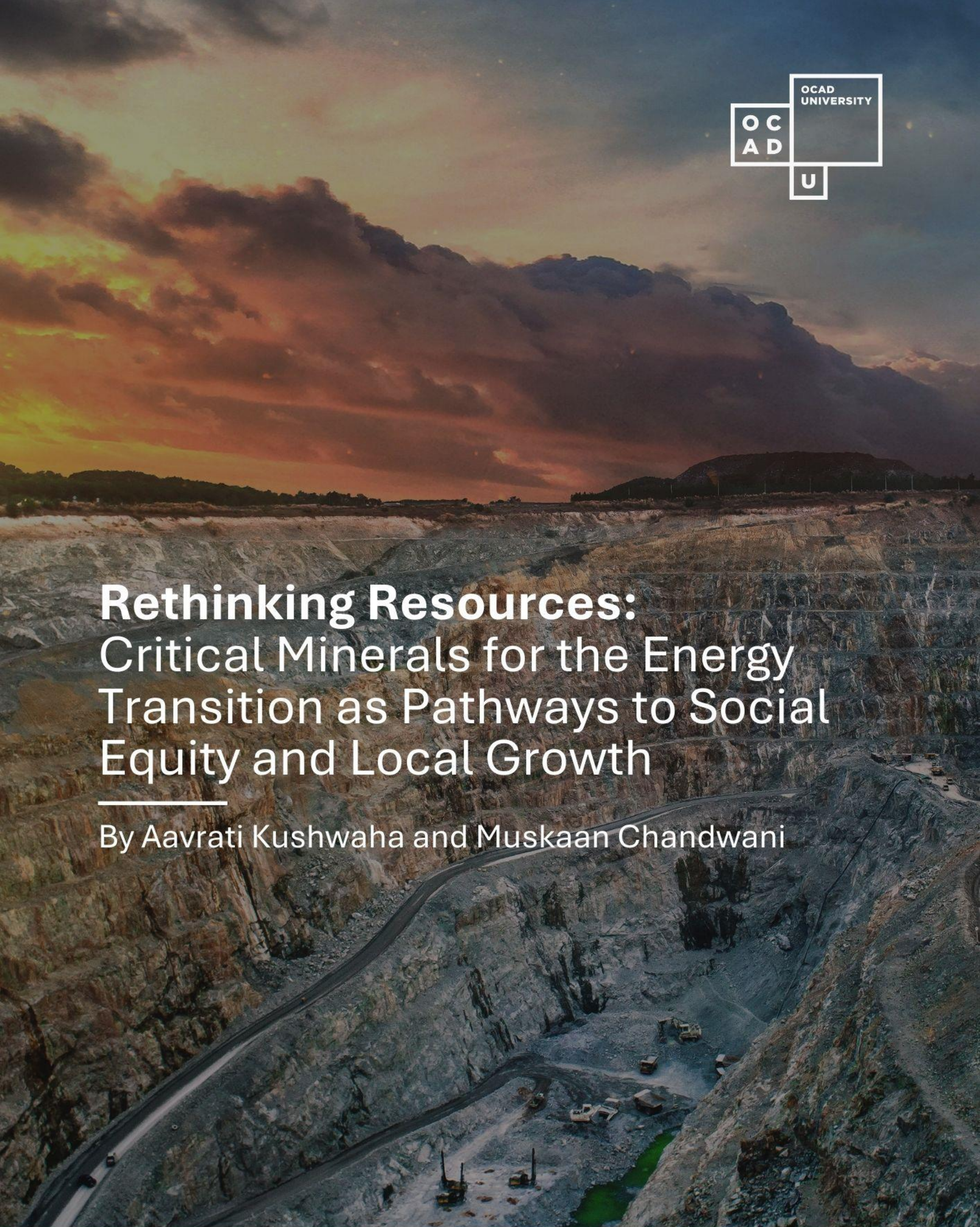

Rethinking Resources:
Critical Minerals for the Energy Transition as Pathways to Social Equity and Local Growth

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Abstract

This research examines how social equity can be embedded in critical minerals extraction for the renewable energy transition. Our study reveals that the shift to renewable technologies has created a mineral-intensive dependency that risks perpetuating colonial extraction patterns in the Global South. Through systems mapping and strategic foresight, we identified five interconnected equity dimensions requiring intervention: indigenous rights, livelihood impacts, environmental justice, geopolitical power dynamics, and climate finance.

Our scenario development identified "Thriving within Limits" as the preferred future, where resource governance prioritizes need-based extraction and equitable benefit distribution. The key finding is that embedding social equity requires simultaneous interventions across multiple leverage points. We developed pathways in five categories: paradigm shifts, system goals, structural reorganization, rule changes, and feedback mechanisms. We conclude that successful transition requires transforming underlying power dynamics, not just technologies. The leverage points provide pathways to intervene in the current energy system to ensure that the renewable energy transition benefits are shared equitably, turning critical minerals extraction into opportunities for social equity and local growth rather than continued exploitation.

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All figures are original and designed by the authors of this MRP.

Statement of Contributions

We, Aavrati Kushwaha and Muskaan Chandwani, jointly certify that this research project embodies our collaborative efforts throughout all phases of development. Our partnership involved equal contribution to the comprehensive literature review, detailed systems mapping, and application of foresight methodologies. Together, we formulated research questions, analyzed findings, and synthesized conclusions with shared intellectual investment. Both partners were actively engaged in drafting, refining, and finalizing the research paper, maintaining consistent communication to ensure cohesive integration of our perspectives. We affirm that this work is original and has not been previously submitted for academic credit elsewhere. All referenced sources have been properly cited in accordance with the university's academic integrity standards, reflecting our commitment to scholarly ethics and transparent attribution of ideas.

Glossary

Artisanal Mining	Small-scale mining activity often carried out independently using rudimentary tools and techniques. It is typically informal and unregulated.
Climate Change	Long-term shifts in temperatures and weather patterns, primarily caused by increased levels of greenhouse gases in the Earth's atmosphere.
Critical Minerals	CRMs, as defined by IRENA, refers to those essential for energy transition technologies that have either one or more of the following characteristics: they are produced in a limited number of countries, face significant extraction challenges, or experience a decline in quality (Gielen, 2021).
Decarbonization	The process of reducing or eliminating carbon dioxide (CO2) and other greenhouse gas emissions from energy sources and industrial processes.
Energy Security	The reliable availability of energy at an affordable price. It also involves protecting a nation from disruptions to energy supplies.
Energy Transition	The shift from fossil-fuel-based energy systems to renewable energy sources.
Geopolitics	The influence of geographic factors (such as resources, location, and population) on international politics and power relationships.
Greenhouse Gases (GHG)	Gases that trap heat in the atmosphere and contribute to global warming.
Global North	Developed countries with economic and political power.
Global South	The Global South encompasses developing nations characterized by economic disadvantage, often with histories of colonization and ongoing challenges with industrialization and democratic stability. While traditionally associated with geographic location, the term more accurately describes countries and populations marginalized within the global economic system or negatively impacted by capitalist globalization (World Population Review, n.d.)
Green Extractivism	The appropriation of natural resources, often in the Global South, to support renewable energy technologies and infrastructure in a way that replicates or exacerbates historical patterns of exploitation.
Indigenous Communities	Distinct social and cultural groups who share ancestral ties to a particular territory and who often maintain unique cultural practices and social structures.
Local Growth	Economic and social development within a specific geographic area.
Marginalization	The process by which a group is pushed to the edge of society and prevented from participating fully.
Net Zero	A state in which the amount of greenhouse gas emissions produced is balanced by the amount removed from the atmosphere.
Renewable Energy (RE)	Energy derived from natural processes that are replenished constantly, such as solar, wind, hydro, geothermal, and biomass.
Resource-rich countries	Countries with significant natural resource deposits, particularly minerals and metals
Total Demand	Total demand of critical minerals globally

Abbreviations

CRM	Critical Raw Minerals
DRC	Democratic Republic of the Congo
ESG	Environmental, Social, and Governance
EV	Electric Vehicles
FPIC	Free, Prior, and Informed Consent
GHG	Greenhouse Gas
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
LCOE	Levelized Cost of Electricity
MRP	Major Research Project
NDC	Nationally Determined Contribution
NZE	Net-Zero Emissions
OECD	Organisation for Economic Co-operation and Development
RE	Renewable Energy
SDG	Sustainable Development Goal
SME	Small and Medium Enterprise
STEEP+V	Social, Technological, Economic, Environmental, Political + Values framework
UNCTAD	United Nations Conference on Trade and Development
WEF	World Economic Forum
UN	United Nations
WRI	World Resource Institute

1. Introduction

Since the beginning of complex human societies, energy has served as a catalyst for progress and development. From the discovery of fire, which enabled humans to cook, create tools, and thrive, to the coal-powered engines of the Industrial Revolution that sparked mass production and urbanization, energy has fueled development. Today's economy continues to harbor the spirit of mass production, largely driven by fossil fuels. The rapid acceleration of digitization has further amplified global energy demand, as everything from data centers to smart technologies requires a constant and reliable power supply to function. Hence, reliable access to energy is fundamental for building and maintaining essential infrastructure and communication networks. In turn, these structures are critical for supporting commerce, education, healthcare delivery, and connectivity, all which fuel economic activity and improve quality of life.

1.1. Energy Sector and Climate Change

According to the International Energy Agency (2023), more than 80% of the total energy supply globally comes from fossil fuels. Fossil fuels remain the largest sectoral source of global greenhouse gas (GHG) emissions worldwide, contributing to approximately 73% of total global emissions (Ge et al., 2024). From 1990 to 2021, global greenhouse gas (GHG) emissions grew by 51%, with emissions coming from 5 sectors: energy, agriculture, industrial processes, waste, and land use and forestry. The energy sector accounted for the most emissions by far, including electricity and heat, transportation, manufacturing and construction and buildings (Ge et al., 2024). Since the industrial revolution, fossil fuel consumption has increased exponentially- from just 7 Mtoe in 1800 to over 140,000 TWh (about 12,000 Mtoe) in 2023 (Statista, 2024). Although this reliance has led to industrial progress, it has led to increased carbon emissions, with over 2,600 billion metric tons of CO_2 released since 1850 (Statista, 2024b). These carbon emissions have led to climate change and global warming.

With efforts to restrict the temperature increase to 1.5°C above pre-industrial levels, the international community came together in 2015 to adopt the Paris Agreement, a legally binding international treaty on climate change that commits countries to limit global warming to well below 2°C (United Nations Framework Convention on Climate Change, 2015). Achieving this requires a dramatic reduction in GHG emissions, ultimately reaching *a net zero*- scenario by the 21st century. The global pathway to achieve this goal has opened doors to a normative scenario that shows a path for the Global Energy sector by transitioning to renewable energy to limit CO2 emissions by 2050. The agreement echoes historical global environmental efforts, including the Montreal Protocol of 1987 (The Montreal Protocol on Substances That Deplete the Ozone Layer | Ozone Secretariat, n.d.), which successfully mobilized nations to phase out ozone-depleting substances and reverse the deterioration of the ozone layer. However, unlike the enforceable and unified approach to the ozone crisis, the response to the role of energy in climate change has been inconsistent and siloed. Despite international agreements, global dialogues, and national policies to phase out fossil fuels, their use and activities continue to grow in many regions which are influenced by governments and oil and gas lobbyists. Even countries committed to net-zero targets and climate financing are shifting trajectories, shedding light on the disconnect between international ambitions and national energy policies.

1.2. Global Energy Demand

According to the Global Energy Review 2025 by the International Energy Agency (IEA, 2025), global energy demand rose by 2.2% in 2024, representing an increase from the average annual demand increase of 1.3% between 2013 and 2023, as emerging economies industrialize, digital infrastructure expands, and electrification accelerates. Emerging and developing economies were responsible for over 80% of the increase in global energy demand in 2024 (IEA, 2025), highlighting their growing role in global energy consumption. Data centers now consume 1.5% of worldwide electricity and could double their share by 2030, while electric vehicles may reach 30% of new sales in the same timeframe. Urbanization drives further increases, with cities already accounting for 75% of primary energy use (UN-Habitat, 2021) as the global population heads toward 9.8 billion by 2050 (United Nations, n.d.). Simultaneously, industrial growth in developing nations like India, Indonesia, and Brazil is intensifying electricity consumption. At the same time, the automation of smart homes and digital technologies adds new layers of demand despite efficiency improvements. As mentioned in the previous section, climate change accelerates the transition to renewable energy. Renewables generated nearly 30% of global electricity in 2023, with global renewable electricity generation projected to surge by almost 90% by 2030 (IEA, 2024).

Developing and developed nations are adopting renewable energy pathways to drive long-term energy sustainability and security. Solar, wind, hydropower, and battery storage systems are being deployed to decarbonize the power grid and meet growing energy demands. A sustainable future demands a secure global energy system powered by infinite natural resources such as wind, solar, and thermal energy, but at what hidden costs? While the transition to renewable energy is a climate change necessity and offers a clear pathway to reduce emissions, it is equally important to recognize the shifting burden of the energy system from carbon-intensive fuels to critical mineral-intensive technologies and infrastructure.

Fossil fuels, being finite in nature, generate significant environmental damage through carbon emissions and pollution when extracted and burned. At the same time, renewable energy technologies are built to harness infinite natural resources and are built using resource-intensive infrastructure, making them reliant on critical minerals (Tennant, 2025). Critical minerals (CRMs) lie at the heart of this transition, as they are essential for infrastructure and renewable energy technologies such as wind turbines, solar panels and batteries.

1.3. Types of Critical Minerals and Renewable Energy Technologies

This study focuses on the role of four critical minerals, cobalt, copper, nickel, and lithium, essential in building infrastructure to harness renewable energy. The data for these minerals have been sourced from IRENA Outlook 2021 report, which highlights the increasing demand for these critical minerals for the renewable energy transition and emphasizes the need to address supply, demand, and geopolitical challenges for a sustainable transition (Gielen, 2021).

The following sections detail their contributions and associated supply chain considerations:

- **Cobalt:** Dominantly used in lithium-ion batteries, cobalt production is geographically concentrated in the Democratic Republic of Congo, raising concerns about supply security. As a byproduct, its availability is dependent on copper and nickel mining. Anticipated demand increases, particularly from the electric vehicle sector, highlight the need for supply diversification and battery technology innovation.
- **Copper:** Essential for electrical infrastructure, copper demand is projected to rise with increasing electrification. While resource availability is not a primary concern, declining ore grades present challenges for future production.
- **Nickel:** The growing use of nickel in battery cathodes is driving demand, prompting exploration of alternative battery chemistries. While these alternatives offer potential for reduced nickel dependence, they currently exhibit performance limitations.
- **Lithium:** As a key component in electric vehicle batteries, lithium production must scale rapidly to meet the projected growth in electric vehicle adoption.

As the world accelerates efforts to scale up renewable energy and meet growing energy demands, the rush to secure the critical minerals is creating forms of social and economic inequities especially for resource-rich countries in the Global South. The global narrative around the transition to renewable energy is energy security and climate action, but it carries unintended negative externalities to deeply embedded structural inequalities. On one hand, it promises economic growth for many resource-rich nations. On the other, it brings with it the very real risk of deepening long-standing social and environmental challenges in vulnerable communities. The race to obtain essential minerals is posing additional risks, such as environmental, social, and geopolitical ones, including soil erosion, depletion of water resources, and patterns of neo-colonial control over resources. These challenges are further exacerbated by geopolitical risks, the absence of benefit-sharing models, and disruptions in global supply chains of CRMs.

The efforts to achieve a net zero emissions (NZE) target have called for the extensive deployment of a wide range of renewable energy technologies, which rely on the supply chain of minerals such as copper, lithium, nickel, and cobalt. This necessitates a deeper understanding of both their supply chains and value chains. The supply chain refers to the operational steps while the value chain emphasizes where and how economic, social, and environmental value is created and distributed. While the supply chain maps the physical flow of minerals from extraction through processing, manufacturing, deployment, and end-of-life management, the value chain focuses on who captures economic returns, where innovation occurs, and how benefits and burdens are distributed across stakeholders and geographies.

The narrative needs to consider the fundamental reality that the transition comes with a human and social equity cost. For individuals working in the supply chains, to communities situated near mining operations, or those facing land displacement due to government acquisition for renewable energy infrastructure, the shift is resulting in growing displacement, land dispossession, marginalization of communities. To offer a unique angle to the discourse on critical minerals and the transition to renewable energy, this MRP critically challenges the practices and patterns that resource extraction of CRMs in the Global South is a necessity and an acceptable cost driving building low-carbon economy. By exploring the possible futures in 2050 through understanding the current energy system and providing alternative perspectives and novel approaches this research prioritizes social equity and local growth within this crucial context.

1.4. Why 2050?

The year 2050 serves as an important milestone in global sustainability development and climate action. Major economies such as Canada, EU, Australia, and even emerging economies such as Colombia, Vietnam, Peru, and Brazil have made commitments in climate agreements that aim to achieve net-zero carbon emissions by this year (Net Zero Scorecard, 2023). The Paris Agreement and numerous national climate strategies set 2050 as the endpoint for carbon neutrality, making it the definitive horizon for transformative change in energy, transportation, industry, and society. By focusing on 2050, we create a timeline that is distant enough to allow for significant system-wide transformations and close sufficient to motivate immediate action. This timeline recognizes the urgency of climate change and the practical realities of transforming complex global systems. 2050 is also consistent with demographic and technological forecasts that predict significant shifts in population, urbanization, automation, and resource demands. It represents the convergence of several transformative trends that will reshape our world.

1.5. Expanding from Social Equality to Social Equity

Social Equality in the context of critical minerals for the renewable energy transition would entail treating all actors the same within the system. This approach does not account for the contextual differences of various factors such as unequal access to resources, historical impacts, and existing vulnerabilities. Equality does not account for different starting points and refers to providing all actors with the same power, rules, and processes. Our focus expands beyond to social equity, that considers the contextual differences among actors in the energy system and recognizes the complexities and nuances of these relationships. It acknowledges the lived experiences of different actors while recognizing that some may hold economic, political, or structural competitive advantages. The focus of social equity is the contextual and fair distribution of burdens, benefits, and value across the system's value chain.

1.6. Just Transition and Social Equity

As the current trajectory of the global transition to renewable energy threatens to sustain current inequities, this requires a "just transition", creating employment opportunities and ensuring that no one is left behind (International Labour Organization, n.d.). While the just transition emphasizes the change process, our research specifically investigates the outcomes i.e. social equity to analyze the distribution of benefits, burdens, and value during the transition across various stakeholders. This research seeks to prevent the renewable energy era from replacing environmental neglect with social neglect, as exploitation in the Global South cannot be justified as a cost for global energy security and climate action.

1.7. Classes and Marginalization

The parallel structures between the Fossil Fuels Era and the transition to renewable energy reveal a disturbing reality: our energy systems remain rooted in deep historical patterns of colonization. The power dynamics remain largely the same as the Global North leads in decision-making and innovation, while the Global South continues to serve as the extraction zone. For example, communities in Nigeria's Niger Delta have suffered from devastating pollution resulting from Shell's oil extraction operations, compelling many residents to abandon their homes and relocate (Chang et al., 2024). The renewable transition risks repeating colonial patterns, where the benefits are captured by those at the top, and those at the bottom carry the burdens.

Disguised under the ruse of climate action, "green extractivism" is a term coined to critique how the transition to a low-carbon economy can reproduce colonial patterns of resource extraction and wealth accumulation (Deberdt & Le Billon, 2024). Deberdt and Le Billon (2024) argued that the green transition does not distribute benefits equally but introduced a redefinition of the class categories based on the access to and consumption of green technologies:

- **Ultra-carbonized class:** very rich people and companies that control green tech and still live high-carbon lifestyles. They profit from the green transition.
- **Decarbonized class:** wealthy people who buy electric cars and solar panels. Drivers of the green transition.
- **Still-carbonized class:** lower middle class with limited earnings who want to join the renewable energy transition but cannot afford it
- **Uncarbonized class:** people, mostly in poorer countries, who live in territories that provide minerals for the renewable energy transition

Applying this lens helps establish the framing to focus on the value chain to shift the value towards the still carbonized and uncarbonized classes. Therefore, our research looks into the spectrum of harms and negative externalities arising from the extraction of CRMs' supply chain for the renewable energy transition through a social equity lens.

2. The Foundation of the Renewable Energy Transition: Critical Minerals

2.1. Meeting Net Zero Emissions Targets through Renewable Energy Transitions

The supply chain of critical minerals spreads across Global North countries like Canada, Germany, Australia and Global South countries such as Indonesia, China, India, Brazil, and DRC. As countries race to achieve net-zero emissions targets, competition for these critical minerals intensifies, creating potential threats to energy security. This evolving energy landscape demands a corresponding evolution in our approach to energy security, one that acknowledges the interconnected nature of CRMs supply chains and prioritizes both cooperation and strategic resource management. According to one of the scenarios, the International Energy Agency (IEA, 2024), where all climate commitments and national energy policies that governments have officially announced are implemented on time and in full, demand for critical minerals more than double by 2030 and triple by 2050, while in the NZE Scenario, the swifter adoption of renewable energy technologies implies an even more pronounced surge in demand for critical minerals, nearly triple by 2030 (IEA, 2024). With this increase, what could the possible impact be on the mining sector? Will this lead to a potential rise in CRMs mining? If yes, how can the risks and challenges associated with it be mitigated while keeping profits and social equity in mind?

The mining sector currently accounts for 4 to 7% of global GHG emissions in terms of Scope 1 and Scope 2 emissions. As renewable energy deployment expands, mining for CRMs will increase correspondingly. This additional mining activity would contribute to global GHG emissions. However, this represents a shift in mining activities - from fossil fuel mining to critical mineral mining. While CRM mining does produce emissions, the net effect is a reduction in global emissions as fossil fuel mining and related infrastructure decrease (International Mining and Resources Conference [IMARC], n.d.). Given the NZE target, possible challenges/ threats could be associated with achieving it. With rapidly growing renewable technologies that allow for more electrification of vehicles, the production of solar panels and wind turbines could be subject to price volatility, geopolitical influence, and even disruptions to supply due to wars (Liang et al., 2023).

2.2. Supply Chain of Critical Minerals

While critical minerals serve as a foundation of a low-carbon economy driven by renewable energy, their supply chains are complex, geographically concentrated, and often facing environmental, social, and geopolitical challenges. The global supply chain for critical minerals consists of multiple stages, each characterized by varying degrees of value addition and geographical concentration. Understanding these stages is crucial for identifying supply chain vulnerabilities and strategic opportunities in the energy transition.

Figure 01: Supply Chain Stages for Critical Minerals *in the Energy Transition*

Supply Chain Stage	Short Definition	Value Addition	Common Locations
Extraction	Mining raw minerals from the earth.	Low	Congo, Chile, Australia, Indonesia Brazil, South Africa
Processing and Refining	Transforming raw minerals into usable minerals.	Medium	China, South Korea, Japan, Germany, Finland, Russia, Canada.
Manufacturing	Creating finished products from refined minerals.	High	China, United States, Germany, South Korea, Japan, European Union countries

This figure is original by the authors

Source: Data from USGS (2023), IEA (2022), and IRENA (2022). https://evboosters.com/ev-charging-news/the-countries-that-dominate-the-critical-material-supply-chains/ legend

This Figure 01 illustrates the three primary stages in critical minerals supply chains, highlighting how economic value increases at each subsequent stage while geographical distribution varies significantly.

Notably, extraction often occurs in resource-rich developing countries, while higher-value processing and manufacturing activities are concentrated in industrialized nations and China.

The Extraction stage, where minerals such as cobalt, lithium, and nickel are mined from various geological formations concentrated in specific regions and countries. This stage requires substantial financial investments and is often labor-intensive. The extracted ores then undergo processing and refining, the second stage, characterized by energy-intensive technologies aimed at transforming raw minerals into usable forms. These intermediate products are then transported to manufacturing facilities, where they are integrated into components for batteries, magnets, and other essential technologies. The geographical separation between extraction sites and manufacturing hubs adds another layer of complexity of transportation to the supply chain. Finally, as these technologies reach the end of their life cycle, the focus shifts to recycling and recovery, an increasingly vital stage aimed at mitigating resource depletion and minimizing environmental impact. However, the intricacies of separating and purifying minerals from complex end-products present significant technical and economic challenges.

2.3. Environmental Impacts of the Extraction and Refining of Critical Minerals

Renewable energy technologies rely on critical minerals, but their extraction and refining processes involve environmental trade-offs. Although generally less impactful than fossil fuels, mining (especially for lithium and cobalt) can cause pollution and land degradation. Labay et al. (2017) suggest that over 16% of global deposits are in water-stressed areas, where mining could further strain limited water supplies.

The Lithium Triangle, spanning parts of Argentina, Bolivia, and Chile, is a critical region for lithium production and holds over 50% of the world's lithium reserves. Lithium is commonly extracted through brine mining, where saltwater from underground reserves is pumped to the surface and evaporated to isolate it. Producing 1 ton of lithium requires evaporating 2 million liters of water, depleting underground aquifers and surface water sources (Wetlands International Europe, 2023).

Another example is Nickel extraction in Indonesia, the world's largest producer, which has significant environmental impacts, particularly on islands like Sulawesi and Halmahera. The Indonesian government has billed its nickel policy as a push toward renewable energy. However, Nickel mining and extraction practices have led to extensive forest loss, resulting in at least 5,331 hectares (13,173 acres) of deforestation on Halmahera alone (Indriyatno, 2024).

Given the potential for significant environmental damage in these countries in the Global South from CRM extraction, particularly as demand increases to achieve Net-Zero Emissions (NZE), the renewable energy transition must not come at the expense of environmental sustainability and social equity. This Major Research Project will subsequently prioritize examining the social aspects inherent in CRMs extraction practices, which are detailed further in the section on the social impacts of CRMs.

2.4. Global Critical Minerals Supply Process

To further illustrate the geographical concentration of critical material supply, Figure 02 lists countries that showcase various global critical mineral supply chain processes.

Figure 02: Showcasing Global CRMs Supply Chain Process and its Geographically Concentration

	Copper	Lithium	Cobalt
Countries that export (Export + Mining)	Democratic Republic of Congo Indonesia Australia	Australia Chile	Chile Peru Indonesia Democratic Republic of Congo
Countries that import		China Korea Japan	China Japan
Countries that process critical minerals	China Finland Malaysia	China Chile Argentina	China Chile Japan

	Copper	Lithium	Cobalt
Projected demand for CRMs in 2050 (Mt/Year)	50-70 Mt/ year	2-4 Mt/ year	0.5-0.6 Mt / year
Projected demand increase (2020 to 2050)	~100%	~600%	~300%

This figure is original by the authors.
Source: (Gielen, 2021)

1. **Mining and Export Concentration:**
- Lithium extraction is dominated by Australia and Chile
- Cobalt is primarily mined in the Democratic Republic of Congo, with additional sources in Chile, Peru, Indonesia
- Nickel extraction is distributed across several countries including Philippines, New Caledonia, Indonesia, Russia, Australia, and Finland, however dominated by Indonesia
- Copper is mined in the Democratic Republic of Congo, Indonesia, and Australia

2. **Import Dependencies:**
- China appears as a major importer across multiple minerals
- Japan and Korea depend heavily on lithium imports
- For cobalt, China and Japan are primary importers
- China and Canada are the main nickel importers

3. **Processing Bottlenecks:**
- China dominates processing across all four minerals, creating a critical bottleneck
- Some producing countries (Chile, Indonesia, Russia) have developed processing capabilities
- Finland and Malaysia have significant copper processing capacity

4. **Future Demand Projections:**
- Future demand projections for critical minerals reveal volume variations, underscoring the different minerals' economic significance. Broadly used minerals like copper, with a projected demand of approximately 100% in 2050 from 2020, which have diverse applications across the energy and other industries, will experience relatively less impact from the energy transition compared to specialized minerals like lithium, with a projected demand increase of approximately 600% in 2050 from 2020, which are crucial for specific energy technologies.

In processing, China holds near-monopolies on refined natural graphite and dysprosium and controls a large share of refined cobalt (70%), lithium (nearly 60%), and manganese (almost 60%). This concentration creates significant supply chain vulnerabilities, as evidenced by past Chinese export restrictions targeting Japan and the United States (Gielen, 2021).

Figure 02 further underscores a critical geopolitical challenge to maintain energy security and a secure supply chain. While extraction is distributed across various countries, processing is heavily concentrated in China, creating a strategic bottleneck that poses risks to the global energy transition. This advantage highlights the urgent need for supply chain diversification and the development of processing capacity in other regions. In relative terms, total demand use is more pronounced for lithium, followed by cobalt. The impact on copper demand is less pronounced. The aspect to understand here is how demand growth of CRMs will be affected by CRMs trade supply/ demand (Gielen, 2021).

2.5. Renewable Energy and Critical Minerals: Increased Demand

Figure 03: World mine production and demand of lithium, cobalt, nickel and copper in metric tons

Critical Mineral	Demand in 2025	Projected Demand in 2050	Percentage Increase
Lithium	312 Metre Tons/ year	1313 Metre Tons/ year	~300%
Cobalt	280.8 Metre Tons/ year	519.71 Metre Tons/ year	~85%
Copper	27,872.96 Metre Tons/ year	38,817.62 Metre Tons/ year	~40%
Nickel	4,033.93 Metre Tons/ year	6,196.07 Metre Tons/ year	~50%

This figure is original by the authors.

Source: UNCTAD based on data from IEA and USGS (Critical Minerals Boom: Global Energy Shift Brings Opportunities and Risks for Developing Countries, 2024)

UN Trade and Development (UNCTAD) projections based on data from the International Energy Agency indicate that by 2050, for example, lithium min demand could rise by over 300%, with similar increases for nickel, cobalt and copper (See Figure 03). However, data from Global Critical Minerals Outlook 2024 report suggests that since 2019 there has been total demand growth for renewable energy applications. For example, the total demand growth for lithium rose by 30% in 2023 and demand for nickel, cobalt, graphite and rare earths expanding by 8-15%. This has led to China's massive expansion of EV battery production capacity reaching 1,400 GWh in 2023, up from 895 GWh in 2022. Chinese companies also operate 84% of global lithium-ion battery mega factories (*How The World Reached 1 TWh of Battery Production | Benchmark Source*, n.d.).

However, this has created a counterintuitive trade pattern: while total demand increases, China's exports of these minerals are simultaneously decreasing. For example, Chinese lithium exports decreased 19% in 2023 despite increased production and refined cobalt exports from China dropped 24% year-over-year. This occurs because China is redirecting more of its domestic mineral supply to feed its growing battery manufacturing industry, rather than exporting these resources. This represents a strategic trade reorientation rather than a decrease in overall Total demand, as China prioritizes its internal supply chain for electric vehicle production. The relationship between critical mineral trade patterns of export/ import and total demand highlights the complexity of these markets. While overall demand follows fairly predictable technology adoption trends tied to electric vehicle sales and renewable energy deployment, trade flows reflect a more complex interplay of geopolitics, industrial policy, and strategic positioning.

2.6. Geopolitical Risks associated with CRMs

The global supply chain for critical minerals essential to the energy transition faces six principal geopolitical risks in the short to medium term (IRENA, 2023). These include external shocks such as wars or pandemics that disrupt established supply routes, exemplified by Russia's invasion of Ukraine, which caused global economic upheaval and supply chain disruptions (Bentham, 2023c). Resource nationalism, where countries prioritize domestic interests through expropriation or forced joint ventures, is evident in Mexico's lithium nationalization and Indonesia's bans on raw nickel exports (MINING.COM, 2023). Export restrictions, such as China's embargo on rare earth elements (REEs) to Japan in 2010 and recent controls on gallium and germanium products, highlight the vulnerability of supply chains to unilateral actions ("Resource Realism: The Geopolitics of Critical Mineral Supply Chains," 2023). Mineral cartels, like OPEC-inspired efforts by developing nations to control critical mineral prices, pose risks of price manipulation and reduced market stability (The New Curse of Critical Minerals, 2024). Political instability in key producing regions, such as coups in Africa (e.g., Gabon and Niger) and governance failures in the Democratic Republic of Congo (DRC), disrupt mining operations and exacerbate risks for investors (Hendrix, 2023). Market manipulation through hoarding or speculative practices by non-state actors can further destabilize supply chains, as seen during REE price spikes following China's export restrictions (*The New Curse of Critical Minerals*, 2024b). These interconnected risks amplify vulnerabilities, threatening the security and affordability of minerals crucial for renewable energy technologies and electrification. For instance, The US-China trade war has grown more serious, with China using its control over vital raw materials to fight back against US tariffs by limiting exports of rare earths, graphite, and battery metals. These restrictions have broken supply chains and forced companies to look for new suppliers in countries like India, Vietnam, and Mexico, while dealing with higher costs for manufacturing (Patel, 2025).

2.7. Social Impacts of Critical Minerals Extraction

In our research to understand various social equity dimensions around CRMs extraction, we have taken into consideration various case studies, reports, and facts from three countries, namely, India, Indonesia, and Brazil. While all three countries are actively pursuing critical mineral strategies to support their energy transitions, they have a few similarities in terms of their economic state, geographical location, and population numbers but face unique challenges:

- **India** is focused on reducing import dependency but needs stronger safeguards for social equity.
- **Brazil** must address deforestation and Indigenous rights while leveraging its mineral wealth.
- **Indonesia** is prioritizing economic gains but struggles with severe environmental degradation and community displacement.

India

As the world's most populous nation with over 1.4 billion people, India plays a crucial role in global climate change mitigation. The country faces severe environmental challenges including extreme heat, air pollution, and water contamination. To meet international climate commitments, India must eventually transition away from coal-fired power plants while significantly expanding solar and wind energy capacity. Currently, coal dominates India's energy landscape, accounting for approximately 70% of the country's 2.2 gigatons of energy-related CO_2 emissions in 2020. Achieving Paris Agreement targets will require India to rapidly reduce its coal consumption—a transition that raises important questions about social equity and political feasibility. This transformation must balance urgent climate action with the nation's developmental needs and ensure a just transition for communities dependent on the coal industry. India has launched ambitious initiatives like the National Critical Minerals Mission to secure essential resources for its energy transition. With a $4 billion investment plan, India aims to boost domestic production, recycling, and overseas acquisitions of critical minerals such as lithium, cobalt, and nickel (Tripathi, 2025). However, India faces challenges like heavy import dependency (100% for lithium and cobalt) and geopolitical risks due to reliance on China for key minerals. Additionally, Indigenous communities in India frequently protest the government taking their ancestral lands and the environmental harm caused by mining operations. While India's Constitution offers protections like the Fifth and Sixth Schedules, Forest Rights Act, and PESA, these laws are often poorly enforced. Despite measures like the 1/70 Act meant to prevent land alienation, tribal advocates consistently report violations and corporate encroachment on their territories (Express News Service & Express News Service, 2025). While India has emphasized reforms to improve mining practices and reduce environmental impacts, social equity concerns—such as displacement of Indigenous communities—remain under-addressed (Pandey, 2025).

Brazil

Brazil holds vast reserves of critical minerals like nickel and copper but struggles with balancing extraction with environmental protection. For example, Brazil possesses approximately 20% of global reserves of graphite, nickel, manganese, and rare earth elements (REEs), yet production often falls short of sustainable practices (Ausenco, 2024). Mining activities have led to significant deforestation in the Amazon rainforest, which contributes to Brazil's status as the seventh-largest greenhouse gas emitter globally, with deforestation accounting for a major share (Brazil's Critical Minerals and the Global Clean Energy Revolution, 2024). Pollution of local water sources is another concern, particularly in regions like Minas Gerais, where lithium mining projects have expanded rapidly. Indigenous communities are disproportionately affected, facing land degradation and loss of traditional livelihoods due to mining operations. Despite these challenges, Brazil has made strides in promoting sustainable mining practices, such as its $815 million Strategic Minerals Initiative, which aims to integrate value-added manufacturing and reduce dependency on raw exports (Traviss, 2024). However, governance challenges and social conflicts over land rights persist, highlighting the need for stronger enforcement mechanisms to ensure a just transition.

Indonesia

Indonesia is a global leader in nickel production, with the largest reserves worldwide, but faces significant environmental and social challenges. Nickel mining has caused deforestation, water pollution, and biodiversity loss, particularly in regions like Sulawesi and Halmahera. For example, between 2000 and 2019, Indonesia accounted for 58% of tropical forest loss directly linked to mining, with nickel concessions clearing nearly 378,970 acres of forest since 2000. On Halmahera Island alone, nickel mining has resulted in 5,331 hectares (13,173 acres) of deforestation (Indriyatno, 2024b).

Sulawesi's forests, home to endemic species like the Celebes crested macaque and Peleng tarsier, are increasingly threatened. Additionally, toxic runoff from mining operations contaminates drinking water and reduces fish stocks, impacting livelihoods in communities near industrial zones like the Indonesia Morowali Industrial Park (The Importance of Equitable, Sustainable and Fossil-free Automotive Supply Chains: A Case Study on Nickel Mining and Processing in Indonesia - Lead the Charge, 2024).

Social impacts are equally pronounced. Indigenous Bajau communities—known as "Sea Nomads"—have been displaced as traditional lands are converted into industrial zones. They face health issues such as skin infections from polluted waters and loss of livelihoods tied to fishing and agriculture. In Baliara village, contaminated water has led to child drownings and deprived children of swimming skills essential for survival in island communities. Furthermore, mining projects often proceed without Free, Prior, and Informed Consent (FPIC), exacerbating land rights violations (Nickel Industry Costs Lives and Livelihoods in Indonesia’s Last Nomadic Sea Tribe - Mighty Earth, 2024).

While Indonesia has implemented export bans on raw nickel to promote domestic processing and economic growth—leading to a 234% increase in deforestation around smelters—its approach lacks comprehensive measures to ensure environmental sustainability and community welfare (IUCN NL, 2024). These interconnected challenges highlight the urgent need for stricter enforcement of environmental laws and inclusive policies that prioritize both ecological preservation and social equity.

2.8. The Social Impact on Indigenous Communities

While also looking at various countries’ cases and contexts, we think it is important to specially mention how CRMS extraction practices affect indigenous communities. Studies exploring mineral development in Indigenous territories reveal that these projects frequently disrupt family life. Workers often experience prolonged absences and demanding shift schedules, creating substantial strain on family relationships. This adjustment is particularly challenging for community members and families unaccustomed to such work arrangements, forcing abrupt changes to traditional family dynamics (*PDAC Social Impact Study, 2022*).

The pressure extends beyond individual families to broader community structures. Global industrial expansion represents a significant threat to Indigenous lands, with nearly 60% of these territories facing moderate to high risk of disruption or appropriation. Even more concerning is that 37 nations exhibit a critical combination of high threat levels alongside heightened vulnerability due to inadequate recognition of Indigenous rights and representation in resource management decisions. This dangerous combination substantially increases the risk of unwanted land conversion (*PDAC Social Impact Study, 2022*).

The lack of meaningful consultation and consent processes often means Indigenous communities have little control over how extraction projects proceed on their traditional territories, despite bearing the most direct social, cultural, and environmental consequences of these activities.

2.9. Identifying Social Equity Dimensions in Critical Minerals Extraction

We have analyzed the CRMs extraction landscape across these three countries, i.e. India, Brazil, Indonesia and identified several crucial social equity dimensions that must be addressed. In energy systems, externalities span economic, social, and environmental dimensions. When left unaddressed, they can exacerbate existing inequalities and undermine long-term sustainability for near sighted goals. These dimensions are deeply interconnected, with challenges in one area often exacerbating problems in others. Addressing social equity in critical minerals extraction requires holistic approaches that consider all these dimensions simultaneously.

Dimension 01: Indigenous Rights and Land Sovereignty

This dimension upholds Indigenous peoples' sovereign rights over their ancestral lands and resources, ensuring their ability to protect cultural identity and traditional ways of life from extractive industry disruptions while maintaining autonomy over their territories. Social equity dimensions that must be addressed:

- The displacement of communities like Indonesia's Bajau "Sea Nomads" represents a violation of their historical connection to coastal areas, disrupting centuries-old relationships with marine environments (Yuniar & Yuniar, 2024).
- The statistic that 60% of global Indigenous territories face moderate to high risk of disruption indicates a systemic and widespread threat to Indigenous land rights worldwide
- According to recent research by scientists at The Nature Conservancy, industrial development poses a threat to more than 60% of lands belonging to Indigenous Peoples. This endangered territory spans 22.7 million square kilometers across 64 countries—an area nearly seven times the size of India. These findings highlight a significant global challenge to Indigenous land rights (The Nature Conservancy, 2023).
- According to recent research by scientists at The Nature Conservancy, industrial development poses a threat to more than 60% of lands belonging to Indigenous Peoples. This endangered territory spans 22.7 million square kilometers across 64 countries—an area nearly seven times the size of India. These findings highlight a significant global challenge to Indigenous land rights.
- Free, Prior, and Informed Consent (FPIC) is a critical international standard requiring governments and companies to consult with Indigenous peoples before undertaking projects affecting their lands, but this process is frequently bypassed or implemented superficially (Yuniar & Yuniar, 2024).
- The disruption of traditional family structures and community dynamics occurs when mining operations fragment communities, force relocations, or introduce dramatic socioeconomic changes that undermine social cohesion and cultural continuity.

Dimension 02: Livelihood Impacts and Economic Justice

This dimension examines how extractive industries impact local economic systems, focusing on the equitable distribution of benefits while safeguarding traditional livelihoods such as fishing and agriculture from disruption. It ensures local communities receive fair economic returns from resource development occurring within their territories. Social equity dimensions that must be addressed:

- Traditional livelihoods tied to fishing and agriculture are often permanently damaged by mining operations through water pollution, land degradation, and ecosystem disruption
- The global supply chains for critical minerals typically concentrate profits at the processing and manufacturing stages rather than at the extraction stage, leaving resource-rich but economically poor countries with disproportionately small shares of the value.
- High-value processing activities tend to remain in industrialized nations, creating a neo-colonial pattern where raw minerals flow from developing to developed countries (Dogan et al., 2025).
- Just transition support should include skills development, alternative livelihood creation, and direct benefit-sharing mechanisms to ensure that affected communities can adapt economically.

Dimension 03: Environmental Justice

This dimension addresses environmental justice concerns, focusing on how mining impacts are unequally distributed across communities. It upholds the principle that environmental burdens, including water contamination, health hazards, and ecosystem degradation—should not disproportionately affect marginalized populations, ensuring equitable protection for all communities affected by extractive activities. Social equity dimensions that must be addressed:

- Marginalized communities often face disproportionate environmental burdens because mines are frequently located in areas with less political power and regulatory oversight.
- Water contamination from acid mine drainage, heavy metals, and processing chemicals directly threatens drinking water sources and food security for nearby communities.
- The health impacts documented in Indonesia, including skin infections from polluted waters, represent just one category of health consequences that often include respiratory diseases, neurological disorders, and increased cancer risks.

- The deforestation of 5,331 hectares in Halmahera exemplifies how mining operations can cause extensive habitat destruction in biodiverse regions that Indigenous communities depend upon for food, medicine, and cultural practices (Yuniar & Yuniar, 2024).

Dimension 04: Geopolitical Power Dynamics
This dimension examines how the uneven global distribution of critical minerals shapes international power dynamics. It addresses how resource ownership creates strategic advantages for some nations while generating vulnerabilities for others, encompassing issues of resource nationalism, import dependencies, and processing monopolies that can entrench geopolitical inequalities. Social equity dimensions that must be addressed:

- Resource nationalism represents efforts by resource-rich countries to exercise greater control over their mineral wealth, often in response to historical exploitation.
- Import dependencies, such as India's 100% dependency on lithium, create significant vulnerabilities that affect national security and economic planning (Konda & Rakheja, 2024).
- Processing bottlenecks dominated by China create strategic vulnerabilities for other nations and give China significant leverage in international relations (Resource Realism: The Geopolitics of Critical Mineral Supply Chains, 2023b).
- "Greenflation" refers to price increases in renewable technologies due to critical mineral scarcity, potentially making clean energy transitions less accessible to poorer nations and communities (Sharma, 2021).

Dimension 05: Climate Justice and Finance
This dimension addresses the equitable distribution of climate finance in the mineral extraction context. It ensures developing nations have fair access to the massive funds required for energy transition—projected to reach $7.4 trillion by 2030 and over $10 trillion by 2050—without exploitation under sustainability pretexts (Allen & Overy & Climate Policy Initiative, 2023). As Global South countries balance decarbonization with healthcare, poverty, and infrastructure needs, just transition frameworks must create quality jobs, support workers for a just and equitable transition to a low-carbon future. Social equity dimensions that must be addressed:

- The USD 7.4 trillion needed by 2030 to deliver Net Zero equitably represents a massive financing gap that most developing nations cannot address without substantial international support (Allen & Overy & Climate Policy Initiative, 2023).
- Nations of the Global South face the challenge of balancing decarbonization investments with other urgent needs like healthcare, education, and poverty reduction.
- Climate finance mechanisms must be designed to reach affected communities directly rather than being captured by elites or multinational corporations.
- Financial flows intended to support just transitions must be protected from becoming loopholes that allow continued exploitation under a veneer of sustainability.

These dimensions are deeply interconnected, with challenges in one area often exacerbating problems in others. Addressing social equity in critical minerals extraction requires holistic approaches that consider all these dimensions simultaneously.

3. Recurring Themes and Gaps Across Literature Review

The transition toward renewable energy technologies has intensified demand for critical minerals, raising complex social equity challenges in extraction practices. Our literature review examined diverse sources, including academic research, international reports, government publications, and industry documents. This review identified significant gaps, particularly the absence of social equity in the system of critical minerals, which informed our social equity-centered analytical lens. Document analysis of industry reports, media coverage, and scholarly publications provided evidence-based insights into the social implications of increased mineral demand on Global South countries. Through which we have found various recurring themes in our literature review as below:

3.1. Recurring Theme Analysis in Critical Minerals Literature

Theme 01: The Paradox of "Renewable" Energy Transition

The theme of the paradox of "renewable" energy transition emerged from the literature highlighting contradictions between green technology's environmentally friendly image and the extractive realities required for implementation. The International Energy Agency (2021) documents how renewable energy technologies demand significantly more mineral resources than traditional fossil fuel systems, creating new extraction demands. This paradox manifests strongly in places like Indonesia, where research shows Chinese-linked "green" nickel mining operations have accelerated deforestation, directly contradicting sustainability claims (Yuniar & Yuniar, 2024). The social impact is equally concerning, as the Mighty Earth report (2024) reveals how allegedly eco-friendly supply chains have devastated local ecosystems and communities, including Indonesia's last nomadic sea tribe. Deberdt and Le Billon's (2024) concept of "climate extractivism" provides a theoretical framework for understanding how low-carbon transitions exposes asymmetric power dynamics and colonial resource extraction patterns, effectively transferring rather than eliminating ecological damage while perpetuating global inequities.

Theme 02: Distributive Justice and Benefit-Sharing

The theme of distributive justice and benefit-sharing emerged from literature that critically examines the inequitable distribution of economic benefits and burdens across critical mineral value chains. The World Economic Forum (2024) white paper identifies significant gaps between resource extraction and local development outcomes, revealing a fundamental disconnect in how mineral wealth translates to community benefits. This asymmetry is further quantified by UNCTAD data, which demonstrates that processing and manufacturing stages—typically located in the Global North—capture substantially higher economic returns than extraction activities predominantly situated in the Global South (Critical minerals boom, 2024b). Recognizing these inequities, the UNDP policy paper (2023) emphasizes the urgent need for robust benefit-sharing frameworks that ensure financial returns and development opportunities reach affected communities rather than being concentrated among corporate and national elites. The Business & Human Rights Resource Centre report (2023) reinforces this concern by highlighting the widespread absence of effective benefit-sharing mechanisms in most extraction operations, demonstrating how current practices systematically disadvantage regions bearing the environmental and social costs of supplying minerals essential for global climate action.

Theme 03: Vulnerable Communities in Extraction Zones

The theme of vulnerable communities in extraction zones emerged from literature documenting the disproportionate impacts of critical mineral extraction on specific marginalized groups. The Nature Conservancy's research reveals the massive scale of the threat, quantifying that industrial development—including mining—endangers more than 60% of Indigenous lands globally, affecting 22.7 million square kilometres across 64 countries (The Nature Conservancy, 2023). This territorial encroachment is accompanied by severe social consequences, as detailed in the PDAC "Social Impact Study" (2022), which demonstrates how mineral development frequently disrupts Indigenous family structures and community dynamics, undermining cultural continuity and traditional governance systems. The impacts are particularly acute for certain demographic groups, with the ILO report (2019) documenting widespread child labor in mining operations directly connected to critical mineral supply chains. Gender dimensions add another layer of vulnerability, as highlighted in the KIT Royal Tropical Institute's research (2020), which details how mining operations in Africa generate gender-specific impacts including increased sexual and gender-based violence, economic marginalization, and disproportionate health burdens for women in extraction communities.

Theme 04: Governance Frameworks for Just Transition

The theme of governance frameworks for just transition emerged from literature exploring the institutional systems required to ensure social equity in energy transitions. The UNDP's "Just Energy Transition: Governance Needs and Implications" (2023) analyzes the multifaceted governance requirements for equitable transitions, emphasizing how policy coordination across sectors and scales is essential for managing complex socio-environmental challenges (United Nations Development Programme, 2023). Complementing this macro perspective, the Intergovernmental Forum on Mining's "Mining Policy Framework" (2023) provides specific governance guidelines for sustainable mineral development, outlining regulatory approaches that balance economic development with environmental protection and social welfare (Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development, 2023). The World Economic Forum's "Fostering Effective Energy Transition" (2023) contributes a comparative dimension by assessing governance readiness across countries, revealing significant disparities in institutional capacity to manage just transitions (McKinsey & Company, 2023).

Theme 05: Supply Chain Transparency and Accountability

The theme of supply chain transparency and accountability emerged from literature addressing the significant visibility challenges throughout critical mineral value chains. The IEA's "Global Critical Minerals Outlook 2024" specifically addresses market dynamics and supply chain transparency challenges, highlighting how information asymmetries create vulnerabilities for both producers and consumers in transition mineral markets (International Energy Agency, 2024). Building on this foundation, the World Economic Forum's "Securing Minerals for the Energy Transition" (2024) discusses specific transparency mechanisms across the value chain, proposing traceability standards and verification protocols to enhance accountability from extraction through processing to end use. The IEEFA's report on "India's Hunt for Critical Minerals" provides a concrete case study documenting how supply chain opacity creates dependencies and vulnerabilities for developing economies attempting to secure critical mineral resources essential for their own energy transitions (Konda & Rakheja, 2024). From a geopolitical perspective China holds near-monopolies on refined natural graphite and dysprosium and controls a large share of refined cobalt (70%), lithium (nearly 60%), and manganese (almost 60%). This concentration creates significant supply chain vulnerabilities, demonstrating how concentration in processing activities can enable market manipulation and undermine governance efforts (Gielen, 2021).

Theme 06: Policy Integration Across Jurisdictions

The theme of policy integration across jurisdictions emerged from literature examining how policies must be coordinated from local to global levels to address critical mineral challenges effectively. The Canadian Critical Minerals Strategy (2022) exemplifies national-level policy approaches while acknowledging international dimensions, demonstrating how domestic resource development must align with global supply chain dynamics and diplomatic relationships. Providing broader context, the Policy Center for the New South's brief analyses cross-jurisdictional policy challenges, highlighting how geopolitical tensions and competing national interests complicate coordinated mineral governance frameworks (Policy Center for the New South, 2022). While Brazil's $815 million Strategic Minerals Initiative, which aims to integrate value-added manufacturing and reduce dependency on raw exports (Traviss, 2024). However, governance challenges and social conflicts over land rights persist, highlighting the need for stronger enforcement mechanisms to ensure a just transition. The IGF's Mining Policy Framework (2023) addresses these multi-level governance challenges by proposing integration mechanisms that connect local, national, and international policy domains in mineral development, emphasizing how vertical policy coherence is essential for equitable and sustainable mineral development.

3.2. Research Gaps in the Literature Review

From analyzing the recurring themes across the literature review, we identified 5 gaps in the literature:

Gap 01: Disconnect Between Theoretical Equity and Practical Implementation

This gap reveals how current literature offers conceptual frameworks for equity without providing operational guidance for implementation in extraction contexts. While the IGF’s Mining Policy Framework (2023) articulates principles for sustainable mining, it lacks detailed mechanisms for translating these principles into operational practices. There are plenty of good ideas about fairness in mining, but few clear instructions on how to make them work in real situations. This could leave companies and governments guessing about how to put fair practices into action.

Gap 02: Absence of Standardized Social Equity Metrics
The literature lacks consistent, validated metrics for measuring social equity outcomes in critical mineral contexts. Documents like the Green Policy Platform's "reference offer conceptual approaches but no standardized measurement frameworks (Brears, 2021). Unlike environmental impacts that can be easily measured, there lacks good contextual ways to measure how mining affects people and communities. Without consistent measurements, it is hard to compare projects or know if things are actually improving for local people.

Gap 03: Insufficient Integration of Rapid Deployment and Social Equity
There's a stark division in the literature between works focused on accelerating renewable energy deployment and those addressing social impacts. Few works successfully integrate these imperatives or examine their tensions and potential synergies such as the report "Global Perspectives on Community Energy for a Just Transition" effectively integrates energy transition with equity through community energy systems (Eales, 2024). Most studies either focus on quickly developing renewable energy or on making sure projects are fair to communities – rarely both together. This creates a false choice between acting fast on climate change and treating people fairly.

Gap 04: Limited Research on Community-Centered Governance Models
While studies like PDAC's "Social Impact Study" (2021) document impacts on communities, there's insufficient research on governance models that genuinely redistribute authority to affected communities. Most literature acknowledges community consultation but stops short of exploring models where communities have decision-making power over resource development. Most studies either focus on quickly developing renewable energy or on making sure projects are fair to communities – rarely both together. This creates a false choice between acting fast on climate change and treating people fairly.

Gap 05: Inadequate Exploration of Vertical Policy Integration
The literature presents fragmented analyses of policy at different jurisdictional levels without sufficient examination of vertical integration challenges. Documents like the "Canadian Critical Minerals Strategy" (2022) provide regional perspectives but inadequately address how these interact with local and global governance systems (Service Canada, 2023). Policies at local, national, and international levels often don't work well together. Studies typically look at each level separately, missing how these different layers of rules affect each other and create confusion.

These research gaps highlight a central challenge that as the recognition of social equity's importance in energy transitions grows, the field lacks contextual frameworks and pathways for translating this recognition into practice. Addressing these gaps is essential not only for advancing scholarly understanding but also for ensuring that the renewable energy transition promotes social equity across global value chains. Future research must prioritize developing practical snd contexual frameworks with measurable outcomes that bridge the divide between theoretical principles and implementation realities.

4. Objective of the Major Research Project

The objective of this research paper is to examine how social equity can be meaningfully integrated into the extraction practices of critical minerals, as pathways, as the world accelerates its transition toward renewable energy technologies to achieve NZE by 2050. The global push for decarbonization has triggered a dramatic surge in demand for CRMs, such as lithium, cobalt, nickel, and copper, resulting in intensified mining activities across mineral-rich regions, particularly in the Global South. While this "greenflation" is essential for scaling up clean energy infrastructure, it also brings significant environmental and social challenges, including land dispossession, health risks, and deepening inequalities for workers and Indigenous communities whose livelihoods are directly affected by extraction projects.

This research aims to identify the pathways and opportunity spaces for embedding social equity into CRM value chains. It will assess the threats and challenges faced by vulnerable communities, especially in the Global South while making sure the Global South is not being exploited by Global North. Beyond visible social impacts, the research will consider the broader implications at different stages of the supply chain of CRM demand growth, such as the expansion of lithium mining and deep-sea mineral extraction, which often encroach on Indigenous territories and traditional agrarian lands, exposing marginalized groups to dispossession, exploitation, and health hazards. While the green transition promises reduced emissions, it risks shifting the burden of climate mitigation onto those least responsible for emissions, while concentrating on the benefits among privileged actors (Deberdt & Le Billon, 2024).

Primary Research Question:
The primary question this major research project aims to answer is:

- How can policy frameworks be shaped over the (25 years) for countries rich in critical minerals in driving a just energy transition while prioritizing social equity?

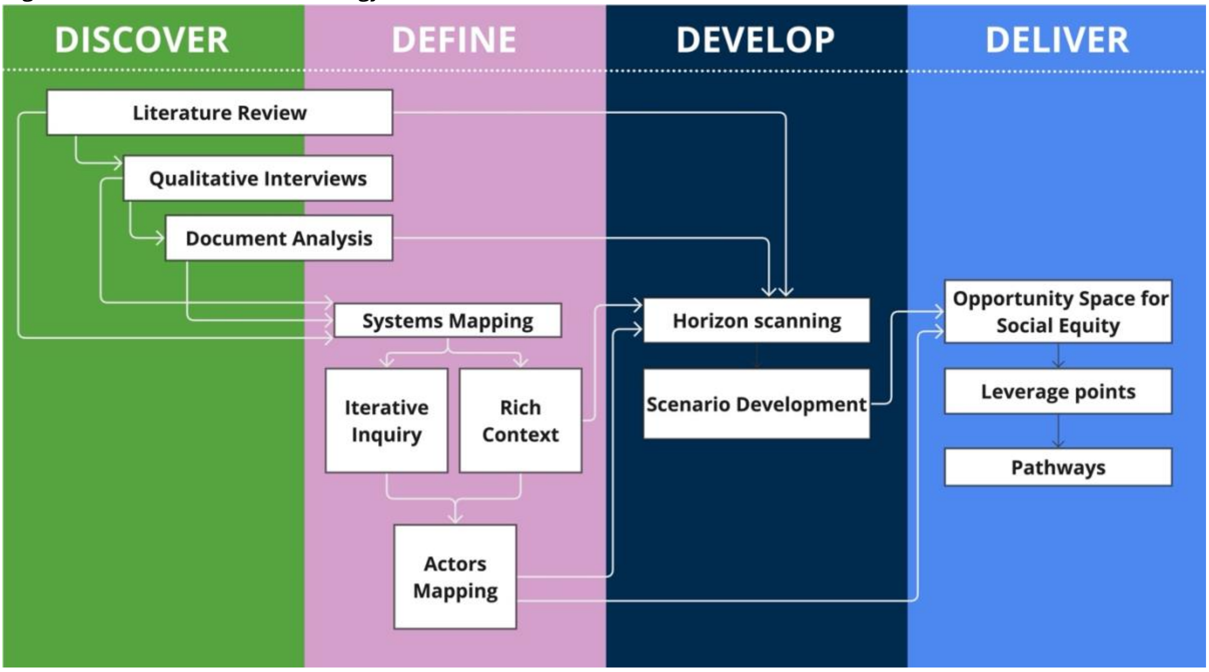
Secondary Research Questions:

- What are the best practices from other sectors such as communication technology that have successfully enhanced social resilience in the face of major transitions, and how can these be applied to the just energy transition?
- What future trends in global trade and economic integration could influence the equitable distribution of critical minerals and just transition?
- What are the social harms and negative externalities associated with current practices in supply chain stages of critical minerals in Global South Countries?
- With rapidly growing tech innovation in advancing net-zero visions, how will this affect the role of critical minerals in geopolitics?
- How can impact assessments be integrated into policy development to ensure equitable outcomes for critical minerals distribution?

5. Methodology: Unlocking the grid

The transition to renewable energy, like an aging power grid, cannot simply be rebuilt from scratch. It must be carefully unlocked, restructured, and rerouted to distribute power more equitably. For our research, we used a combination of methods and tools from disciplines including systems thinking and strategic foresight. Our project follows a design thinking process structured to move from problem discovery (Discover) to opportunity framing (Define), and from ideation (Develop) to intervention design (Deliver). Each stage through its journey contributed to building an equity-first understanding of the critical minerals landscape.

Figure 04: Research Methodology



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5.1. Discover: Understanding the Landscape

The phase focused on understanding the current landscape of critical minerals and the global energy transition. Data for the research project has been gathered from secondary sources.

Literature Review and document analysis

The research began with grounding our knowledge in the existing discourse. This included a comprehensive review of academic research, government publications, international organizations report (IEA, UN, WRI), sustainability frameworks, and case studies. Our review helped identify key gaps, especially the lack of social equity integration across supply chain discussions and informed the development of our equity-centered lens. Document analysis was conducted of industry reports, media coverage, and publication for evidence-based insights and to understand the social implications of the increased demand for critical minerals on the Global South.

Expert Interviews

Semi-structured interviews were conducted with 8 different experts from diverse professional backgrounds who were interviewed in their professional capacities, not as research subjects. These experts, including international organization professionals, industry consultants, business professionals from supply chain management, and a renewable technology company founder, provided insights based exclusively on publicly available or published information accessible through their professional roles. The interviews specifically focused on supply chain challenges for critical minerals in renewable energy technologies, policy approaches to securing critical mineral supplies, industry perspectives on mineral sourcing strategies, and technical considerations. No personal data was collected, and participants were approached only as experts with domain expertise to share publicly available information and industry knowledge. This approach was determined to be exempt from the Research Ethics Board (REB) requirements as it did not involve studying the individuals themselves.

5.2. Define: Framing the System

From the insights and knowledge gathered from the discovery phase, the second phase focuses on converging these insights into a system-level understanding and structural exploration. Various system tools such as Iterative Inquiry, Rich Context, and Actors Mapping were employed to identify the boundaries of the system, stakeholder roles, provide a deeper understanding of relationality within the current regime, and establish a system-level understanding, both contextually and socially informed.

Iterative Inquiry

In order to frame the boundaries of the system around our research objectives, iterative inquiry has been used to frame the system in the defining phase. This approach allows us to elaborate on the system boundaries, specifically how the transition to renewable energy in the context of CRM extraction affects social impacts. The Iterative Inquiry tool (Jones & Van Ael, 2022, p. 44) offers a structured approach to exploring a system's boundaries, subsystems, and core functions. By identifying the structures, processes, and purposes that shape the system, this method establishes a foundation for comprehensive analysis. Developed by Jones and Van Ael (2022, p. 44) as an adaptation of Jamshid Gharajedaghi's systems inquiry Gharajedaghi (2011), Iterative Inquiry maps systems across multiple levels—micro, meso, exo, and macro—revealing their hierarchies, interdependencies, and dynamic feedback loops.

Rich Context Map

After framing the system through iterative inquiry, literature review, and insights from expert interviews, we wanted to explore niche innovations and long-term trends involved in the extraction of the CRM value chain. Hence, the Rich Context Mapping tool was used. Rich Context helps to visualize interactions across multiple system levels, landscape trends, current regime practices, and niche innovations to identify significant forces and potential pathways for transformation (Jones & Van Ael, 2022, p. 54). By gathering evidence from diverse sources and visually mapping the relationships between current regime structures and emerging trends, the tool enables to identify emerging trends that could shape the system and potential pathways for change for key stakeholders. It also helps to better anticipate future challenges and opportunities.

Actors Mapping

Drawing from the Actor Mapping Framework by Jones and Van Ael (2022, p. 50) which emphasizes the interplay between power, knowledge, and influence in complex systems, the actors map identifies the key actors and the relationships that will shape the pathways towards social equity in the global transition to renewable energy. Zooming into the extraction of critical minerals for the transition, the tool plots the relevant actors of the energy system on the axis of power and knowledge.

This combination of tools established a comprehensive foundation that integrated both contextual and social perspectives, creating a robust basis for developing trends and drivers to construct scenarios in the subsequent project phases.

5.3. Develop: Generating Futures

Horizon Scan

A horizon scan was conducted to synthesize signals of change to identify emerging trends, risks, and opportunities to anticipate future disruptions. It involves monitoring external environments (e.g., social, technological, economic) to detect early signals of change, enabling organizations to prepare for potential challenges and leverage opportunities proactively (Grabtchak, 2024; Bourne, 2024). Each trend was evaluated considering its potential impact on the global transition to renewable energy, the utilization of critical minerals, and the implications for social equity. The methodology involved analyzing recent literature, reports, policy documents, and news sources to capture both mainstream and emerging trends. STEEPV is an expanded version of the PESTLE framework, analyzing Social, Technological, Economic, Environmental, Political, and Values drivers of change. It provides a structured lens to categorize and assess factors influencing future scenario (Amelia, n.d.).

This forward-looking approach anticipates possible shifts in global geopolitics, green corruption, green extractivism, and shifts in global trade. This approach supported the development of scenarios and informed strategic foresight around how mineral-rich countries might navigate future uncertainties while embedding principles of social equity and local value creation. By employing horizon scanning through the STEEP+V framework, our research gained a structured yet comprehensive view of potential futures, allowing for more resilient planning for pathways for transitioning to renewable energy.

Scenario Development

Foresight techniques generate scenarios, which are narratives about potential futures. As Maree Conway (2017) emphasizes, scenarios are not predictions but tools for reflection and strategic exploration that spark new thinking, challenge existing assumptions, and uncover hidden biases. By exploring the interplay between evidence and imagination, scenarios help researchers and decision-makers navigate uncertainty by examining what might happen if key drivers change course, what systemic consequences might arise, and how current decisions shape future pathways (Conway, 2017). Voros (2017) states that scenario creation should be the culmination of thorough information gathering, rigorous analysis, and critical interpretation, with drivers serving as core building blocks for exploring divergent pathways.

Building on insights from systems mapping and horizon scanning, plausible future scenarios can be developed using frameworks like Dator's Four Futures and back-casting approaches. Jim Dator's groundbreaking model, published in 1979, classifies societal futures into four recurring narratives: Continued Growth (sustained growth of current systems), Collapse (systemic breakdown due to crises), Disciplined (strict adaptation to limits), and Transformation (radical societal reinvention) (Dator's Four Futures – the Foresight Guide, 2022). Rooted in empirical analysis of cultural and political narratives, Dator's model suggests all plausible futures emerge from these archetypes, which serve as lenses to explore uncertainties, threats, opportunities, and design strategies resilient to diverse trajectories. Dator emphasizes that no single archetype is inherently "likely" or "desirable," urging equal consideration of each to navigate complex, contested futures (Dator's Four Futures – the Foresight Guide, 2022).

The creation of four future worlds represents a **back casting** approach to futures studies. This method, coined by Robinson (1982) fundamentally differs from traditional forecasting. While forecasting attempts to predict the most likely future conditions based on current trends, back casting works backward from desired endpoints to identify necessary actions in the present. In this process, normative narratives were constructed specifically to:

- Provoke critical thinking about possible futures
- Highlight the necessity of pathways toward social equity
- Examine key drivers of change, opportunities, and threats
- Establish a vision of a desirable world

These scenario explorations enabled back casting identifying specific actions and leverage points that must be activated today to build futures rooted in social equity and local value creation. By starting with desired end-states rather than probable outcomes, back casting provides a framework for understanding what interventions are necessary to achieve preferred futures. The approach emphasizes normative thinking (what should be) over predictive thinking (what will be), allowing stakeholders to envision and work toward futures that embody their values and aspirations.

5.4. Deliver: Intervening in the System

Drawing on the three previous stages, the final stage of our research project lays out the opportunity space through synthesized findings where equity can be embedded in the value chain of CRMs extraction.

Recommendations and Leverage Points

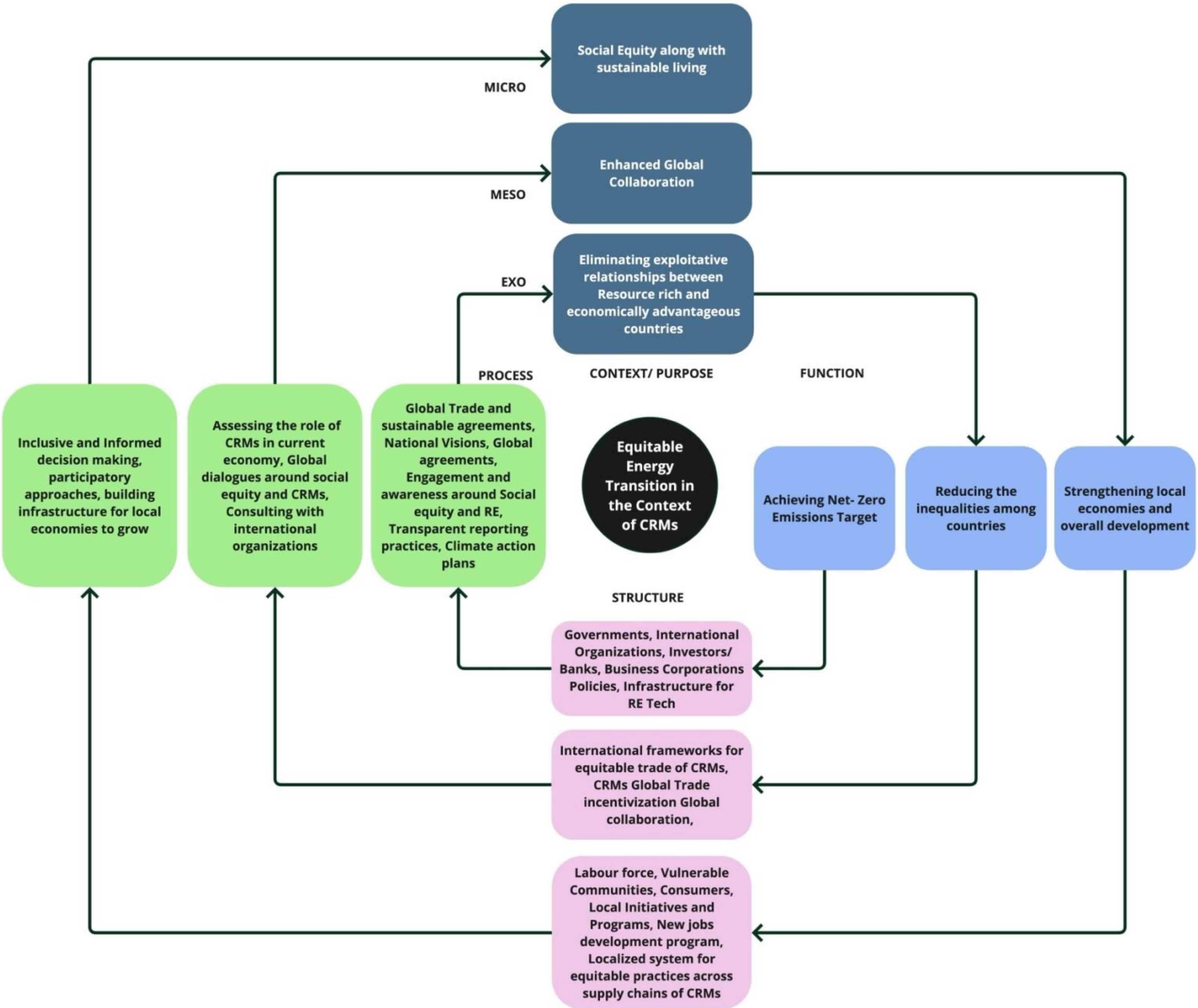
Leverage points, inspired by Donella Meadows' framework, were identified as entry points to build pathways for the world we desire through the lens of social equity and critical minerals (Meadows, 2015). These leverage points form the basis of pathways to drive social equity and local value creation for mineral-rich countries in the global south.

6. Framing and Mapping the System

To deeply understand the system, it must be explored from multiple perspectives, with each perspective building layers of insight over time. This approach involves looking at the system in a broad frame to understand the possible connections and dynamics or “threads” that are woven into the current landscape of transition to Renewable Energy and its social impact on vulnerable communities. By layering insights and hypotheses and supporting research, this process enables deeper understanding to support foresight, scenario building, and analysis. In this section of the report, a diverse set of systems, methods, and tools are employed to examine the dynamics and connections that can aid in enabling a socially equitable transition to Renewable Energy.

6.1 Iterative Inquiry

Figure 05: Iterative Inquiry identifies structures, processes, and purposes in the renewable energy transitions, while highlighting the central role of CRMs and their social impacts at Exo, Meso, and Micro level.



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In this iterative inquiry, we present a flow diagram—a series of arrows connecting each station—linking each function to the next steps; the purpose of the iteration cycle is to "connect the threads" - enlarging the purpose or context at each level. Usually, it flows from micro to meso to exo and to macro as the last level. However, for our systems framing, we have used the top-down approach, i.e., flowing from exo to meso to micro. We employed this approach as rising global temperatures have shifted our climate response from long-term planning to immediate action (Almulhim et al., 2024). This exosystem-level climate crisis is driving unprecedented demand for critical minerals essential to renewable technologies, with annual mineral demand for clean energy technologies projected to increase by 2-6 times by 2040 (IEA, 2024). This shift is creating ripple effects that ultimately reshape micro-level dynamics. By starting with the big picture, we can better understand how these large environmental shifts ultimately impact micro-level systems, aligning with systems thinking frameworks that emphasize understanding complexity across multiple scales (Gharajedaghi, 2011).

The Exo Level

The Exo level is the outermost level through which we have framed our system in the context of equitable energy transition regarding CRMs. This level begins with achieving net zero emissions targets for the equitable renewable energy transition. The Paris Agreement laid the foundation for the world to limit global temperature increase and GHG emissions, eventually achieving NZE targets (United Nations Framework Convention on Climate Change, 2015). This set the world in motion by establishing more international agreements and encouraging countries worldwide to embark on their climate action plans. Currently, 151 countries have announced net-zero targets representing 88% of global emissions (Energy & Climate Intelligence Unit, 2023). However, if our iterative inquiry were to focus on driving energy security through the RE transition, we recognize would limit the focus to a specific country or region, instead of all countries working together.

Framing the system from the lens of the factors at play from an ecosystem level to the micro level allows to drive equity for the vulnerable communities at the micro level. This approach is especially relevant given that indigenous communities currently steward approximately 32% of the world's land—areas that overlap with 50% of planned or existing mining activities for energy transition metals (Kennedy et al., 2023). In order to achieve NZE targets, various agencies and stakeholders need to be involved in the decision-making process. They are mostly government, international organizations, investment banks and business corporations—which are mostly involved in driving economic growth towards sustainable development and adoption of various RE technologies. (EY, 2023; Latinia, 2024). The renewable energy transition will require an estimated $4 trillion in annual investments by 2030 (Climate Policy Initiative, 2025), highlighting the crucial role these stakeholders play. Governments, business corporations, and banks laid out the foundation for extraction practices around CRMs to adopt RE technology for NZE targets. Eventually, looking at various ways to extract and manage trade around CRMs to support manufacturers of CRMs.There are various processes which need to be undertaken to achieve the larger objective of NZE targets. These include global trade and sustainable agreement, climate action plans, national visions around energy security (World Economic Forum, 2025). Additionally, increase in transparent reporting practices to enable equitable and informed decision making for the betterment of all sections of society especially vulnerable and indigenous communities. This transparency is particularly important given that critical mineral mines have been tied to an average of 111 violent incidents and protests annually (Global Witness, 2024). And this can happen by spreading awareness around social equity while adopting RE tech and in CMRs extraction practices. At the end—this had led to the purpose of mitigating exploitative relationships between resource-rich and economically advanced nations, which is particularly relevant considering that rich countries have drained an estimated $152 trillion from the Global South since 1960 (Hickel et al., 2021). This is the defining state for the EXO level for the entire system.

The Meso Level

The Meso level focuses on the transition from achieving Net-Zero Emissions goals to reducing inequality among countries in terms of energy security, environmental impact, and social benefits for their populations. Widespread processes such as—assessing the role of CRMs, facilitating global dialogues around social equity and CRMs and consulting with international organization—are designed to align with NZE targets and Gap reduction between countries. This assessment is particularly important given the projected increase in demand for critical materials, which could rise by over 400% for key minerals like lithium, cobalt, and nickel under IEA Net-Zero emission by 2050 scenario (Liang et al., 2023).

Achieving this necessitates robust International Frameworks for the equitable trade of CRMs and the introduction of more global incentives that ensure fair trade between countries in the Global South and North (European Critical Raw Materials Act, n.d.). The World Economic Forum (2024) has identified this need and emphasized that "securing critical minerals for the energy transition requires coordinated international governance frameworks that prioritize equitable access across developed and developing economies." This level prominently looks at Global collaboration and process/measures revolving around it. Hence, leading to enhanced Global collaboration when it comes to CRMs supply chain and trade among countries.

The Micro Level

Micro level here introduces strengthening of local economies and overall development of vulnerable communities. This happens when financial investments and new jobs are introduced for various communities involved at various stages of CRMs supply chain. The Prospectors & Developers Association of Canada (2022) Social Impact Study found that mining operations can create substantial local economic benefits when proper frameworks ensure community participation and benefit-sharing. Additionally, consumers adopt a sustainable approach involving ethical and equitable sourcing of the products they are looking to buy/sell, with recent research showing consumers are willing to pay a 9.7% premium for sustainable products even amid cost-of-living concerns (PwC, 2024).

At the micro-level, these changes are driven by processes that actively involve consumers, vulnerable communities, and the labor force in decision-making through participatory approaches to the renewable energy transition, fueled by increased CRM demand. Eales (2024) demonstrates how community-centered energy projects that incorporate local knowledge and participation can significantly improve social outcomes in energy transition efforts. As these communities engage and recognize their rights and value within the system, their ability to achieve social equity is significantly enhanced. This is further supported by the development of local infrastructure that fosters growing local economies. Crucially, the external factors at the Exo level—such as global trade agreements, climate action plans, and policy frameworks—lay the essential foundation for these micro-level transformations.

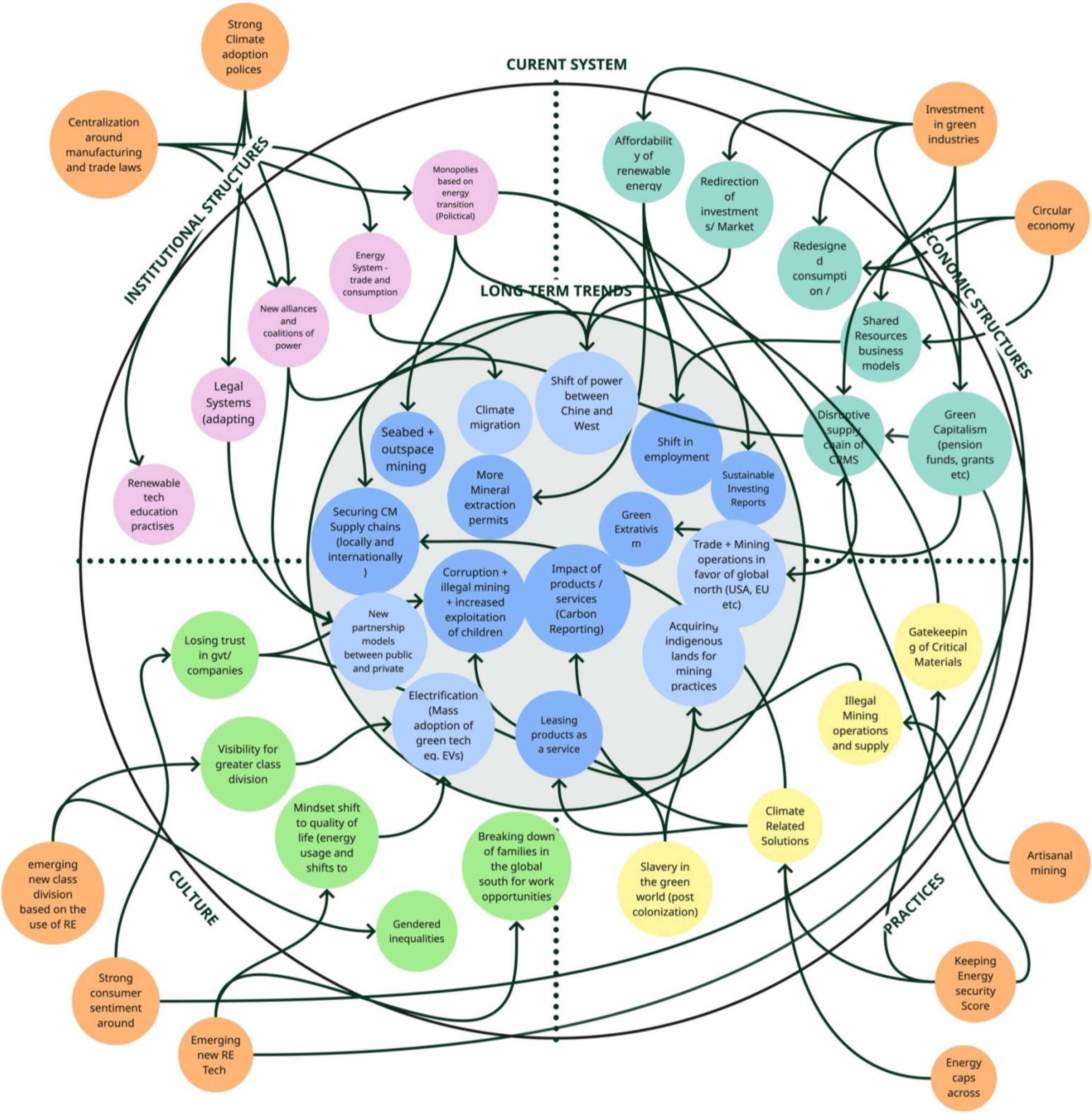
Interconnections Across Levels

Across these levels, the iterative inquiry reveals dynamic interactions and ripple effects that can empower vulnerable communities and foster greater social equity. For instance, the push for Net-Zero Emissions is driving massive production of EVs, with the U.S. Bureau of Labor Statistics projecting electric vehicle sales to rise from 8.3% of new light-duty vehicle sales in 2022 to 18% by 2030 (Ice & C., 2023). This surge in EV manufacturing requires a huge number of CRMs, hence driving its total demand globally. The United Nations Environment Programme notes that a typical electric car requires six times the mineral inputs of a conventional car, including lithium, nickel, and cobalt for electric vehicles. (United Nations Environment Programme, 2023).

However, policies specifically designed to achieve social equity during this renewable energy transition, alongside equitable trade agreements and incentives, can help in adoption to renewable transition without leaving anyone behind. As argued by Brears (2021), enhancing social equity in the green economy requires linking environmental factors with social considerations to ensure the transition delivers benefits across all segments of society. These measures can help distribute the benefits of renewable energy more equitably, preventing the concentration of advantages among a limited group and mitigating the risk of new or exacerbated socio-economic disparities, as outlined in the United Nations Development Programme's (2023) framework for just energy transition. These interdependencies underscore the recursive nature of systemic transformation, where changes at one level resonate throughout the entire system, creating what Owen et al. (2022) describe as "complex interactions between energy transition minerals and land-connected peoples" that demand holistic governance approaches.

6.2 Rich Context

Figure 06: This tool helped identify possible emerging trends through various structures and practices in the current regime and looked at emerging innovations that could possibly solve the challenge of our MRP, which is to drive social equity for the renewable energy transition in value chain extraction of CRMs.



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The current regime includes the associated practices, niche innovations, and their interplay with institutional (rules, regulations, power dynamics), economic (markets, financing, production-distribution systems), cultural (norms, values), and behavioural (routines) structures. The literature review across academic papers, industry reports, and policy documents, helped to establish the landscape through identification of dynamics of the current system and emerging trends. Through the analysis of current regime elements and emerging niche innovations, we traced connections leading to emerging trends that could influence social equity in the extraction of CRMs. To exemplify the process, we have highlighted how four these trends emerging as below:

Emerging Trend 01:
As renewable energy technologies (niche innovations) advance to combat climate change, they intensify demand for critical minerals like lithium and rare earth elements needed for batteries and components (Brazil's Critical Minerals and the Global Clean Energy Revolution, 2024). This technological progression has accelerated mining in biodiversity-rich regions where exploitative extraction practices (practices) target vulnerable indigenous populations with minimal legal protections. In Brazil, lithium mining operations pollute water sources and degrade indigenous territories, while in Nigeria's Niger Delta, Shell's extraction activities have made traditional lands uninhabitable through severe contamination (Chang et al., 2024). Similarly, Bajau "Sea Nomads" face displacement as their coastal areas becomes industrialized zones. The displacement of indigenous communities from their lands for mining operations emerges from the intersection of exploitative practices and innovations in renewable energy technology therefore, leading to loss of land and livelihoods.

Emerging Trend 02:
Rising global tensions are driving countries to form regional alliances for enhanced energy security. This shift stems from established renewable energy trade patterns and emerging power coalitions, accelerated by centralized manufacturing and protective trade laws. Kazakhstan and Azerbaijan's "Middle Corridor" collaboration exemplifies this trend (Cutler, 2025), marking a strategic pivot from global systems toward regional partnerships focused on resource security and shared interests.

Emerging Trend 03:
China's processing dominance over critical minerals is reshaping geopolitical power structures. With near-monopolies on refined natural graphite and dysprosium, and controlling majorities of refined cobalt (70%), lithium (60%), and manganese (60%), China has created significant leverage in global supply chains (Holland, 2024; Gielen, 2021).This strategic control enables China to exert influence through selective export restrictions, as demonstrated in past actions against Japan and the United States. In response, this leading to the emerging trends where nations are centralizing manufacturing policies and implementing protective trade laws to secure their own supply chains, complicating the power dynamics between China and Western countries.

Emerging Trend 04:
This trend of trade and mining operations favouring the Global North emerged as a result from the institutional structures of “Monopolies based on energy transition" interacting with the niche innovation of "Centralization around manufacturing and trade laws." With evidence suggesting, this trend emerged from the continuation of colonial extraction patterns, rich countries systematically extracting an estimated $152 trillion from the Global South since 1960 (Hickel et al., 2021). Even new green initiatives perpetuate these exploitative dynamics, as shown by Deberdt and Le Billon's (2024) "green extractivism" concept, while policies like the European Critical Raw Materials Act (European Commission, n.d.) secure supply chains for developed economies without addressing historical inequities, reinforcing political monopolies that benefit the Global North at the expense of resource-rich developing nations.

These emerging trends provided us with a starting point in looking into the horizon scanning to further establish trends and drivers that could influence the future. The tools ultimately illustrate how the renewable energy transition is not merely a technological shift but a complex socio-technical transformation that requires an understanding of the interconnected nature of minerals, practices, institutions, and cultures. The evidence from current regime elements and niche innovations helps forecast how these trends will likely evolve, providing the foundation for our future scenarios.

6.3. Actors Map

The actors are positioned across 4 concentric circles which represent the different levels of influence in the system of interest.

- **The Individual level** encompasses all those actors that are directly related, impacted, experience, influence, or respond to the decisions and actions in the extraction of critical minerals.
- **The Institutional Level** comprises of organizations and institutes that formalize and operationalize the system through strategies, mechanisms, decision-making, and rules of the system.
- **The Society Level** includes external actants that shape the values, behavior, the sentiment, and direction of the system.
- **The Ecosystem level** includes the broader environmental, political, and economical factors at play that influence boundaries for the system.

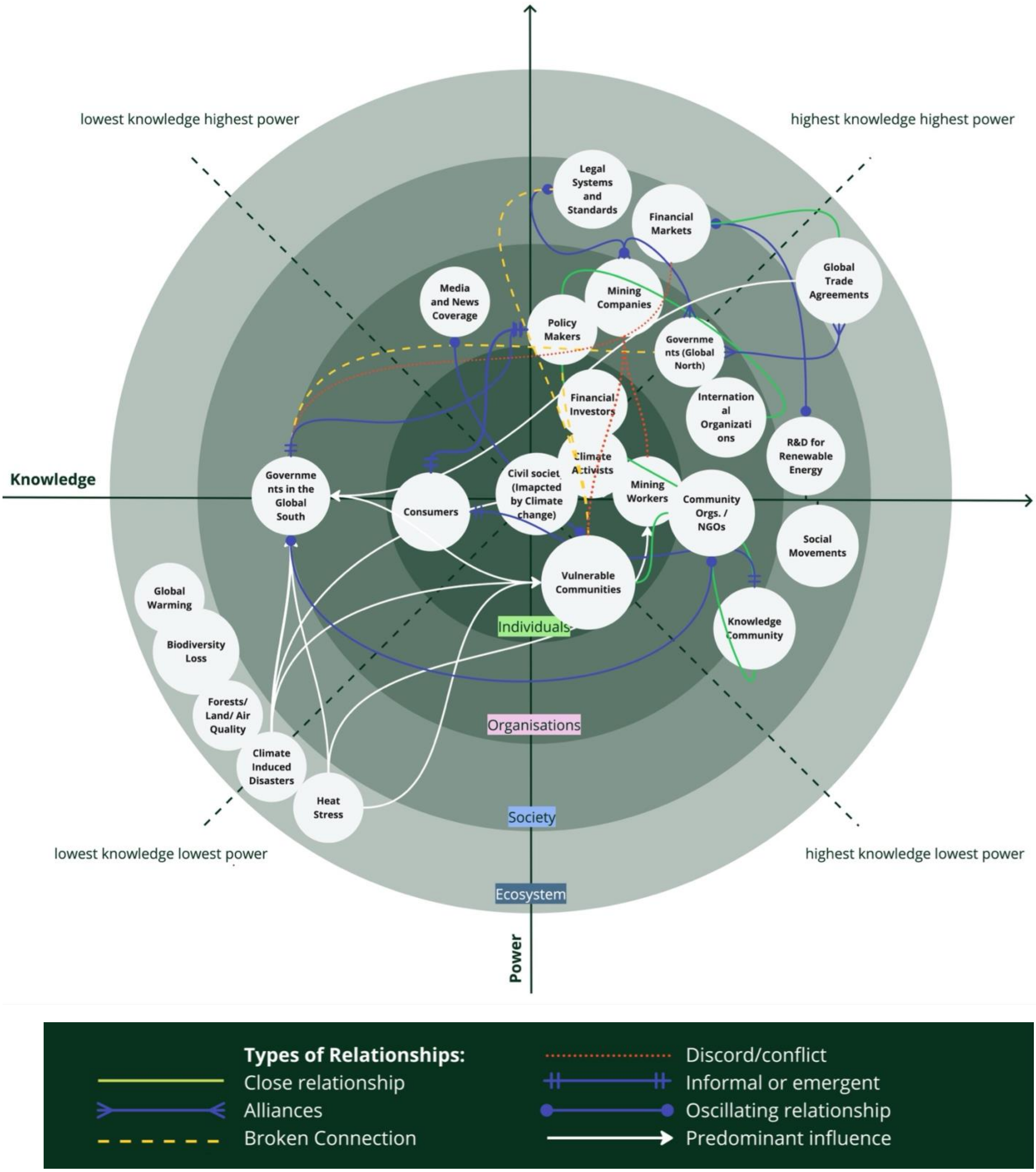
To understand the extraction stakeholder complexities of critical minerals for the renewable energy transition, it is important to observe it through a multi-level perspective. Each level influences the system in different capacities moving outwards from individual actors, such as mining workers, consumers, vulnerable community members to examine the broader ecosystem factors such climate induced heat stress at play. The selection of actors has been informed through a combination of literature review and the conducted expert interviews. We recognize that the identified actors may not represent all the stakeholders, agencies, and players, particularly in emerging development contexts.

Relationship Types in the System

The relationships between these actors exist in different capacities. The mapping highlights the connections between various actors to provide a view of the directional relationship that shapes the influence, impact, decision-making, and value integration. The relationships are identified through 7 types in this system which have: Close Relationship (Shared Goals and Mutual Trust), Alliance (Formal Agreement), Broken Connection (Deteriorated Relationships), Conflict (Competing tensions, historical grievances), Informal/Emergent Connection (Early-stage relationships or noninstitutionalized), Oscillating Role (Shifts between roles), and Predominated Actor (Hold dominance over the system or one aspect of it).

6.3 Actors Map

Figure 07: Actors Map Illustrates Key Stakeholders and Relationships Shaping Pathways Towards Social Equity in the Global Transition to Renewable Energy.



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The actors' map illustrates the complex web of relationships characterizing the current critical minerals extraction system. The analysis of these interconnections revealed three predominant patterns that influence social equity outcomes across the value chain: power asymmetries among key actors, Climate Vulnerability and systemic exclusion of Vulnerable Communities, and Emergent Relationships and transformation potential that provide avenues for a more equitable system. These dynamics function across several scales, from local communities to global markets, and help explain why certain actors retain privileged positions while others remain persistently disadvantaged.

Power asymmetries arise most prominently in North-South dominance patterns, where governments in the Global North maintain predominant relationships with governments in the Global South, controlling demand patterns, investment flows, and access technology. This asymmetry creates ripple structural inequalities where extraction serves the global north while communities in the global south bear the cost. Similarly, various corporate-community imbalances reveal how mining corporations exercise power dominance over vulnerable communities and mining workers. Despite mining workers having moderate knowledge, their low power of influence in the system perpetuates exploitative labor conditions for profits, with corporate influence often extending into policy-making spaces where community voices are systematically excluded. This creates predominated structural pressure on the Global South nations to provide raw minerals but limits their ability to develop processing capacity. For example, the DRC produces a record 3.3 million metric tons of copper annually, but most major mines are controlled by foreign companies from China and the US, limiting opportunities for local value addition and industrial development (Statista, 2025). Tenke Fungurume, for instance a large mining project in the DRC, is 80% owned by CMOC, Chinese mining company (MacKenzie, 2025).

Climate vulnerability further exacerbates existing power structures, with climate-induced disasters and heat stress disproportionately affecting vulnerable communities and mining workers who have limited adaptation or influence. Increasing heat stress primarily affects governments in the Global South as it complicates their ability to protect citizens as they simultaneously manage extraction demands. These climate challenges mix with legal and regulatory issues, where official systems fail to connect properly with at-risk communities and provide uneven protections for workers, which largely depend on how well local governments can manage. For instance, in Indonesia's nickel mining regions, communities face a double burden increasing heat waves that reduce worker productivity and safety, while government resources are focused on managing these climate impacts and overseeing extraction operations that support national economic goals.

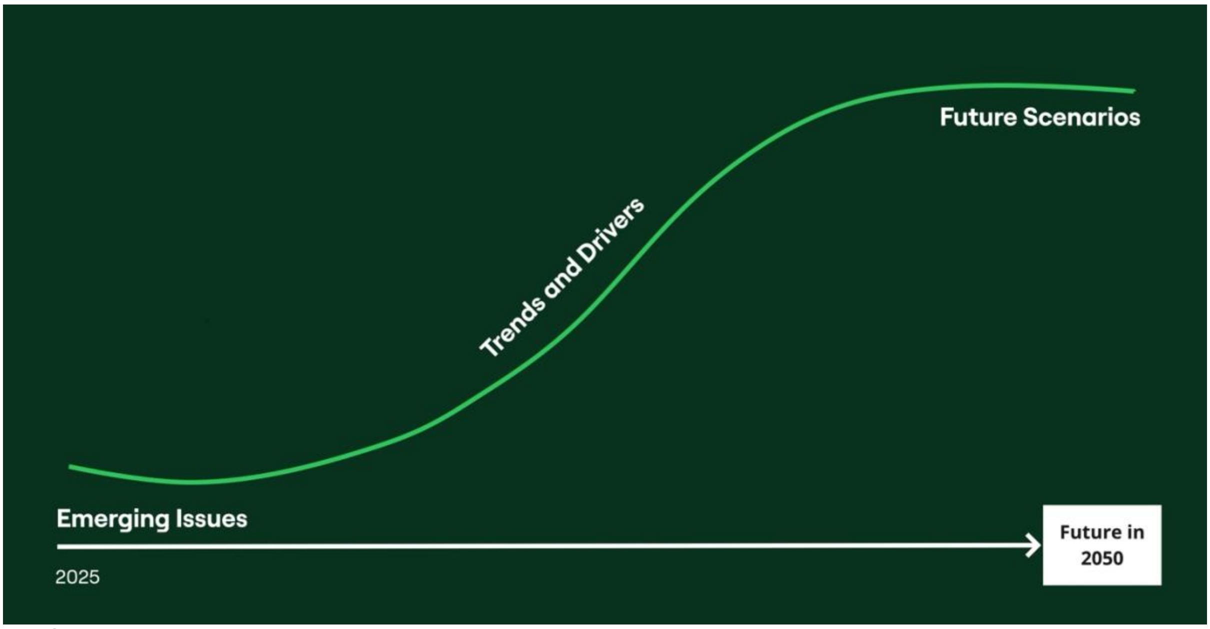
Despite these entrenched challenges, the Actor's Map identifies promising emergent relationships that could suggest transformation potential. Knowledge democratization pathways are forming between consumers and knowledge institutions, creating opportunities for greater awareness of extraction impacts. Climate activists with high power and knowledge can strategically bridge information gaps for civil society groups affected by climate change, while community organizations and NGOs in the Global South, despite limited global power, possess valuable contextual knowledge that could influence institutional actors. Building partnerships among different groups, especially between community organizations, policymakers and international organizations, can be key to adding fairness into governance systems, as contextual knowledge and can effectively shape what consumers know and how companies act with their moderate power and strong knowledge. For example, the growing environmental awareness has led households to prioritize renewable energy adoption, driven by cultural values around sustainability and climate responsibility. This shift is evident in residential solar uptake and community energy projects that align with local cultural narratives (e.g., Bali's integration of environmental stewardship into energy transition policies through sacred natural elements) (Harsamto & CASE Indonesia, 2022).

7. Employing Strategic Foresight

The previous phase of ‘Discover’ and ‘Define’ helped answer questions such as ‘What are the existing research gaps and why social equity?’ and ‘What are the existing boundaries of the energy system for this research?’ by understanding the structural, relational, and contextual dynamics between the CRM’s value chain and social equity. The phase of discovery helped in laying out the broader context of factors involved in the transition to renewable energy and the relational dynamic between the total demand of CRMs and social equity. The define phase mapped out interdependencies, actors' relationships, and possible long-term trends, highlighting opportunities and systemic forces around this transition to RE.

While this provides essential context for understanding present-day dynamics, it does not account for how these dynamics may evolve over time, especially in the next 25 years. To address the research objective—“to identify and analyze, through future trends, the opportunity spaces for embedding social equity into CRM extraction.” This phase, Develop, looks at how the global RE transition can evolve into the future context in the time set in 2050 and how those changes would look for social equity. Systems mapping seeks to understand **what and how things are and who is involved**, while strategic foresight methodologies explore **how things might change in the future.**

Figure 08: Foresighting the Future



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Strategic foresight methodologies equip researchers, strategists, and policymakers to navigate uncertainty, identify emergent opportunities, and develop adaptive strategies and recommendations. Unlike traditional strategic planning, which relies on linear extrapolation of historical data, strategic foresight treats uncertainty as an inherent feature of complex systems (Voros, 2003). While planning prioritizes fixed goals and measurable outcomes, foresight emphasizes exploratory analysis of multiple plausible futures. As Conway (2017) notes, foresight enables organizations to “systematically explore possible futures, understand external challenges, and craft strategies resilient to long-term shifts.” In this study, strategic foresight operates as both a methodological tool and an analytical lens, extending the Discover and Define (systems mapping) phase into future contexts by mapping how current signals and drivers may evolve. This approach identifies threats, opportunities, and transformative potential across divergent pathways for recommendations.

In building future scenarios, we anchored our approach in **Dator’s Generic Images of the Future** framework to ensure consistency and ground the plausible future scenarios within the energy system's context.

Building on this foundation, the foresight process began with **horizon scanning** to identify signals and trends, followed by the identification of **drivers of change**. These components informed the future scenario construction, based on technological, socio-political, environmental, and economic trends and drivers that may reshape the critical minerals value chain and its impact on social aspects during the transition to renewable energy.

7.1 Horizon Scanning

Horizon scanning helped identify emerging developments across multiple domains that could significantly influence the future landscape of CRMs in energy transitions and their social equity implications. A summary chart of the identified trends follows below, offering a high-level overview.

A summary table of the identified trends offering a high-level overview. More detailed description including the future implication and signal references can be found below the table.

Figure 09: A summary of the identified trends offering a high-level overview

Trends	Description	Future Implications in 2050
Social Despair: Loss of Lives, Culture, Land, and Heritage STEEP+V: Social	The renewable energy transition's critical mineral demand fuels geopolitical competition, encroaching on Indigenous lands and threatening cultural and livelihood practices.	• Climate-driven resource scarcity by 2050 will escalate Indigenous-industry conflicts and blur activism with armed resistance. • Inadequate policies and greenwashing will fail Indigenous rights, overwhelming legal systems. • Mining profits enrich corporations while Indigenous communities face health crises and cultural loss. • Displacement and digitalization erase Indigenous languages and traditions, deepening generational alienation.
New Forms of Slavery through Green Extractivism STEEP+V: Economic, Values	The green transition risks deepening class divides by enabling privileged groups' "guilt-free" decarbonization while perpetuating exploitative systems through green extractivism justified by tech demands like EVs and solar grids.	• Clean energy access becomes a class divider, leaving the "uncarbonized" in persistent insecurity. • Corporate lobbies entrench neo-colonial resource extraction via "survival" policies. • Hazardous labour and climate disasters worsen health inequities in the Global South.
Global Temperature rise STEEP+V: Environment	Accelerating climate impacts like floods, sea-level rise, and extreme heat are driving global climate adaptation policies, with the Global South facing due to population pressures, resource constraints, and environmental strain.	• Climate policies in the Global South promise economic growth if labor rights and equity are prioritized. • Rising climate migration threatens geopolitical stability, necessitating collaborative, humane solutions. • Heat waves and heat stress outpace adaptation capacity in Global South extraction zones • Public health systems in Global South lack financing to address climate-related health demands.

Trends	Description	Future Implications in 2050
Boom in Green Industries STEEP+V: Economic, Environment	The renewable energy surge driven by AI, electrification, and consumer awareness presents opportunities but risks like resource dependencies and infrastructure gaps, requiring balanced climate finance to ensure an equitable, sustainable net-zero transition.	• Green job promises faltered, widening inequalities and trust gaps through automation and corruption. • Public-private green partnerships risk corporate capture and weakened accountability. • Global North's resource extraction entrenches renewable energy inequalities. • Green contracts fuel corruption and exploitation in Global South communities. • Mitigate risks via transparency, oversight, and rights-centric policies.
Divided World Between the West and China STEEP+V: Political	Western-Chinese tensions over security, energy, and technology threaten global peace, undermine climate collaboration, and obstruct net-zero progress despite urgent demands for cooperation.	• West-China competition bifurcates digital spaces, stifling innovation through isolated tech spheres. • Geopolitical tensions disrupt clean energy supply chains, inflating costs and delaying climate action. • An AI arms race sacrifices safety, causing destabilizing economic shocks like Deep Seek's $1tn market wipeout.
The New Power Brokers: Lobbyists Aiding in formation of Government's policy STEEP+V: Political	The tech sector's rapid growth—driven by AI innovation, electrification, and market consolidation—has enabled a handful of dominant firms and influential founders to shape global technological and energy transitions, while governments struggle to regulate or keep pace with their disruptive influence.	• AI-powered digital giants shape laws, fragmenting global regulations and altering citizen rights. • Few dominant firms control markets, limiting innovation and diversity. • AI-driven influence erodes trust, capturing governance and prompting calls for new accountability.
A Multitrack World: From Globalization to Regionalization STEEP+V: Economic, political	As global institutions weaken and geopolitical tensions intensify, regions are forging their own development pathways through new trade corridors, localized security alliances, and joint economic strategies—reshaping global governance into a fragmented, multipolar order where cooperation is increasingly regional, not global.	• Regional financing replaces traditional foreign aid, prioritizing local value addition • Intra-regional trade increases as global supply chains fragment • Uneven distribution of resources creates winners and losers among regional blocs • Financial market volatility rises due to trade pattern disruptions and commodity uncertainties

Trends	Description	Future Implications in 2050
Changing Consumer Sentiments and Behaviours STEEP+V: Values	Modern consumers, especially younger generations, are increasingly making purchasing decisions based on their personal values rather than solely on price or convenience. Represents an emerging shift in the consumer mindset from purely transactional to relationship- and impact-oriented.	• Pressure on markets for increased reporting and financial markets • Change in material design, package design, and sustainability practices for products • A growing base of values-driven consumers • Increase in greenwashing of products with sustainability premiums

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Various geopolitical factors around trends such as the green industries boom, regionalization, world divide, and power shifts have the potential to ripple to other trend formations such as changes in consumerism sentiment, colonization in the name of greenflation, and social disruptions for vulnerable groups in the system. These trends have given rise to various forces will guide the future scenarios and prepare for disruptions while constructing scenarios

Trend 01: Social Despair: Loss of Lives, Culture, Land, and Heritage
Context
The global transition to renewable energy, while essential for mitigating climate change, is creating an unprecedented surge in demand for critical minerals. This demand, coupled with intense geopolitical competition to secure these resources, is driving a relentless push into remote territories traditionally occupied by Indigenous communities. This dynamic creates a perfect storm of challenges, profoundly impacting their cultural practices and livelihoods.

Signals
- Mining projects disrupt family life through prolonged worker absences and demanding schedules (PDAC Social Impact Study, 2022).
- 334 violent incidents linked to critical mineral mining occurred from 2021-2023, with 90% affecting fewer wealthy nations (Global Witness, 2024).
- Indigenous lands face accelerated climate impacts alongside mining threats, prompting legal challenges (United Nations Environment Programme, 2023)
- Nearly 60% of Indigenous territories face moderate to high risk from industrial expansion, with 37 nations showing critical vulnerability due to inadequate rights protection (Kennedy et al., 2023)

Future Implications
- **Intensified Climate-Induced Conflict:** By 2050, resource competition will intensify as climate change alters landscapes. Indigenous territories will face pressure from climate refugees, while protests evolve into sophisticated transnational movements challenging state and corporate authority.
- **The Limits of Governmental Intervention:** Policies will remain insufficient to address historical injustices. Political instability will hinder protection of Indigenous rights, while "greenwashing" erodes trust, and legal systems face unprecedented challenges.
- **Exacerbated Social and Economic Disparity:** Mining operations will entrench inequality with short-lived economic benefits. Communities will face environmental health threats, while traditional knowledge and food security deteriorate as community structures change.
- **Cultural Erosion and Loss of Identity:** Displacement will accelerate irreversible cultural heritage loss. Younger generations will experience alienation from ancestral lands, contributing to mental health crises. Digital preservation efforts will prove inadequate substitutes for lived cultural experiences.

Trend 02: New Forms of Slavery through Green Extractivism
Context
The current green transition, driven by electrification and consumption, risks exacerbating class struggle by offering privileged classes a 'profitable redemption' through guilt-free decarbonization, despite potential climate benefits like EVs' lower emissions (US EPA 2023). This reinforces historical power dynamics, where wage inequalities are political artifacts, not natural outcomes. Further, green extractivism is justified by consumer demand for transition technologies, as exemplified by LKAB's CEO — "without mines, there can be no electric vehicles" (LKAB 2023), thus continuing exploitative systems. LKAB (2023) Europe's largest deposit of rare earth metals is located in the Kiruna area. (LKAB, 2023)

Signals
- Green New Deals and Climate Mitigation Policies impose industrial priorities on extractive regions while benefiting high emitters (Owen et al., 2023).
- Tesla's "Volt Rush" (Sanderson, 2022) accelerates demand for EVs and extractivism in vulnerable regions.
- Rich nations extract resources from the global South through systematic price differentials, creating a "hidden transfer" now totaling $2.2 trillion annually (Hickel et al., 2021).

Future Implications
- **Increased Class War Based on Energy Accessibility and Usage; Formation of an Extractive Economy at the Expense of the Uncarbonized Class:** By 2050, access to clean energy will define class divisions, creating an "uncarbonized class" facing persistent energy insecurity.
- **Big Lobbyists Controlling Economic and Labor Policies; "Survival of the Fittest" Race:** Corporate lobbies will shape economic policies to maximize resource appropriation from the Global South, establishing a neo-colonial system of exploitation.
- **Health Conditions in the Global South Deteriorating Due to High Labor Demands and Climatic Conditions:** Intensified labour demands in hazardous conditions combined with climate deterioration will trigger widespread health declines in the Global South, disproportionately affecting marginalized communities.

Trend 03: Global Temperature Rise
Context
With fast paced climate changes in climate leading to increased floodings, including river flooding, sea-level rise, and extreme temperatures; the governments and international agencies are now implementing actions to tackle climate change by introducing climate adoption policies. Global South is going to be affected directly in the coming years. Many countries in the Global South are grappling with rapid population growth, which strains the environment and diverts resources, posing challenges to local and regional sustainability.

Signals
- Heatwaves killed 4,200 workers globally in 2020, with 231 million exposed; India reported 3,000+ heat-related deaths (Staff, 2024).
- Pakistan's 2022 floods affected 33 million people; Bangladesh's flash floods impacted 4.2 million; South Asia faces potential displacement of 800 million by 2040 (Almulhim et al., 2024).
- Global response is shifting to adaptation through NDCs and critical minerals policies that prioritize vulnerable communities (Member States Adopt Policy, 2024; WEF, 2025)

Future Implications
- **Economic Opportunity and Just Transition in the Global South:** Climate adaptation policies offer investment potential for Global South nations. Clean technology transition could generate wealth if labour rights are protected, and exploitation prevented.
- **Climate Migration and Geopolitical Tensions:** Heat stress will trigger migration toward the Global North. Mountainous countries face challenges as glaciers retreat, affecting water supplies and agriculture. Temperature increases of 1-6°C will intensify cross-border movement, potentially escalating geopolitical tensions (Almulhim et al., 2024).

Trend 04: Boom in Green Industries

Context

AI development, electrification, and rising consumer awareness are fuelling a renewable energy boom. However, this growth brings both benefits and risks: resource dependencies, technological disruption, infrastructure challenges, and environmental impacts. To achieve net-zero goals, we must balance these factors with increased climate finance, ensuring an equitable, sustainable, and resilient green transition.

Signals

- Global EV fleet expanded from 22,000 in 2011 to over 2 million by 2021, driven by environmental concerns, more options, better batteries, and lower costs (Ice & Barreda, 2023)
- India possesses advantages like China in green industries but faces higher emissions due to fossil fuel dependence (Sinha, 2023)
- Deloitte estimates data centres will drive approximately 44 GW of additional energy demand by 2030, while AI enhances grid management capabilities (Deloitte, 2024).

Future Implications

- **The Broken Promise of Green Job Creation**: The promised green job revolution may prove illusory as automation limits job creation while public funds support 'greenwashing.' The disconnect between expectations and limited skilled positions risks eroding public trust.
- **New partnership models between public and private sector:** By 2050, novel collaboration frameworks between governments and companies will accelerate the green transition but may blur accountability lines and prioritize corporate interests.
- **The Reconfiguration of Global Resource Flows:** North-Centric Green Extraction: Global North corporations will increasingly extract critical minerals from the Global South, potentially worsening inequalities and causing environmental degradation in vulnerable regions.
- **The Shadow of Green Corruption:** Public Trust and Ethical Concerns (2025): The minerals rush risks replicating the "resource curse." Latin America saw $80 billion in green investments (2010-2015) alongside opaque licensing practices (Sayne et al., 2024) threatening public trust and increasing exploitation of marginalized communities.

Trend 05: Divided world between the West and China

Context

Western-Chinese relations are dangerously strained, creating significant uncertainty for the Global Peace and Order. Security including Energy security and technology tensions are acute, and this friction risks undermining essential global collaboration on climate change and sustainable development. Despite the undeniable need for unprecedented international cooperation to reach net-zero emissions, the current geopolitical scenario will actively hinder such efforts.

Signals

- European Commission initiated investigations into Chinese EV subsidies, with President von der Leyen promising decisive action against "market distortions and unfair competition" (European Commission, 2023).
- China's monopoly on critical minerals threatens U.S. clean energy transition, with dependence growing "as clean energy technologies and semiconductors increased" (Holland, 2024)
- The Democratic Republic of Congo seeks to reduce Chinese mining dominance, with Mines Minister Pakabomba aiming to "attract better investors, more investors and diversified investors" (MINING.COM, 2024).
- China filed a WTO dispute against U.S. semiconductor export controls, with concerns that the U.S. may ignore rulings, highlighting declining trust in international agreements (Kharpal, 2022)

Future Implications

- **Fractured Digital Ecosystems:** Competition between West and China could create a "digital iron curtain" fracturing communication platforms, social networks, and knowledge-sharing along geopolitical lines, stifling global innovation and cooperation.

- **Supply chain disruptions for Clean Energy Transition:** Trade restrictions and tensions could dramatically inflate renewable technology costs, forcing costly localized supply chains that slow global sustainable energy transition and worsen climate impacts.
- **Unregulated AI Race:** U.S. and China will likely prioritize rapid AI development amid escalating tensions, potentially making effective international safety measures impossible to implement.

Trend 06: The New Power Brokers: Lobbyists Aiding in the formation of Government's Policy
Context
With growing market in tech and growing energy demands, a small number of tech firms and in some cases strong company founders has gained large attention and power to influence in this digital age while driving strong changes towards electrification, AI innovation and driving market forces. This new kind of market certainly has been shaped by certain big companies with government playing a role of a follower as it is difficult for them to decide how to catch up in this age of rapid innovation work.

Signals
- Seven AI companies (Amazon, Anthropic, Google, Inflection, Meta, Microsoft, OpenAI) made voluntary White House commitments in July 2023, but these lack sufficient rigor and independent oversight (Heikkilä, 2024)
- Zuckerberg appointed former political leaders to senior roles, noting: "We need a senior leader… who can lead and represent us for all of our policy issues globally" (Culliford, 2022)
- Following his Twitter acquisition, Musk implemented changes and used the platform to influence public sentiment toward Trump, demonstrating tech leaders' growing policy influence (Duffy, 2025)

Future Implications
- **Corporate Terms Superseding Laws:** Digital ecosystems with advanced AI will increasingly challenge governmental authority. "Algorithmic sovereignty" will reshape citizen rights, creating fragmented legal frameworks affecting data privacy and dispute resolution.
- **The Consolidation of Market Power and the Stifling of Decentralized Innovation:** Hyper-consolidation will create a "walled garden" economy where few entities control infrastructure and data flows. Proprietary platforms will reduce opportunities for SMEs and disruptive innovation, potentially creating monocultures of thought.
- **The Shifting Landscape of Political Influence and the Crisis of Civic Trust:** By 2050, AI-driven lobbying and information manipulation will fundamentally alter government-corporate relations. Digital giants' ability to shape discourse and policy will create perceived "capture" of governance, fueling cynicism and necessitating new accountability models.

Trend 07: A Multitrack World: From Globalization to Regionalization
Context:
The trend, globalization to regionalization, indicates a growing shift from existing global structures, with countries such as Indonesia trying to make processing in the country apart from extracting nickel to gain larger value from the minerals. The global supply of critical minerals is shifting from a globalized model to a more regionalized approach due to geopolitical tensions, resource nationalism, and supply chain vulnerabilities. Countries and regions are securing their own CRM supply chains through onshoring, nearshoring, and regional trade agreements to reduce dependency on single-source suppliers like Russia and reduce the influence of the Global North.

Signals:
- A new undersea fiber-optic cable connecting Azerbaijan and Kazakhstan (part of China's Digital Silk Road) demonstrates regional technology collaboration rather than isolated national strategies (Cutler, 2025)
- Japan, South Korea, and China agreed to improve semiconductor supply chain cooperation despite historically tense relationships, forming new partnerships to counter global power restrictions (Reuters, 2025)
- Burkina Faso, Mali, and Niger's withdrawal from ECOWAS reflects a Sahel geopolitical shift where military-led governments contest Western-supported institutions, showing Global South countries' desire for independence from former colonial powers (Mwangi, 2025)

Future Implications

- **Regional Realignment & Development Autonomy:** As Global South countries form regional alliances; traditional Northern aid diminishes while local growth opportunities increase through strengthened regional collaboration.
- **Establishment of Infrastructure and Innovation Networks:** Regional processing capabilities will reconfigure trade relationships, while digital infrastructure developments facilitate faster knowledge sharing within regions, potentially closing development gaps between neighboring countries.
- **Geographic Vulnerability & Market Volatility:** Countries lacking critical minerals or strategic geographic positions may face economic marginalization, with increased financial market volatility due to disrupted trade patterns as international institutions face challenges from emerging powers rejecting Western influence.

Trend 08: Changing consumer sentiment and behavior

Context:

The trend of Changing consumer attitudes and behavior represents a fundamental shift in demand market dynamics, with consumers increasingly making purchasing decisions based on personal ethics, sentiments, sustainability considerations, and social impact rather than solely on price or convenience. This marks a profound evolution from transactional consumer relationships to impact-oriented engagement with brands and products. The energy transition necessitates a significant increase of critical minerals, which in turn creates a conflict between consumer sustainability values and the realities of the supply chain and operation chains in terms of energy. As this trend emerges, it creates both unprecedented pressure on current practises and new market opportunities.

Signals

- Consumers are willing to pay a 9.7% sustainability premium despite cost-of-living concerns (PricewaterhouseCoopers, 2024)
- Stock markets are being questioned about their ability to authenticate company statements regarding forced labor safeguards, showing ethical supply considerations directly affecting capital markets (BBC) (Race, 2025)
- Legal actions against Apple from both the Democratic Republic of Congo (regarding conflict minerals) and American consumers (challenging "carbon neutral" claims) highlight mounting pressure from producing countries and end users (Calma, 2025; Shankar, 2024)

Future Implications

- **Increased Reporting and Accountability:** Financial markets are evolving to incorporate sustainability metrics into investment decisions, creating pressure for verifiable reporting and legal vulnerability when claims don't match practices.
- **New product design standards:** Businesses are increasing R&D in sustainable minerals that maintain performance standards, accelerating circular economy principles in product design from material selection to end-of-life reclamation.
- **Consumer Value Alignment & Marketing Evolution:** Authentic sustainability now commands loyalty and price premiums, while greenwashing backfires with sophisticated consumers. Marketing is evolving from feature-benefit messaging to demonstrating shared values with consumers seeking relationship-based brand interactions.

7.2. Drivers of Change

Through mapping the trends, key drivers of change have been identified that can shape and influence how the future might unfold. These underlying dynamics may propel or hinder transformation, create new opportunities, and pose potential threats, guiding in the process of trend analysis and constructing scenarios.

01. Technological Drivers

Increased renewable energy cost-competitiveness with fossil fuels

The dramatic cost reductions in solar PV (85% since 2010) and onshore wind (approximately halved) have made making renewables cost-competitive with fossil fuels globally, driven by learning curve effects and technological advancements (World Economic Forum, 2021). Solar PV's levelized cost of electricity (LCOE) fell 56% below fossil fuel alternatives in 2023, while onshore wind undercut them by 67%, with battery storage costs dropping 89% since 2010 (International Energy Agency, 2023). Additionally Average EV MSRP (Manufacturer's Suggested Retail Price) remains 42% higher than gas cars (Q1 2024), peaking at 58.5% for compact SUVs (O'Dell, 2024). This has however had led to slower adoption rate for renewable energy tech options for consumers. However, this transition relies heavily on critical minerals: solar requires silicon, silver, copper, and indium; wind turbines depend on rare earths (neodymium, dysprosium), manganese, and platinum; and EV batteries need lithium, cobalt, and nickel. These minerals face supply chain risks due to geographic concentration, ESG concerns, and projected Total demand surges—lithium demand alone could rise nearly 90% by 2050 under net-zero scenarios (United Nations Environment Programme, 2023).

02. Economical Drivers

Reduced reliance on volatile fossil fuel markets and geopolitical risks

Distributed energy and renewables, which are more adaptable to site-based production, are becoming more desirable after Paris Agreement announced in 2015 and let to the goal of achieving NZE targets by various countries by 2050. Various countries in EU, America and Asia, are focusing on securing CRMs supply chain to ensure high levels of energy security. For instance, The EU's Critical Raw Materials Act aims to enhance energy security by reducing dependencies on foreign imports and minerals essential for Renewable Energy tech like batteries, solar panels and wind turbines. This Act has put a cap to not exceed 65% reliance for CMRs supply on a one single country. However, research says that higher energy security has a negative effect on renewable adoption, with energy insecurity driving growth in renewables (Higher Energy Security and Economic Complexity May Hamper Renewable Energy Development., 2023). Additionally, the Russia-Ukraine war has intensified resource competition and fossil fuel instability among countries, acting as a catalyst for renewable energy adoption while exposing vulnerabilities in critical mineral supply chains. Repower EU plan, driven by energy security concerns, aims for 45% renewable energy by 2030, with €110 billion invested in 2023 alone and solar/wind surpassing fossil gas in electricity generation by 2022 (Holman, 2024).

Market dynamics

Global investments in renewable energy and electrified transport now exceed $1.5 trillion annually, driven by their long-term profitability and lower environmental risks compared to fossil fuels, with solar PV alone projected to account for 50% of renewable energy tech investments in 2025 (Muhire et al., 2024). However, this rapid scale-up intensifies reliance on critical minerals like lithium, cobalt, copper, and rare earth elements, which are essential for technologies such as solar panels, wind turbines, and electric vehicle batteries. Demand for these minerals could rise sixfold by 2050 and USD 7.4 trillion by 2030 and USD 10+ trillion by , while supply chains remain vulnerable due to geopolitical concentration (e.g., China refines 40-50% of global lithium and cobalt) (Climate Policy Initiative, 2025). To sustain this growth, strategies like ethical mining, recycling, and diversifying supply chains—supported by policies such as Canada's $4B Critical Minerals Strategy—are critical to mitigating bottlenecks and ensuring the energy transition's affordability and speed (Prospectors & Developers Association of Canada, 2024).

03. Political Drivers

Tools for Global Governance

The introduction of the Paris agreement in 2015 has been a pivotal driver of RE adoption which in turn has led to an increase in total demand for CRMs. By committing 194 countries to limit global warming to well below 2°C, the agreement catalyzed Nationally Determined Contributions (NDCs) that prioritize RE deployment. To limit global warming to 1.5°C, CO_2 emissions must drop ~50% by 2030 (relative to 2020 levels) and reach net-zero by 2045–2050, requiring 7.6% annual reductions (32 Gt CO_2 cut) through 2030, while total GHG emissions need net-zero status by 2060–2080 (United Nations Framework Convention on Climate Change, n.d.). However, various challenges around securing supply chain of CRMs exists due to geopolitical and geographical concentration of CRMs, green extractivism and exploitation of vulnerable communities and mining workers. Paris Agreement has enabled the Global North and Global South to follow on achieving NZE targets as well though large renewable energy deployment. This is possible as 80% of NDCs target renewable energy electricity, only 30% address heat and transport sectors, leaving room for expanded mineral-intensive electrification (Renewable Power Generation Costs in 2023, 2024).

04. Environmental Drivers

Global Temperature Rise

Rising global temperatures have fundamentally transformed our climate response, shifting from mere mitigation to urgent adaptation. As extreme weather events intensify worldwide, the imperative to transition from fossil fuels has accelerated dramatically, driving unprecedented demand for critical minerals essential to renewable technologies. This urgency is quantifiable: global migration increases 1.9% per degree Celsius rise, while the tropical Andes have already lost significant glacial mass due to temperature increases of just 0.5-1°C over the past 15 years (Almulhim et al., 2024).

05. Social Drivers

Ethical and Climate Conscious Consumers

Growing environmental awareness has led households to prioritize renewable energy adoption, driven by cultural values around sustainability and climate responsibility. This shift is evident in residential solar uptake and community energy projects that align with local cultural narratives (e.g., Bali's integration of environmental stewardship into energy transition policies through sacred natural elements) (Harsamto & CASE Indonesia, 2022). Additionally, the corporate emphasis on environment, social, and governance goals becomes a driver for RE transition. Households and corporations—particularly tech giants like Apple and Google—are prioritizing 100% renewable energy to meet climate-conscious expectations, driving a surge in wind, solar, and battery projects that rely on lithium, cobalt, and rare earth elements. For instance, there has been increasing power influence by tech firms to dominate RE procurement with their power purchase agreements accounting for half of the global deals in 2023.

Neocolonialism

Global South nations resist extractive practices by prioritizing local renewable projects. Neocolonialism is one of drivers for global energy transition as Global South nations resist extractive models that prioritize wealthy economies' interests, exemplified by resource exploitation for renewable technologies Hamouchene (2025) and the push for "green extractivism" through critical mineral extraction (Deberdt & Billon, 2024). Countries are advancing locally owned renewable projects, such as Ecuador's community-led hydropower systems, to retain economic benefits and decision-making power while rejecting energy models that replicate historical exploitation (Hamouchene, 2021). This resistance of extractive practices by Global South is accelerating the process of decentralization.

These realities have reframed critical minerals as essential adaptation resources rather than simply industrial inputs, contextualizing the complex geopolitical, economic, and ethical debates surrounding their extraction and distribution as societies simultaneously adapt to current climate challenges while working to prevent catastrophic future scenarios.

7.3. Constructing Scenarios

The year 2050, was selected because a 25-year time makes for the slow transformative nature of energy sector and hence, influencing the renewable energy transition. This timeframe is also relevant given the accelerating pace of change in domains in focus such as climate change, geopolitical scenarios and global economic fragility and Paris agreement timelines to achieve NZE targets by 2050. These forces are evolving rapidly and are also highly interconnected, with the potential to create impacts across social, economic, and environmental systems.

In building plausible scenarios, we began with Dator's Generic Images of the Future framework to establish analytical consistency, ensuring our scenarios were firmly grounded in systems context. We then progressively built each scenario with increasing detail, creating comprehensive descriptions of how each potential future would manifest across multiple dimensions. Through scenarios building, the opportunities and threats identified in the desired future, helps establish possible leverage points to drive the next steps in this research: recommended pathways. Additionally, as per objectives which is to focus on extraction of critical minerals, we have identified implications of each scenario based on the social harms identified in extraction of critical minerals for the renewable energy transition. The implications of each would help us identify who benefits, who has the power, and who is impacted in each of the scenarios.

Dator’s Generic Images of the Future framework

After Horizon Scanning, in order to provide grounding for various scenarios we decided to use Dator’s Generic Images of the Future Framework. To establish a robust foundation for the four Dator's Future scenarios, ten key parameters were identified that could significantly influence in enabling and driving the global renewable energy transition while simultaneously shaping the trajectory of our collective future.
Established Parameters:

- **Renewable Energy Technology**: This parameter measures how clean energy technologies are deployed, including their cost, adoption rate, and regulatory framework. It addresses the technical solutions available for energy generation, distribution, and storage, and how these technologies are integrated into existing infrastructure.
- **Economy**: This parameter describes the fundamental economic structure supporting or hindering the energy transition. It encompasses economic models carbon dependency, and whether the economy prioritizes growth, sustainability, or a balance between them.
- **Role of Business**: This parameter examines how commercial entities operate during the energy transition, including their size (multinational vs. SME), governance principles, and primary motivations. It addresses whether businesses lead or follow in the transition process and their accountability to stakeholders.
- **Role of Oil & Gas Companies:** This specific parameter tracks how traditional fossil fuel companies respond to the energy transition. It examines whether they pivot, resist, adapt, or decline, and how they leverage their existing resources, expertise, and market position in a changing energy landscape.
- **Energy Security**: This parameter measures the stability, reliability, and equity of energy access across globe. How will it look like for countries in Global North and Global South. It considers dependency on global supply chains, vulnerability to disruption, and whether energy provision is driven primarily by profit motives or social needs.
- **Geopolitical Conditions**: This parameter captures international relations and power dynamics as they relate to energy and resources and how it would look like for each scenario here. It also looks at cooperation versus competition between nations, stability of international agreements, and how resource distribution affects political relationships.
- **Consumer Sentiment**: This parameter addresses public attitudes toward energy choices, sustainability, and consumption patterns. It includes willingness to make lifestyle changes, tolerance for price premiums on sustainable options, and the balance between ethical considerations and practical affordability.
- **Extraction of Critical Minerals:** This parameter focuses specifically on how materials essential for renewable technologies are sourced and in what quantity.
- **Investments into Green Technology**: This parameter tracks financial flows directed toward renewable energy innovation and deployment. It includes both public and private investment levels,

research priorities, and whether funding focuses on incremental improvements or transformative technologies.

The table below showcases the four futures that have been built on the parameters explained above.

Figure 10: Dator's Four Futures

Parameter	Continued Growth	Collapse	Disciplined	Transformation
Renewable Energy Technology	Lower adoption, more expensive	Adoption only where highly profitable	Regulated adoption	Higher adoption, regulated adaptation
Economy	Oil/gas dependent, debt-driven, centralized	Internal market growth, scarcity-based economy	Shared economy, resource conflicts	Knowledge-based circular economy, less energy-dependent
Role of Business	Decentralization, profit-driven, multinational dominance	Black markets rise, profit-driven	Middle-market emergence, some industry failure, SME growth	SME growth, accountability for renewable transition
Role of Oil & Gas Companies	Resource acquisition, strong lobbying	Mining/resource monopoly, exploiting CRMs advantages	Minimal demand, restrictive laws	Regulated influence
Energy Security	Supply chain dependence	Global inequality increases	Security driven by profit, improved systems	Energy independence focus
Geopolitical Conditions	Unstable politics, coalition-based	Corruption, instability	Division by resource access, China/US dominance	Balanced power, new global alliances
Consumer Sentiment	Demand for affordable ethics, cheap vs. green product division	Low engagement, selective protest groups	Strong ethical and sustainable priorities	Strong ethical and sustainable priorities
Extraction of Critical Minerals	Uncontrolled high extraction	Unregulated extraction	Regulated control	Regulated circular systems
Investments into Green Technology	Minimal	Decreasingg	Regulated	Increasing

This figure is original by the authors

Each scenario introduces a plausible future, with the key drivers, and the implications based on the social harms and negative externalities identified in extraction of critical minerals for the renewable energy transition. The implications of each identify who benefits, who has the power, and who is impacted in each of the scenarios.

7.3.1 Continued Growth: Growth at all Costs

Summary

In 2050, growth at all costs, the business-as-usual scenario is where fossil fuels remain dominant in energy-intensive economies. Despite high costs and limited support, oil and gas companies leverage their competitive advantages and control the gradual increase in renewable adoption for profits. Carbon-dependent economic systems benefit elites while multinationals practice "green capitalism." Oil and gas companies expand under the decarbonization pretense with strong lobbying influence. Energy security remains unstable and dependent on vulnerable supply chains as nations miss net-zero targets. Geopolitical alliances form on self-interest rather than climate cooperation. Consumers struggle between ethical products and affordability. Renewables are largely viewed for profit gains by lobbyists and oil and gas companies as they expand their control over critical minerals through their strategic positioning and access to finance. Unmitigated climate change triggers cascading effects: intensifying social and economic disasters, chronic supply chain disruptions, land displacement, and significant loss of productivity. Hence, the focus is on climate adaptation and reducing environmental consequences under the pretense of a “green economy”.

Assumptions About Drivers' Behaviors

- **Increased renewable energy cost-competitiveness with fossil fuels:** The cost of adopting renewable technology is becoming more expensive due to minimal investments in scalable RE technologies, geopolitical instabilities, and persistent supply chain disruptions. Investments in renewable energy are predominated by meeting the growing energy needs of the global north. Economic models remain carbon-intensive, and innovation is largely incremental.
- **Reduced reliance on volatile fossil fuel markets and geopolitical risks**: Energy security remains unstable. Supply chains prioritize certain regions, leaving many communities behind. The Global South lacks sufficient financing to participate competitively in the critical minerals sector, especially as current supply chains are not designed to be inclusive.
- **Market dynamics:** Economic systems continue to be carbon intensive. There is a lack of financial support for the Global South to become energy independent. Fossil fuel-based economies benefit elites, while green growth is exploited by multinationals. Few regions concentrate renewable investments, and limited financing hinders developing economies' ability to achieve energy independence. Their ability to become energy independent is restricted due to limited financing. become energy independent. Extractive practices continue to meet the energy demands of the Global North
- **Tools for Global Governance:** International national development plans and policies are unable to effectively enforce international agreements like the Paris Agreement due to debt-driven economies, lack of implementation pathways, and geopolitical instability. The Global North often designs these agreements, excluding the voices and realities of the Global South.
- **Global Temperature Rise:** There is an increase in climate-migration patterns due to increased heat stress and heat waves that impact Global South Regions, especially the vulnerable communities. This triggers widespread productivity losses through cascading climate disasters, land displacement, and systemic disruptions across affected regions.
- **Ethical and climate-conscious consumers**: There is growing consumer sentiment toward ethical and affordable products. However, in debt-driven economies, consumers often lack clear pathways to make impactful decisions or influence supply chains for meaningful change.
- **Neocolonialism:** There is rising resistance from the Global South due to the increased mining of critical minerals primarily for profit. The absence of strong, enforceable laws and protections for vulnerable communities and mining workers further fuels this resistance.

Narration

The solar rays glittering on the headquarters of Global Energy Consolidated catch the morning sun, casting reflections across the climate-controlled boulevard below. These highly visible symbols of "progress" stand in stark contrast to the reality they hide fossil fuel consumption that has continued to climb despite decades of promised reductions. Inside the building, executives review quarterly projections for their "transition portfolio" - a carefully crafted collection of renewable projects that generate impressive sustainability reports while representing barely 15% of their actual business operations. The real profits still flow from what they call "legacy energy assets", the oil fields, gas terminals, and coal plants they've maintained while purchasing the right to call themselves "climate leaders." A holographic display shows their extensive holdings across both sectors: the fossil fuel operations that power their profits and the renewable energy companies they have systematically acquired since the mid-2020s. This dual strategy has proven devastatingly effective – they have captured the technologies that once threatened them and transformed potential competition into subsidiary revenue streams. The warning signs were evident as early as 2025, when fossil fuel subsidies remained firmly in place despite climate commitments. Oil and gas companies began strategic acquisitions of renewable startups, presented as "supporting the transition" while actually consolidating control over energy futures. By 2027, resource-driven conflicts had escalated, particularly in regions rich with lithium and cobalt. As climate targets fell short, governments pivoted from mitigation to adaptation, effectively abandoning the goal of preventing climate change in favor of surviving it. Carbon markets expanded, allowing high emitters to continue business as usual through increasingly questionable offset programs.

The 2030 deadline for the Sustainable Development Goals came and went with no significant progress. The new global development framework, heavily influenced by corporate stakeholders, emphasized "realistic pragmatism" - a term that disguised the abandonment of equity considerations and binding environmental protections. In 2033 came perhaps the most crucial shift in narrative: major oil and gas corporations were formally recognized as "transition leaders" by international bodies, having successfully positioned themselves as indispensable to renewable energy development through their mineral holdings and manufacturing capacity. The mining operations for these "critical transition minerals" ironically became more carbon intensive as easily accessible deposits were depleted.

The mineral crisis of 2037 saw prices spike dramatically amid geopolitical tensions and competitive nationalism. Resource-rich countries in the Global South found themselves caught in new forms of extractive colonialism, with infrastructure development conditional on exclusive mineral rights. The machinery excavating these minerals ran almost exclusively on fossil fuels, with emissions conveniently excluded from corporate carbon reporting. By 2040, environmental regulations that had taken decades to establish were systematically dismantled in the name of "energy security" and "mineral independence." Deep-sea mining operations expanded rapidly despite devastating oceanic impacts, justified by manufactured scarcity narratives and the supposed imperative of technological progress.

The collapse of multinational climate cooperation in 2045 merely formalized what had been evident for years. Public trust in global institutions had been completely eroded, while the ultra-carbonized class continued to profit from both problems and asserted solutions. Now in 2050, the language of environmentalism has been thoroughly co-opted. Sustainability refers to sustaining profits, not ecosystems. Resilience means protecting assets, not communities. Climate action translates to climate adaptation for those who can afford it. The average consumer faces impossible choices: purchase the cheapest products with hidden carbon costs or pay substantial premiums for "green" alternatives that often prove to be elaborate marketing constructs. Even conscientious consumers find themselves trapped in systems designed to make genuine ecological choices nearly impossible. Meanwhile, the actual machinery of extraction has simply shifted its geography and targets. The fossil fuel infrastructure that once focused on oil fields now powers massive mining operations that tear through previously protected lands to extract minerals. These minerals flow to manufacturing centers where workers face hazardous conditions assembling solar panels and batteries – components that are designed for obsolescence to maintain consumption cycles.

The ultra-carbonized class that emerged in the 2030s now controls both traditional energy and the "green alternatives," having positioned themselves as indispensable to both paradigms. Climate refugees face militarized borders established by nations that once spoke passionately about global solidarity. Resource nationalism has replaced international cooperation, with wealthy countries guarding their technological advantages and energy security through increasingly aggressive foreign policy. The planet warms more slowly than worst-case scenarios predicted, but it warms nonetheless, while those who created the crisis now profit from selling limited protections against its consequences. Energy demand is left unchecked, especially in the Global North, where renewables now fuel AI-powered systems, automation, and extensive data centers. In the end, the green transition wasn't a transformation; it was capitalism as usual.

Back-casting Timeline: "Growth at all costs" (2025-2050)

- **2025:** Global fossil fuel subsidies persist, oil/gas firms strategically enter green sectors, setting up corporate control.
- **2027:** Global CRM wars around securing supply chains increase, failed climate commitments shift focus to adaptation and offsets.
- **2030:** Corporate-influenced next global development agenda lacks enforcement on equity/sustainability.
- **2033:** Oil/gas firms globally recognized as 'transition leaders' after acquisitions, CRM mining becomes more carbon-intensive.
- **2037:** Global CRM prices spike due to geopolitic, Global South faces interven and extraction dependency.
- **2040:** Global mineral scarcity justifies less regulated, destructive mining; global climate cooperation erodes.
- **2045:** Failed global development agenda leads to public distrust, adaptation is survival for many nations.
- **2050:** Global energy-intensive economies rely on fossil fuels, oil/gas corporations dominate CRMs and renewables.

Opportunities and Threats

The following table showcases the opportunities and threats identified across the scenario development for Continued Growth: Growth at all Costs.

Figure 11: Opportunities and Threats for Continued Growth: Growth at all Costs

Opportunities	Threats
Regional blocs in the Global South explore limited alliances to protect economic sovereignty and resist full market capture.	The global renewable energy markets dominated by oil and gas companies and with increased control over extraction for critical minerals.
Despite limited choices, a growing ethical and climate-conscious consumer base can pressurize markets for supply chain transparency and more responsible sourcing.	Global North capitalizes on the Global South by shifting carbon-intensive foreign owned projects like data centers powered by local renewables, offering minimal to no local value addition.
Grassroots movements gain public support to pressure institutions and build alternative governance models.	Loss of productivity due to unmitigated climate change and heat stress
	Lack of regulatory practices and reporting could lead to fragmentation of distribution of benefits to communities most impacted. What is not monitored cannot be managed.
	Global South countries remain locked into the low value ends of the supply chain, unable to move into processing, refining, or manufacturing stages.
	Clean energy is available but not equitably. the Ultracabonized class in the Global North enjoy 24/7 clean power while vulnerable communities' rural regions in the Global South remain off-grid, energy-poor, and vulnerable to blackouts.

This figure is original by the authors

Implications

Power Dynamics

A future where power has become increasingly concentrated in the hands of oil and gas companies that have strategically positioned themselves as the renewable energy transition leaders. These companies maintain their dominance over the global energy system through several mechanisms:

- **Dual Portfolio Strategy** - They maintain profitable fossil fuel assets while acquiring renewable technologies and companies that once threatened their business model.
- **Resource Control** - By 2050, they control both traditional fossil fuel extraction and the minerals necessary for renewable technology, creating a monopolistic grip on the entire energy sector.
- **Narrative Capture** - Co-opted the language of environmentalism, sustainability, and transition, allowing them to present themselves as solutions to problems they continue to cause.
- **Policy Influence** - The dismantling of environmental regulations in the name of energy security leading to lobbying to shape governance in their favor.

Who benefits?

- **The "Ultra-Carbonized Class"** - Positioned themselves to profit regardless of which energy paradigm dominates.
- **Lobbyists** - Former oil and gas companies that have successfully diversified to control renewable markets while maintaining fossil fuel operations. Their strategic acquisitions of renewable startups beginning in 2025 allowed them to neutralize competition.
- **Countries in the Global North** - Countries practicing resource nationalism and implementing militarized borders to protect their energy security and technological advantages.

Who is impacted?

- **Vulnerable Communities** - Especially those in resource-rich regions of the Global South who face:
    - Hazardous working conditions in mining operations and manufacturing centers
    - Family displacement due to resource extraction
    - Exploitation through low wages
    - Loss of land rights and community displacement
- **The "Still-Carbonized Class**" - Those trapped in debt economies created by green capitalism, forced to pay premiums for supposedly green products or remain dependent on carbon-intensive alternatives.
- **The "Uncarbonized Class**" - Those whose territories provide the minerals for the green transition without receiving benefits.
- **Climate Refugees -** People displaced by climate impacts who face militarized borders established by nations that once spoke passionately about global solidarity.
- **Consumers-** Faced with the impossible choices between affordable products with hidden carbon costs or expensive greenwashed alternatives.

7.3.2. Collapse: Race for the Green Dollar

Summary

In 2050, what began as an environmental movement has been captured by corporate interests, transforming "green technology" into a vehicle for wealth accumulation rather than planetary healing. Multinational corporations and powerful lobbying groups dominate the renewable energy landscape, creating monopolized markets that severely limit true sustainability progress. Renewable energy adoption remains surprisingly minimal considering less climate investment, as greenflation has concentrated both power and wealth in the hands of a few global lobbyists. Consumers find themselves with vanishingly few options to exercise climate-conscious or ethical purchasing choices, trapped in a system that offers the appearance of sustainability while delivering little environmental benefit.

The ultra-wealthy have successfully reframed environmental crisis as opportunity, accumulating unprecedented wealth through "green extractivism" – mining and resource acquisition conducted under the banner of building a "Green World." This narrative mask the continued exploitation of natural resources and vulnerable communities. Geopolitical tensions have intensified, particularly between China and Western powers, as they compete for control of critical mineral resources. This global divide has created an unstable international system where cooperation on climate challenges has become nearly impossible. In this economically volatile landscape, vulnerable communities and mining workers exist in perpetual danger. Without strong regulations governing the extraction of critical raw materials, exploitation flourishes under the cynical banner of growing "Race for the green dollar."

Assumptions About Drivers' Behaviours

- **Renewables cost-competitiveness with fossil fuels:** Despite core renewable technologies becoming more economical compared to fossil fuels, the costs from extraction to deployment in the CRM value chains have increased substantially, mostly due to privatization of resource-rich lands, capitalization of previously common resources, and monopolistic market consolidation.
- **Reduced reliance on volatile fossil fuel markets and geopolitical risks:** The unstable and hypercompetitive geopolitical environment has undermined energy security globally. Access to energy resources is increasingly governed by tightly controlled market regulations and nationalistic policies that restrict supply chain.
- **Market Dynamics:** The supply chain for critical raw materials has become thoroughly monopolized by multinational corporations and their lobbyists, severely limiting the growth potential for genuinely sustainable renewable energy solutions.
- **Tools for Global Governance:** The Paris Agreement, now 35 years old, has faded into irrelevance as most nations have started to abandon their Nationally Determined Contributions. New international frameworks primarily address the growing world divide and energy security concerns rather than climate action.
- **Global Temperature Rise:** Acceleration of climate induced migration as the environment is deteriorating due to the extractive-economic model driving the renewable transition.
- **Ethical and Climate Conscious Consumers:** Consumer sentiment regarding ethical sourcing and climate-conscious consumption has reached new lows as green capitalism systematically eliminates meaningful consumer choice under the illusion of environmental responsibility.
- **Neocolonialism:** Global South has lost most of its power of MNCs and Lobbyists and the resistance towards extractive practices has become nil as the power shifts to different actors in the system.

Narration

It is 2050, the sun sets over what was once a pristine rainforest but now a vast pit mine stretching to the horizon. Excavators branded with eco-friendly logos extract lithium proclaiming, "Building a Sustainable Tomorrow." The reality: corporate capture of green extactivism.

What began in the early 2020s as a genuine movement toward sustainability has now shifted into something completely unrecognizable. The warning signs were there as early as 2025, when multinational energy giants began aggressively acquiring renewable startups and absorbing them into existing corporate structures. These acquisitions were celebrated as "mainstreaming green technology," but represented the first stage of monopolistic control. By 2027, the "Sustainability Premium" had entered the global landscape as corporations began charging higher prices for minimally improved environmental standards. This pricing strategy effectively transformed sustainability from a universal goal into a luxury good, accessible only to the wealthy while creating the illusion of progress. The world now operates under "green extractivism", a concept that first entered the global narrative in 2029 when the first major scandals revealed the devastating environmental and social impacts of supposedly sustainable mining operations.

Five global lobbying conglomerates now control virtually all patents and rights related to renewable energy technologies, a monopolization that began around 2033 when they secured control over green technology patents. By 2037, the renewable energy supply chain had become 80% monopolized, eliminating meaningful competition and consumer choice. What should have been humanity's saving hope has become an economic prison. Solar panels, wind turbines, and battery storage are now luxury items available only to those who can afford the increasing "Sustainability Premiums".

In major cities, corporate headquarters have rooftop gardens, while the minerals that built them were extracted through broken communities. The ultra-carbonized class are shelter in climate-controlled comfort, protected from the chaos their choices helped create. "We believed we were supporting the planet by paying sustainability premiums, but the reality is that we were simply funding the creation of new monopolies" says a consumer advocate.

International cooperation and agreements have fractured along resource lines. China and Western powers have abandoned any pretense of cooperation, instead they for critical minerals. This divide became formalized in 2041 when the two powers established separate environmental standards frameworks, cementing the global divide and breaking away from international cooperation models. These critical minerals have become the oil of the 21st century, with the crucial difference that they were supposed to end resource conflicts, not create new ones. The first widespread climate-related resource conflicts erupted in 2039 as nations competed for to secure supply chains. What began as economic competition evolved into wars and direct military confrontation, all conducted under the banner of securing sustainable futures. Two incompatible environmental standards frameworks now govern the world, neither with any genuine commitment to ecological preservation nor international support. Nations align with one or the other based purely on economic self-interest. The Paris Agreement, abandoned in 2031 as multinational corporations gained controlling influence in climate policy formation, represents perhaps the last moment humanity might have chosen cooperation over competition.

In the resource-rich regions of the Global South, corporate-governed mining territories operate with licence. The first such territories were established in 2046, operating with minimal state oversight or environmental accountability. These entities, legally distinct from their parent corporations but entirely controlled by them, represented the final evolution of corporate power from influencing states to replacing them entirely. The term "neocolonialism" has changed to something more straightforward and unreserved. Mining operations, both legal and illegal, are thriving with minimal distinction between them in practice. Since 2034, artisanal mining became widespread as communities desperately sought economic opportunities. Illegal mining operations led to unprecedented human rights violations in both renewable and non-renewable resource sectors.

Workers labor in conditions replicating early industrial revolution, all to extract the minerals for products marketed as “sustainable”. "My grandfather fought against the oil companies," says one indigenous community member near a massive cobalt mine. "We thought renewable energy would be different, but we have lost even more land, and the rivers flow with new poisons." Climate migration has accelerated, with displaced communities find themselves unwelcome wherever they go. Culture, language, and heritages are being lost as people are forced to abandon ancestral homes and ways of life.

For the average consumer, the promise of ethical purchasing has proved to be an illusion. In 2043, international standards for ethical sourcing collapsed as enforcement mechanisms were systematically deprioritized to serve lobbying interests. Products come labeled with meaningless certifications created by the very corporations they regulate. By 2035, the term "greenwashing" is no longer in use not because the practice had ended, but because it has become the norm. The monopolization of the green economy has been so thorough that the concept of consumer choice has become a matter of the past.

Despite decades of "green innovation," actual environmental indicators continue to decline. Heat waves make increasingly large portions of the globe uninhabitable for parts of the year. Marine ecosystems collapse as newly legalized seabed mining operations destroy habitats in the name of extracting minerals for "clean energy." Perhaps most devastating is the knowledge of what might have been. The technological capability to create a genuinely sustainable world existed. Early innovations in community-owned renewable energy, circular economy principles, and regenerative agriculture indicated a promising future. But each was systematically acquired, marginalized, or regulated out of existence by established interests that recognized the threat they posed to centralized profit models.

As 2050 unfolds, the "Race for the Green Dollar" has reached its logical conclusion. The economy built on monopolized critical minerals and renewable energy technology has failed to address the very challenges that gave it legitimacy, leading to an unprecedented concentration of wealth. Lobbyists have built an economy on the monopolization of critical raw minerals supply chains and renewable energy technology. Resource conflicts and extractivism have become normalized as the necessity of the green transition, while the planet continues to face environmental crisis. The "Race for the Green Dollar" reaches culmination as lobbyists build up the economy on monopolization of CRMs supply chain and RE technology while resource conflicts, and extractivism become normalized as "inevitable aspects" of the green transition.

Back-casting Timeline: "Race for the Green Dollar" (2025-2050)

- **2025:** Multinational energy giants are acquiring innovative solar startups, absorbing them into existing corporate structures.
- **2027:** "Sustainability Premium" becomes common marketing term as corporations charge higher prices for minimally improved environmental standards
- **2029:** First major "green extractivism" scandals reveal devastating environmental and social impacts of supposedly sustainable mining operations.
- **2031:** Paris Agreement targets are abandoned as multinational corporations gain controlling influence in climate policy formation.
- **2033:** Five major Lobbyists secure monopolistic control over green technology patents, effectively stifling innovation and affordability and mining operations.
- **2034:** Artisanal mining will become widespread and Illegal mining operations lead to more human rights violation both in renewable and non-renewable sector
- **2035:** The term "greenwashing" falls out of use as consumers accept corporate environmental narratives without question
- **2037:** Renewable energy supply chain has been 80% monopolized, eliminating meaningful competition and consumer choice.
- **2039:** First widespread climate-related resource conflicts erupt as nations compete for secure CRMs supply chain.
- **2041:** China and Western powers formalize their separate environmental standards frameworks, leading the global divide
- **2043:** International standards for ethical sourcing collapse as enforcement mechanisms are systematically dismantled for Lobbyists interests.
- **2046:** First corporate-governed territories established in resource-rich regions, operating with minimal state oversight or environmental accountability.
- **2050:** The "Race for the Green Dollar" reaches culmination as lobbyists build up the economy on monopolization of CRMs supply chain and RE technology while resource conflicts, and extractivism become normalized as "inevitable aspects" of the green transition.

Opportunities and Threats

The following table showcases the opportunities and threats identified across the scenario development for Collapse: Race for the Green Dollar.

Figure 12: Opportunities and Threats for Collapse: Race for the Green Dollar

Opportunities	Threats
More transparency in reporting around mining operations and practices	Not taking any action to prevent climate change by govt and companies both
Government taking back control to serve for humanity	Human greed for innovation and Survival
Incentives to make CETs affordable	Corruption
More coalitions/ agreements among countries to ease out the supply chain and promote equitable distribution of CRMs	Not focusing on human rights/ workers' rights
more opportunity in climate financing models	Regulations around illegal mining of CRMs
	Declining in the well-being of workers and vulnerable group of people

This figure is original by the authors.

Implications

Power Dynamics

In this scenario, power has shifted dramatically to corporate lobbying interests, creating a system of extraction and exploitation under the disguise of sustainability:

- **Lobbying Conglomerates** - Five global lobbying conglomerates now control virtually all patents and rights related to renewable energy technologies, having secured this monopolistic position beginning around 2033.
- **Corporate Governance** - By 2046, corporate-governed mining territories operate with near-complete autonomy in resource-rich regions of the Global South, representing the "final evolution of corporate power from influencing states to replacing them entirely."
- **Geopolitical Division** - Since 2041, China and Western powers have established separate environmental standards frameworks, fractured international cooperation and created a global divide where nations align based purely on economic self-interest.
- **Patent Control** - The monopolization of green technology patents entrenches the current trend towards IP control and global patent regimes, allowing corporations to extract maximum profit through "Sustainability Premiums."

Who Benefits?

- **The Ultra-Carbonized Class** - Like the first scenario, elites benefit from both the problems and purported solutions, sheltering "in climate-controlled comfort, protected from the chaos their choices helped create."
- **Lobbying Conglomerates** - These entities have built an economy based on the monopolization of critical raw minerals supply chains and renewable energy technology, allowing them to extract maximum profit while minimizing environmental responsibility.
- **Ultracarbonizied class** benefits as they monopolize the renewable energy market by introducing "Sustainability Premium" becomes common marketing term as corporations charge higher prices for minimally improved environmental standards.
- **Mining Corporations** - Both legal and illegal mining operations thrive with minimal distinction between them, extracting resources with limited oversight while marketing themselves as essential to the green transition.

Who is Impacted?

- **Vulnerable Communities -** Particularly those in resource-rich regions who experience:
    - Hazardous working conditions "replicating the early industrial revolution"

  - Family displacements as communities are uprooted for mining operations
  - Exploitation through low wages
  - Loss of land rights and community displacement
  - Child labour and forced labour due to green extractivism
- **Indigenous Peoples** - As expressed by one indigenous community member: "We thought renewable energy would be different, but we have lost even more land, and the rivers flow with new poisons."
- **Consumers** - Faced with "meaningless certifications created by the very corporations they regulate" and the collapse of ethical sourcing standards in 2043, consumers have lost any meaningful choice in the marketplace.
- **The Still-Carbonized Class** - Those who remain dependent on carbon-intensive systems but lack the protections needed against the extractive practices of critical raw minerals mining.
- **The Uncarbonized Class** - Communities whose territories provide the raw minerals for the green transition but receive none of the benefits and suffer the greatest environmental consequences.
- **Climate Migrants** - Displaced communities "find themselves unwelcome wherever they go," with cultures, languages, and heritages being lost as people are forced to abandon ancestral homes.

7.3.3 Disciplined: "Thriving within limits"

This scenario explores the question “what ought” to happen to create the most promising conditions favourable scenario in the favour of embedding social equity in the global transition to renewable energy? It envisions a future that support vulnerable communities and mining workers while in a regulated economy that is coalition-based, a need-driven demand based. It represents a baseline scenario; Oil and Gas companies hold power and influence which has shifted to governments in “Thriving within limits”. This shift has largely shaped how markets, consumers, vulnerable communities, and mining workers will enjoy regulated policy and reporting standards, benefiting these groups.

Summary

In 2050, the Disciplined World represents a transformed energy-capitalist system where economic growth is carefully managed rather than maximized, prioritizing equitable distribution of minerals critical to the renewable energy transitions through coalition-based, need-driven demand systems. Renewable energy adoption has scaled up through collaborative approaches focused on actual needs, while energy security is ensured through a managed transition from fossil fuels. This disciplined approach emphasizes shared benefits through innovative value-sharing business models supporting small and medium enterprises, with regional cooperation replacing global supply chains. The entire system is anchored by rigorous reporting and sustainability standards ensuring transparency and accountability across all sectors, representing a fundamental shift from profit maximization to optimizing wellbeing within planetary boundaries.

Assumptions of the drivers’ behaviours

- **Renewable energy cost-competitiveness with fossil fuels:** Access to renewable Energy becomes more becomes more affordable. RE and Fossil fuels share a fair share of the market, as regulated management of critical minerals leads to making RE more affordable and scalable.
- **Reduced reliance on volatile fossil fuel markets and geopolitical risks:** A stable CRM supply chain is secured through global governance that includes both the Global North and South. Fair trade policies ensure shared responsibility for energy security and equitable access for the Global South.
- **Market dynamics:** Critical minerals management for the renewable energy transition has increased the competitiveness of the RE industry, which has led to increased investments by 8-fold in 2050.
- **Tools for Global Governance:** The Paris Agreement and future international climate frameworks integrate social equity as a mandated priority, guiding countries to adopt, adapt, and thrive through their NDCs. New international agreements enhance Global South representation, promoting equitable resource sharing and a need-based extraction model that secures energy access for both the Global South and North.
- **Global Temperature Rise:** Through coordinated and regulated global action, temperature rise has been stabilized, dramatically reducing climate-induced displacement and migration pressures in vulnerable regions.
- **Ethical and Climate Conscious Consumers:** Consumers expect, and demand ethically produced goods. Strictly regulated supply chains have fostered a culture of accountability, expanding demand for transparent, sustainable, and socially responsible products across sectors.
- **Neocolonialism risks:** There is a synergy between the Global North and Global South where critical minerals for renewable energy is seen as a common resource. Global North takes accountability and focuses efforts and financing through a social lens to protect the global south from the consequences of critical minerals extraction, reducing resistance and fostering trust through equitable collaboration.

Narration

In the bright morning of 2050, a delegation from the Pan-African Mineral Governance Coalition enters the glass atrium of the Global Resource Management Center in Singapore. Their arrival represents one more successful chapter in the remarkable transformation of our economic systems over the past 25 years. They have come to present data on their innovative lithium reclamation projects, technology that will further reduce primary extraction needs while ensuring their region maintains its crucial role in the renewable energy value chain. Society has abandoned the relentless pursuit of unconstrained growth in favor of a more measured approach to prosperity. The transformation was not a rejection of markets or organisations but rather their thoughtful redirection toward genuine wellbeing within planetary boundaries. The central principle of this disciplined economy is remarkably simple: critical resources are managed based on actual needs rather than maximum profit potential. The extraction, processing, and distribution of minerals vital to renewable energy technologies are governed by coalition-based frameworks that prioritize equitable access over market dominance. This shift has not diminished prosperity but instead redefined and redistributed it. Small and medium enterprises emerge under innovative value-sharing business models that prioritize community benefits and worker ownership. Regional manufacturing hubs, connected through collaborative rather than competitive frameworks, have replaced the vulnerable global supply chains of earlier decades. The deployment of renewable energy is based on actual needs and guided by a lens of energy security for all.

In 2026, a coalition of mineral-rich nations established the first comprehensive Mineral Resources Governance Framework, introducing the revolutionary concept of need-based extraction quotas. This marked the beginning of the end for purely profit-driven resource exploitation models that had dominated for centuries. By 2028, the successful circular economy industrial park model proved the viability of material reuse systems at scale, establishing a blueprint quickly replicated across continents. The 2030 Paris Agreement amendment represented perhaps the most crucial turning point, with binding provisions for North-South mineral sharing that fundamentally transformed resource geopolitics. Developed nations committed to technology transfer and infrastructure support in exchange for collaborative resource stewardship.

In 2033, several pioneering nations formally adopted Social Equity indicators as complements to GDP to measure progress, institutionalizing the shift away from the growth maximization paradigm that had defined economics for generations. The global carbon pricing system reached its effectiveness threshold in 2035, dramatically accelerating renewable energy investments while creating funding streams for benefit-sharing business models that could now compete with traditional corporate structures. A critical technological breakthrough came in 2038, when mineral recycling efficiency reached 45%, substantially reducing primary extraction needs and alleviating pressure on the Global South's ecosystems and communities.

By 2042, regulated energy democracy frameworks between China and Western nations formalized resource-based international agreements, replacing the competitive tensions that had characterized previous decades. The 75% global renewable energy access milestone achieved in 2045 demonstrated the effectiveness of need-driven distribution systems, proving that collaborative approaches could succeed where pure market forces had failed. By 2048, economic planning systems optimized for wellbeing within planetary boundaries became the dominant paradigm in major economies worldwide, culminating in the fully realized "Disciplined Thriving World" we inhabit today. The daily experience of living in this disciplined world feels less revolutionary than the changes that created it. People still work, innovate, and consume but within frameworks that prioritize sufficiency over excess and cooperation over competition. Energy has become more affordable and accessible through the careful management of critical minerals, with renewable and traditional energy sources sharing markets under regulatory systems that ensure fair access. This balanced approach has increased renewable energy investments eightfold since 2025, while simultaneously securing stable supply chains through global governance structures that include both Northern and Southern nations.

The take-use-dispose consumer culture has been replaced by a demand for products designed for longevity, repairability, and ethical production. This shift was not driven solely by individual virtue but by strictly regulated supply chains that fostered accountability and transparency across sectors. The feared tensions between the Global North and South have transformed into synergetic partnerships. The extractive neocolonial dynamics that many predicted would characterize the energy transition instead gave way to accountable, collaborative, and contextual frameworks where critical minerals are treated as common resources, with extraction driven by collective needs and growth rather than competition.

Back-casting Timeline: " Thriving withing limits" (2025-2050)

- **2026:** First comprehensive Mineral Resources Governance Framework established by coalition of mineral-rich nations, introducing the foundational concept of need-based extraction quotas rather than profit-driven exploitation.
- **2028:** Breakthrough circular economy industrial park model demonstrated in Southeast Asia, proving viability of material reuse systems at scale and establishing blueprint for regional manufacturing hubs.
- **2030:** Critical Paris Agreement amendment ratified with binding provisions for North-South mineral sharing, fundamentally transforming the geopolitics of resources and energy transition.
- **2033:** Social Equity indicators formally adopted by pioneering nations as complement to GDP, marking first institutional shift away from growth maximization paradigm.
- **2032:** Stringent reposting practices around reporting and traceability have been introduced to ensure fair benefit sharing economy
- **2035:** Global carbon pricing reaches effectiveness threshold, dramatically accelerating renewable energy investments and enabling benefit-sharing business models to compete with traditional corporations.
- **2038:** Critical mineral recycling efficiency breakthrough (45%) substantially reduces primary extraction needs, alleviating pressure on resource-rich regions in Global South.
- **2042:** Regulated Energy democracy frameworks between China and the West based on resource availability in international agreements
- **2045:** Renewable energy access reaches 75% globally through collaborative approaches, demonstrating the effectiveness of need-driven distribution systems over market-only approaches.
- **2048:** Economic planning systems optimized for wellbeing within planetary boundaries become the dominant paradigm, replacing growth-focused capitalism in major economies worldwide.
- **2050:** The "Disciplined World" vision realized: an economic system where resources are managed based on need, benefits are shared equitably, and prosperity is redefined within ecological limits.

Opportunities and Threats

The following table showcases the opportunities and threats identified across the scenario development for Disciplined: "Thriving within limits".

Figure 13: Opportunities and Threats for Disciplined: "Thriving within limits"

Opportunities	Threats
Regulation of critical minerals within coalitions based on needs: mining for critical minerals is managed based on demand needs.	Division of power and increased geopolitical tensions.
air labour practices and more emphasis on human rights for vulnerable communities	Potential increase in illegal practices and corruption in critical mineral supply chains despite regulatory frameworks.
Localized efforts to increased waste management to secure critical minerals for energy security without overreliance.	Increase of non-renewable energy infrastructure waste as systems are retired.
Material innovation and sustainability standards drive the development lower environmental and social-impact tech solutions.	Potential increase in illegal practices and corruption in critical mineral supply chains despite regulatory frameworks.
Enhanced local efforts to manage waste and recover critical minerals, reducing overreliance on new extraction.	Over-regulation in some sectors may hinder innovation or create barriers to entry for under-resourced actors.
High consumer demand for transparency drives adoption of traceability tools (e.g., blockchain, digital twins) in supply chains.	Compliance enforcement may vary across countries, risking uneven implementation and slower global progress.

Opportunities	Threats
Increased regulated manufacturing capacity for solar panels, wind turbines, and battery storage will create pathways for employment opportunities.	Even with regulation, corruption and black-market trading continue to threaten managed supply chains.
Consumer demand for ethical and green products drives innovation in supply chain transparency. technologies (blockchain, digital twins, etc.) that can verify ethical sourcing.	
North-South collaboration moves beyond foreign aid to co-ownership of resources and contextual accountability on both sides.	
Community-centred energy systems based on demand to build local resilience in times of global volatility.	
Enables a redefining of value beyond extraction to sufficiency and social value for example care, repair, and community wellbeing.	

This figure is original by the authors.

Implications

Power Dynamics

- **Governments** in the Global South - Governments have reasserted authority through frameworks like the 2026 Mineral Resources Governance Framework with need-based extraction quotas, regaining control from corporate interests.
- **Coalition-Based Governance** - The Pan-African Mineral Governance Coalition exemplifies how regional bodies now have significant influence in the management of critical resources, creating more balanced power dynamics between resource-rich and resource-consuming nations.
- **Local Communities** - Communities directly affected by resource extraction have gained meaningful decision-making power, transforming from victims of extraction to active stakeholders in governance.
- **International Collaboration** - The 2042 "regulated energy democracy frameworks between China and Western nations" have replaced competitive tensions with formalized resource-based international agreements.
- **Multi-Stakeholder Institutions** - The Global Resource Management Center in Singapore represents a new form of collaborative governance where different regions share technology and data rather than competing for resource dominance.

Who Benefits?

- **The Global South** - Benefits from data-driven decisions that improve planning and resource management. International agreements include "binding provisions for North-South mineral sharing" fundamentally transformed resource geopolitics in their favor.
- **Vulnerable Communities** - Experience increased protection of rights through transparency and accountability mechanisms.
- **Small and Medium Enterprises** - Thrive under "innovative value-sharing business models that prioritize community benefits and worker ownership," creating economic opportunities beyond large corporations.
- **Local Communities** - Gain from "Regional Coalitions for energy access" and the establishment of regional manufacturing hubs that keep value within communities rather than extracting it to distant corporate headquarters.
- **The Uncarbonized Class** - Benefits from more evidence-based data to influence global trade agreements and negotiations and decision making, giving previously marginalized groups a voice in resource governance.

Who is Impacted?

- **Industries Driven by Fossil Fuels** - Face significant disruption as the world achieves "75% global renewable energy access" by 2045, requiring major business model transformations.
- **The Ultra-Carbonized Class** - Experiences a reduction in power as the economic paradigm shifts from growth maximization to optimizing wellbeing within planetary boundaries.
- **Traditional Corporate Structures** - Must adapt to compete with new "benefit-sharing business models" that emerged after the global carbon pricing system reached effectiveness in 2035.

7.3.4. Transformation: Circularity-Driven Future

Summary

Set in 2050, this is a Circularity Driven scenario which represents a transformation of global energy systems and economic models built around circular economy principles, prioritizing resource conservation, regeneration, and sustainable knowledge transfer. This scenario falls under the transformative pathway with higher adoption, regulated adaptation, and knowledge-based circular economy that's less energy-dependent than previous economic models. There is higher adoption of RETs because of increased climate finance which has led to increased but regulated CRMs mining. Consumers sentiments are based on strong ethical sourcing practices and climate conscious perspective.

Assumptions About Drivers' Behaviours

- **Renewables cost-competitiveness with fossil fuels:** With widespread use of RE adoption and increased production, has led to dramatic low cost of RE tech lower than fossil fuel-based tech. This has happened in the solar PV and electrification of vehicles.
- **Reduced reliance on volatile fossil fuel markets and geopolitical risks:** Energy independence has increased at regional and local levels through distributed generation. The circular approach has reduced vulnerability to supply chain disruptions.
- **Market Dynamics:** The circularity driven has accelerated further the demand of CRMs by ten-fold which has led to increased production of RE technology.
- **Tools for Global Governance:** Resource nationalism has declined as countries recognize interdependence in circular minerals. International agreements focus on more knowledge sharing and technology transfer rather than extractive economy. Paris agreement among counties for GN and GS is on track and has allowed for shared based economy.
- **Global Temperature Rise:** Through coordinated and regulated global action, temperature rise has been stabilized, dramatically reducing climate-induced displacement and migration pressures in vulnerable regions.
- **Ethical and Climate Conscious Consumers**: Consumers have embraced product -as- service models and prioritize access over ownership. Consumer has started to demand transparency in supply chain as the economy is more circular hence increased climate conscious consumer's base.
- **Neocolonialism:** The scenario emphasis increased return, reuse and repurpose principles with mixing of clear knowledge and technology. Mining for CRMs have decreased hence, Global South resistance to extractive practices of CRMs.

Narration

It is 2025, and collectively humanity has achieved what many thought impossible just 25 years ago, a global economy fundamentally transformed by circular principles. This transformation represents not only an incremental shift but a complete reimagining of how society creates and distributes value, with profound implications for energy systems, resource use, and human wellbeing.
Walking through a city in 2050, and there is no waste in sight. Buildings constructed from modular, sustainable, and reusable components. Transportation systems run on renewable energy generated locally. Products are designed for reuse, repair, and eventual disassembly and their component are tracked through sophisticated digital tags.

This reality has emerged due to convergence of necessity and opportunity. By 2027, global renewable energy technology production capacity had doubled, driving a 30% cost reduction through economies of scale. This dramatic shift made renewable energy not just competitive with fossil fuels but competitively cheaper, accelerating adoption across sectors, industries, and regions. Meanwhile, the concept of product-ownership underwent a profound transformation. In 2028, product-as-service business models reached 15% market share in consumer electronics and appliances, signaling the beginning of a shift away from traditional ownership. Consumers began paying for access and outcomes rather than products, incentivizing manufacturers to design for longevity and circularity.

By 2029, these shifts contributed to a milestone achievement: 65% of Paris Agreement signatories met their interim targets through circular economy principles and renewable energy deployment. This success demonstrated the power of circularity not just as an economic model but as a climate solution. The legal framework supporting this transition strengthened in 2031 when "Right to Repair" legislation became standard across North America, the European Union, and parts of Asia. This legal shift empowered consumers and independent repair businesses while compelling manufacturers to design products for easier maintenance and longer lifespans.

As circular systems matured, a remarkable shift occurred in resource demands. In 2035, despite growing clean energy deployment, the demand for Critical Minerals peaked as circular supplies reached 40% of market needs. This pivot turning point demonstrated how the circular economy could separate prosperity from resource extraction, particularly benefiting regions that had historically borne the environmental and social costs of mining. By 2037, circular business models become the norm in construction, automotive, and electronics sectors. Companies that once profited from planned obsolescence now built their value propositions around durability, repairability, and material recovery. This shift represented not just a technical change but a fundamental reimagining of value creation.

A critical point arrived in 2040 when secondary raw minerals markets exceeded primary markets in volume for the first time for most minerals and rare earths. This milestone signaled that the global economy had begun treating waste as a resource, with profound implications for mining activities and international relations. The transition away from fossil fuels accelerated with the phasing out of the last major fossil fuel subsidy programs in 2042, as renewable energy reached price parity everywhere. This shift completed the energy transition that had begun decades earlier, cementing renewable energy as the foundation of the global economy.

Perhaps the most profound transformation occurred in how nations relate to one another regarding resources. In 2045, international resource governance shifted from an extraction focus to circular material flow management. Countries began seeing themselves not as competitors for scarce resources but as stewards of minerals in continuous cycles. This new paradigm culminated in 2048 when resource nationalism policies were largely abandoned as nations recognized that an interdependent circular economy proved more beneficial than resource hoarding. The Global South, once treated primarily as a source of raw materials, emerged as a leader in circular innovation particularly in design approaches that maximized value from minimal resources. By 2049, consumer behavior had fundamentally transformed, with ownership of new products no longer serving as a primary status symbol in most societies. Instead, people derived status from responsibility, participation in regenerative systems, and access to services that enhanced wellbeing while minimizing ecological impact.

The culmination of these changes is visible in 2050, as the global economy operates on circular principles with 85% of minerals in continuous loops, minimal virgin resource extraction, and democratized renewable energy systems. Energy independence has increased at regional and local levels through distributed generation, while the circular approach has dramatically reduced vulnerability to supply chain disruptions. International agreements now focus on knowledge sharing and technology transfer rather than controlling extractive economies. The Paris Agreement goals are on track, supporting a shared-based economy that benefits both the Global North and South.

This circularity-driven transformation has not just changed how we produce and consume goods but instead has redefined our relationship with minerals, energy, and ultimately with each other. By prioritizing resource conservation, regeneration, and through sustainable knowledge transfer, humanity has created an economy that serves human needs while respecting planetary boundaries, proving that prosperity does not have to come at the expense of the planet. needs while respecting planetary boundaries, proving that prosperity does not need to come at the expense of the planet.

Back-casting Timeline: " Circularity " (2025-2050)

- **2027:** Global RETs (Renewable Energy Technologies) production capacity doubles, driving 30% cost reduction through economies of scale.
- **2028:** Product-as-Service business models reach 15% market share in consumer electronics and appliances sectors.
- **2029:** Paris Agreement interim targets met by 65% of signatories through circular economy principles and renewable energy deployment.

- **2031:** "Right to Repair" legislation becomes standard across North America, EU, and parts of Asia.
- **2035:** CRM (Critical Raw Minerals) demand peaks as circular supplies reach 40% of market needs, reducing new mining pressure.
- **2037:** Circular business models become dominant in construction, automotive, and electronics sectors.
- **2040:** Secondary raw minerals markets exceed primary markets in volume for the first time for most metals and rare earths.
- **2042:** Last major fossil fuel subsidy programs phased out globally, as renewable energy reaches price parity everywhere.
- **2045:** International resource governance shifts from extraction focus to circular material flow management.
- **2048:** Resource nationalism policies largely abandoned as interdependent circular economy proves more beneficial.
- **2049:** Consumer behaviour fundamentally transformed - ownership of new products no longer primary status symbol in most societies.
- **2050:** Global economy operates on circular principles with 85% of minerals in continuous loops, minimal primary resource extraction, and democratized renewable energy systems.

Opportunities and Threats

The following table showcases the opportunities and threats identified across the scenario development for Transformation: Circularity-Driven Future

Figure 14: Opportunities and Threats for the Transformation: Circularity-Driven Future

Opportunities	Threats
Growth in repair, refurbishment, remanufacturing, and recycling sectors allows for job creation along with programmes to upskill	Shift from ownership to access models requires significant behavioural change so there is going to be some cultural resistance
Distributed energy generation creates economic opportunities in previously marginalized regions	Traditional mining regions face economic hardship without careful job transition planning to RE
International policies to support coalitions and Just transition-based trade agreements	Different regulatory approaches could create inefficiencies and loopholes Like corruption etc
Opportunity for more equitable North-South Relations where technology transfer and knowledge sharing replace extractive relationships	There could be various challenges to retain balance between private and public interests
Dramatically decreased mining activity preserves ecosystems and allow for less exploitation of vulnerable communities	Product-as-service models could exclude those unable to maintain regular payments
	Nations or corporations may benefit from others' circularity while avoiding costs themselves
	Companies with business models tied to linear economy may actively oppose changes

This figure is original by the authors.

Implications

Power Dynamics

- **Governments in Global North and South** - Have gained influence through creating legal frameworks around circularity, such as the "Right to Repair" legislation that became standard across North America, the European Union, and parts of Asia by 2031.

- **Local Governments** - Have increased authority as they leverage waste management systems to tap into various stages of critical mineral recovery and foster local circular economies.
- **Consumers** - Have gained significant power through changed consumption patterns, with product-as-service business models reached 15% market share by 2028 in consumer electronics and appliances, fundamentally altering manufacturer incentives.
- **International Governance Bodies** - By 2045, international resource governance shifted from an extraction focus to circular material flow management, creating new cooperative power structures.
- **Distributed Power Systems** - Energy independence has increased "at regional and local levels through distributed generation," decentralizing power both literally and figuratively.

Who Benefits?

- **Consumers -** Benefit from the transformation of ownership models, prioritizing "access over ownership" through product-as-service models, while gaining access to genuinely green technology.
- **The Global South -** Benefits from a "shared-based economy" through adopting principles of circularity. The narrative specifically notes that "The Global South, once treated primarily as a source of raw minerals, emerged as a leader in circular innovation."
- **The Still-Carbonized Class -** Receives greater protection through increased access to energy and employment opportunities in the circular economy.
- **Vulnerable Communities -** Gain protection as the scenario demonstrates "how the circular economy could separate prosperity from resource extraction, particularly benefiting regions that had historically borne the environmental and social costs of mining."
- **Local Communities -** Become "more empowered as they are included in different stages in recycle, reuse and repair," creating new economic opportunities within circular business models.

Who is Impacted?

- **The Ultra-Carbonized Class -** Cannot operate purely for profit as before, with "companies that once profited from planned obsolescence now built their value propositions around durability, repairability, and material recovery.
- **National Governments -** See reduction in traditional power as "resource nationalism policies were largely abandoned by 2048, with nations recognizing that an interdependent circular economy proved more beneficial than resource hoarding.
- **Fossil Fuel Industries -** Face terminal decline following "the phasing out of the last major fossil fuel subsidy programs in 2042," as renewable energy reached price parity globally.
- **Multinational Corporations -** Must fundamentally reassess their business model and redesign structures and processes to meet circularity principles, transforming how they create and capture value.
- **Mining Industries -** Experience dramatic change as secondary raw minerals markets exceeded primary markets in volume for the first time for most minerals and rare earths" by 2040, fundamentally altering extraction economics.

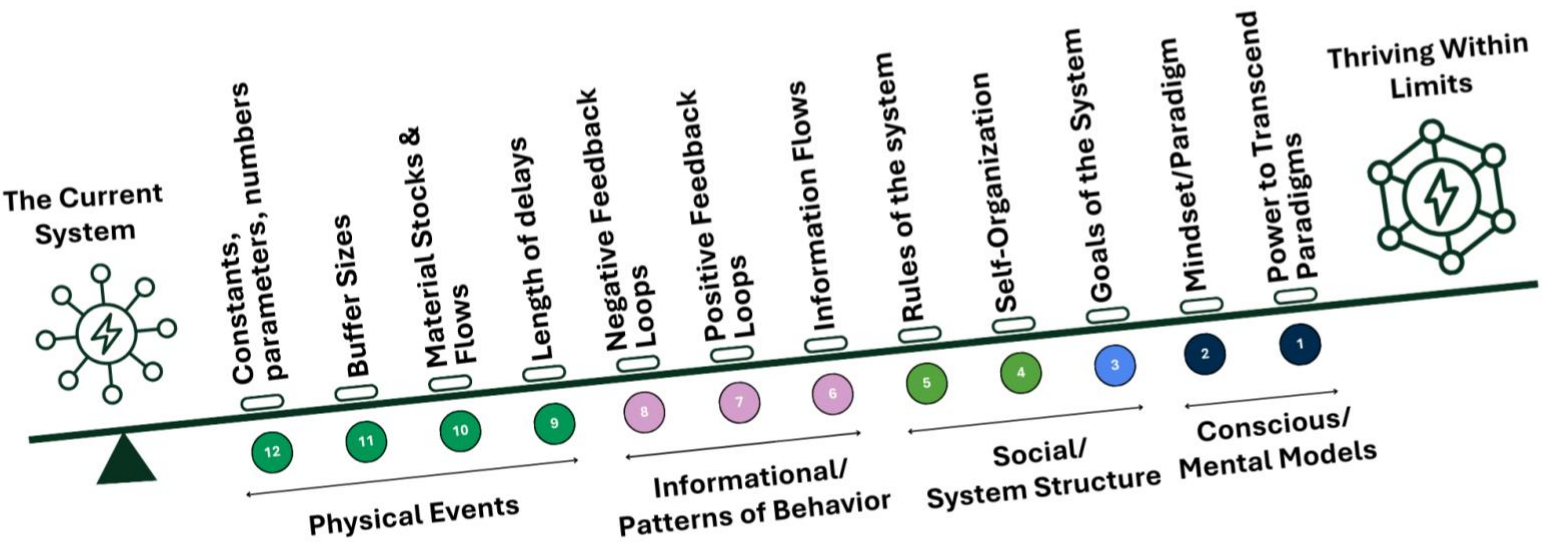
8. Recommended Pathways by Identifying the Leverage Points for Critical Minerals Extraction for Social Equity

This part of the research, aims to answer the questions "what recommended pathways can be introduced in the system to support policy around CRMs extraction practices to incorporate social equity?". The pathways and recommendations below were developed through an iterative and reflective process that synthesized findings from all phases of the research process: from framing the systems, actors mapping, horizon scanning and scenario building. After providing a comparative lens for understanding potential plausible futures, to develop pathways recommendations our research looks at the scenario "Thriving within limits", discipline as the most normative future (Preferred). Because this scenario has been able to focus on social equity by following stringent policies, global agreements and reporting practices which have empowered/benefits vulnerable communities, consumers and mining workers. Particularly looked at various opportunities and threats which arrived in the "Thriving within limits" scenario to identify leverage points in the global renewable energy transition where strategic interventions can be implemented through proposed pathways.

Meadows and The Sustainability Institute (1999) define leverage points as specific places within a complex system where a small shift can result in big changes in the system. Donella Meadows, a systems scientist, devised the concept as a means of identifying the most effective areas in a system to engage in order to effect transformative change. Leverage points can be seen as pressure points of a system where targeted interventions can have disproportionate effects that can ripple across the structure (Meadows and The Sustainability Institute,1999). They range from shallow points (such as adjusting parameters or constants) to deep points (such as changing the system's goals or paradigms).

Places to Intervene in a System

Figure 15: Series *of intervention points ranked from least effective (12) to most powerful (1), represented as a lever with increasing leverage as you move upward.*



This figure is original by the authors.

Categories of Leverage Points: Moving from Deep to Shallow Leverage Points

Conscious/Mental Models

1. Power to Transcend Paradigms refers to recognizing that all paradigms are partial truths and maintaining the flexibility to move between different ways of understanding.
2. Mindset/Paradigm refers to transforming the shared beliefs, values, and underlying assumptions that determine how reality is perceived and what interventions are considered possible.

Social/System Structure

3. Goals of the System refers to changing what the system is fundamentally designed to achieve, which determines its overall direction, priorities, and behavior patterns.
4. Self-Organization refers to enhancing or preventing the system's inherent ability to evolve its own structure, create new relationships, and generate complexity without external forces in play.
5. Rules of the System refers to altering policies, laws, incentives, and consequences that define the boundaries and constraints of the system.

Informational/Patterns of Behavior

6. Information Flows refers to adjusting who has access to what information, modifying what data is gathered, and how knowledge is disseminated within the system.
7. Positive Feedback Loops refers to adjusting self-reinforcing cycles that could create positive ripples in the system, potentially driving rapid growth, decline, or system transformation.
8. Negative Feedback Loops refers to enhancing or weakening the self-correcting mechanisms where a system responds to changes by pushing back.

Physical Events

9. Delays refer to the duration of time between an action taken and their consequences, which could impact stability and decision-making.
10. Material Stocks & Flows refers to altering physical structures and the movement of physical elements through the system. This
includes logistics, transportation networks, resource extraction rates, heat waves, or pollution.
11. Buffer Sizes refers to altering the capacity of stabilizing components that enable systems to absorb transformations, shocks, or changes while preserving functionality during disturbances.
12. Constants, Parameters & Numbers refers to adjusting specific variables within the system, such as subsidies, taxes, or standards.

8.1. Leverage Points and Pathways: Interventions for Social Equity in Critical Mineral Extraction During the Renewable Energy Transition

Paradigm Shifts (Leverage Points 1-2): Transforming the system's deepest beliefs and assumptions

1. **Redefining Value Beyond Extraction**

- From viewing CRMs as commodities to understanding them as common resources
- Incorporating multiple dimensions of value: economic, social, ecological, and cultural
- Recognizing the intrinsic rights of affected communities and ecosystems

Key Stakeholders:

- R&D for Clean Energy Technology Specialists: Essential for redefining technological value chains with social values embedded
- Social Movements Advocates for paradigm change through mobilization and narrative shifting
- Policy Think Tanks Develop alternative valuation frameworks
- Global Policy Agreement Bodies Establish international norms for value redefinition

2. **Indigenous Knowledge Integration**

- Centering Indigenous perspectives and knowledge systems in resource governance
- Recognizing cultural, and spiritual connections to land and resources
- Moving from extractive to regenerative relationships with nature

Key Stakeholders:
- Indigenous Communities Holders of traditional knowledge systems
- International Organizations: Can serve as bridges between knowledge systems
- Government Agencies: Control formal integration of knowledge systems into policy
- Knowledge Platforms: Document and translate indigenous knowledge for broader audiences

3. Cooperative Stewardship Paradigm
- Shifting from competitive resource acquisition to collaborative stewardship
- Developing shared responsibility frameworks between Global North and South
- Embracing sufficiency rather than unlimited growth as a guiding principle

Key Stakeholders:
- Policy Makers: Create formal collaborative frameworks
- Media and News Coverage: Shape narratives about resource relationships
- Financial Market: Must align investment frameworks with stewardship principles
- Organizations in the relationship sphere: Bridge between stakeholder groups

Pathways
- **Redefining CRMs as global shared resource rather a commodity**: This pathway focuses on fundamentally changing how we conceptualize CRMs - moving away from seeing them primarily as market commodities to viewing them as shared resources that belong to all. This shift in perspective recognizes that minerals aren't just economic assets but have multiple dimensions of value including social significance. The strategy involves developing new frameworks that prioritize collective stewardship over private ownership and extraction for profit. This pathway aims to transform the foundational beliefs that drive resource exploitation.
- **Center Indigenous perspectives in governance**: This pathway recognizes that Indigenous knowledge systems offer valuable alternative approaches to resource management that have been largely marginalized in mainstream decision-making. By intentionally elevating and integrating Indigenous perspectives in governance structures, this pathway seeks to incorporate traditional ecological knowledge, holistic worldviews, and cultural understandings of human-nature relationships. This isn't just about consultation but about fundamentally reshaping governance systems to recognize Indigenous communities as rightful decision-makers with unique wisdom about sustainable resource relationships.
- **Replace competition with collaboration**: This pathway addresses the problematic competitive framework that drives resource acquisition and often leads to exploitation. Instead, it promotes collaborative stewardship where stakeholders work together toward shared goals rather than competing for maximum resource extraction. This requires developing new models of international cooperation and dialogue particularly between Global North and South and embracing sufficiency rather than unlimited growth as a guiding principle. The strategy involves creating formal collaborative frameworks where mutual benefit replaces zero-sum competition.

Social/System Structure (Leverage Point 3): Reorienting what the system is trying to achieve

1. Need-Based Resource Management
- Creating extraction quotas based on demonstrated societal needs rather than market demand
- Prioritizing critical applications over luxury consumption
- Balancing climate adaption with social equity considerations

Key Stakeholders:
- Policy Makers and International Organizations: Establish international frameworks for need assessment
- Governments: Implement quota systems and priorities
- Civil Society Advocate for social needs prioritization
- Mining Companies: Must adapt business models to need-based extraction

2. Equitable Distribution Mechanisms

- Ensuring fair allocation of benefits from extraction across the supply chain
- Creating preference systems for local communities in resource-rich regions
- Establishing international agreements on priority uses during supply constraints

Key Stakeholders:
- Legal Systems and Frameworks: Establish binding distribution rules
- Financial Markets: Develop investment models that value equitable distribution
- Vulnerable Communities: Primary beneficiaries requiring direct involvement
- International Organization: Monitor and advocate for equitable distribution

3. Just Transition Objectives
- Prioritizing quality job creation, upskilling and social protection for affected communities
- Developing comprehensive adaptation and resilience measures
- Creating compensation mechanisms for livelihood losses

Key Stakeholders:
- Mining Workers Central to defining meaningful transition measures
- Labor Unions Advocate for worker protections and rights
- Policy Makers and Knowledge Institutions: Develop transition frameworks and best practices
- Governments: Implement and fund transition programs

Pathways:
- **Creating need-based extraction models**: This pathway challenges the market-driven approach to resource extraction by establishing limits based on actual societal needs rather than profit potential. It requires developing mechanisms to assess genuine need, prioritize critical applications over luxury consumption, and balance climate action with social equity considerations. This strategic approach involves quota systems that ensure minerals are directed toward their highest social value use rather than their highest profit use.
- **Implement benefit-sharing across supply chains**: This pathway focuses on ensuring equal benefits from supply chain CRMs extraction, particularly to those communities and regions where extraction occurs. The strategy involves creating preference systems for local communities in Global South and establishing international agreements on priority uses during supply constraints. This approach addresses the historical inequities where extraction impacts are localized but benefits flow elsewhere especially to Global North.
- **Prioritize Mining workers:** This pathway centers the needs of mining workers and affected communities in transition planning. Rather than focusing solely on technological or economic aspects of the energy transition, this approach prioritizes quality job creation, social protection, adaptation measures, and compensation mechanisms for livelihood losses. The strategy involves recognizing that a truly sustainable transition must include concrete measures to ensure social wellbeing and justice.

Social/System Structure (Leverage Points 4-5): Reorganizing the relationships between system elements

1. North-South Co-ownership Models
- Establishing genuine collaboration beyond traditional aid relationships
- Creating joint governance mechanisms with equal decision-making power
- Developing shared responsibility frameworks for environmental and social outcomes

Key Stakeholders:
- Global Policy Agreement Bodies Create enabling international frameworks and Monitor cooperation effectiveness
- Governments both in GN and GS Implement bilateral and multilateral agreements
- Policy Makers: Build diplomatic consensus

2. **Community-Centered Development**
    - Decentralizing decision-making to appropriate local levels
    - Creating direct connections between extraction impacts and benefits
    - Building local resilience against global volatility

    Key Stakeholders:
    - Vulnerable Communities: Central to defining community priorities
    - Indigenous Communities: Often most affected by extraction projects
    - Local Government: Implement community-centered approaches
    - Mining Companies: Must adapt operations to community-centered models

    Pathways
    - **Create shared governance and ownership structures**: This pathway addresses power imbalances in global resource governance by establishing genuine collaboration beyond traditional aid relationships. It involves creating joint governance mechanisms with equal decision-making power between Global North and South stakeholders and developing shared responsibility frameworks for environmental and social outcomes. This strategic approach reconfigures relationships between system actors toward more equitable power distribution.
    - **Pathway: Decentralize decision-making**: This pathway focuses on moving decision authority to more appropriate local levels where impacts are most directly felt. The strategy involves creating direct connections between extraction impacts and benefits and building local resilience against global volatility. This approach recognizes that centralized decision-making often fails to account for local contexts and priorities and aims to empower communities to have meaningful control over resource decisions that affect them.

Informational/Patterns of Behavior (Leverage Points 6-8): Changing the constraints and information available to actors

1. **Fair Labor and Human Rights Framework**
    - Establishing enforceable standards for working conditions in extraction
    - Creating meaningful mechanisms for addressing rights violations
    - Incorporating worker voice and agency in ongoing monitoring

    Key Stakeholders:
    - Legal Systems and Frameworks: Establish binding labor standards
    - Mining Workers: Provide ground-level insights on conditions
    - Labor Unions: Advocate for worker protections
    - International Organizations: Monitor human rights compliance

2. **Transparency and Traceability Systems**
    - Implementing blockchain-verified supply chains for critical minerals
    - Creating open-source tracking platforms accessible to all stakeholders
    - Developing standardized social impact reporting frameworks

    Key Stakeholders:
    - R&D for Clean Energy Technology: Develop traceability technologies
    - Mining Companies: Implement transparency systems in operations
    - Consumers: Drive demand for transparent products
    - Media and News Coverage: Amplify transparency findings

3. **Free, Prior, and Informed Consent Requirements**
    - Mandating meaningful consultation with affected communities
    - Establishing veto rights for communities facing significant impacts
    - Creating independent verification of consultation processes

Key Stakeholders:

- Indigenous Communities: Principal rights-holders in FPIC processes
- Legal Systems and Frameworks : Establish binding FPIC requirements
- Governments: Implement and verify consent processes
- International Organisations: Monitor FPIC implementation

Pathways:

- **Establish binding standards**: This pathway focuses on creating enforceable rules for labor conditions and human rights in mineral extraction. Rather than voluntary guidelines that can be ignored, this approach emphasizes legally binding standards with meaningful consequences for violations. The strategy involves incorporating worker voice in ongoing monitoring to ensure standards reflect real needs and experiences rather than just top-down requirements.
- **Implement supply chain visibility**: This pathway addresses information asymmetries by making resource flows transparent to all stakeholders. The strategy involves implementing technologies like blockchain verification for CRMs supply chains and creating open-source tracking platforms accessible to all. This approach recognizes that meaningful accountability requires accurate information about where minerals come from and under what conditions they were extracted.
- **Mandate meaningful consultation**: This pathway focuses on ensuring that affected communities have genuine input into extraction decisions through requirements for Free, Prior, and Informed Consent. The strategy involves establishing community veto rights for significant impacts and creating independent verification of consultation processes. This approach addresses power imbalances by ensuring communities can make informed decisions about resource projects rather than having changes imposed on them.

Physical Events (Leverage Points 9-12): Strengthening or creating mechanisms that can alter system behavior

1. Community Monitoring Initiatives

- Establishing community-led impact assessment teams
- Creating accessible grievance mechanisms with enforcement authority
- Developing real-time monitoring systems for environmental and social impacts

Key Stakeholders:

- **Vulnerable Communities**: Lead monitoring efforts with their contextual knowledge
- **Governments**: Provide enforcement authority
- **International Organizations**: Support capacity building for monitoring
- **R&D for Renewable Energy Technology**: Develop monitoring technologies

2. Benefit-Sharing Agreements

- Linking extraction volume to community benefit distribution
- Creating automatic escalation and trickling down of benefits during price increases
- Establishing community ownership stakes in extraction operations

Key Stakeholders:

- Mining Companies: Implement agreements in operations
- Legal Systems and Frameworks: Establish binding agreement structures
- Financial Markets: Value and validate benefit-sharing models
- Community Organizations: Negotiate agreement terms

3. Regulatory Enforcement Mechanisms

- Developing international certification systems around accomplishing benefit-sharing models and social equity
- Creating financial penalties for non-compliance with social standards
- Establishing import restrictions based on social performance

Key Stakeholders:

- Policy Makers: Establish international enforcement frameworks
- Governments: Implement enforcement measures
- Civil Society, Social Movements, and Consumers: Apply pressure for rigorous enforcement
- Legal Systems and Frameworks Create binding compliance mechanisms

Pathways:

- **Establish local oversight capacity**: This pathway empowers communities to monitor and report on extraction impacts in real-time. The strategy involves establishing community-led impact assessment teams, creating accessible grievance mechanisms with enforcement authority, and developing monitoring systems for environmental and social impacts. This approach strengthens feedback loops by ensuring those most affected by extraction can generate reliable information about impacts and trigger responses when needed.
- **Link benefits to extraction impacts**: This pathway creates direct connections between the scale of extraction and the benefits flowing to vulnerable communities. The strategy involves automatic escalation of benefits during price increases and establishing community ownership stakes in extraction operations. This approach addresses power imbalances by ensuring extraction cannot proceed without proportional benefits flowing to those experiencing the impacts.
- **Create consequences for non-compliance**: This pathway focuses on establishing meaningful enforcement mechanisms to ensure standards are followed. The strategy involves developing international certification systems with real consequences, creating financial penalties for non-compliance with social standards, and establishing import restrictions based on social performance. This approach recognizes that without consequences, standards and requirements often remain ineffective and creates feedback loops that can alter system behavior through meaningful incentives and penalties.

Successfully embedding social equity in critical minerals extraction requires interventions across multiple leverage points, with particular emphasis on transforming underlying paradigms and system goals. By addressing power imbalances, ensuring participation from stakeholders, and creating robust accountability mechanisms, this framework provides a pathway towards social equity in the renewable energy transition. The challenge lies not in technical solutions alone but in fundamentally reimagining and redesigning our relationship with resources and with the vulnerable communities.

Implementing these requires acknowledging and working with the existing stakeholders while gradually shifting power dynamics to create more equitable outcomes. This process must be iterative, adaptive, and deeply committed to centering the voices of those who have traditionally been marginalized in resource extraction decisions.

Future Scope

Digital Information Campaign: Convert the research paper into engaging digital content across multiple platforms to raise public awareness about the critical minerals in everyday devices and their connection to renewable energy transition.

Policy Maker Engagement: Conduct workshops with various stakeholders to contextualize our research findings into practical pathways that can guide balanced decision-making around renewable energy and mineral extraction challenges.

International Policy Integration: Develop frameworks and guidelines for international and government organizations to incorporate our proposed pathways into their policy briefs, ensuring responsible approaches to renewable energy transition globally.

Future Research Scope: Future research could include examining practical applications of equity frameworks in mineral extraction settings, exploring alternative economic models emerging from renewable energy transitions across different contexts, and investigating social equity challenges throughout the entire critical minerals value chain.

Conclusion

With growing energy demands and the climate challenges caused by the current global energy system, achieving the climate goals set by the Paris Agreement and endorsed by the international community requires a radical transformation of the energy system. Systematic changes are necessary to accelerate the decline in fossil fuel use and rapidly scale up clean energy technologies, including renewable energy.
This research project sought to address the primary research question: **How can policy frameworks be shaped over the next 25 years for countries rich in critical minerals, driving a just energy transition while prioritizing social equity?**

The transition to renewable energy is not simply a technological shift; it is a complex societal transformation driven by the urgent need to decarbonize and mitigate climate change. However, as the research reveals, the escalating demand for minerals like lithium, cobalt, nickel, and copper to fuel clean energy technologies—projected to more than double by 2030 and triple by 2040—threatens to replicate and exacerbate historical patterns of exploitation in the Global South. The pursuit of a "green" energy system risks perpetuating a "green extractivism" that prioritizes resource acquisition over the rights and wellbeing of vulnerable communities, mirroring the injustices of the fossil fuel era.

Throughout this research, the concept of social equity has served as a guiding principle, emphasizing the need for a just distribution of both the benefits and burdens of the energy transition. To address the research question, this study employed a mixed-methods approach, combining systems thinking and strategic foresight within a design thinking framework.

The methodology followed four iterative phases:

- **Discover:** This phase involved a comprehensive literature review, expert interviews, and document analysis to establish a foundational understanding of the energy system, critical minerals landscape, and the social equity challenges at stake.
- **Define:** Systems mapping tools, including Iterative Inquiry, Rich Context Mapping, and Actor Mapping, were utilized to analyze the complex interrelationships within the critical minerals system and to identify key actors and power dynamics.
- **Develop:** Strategic foresight techniques, such as horizon scanning and scenario development, were employed to explore potential future trajectories of the energy transition and their implications for social equity.
- **Deliver:** The culmination of the research involved the identification of leverage points and the development of pathways for embedding social equity into decision making and policy frameworks governing critical mineral extraction.

The findings of this research highlight the urgent need to move beyond a narrow focus on resource acquisition and embrace a more holistic and equitable approach to the energy transition. This requires a fundamental reimagining of the relationship between nations, corporations, communities, and the environment. Ultimately, the transition to renewable energy presents an unparalleled opportunity to forge a future that is not only environmentally sustainable but also socially just.
However, realizing this vision necessitates a proactive and unwavering commitment to centering social equity alongside environmental goals, ensuring that the pursuit of a sustainable energy system does not come at the expense of human dignity, social justice, and the wellbeing of vulnerable populations.

References

Allen & Overy & Climate Policy Initiative. (2023). How big is the Net Zero financing gap? In *allenovery.com*. https://www.climatepolicyinitiative.org/wp-content/uploads/2023/09/How-big-is-the-Net-Zero-financing-gap-2023.pdf

Almulhim, A. I., Alverio, G. N., Sharifi, A., Shaw, R., Huq, S., Mahmud, M. J., Ahmad, S., & Abubakar, I. R. (2024). Climate-induced migration in the Global South: an in-depth analysis. *Npj Climate Action*, *3*(1). https://doi.org/10.1038/s44168-024-00133-1

Amelia, N. (n.d.). *STEEP Analysis Explained: Steps to Conduct, Benefits & More*. https://www.edstellar.com/blog/steep-analysis

Ausenco. (2024, October 28). *Seize the opportunity: How Ausenco is helping Brazil's mining sector embrace the energy transition - Ausenco English*. Ausenco English. https://ausenco.com/insights/seize-the-opportunity-how-ausenco-is-helping-brazils-mining-sector-embrace-the-energy-transition/

Bentham, J. (2023c, November 10). Navigating geopolitical challenges in critical minerals projects. *Global Mining Review*. https://www.globalminingreview.com/mining/10112023/navigating-geopolitical-challenges-in-critical-minerals-projects/

Bourgoin, J., Interdonato, R., Grislain, Q., Zignani, M., & Gaito, S. (2024). Mining resources, the inconvenient truth of the "ecological" transition. World Development Perspectives, 35, 100615.

Bourne, C. (2024, December 6). *Horizon scanning: what is it and why is it beneficial? | NorthRow*. NorthRow. https://www.northrow.com/blog/horizon-scanning-what-is-it-and-why-is-it-beneficial

Brazil's critical minerals and the global clean energy Revolution. (2024, October 2). Wilson Center. https://www.wilsoncenter.org/article/brazils-critical-minerals-and-global-clean-energy-revolution

Brears, R. C. (2021, December 5). Enhancing social equity in the green economy: linking the 'E' and the 'S' in ESG. Our Future Water. https://www.ourfuturewater.com/2021/08/11/enhancing-social-equity-in-the-green-economy/

Business & Human Rights Resource Centre. (2024). Exploring shared prosperity: Indigenous leadership and partnerships for a just transition. https://www.business-humanrights.org/en/from-us/briefings/exploring-shared-prosperity-indigenous-leadership-and-partnerships-for-a-just-transition/

Calma, J. (2025, February 28). Apple accused of misleading consumers with Apple Watch 'carbon neutral' claims. The Verge. https://www.theverge.com/news/621537/apple-watch-carbon-neutral-lawsuit

Chang, A., Liu, R., & Craig, J. (2024, August 27). 'We were eating, drinking, breathing the oil': the villagers who stood up to big oil – and won. *The Guardian*. https://www.theguardian.com/environment/ng-interactive/2022/jun/01/oil-pollution-spill-nigeria-shell-lawsuit

Climate Policy Initiative. (2025, April 28). Global Landscape of Climate Finance 2024 - CPI. CPI. https://www.climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2024/

Conway, M. (2017). Foresight Infused Strategy Development: A How-to Guide for Using Foresight in Practice. Foresight Futures.

Cooperación Climática. (n.d.). *Comparative Study of Subnational Best Practices for the Energy Transition*. https://cooperacionclima.com.mx/recursos/descarga?id=421

Critical mineral mines tied to 111 violent incidents and protests on average a year. (2024, November 7). Global Witness. https://globalwitness.org/en/campaigns/transition-minerals/critical-mineral-mines-tied-to-111-violent-incidents-and-protests-on-average-a-year/

Critical minerals boom: Global energy shift brings opportunities and risks for developing countries. (2024b, April 26). UN Trade and Development (UNCTAD). https://unctad.org/news/critical-minerals-boom-global-energy-shift-brings-opportunities-and-risks-developing-countries

Culliford, E. (2022, February 16). Meta CEO Zuckerberg promotes Nick Clegg to lead on policy issues. Reuters. https://www.reuters.com/business/zuckerberg-says-nick-clegg-take-new-role-president-global-affairs-2022-02-16/

Cutler, R. M. (2025, April 3). How Kazakhstan and Azerbaijan are rewiring the Middle Corridor - The Times of Central Asia. The Times Of Central Asia. https://timesca.com/how-kazakhstan-and-azerbaijan-are-rewiring-the-middle-corridor/

Dator's Four Futures – The Foresight Guide. (2022, March 8). https://foresightguide.com/dator-four-futures/
Deberdt, R., & Le Billon, P. (2024). Green transition's necropolitics: Inequalities, climate extractivism, and carbon classes. *Antipode*, *56*(4), 1264-1288.
Deloitte. (2015). Innovation: State of play. https://www2.deloitte.com/content/dam/Deloitte/mx/Documents/manufacturing/Innovation_State_of_Play.pdf
Deloitte. (2024). 2024 renewable energy industry outlook. https://www2.deloitte.com/us/en/insights/industry/renewable-energy/renewable-energy-industry-outlook.html
Dogan, B., Huang, Z., Perez, D., Pitterle, I., Rokosz, K., Vergara, S., United Nations, Department of Economic and Social Affairs, Rashid, H., Global Economic Monitoring Branch, Mukherjee, S., Dominovic, A., Cox, I., & Roeller, L. K. (2025). Harnessing the potential of critical minerals for sustainable development. In *World Economic Situation and Prospects 2025* [Book-chapter]. https://desapublications.un.org/sites/default/files/publications/2025-01/WESP%202025_Harnessing%20the%20Potential%20of%20Critical%20Minerals%20for%20Sustainable%20Development_WEB.pdf
Duffy, C. (2025, January 30). The 'Muskification' of the federal government is in full swing. *CNN*. https://www.cnn.com/2025/01/29/tech/elon-musk-government-cuts-twitter-takeover/index.html
Eales, A. (2024). Global Perspectives on Community Energy for a Just Transition: The Case for UK-Africa Community Energy Twinning.
European Commission. (2023). Commission launches investigation on subsidised electric cars from China. In European Commission - Press Release. https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_23_4752/IP_23_4752_EN.pdf
European Critical Raw Materials Act. (n.d.). European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan/european-critical-raw-materials-act_en
EVBoosters Editorial Board. (2024, September 13). The countries that dominate the critical material supply chains. EVBoosters. https://evboosters.com/ev-charging-news/the-countries-that-dominate-the-critical-material-supply-chains/
Express News Service, & Express News Service. (2025, February 12). *Government has no intention of amending 1/70 Act, says CM Chandrababu Naidu*. The New Indian Express. https://www.newindianexpress.com/states/andhra-pradesh/2025/Feb/12/government-has-no-intention-of-amending-170-act-says-cm-chandrababu-naidu
EY. (2023). Six ways that governments can drive the green transition. https://www.ey.com/en_gl/insights/government-public-sector/six-ways-that-governments-can-drive-the-green-transition
Ge, M., Friedrich, J., & Vigna, L. (2024, December 5). *4 Charts Explain Greenhouse Gas Emissions by Sector*. World Resources Institute. https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors
Gharajedaghi, J. (2011). Systems thinking: Managing chaos and complexity: A platform for designing business architecture. Elsevier.
Gielen, D. (2021). Critical minerals for the energy transition. *International Renewable Energy Agency, Abu Dhabi*.
Government of Canada. (n.d.). Canadian critical minerals strategy. https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html
Grabtchak, A. (2024, August 13). *How to do horizon Scanning: A Step-by-Step Guide — Futures Platform*. Futures Platform. https://www.futuresplatform.com/blog/how-to-horizon-scanning-guideline
Hamouchene, H. (2021, September 2). Energy transitions and colonialism – Centre tricontinental. Centre Tricontinental. https://www.cetri.be/Energy-transitions-and-colonialism?lang=fr
Hamouchene, H. (2025, April 10). The energy transition in North Africa | Transnational Institute. Transnational Institute. https://www.tni.org/en/article/the-energy-transition-in-north-africa
Harsamto, V. H. & CASE Indonesia. (2022). The influence of socio-cultural perspectives on the energy transition narrative in Bali. In A. Tampubolon & T. A. Purnomo (Eds.), *CASE Insights*.

https://caseforsea.org/wp-content/uploads/2023/01/The-Influence-of-Socio-cultural-Perspectives-on-the-Energy-Transition-Narrative-in-Bali.pdf
Heikkilä, M. (2024, July 24). AI companies promised to self-regulate one year ago. What's changed? *MIT Technology Review*. https://www.technologyreview.com/2024/07/22/1095193/ai-companies-promised-the-white-house-to-self-regulate-one-year-ago-whats-changed/#:~:text=One%20year%20ago%2C%20on%20July,a%20safe%20and%20trustworthy%20way
Hendrix, C. S. (2023, September 19). *Political unrest in Africa threatens global critical mineral supplies and their futures*. PIIE Charts. Retrieved from https://www.piie.com/research/piie-charts/2023/political-unrest-africa-threatens-global-critical-mineral-supplies-and
Hickel, J., Sullivan, D., & Zoomkawala, H. (2021, May 6). Rich countries drained $152tn from the global South since 1960. Al Jazeera. https://www.aljazeera.com/opinions/2021/5/6/rich-countries-drained-152tn-from-the-global-south-since-1960
Higher energy security and economic complexity may hamper renewable energy development. (2023, October 19). Environment. https://environment.ec.europa.eu/news/higher-energy-security-and-economic-complexity-may-hamper-renewable-energy-development-2023-10-19_en
Holland, M. (2024, June 14). Tensions rise over China's control of critical materials. Search CIO. https://www.techtarget.com/searchcio/news/366589035/Tensions-rise-over-Chinas-control-of-critical-materials
Holman, R. (2024, December 13). How the energy crisis sped up Europe's green transition. European Investment Bank. https://www.eib.org/en/essays/europe-energy-transition-renewable
How the world reached 1 TWh of battery production | Benchmark Source. (n.d.). Benchmark Source. https://source.benchmarkminerals.com/article/how-the-world-reached-1-twh-of-battery-production
Ice, J. C. a. L. (2023b, February 16). Charging into the future: the transition to electric vehicles. Bureau of Labor Statistics. https://www.bls.gov/opub/btn/volume-12/charging-into-the-future-the-transition-to-electric-vehicles.htm
IEA (2024), *Global Critical Minerals Outlook 2024*, IEA, Paris https://www.iea.org/reports/global-critical-minerals-outlook-2024
IEA. (2025). Global energy review 2025. https://www.iea.org/reports/global-energy-review-2025
Indriyatno, H. (2024, February 26). *Indonesian nickel project harms environment and human rights, report says*. Mongabay Environmental News. https://news.mongabay.com/2024/02/indonesian-nickel-project-harms-environment-and-human-rights-report-says/
Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development. (2023). *Mining policy framework*. https://www.igfmining.org/country-support/mining-policy-framework/
International Energy Agency. (2023, June). Will solar PV and wind costs finally begin to fall again in 2023 and 2024? In Renewable energy market update - June 2023. https://www.iea.org/reports/renewable-energy-market-update-june-2023/will-solar-pv-and-wind-costs-finally-begin-to-fall-again-in-2023-and-2024
International Energy Agency. (2024). Global critical minerals outlook 2024. https://www.iea.org/reports/global-critical-minerals-outlook-2024
International Energy Agency. (2024). Renewables 2024: Analysis and forecast to 2029. https://iea.blob.core.windows.net/assets/17033b62-07a5-4144-8dd0-651cdb6caa24/Renewables2024.pdf
International Energy Agency. (n.d.). The role of critical minerals in clean energy transitions. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions
International Labour Organization. (n.d.). Climate change and financing a just transition. Retrieved February 27, 2025, from https://www.ilo.org/resource/other/climate-change-and-financing-just-transition
International Renewable Energy Agency. (n.d.). Critical materials for the energy transition. https://www.irena.org/Technical-Papers/Critical-Materials-For-The-Energy-Transition
IUCN NL. (2024). *Nickel rush in Indonesia: Deforestation rates double around nickel-processing plants*. https://www.iucn.nl/en/news/nickel-rush-in-indonesia-deforestation-rates-double-around-nickel-processing-plants/
Jones, P. H., & Van Ael, K. (2022). *Design journeys through complex systems: Practice tools for systemic design*. Amsterdam: Bis Publishers, 2022.

Kennedy, C. M., Fariss, B., Oakleaf, J. R., Garnett, S. T., Fernández-Llamazares, Á., Fa, J. E., ... & Kiesecker, J. (2023). Indigenous Peoples' lands are threatened by industrial development; conversion risk assessment reveals need to support Indigenous stewardship. One Earth, 6(8), 1032-1049

Kharpal, A. (2022, December 14). China brings WTO case against U.S. and its sweeping chip export curbs as tech tensions escalate. CNBC. https://www.cnbc.com/2022/12/13/china-brings-wto-case-against-us-chip-export-restrictions.html

KIT Royal Tropical Institute. (2020). Sexual and gender-based violence in the mining sector in Africa. https://www.kit.nl/wp-content/uploads/2020/09/SGBV-in-the-Mining-Sector-in-Africa.pdf

Konda, C., & Rakheja, K. (2024, October). India's hunt for critical minerals: Import dependencies make diversifying supply sources and addressing trade risks the need of the hour. Institute for Energy Economics and Financial Analysis. https://www.ieefa.org/resources/indias-hunt-critical-minerals

Labay, K., Burger, M.H., Bellora, J.D., Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, Bradley, D.C., Mauk, J.L., and San Juan, C.A., 2017, Global Distribution of Selected Mines, Deposits, and Districts of Critical Minerals: U.S. Geological Survey data release, https://doi.org/10.5066/F7GH9GQR.

Latinia. (2024). Responsible banking: The path to sustainability. https://latinia.com/en/resources/responsible-banking-sustainability

Liang, Y., Kleijn, R., & Van der Voet, E. (2023). Increase in demand for critical materials under IEA Net-Zero emission by 2050 scenario. *Applied Energy*, *346*, 121400.

MacKenzie, A. (2025, January 16). *How has the DRC become a powerhouse in the copper industry? - Fastmarkets*. Fastmarkets. https://www.fastmarkets.com/insights/how-has-the-drc-become-a-powerhouse-in-the-copper-industry/#:~:text=A%20number%20of%20the%20copper,the%20DRC%20government%20(20%25

McKinsey & Company. (2023, November). *A framework for fostering effective energy transitions*. https://www.mckinsey.com/~/media/mckinsey/industries/oil%20and%20gas/our%20insights/a%20framework%20for%20fostering%20effective%20energy%20transitions/fostering-effective-energy-transition.pdf

Meadows, D. (2015). Leverage points-places to intervene in a system.

Meadows, D., H. & The Sustainability Institute. (1999). Leverage points: places to intervene in a system. The Sustainability Institute, 1. https://donellameadows.org/wp-content/userfiles/Leverage_Points.pdf

Member States adopt policy to strengthen health sector in the face of climate change, focusing on vulnerable populations and equity. (2024, October 1). PAHO/WHO | Pan American Health Organization. https://www.paho.org/en/news/1-10-2024-member-states-adopt-policy-strengthen-health-sector-face-climate-change-focusing

MINING.COM. (2023, August 11). *A vicious cycle of rising resource nationalism - MINING.COM*. https://www.mining.com/web/a-vicious-cycle-of-rising-resource-nationalism/

MINING.COM. (2024, October 9). Congo wants to pivot away from China's dominance over its mining - MINING.COM. https://www.mining.com/web/congo-wants-to-pivot-away-from-chinas-dominance-over-its-mining/

Muhire, F., Turyareeba, D., Adaramola, M. S., Natongo, M., Atukunda, R., & Olyanga, A. M. (2024). Drivers of Green Energy Transition: A Review. Green Energy and Resources, 100105.

Mwangi, N. (2025, January 29). Sahel states exit ECOWAS, launch regional passport and joint military. Peoples Dispatch. https://peoplesdispatch.org/2025/01/29/sahel-states-exit-ecowas-launch-regional-passport-and-joint-military/

Net zero scorecard. (2023, March 9). Energy & Climate Intelligence Unit. https://eciu.net/netzerotracker

Nickel industry costs lives and livelihoods in Indonesia's last nomadic sea tribe - Mighty Earth. (2024, December 20). Mighty Earth. https://mightyearth.org/article/from-forests-to-electric-vehicles/

O'Dell, J. (2024, May 8). Big Gap Remains in Average Price of Electric Car vs. Gas Car. Edmunds. https://www.edmunds.com/car-buying/average-price-electric-car-vs-gas-car.html

Owen, J. R., Kemp, D., Lechner, A. M., Harris, J., Zhang, R., & Lèbre, É. (2022). Energy transition minerals and their intersection with land-connected peoples. Nature Sustainability, 6(2), 203–211. https://doi.org/10.1038/s41893-022-00994-6

Pandey, K. (2025, February 7). *India approves mission to bridge mineral gap in energy transition*. Mongabay-India. https://india.mongabay.com/2025/02/india-approves-mission-to-bridge-critical-mineral-gap-in-energy-transition/
Patel, L. (2025, April 9). US-China trade war: Who really gains? Lomit Patel. https://www.lomitpatel.com/articles/us-china-trade-war-who-really-gains/
Policy Center for the New South. (2022, May). *The energy transition amidst global uncertainties: A focus on critical minerals.* https://www.policycenter.ma/sites/default/files/2022-05/PB_37-22_Berrahab.pdf
Press, E., Van de Graaf, T., Lyons, M., Garcia, I. E., Rath, E., & Gibson, B. (2023). Geopolitics of the energy transition: Critical materials.
PricewaterhouseCoopers. (2024, May 15). Consumers willing to pay 9.7% sustainability premium, even as cost-of-living and inflationary concerns weigh: PwC 2024 Voice of the Consumer Survey | PwC. PwC. https://www.pwc.com/gx/en/news-room/press-releases/2024/pwc-2024-voice-of-consumer-survey.html
Prospectors & Developers Association of Canada. (2022). *PDAC social impact study 2022*. ISSUU. https://issuu.com/pdac-web/docs/pdac-social-impact-study_2022?fr=sOGQ4NjQ3ODEyNjA
Prospectors & Developers Association of Canada. (2022). Social impact study 2022. https://issuu.com/pdac-web/docs/pdac-social-impact-study_2022?fr=sOGQ4NjQ3ODEyNjA
Prospectors & Developers Association of Canada. (2024, November 28). Critical mineral. PDAC. https://pdac.ca/programs-and-advocacy/geoscience/critical-mineral#:~:text=Canada's%20Critical%20Minerals%20Strategy%20is,and%20digital%20economy.%E2%80%9D%20The%20Critical
PwC. (2024). *People & prosperity at risk: The PwC Global Risk Survey 2023*. https://www.pwc.com/gx/en/issues/esg/people-and-prosperity-at-risk.pdf
Race, M. (2025, January 10). Shein checks urged after refusal to answer "basic" questions. https://www.bbc.com/news/articles/czxk6nnk6p9o
Renewable power generation costs in 2023. (2024, September 1). https://www.irena.org/Publications/2024/Sep/Renewable-Power-Generation-Costs-in-2023
Researchgate. (2024). Energy transition and mining in the global south. https://www.researchgate.net/publication/389042467_Energy_Transition_and_Mining_in_the_Global_South
Reuters. (2025, April 1). China, Japan, South Korea will jointly respond to US tariffs, Chinese state media says. Reuters. https://www.reuters.com/world/china-japan-south-korea-will-jointly-respond-us-tariffs-chinese-state-media-says-2025-03-31/
Robinson, J. (1982). Energy backcasting: A proposed method of policy analysis. *Energy Policy, 10*(4), 337-344.
Sanderson, H. (2022). *Volt rush: The winners and losers in the race to go green*. Simon and Schuster.
Sayne, A., Fitzgerald, S., & Shipley, T. (2024). *Ten red flags for corruption risk in transition minerals licensing and contracting*. https://resourcegovernance.org/sites/default/files/2024-12/Ten_Red_Flags_Corruption_Risk_Transition_Minerals.pdf
ScienceDirect. (2022). [Article title not specified]. https://www.sciencedirect.com/science/article/abs/pii/S0038012122001409
Service Canada. (2023, September 12). *The Canadian Critical Minerals Strategy*. Canada.ca. https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html
Shankar, P. (2024, December 23). Why has DRC filed criminal charges against Apple over 'conflict minerals'? Al Jazeera. https://www.aljazeera.com/news/2024/12/20/why-has-drc-filed-criminal-charges-against-apple-over-conflict-minerals
Sharma, R. & Morgan Stanley Investment Management. (2021). *'Greenflation' threatens to derail climate change action*.
Staff, S. (2024, November 8). Extreme weather events caused over 3,000 deaths in India this year: Report. Scroll.in. https://scroll.in/latest/1075427/extreme-weather-events-caused-over-3000-deaths-in-india-this-year-report%E2%80%AF%E2%80%AF
Statista. (2024a, August 15). *Global fossil fuel consumption 1965-2023*. https://www.statista.com/statistics/1302754/fossil-fuel-energy-consumption-worldwide/

Statista. (2024b, December 10). *Global cumulative CO_2 emissions from fossil fuels and land use 1850-2023, by country*. https://www.statista.com/statistics/1267683/cumulative-co2-emissions-fossil-fuel-land-use-forestry-worldwide-by-country/
Statista. (2025, March 5). *Copper mine production in DR Congo 2010-2024*. https://www.statista.com/statistics/1276790/copper-production-in-democratic-republic-of-the-congo
Sumant Sinha. (2024, October 10). The U.S., EU, and India must urgently come together in a free trade agreement on clean energy, says the CEO of one of India's largest renewables company. https://sumantsinha.com/authored-articles/us-eu-india-must-come-together-free-trade-agreement-clean-energy
Tennant, E. (2025, January 24). *The dirty truth about fossil fuels and pollution*. Citizens' Climate Lobby. https://citizensclimatelobby.org/blog/advocacy/the-dirty-truth-about-fossil-fuels-and-pollution/
The importance of equitable, sustainable and fossil-free automotive supply chains: a case study on nickel mining and processing in Indonesia - Lead the Charge. (2024, April 11). https://leadthecharge.org/resources/the-importance-of-equitable-sustainable-and-fossil-free-automotive-supply-chains-a-case-study-on-nickel-mining-and-processing-in-indonesia/
The Nature Conservancy. (2023). Amid industrial development threats to lands, major opportunities to support indigenous stewardship. Retrieved from https://www.nature.org/en-us/what-we-do/our-insights/perspectives/indigenous-lands-development-risk-solutions-study/
The new curse of critical minerals. (2024, July 4). CEPR. https://cepr.org/voxeu/columns/new-curse-critical-minerals
The role of mining in the race to net zero emissions | International Mining and Resources Conference (IMARC). (n.d.). https://imarcglobal.com/news/articles/the-role-of-mining-in-the-race-to-net-zero-emissions
Traviss, M. (2024, February 19). *Brazilian Critical Minerals: Developing Brazil's critical mineral deposits*. Innovation News Network. https://www.innovationnewsnetwork.com/brazilian-critical-minerals-developing-brazils-critical-mineral-deposits/43944/
Tripathi, B. (2025, March 5). *India's $4-billon bet to secure critical minerals*. Context by TRF. https://www.context.news/just-transition/indias-4-billon-bet-to-secure-critical-minerals
U.S. Geological Survey. (2017). Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply (Professional Paper 1802). https://mrdata.usgs.gov/pp1802/
UN-Habitat. (2021). *Urban energy*. https://unhabitat.org/topic/urban-energy
United Nations Development Programme. (2023, November 13). *Strengthening energy governance systems: Energy governance framework for just energy transition*. https://www.undp.org/publications/strengthening-energy-governance-systems-energy-governance-framework-just-energy-transition
United Nations Development Programme. (2023, November). Strengthening energy governance systems: Energy governance framework for just energy transition. https://www.undp.org/sites/g/files/zskgke326/files/2023-11/undp-strengthening-energy-governance-systems.pdf
United Nations Environment Programme. (2023). *Enhancing social equity in the green economy: Linking E and S in ESG*. Green Policy Platform. https://www.greenpolicyplatform.org/research/enhancing-social-equity-green-economy-linking-e-and-s-esg
United Nations Environment Programme. (2023, August 8). *As climate crisis alters their lands, Indigenous Peoples turn to the courts. UNEP*. https://www.unep.org/news-and-stories/story/climate-crisis-alters-their-lands-indigenous-peoples-turn-courts
United Nations Environment Programme. (2023, July 26). *Critical energy transition minerals*. https://www.unep.org/topics/energy/renewable-energy/critical-energy-transition-minerals
United Nations Framework Convention on Climate Change. (2015). Paris agreement. https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf
United Nations Framework Convention on Climate Change. (n.d.). The Paris Agreement. https://unfccc.int/process-and-meetings/the-paris-agreement
United Nations, Department of Economic and Social Affairs, Population Division. (2019). *World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100*.

https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100
United Nations. (2015). Social sustainability through accessibility and equity. https://sustainabledevelopment.un.org/content/documents/5918Social%20sustainability%20through%20accessibility%20and%20equity.pdf
Voros J (2003), 'A generic foresight process framework', Foresight, vol. 5, no. 3, pp. 10-21. doi:10.1108/14636680310698379
Voros, J (2017), 'Big History and anticipation: Using Big History as a framework for global foresight', in R Poli (ed.) Handbook of anticipation: Theoretical and applied aspects of the use of future in decision making, Springer International, Cham. doi:10.1007/978-3-319-31737-3_95-1
Wetlands International Europe. (2023, October 18). *World Water Day: The water impacts of lithium extraction - Wetlands International Europe*. https://europe.wetlands.org/blog/world-water-day-the-water-impacts-of-lithium-extraction/
World Economic Forum. (2021, October). Which factors accelerate the growth of renewable energy? https://www.weforum.org/stories/2021/10/which-factors-accelerate-the-growth-of-renewable-energy/
World Economic Forum. (2024). Securing minerals for the energy transition. https://www3.weforum.org/docs/WEF_Securing_Minerals_for_the_Energy_Transition_2024.pdf
World Economic Forum. (2025). *Accelerating the energy Transition: Unpacking the business and economic cases*. https://reports.weforum.org/docs/WEF_Accelerating_the_Energy_Transition_2025.pdf
World Population Review. (2025). *Global South Countries 2025*. https://worldpopulationreview.com/country-rankings/global-south-countries#what-is-the-global-south
Yuniar, R. W., & Yuniar, R. W. (2024, April 18). Chinese-linked nickel miners in Indonesia accelerating deforestation, threatening indigenous Bajau people: report. *South China Morning Post*. https://www.scmp.com/week-asia/health-environment/article/3259476/chinese-linked-nickel-miners-indonesia-accelerating-deforestation-threatening-indigenous-bajau