SUB-THEME 1: CORPORATE SUSTAINABILITY AND GREEN INNOVATION

Green Innovation Adoption in Zimbabwe's Mining Sector: Barriers, Drivers, and Strategic Pathways

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Abstract

Zimbabwe's mining sector encompassing platinum, gold, and chrome extraction is among the country's most significant economic contributors, accounting for 16–18% of GDP and over 60% of export earnings, yet it remains a leading source of environmental degradation, community displacement, and carbon-intensive operations. As global green economy imperatives intensify, mining corporations face mounting pressure to adopt green innovative technologies and sustainable operational practices. This study examines green innovation adoption in Zimbabwe's mining sector through a concurrent mixed-methods design combining structured executive surveys across 47 mining companies and in-depth case studies of three purposively selected operations spanning large-scale PGM, medium-scale gold, and artisanal and small-scale mining (ASM) contexts. Drawing on Institutional Theory, Stakeholder Theory, and the Resource-Based View, the study identifies a multi-dimensional barrier landscape comprising structural-financial constraints ($M = 4.31/5.00$), technological access limitations, regulatory inconsistency (a significant independent deterrent, $\beta = -0.34$, $p < 0.01$), and social-community barriers unique to ASM contexts. Concurrently, it maps three principal adoption drivers: international market and supply chain demands, investor ESG pressure, and community advocacy. The study's principal contribution is the Zimbabwe Mining Green Innovation Framework (ZiMGIF)a structured four-layer conceptual model integrating the institutional environment, stakeholder ecosystem, organisational capabilities, and innovation outcomes that delineates the causal pathways through which barriers and drivers shape green innovation trajectories. Findings confirm that adoption is predominantly incremental, externally driven, and confined to a large-operator vanguard, leaving SMEs and ASMs substantially outside the green transition. The study connects its analysis to Zimbabwe's National Development Strategy, the Paris Agreement NDC commitments, and the UN SDGs, offering actionable recommendations for corporate managers, policymakers, and development finance institutions committed to advancing a just and inclusive green transition in sub-Saharan Africa.

Key Words : Green Innovation, Mining Sustainability, Zimbabwe , ESG Compliance, Environmental Degradation

1. Introduction

The global transition to a green economy has placed unprecedented demands on resource-extractive industries, compelling them to reconcile historically carbon-intensive and ecologically disruptive operations with the imperatives of environmental stewardship, social responsibility, and long-term economic viability. The mining sector, as a foundational pillar of industrial supply chains and national revenue in resource-rich developing economies, occupies a peculiarly contested position within this transition. On one hand, it supplies the critical minerals lithium, cobalt, platinum, and rare earth elements indispensable to renewable energy technologies and electric mobility. On the other, it continues to generate some of the world's most severe localised environmental impacts, including land degradation, water contamination, biodiversity loss, and greenhouse gas emissions (Spiegel, 2017; Franks, 2015).

Zimbabwe's mining sector exemplifies these contradictions acutely. The sector contributes approximately 16 to 18 percent of the country's Gross Domestic Product (GDP) and accounts for over 60 percent of export earnings (Zimbabwe Mining Development Corporation, 2022). Platinum Group Metals (PGMs), gold, and chrome are the dominant extractives, with Zimbabwe holding the world's second-largest known platinum reserves. Yet the environmental legacy of mining operations spanning abandoned mine sites contaminated with acid drainage, displaced rural communities, deforested catchments, and polluted waterways constitutes a significant sustainability liability that contradicts Zimbabwe's commitments under the Paris Agreement and its own National Development Strategy (NDS1: 2021–2025 and NDS2: 2026–2030).

Green innovation, broadly defined as the development and deployment of novel products, processes, technologies, and organisational arrangements that reduce ecological impact while creating economic and social value (Chen et al., 2006; Kemp & Pearson, 2008), has emerged as a strategic imperative for mining corporations navigating this transition. However, adoption rates in sub-Saharan Africa remain conspicuously low relative to global peers, constrained by a confluence of structural, institutional, financial, and knowledge-related barriers that existing literature has yet to analyse comprehensively in the Zimbabwean context (Boateng et al., 2021; Nhamo & Chikodzi, 2021).

This paper addresses that gap. It poses the central research question: What factors drive and impede the adoption of green innovation in Zimbabwe's mining sector, and through what strategic pathways can corporations advance a sustainable green transition? To answer this question, the study deploys a mixed-methods research design, develops a structured conceptual model the Zimbabwe Mining Green Innovation Framework (ZiMGIF) and generates findings with direct relevance to corporate strategy, national policy, and international development finance. The paper proceeds as follows: Section 2 reviews the relevant theoretical and empirical literature; Section 3 outlines the research methodology; Section 4 presents and discusses key findings; Section 5 addresses economic, managerial, and business implications; and Section 6 concludes with contributions, limitations, and directions for future research.

2. Literature Review

2.1 Conceptualising Green Innovation in Extractive Industries

Green innovation scholarship has evolved considerably since the foundational work of Fussler and James (1996), who introduced the concept of 'eco-innovation' as the commercial development of environmentally superior products and processes. Subsequent definitional refinements have distinguished between incremental green innovations such as energy-

efficiency improvements or pollution abatement technologies and radical or disruptive innovations that fundamentally reconfigure production systems (Rennings, 2000). For the extractive sector, green innovation encompasses environmental management systems (ISO 14001 certification), cleaner production technologies, renewable energy substitution in energy-intensive operations, water recycling and zero-liquid-discharge systems, and mine site rehabilitation protocols (Mudd, 2010).

In the African context, the adoption of green innovation in mining is shaped by a distinctive set of institutional and structural conditions. Boateng et al. (2021) demonstrated that South African platinum mining firms adopted green practices primarily in response to regulatory pressure and reputational risk, rather than intrinsic ecological motivation a finding that aligns with institutional theory's emphasis on coercive isomorphism (DiMaggio & Powell, 1983). Nhamo and Chikodzi (2021) similarly found that Zimbabwean firms were largely reactive rather than proactive in their environmental strategies, citing limited state enforcement capacity and the dominance of short-term profit imperatives. These findings point to a structural agency gap: the enabling conditions for voluntary green innovation adoption are insufficiently developed in Zimbabwe's institutional environment.

2.2 Theoretical Frameworks

Three theoretical frameworks inform the current study. First, Institutional Theory (DiMaggio & Powell, 1983; Scott, 1995) provides a lens for understanding how coercive pressures (regulatory requirements), normative pressures (professional norms and industry standards), and mimetic pressures (imitation of industry leaders) shape organisational decisions to adopt or resist green innovation. Zimbabwe's mining sector is subject to coercive pressures from the Environmental Management Agency (EMA) and international certification bodies, normative pressures from global ESG reporting frameworks such as the Global Reporting Initiative (GRI) and the Taskforce on Climate-Related Financial Disclosures (TCFD), and mimetic pressures from multinational peers operating in the sector.

Second, Stakeholder Theory (Freeman, 1984; Mitchell et al., 1997) foregrounds the role of diverse actors' shareholders, governments, local communities, financiers, and civil society in shaping corporate environmental behaviour. The theory posits that corporations capable of effectively managing multiple, sometimes conflicting, stakeholder demands are better positioned to sustain competitive advantage in transitional contexts. In Zimbabwe's mining sector, community advocacy, investor ESG screening, and government development imperatives constitute the principal stakeholder pressures that can catalyse or retard green innovation adoption.

Third, the Resource-Based View (Barney, 1991; Hart, 1995) holds that superior environmental performance stems from rare, inimitable, and non-substitutable organisational capabilities including green knowledge assets, technological competencies, and managerial expertise. Hart's (1995) 'natural resource-based view' extended this logic to argue that pollution prevention, product stewardship, and sustainable development capabilities constitute distinct and strategically valuable resource bundles. For Zimbabwean mining corporations constrained by limited financial and human capital, the RBV underscores the importance of capability building as a precondition for sustained green innovation adoption.

2.3 Barriers to Green Innovation in Developing Economy Mining Contexts

A substantial body of literature identifies capital constraints as the single most pervasive barrier to green innovation adoption in low-income mining contexts (Halme & Korpela, 2014; Kolk & van Tulder, 2010). Zimbabwe's mining sector operates within a deeply

challenging macroeconomic environment characterised by currency instability, high borrowing costs, limited access to long-term capital markets, and constrained fiscal space for public investment in green infrastructure (Muzamhindo et al., 2021). These conditions render the upfront capital outlays required for renewable energy installations, water treatment systems, and tailings management facilities prohibitive for many operators.

Technological access limitations constitute a second critical barrier. While green technologies are increasingly cost-competitive globally, knowledge-intensive innovations such as real-time environmental monitoring systems, bioremediation technologies, and advanced tailings storage facilities require technical expertise, maintenance infrastructure, and vendor support ecosystems that are inadequately developed in Zimbabwe (UNEP, 2020). Regulatory inconsistency compounds this challenge: the frequent revision of Zimbabwe's mining regulations, the coexistence of multiple overlapping regulatory frameworks, and the limited enforcement capacity of the Environmental Management Agency create an unpredictable operating environment that discourages long-term sustainability investment (Sibanda & Mupfumira, 2020).

Knowledge gaps manifesting in inadequate awareness of green technologies, limited capacity for environmental impact assessment, and insufficient managerial understanding of ESG frameworks represent a fourth structural barrier (Schuchard et al., 2011). These gaps are particularly acute among junior and mid-sized mining operators and among artisanal and small-scale miners (ASMs), who account for a significant share of Zimbabwe's gold production but operate almost entirely outside formal environmental governance structures (Spiegel, 2012; Hilson, 2012).

2.4 Drivers of Green Innovation Adoption

Against this barrier landscape, three principal adoption drivers have been identified in the literature. International market demands and commodity pricing premiums for responsibly sourced minerals have emerged as powerful commercial incentives, particularly in platinum and chrome markets where European and Asian buyers increasingly demand supply chain due diligence and environmental certification (Hilson & Murck, 2000; ICMM, 2020). Investor pressure for ESG compliance has accelerated significantly following the 2015 Paris Agreement and the subsequent proliferation of green finance instruments, with major institutional investors divesting from or engaging with carbon-intensive operations in line with Net Zero commitments (Friede et al., 2015; Krueger et al., 2020). Community advocacy expressed through environmental litigation, protest, and participatory governance mechanisms has also demonstrated a capacity to impose reputational and operational costs on non-compliant operators, compelling more responsive corporate environmental behaviour (Bebbington et al., 2008; Idemudia, 2010).

3. Research Methodology

3.1 Research Philosophy and Design

This study adopts a pragmatist research philosophy, recognising that complex, multidimensional phenomena such as green innovation adoption are best understood through the integrated application of qualitative and quantitative methods that complement each other's explanatory strengths (Creswell & Plano Clark, 2018). A concurrent mixed-methods design was employed, wherein quantitative survey data and qualitative case study evidence were collected and analysed in parallel and subsequently synthesised at the level of interpretation.

This design enables both statistical generalisation across the sector and contextualised, thick description of organisational processes that surveys alone cannot capture.

3.2 Quantitative Component: Executive Survey

A structured questionnaire was administered to senior managers and executives across a purposively selected sample of 47 mining companies operating in Zimbabwe's platinum, gold, and chrome sub-sectors. Respondents held positions including Chief Executive Officer, Chief Sustainability Officer, Environmental Manager, and Operations Director positions with direct responsibility for green innovation decision-making. The questionnaire comprised 62 items organised across five dimensions: (1) current green innovation practices, (2) perceived barriers to adoption, (3) perceived drivers of adoption, (4) ESG strategy and reporting maturity, and (5) stakeholder engagement mechanisms. Responses were recorded on five-point Likert scales. Descriptive statistics, factor analysis, and regression analysis were employed to identify the relative significance of barriers and drivers and to explore their relationships with adoption outcomes.

3.3 Qualitative Component: Case Studies

Three purposively selected case studies were conducted to provide in-depth contextualisation of the survey findings. The cases represent operations of varying scales, ownership structures, and green innovation maturity levels: a large multinational PGM (Platinum Group Metals) producer operating in the Great Dyke region; a medium-sized domestically owned gold mining company in Mashonaland West; and an artisanal and small-scale mining cooperative in Midlands Province. Data were collected through semi-structured interviews (n = 24 across all cases), direct site observation, and document analysis of environmental compliance records, sustainability reports, and community engagement frameworks. Interviews were transcribed verbatim and analysed through thematic analysis using NVivo 12, with themes deductively informed by the study's theoretical frameworks and inductively refined through iterative engagement with the data.

3.4 Validity, Reliability, and Ethics

Construct validity was enhanced through triangulation across data sources and methods, as well as through member-checking with key informants. Internal consistency of survey scales was assessed using Cronbach's alpha, with all dimensions exceeding the accepted threshold of 0.70. The research was conducted in accordance with the ethical guidelines of Midlands State University, Zimbabwe. Informed consent was obtained from all participants, confidentiality was assured, and data were anonymised at the point of transcription. Institutional access to the three case study sites was negotiated through formal written agreements.

4. Findings and Discussion

4.1 State of Green Innovation Adoption in Zimbabwe's Mining Sector

Survey findings reveal a sector characterised by uneven and predominantly incremental green innovation adoption. Approximately 68 percent of respondent organisations reported implementing at least one form of green innovation practice, though the depth and sophistication of these practices varied enormously. Energy efficiency improvements primarily through LED lighting retrofits and blast optimisation to reduce diesel consumption were the most commonly reported measures (cited by 71% of respondents), consistent with their relatively modest capital requirements and near-term operational cost savings. Renewable

energy adoption was considerably less prevalent: only 22 percent of surveyed companies had installed solar photovoltaic systems, and a mere 8 percent had implemented wind energy solutions, despite Zimbabwe's substantial solar irradiance potential.

Water recycling and conservation measures were reported by 54 percent of respondents, driven primarily by operational necessity in the context of Zimbabwe's recurrent droughts and deteriorating water infrastructure. Tailings management and mine rehabilitation practices, by contrast, were reported by only 31 percent of companies a finding that corresponds with widespread observations of inadequate post-mining land rehabilitation across the sector. ISO 14001 environmental management certification, a widely recognised proxy for systematic environmental governance maturity, was held by only 17 percent of sampled companies, predominantly large multinational operators. These patterns suggest that green innovation adoption in Zimbabwe's mining sector is primarily cost-driven and reactive rather than strategically motivated, with the most demanding and capital-intensive environmental improvements confined to a small corporate vanguard.

4.2 The Barrier Landscape: A Multi-Dimensional Analysis

Factor analysis of barrier items yielded four distinct barrier dimensions, broadly consistent with the literature review's conceptual framework. The first and most heavily loaded factor designated Structural-Financial Barriers encompassed items related to capital scarcity, high cost of capital, limited access to green finance instruments, and macroeconomic instability. Mean scores for capital constraint items were consistently the highest of all barrier categories ($M = 4.31$, $SD = 0.72$ on a five-point scale), with 89 percent of respondents rating capital availability as a significant or very significant barrier. Qualitative data from case studies corroborated and enriched these findings. The Environmental Manager at the large multinational PGM producer articulated the challenge thus: 'We can identify the technologies we need. The peer-reviewed evidence is not in question. What is in question is whether the balance sheet can sustain the capital commitment in an economy where US dollar financing is not readily available and where our revenue projections carry significant currency risk.' This testimony underscores that capital constraints in Zimbabwe are not merely a matter of absolute financial scarcity but are deeply entangled with macroeconomic volatility and currency risk a combination that renders long-term sustainability investment particularly difficult to finance.

The second factor Technological and Knowledge Barriers encompassed items related to limited access to green technologies, absence of local technical expertise, inadequate vendor and maintenance ecosystems, and deficient managerial familiarity with ESG frameworks. Technological access barriers were rated as significant by 76 percent of respondents. Case study evidence from the domestically owned gold company illustrated the practical dimension of this barrier: the company had invested in a water recycling system procured from South Africa but had been unable to operate it at designed capacity for over two years due to the unavailability of replacement components and qualified maintenance technicians in Zimbabwe. This finding points to a fundamental structural weakness in Zimbabwe's green technology ecosystem: the absence of domestic green technology manufacturing, servicing, and skills development capacity creates a systemic dependency on imported solutions that are chronically vulnerable to supply chain disruptions.

The third factor Regulatory and Governance Barriers encompassed perceptions of regulatory inconsistency, uncertainty regarding enforcement, and the absence of credible long-term policy signals. Regression analysis revealed that regulatory uncertainty was a statistically significant negative predictor of green innovation investment intention ($\beta = -0.34$, $p < 0.01$), even after controlling for capital availability, suggesting that policy incoherence constitutes an

independent deterrent beyond financial constraints. This finding has significant implications for the design of public policy: mere financial incentives for green investment are insufficient if they are not accompanied by stable, predictable, and credibly enforced environmental governance frameworks.

The fourth and final barrier factor Social and Community-Related Barriers was perhaps the most contextually distinctive finding of the study. Several respondents, particularly those from the ASM cooperative case study, identified the social complexity of green transition as a significant operational challenge. Green transition in ASM communities often requires changes to labour processes, adoption of capital inputs, and compliance with formal governance structures that are perceived by miners as threats to livelihoods and traditional ways of working. The cooperative's community liaison coordinator articulated this tension with clarity: 'Our members understand that mercury (used in gold amalgamation) is harmful. They have seen the health impacts. But the alternative processing methods require equipment they cannot afford and training they cannot access. Green means different things when you are operating at the margins of subsistence.'

4.3 Drivers of Adoption: International Pressures and Domestic Advocacy

Empirical findings confirm that the most powerful adoption drivers operate through external market and investor channels rather than through domestic regulatory incentives. International market demands particularly buyers' requirements for Responsible Mining Assurance (IRMA) and London Bullion Market Association (LBMA) certification were identified by 83 percent of respondents in the large-scale sub-sector as a significant driver of green investment. For the multinational PGM producer, ESG compliance was explicitly embedded in customer contracts: failure to meet specified environmental thresholds would trigger contract renegotiation, providing a direct commercial incentive that domestic regulation alone had failed to create. This finding corroborates the broader literature on the 'California Effect' in environmental regulation, wherein market access requirements set by demanding consumers function as de facto regulatory standards that travel along global supply chains (Vogel, 1997).

Investor pressure, measured through the adoption of ESG reporting frameworks and the receipt of investor environmental engagement queries, was identified as a significant driver by 61 percent of large-scale respondents but by only 9 percent of small and medium-scale operators a disparity that reflects the differential exposure of companies to international capital markets. Companies listed on international stock exchanges or receiving financing from development finance institutions with ESG requirements (such as the International Finance Corporation or the African Development Bank) were substantially more likely to have formalised green innovation strategies, suggesting that ESG-linked conditionalities in development finance instruments are an effective though limited in reach mechanism for driving adoption.

Community advocacy emerged as the most contextually contingent driver. In areas with active civil society organisations and communities with prior experience of environmental harm particularly former mining districts affected by acid mine drainage and stream contamination community advocacy had demonstrably catalysed corporate environmental investment through both direct engagement and legal mechanisms. In areas with weaker civil society capacity, however, community pressure was diffuse and easily managed through tokenistic consultative processes, underscoring the importance of community capacity-building as a complementary policy intervention.

4.4 The Zimbabwe Mining Green Innovation Framework (ZiMGIF)

Synthesising the theoretical frameworks and empirical findings, this study proposes the Zimbabwe Mining Green Innovation Framework (ZiMGIF) as a structured conceptual model for understanding, predicting, and strategically advancing green innovation adoption in Zimbabwe's mining sector. The framework comprises four interrelated layers, described below and illustrated in Table 1.

Table 1: The Zimbabwe Mining Green Innovation Framework (ZiMGIF)

ZiMGIF Layer	Core Components	Theoretical Grounding	Strategic Intervention
Layer 1: Institutional Environment	Regulatory frameworks, policy coherence, EMA enforcement, international standards (GRI, TCFD, LBMA)	Institutional Theory (DiMaggio & Powell, 1983)	Policy stability, credible enforcement, harmonised standards
Layer 2: Stakeholder Ecosystem	Investor ESG mandates, community advocacy, supply chain buyer requirements, government development imperatives	Stakeholder Theory (Freeman, 1984)	Multi-stakeholder platforms, community capacity building, ESG-linked finance
Layer 3: Organisational Capabilities	Green knowledge assets, environmental management maturity, managerial competencies, R&D investment	Resource-Based View (Hart, 1995)	Capability building, technical assistance, knowledge transfer
Layer 4: Innovation Outcomes	Adoption type (incremental vs. radical), depth (operational vs. strategic), breadth (scope of innovations adopted), and sustainability performance	All three frameworks	Monitoring, evaluation, reporting, and adaptive management

The ZiMGIF posits that green innovation adoption in Zimbabwe's mining sector is the product of dynamic interactions between the institutional environment, the stakeholder ecosystem, and organisational capabilities. When institutional conditions are weak characterised by regulatory inconsistency and limited enforcement neither stakeholder pressure

nor organisational capability can independently compensate: the result is a low adoption equilibrium in which market forces and community advocacy cannot fully substitute for effective governance. Conversely, when all three layers are adequately developed and mutually reinforcing, the framework predicts a high adoption trajectory characterised by both incremental and radical green innovation, sustainable performance improvement, and competitive advantage in ESG-sensitive markets.

The framework also accommodates the distinctive challenges of artisanal and small-scale miners (ASMs), for whom the standard adoption pathway driven by ESG investor pressure and supply chain buyer demands is largely inaccessible. For ASMs, the framework prescribes a distinct intervention pathway: progressive formalisation supported by technical assistance, simplified regulatory compliance mechanisms, cooperative access to green technology financing, and integration into traceable, responsibly sourced supply chains. This pathway acknowledges that ASMs constitute both a significant environmental risk being responsible for most mercury pollution in Zimbabwe's waterways and an equity imperative, given that they provide livelihoods for an estimated 1.5 million people across the country (World Bank, 2019).

4.5 Water Conservation and Mine Site Rehabilitation

Two thematic issues warrant specific discussion given their prominence in empirical findings and their significance for Zimbabwe's green transition. Water conservation emerged as the area of greatest overlap between environmental urgency and operational self-interest. Zimbabwe's mining operations are concentrated in the Midlands, Matabeleland, and Mashonaland provinces, all of which have experienced significant declines in rainfall reliability over the past two decades, consistent with regional climate projections under 1.5°C and 2°C warming scenarios (IPCC, 2022). Water stress has imposed direct operational costs on mining companies through reduced process water availability, increased pumping costs, and regulatory restrictions on water extraction that have created a commercially motivated demand for water efficiency investment independent of green ideology or ESG compliance. Survey findings corroborate this dynamic, with water recycling investments frequently justified to boards based on operational cost reduction rather than environmental stewardship.

Mine site rehabilitation represents the sector's most significant unresolved environmental liability. An estimated 4,800 abandoned mine sites exist in Zimbabwe, the majority of which have never been formally rehabilitated (EMA, 2021). The absence of mandatory financial assurance instruments such as rehabilitation bonds or environmental trust funds means that the costs of remediation are effectively externalised to the state and affected communities. Case study evidence from the Midlands Province illustrated the human dimension of this failure vividly: residents in communities adjacent to a defunct chrome operation reported contaminated groundwater, elevated prevalence of respiratory illness, and near-total loss of agricultural productivity in affected soils. The affected community's traditional leader summarised the situation with measured precision: 'The company came, extracted what it needed, and left. The poison stayed. That is not development; that is transfer of harm.' This testimony reflects a broader pattern of environmental injustice that the green economy transition must explicitly address through retroactive rehabilitation obligations, community-controlled restoration processes, and innovative financing mechanisms such as blended finance and environmental bonds.

5. Economic, Managerial, and Business Implications

5.1 Implications for Corporate Strategy and Management

The findings of this study carry several direct implications for corporate strategy and management practice in Zimbabwe's mining sector. First, the demonstrated primacy of institutional and financial barriers over purely attitudinal barriers indicates that voluntary corporate sustainability commitments, while necessary, are insufficient in the absence of enabling conditions. Mining corporations seeking to advance green innovation adoption should therefore pursue a dual strategy: building internal environmental management capabilities while actively engaging in collective advocacy for policy reform and improved access to green finance. This dual strategy aligns with the 'institutional entrepreneur' role that Hart and Sharma (2004) attribute to sustainability-oriented corporations in transitional institutional environments.

Second, the strong empirical association between supply chain buyer requirements and green innovation investment suggests that strategic supply chain positioning specifically, orientation toward markets and buyers that impose credible environmental standards is a powerful lever for sustainability transformation. For Zimbabwean mining companies seeking to access European, North American, and East Asian markets with progressive ESG procurement policies, green certification and traceable supply chain systems represent not merely compliance costs but genuine sources of competitive differentiation and market access.

Third, the finding that regulatory uncertainty functions as an independent deterrent to green investment beyond financial constraints underscores the importance of government's role in creating credible long-term policy commitments. Corporations cannot confidently invest in long-lived sustainability assets (solar installations, water recycling systems, rehabilitation trust funds) without reasonable assurance that the regulatory environment in which those investments were designed will persist. Governments and regulatory bodies should therefore prioritise policy stability, transparent enforcement, and long-term green investment signals including carbon pricing roadmaps, mandatory ESG disclosure requirements, and green public procurement policies as foundations for private sector green innovation.

5.2 Implications for Development Finance and Green Economy Transition

The analysis identifies a critical gap in the financing architecture for green innovation in Zimbabwe's mining sector. Conventional commercial finance is systematically misaligned with the risk profile, time horizon, and return structure of green innovation investments: these investments typically entail high upfront capital costs, generate diffuse and sometimes non-monetisable environmental benefits, and require long payback periods that commercial lenders are unwilling to accommodate in Zimbabwe's volatile macroeconomic environment. This financing gap has profound implications for the green economy transition: it means that market forces alone even those mediated by ESG investor pressure cannot mobilise the scale of green capital required for a sector-wide sustainability transformation.

Bridging this gap requires a combination of blended finance instruments, concessional lending, green bonds, and climate finance mechanisms that de-risk private investment by absorbing first-loss tranches, offering interest rate subsidies, or providing guarantees against regulatory and currency risk. International climate finance channels including the Green Climate Fund, the Climate Investment Funds, and bilateral development finance institutions have a critical role to play in capitalising such instruments for Zimbabwe's mining sector, particularly for smaller operators and ASM communities that lack the institutional capacity to access standard climate finance modalities. The African Development Bank's African Minerals Development Centre (AMDC) and the African Union's Africa Mining Vision provide relevant continental frameworks within which such financing architectures could be operationalised.

5.3 Connections to National and Global Policy Frameworks

Zimbabwe's National Development Strategy (NDS1:2021-2025) explicitly incorporates green economy principles, including commitments to sustainable mining, renewable energy transition, and climate resilience. However, the translational gap between these policy commitments and on-the-ground implementation remains vast, reflecting broader challenges of institutional capacity, financing, and private sector alignment. The ZiMGIF offers a diagnostic and prescriptive tool for operationalising NDS green economy commitments within the mining sector, identifying the specific institutional, stakeholder, and capability-building interventions required at each layer of the framework. Alignment with SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals) is explicit and deliberate within the framework's design.

The Paris Agreement's nationally determined contribution (NDC) framework provides a further policy anchor for green innovation in mining. Zimbabwe's revised NDC (submitted in 2021) commits to a 33 percent reduction in greenhouse gas emissions by 2030, with the mining sector identified as a priority mitigation area. Meeting this commitment will require structural green innovation across the sector particularly in energy use (which accounts for most mining-related emissions) and in methane management in coal-adjacent operations. The findings of this study suggest that meeting NDC targets will require a fundamentally new approach to policy design: one that acknowledges the structural barriers identified by the ZiMGIF and designs NDC implementation mechanisms that are calibrated to Zimbabwe's economic constraints rather than transplanted from high-income country policy toolkits.

6. Conclusion

This study has examined the adoption of green innovation in Zimbabwe's mining sector through a mixed-methods research design, generating empirical findings that illuminate a multi-dimensional barrier landscape, a set of commercially and politically potent adoption drivers, and the conditions under which barriers and drivers interact to shape innovation outcomes. The principal theoretical contribution of the study is the Zimbabwe Mining Green Innovation Framework (ZiMGIF), which integrates Institutional Theory, Stakeholder Theory, and the Resource-Based View into a structured four-layer model that captures the causal architecture of green innovation adoption in a developing economy extractive context.

The study's empirical findings confirm that green innovation adoption in Zimbabwe is predominantly incremental, externally driven, and confined to a corporate vanguard of large, internationally connected operators leaving small and medium enterprises, and artisanal and small-scale miners, substantially outside the green transition. Overcoming this stratification requires a differentiated policy response: one that combines credible institutional reform, targeted capability-building, ASM formalisation pathways, blended finance instruments, and multi-stakeholder governance platforms into a coherent national strategy for sustainable mining.

The study's limitations should be acknowledged. The sample of 47 companies, while carefully selected, does not constitute a representative census of Zimbabwe's mining sector, and the exclusion of junior explorers and companies operating in the coal and diamonds sub-sectors limits the generalisability of findings. Furthermore, the snapshot nature of cross-sectional data collection precludes causal inference about the dynamic processes through which barriers and drivers evolve over time. Future research should pursue longitudinal designs that track green innovation trajectories, comparative studies that position Zimbabwe within the

broader Southern African regional context, and impact evaluations of specific green finance instruments deployed in the mining sector.

Notwithstanding these limitations, this study makes a distinctive contribution to the growing body of knowledge on green economy transition in developing and emerging economies. By grounding theoretical analysis in rich empirical evidence from Zimbabwe, and by developing a context-specific conceptual framework rather than reproducing Eurocentric models, the study advances the case for context-sensitive, equity-conscious approaches to green innovation that take seriously the structural constraints and development imperatives of sub-Saharan Africa. The green economy transition, if it is to be genuinely just and inclusive, must be built on such foundations.

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