corporate disclosures; these limitations are explicitly flagged in Section 4 where they affect analytical confidence. The Mineral Resources Act (Karanovic & Partners, 2025) and the 2025 EC monitoring report (European Commission, 2025) are recent documents whose practical implementation outcomes are not yet observable; assessments of their effect are therefore necessarily provisional.

Future research priorities include: (i) a systematic national tailings inventory based on standardised geochemical sampling, extending the characterisation work of Steiner et al. (2022) and Šajin et al. (2022) to provide quantitative reserve estimates and mineral liberation data required for recovery feasibility assessment; (ii) economic modelling of secondary CRM recovery feasibility at specific sites, incorporating process engineering, mineral liberation, and

water management cost estimates; (iii) primary social science research (community surveys, stakeholder interviews) to quantify social licence barriers and benefit-sharing preferences; and (iv) longitudinal tracking of EIA/SEA alignment implementation to assess whether the 2025 Act's strategic project provisions create durable permitting improvements or replicate prior project dispute patterns.

9. REFERENCES

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