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EXECUTIVE SUMMARY

MARKET ASSESSMENT ON CRITICAL MINERALS INNOVATION IN DEVELOPING COUNTRIES



UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Market assessment of technological innovations in the midstream and downstream segments of Critical Minerals value chains in developing countries - Columbia Center on Sustainable Investment (CCSI) and Columbia Engineering

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UNIDO is a specialized agency of the United Nations with a unique mandate to promote, dynamize and accelerate industrial development. Our mandate is reflected in Sustainable Development Goal (SDG) 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation", but UNIDO's activities contribute to all the SDGs. UNIDO's vision is a world without poverty and hunger, where industry drives low-emission economies, improves living standards, and preserves the livable environment for present and future generations, leaving no one behind.



The Columbia Center on Sustainable Investment (CCSI), a joint center of Columbia Law School and Columbia Climate School at Columbia University, is a leading applied research center and forum dedicated to the study, practice, and discussion of sustainable international investment. Our mission is to develop and disseminate practical approaches and solutions, as well as to analyse topical policy-oriented issues, in order to maximise the impact of international investment for sustainable development. The Center undertakes its mission through interdisciplinary research, advisory projects, multi stakeholder dialogue, educational programmes, and the development of resources and tools.



The mission of The Fu Foundation School of Engineering and Applied Science is to expand knowledge and advance technology through research, while educating students to become leaders informed by an engineering foundation. Enriched with the intellectual resources of a global university in the City of New York, we push disciplinary frontiers, confront complex issues, and engineer innovative solutions to address the grand challenges of our time. We create a collaborative environment that embraces interdisciplinary thought, integrated entrepreneurship, cultural awareness, and social responsibility, and advances the translation of ideas into practical innovations.

Key Findings



This assessment examines **technological innovation in critical minerals in developing countries**, focusing on the **midstream** (processing and refining) and **downstream** segments (manufacturing, extraction from secondary sources, and end-of-life treatment). It navigates the nexus of stakeholders, policies, initiatives, financial mechanisms, technologies, and impacts on the Sustainable Development Goals (SDGs). Starting from an analysis of 30 countries during Phase 1, deep-dives were conducted during Phase 2 in three from each developing region: **Africa, Asia and South Pacific (ASP)**, and **Latin America and the Caribbean (LAC)**.



A robust **enabling environment** is essential for innovation in critical minerals, requiring institutional capacity and financial and technical resources within the government to shape conducive policy, legal, and regulatory frameworks; accessible, affordable, and sufficient finance from public and private institutions; and partnerships and other collaborative initiatives among stakeholders at the national, regional, and global levels.



The 30 developing countries were rated according to their **policy readiness** level: 50% rated high in renewable energy targets and policies for technological innovation, research and development (R&D), and critical minerals processing and refining; 30% in policies for assembly and manufacturing; and 6.7% in policies for circular economy, recycling, and waste management.



Common in developing countries' successes in fostering an enabling environment for critical minerals innovation are **policy frameworks that emphasise domestic industrial development** beyond the exploration and extraction phase. Policy efforts are often **structured in a way to reinforce rather than compete with other development priorities**, such as the development of the upstream segment, economic diversification, infrastructure development,



education and upskilling, environmental sustainability, access to clean energy, and poverty eradication.

Initiatives by international organizations, governments, industry, and other stakeholders support technological innovation in critical minerals in developing countries. A total of **100** global, regional, and national initiatives were analysed, including financing mechanisms (**53%**) and other initiatives (**47%**); they seek to either finance innovation projects or build up the enabling environment for mid- and downstream activities. **Gaps** in these initiatives include the need for greater scale; finer coordination among them as to policy interventions, minerals, and segments to be prioritised in different markets; and increased sharing of knowledge and data on technologies and their drivers and barriers.



Technological innovation in critical minerals in developing countries relies primarily on technology transfer from developed countries. With that said, **homegrown technological innovation in the mid- and downstream segments is slowly emerging in developing countries**, supported by policy frameworks, incentives, and initiatives implemented largely within the last half-decade.



Mid- and downstream activities offer **substantial opportunities for developing countries** to advance various SDGs, including decarbonisation, poverty eradication, gender equality, affordable and clean energy, industrialisation, technological innovation, infrastructure development, circularity, and environmental stewardship.

1. Introduction

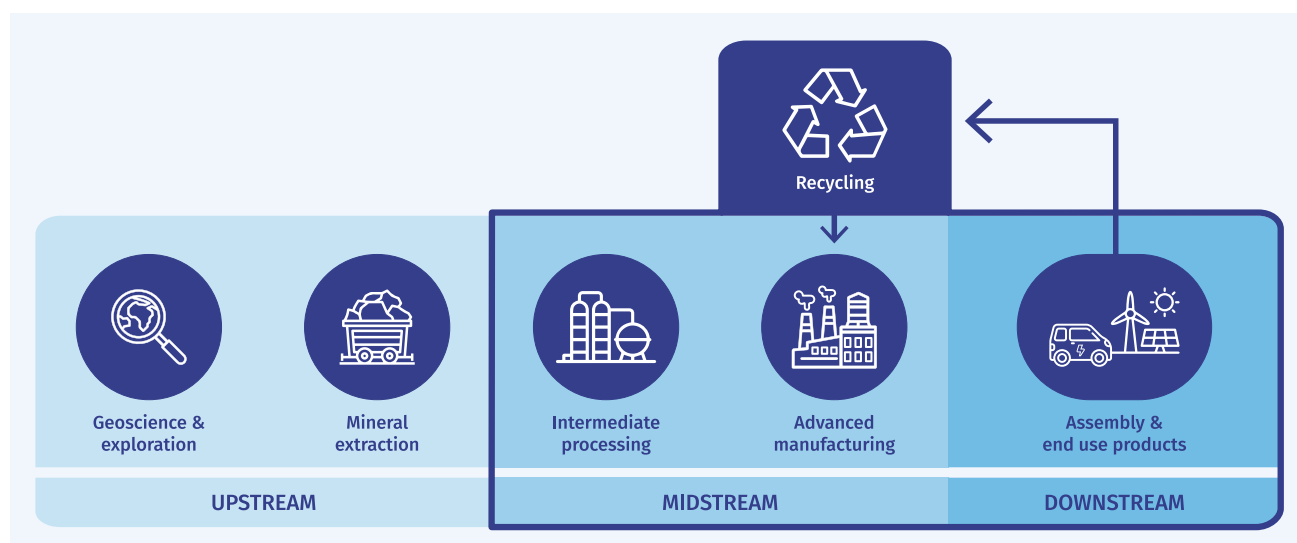
This summary presents the findings of a comprehensive market assessment of innovative clean energy and other decarbonisation technologies in the mid- and downstream segments of critical minerals value chains in developing countries. The market assessment was commissioned by the United Nations Industrial Development Organization (UNIDO) and conducted by a team of economic, legal, policy, and engineering experts from the Columbia Center on Sustainable Investment (CCSI) and the Fu Foundation School of Engineering and Applied Science at Columbia University. It encompasses the collection and analysis of quantitative and qualitative primary data and the production of secondary data and leverages the research team's deep technical knowledge and extensive network of industry stakeholders.

Starting from an analysis of 30 countries during Phase 1 (see Section 2 of the report), deep-dives were conducted during Phase 2 (see Section 3 of the report) in three countries from each developing region: Africa, Asia and South Pacific (ASP), and Latin America and the Caribbean (LAC). The assessment covers various dimensions. It maps out key policies, innovators, technologies, stakeholders, and initiatives in technological innovation in critical minerals value chains. It also identifies specific projects and countries with the potential for such technologies, the financial delivery mechanisms

by which investment and expertise will be carried out to them, and the potential impacts of the technologies on the achievement of key Sustainable Development Goals (SDGs). This assessment focuses on the mid- and downstream segments of critical minerals value chains.

- Midstream:** encompasses the processing and refining of critical minerals into usable forms as well as the recovery of resources from mining by-products such as process tailings, electrorefining sludge, and pyrometallurgical slag.
- Downstream:** extends beyond the manufacturing, assembly, and distribution of final products, and also covers the recovery, repurposing, and recycling of valuable materials from secondary resources, such as end-of-life manufactured goods.

The strategic evaluation of mid- and downstream technologies and markets in this assessment will be useful for activities and organizations focused on accelerating innovation in critical minerals in developing countries. Initiatives such as the Accelerate-to-Demonstrate (A2D) Facility are instrumental in facilitating the development, deployment, and scale-up of technological innovation in developing countries.



While several lists of critical minerals exist, this market assessment zooms into energy critical minerals that play a key role in energy storage, the production of strong permanent magnets, and the production and catalysis of renewables-based hydrogen (see more details about the selection of critical minerals in Section 1 of the report).

List of Critical minerals analysed	
•	Lithium
•	Nickel
•	Manganese
•	Cobalt
•	Graphite
•	Rare Earth Elements (REEs)
•	Copper
•	Platinum Group Metals (PGMs)

The Technology Readiness Level (TRL) is used as the criterion to systematically select and evaluate relevant technologies. The TRL is a scale used to assess the maturity of a particular technology during its development. It consists of nine levels. This scale is widely used to evaluate the progress of technology development and its readiness for deployment or commercialisation.

Deployment	9	Actual system proven in operational environment
	8	System complete and qualified
	7	System prototype demonstration in operational environment
Development	6	Technology demonstrated in relevant environment
	5	Technology validated in relevant environment
	4	Technology validated in lab
	3	Experimental proof of concept
Research	2	Technology concept formulated
	1	Basic principles observed

This assessment focuses on companies and technologies at maturity levels of TRL 6–7 within developing countries. However, in the field of mineral processing and extractive metallurgy, technology development and implementation—from conception to commercialisation—are expensive, labour-intensive, and slow (occurring over 5–15 years depending upon type and complexity of the technology). This is a significant barrier for companies and start-ups in developing countries. Consequently, companies in developed countries often look for opportunities to transfer their mature technologies and know-how to developing countries. Therefore, to capture such opportunities, this report also covers more mature technologies and innovations from developed countries at TRL 8–9 to the extent they present the opportunity of being transferred to developing countries. To summarise, the following TRL ranges are covered:

- **Target TRL 6–7:** This range is chosen for technologies in developing countries. They would likely be at higher TRL in the developed countries, but may still require validation and refinement in relevant local and regional environments in developing countries.
- **Target TRL 8–9:** This range is chosen for technologies in developed countries that are ready for deployment, and thus have potential for replication in developing countries. These technologies have been proven in operational environments and are ready for commercialisation or large-scale implementation.

The technologies analysed in this assessment can be grouped into five major categories:

Physical-mechanical
• Sorting, flotation, magnetic separation, gravity separation, electrostatic, triboelectric, eddy current separation
Hydrometallurgy
• Leaching: Inorganic acids, organic acids, inorganic bases, oxidising and reducing agents, inorganic compounds, complexing agents, water, microbes
• Leach solution concentration and metal extraction
Pyrometallurgy
• Roasting, calcining, sintering, pelleting and briquetting, smelting, volatilisation (retorting), refining, segregation
Electrometallurgy
• Electrowinning, electrefining, molten salt electrolysis, electrochemical separations
Bio-based
• Biomining (biometallurgy), bioleaching, biosorption, phytomining.

Most often, critical minerals extraction from secondary sources (mid- and upstream) comprises technologies from a combination of these categories. Although many of the technologies in these categories are mature, there are many that are either recently developed or emerging. Novel sorting methods, phytomining, and several bio-based processes are examples of emerging technologies.

This market assessment also examines the interplay between technological innovation in the mid- and downstream segments of critical minerals value chains and the SDGs. The theory of change as well as the qualitative and quantitative assessments,

link policies, initiatives, and innovations to specific SDGs, with a focus on poverty eradication, gender equality, clean energy, and climate action. This analysis includes data compilation, stakeholder interviews, and thematic analyses to uncover the multifaceted impacts of technological advancements on sustainable development, culminating in actionable recommendations for policymakers, industry leaders, and financiers—including the A2D Facility and climate finance delivery mechanisms and programmes—on priorities and opportunities to channel development and climate finance to critical minerals innovation and to leverage innovation to achieve the SDGs.

2. Phase 1: Market Assessment of 30 Developing Countries

During Phase 1 of the market assessment (see Section 2 of the report), out of the 131 countries and territories outside of Europe on the Organisation for Economic Co-operation and Development's (OECD) Development Assistance Committee (DAC) List of Official Development Assistance (ODA) Recipients, 30 developing countries of focus were identified based on criteria including mid- and downstream critical minerals imports, policy readiness, and governance and innovation indicators.

- Countries in Africa: Egypt, Kenya, Mauritius, Morocco, Namibia, Nigeria, Senegal, South Africa, Tanzania, Tunisia, Zambia
- Countries in ASP: Cambodia, Georgia, India, Indonesia, Jordan, Kazakhstan, Malaysia, Philippines, Thailand, Türkiye, Viet Nam,
- Countries in LAC: Argentina, Bolivia, Brazil, Colombia, Dominican Republic, Ecuador, Mexico, Peru

Phase 1 achieved a macro-level understanding of the relevant stakeholder groups and their actual and potential roles in technological innovation in the mid- and downstream segments of critical minerals value chains.

Stakeholders relevant to technological innovation in the mid- and downstream segments of critical minerals value chains span across the public and private sectors. Phase 1 focused on a preliminary mapping of global and regional stakeholders, and, to a lesser degree, national stakeholders, through a preliminary identification and categorisation of who these stakeholders are and what roles they play. The mapping led to a broader understanding of the major players and their roles, facilitating a macro-level perspective on stakeholder dynamics.

During Phase 1, the enabling **policy and regulatory environment** of the 30 countries selected was evaluated, assessing aspects such as renewable energy frameworks, legal frameworks for mining, fiscal incentives affecting decarbonisation technologies, and circular economy regulations or frameworks that support sustainable resource management and recycling. This preliminary assessment served to rank the countries based on their innovation-friendly environments and identify those with the greatest potential for fostering technology development in the mid- and downstream segments of critical minerals value chains.

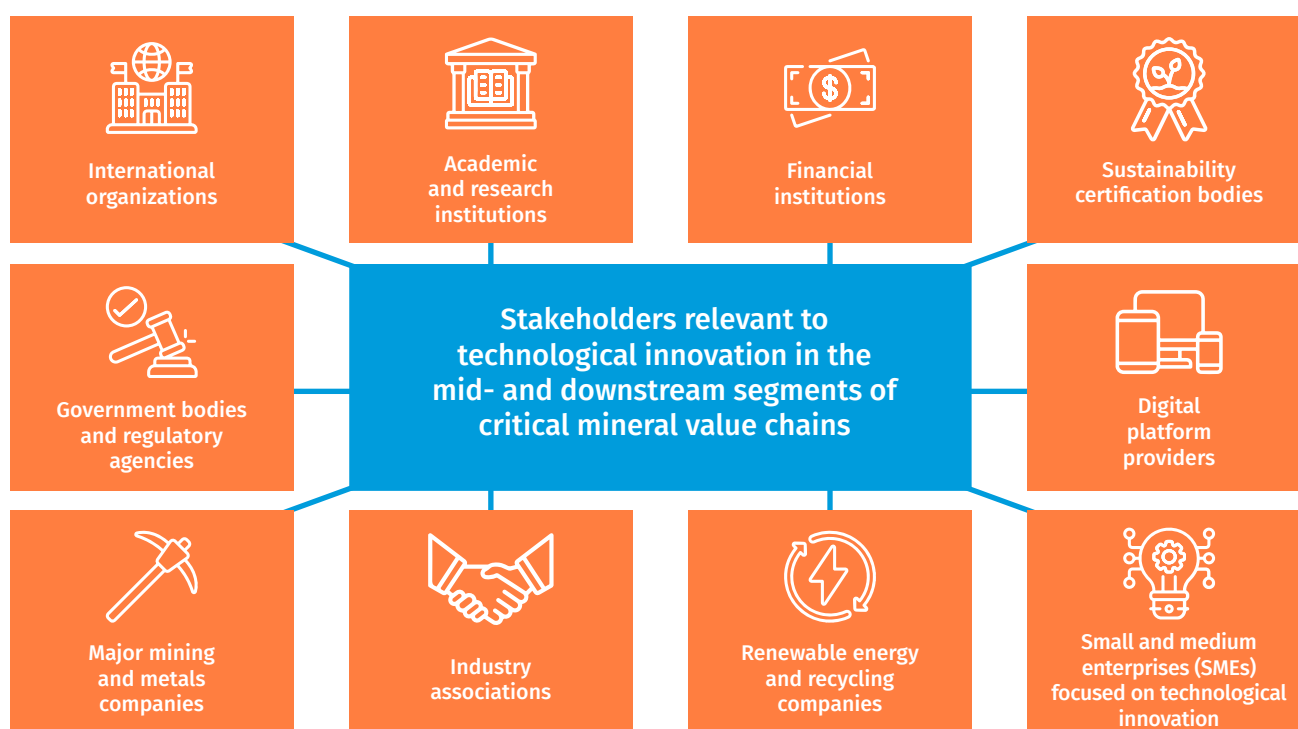


TABLE. Analysis of policy, legal, and regulatory environments in the 30 Phase 1 developing countries

	Africa	ASP	LAC
High	Morocco Namibia South Africa Zambia	India Indonesia Türkiye	Argentina Brazil Mexico
Medium	Egypt Tanzania Tunisia	Georgia Malaysia Kazakhstan Philippines Thailand	Bolivia Colombia Peru
Low	Kenya Mauritius Nigeria Senegal	Cambodia Jordan Viet Nam	Dominican Republic Ecuador

Countries rated **high** implemented comprehensive and robust policies and incentives that encourage technological innovation, facilitate advanced critical mineral processing, support domestic industries that manufacture or assemble products derived from critical

minerals, and promote the circular economy. Countries rated **medium or low** are still in the process of establishing comprehensive policy and regulatory infrastructure. Even in nascent policy frameworks, there is a trend toward R&D, innovation, sustainability, and circularity.

The analysis of **initiatives** identified and evaluated ongoing and emerging collaborative efforts aimed at developing, deploying, and scaling up technological innovations in the mid- and downstream segments of critical minerals value chains that help overcome challenges in these segments, improve their efficiency, and contribute to the SDGs, notably climate action and clean energy goals.

Phase 1 focused on mapping global and regional initiatives, and, to a lesser degree, national ones, to provide a high-level understanding of the landscape of relevant initiatives, such as partnerships, collaborations, and consortia including public and private stakeholders within critical minerals value chains, and programs by international organisations and governments.

TABLE. Landscape of initiatives (Phase 1)

Initiative	Type	Key technologies involved	Key stakeholders involved	Geographic focus
World Economic Forum's UpLink	Platform for innovators to present their solutions to global challenges	• Waste management systems • Greenhouse gas emission reduction innovations • Resource efficiency technologies	• Startups • Academic institutions • Industry	• Global
Prospect Innovation	Accelerator for technological innovation in the mining sector	• Energy generation and storage • Recycling and recovery • Robotics, mobility, and hardware • Data capture, analytics, and AI • Carbon capture • Synthetic Biology	• Research institutions • Mining companies • Venture capital firms	• Americas • ASP • Europe
Global Battery Alliance (GBA)	Public-private partnership that promotes sustainable battery value chains	• Battery recycling • Tracking methods for batteries in the value chain ("Battery Passport")	• Government • Civil society • Industry	• Africa • Asia • Europe
World Bank Group's Climate Smart Mining (CSM) Initiative	Initiative to provide guidance and technical support on decarbonisation and sustainability in mineral value chains in developing countries	• Critical minerals recycling • Reusing and repurposing EOL materials	• Government • International organizations • Local communities	• Developing countries
Activate.org	Fellowship that supports entrepreneurial scientists and engineers in developing technologies for global challenges	• Broad; supports original ideas of its fellows	• Academia • Government • Corporations • Philanthropic foundations	• United States

The analysis of **financial delivery mechanisms** identified and categorised various funding sources and support mechanisms relevant to facilitating the development, deployment, and scaling up of technological innovations in the mid- and downstream segments of critical minerals value chains.

Phase 1 focused on mapping global and regional mechanisms, and, to a lesser degree, national

ones, to provide a high-level understanding of the landscape of relevant financial delivery mechanisms. The preliminary mapping categorised them according to the predominant public or private nature of their funding source, to help guide stakeholders in identifying financing opportunities and gaps and evaluating the potential roles of various financing sources and models in supporting technological innovation.

TABLE. Landscape of financial delivery mechanisms (Phase 1)

 Public Sources	 Private Sources
• Multilateral Development Banks (MDBs) • Multilateral Climate Finance Funds • National Development Banks • Bilateral Development Agencies • Government Grants and Subsidies • Sovereign Wealth Funds (SWFs)	• Venture Capital • Corporate Venture Capital • Private Equity • Accelerators and Incubators • Private Banks • Impact Investment Funds

3. Phase 2: Deep-Dive Market Assessment of Nine Developing Countries

For Phase 2 of the market assessment (see section 3), out of the 30 Phase 1 countries, nine countries were selected for a deep dive: Namibia, South Africa, and Zambia (Africa); India, Indonesia, and Türkiye (ASP); and Argentina, Brazil, and Mexico (LAC). A comprehensive methodology was used to evaluate and rank countries' level of enabling environment for technology innovation in the mid- and downstream segments of the critical minerals value chain, based on weighted quantitative and qualitative indicators of their policy and technology readiness, the long-term financial sustainability of technological

innovation, and knowledge production and sharing (see Appendix A for methodological details).

Phase 2 achieved a deeper understanding of the relevant technologies and markets in the nine selected countries, based on the continued collection of quantitative and qualitative data from the review of written materials (policy documents, legal frameworks, and various reports) as well as interviews with various stakeholders from international organizations, governments, financial institutions, mining companies, industry

associations, and academic and research institutions, among others.

A robust **enabling environment** is essential for technological innovation in the mid- and downstream segments of critical minerals value chains, requiring institutional capacity and financial and technical resources within the government to shape conducive policy, legal, and regulatory frameworks; accessible, affordable, and sufficient finance from public and private institutions; and partnerships and other collaborative initiatives among stakeholders at the national, regional, and global levels.

Common among developing countries' successes in fostering such an environment are **policy, legal, and regulatory frameworks that emphasise domestic industrial development** beyond the exploration and extraction phase. Policy efforts in developing countries to advance the mid- and downstream segments, and technological innovation within them, are often **structured in a way to reinforce rather than compete with other development priorities**, such as the development of the upstream segment, economic diversification, infrastructure development, education and upskilling, environmental sustainability, access to clean energy, and poverty eradication.

Numerous R&D initiatives and investments exist in developing countries, particularly in deep-dive countries. Successful initiatives prioritise R&D frameworks and stakeholder collaboration. **National research institutions** like Argentina's National Scientific and Technical Research Council (CONICET), Brazil's Centre for Mining Technology (CETEM), and South Africa's Council for Scientific and Industrial Research are increasingly partnering with mining, renewable energy, and battery companies to broaden access to funding for innovative projects. Investment into **critical mineral and clean energy hubs** like Brazil's Mining Hub and Mexico's Sonora Plan also empower innovation through funding and capacity building for workers. Once innovative projects yield results, successful governments continue to invest in and incentivise their adoption; for example, Türkiye pushed tax incentives for its first domestically-produced EV in 2023.

Domestic financial delivery mechanisms through grants and loans provided by national governments and development banks are at the core of enabling innovation in developing countries, often supported by incubators and complemented by private sources, including venture capital and impact funds. Direct funding from national development banks also play a large role in successfully providing financial sustainability for innovation projects,

as the Development Bank of South Africa provided over USD 1 billion in lending for renewable energy projects.

International funders and partnerships are also integral to the success of innovative projects in critical minerals. International organizations facilitate initiatives such as UNIDO's A2D Facility, which accelerates the commercialisation of innovative clean energy technologies in developing countries focusing on critical minerals, or the World Bank's RISE Partnership in Southern Africa, offering technical assistance and policy advice to governments as well as finance for governments and the private sector. Collaborative initiatives with development partners—including Australia, China, the EU, Japan, the United Kingdom, and the United States—with all Phase 2 developing countries are commonplace (for example, the Minerals Security Partnership, the United States–India Initiative on Critical and Emerging Technology, the EU–Zambia Memorandum of Understanding on a Partnership on Sustainable Raw Materials Value Chains, the Australia–India Strategic Research Fund, and the United Kingdom–South Africa Partnership on Minerals for Future Clean Energy Technologies). Relationships include strict funding from partners—for example, the Chinese government provided Indonesia with USD 7.3 billion in investments in 2023 through the Belt and Road Initiative (BRI)—as well as research initiatives like Namibia's joint statement of cooperation with the Japan Organization for Metals and Energy Security (JOGMEC).

A key takeaway from the assessment is that **technological innovation in the mid- and downstream segments of the value chain in developing countries relies primarily on technology transfer** from developed countries. With that said, **homegrown technological innovation in the mid- and downstream segments of the critical minerals sector is slowly emerging in developing countries**. Existing technologies are nascent, supported by policy frameworks, incentives, and initiatives implemented largely within the last half-decade. The map indicates noteworthy technologies arising from indigenous technological development, minerals of focus, and technological trends in the nine deep-dive developing countries.

POLICY HIGHLIGHTS IN AFRICA, ASP, AND LAC COUNTRIES



INITIATIVES IN AFRICA, ASP, AND LAC COUNTRIES

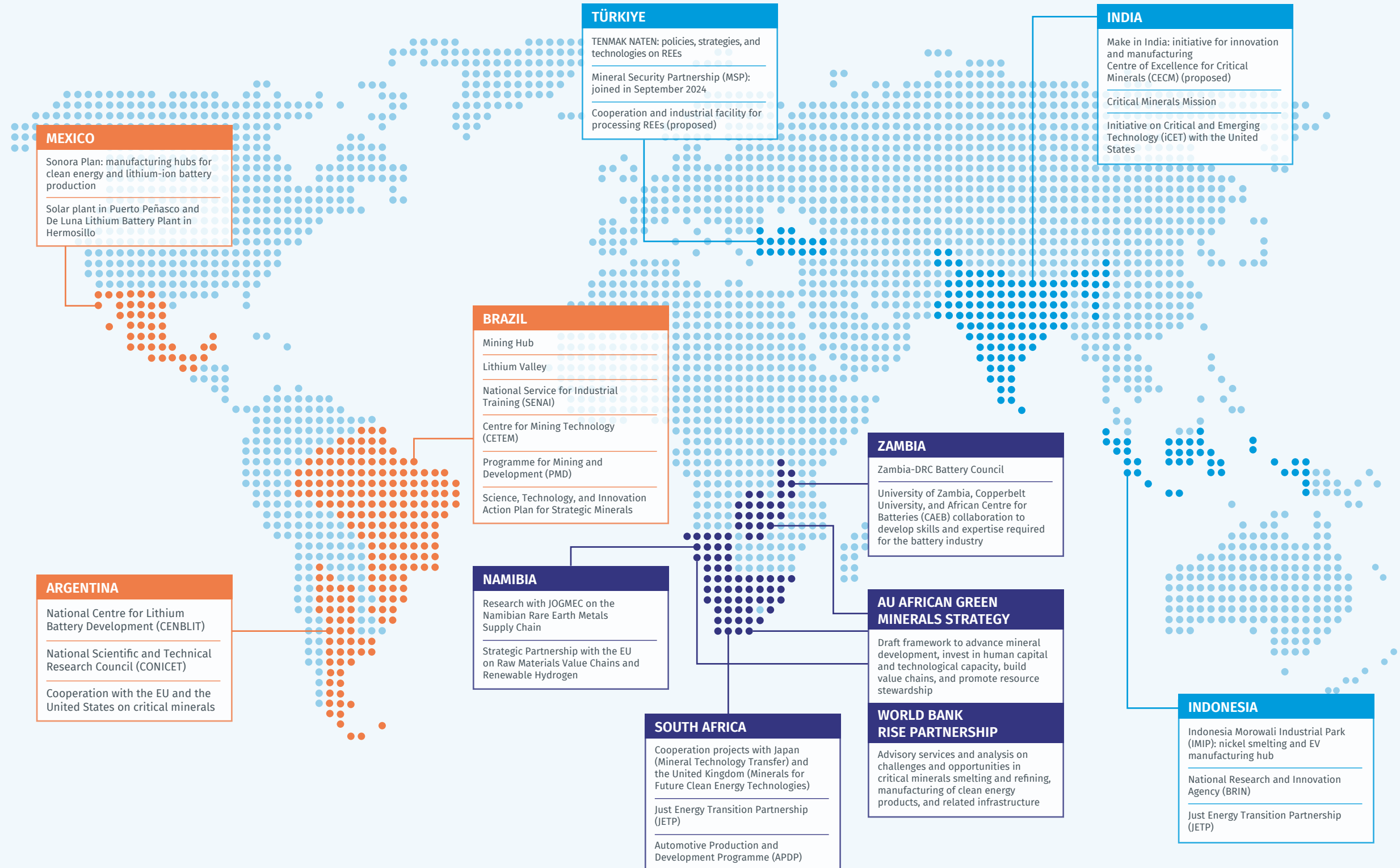


TABLE. Selected financial delivery mechanisms for technological innovations in the mid- and downstream segments of critical minerals value chains in Africa (Namibia, South Africa, Zambia), ASP (India, Indonesia, Türkiye), and LAC (Argentina, Brazil, and Mexico)				
Country / Region	Financial Delivery Mechanism	Description	Amount	Date
 Africa	Sustainable Energy Fund for Africa (SEFA) (AfDB)	Finance for governments and technical assistance grants for public and private entities	USD 95 million	SEFA 1.0: 2011–2020 SEFA 2.0: 2021–2030
	Green Investment Programme Africa (GIPA) (AfDB)	Investment in low-carbon projects by MSMEs	Not specified	2023–2033
	Youth Entrepreneurship and Innovation Multi-Donor Trust Fund (AfDB)	Technical and financial support to youth- and women-led startups and SMEs	USD 40 million	2017–2025
	Innovation & Entrepreneurship Lab (AfDB)	Incubator and financial support for startups	USD 9.5 million	2019–2025
	Africa Circular Economy Facility (ACEF) (AfDB)	Circular economy policy support for governments, business support for startups and SMEs	USD 4.3 million	2022–2026 with possibility of extension
Namibia	Namibia Industrial Development Agency (NIDA)	Financing mechanism for government-identified priorities in the industrial sector	Not specified	Not applicable
	Development Bank of Namibia (DBN)	Funding for renewable energy projects	Not specified	Not applicable
	Bank Windhoek’s Sustainability Bond	Partly allocated towards renewable energy projects	USD 23.1 million	Annual; first tranche was in 2021
	Roadmap for the EU–Namibia strategic partnership on sustainable raw materials value chains and renewable hydrogen	Turning the Port of Walvis Bay into a critical minerals hub for processing and refining	USD 1.1 billion	2021–2027
South Africa	South Africa’s Industrial Development Corporation’s (IDC) Beneficiation Strategic Business Unit (SBU)	Funding for businesses processing critical metal products to expand their production capacity	From USD 60,000 to 60 million per business	Not applicable
	Development Bank of South Africa’s (DBSA) Renewable Energy Independent Power Producer Procurement Programme (REIPPP)	Senior debt to renewable energy projects	USD 1 billion	Seventh Bid Submission Phase ended April 2024
	DBSA Climate Finance Facility (CFF)	Green bank for climate change infrastructure projects	USD 110 million	Launched 2019, 5-yr implementation period, 20-year lifespan
	DBSA Embedded Generation Investment Programme (EGIP)	Funding for local innovation in PV and wind energy generation, especially for Black-owned businesses	USD 200 million	Launched in 2019, no definitive end date
	DBSA Green Fund	Funding of up to USD 1.5 million for project preparation and technical support, and USD 4 million for investment	USD 63 million	Launched in 2012, no definitive end date
Zambia	Strategic partnership between the EU and Zambia (Global Gateway)	Funding for projects involving local value addition and technology development in critical minerals value chains	Not specified	2023–2030
	World Bank’s Scaling Solar Initiative	Advisory services, contracts, financing, and insurance, enabling governments and utilities to transparently procure affordable solar power	USD 100 million	Launched 2015; ongoing; projects take 2 years
	Citizens Economic Empowerment Commission of Zambia (CEEC)	Pursues value chain development by investing in local industry, albeit mostly in the agriculture sector	Not specified	Ongoing; est. 2006
 ASP	Asian Development Bank (ADB) and potential facility for critical minerals value addition	Loans, grants, guarantees for downstream projects in EV battery manufacturing	Not specified	Not applicable
	Asian Infrastructure Investment Bank’s (AIIB) Venture Capital (VC) Investment Programme for Green and Technology-Enabled Infrastructure	Small-scale VC funds to early-stage companies to support sustainable green technological innovation and innovative business models	USD 130 million	Est. December 2022, “three-year captive VC investment programme
India	Australia–India Strategic Research Fund (AISRF)	Grants for collaborative R&D projects, including in downstream processing, recycling, and tailings reclamation of critical minerals	Between USD 0.3 and 0.7 million	Round 15 application window: Jan–Mar 2023
	CSIR-National Institute for Interdisciplinary Science and Technology (NIIST)	Support for projects advancing critical minerals extraction and beneficiation techniques	USD 50 million	Announced Aug 2024
	Government initiatives Digital India and Startup India	Support for entrepreneurs with seed funding for research and innovation in multiple sectors, including critical minerals	Not specified	Digital India: July 2015 Startup India: January 2016
India and Türkiye	Minerals Security Partnership (MSP) Finance Network	Co-financing from development finance institutions and export credit agencies for projects in critical minerals value chains	Not specified	Announced 2022, no end date
Indonesia	China’s Belt and Road Initiative	Investments in infrastructure, including for critical minerals value chains	USD 7.3 billion	Announced 2013, could last until 2049
Türkiye	World Bank’s Accelerating the Market Transition for Distributed Energy programme	Grants and loans for solar energy and battery storage projects, including by supporting SMEs to adopt new technologies	USD 1.01 billion	Launched March 2024
	Turkish Growth and Innovation Fund (TGIF), backed by an EUR 60 million commitment from the European Investment Fund (EIF)	Equity investment in innovative and technology-oriented businesses with high growth potential	USD 218 million	Est. 2016
	High Technology Investment Programme (HIT-30)	Incentives for battery production, semiconductor manufacturing, and other EV-specific technology.	USD 30 billion	2024–2030
 LAC	Inter-American Development Bank (IDB)	Financing for projects that enhance the value chain for critical minerals, facilitate public-private partnerships, and improve resource efficiency	Not specified	Not Applicable
Argentina	International Finance Corporation (IFC)	Loan for developing the Sal de Vida lithium operation in Catamarca	USD 180 million	July 2023
	International Finance Corporation (IFC) RenovAr programme	Financing renewable energy projects	USD 11 billion as of May 2024	Launched 2016, fully implemented by 2025
Brazil	Brazil Critical Minerals Fund, a partnership between the National Bank for Economic and Social Development (BNDES), the mining company Vale, and the Ministry of Mines and Energy	Stimulating investments in critical minerals, targeting SME projects to enhance supply chain capabilities for clean energy technologies and decarbonisation beyond extraction	USD 200 million	Mobilises investments in March 2025
	Funding Authority for Studies and Projects (FINEP)	Grants, loans, and equity investments for companies, universities, and research institutions	USD 7 billion in the period 2024–2028	2024–2028
	New Industry Brazil (NIB) programme, a partnership between Brazil’s Funding Authority for Studies and Projects (FINEP) and BNDES	Financing technological innovation at an interest rate of 1.7% per annum	USD 3.5 billion	2024–2033
Mexico	Nacional Financiera (NAFIN)	Development funding allocated for sustainable debt into projects that help to achieve the SDGs	USD 395 million	Launched in 2021 USD 326 million due 2031 USD 65 million due 2026
	Banco Nacional de Obras y Servicio Públicos (BANOBRAS)	Funding for social and environmental development projects, notably in infrastructure and energy	Not specified	Not applicable
	Banco Nacional de Comercio Exterior (BANCOMEXT)	Loans for direct and indirect exporters in critical minerals value chains	USD 3 million	Not specified

SDG Assessment - Theory Of Change			
DIRECT LINKAGES		INDIRECT LINKAGES	
1 NO POVERTY 	Mid- and downstream activities can drive poverty alleviation and economic growth by creating jobs, fostering skill diversification, and increasing government revenues.	5 GENDER EQUALITY 	Targeted interventions can promote gender equality by encouraging women's participation in technical and leadership roles and reducing time poverty for women.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 	Investment in R&D and mid- and downstream facilities promotes industrial development, technological innovation, and expansion of resilient infrastructure.	7 AFFORDABLE AND CLEAN ENERGY 	Mid- and downstream activities produce components essential for clean energy technologies. Local operations support just transitions and renewable energy deployment.
13 CLIMATE ACTION 	Mid- and downstream activities produce components essential for renewable energy systems and decarbonisation technologies, reducing local and global emissions.	12 RESPONSIBLE CONSUMPTION AND PRODUCTION 	Mid- and downstream activities can promote responsible consumption and production by enabling efficient refining, manufacturing, and recycling practices that minimise impacts.
		15 LIFE ON LAND 	Innovation in the mid- and downstream segments can reduce the impact on terrestrial ecosystems by minimising emissions, waste, and stress on water, land, and biodiversity.

Such technological innovations in the mid- and downstream segments of critical minerals value chains and their enabling policy frameworks have the potential to contribute to **advancing the SDGs in developing countries**. Mineral beneficiation strategies can develop the domestic workforce and industry, relating to SDGs 1 and 9. The growing workforce coupled with targeted interventions can promote opportunities for women in mining communities, bolstering SDG 5. Mid- and

downstream activities produce components essential to renewable energy systems and decarbonisation technologies, contributing to clean energy transitions and climate change mitigation under SDGs 7 and 13. Finally, embedding circular economy innovation into mid- and downstream processes contributes to responsible consumption and production under SDG 12 and supports reducing environmental impacts in line with SDG 15.

Technological Innovation in Developing Countries

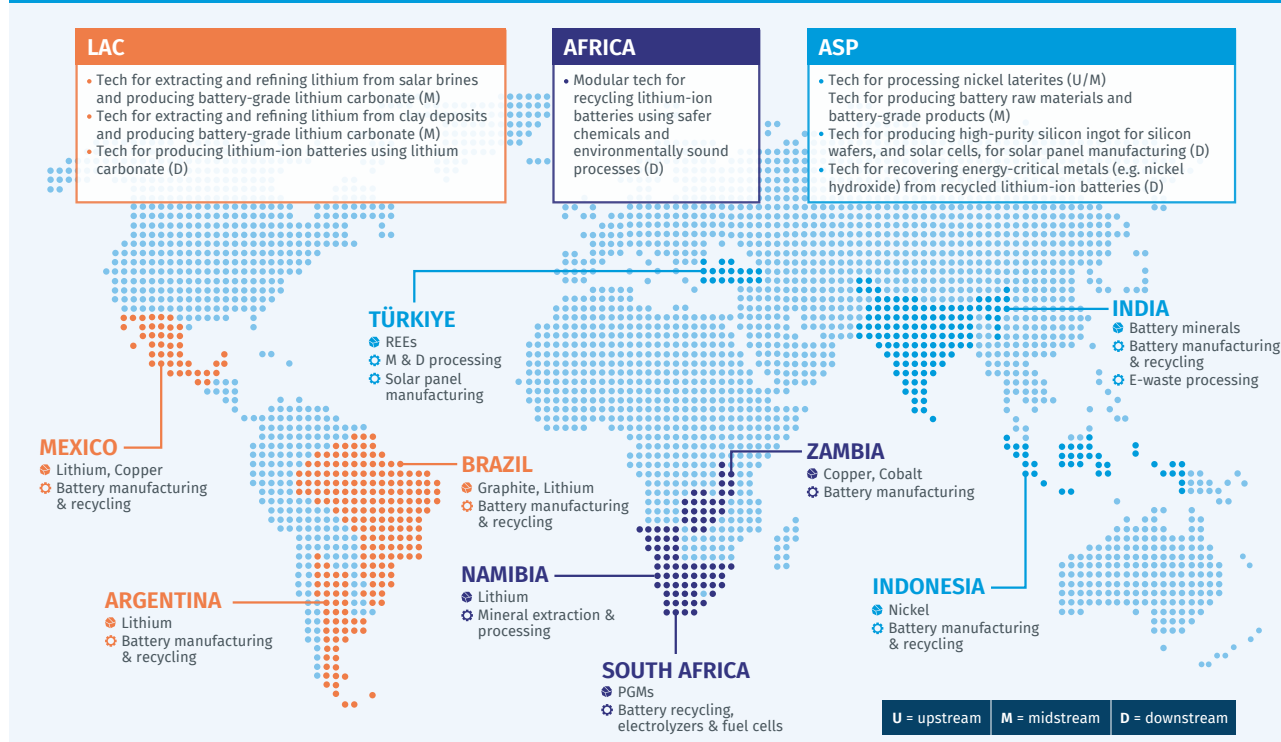


TABLE. Enabling environment in the deep-dive countries

	STRENGTHS	AREAS FOR IMPROVEMENT
 AFRICA	- Mineral beneficiation strategies    - Bilateral cooperation with developed countries (e.g. EU-Namibia Strategic Partnership on Raw Materials Value Chains and Renewable Hydrogen [USD 1.1 billion]; South Africa-UK Minerals for Future Clean Energy Technologies Partnership; partnership between Zambia and the Japan Organization for Metals and Energy Security) - Regional initiatives (e.g. African Green Minerals Strategy and DRC-Zambia Battery Council)    - Industrial development agencies    - Policies advancing SDGs  	- Circular economy, recycling, and waste management policies    - Power and logistics infrastructure constraints to industrial development    - Government institutional capacity to build up and enforce regulatory frameworks    - Policies advancing SDGs  
 ASP	- Circular economy, recycling, and waste management policies    - Tax incentives for technology development    - Special Economic Zones (SEZs) for industrialisation and downstream activities    - Cooperation with developed countries: Minerals Security Partnership   - National financial mechanisms (e.g. Make in India; Indonesia Battery Corporation; Turkish Growth and Innovation Fund [USD 218 million]) - Policies advancing SDGs  	- Regional cooperation and initiatives - Reliance on imported fossil fuel-based energy - Policies advancing SDGs  
 LAC	- Financial incentives for companies in mid- and downstream segments (e.g. tax rebates and exemptions)    - State-owned company for lithium value chain  - R&D frameworks and initiatives   - Industry-led initiatives to coordinate stakeholders: Mining Hub  - Multilateral development bank (MDB) support (e.g. International Finance Corporation [IFC] loans and Inter-American Development Bank [IDB] programmes) - Policies advancing SDGs   	- Stringent circular economy policies on critical minerals    - Policies governing mid- and downstream activities are fragmented across different ministries and minerals, lacking cohesive national frameworks    - Regional cooperation and initiatives - Policies advancing SDGs 

Ten Recommendations to Ramp up Technological Innovation in the Mid- and Downstream Segments

This summary of findings understates that the mid- and downstream segments of critical minerals value chains in developing countries, and technological innovation within them, vary **highly across regions and countries, depending on their focus minerals and on the various SDG impacts considered**. The following recommendations are based on broad trends

across three completely different contexts, and will have to be carefully implied with the local political and technological environment in mind. Specific recommendations tailored to governments, innovators, and other stakeholders in (or seeking to operate in) the various developing countries covered by this assessment lie outside the scope of this work.



International support to developing country governments and stakeholders in the innovation ecosystem should be increased, including through technical assistance, capacity building, policy advice, and access to finance.



Developing countries should prioritise the **development of energy, communications, and logistics infrastructure** to address broader industrial development constraints, in line with the SDGs and national priorities and strategies.



International and regional organizations and development finance institutions should build on initiatives for the **enabling environment** (e.g. World Bank's RISE Partnership) and **specific innovation projects** (e.g. UNIDO's A2D Facility).



Special programmes should be created to support **small and medium enterprises (SMEs)** involved in technological innovation in developing countries to partner with other stakeholders and access funding opportunities, including UNIDO's A2D Facility.



A global multi stakeholder platform should be created to coordinate initiatives, foster collaboration, and share knowledge and data on technological innovation. UNIDO is well-positioned to house such a platform.



Policymakers should **incentivise circular policies and practices** through regulations, incentives, and innovation funding; the private sector should **strengthen the business case for circularity** by showcasing cost savings, new revenue streams, and improved resource efficiency.



UNIDO should lead in ensuring the **continuous gathering, transparency, and analysis of data on innovation**—for example, through rolling surveys and public databases—going beyond the discrete exercise of this assessment.



Industry-led initiatives to coordinate mining value chain stakeholders around common challenges and priorities for innovation—such as Brazil's Mining Hub and other initiatives led by mining associations—should be encouraged and expanded.



Developing country policy should provide regulatory guidelines, support domestic collaborations, and offer innovation incentives; **developed country policy** should promote international cooperation, facilitate knowledge and technology transfer, and provide access to finance.



Besides fostering technological innovation in developing countries, international organizations and governments should put in place **regulatory and financial conditions to facilitate technology transfer** from companies based in developed countries.



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