IIGF 中央财经大学绿色金融国际研究院
INTERNATIONAL INSTITUTE OF GREEN FINANCE

ADVANCING MINERAL-ENERGY NEXUS FOR DEVELOPMENT (MEND) IN AFRICA: FROM A CONCEPT TO PRACTICES

Commissioned by

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Report Series on China and Africa's Energy Transition

Report 01: Zimbabwe

About The International Institute of Green Finance (IIGF)

The International Institute of Green Finance (IIGF) of Central University of Finance and Economics (CUFE) is an independent and non-profit think tank established in Beijing, China. It conducts research within a range of areas of green finance such as credit, bonds, insurance, carbon-trading, information disclosure, as well as risk assessment. The IIGF works with numerous stakeholders in green finance both within and outside China.

Authors

Wei Shen, International Institute of Green Finance

Zhengyun Zhou, International Institute of Green Finance

Tsitsi Musasike, Boston University

Tinotenda Chidhawu, University of the Western Cape and University of Zimbabwe

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This report is the first of the series of two. Our second report in the series is *From Green Energy to Green Hydrogen: The Role of Chinese Investments in Egypt's Future Energy Landscape.*

Executive Summary

- The surging needs for transition minerals, such as cobalt, copper, lithium and nickel, provides both tremendous opportunities and challenges for the resource rich African countries. Foreign investments into the mining sector could be essential for both national economic catching up and a just local development, if properly governed.

- Electricity supply, among other infrastructure gaps, are one of the major obstacles to achieve the potential national and local benefits accrued from mining investments. We hereby developed an analytical framework to explore this issue, known as the Mineral-Electricity Nexus for Development (MEND) approach. MEND is essentially an analytical framework to assess the possibilities in creating a collaborative governance system that consisting multiple stakeholders to achieve various developmental goals.

- The indicators of a successful MEND approach in a specific national context are based on the achievements of four potential developmental benefits, known as (1) local electrification, (2) climate mitigation (via deployment of renewable energy solutions), (3) enhanced power infrastructures, and (4) re-distributive revenues for long-term sectoral development and governance.

- An in-depth case study of a Chinese lithium mining project in Zimbabwe (known as Z1) is conducted under the MEND framework. Zimbabwe is representative in terms of its tremendous resources for transition mineral but chronicle shortages of power supply and infrastructures. Zimbabwe government's aspiration of enhancing processing capacity and added value of the mining activities can be severely jeopardised due to its energy crisis.

- Chinese investments dominate Zimbabwe's mining and electricity sectors in the past two decades. Our investigation, based on interviews, focus groups and survey among both Chinese and Zimbabwean stakeholders, indicate the impacts of current corporate strategies and practices on power solutions of Chinese mining investments in Africa.

- We find that innovative power solutions were adopted for the Z1 project, with a sleeved-PPA arrangement in place and a top-up solar PV plant in plan. These innovations are

expected to provide reliable and affordable power solutions but its spill-over effect on local electrification is limited. The Chinese investor is therefore providing additional CSR efforts to address local energy poverty.

- The case study indicates that to achieve a more inclusive and sustainable power solution for the mining facility and surrounding communities, a more coordinated approach is needed to link public, private, and civil actors. It is beyond individual investor's capacity to achieve four pillars of MEND, and additional support from both state and non-state actors is essential.

- The case study reveals that state utility's wiliness to support a sleeved-PPA arrangement, civil society organisations' support for the localised power solutions, Chinese policy banks and development financiers' support for blended finance and de-risking instruments, are crucial for the implementation of MEND. Chinese and Zimbabwean government are recommended to prescribe supportive policies to advance the MEND and deter another round of resource curse.

- The case study indicate that the success of MEND relies compeletly on the cash flow generated out of the selling of preliminarily processed minerals. It has broader implications on how resource-infrastructure complex should be developed and financed in African context. The MEND approach is notably different from previous Chinese model in financing mega infrastructure projects with limited revenue generation contribution.

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List of Abbreviation

AfDB	African Development Bank
BRI	Belt and Road Initiative
CCCMC	China Chamber of Commerce of Metals, Minerals & Chemicals Importers & Exporters
CDP	Community Development Program
CPPA	Corporate Power Purchase Agreement
CSO	Civil Society Organisation
CSR	Corporate Social Responsibility
DFI	Development Finance Institution
DRC	the Democratic Republic of Congo
ECA	Export Credit Agencies
EPC	Engineering Procurement Construction
EU	European Union
SAPP	Southern African Power Pool
SDGs	Sustainable Development Goals
SOE	State-owned Enterprise
SSA	Sub-Saharan Africa
IPP	Independent Power Producer
kWh	Kilowatt-hour
MEND	Mineral-Electricity Nexus for Development
MEE	The Ministry of Ecology and Environment of the People's Republic of China
MoF	The Ministry of Finance and Economic Development
MW	Megawatt
NDRC	The National Development and Reform Commission
PPA	Power Purchase Agreement
PV	Photovoltaic
USD	United States Dollar
ZESA	Zimbabwe Electricity Supply Authority
ZERA	Zimbabwe Energy Regulatory Authority
ZETDC	Zimbabwe Electricity Transmission and Distribution Company
ZPC	Zimbabwe Power Company
ZWD	Zimbabwean dollar

1. Introduction: China and powering the mining sector in Africa

In recent years, Chinese overseas investments in renewable energy and transitional mineral sectors have attracted tremendous academic, professional, and political attention. The general rhetoric in the global North is a rather divided one, as many believe China has been investing too little in renewable energies in the global South, but too much in the critical minerals instead.[1] For example, since Chinese President Xi Jinping announced in 2021 that China would stop financing coal-fired power plants, there has been an intense discussion on how to convince China to scale up its renewable energy investments, particularly in Africa (Ayele et al, 2021; Zhou and Ma, 2023). Yet, China's massive investments in mining and processing critical minerals, particularly in the African and Latin American region, have created a parallel but rather contrasted discussion, when Western countries expressed openly their concern about China's growing dominance in the global value chain of EV batteries and the urgent need to implement a proper 'di-risking' strategy (Demarais, 2023).

However, one critical voice is often missing during these ongoing debates, namely that from the recipient countries of Chinese investments, who are supposed to be the main beneficiaries of Chinese 'green' investments. Considering that many of these recipient countries are in the global South, it is increasingly clear that they have distinctively different concerns regarding the growing Chinese investments in the green energy and critical minerals sectors. Given that the investments in these two strategic sectors would have profound impacts on their development trajectory both at the national and local levels, two inter-related questions emerged as particularly acute:

The first question is about national-level development for the recipient countries, by asking how they could seize the opportunities to foster green industrial capacities as the engine for their sustainable development. As wind, solar, and transitional minerals are becoming newly endowed strategic resources, just like fossil fuels and precious minerals once played, how these countries achieve notable economic/industrial 'catching-up' with new endowment and prevent another round of 'resource curse'?

[1] Also known as transition minerals, which are crucial for climate action, including cobalt, copper, lithium and nickel that are essential for technologies such as solar panels, wind turbines and electric vehicles.

At the local level, the inquiry is about local development opportunities or benefits accrued from these green investments, and the need to achieve a 'just transition'. It asks how local communities and residents can be provided with better public goods and learning opportunities in relation to these investments, and how the locals can be empowered to take on an inclusive development journey as a result.

This paper aims to tackle these two interrelated questions via a micro-level analysis regarding the provision of sustainable energy supply for critical mining and processing activities in Africa. On the national level, the governance of mining and electricity sectors has become increasingly converging in recent years after many host governments with rich mineral resources have announced ambitious industrialisation plans. These intervention policies encourage investors to develop additional processing capacities, as initial steps to prevent resource grabbing and promote industrial capacities at home. Yet, the shortage of power infrastructures and supply to the mining/processing sites is a major constraint, particularly where close to 80% of these mining activities are to be located in rural and indigenous territories in Africa (Owen et al, 2023). Innovative and practical solutions are urgently needed on the ground.

On the other hand, energy-intensive activities such as ore processing facilities, once installed as requested by the host governments, can bring unprecedented opportunities to increase local electrification for the surrounding communities. Achieving universal energy access by 2030 is an essential element of the UN Sustainable Development Goals (SDGs), with sub-Saharan Africa (SSA) the most challenging region. Currently, around 43% of the population in SSA remains unconnected to modern energy systems (IEA, 2022). Powering the mining sites in previously unconnected areas provides a gleaming yet unique chance for achieving SDG 7. Hence, power solutions for mining and processing critical minerals deserve special scrutiny.

In this report, we developed an analytical framework to explore this issue, known as the Mineral-Electricity Nexus for Development (MEND) approach. Our study is based on both desk and field investigation, which comprises an in-depth case study of a Chinese lithium mining project in Zimbabwe. This country has long been a destination for Chinese investments in both the electricity and mineral sectors. Yet the power supply crisis and booming mineral investments make it a perfect test ground for any potential MEND solution.

Our investigation revealed both the attainment and limitations of the current power solutions on the ground and the tremendous innovative and experimental capacities among the key stakeholders involved in the deal. We also argue that to achieve a more inclusive and sustainable solution for powering the mining site and surrounding communities, a more coordinated approach is needed to link public, private and civil actors from both investing and recipient countries.

Although most of our analysis focuses on the micro-dynamics at the project level, it is also situated in the broader and fast-changing landscape of Chinese overseas lending and project finance, particularly in Africa. Given the mounting debt service burden and deteriorating public finance situation in many SSA countries, large infrastructure development backed by sovereign credit or guarantees is no longer a viable model. Consequently, there has been a sharp decline in Chinese loans in Africa since 2017 (Moses et al, 2023). The MEND concept indicates a potential alternative where private-led solutions can be explored, given proper support from the public, financial, and even civil sectors. It is believed that such a successful MEND approach has the potential to fully capture the value of critical minerals and to contribute to both national and local development in the recipient countries.

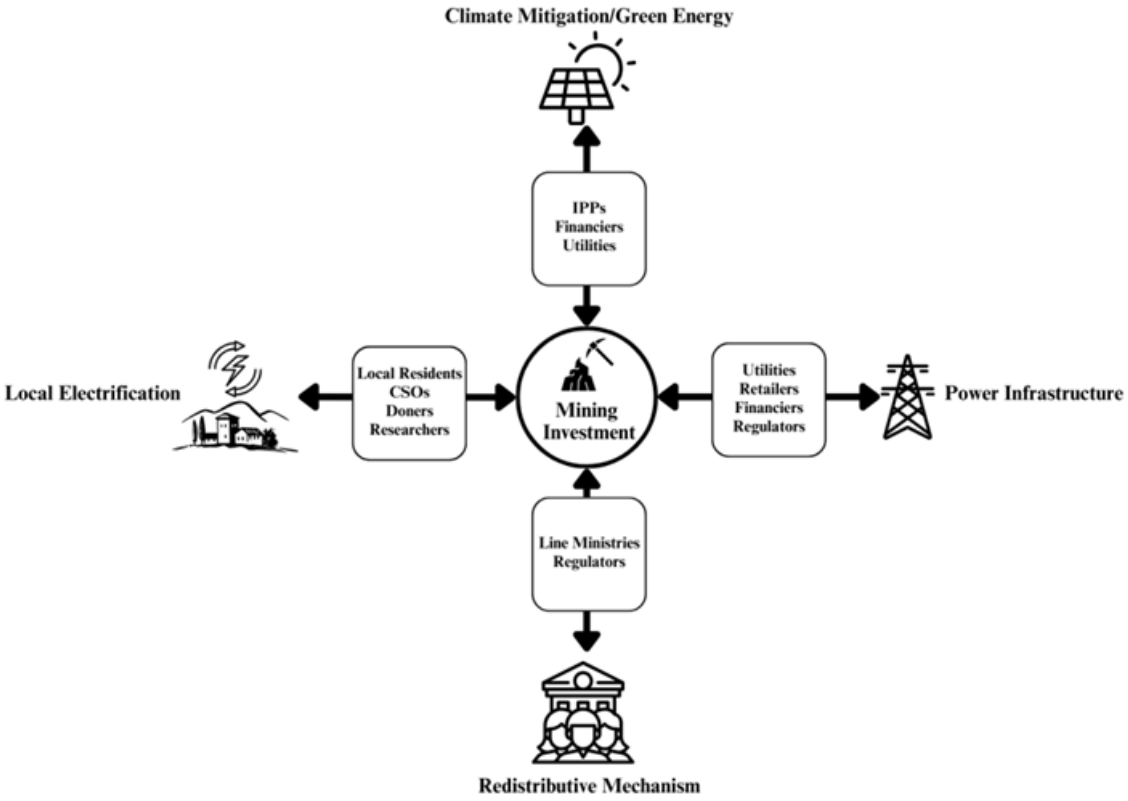
2. Conceptualizing the Mineral-Energy Nexus for Development (MEND)

Our conceptual assumption is that the power solutions for critical mining investments could generate multiple implications for both national and local development. The potential developmental benefits and the required collaborative partners are illustrated in *Figure 1*.

The first notable benefit of a MEND solution is the additional power infrastructures that are developed for powering the mining facilities. At the outset, investors need to secure any missing power infrastructures on site, often known as the ‘last mile’ challenges. These infrastructures may include transmission lines and substations if the aim is to connect to the national grid or independent or self-sustaining power generation systems. In the former case, if the public utilities in the recipient countries are not capable of delivering these infrastructures in time, either due to funding or technical constraints, the investors must step in to develop these facilities with their own financial and technical resources. However, the ownership of these power infrastructures is often shared with or transferred to the public utilities completely, with a payback arrangement agreed by both parties. In the latter case, the infrastructures are largely privately owned, either

exclusively by the mining investors or shared with an independent power producer or developer. In either way, these additional power infrastructures will aggregately re-configure the power supply landscape in the recipient countries.

Figure 1. MEND: Developmental benefits and required partners



Source: Authors' own creation

The second benefit is related to clean energy transition and climate change mitigation. Renewable energies from wind and solar resources have the potential to provide clean and sustainable energy solutions for mining activities, thanks to their fast-dropping cost and flexible applications in both on-grid and off-grid settings. Investments in renewable energy capacities, even exclusively for mining operations, would benefit the investors not only with complementary and cost-effective power supply but also enhance their ESG performance and corporate reputation. The aggregated mitigation effect of these solutions would help the recipient countries meet their national climate targets and international pledges.

The third benefit, as mentioned earlier, is the possibility of providing additional access to local electrification. The power infrastructures developed for the mining operations may be shared with local communities under certain conditions and arrangements. In theory, mining activities can provide a crucial anchor load to significantly reduce the overall cost of electricity access and consumption in the neighborhood (Banerjee et al, 2015). If these infrastructures are publicly owned, then the public utility may be responsible for developing additional power distribution systems for local households. Otherwise, the investors may take up the role under their CSR budget. In both cases, load sharing and tariff schemes need to be carefully designed. Civil society groups or local entrepreneurs can also play a vital role, particularly by providing maintaining capacities for these programmes.

The last implication is rather indirect, concerning the re-distributive potential at the national level. The national power system can be further upgraded through the revenues generated from mining investments aggregately. This is particularly acute for recipient countries with significant mining income but under-developed power systems, such as the DRC, Zimbabwe, and Zambia. In the long run, the surging electricity demand from the fast-expanding critical mining sectors can be hardly supported by project-based or captive power solutions, particularly when additional processing facilities are to be implemented. Any attempt to move up in the green value chains, such as solar panels, batteries, or electric vehicles, are typically more energy-intensive industrial processes, which demand a well-balanced and functioning power system consisting of both centralized and distributive capacities. As the funding for developing such a balanced system in most SSA countries is constrained, taxes and royalties from the mining sector are crucial. Yet, establishing such a positive feedback loop between mining and power systems requires proper institutional frameworks, which is beyond this research to tackle.

As illustrated above, these four types of potential developmental benefits emerged to articulate the framework of a successful MEND approach in a specific national context, known as (1) local electrification, (2) climate mitigation (via renewable energy technologies), (3) enhanced power infrastructures, and (4) re-distributive revenues for structural development in both energy and mining sectors. Achieving these potential benefits, however, often requires rigorous collaborations among various stakeholders centered around the mining investments, as illustrated in *Figure 1*. For example, the infrastructure pillar needs a cooperative state utility, capable IPPs, and

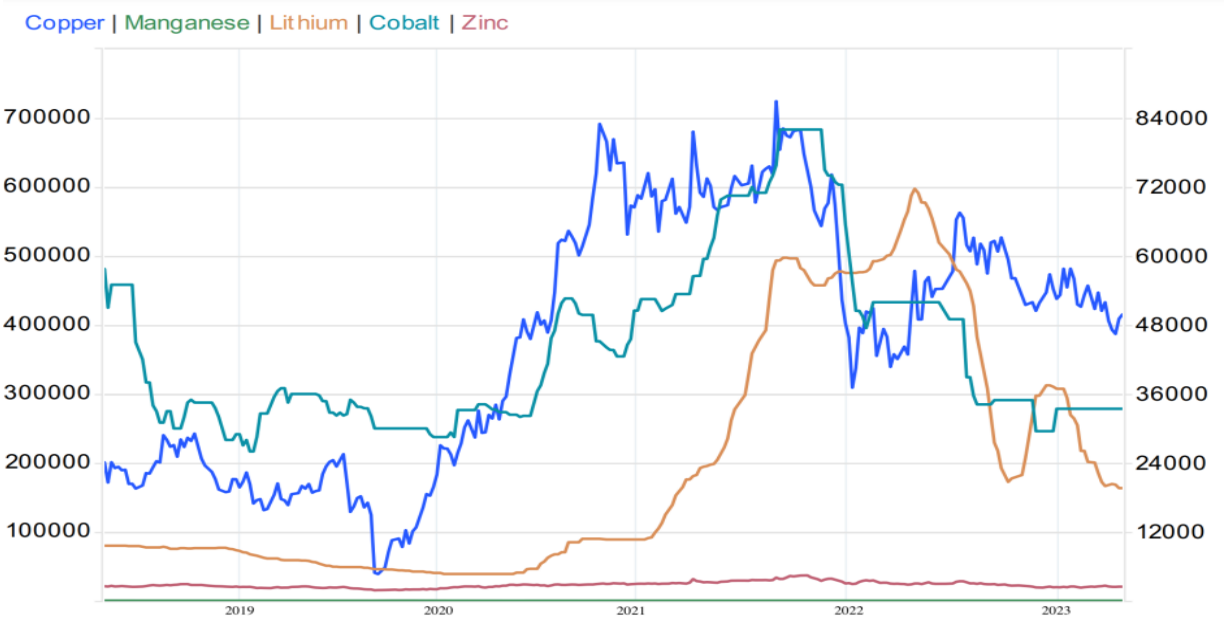
commercial financiers, whereas enhancing local electrification requires inputs from international donors, philanthropy or civil society organisations (CSOs), or development finance institutions (DFIs). The MEND approach is therefore viewed as a collaborative governance structure that consists of several actor networks to sustain each pillar.

Yet at the center of these actor networks are the mining investors, who will be making ultimate decisions on specific energy solutions for their investments. Our analysis indicates that Chinese investors would treat various factors largely as different sets of transactional activities associated with risks and uncertainties that need to be properly managed. The MEND framework from the perspective of investors, is basically a risk-sharing mechanism with other stakeholders. The ultimate success, however, relies upon the success of mining investment. If the mining operation is in trouble, so are the affiliated power solutions and other supportive infrastructures. Consequently, all the co-benefits would almost certainly be forfeited. The key perceived risks for a critical mining investment normally include completion or maintenance risks, political or regulatory risks, commercial or market risks, community-level risks (environmental and social), and organizational or managerial risks, which are to be explored in detail:

- Completion or operational risks refer to the physical establishment and production activities of the investment project. The investors need to assess the likelihood of both the power solution and the main mining/processing facilities being completed timely and coordinated. During the construction period, any delay on each side would certainly affect the other. Similarly, during the maintenance or operational period, any technical problems in the power supply system would affect mining or processing operations, and vice versa. Therefore, the completion and operational risks can double for some MEND solutions, particularly for those self-supply systems. The successful MEND solution hence requires capable developers and contractors at both ends, with strong track records in technical and managerial capacities plus notable local experience. The investors must establish efficient communications with these actors throughout the project cycle.
- Market or commercial risks involve uncertainties associated with the off-taker of electricity and mineral products. Many critical minerals appeared to be particularly vulnerable to both price hikes and plummet in recent years (see Figure 2). This vulnerability encompasses

fluctuations in demand from downstream sectors, oscillations in the prices of mineral commodities, and diminishing product demand due to technological progress or even abruption. These market fluctuations can potentially erode the revenue of the mining investment, imposing a significant risk to its operational stability. For some MEND solutions, such as a self-supply system, the IPP usually prefers stable tariff revenue in the long run and is reluctant to share any market risks related to mining or downstream activities. The nexus thinking, however, needs to reconcile the 'high-risk, high-gain' and 'low-risk, low-gain' strategies between mining investors and IPPs. In case the IPPs and mining investors are both from China, the coordination prospect for sharing these commercial risks can be higher. Yet, the outcome still depends on the negotiation and bargaining power of the two parties, as manifested in their contractual arrangements, known as a corporate power purchase agreement (CPPA). On the contrary, if the power is supplied via public utility and the national grid, the main concern is the stability of the electricity supply and the potential risks of the utility breaching the PPA, particularly around the electricity tariff or curtailed supply.

Figure 2. Transitional minerals price change from 2018-2023 (CNY).



Source: Trading Economics, 2023

- Political or regulatory Risks: This is often regarded as the most challenging risk to hedge in many SSA countries, not only by the investors but also by the Chinese policy banks and export credit agencies (ECA) who are found often unwilling to accept the sovereign risk of host governments or state utilities. The political risks include war, civil unrest, and sudden or discriminative policy changes that interrupt the operation of the investments. If the power solution is based on self-supply systems, these risks would be shared by the mining investors and IPPs. In the same vein, regulatory changes from either the power or the mining ministries can hit both parties simultaneously due to their 'nexus' status. Some regulatory risks, such as full or partial expropriation, can be existential, whereas other uncertainties such as changing government or leadership or rising geopolitical tensions would be indirect but significant at some point. Although most of these risks, such as war or civil conflicts, impact all parties, they can hit some actors particularly hard. For example, a partial expropriation of the mining assets would certainly have a bigger impact on the mining investors rather than the IPPs, raising the question of how such political events would be responded to and dealt with by both.
- Community-level risks arise as mining operations inevitably intersect with local communities, whose acceptance and social license are the key to the successful MEND solution. Local conflicts, struggles, and resistance can lead to operational interruption or even shutdown, causing both financial and reputational damage. For a self-supply power solution, the IPPs are now closely tied to the mining activities and their operations will also be impacted by the local communities. Nurturing a constructive community relation is consequently a shared interest for both parties. Their CSR strategies or community programs then need to be coordinated too, with the ESG performance would inevitably converge. Local issues encompass various concerns, including access to resources like water, electricity, land, and transportation infrastructures. The local employment from both the mining and power supply facilities needs to be co-evaluated. Both IPPs and investors need to be on the same page for these specific local issues, including pollutant discharges, biodiversity preservation, indigenous rights, involuntary resettlement, child or forced labor, cultural heritage preservation, and community health and safety. Ideally, shared grievance mechanisms can be established.

- Organizational and managerial risks: mining and processing are typically labor-intensive activities that require a large number of employees from the recipient countries. It also requires sufficient managerial skills from the home countries or head offices, particularly at the initial stage for the training of the newly recruited workers. In addition, in dealing with various cultural and communication barriers, specialists are often needed to maintain good relations with the locals. Complaints and dissatisfaction within the investment entity usually include wage disputes, working conditions, lack of learning opportunities, and implicit or explicit racial, or gender-related discrimination. These internal challenges can lead to the disruption of the MEND arrangement if not properly handled, which again requires a more coherent organizational strategy and internal code of conduct among all parties on site.

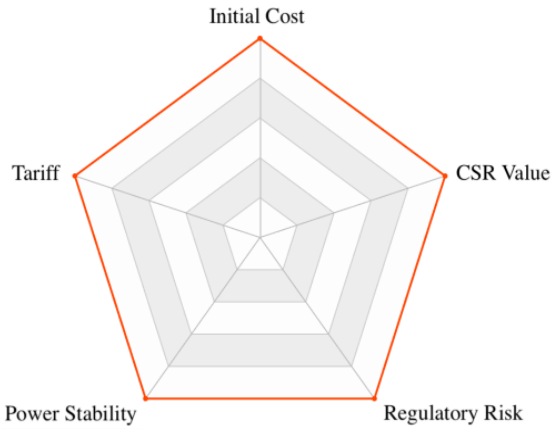
  Organizational risks would also involve potential confrontational encounters between the employees (of the recipient or investing countries alike) and local residents, which is somehow related to the community-level risks mentioned above. In the long run, industrial mining and associated power supply projects hiring large numbers of local employees would inevitably transform the local rural communities into a 'mining town', with a distinctive social-economic system compared to the previous one. During this transformative process, struggles are inevitable, as manifested in many places.

The specific power solutions are in general based on the calculation of managing these risks and uncertainties, usually along the spectrum between a grid-supply to a self-supply arrangement (see *Figure 3*). There are different power options to provide flexible and even tailor-made solutions (Banerjee et al, 2015). The availability of renewable energy resources, particularly solar PV technology, significantly enhanced the range of choices for investors as it is now possible to develop hybrid systems that combine both grid-supply and self-supply options. Another advantage of solar PV options is that they can be added at almost any stage of project development. The disadvantage is that as intermittent power resources, they are unlike to meet the energy demand solely when most mining and processing operations require continuous and uninterrupted power supply. The multiple choices available also test investors' innovative and networking capacities to work out the most suitable solutions, together with different partners and stakeholders.

Innovative models are both emerging on the ground and in literature. For example, to reduce the

instability and curtailment risks of the grid-supply option, a 'sleeved' arrangement is applied when additional power service providers are involved to provide an additional layer of security and stability in the power supply, as we see later in the Zimbabwe case study. For hybrid or self-supply systems, it is increasingly prominent to include an IPP in developing and managing the power generation system. In theory, these systems can also be connected to the local communities or the national grid (for reselling purposes), as ways to generate additional CSR or profit when there is a surplus in power supply. However, such arrangements are not yet observed among Chinese investments in our field investigation. In general, the final solution is often based on several concerns, including initial cost, tariffs or operational cost, reliability of the power supply, resilience to regulatory risks, and additional CSR value, each speaks to specific risk factors mentioned above (see Figure 3).

Figure 3. Determinant Factors for Specific MEND Solutions



Source: Authors' own creation

One pending issue is regarding the attitude of financial institutions in supporting these innovative power solutions, which are largely different from the conventional financial models backed by sovereign guarantees. For example, in the sleeved arrangement, it is unclear if the enhancement of the power supply stability via the service provider can convince the Chinese financiers. In the hybrid or self-supply arrangement, the commercial and political risks are largely shared by the IPPs and mining investors, as mentioned earlier, which requires the financial institutions to adjust their risk assessment for both activities. As mentioned, one of the key features of a MEND solution

is the risk-sharing mechanisms among power suppliers and mining investors. However, such a 'nexus' status imposes challenges for their bankability test, regarding whether they should be evaluated jointly or separately.

In this section, we have illustrated the potential four sets of developmental benefits a nexus mineral-electricity solution could bring. Yet the actual power solutions for the mining activities are highly heterogeneous and contextualized, influenced by various risk factors and concerns of the investors. Therefore, the actual implications of a MEND solution require in-depth case-specific studies to reveal its complex dynamics and actual impacts. In the following section, we will focus on a specific lithium mining project in Zimbabwe (Project Z1) to advance our understanding of this challenge.

3. Applying the MEND framework in Zimbabwe: A Case Study of Project Z1

3.1.Zimbabwe in a nutshell: mineral booming and power crisis

Both electricity and lithium mining have emerged as critical sectors for Zimbabwe's sustainable economic transition.[2] Zimbabwe's rich mineral resources provide an unprecedented window of opportunities, both for foreign exchange earnings and for industrial development via investments in mineral processing facilities. In theory, the earnings from the booming mining sector would be redistributed efficiently to finance essential electricity infrastructures, which have been significantly under-invested in the past few decades. In return, an increasingly robust and reliable power supply system would support the fast-growing mining and processing operations, and further enhance their productivity and revenue. With such a positive feedback loop, a mutually supportive mineral-energy nexus can be established, by resolving the dual tasks of promoting industrial capacity and infrastructure development simultaneously.

Figure 4. Zimbabwe Mineral rents (% of GDP)

[2] Zimbabwe has the largest lithium reserves and mines in Africa, with total reserves around 220,000 MT, according to the US Geological Survey.

Source: World Bank

Zimbabwe has an electricity access rate of 62 percent in 2022 but 91.1 percent of households in rural areas are unconnected to the national grid (ZimStat, 2022). The power solutions for the mining sites can potentially address local energy poverty in the surrounding communities, by providing anchor load and additional energy access at a lower cost. These efforts, if implemented, would certainly enhance local acceptance of mining activities and help achieve a just transition (Quiroz et al, 2022). Zimbabwe also has rich and applicable solar energy resources, the possibility of applying solar PV solutions can provide additional power supply and contribute to Zimbabwe's climate pledge under the International Climate Agreement, by taking on a low-carbon development pathway and avoiding a 'carbon lock-in'. Therefore, the MEND framework appears to be an ideal strategy that addresses comprehensively mineral revenues, industrial capacity, energy security, local electrification, and climate mitigation. However, despite the notable potential for achieving these multiple co-benefits, implementing the MEND concept on the ground would face significant challenges and risks. Achieving this ideal scenario requires tremendous efforts in harnessing regulatory, financial, and technical capacities from both supply and recipient countries.

These challenges, including policy incoherence and fragmentation, lack of power and other infrastructures, technical and financial constraints, and community-level complexities, are typical risk factors for investors. China has been the largest source of investments in both mining and electricity sectors in Zimbabwe in the past two decades, and it is how Chinese actors are tackling

these challenges and navigating potential solutions that would provide important lessons on what is needed to implement the MEND concept on the ground.

Mining holds one of the pivotal roles within Zimbabwe's economy. The mining sector contributed approximately 11% to the national GDP and accounted for over 60% of export earnings by 2022 (MoF, 2021)[3]. In 2022, Zimbabwe's total mining revenues reached a historically high level of $5.4 billion and continue to grow in 2023. According to Mr. Ziyambi, the Minister of Justice, Legal, and Parliamentary Affairs, the export revenue from the mining industry in 2023 is expected to exceed the government target of $12 billion and reach a 100% year-on-year growth (Razao, 2023). This notable increase is ascribed to Zimbabwe's abundant lithium resources, as the country's lithium production index was 184.2, which depicts a year-on-year increase of 169.5% in the first quarter of 2023 (ZimStat, 2023).[4] The substantial increase in lithium production has solidified Zimbabwe's standing as an essential global lithium producer and is poised to sustain significant economic revenues for the nation.

However, maximizing lithium revenue is not the ultimate goal for the Zimbabwe government as the heavy reliance on exporting unprocessed ores is believed not a sustainable development strategy. After President Mnangagwa's re-election in August 2023, he reaffirmed his previous commitment to using the country's rich mineral resources to fuel industrialization. In the first post-election cabinet convocation, he underscored the mining sector's enduring significance in shaping Zimbabwe's economic landscape, including encompassing employment generation, augmentation of foreign exchange reserves, technology and knowledge transfer, and community development (Ruzvidzo, 2023).

Our interviewees in the country predominantly endorse such ambition. For example, one private expert in the domain of mineral marketing postulates, "South and Central America are building plants that can be used to trade five years down the road. After five years… our country (Zimbabwe)

[3] The data originates from the Ministry of Finance and Economic Development in Zimbabwe, covering diverse parts such as mineral product sales, license fees, royalties, taxes, and other revenue sources. Consequently, the Mineral Revenue to GDP in Zimbabwe MoF tends to be higher than figures reported by other entities, like the World Bank, which predominantly concentrate on mineral rent.

[4] Data published by the Zimbabwe National Statistics Agency (Zimstat). The Index of Mineral Production (IMP) is an economic indicator that shows relative changes in the volume of output for the mining sector over time, in relation to a given reference period. Construction of the IMP is based on administrative data obtained from the Ministry of Mines and Mining Development.

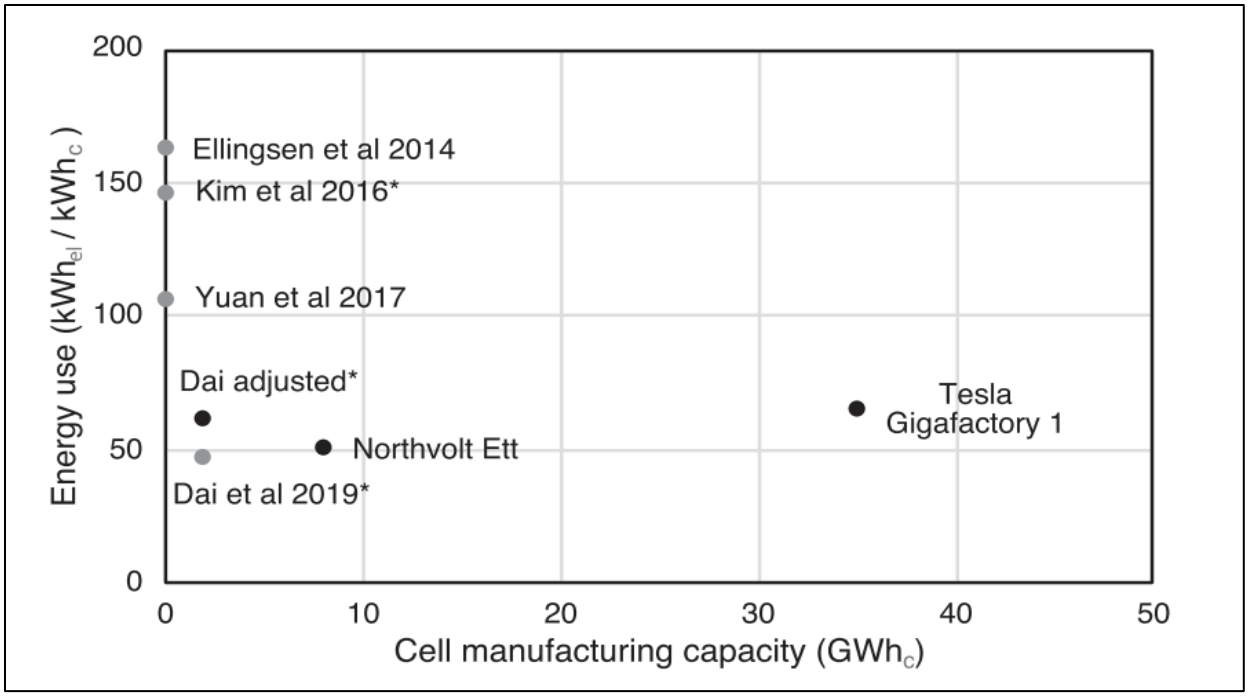
might not be competitive".[5] He believes that in light of these uncertainties in the global market, a long-term vision is critical to explore and push Zimbabwe to achieve sustainable growth via nurturing domestic mining processing and even battery manufacturing capabilities. Moreover, expanding the range of channels for marketing mineral commodities, encompassing local, regional, and even global markets, represents a viable approach to creating added value.

It is based on this logic, that in December 2022, the Zimbabwean government banned the export of raw lithium ore, a measure designed to invigorate the domestic lithium industry and cultivate battery production capabilities at home (Banya, 2022). Zimbabwe's Mines Minister, Winston Chitando, articulated during the Zimbabwe Chamber of Mines annual general meeting in 2023 that the prohibition of exporting unprocessed lithium ore is only the beginning, with further intervening policies on the way. The broader aspiration is to ascend the value chain, encouraging investors to establish local production facilities and to reach manufacturing capacities of battery-grade lithium (Banya & Chingono, 2023). The recently initiated Mapinga battery manufacturing facility holds the promise of acting as a major catalyst within the realm of battery-metal processing, which will encompass the establishment of a battery-metals park dedicated to the processing of various metals, notably lithium, platinum, and nickel (Marawanyika, 2022). Our interview with an expert from the Zimbabwean Ministry of Finance indicates Zimbabwe's regional ambition to establish strategic collaboration with neighboring states in possessing comparable mineral resources jointly, including Zambia and the Democratic Republic of Congo (DRC), to harness economies of scale for this strategic sector.[6]

However, additional processing and manufacturing capacity requires a substantial and stable energy supply. Existing research shows that the present energy outlay for producing 1 kWh of lithium batteries typically falls within the scope of 50-65 kWh, (Kurland, 2020, see *Figure 5*). Although precise energy consumption metrics may vary based on the raw material concentration and specific technology, it is generally valid to claim that higher stages of the production processes are more energy intensive.

Figure 5. Range of Energy Consumption for Lithium Battery Production

[5] Interview with the Minerals Marketing Corporation of Zimbabwe, Harare, JUL 18, 2023
[6] Interview with an official from the Ministry of Finance and Economic Development, Harare, July 21, 2023



Source: Kurland, 2020.

Unfortunately, Zimbabwe has been faced with a chronicle energy supply crisis in the past few decades, which imposes as a major obstacle to achieving the industrial ambition via processing critical minerals. It is estimated that the demand for electricity, primarily within the mining sector, including the encompassing lithium production, is poised to surge by approximately 2,300MW (Chingono, 2023). Zimbabwe grapples with a persistent power deficit. The interview with the experts from Stanbic Bank revealed that the actual demand for electricity in Zimbabwe consistently hovers around 1,750MW, whereas the current generation capacity can be as low as 1,000MW.[7] Our interview with experts from the ZERA (Zimbabwe Energy Regulatory Authority) endorsed this perspective during the interview. He proposed that Zimbabwe's electricity demand is poised to undergo noteworthy expansion, with expectations of escalating from the present 1,800 MW to an excess of 3,320 MW by 2025 and a staggering 6,680 MW by 2040. However, other experts made more conservative estimations between 2250 and 2350 MW by 2025.

As a result, increasing imports and intermittent load-shedding seem to be inevitable.[8] The Hwange thermal power station and Kariba South hydropower station serve as the backbone of the power

[7] Interviews with experts from Stanbic Bank, Harare, on July 20, 2023
[8] Interview with the Zimbabwe Energy Regulatory Authority, Harare, JUL 20, 2023

supply in Zimbabwe. The recent commissioning of the expansion unit 7 and unit 8 in Hwange is a tremendous boost for the energy supply when they are mostly needed, by overhauling the installed capacity of this aging plant to 1520MW. The Kariba South has a total installed capacity of 1,050MW after completing its upgrade in 2018, which serves as another anchor of the national energy supply (African Energy, 2018). It is noted that both upgrading projects were undertaken by Chinese companies. Yet, the actual output from the Kariba South project has been highly unstable since last year, mainly due to weather and hydrological uncertainties. Its supply abruptly diminished to below 300 MW in November 2022, when water levels dwindled to unsustainable levels and caused significant nationwide power cuts (Ndlovu, 2022). The country is importing between 300-450 MW mainly from the Southern Africa Power Pool, with a cost exceeding US$130 million during the initial eight months of 2023, or a 23.2 percent escalation from the corresponding period (Vinga, 2023).

Looking into the future, developing additional thermal and hydro power capacities can be both politically and financially challenging for Zimbabwe due to the shortage of public funding and growing climate and environmental concerns. Hydropower stations on the Zambezi River need to coordinate with Zambia, via The Zambezi River Authority, in which the Zimbabwe side is less influential in the decision-making process.[9] Most international financiers, including the Chinese ones, are now completely shun away from new coal-fired power infrastructures. The increasing likelihood of extreme weather can be expected and exacerbate the existing uncertainties around the large dams, deterring impulses for new hydropower investments. Solar energy can play a more important role, yet despite the financing bottleneck, its intermittent feature is unlikely to meet the tremendous demand of powering the entire mining industry continuously, considering the energy-intensive processing facilities are planned and being developed across the country.

Zimbabwe has been largely inaccessible to international financial institutions in the past 20 years, as the World Bank and IMF have closed their doors since 2001, after multiple defaults. China has been the *de facto* lender of the last resort in the past decades, but its capacity is now significantly constrained due to several sovereign defaults on Chinese loans.

Table 1. Zimbabwe's total external debt (in Million US$)

[9] Interviews with experts from Stanbic Bank, Harare, on July 20, 2023

Indicator		2019	2020	2021
Central Government	Long-term	8,082	8,423	8,398
Monetary Authorities	Long-term	2,463	2,100	4,954
Banks	Long-term	753	872	917
	Short-term	502	658	664
Other Sectors	Long-term	2,543	1,307	1,447
	Short-term	1,090	986	925
Gross External Debt		15,433	14,346	17,305

Source: Zimbabwe Data Portal, Reserve Bank of Zimbabwe

Besides the power generation gap, the 'last-mile challenge' is also significant, as most mining sites are located in remote and rural settings with limited power infrastructure and access. During the field investigation, we surveyed the nearby rural communities of Z1, with merely 36.2% of respondents connected to the national grid (more detailed analysis in the next section). The manager of a Chinese mining company complained during the interview about the obsolete infrastructure in the surrounding areas. He compared the situation to "an old car that has been driven for over 40 years, with all the parts worn out and on the brink of breaking".[10]

There is severe vandalism of power equipment, and maintenance works are nearly non-existent, particularly during the rainy season (The Zimbabwean, 2023). Therefore, the absence of reliable transmission and distribution facilities can be an additional challenge for investors. Currently, power solutions for the mining sites are investors' sole responsibility to resolve, as the regulatory and policy support from the Zimbabwe government is deemed limited. As a result, the specific factors at the project level, such as the location of the investments, cost of grid connection, investors' financial strength, and their relations with both the host government and the local communities, are key determinants for considering the possible energy solutions.

At least in the near run, it is not realistic to expect new government-sponsored generation capacities as ways to power mining facilities in Zimbabwe. The state utility, known as ZETDC, faces multiple challenges including a high consumer default and frequent vandalism on top of an unsustainable

[10] Interview with an anonymous expert from a state-owned company investing in another lithium mining project in Zimbabwe, JUL 20, 2023

low tariff (The Sunday Mail, 2023).[11] Under the provisions of the Electricity Act, ZETDC is mandated to obtain approval from ZERA to increase tariffs, with the newest approval granted in 2023 Oct, the tariff will be increased from an average of USc10.63 to USc12.63 (eBusiness Weekly, 2023). This round of adjustments requests a $2.95 billion extra income to improve ZETDC and ZPC's financial performance (The Herald, 2023). However, Zimbabwe's power regulators are highly cautious about 'tariff hikes' for its potential social impacts. The result is that ZETDC as the off-taker and Zimbabwe's sovereign credit rating would remain 'unbankable' for domestic and international financiers in the foreseeable future.

The investors in the lithium mining and processing facilities in Zimbabwe are left to resolve the power supply challenges between the grid-supply and self-supply options as indicated in the preceding sections. In reality, it seems that in case the 'last mile' issue can be sorted at a reasonable cost, grid-supply options are preferred. If the lithium mining and processing sites are located within a reasonable distance of the national grid and substations, the investors tend to develop the transmission line to solve the last-mile problem. Yet a hybrid or self-supply IPP project model is also on the table. Each option has its advantages and disadvantages. It is noted that the power supply of the Z1 project and another Chinese project in the country have adopted grid-supply options, but both investors are considering top-up solar PV options. Interviewees from the ZPC revealed independent PPAs in chrome and platinum mining projects too. Hence, multiple and hybrid solutions co-exist in Zimbabwe.

Apart from the initial construction cost of the power infrastructures, the tariff for the grid-supply options is usually lower given the ZETDC subsidy mentioned above. One of the disadvantages, however, is the possible load shedding or curtailment that would certainly affect the operation. Although the Zimbabwe government promised to end the electricity rationing after the commissioning of new units at Hwange, no one can guarantee that the power cuts are gone for good. This is particularly acute when considering the uncertainties associated with the Kariba South dam. As the twin cornerstone power plants are being stretched to their capacity limits, the

[11] Zimbabwe boasts one of the lowest electricity tariffs in the region, as ZETDC reportedly procures electricity at USc12/kWh but sells it to consumers at an average of USc10/kWh.

load shedding is likely to come back at a certain point, the key is then to what extent lithium mining as the strategic sector can be exempted from these impacts.

Solar PV options can be added to the grid-connected solutions to enhance the system's flexibility. Interviewees from the ZERA have outlined a hybrid model to support mining activities, by primarily harnessing solar energy during daylight hours and utilizing power from Kariba dam from the late afternoon, hence obviating costly energy storage infrastructures. Chinese SOE, CEEC, has proposed to develop a 1GW floating solar project near Kariba dam, which opens up new options for uplifting the current generation capacities (Reuters, 2023). Besides solar energy resources, it is noted that bagasse/thermal cogeneration was also experimented with nearly 100MW capacity nationwide, though not in the mining sector yet.[12]

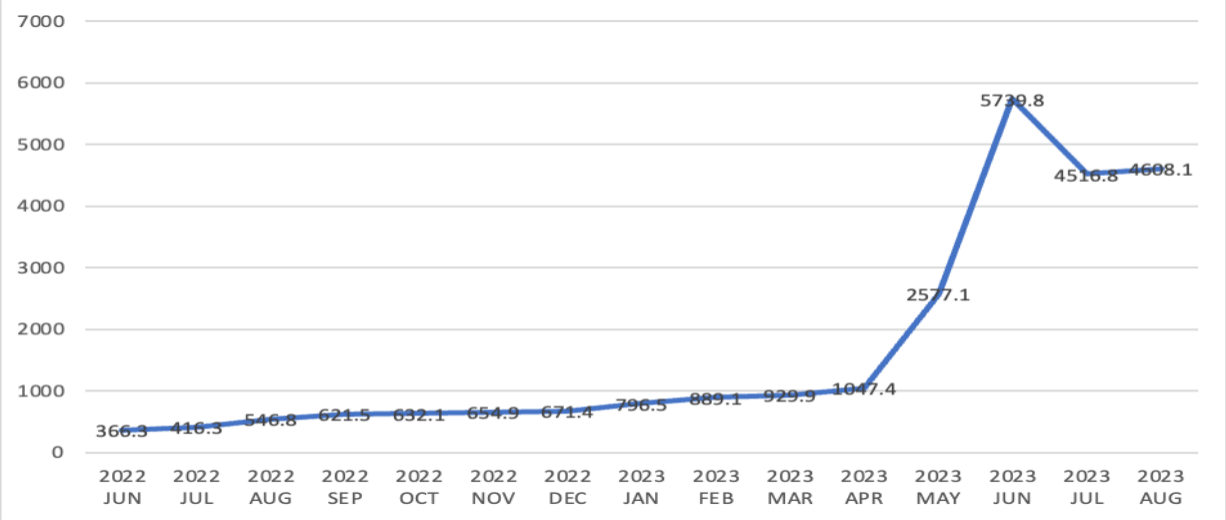
For projects that are difficult to access to the national grid, self-supply options or captive power stations emerged as a sub-optimal choice, often with diesel/gas co-generation solutions. As constructing and maintaining a power plant is often outside the expertise of most mining enterprises, an IPP developer is usually needed based on a CPPA arrangement between the two parties. For this option, solar energy sources can again be applied as a viable complement. Discussion on renewable energy options is gaining ground both among Chinese investors and Zimbabwe regulators. It is believed as a viable strategy with no additional licensing costs according to the interviewee from Zimbabwe regulators. Renewable energy solutions can also benefit from a tax holiday during their initial five years of operation. ZERA is now actively engaged with different government agencies to explore additional incentives that can encourage mining companies to develop captive power stations wherever feasible. A recent successful case is the South African company's 12MW solar PV plant at a cost of approximately $14 million at Blanket gold mine, which was commissioned in the third quarter of 2022 and provides approximately 25% of Blanket's total daily electricity demand.

Another advantage of such an arrangement appears to be the possibility of overcoming the foreign exchange deficiencies in the country, which is a significant impediment in case the state utility (ZETDC) is the off-taker. As IPPs require foreign currency to import equipment for the project construction, the complication arises when ZETDC can only pay in local currency, resulting in

[12] Licenced IPPs in Zimbabwe, ZERA 2023. Available at: https://www.zera.co.zw/electricity3/ipp/

significant discrepancies due to foreign exchange fluctuation and shortage (see Figure 6). Experts from the Stanbic Bank confirmed during interviews that a CPPA between IPPs and private off-takers, particularly with large firms operating in industries that can generate foreign exchange, such as lithium mining investors, makes more sense from the financiers' point of view.[13] The interviewee from the ZERA concurred with this perspective, asserting that although this approach may entail the diversion of ZEDTC's premium clients, facilitating CPPA arrangements is aligned with ZERA's commitment to swiftly resolve the country's energy crisis and supporting the most capable companies within Zimbabwe. It will reduce the pressure from ZETDC amid a severe shortage in power supply, by adding both flexibility and resilience from an increasingly decentralised system.[14]

Figure 6. Foreign exchange rate fluctuation 2022-2023 (ZWD to USD)



Source: Zimbabwe Data Portal, Reserve Bank of Zimbabwe

The MEND approach is therefore arguing for taking Zimbabwe's current energy endowment and constraint seriously when imaging the energy and mining landscape. As conventional energy solutions such as coal and hydro are increasingly unavailable or unstable, and government-sponsored projects become financially unviable, it provides an alternative pathway to power this strategic sector. We believe some forms of hybrid systems that allow embedded generation capacity to be developed at the project level, with a combination of both conventional and

[13] Interview with Stanbic Bank, Harare, JUL 20, 2023
[14] Interview with the Zimbabwe Energy Regulatory Authority, Harare, JUL 20, 2023

renewable energy sources, appear to be the promising route. It also allows Zimbabwe to utilize its renewable energy endowment most flexibly and pragmatically.

However, two issues remain to make the system eventually work. One is related to the risk-sharing mechanisms among key stakeholders mentioned above, namely between project developers, IPPs, and their financiers. The other is related to the impact of the MEND solution for local electrification among other developmental needs, which is to be explored in detail at project level analysis.

3.2.Powering Project Z1: on the ground solutions and implications for MEND

To further understand the potential challenges of applying the MEND concept in Zimbabwe, an in-depth project-level case study has been conducted. Our research design involves both primary and secondary methodologies and was executed by two groups of researchers. Group one consists of Zimbabwean scholars who collected interviews and surveys among national and local policy and community stakeholders in Harare and around the project site. Group two consists of Chinese researchers who are responsible for engaging with the Chinese actors in and around the mining site. The field investigation was implemented in July 2023. To safeguard research ethics, all names (including individual participants, places, and organizations) are kept anonymous in this report.

Z1 project was developed by the Chinese private company PA (hereinafter coded as 'PA'), whose operation has been focusing on Li-ion battery materials such as lithium, nickel, copper, and cobalt. Like many peer competitors in this sector, PA's raw materials are sourced mainly from overseas, particularly in Africa and Asia, whereas the manufactured facilities are mainly located within China. PA has an established track record and relatively extensive experience in investing and running mining activities in Africa, but project Z1 is its first attempt in Zimbabwe. Z1 was commissioned only recently, compared to some long-exited lithium mining activities in the country. The project is located within 4 miles of the local district (hereinafter coded as district 'G1'). The operation includes open-pit mining and preliminary processing facilities, with a capacity of processing 4.5 million metric tons of hard rock into concentrate lithium each year. It is estimated that over 2000 local people were recruited for the construction works and the current contracted local employees remain at over 1000, who are working side by side with around 200 Chinese workers and managers on site.

Project Z1 presents an interesting case for multiple reasons. First, the processing facilities that were added to the mining site impose questions on the power solution, particularly around the cost, stability, and sustainability concerns. Second, adapting to a new national and local context can be challenging even for a relatively experienced Chinese investor such as PA. On the one hand, the ice-breaking or relations-building stage for the project managers can be a valuable window to observe its strategy to manage community relations and policy risks at the preliminary stage. On the other hand, it is also valuable to understand local stakeholders' perceptions and expectations of this 'newcomer' in the neighbourhood. Hence, Z1's energy solutions, risk mitigation strategies, organizational culture, and community relations emerged as the focus of our investigation, as a test of the applicability of the MEND concept on the ground.

3.2.1. Energy solutions for the Z1 project

The Z1 project sorted its energy supply by grid-connected options with a newly extended transmission line from the project site to the nearest substation roughly 30 kilometers away. Apart from the transmission lines, other infrastructures such as new roads and water facilities were developed simultaneously. Our interviews also indicate that this is the common practice for the Chinese mining investors in Zimbabwe, who are expected to procure the requisite infrastructures independently.[15]

The grid-supply option largely solved Z1's current power consumption, currently at 10-20 MW approximately. The energy demand is subject to further increase due to the rising processing capacity. The transmission lines developed by the Z1 are shared with several neighboring farms for additional electricity access. One of the biggest concerns, however, is the unstable power supply and possible curtailment from the utility ZETDC. To hedge this risk, Z1's management secured a deal with a local power service organization (hereinafter coded as E1), a newly established private association, to negotiate with ZETDC's parent entity ZESA (Zimbabwe Electricity Supply Authority) for a more secure and prioritized position for Z1's power supply. In such an arrangement, the E1 buys power from regional or domestic power plants and then supplies this to the member companies. It is somehow a 'sleeved arrangement', where E1 serves as an

[15] Interview with an anonymous expert from a state-owned company investing in another lithium mining project in Zimbabwe, JUL 20, 2023

intermediary off-taker for its member companies (in this case Z1).[16] Such an arrangement helps Z1 to procure a more reliable power supply at a reasonable price since its commissioning, around 12 to 13 cents per kWh according to the Z1 managers.

A sleeved PPA can be a rather innovative move in the Zimbabwe context and not all Chinese mining investors are ready to take on this experiment. For example, another Chinese lithium mining project needs to construct over 120 kilometers of power transmission lines to connect to the national grid. In this case, the ZETDC would subsequently assume operational ownership of these infrastructures and charge a subsidized tariff to the Chinese investor to remunerate the construction costs.[17] During this interview, the EPC contractor for the transmission lines, which is a Chinese state-owned enterprise (SOE), expressed their hesitation to accept the sleeved PPA arrangement, particularly with a newly established organization like E1. It appears that Chinese private companies are more willing to take innovative moves compared to the SOEs.

Managers at Z1 also prepared diesel generators at the mining site as the backup option in case of power outages, which is not yet applied as the sleeved PPA arrangement is doing fine. Managers are also assessing the feasibility of installing additional solar PV capacities as complementary power supplies. In Zimbabwe, the cost of solar systems has been dropping significantly in recent years with some mining investors already trailed in this option. For example, Caledonia Mining installed a 12.2MW solar plant at its Blanket Gold Mine in November 2022, providing a quarter of its daily electricity, and reducing the consolidated cost per ounce of gold produced by approximately US$37 (Caledonia Mining Corporation Plc, 2023). Such successful experiments are encouraging Z1 managers to consider similar options as Z1's annual spending on electricity is estimated at around USD 10 million. Interviewees with the Z1 management indicated that if the projected electricity demand were to increase to 30 MW in the future, their annual expenditure on exclusive electricity usage would likely reach at least USD 20 million.

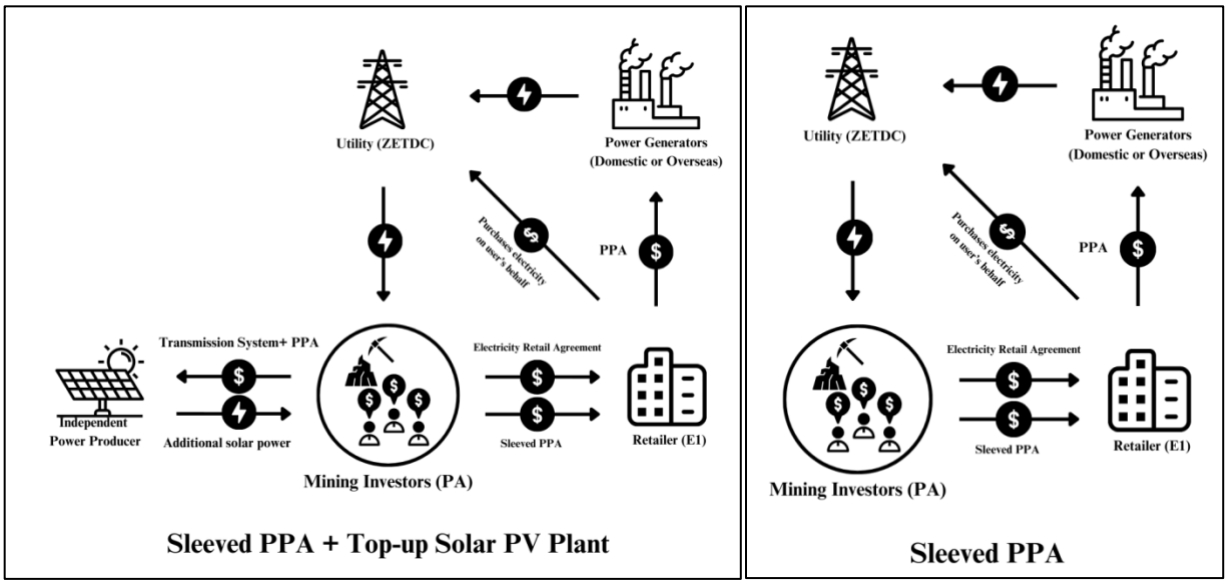
An independent solar PV project could potentially lead to annual savings of up to USD 8 million in electricity costs, according to the Z1 managers. It requires an initial investment of approximately

[16] In a sleeved CPPA, an intermediary utility company handles the transfer of money and energy to and from the power plant on behalf of the buyer. The intermediary takes the energy directly from the power plant and "sleeves" it to the buyer at its point of intake, for a fee.

[17] Interview with an anonymous expert from a state-owned company investing in another lithium mining project in Zimbabwe, JUL 20, 2023

USD 30 million, with a projected payback period of 3-4 years. The planning for such a top-up plant is contingent upon Z1's financial performance, and PA's long-term commitment to this investment in Zimbabwe. In theory, the facility can be structured either with a sleeved or self-supply model (see Figure 7). The current arrangement based on a sleeved PPA has been providing a stable power supply for the Z1 project at a reasonable cost. It remains unclear whether and how the top-up solar plant would be added to the current system. In theory, sleeved PPA is ideal for structuring renewable energy suppliers and end users by providing balancing services.

Figure 7. Two Corporate PPA Options for Mining Investors



Source: Authors' own creation

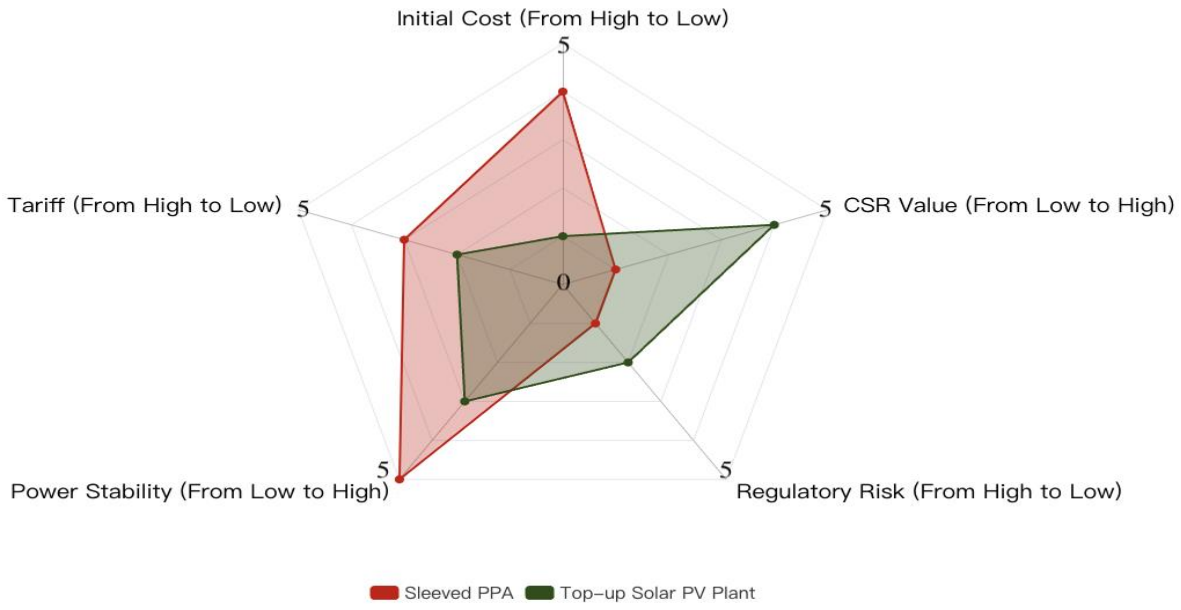
Z1 can also choose the self-supply option for the additional solar power supply, based on a private wire PPA arrangement. It would eventually create a hybrid system with a sleeved PPA providing baseload via the service provider, and a complementary supply of solar power with or without using the national grid. An IPP is likely to be procured according to Z1 managers. "Although the cost payback period of a self-supply solar power plant is long, it can help reduce operating costs and meet our ESG requirements simultaneously. Once technically these solutions prove to be

viable and we are certain that the mining operation would not be affected, we will welcome these options.” [18]

There are several regulatory risks for Z1’s current power solution, among which the potential policy changes in regulating sleeved PPAs can be the most notable one. The sleeved PPA model can be viewed by ZETDC as a threat to its monopoly off-taker position. In the long run, the capacity of E1 to guarantee a stable energy supply at low cost is still too early to judge. In addition, although a total expropriation on Chinese investments in lithium mining and processing assets is unlikely, partial or incremental moves to increase royalties or demand on equity shares cannot be completely ruled out. During the interview, one government official mentioned a proposal of allocating equity shares of the mining operation to the local communities, which would certainly agitate the investors’ nerves if implemented. It is noted that these political risks are currently unhedged as they are deemed rather tolerable by the investors. Yet these risks could affect the confidence of any potential IPPs, and particularly their financiers if needed for funding the top-up solar PV plant. The factors that affect the choice of current sleeved PPA and top-up solar PV plant are illustrated in *Figure 8*. It is illustrated that the major advantage of a sleeved PPA is its stable power supply with reasonable initial cost and tariff, whereas the major advantages of the top-up solar plant are its higher CSR value and lower regulatory uncertainties. The point is that when they are combined to form a hybrid strategy, significant developmental benefits can be reaped.

Figure 8. Determinants for Applying a Sleeved PPA and a Top-up Solar PV Plant

[18] Interview with a manager of Z1, Zimbabwe, JUL 17, 2023



Source: Authors' own creation

3.2.2. From Local Electrification to Local Development

The MEND framework highlights the importance of taking local electrification and other developmental benefits into consideration. The Z1 project applied the sleeved PPA model to solve the energy supply challenge, which provided transmission infrastructure at the initial stage of project development. These transmission infrastructures could benefit the nearby energy end-users in District G1. However, this power solution to the mining site with a sleeved PPA arrangement does not supply any additional load-sharing opportunities. It is then interesting to know what the general perceptions of local residents are of the Z1 project. We conducted a survey in District G1 and collected 152 responses from five nearby villages (see *Figure 9*).

The sample indicates that around 36% of households are grid-connected, and 65% of respondents have a monthly income of less than 75 USD or equivalent. The majority of them (over 55%) are using primitive biomass materials as their major energy sources.

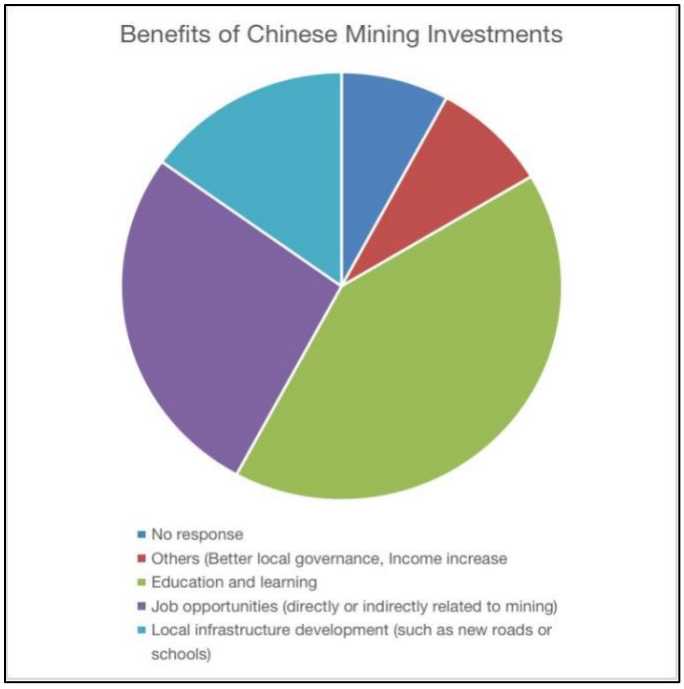
Figure 9. Villagers participating in the survey.

Source: Authors' own archive

There is a strong consensus within the community regarding the positive contributions made by the Z1 project to local development, including education, employment opportunities, and infrastructure enhancement (see Figure 10). According to the Z1's CSR report and interview with the management team, around 1.5 million USD were spent on various community development programs (CDPs). As a result, over sixty percent of community residents express a favorable attitude towards Z1 and the Chinese investors (see Figure 11).

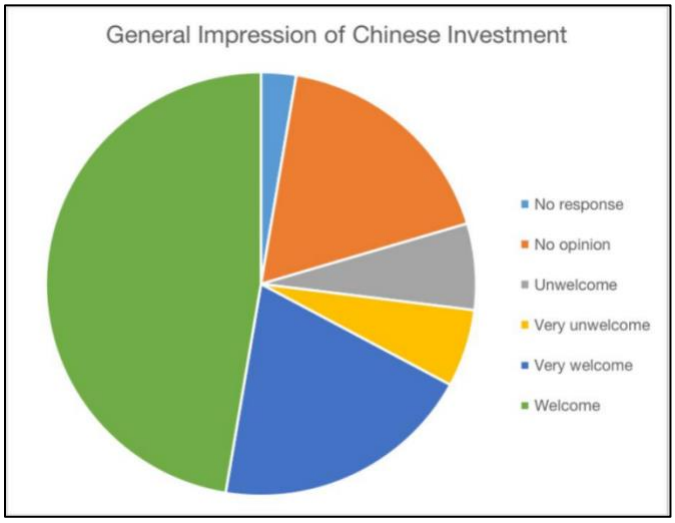
Such favorable perception was further evidenced during the field visits and participatory workshops with the local chiefs, council leaders, and other key stakeholders. However, due to the appalling shortages of public goods and development opportunities, the descriptive statistics also indicate very high hopes from the local residents for the Chinese investors to do more, as the majority (over 70%) of respondents wish Z1 to spend over 5% of their annual income on CDPs. When asked about their priority needs, education and learning opportunities appear to be the most desired (40.8%), whereas public infrastructures including electricity, roads and medical facilities appear to be the second favorable area (38.2%).

Figure 10. Perceptions of the benefits of Z1 to the local communities



Source: Authors' own creation

Figure 11. General Attitude towards Z1 and Chinese investors



Source: Authors' own creation

Managers at Z1 have established a dedicated ESG unit responsible for local community relations and CDPs, which comprises both Zimbabwean and Chinese employees. The ESG unit reports directly to the senior management, who evaluates and approves various CDPs and communication strategies. The added value of Zimbabwean experts on the ESG team is tremendous, as the field

investigation illustrates their profound knowledge of local power structure and culture when engaging with various local stakeholders.

As the energy solution at Z1 does not provide additional electricity access to the local communities, some CDP projects were designed to deliver portable solar lanterns among local villages to alleviate energy poverty in the district. The Z1 also sent engineers to help fix broken electrical equipment in the neighborhood or replace the vandalized ones. A substantial financial commitment went to the local schools, with over US$200,000 spent to refurnish and re-equip five neighboring schools. The supply of water and sports facilities for these schools is also scheduled for the next phase of CDPs. There is no power supply for most of these schools, which appears to be a secondary concern among the teachers and headmasters during our field visit.

Beyond education, Z1's CDPs include the support of local agricultural production by providing seeds, tools, and essential skills training. In addition, most of its food consumption on the mining site is now locally sourced. Z1 also invested in the community's security infrastructure by funding the construction of a local police station, which benefits both its mining operation and the local community. Other CDPs include building a dormitory for the health workers and a water supply system for the local clinic. Z1 is considering establishing a new clinic near the mining site for the next stage. In general, the to-do list of Z1's CDP is long, and local electrification is only one of many issues to be addressed at a later stage.

Within one year since its inception, ZI has made considerable efforts to develop effective local communication and CDPs. Yet the challenges ahead cannot be overlooked. The local community has demonstrated a high degree of receptiveness and expectation for the Chinese investment, which could lead to disappointment in the long run. It is also clear that the gaps in local infrastructures and public goods cannot be fully supplied by the Z1 alone. More cooperative schemes with additional funding, including civil society groups, bilateral or international aid agencies, and philanthropy organisations, are urgently needed to complement the CDPs. During our field study, we found that some Chinese civil society organisations and international social enterprises are engaging with the Z1 management team to explore the cooperative CDPs in the next stage, which can further enhance the capacity of Z1 to implement its CSR strategy. Lastly, the top-up solar PV plant, if eventually implemented, would provide additional opportunities for

increasing local electrification, but additional financial support, careful project design, and capable implementation agencies are probably needed to reap these potentials.

3.2.3. Organizational management and culture

Z1 maintains a local workforce of over 1,000 contracted employees, constituting approximately 85% of its total workforce. Regarding their working hours, the project enforces a rigorous 8-hour workday standard with three shifts per day to meet the requirement of uninterrupted operations in the processing facilities. Some employees do work up to 12 hours from time to time but are usually allowed a full day off after completing two 12-hour shifts consecutively. The monthly salaries of local employees range between USD $100 and $800 (pre-income tax). Jobs like operating forklifts usually get paid at US$350 a month. Z1 maintains a resting and kitchen facility on site for local employees, serving two complimentary meals with local food at a standard of USD $1 per meal. Most local employees live in the neighboring District G (within 5 kilometers) or the nearest city (about 40 kilometers away). Shuttle bus services are provided from District G to the mining site, which helps streamline employees' commuting.

Z1 provides specialized training programs for the local employees to operate various machinery. Chinese employees usually take up supervisory roles, and they also play a pivotal role in maintaining efficiency in completing daily tasks and output targets. Z1 recruits people evenly from the 25 wards within District G. However, there are complaints about rent-seeking incidents and opaqueness during the recruitment process. Such a situation can be difficult to prevent when the average salary offered by the Z1 is lucrative, usually 4 to 5 times higher than the average local income.

Community risks can be further complicated when considering the encounters between the Z1 employees and local residents. Although Z1 is at an early operational stage, it is increasingly clear that the investments are gradually transforming the rural agricultural economy into a more industrial and service-oriented one. PA as the foreign investor is unlikely to meet all the developmental requests of local communities, such as providing jobs for everyone or supplying all the public infrastructure and public goods. Z1 offered impressive welfare and salary for its local employees. Yet, a large group of rich miners can transform the local socioeconomic structures and exacerbate the local inequalities, when ordinary households' income in District G remained much

lower. A transition from a rural community to a 'mining town' will provide both developmental opportunities and challenges in the coming years, which need to be properly understood by all key stakeholders, particularly the PA. Again, addressing these transitional challenges in the neighborhood is beyond the Chinese investor itself. Multi-stakeholder cooperation with civil societies, academics, and officials from both China and Zimbabwe is required to steer and manage the transition toward a more sustainable pathway.

3.3.Implications for Case Study

By applying a MEND concept to Zimbabwe and particularly the Z1 project in detail, we explored how power supply challenges are handled by the various stakeholders on the ground. Several implications emerged out of our investigation. At the outset, the booming lithium mining activities amid power supply constraints in Zimbabwe provide fertile ground for innovative solutions initiated by private stakeholders. The sleeved PPA model for the Z1 project is just one example, whereas other Chinese companies are seeking innovative arrangements to solve the last-mile challenge to power the mining operations. The choice of a specific power option is based on each investor's distinctive capacities and constraints regarding their networks, access to finance, and organizational culture. Yet, it is believed that some of these innovative practices can be transferrable or scalable once proven successful.

The grid-supply options often involve newly constructed power infrastructures, which can help deliberate electricity access to the neighboring communities by the public utility. Yet if a closed-loop self-supply solution is applied based on privately owned infrastructures, the barriers or costs for providing additional electricity access to the local community can be higher. In both cases, renewable energy can be a complementary solution due to its high flexibility in various project stages and application scenarios. However, given the appalling shortage of all sorts of public goods and infrastructures in the local community, electricity access may not be the priority for the local households, particularly when there are more urgent developmental challenges such as water supply, poor school system, and most importantly, chronic poverty. The case study of Z1 revealed that local residents in District G identified jobs and education as a higher priority than electricity supply.

Hence two key messages emerged during the investigation: one is that the CSR program of the investors should be carefully designed to match the priority of the local residents; Second, it is not realistic to expect the investors to deliver all the jobs and public goods/infrastructures to the local communities, *unless other developmental actors can join and provide additional support*. Complementary funding and technical capacity are needed to complement the corporate CDPs, including bilateral or multilateral donors and development agencies, social enterprises, and CSOs or philanthropy organizations. In this regard, the MEND practice needs to be considered as a collaborative mechanism between public, private, and civil organizations. We understand that there would be tremendous coordination challenges from both ends in achieving this goal, but the benefits of such a collaborative mechanism are also unparalleled.

Bearing the mind both the tremendous challenges and benefits of implementing a MEND solution, the actual decision for powering a mining investment is always context-specific. Concerns over various risks, namely around project completion, initial cost, tariffs or operational cost, reliability of the power supply, regulatory risks, and community acceptance, all shape the final choices. At the micro/project level, the MEND framework could help conceptualize a risk-sharing mechanism among all key stakeholders. The political risks such as policy abruptions or expropriation, market risks such as fluctuation of commodity price, and community risks such as local resistance, can be properly harnessed within this risk-sharing mechanism, underpinned by the shared developmental ideations and goals among key actors.

4. Policy Recommendations and Conclusions

For many low-income countries, mining is one of the few sectors that can still attract significant amounts of foreign investments, despite the regional and global economic turmoil in the post-Covid era. Critical minerals, due to their soaring demand in the foreseeable future, can serve as a crucial ‘counter-cyclic’ industry for recipient countries amid grave financial difficulties. It can also produce strategic opportunities to achieve economic restructuring and industrial catching up, even when public investments are drying up. However, capturing these strategic values requires multiple infrastructure support, whereas electricity supply emerged as the most challenging one among SSA countries. There is a lack of public funding or bankable solutions that require urgent, innovative, and scalable answers. Meanwhile, mining investments are opening up unprecedented opportunities for local electrification and other developmental benefits. Neighboring communities

around the mining site could benefit from the anchor loads and CSR funding for access to a modern energy system.

Yet such an ideal solution, framed as a MEND approach that prioritizes national and local developmental needs, requires fundamentally new thinking and practices on how foreign investors should be incentivized, regulated, and supported by a set of new institutions and actor networks. These new networks need to consist of public, private, and civil actors not only from both the recipient and investing countries (in this case SSA countries and China), but regional or international ones. To reach this ideal end game, current capacity and institutional gaps from different parties need to be addressed, with proper policy support from both ends, which are discussed below.

4.1.Supporting innovative power solutions for critical mining activities

From the China end, the policy banks and regulators should provide greater support for the Chinese investors and EPC contractors who are actively seeking innovative power solutions for critical mining investments. Since emerging business models are often different from traditional government-sponsored projects or conventional IPPs, it is a test of state financiers' flexibility and learning capacity to match these new models and trends with upgraded risk assessment methodologies and tools. Most of the mining-related power infrastructures are now supported by corporate or commercial funding, which significantly constrained their scalability, particularly for the Chinese SOE investors and EPCs. The Chinese government has been calling for a shift towards 'small but beautiful' projects under its flagship BRI (Belt and Road Construction Leadership Group, 2023), and we argue that mining-related infrastructures can be a showcase in this category that deserves stronger policy and financial attention. Chinese policy banks and SOEs have long been engaging in the experiment of 'resource-infrastructure' deals in countries like DRC, with notable achievements and setbacks (Landry, 2018; Xu, 2020), which can be valuable lessons in seeking a proper MEND solution in the new era.

From the recipient side, a clearer and more stable regulatory framework is needed for innovative power solutions around last-mile transmission lines, sleeved PPA, and captive or self-supply options. The diversification of power solutions we observed on the ground indicates the flexibility and tolerance of the Zimbabwe government for these bottom-up experiments, which is crucial in

seeking pragmatic and context-specific resolutions. Yet it also unfolds uncertainties regarding how these innovative arrangements are to be regulated in the long run. Clear policy messages could be vital for the rest of the investors, as many are hesitant to follow the pioneers at the current stage.

4.2.Supporting renewable energy solutions with climate benefits

From the Chinese side, the advantage of promoting renewable energy solutions is very clear in terms of its strong technological capacity to deliver solar power facilities for the mines. The challenge again is the need for financing support, as the offtake risks from the mining investors need to be accepted by the policy banks and export credit insurers. In addition, the mining investors and solar energy IPPs need to work out proper sharing arrangements for political, commercial, and even community risks, which may take time and increase the transactional cost. However, besides conventional financing routes, additional resources can be explored, such as China's South-South cooperation funding dedicated to supporting climate mitigation and adaptation in the global South. [19] Such funding can be harnessed to support piloting projects or capacity-building programs. In addition to climate finance, the mitigation effects of these solar PV facilities can be quantified and packaged as carbon credit assets in the global carbon markets. The combination of conventional finance, climate finance, and carbon finance could significantly enhance the bankability and reputational value of these top-up solutions.

From the recipient side, several policies supporting renewable energy infrastructures are already in place. The National Renewable Energy Policy is the primary government document to promote the deployment of renewable sources both on-grid and off-grid (Ministry of Energy and Power Development, 2019). However, additional support can be rendered to reduce tariffs on solar equipment imports and foreign exchanges. In the long run, recipient countries may consider supporting domestic manufacturing capacity on solar PV equipment, meaning that a learning mechanism for domestic entrepreneurs needs to be cultivated, via policy instruments such as a local content requirement. Yet, these measures need to be carefully introduced so that they do not discourage investment inflow. Coordinating industrial and foreign investment policies can be the

[19] The China Climate Change South-South Cooperation Fund was established in 2015 with 20 billion RMB from the central budget. It aims to promote South-South cooperation around climate governance, by enhancing developing countries' capacity to cope with climate change and facilitate the transition to green and low-carbon development.

most challenging task for the recipient governments in Africa to balance short-term and long-term interests.

4.3.Achieving local electrification and developmental benefits

In recent years, Chinese governments and industrial associations have issued several guidelines to encourage more environmentally and socially responsible overseas investments, particularly in the mining sector. These guidelines impose restrictions on Chinese overseas investments that fail to comply with the environmental, energy consumption, and safety standards of the host country (NDRC, 2017), and call for more stringent and effective environmental risk management of Chinese overseas projects, particularly in energy, transportation, and mining sectors (MEE, 2022). China's industrial association of the mining sector, known as the CCCMC, issued and upgraded comprehensive guidelines for responsible mining activities (CCCMC, 2022). However, how these guidelines and proposals can be translated into actions on the ground requires further studies. In this specific case, our research indicates that to what extent the MEND approach could eventually help achieve local electrification is rather context-specific.

From the Chinese side, the investors need to establish both direct and indirect communication channels with the local communities to understand their actual energy-related and heterogeneous developmental demands. Direct communication relies upon strong in-house expertise and local social-cultural-economic knowledge. Indirect communications via intermediaries, such as civil society groups and local researchers, can contribute to co-designing and co-delivering energy-related CDPs. Outsourcing arrangements with local social or commercial enterprises are particularly important for Chinese investors who are not yet equipped with sufficient skillsets and experience in handling complex local situations. In addition to the private-civil partnerships, the Chinese actors also need to consider the possibility of using bilateral aid as complementary sources of support to alleviate local energy poverty, given the strategic value of these mining investments to both sides.

From the recipient side, state utility may need to provide distributive services to the local communities and arrange proper tariff schemes with the mining investor and other end users. For the self-supply option, the public entities can play a rather limited role, but clear policy signals on the captive power options are needed. In addition, there are broader issues that both central and

local governments need to grapple with, particularly regarding the systematic transformation of rural communities as a result of mining investments. Tremendous opportunities and challenges are associated as the traditional agricultural and artisanal mining activities could be melted away swiftly and for good, together with social-economic structures and institutions. On the one hand, new employment and learning opportunities may arise from both mining and peripheral activities. On the other hand, social struggles may emerge around land and water use, growing crimes, and social exclusion or inequalities. If these struggles cannot be properly anticipated, understood, and managed, the MEND solutions are likely to collapse.

4.4.Developing effective and coherent redistributive mechanisms

China attaches no strings to its lending and investments to the global South, and Chinese investors (SOEs and private companies alike) are particularly disinterested in getting involved in recipient countries' domestic politics and decision-making processes. As a result, Chinese actors would have a limited role in shaping recipient countries' redistributive mechanisms around the mining income. However, the potential for Chinese companies to develop large-scale energy infrastructures to support mining, processing, or other industrial activities requires a functioning redistributive mechanism in the recipient countries. For example, the proposed deal of the large floating solar project in Zimbabwe is unlikely to be bankable without considering the nation's mineral income as direct or indirect collateral.

The host governments hence need to articulate coherent policy frameworks concerning the revenue redistribution from the booming mining sector. Taking Zimbabwe as an example, the Mines and Minerals Act of 1963 is undoubtedly obsolete as it lacks explicit provisions on major issues, such as the redistribution of mining revenues, the issuance of mining licenses, and the improvement of a very slack taxation and royalty system. The dearth of specificity in this legislation created considerable uncertainty for the investors. A notable example was the government's arbitrary attempt to raise royalties of lithium mining from 2.5% to 5% in 2022. There is also ambiguity regarding acceptable currency for a royalty payment, either in USD, ZWD, or even an equivalent quantity of ores (Marawanyika and Ndlovu, 2022). The policy processes need to be more transparent, as the ongoing negotiations for a new mining bill are largely behind closed doors, led by the Ministry of Mines and Mining Development. Since this new bill is critical for Zimbabwe's

development strategy, open discussions and consultancy with other line ministries, relevant departments, and external experts could be helpful.

In addition to the regulatory clarity and coherence on royalties, recipient countries also need a smarter planning and budgeting system to develop the most critical infrastructures via lucrative mining income, such as roads, railways, and ports that are crucial both for mining and broader economic development. Prudent and efficient revenue redistribution is required between the mining, fiscal, and infrastructure departments. Concrete and transparent planning would boost the confidence of investors and their financiers in these areas.

Last but not least, the MEND framework is not conceptualized as a bilateral scheme. Rather, its successful implementation often requires regional and even international cooperation. The collaboration among African countries in the region can tremendously boost the prospect of sustainable power solutions and the lasting developmental impacts of the specific investment. For example, the case study showcases the possibilities of procuring power from the neighboring countries via the Southern African Power Pool (SAPP). Cooperation can be based on existing institutions or newly established ones. In 2022, Zambia and the DRC signed a historical cooperation agreement to facilitate the development of the value chain in the electric battery and clean energy sectors, which opened up the possibility of working with regional and international development financiers such as the African Development Bank and EU partners, for the critical infrastructures such as Zambia-Lobito railway project (AfDB, 2023). The rising geo-political tensions have put critical minerals and their supply chains at the center of scrutinization, yet the cooperation among resource-rich countries in the SSA region would enhance the African agency in negotiating deals around critical minerals and renewable energies.

'South-South' collaboration with mineral-rich countries outside the region can also be beneficial. Some of the challenges discussed in this report may have been encountered by countries in other parts of the global South, such as Asia or Latin America. For example, the latest industrial policies in Indonesia's nickel mining sector, or persistent community conflicts in Chile's mining towns, would provide valuable experiences and lessons for African countries and communities if mutual learning opportunities are provided.

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