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TOWARDS SUSTAINABILITY AS JUSTICE? A GLOBAL CONTEXT OF THE EMERGING CRITICAL MINERAL VALUE CHAINS

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Introduction

Efforts to transition the energy system centre on the rapid expansion of renewable and other non-fossil fuel energy capacity, purportedly, at the expense of the existing dominance of fossil fuels.[1] The current mainstream energy and environmental policy approach, as seen in the language and practices of government, industry and civil society, largely holds that such a change, alongside the sequestration of carbon-di-oxide, is necessary to mitigate worsening climate change and its multifaceted impacts. This paper focuses on one dimension of this transition, i.e. the value chain of critical minerals required for building the new energy infrastructure. Elements of this new infrastructure includes photovoltaic panels, wind turbines, batteries for storage and for electric vehicles (EVs), electrolysers to produce green hydrogen, and the vast quantities of wires and components for the networks and control systems needed to integrate it all into a functional infrastructure for the modern world that can out compete the fossil-fuel energy system on technical and financial terms.

This paper asks whether this dimension of the energy transition manifest in the emerging critical mineral production-consumption system (or critical mineral value chains), is oriented toward sustainability as justice. We understand sustainability here as justice in the realization of human well-being outcomes on a shared and finite planet, i.e. within social-ecological limits. This question can also be asked as whether the emerging critical mineral production-consumption system is proceeding to reproduce the dynamics of "extractivism"[2] that characterizes imperialism, dominated the era of colonialism and shaped the fossil-fuels driven industrialization that followed in its aftermath.

The analytical framework used in this paper sees sustainability as coterminous with justice. It sidesteps the more mainstream notion of sustainability and justice. Aside from setting them up as possibly opposed outcomes (e.g. often seen in environment vs. jobs debates), sustainability and justice is also, we argue, incorrect. This point is developed in Section 4. A further contribution of this paper is to propose that the discourse shaping emerging critical mineral value chains can be organized into three broad themes, i.e., urgency, energy security and great power rivalry or geopolitics. Given this discursive construction of critical mineral value chains, the analytical offering of this paper is to examine whether they can engender sustainability as justice. We select one mineral, lithium, to serve as the illustrative empirical basis for this analysis. We find that there is a high probability of injustice and therefore of sustainability being a casualty, at the confluence of competitive accumulation now supplemented by urgency, energy security and great power rivalry. Finally, the paper identifies some elements for shaping critical mineral value chains that might orient them toward sustainability as justice.

[1] Evidence, as seen for example in Energy Institute (2025), suggests that displacement of fossil-fuels, despite rapid growth in renewable energy, is not yet significant.

[2] Understood as "a complex ensemble of self-reinforcing practices, mentalities, and power differentials underwriting and rationalizing socio-ecologically destructive modes of organizing life through subjugation, violence, depletion and non-reciprocity" (Chagnon et al. 2022).

1. What are Critical Minerals?

Critical Minerals is a phrase that needs unpacking. It is used to refer to many elements in the periodic table that are essential for the fabrication of electrical and electronic components required for a range of modern technologies used in information technology, defence, consumer electronics and most importantly, for this paper, in many Renewable Energy Technologies (RETs) such as wind turbines, batteries, hydrogen electrolysers and solar panels. More than a decade ago, Eggert (2010: 49) illustrated the implications for critical minerals of the modern technological transformation: "One factor giving rise to concerns is that the modern mineral-based materials are becoming increasingly complex. Intel estimates that computer chips contained 11 mineral-derived elements in the 1980s, 15 elements in the 1990s, and potentially up to 60 elements in the coming years. General Electric estimates that it uses 70 out of the 83 elements[3] in the periodic table in its products"! More recently, Apple in a publication titled Material Impact Profiles, lists 45 elements that are "commonly found in consumer electronics" (Apple 2019: 11). This rapidly rising "mineral intensity" of modern technologies, writ large, means that critical minerals can now usefully be understood "as the heterogenous matter of contemporary, globalized mass production and consumption" (Hine et al. 2023: 8).

Critical minerals are evidently essential to the current course of technological evolution. Yet the "critical" in critical minerals does not signify this centrality. Instead, critical is a second order, or derived assignation. Following (IISD 2023), two broad considerations are applied to determine if (and therefore, to define) a mineral is critical (sometimes also called strategic). First, whether the mineral is a significant input into an existing or planned industrial or strategic/defence activity in a country but is not domestically available. This scenario signifies import dependence and the resulting vulnerability to disruptions in the supply chain. Country responses to this scenario includes strategies to ensure security of value chains and to address the risk of disruption. The second consideration is one when it is found in abundance in a country and the country has a strategic interest in using this dominance to gain competitive advantage and to capture the potential added economic value for its economy.

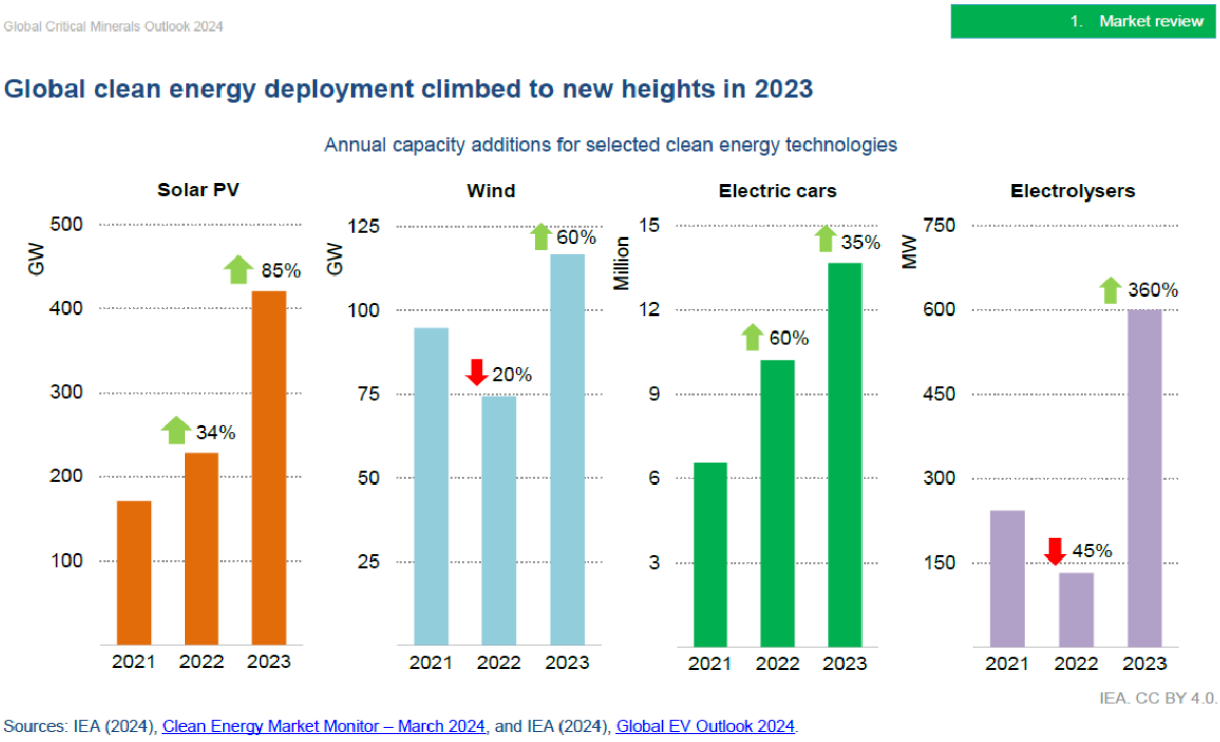
Given that the assignation of "critical" to a mineral is contingent on the economic and strategic contexts of countries, it is not possible to have one universal list of critical or strategic minerals. Different countries and regions (e.g. the EU) have prepared lists from their respective vantages to inform their policy and regulatory priorities. Neither can such a list be permanent. The addition or removal of minerals will depend on the course of technological change and the evolving mineral-trade-strategic circumstances. That said, for now, it is generally understood that between 30 and 50 elements in the periodic table are regarded, across these various lists, as critical minerals (IISD 2023) by different countries.

[3] There are 94 naturally occurring elements on earth. Of these 83 are "primordial," and 11 are found in the decay chains of these. The remaining 24 of the 118 known elements today, are lab synthesized.

2. Energy Transition and Critical Mineral Value chains

The two broad drivers for rapid growth in demand for critical minerals and resulting policy prominence, are the rapidly expanding photovoltaic (PV) capacity and wind energy capacity, and the rapid expansion in the sales of electric vehicles (EVs).[4] As a result of such near exponential growth, the key numbers and trends from the Global Critical Minerals Outlook (International Energy Agency (IEA) 2024) are instructive.

Figure 1: Recent trends in clean energy (IEA 2024, 18).



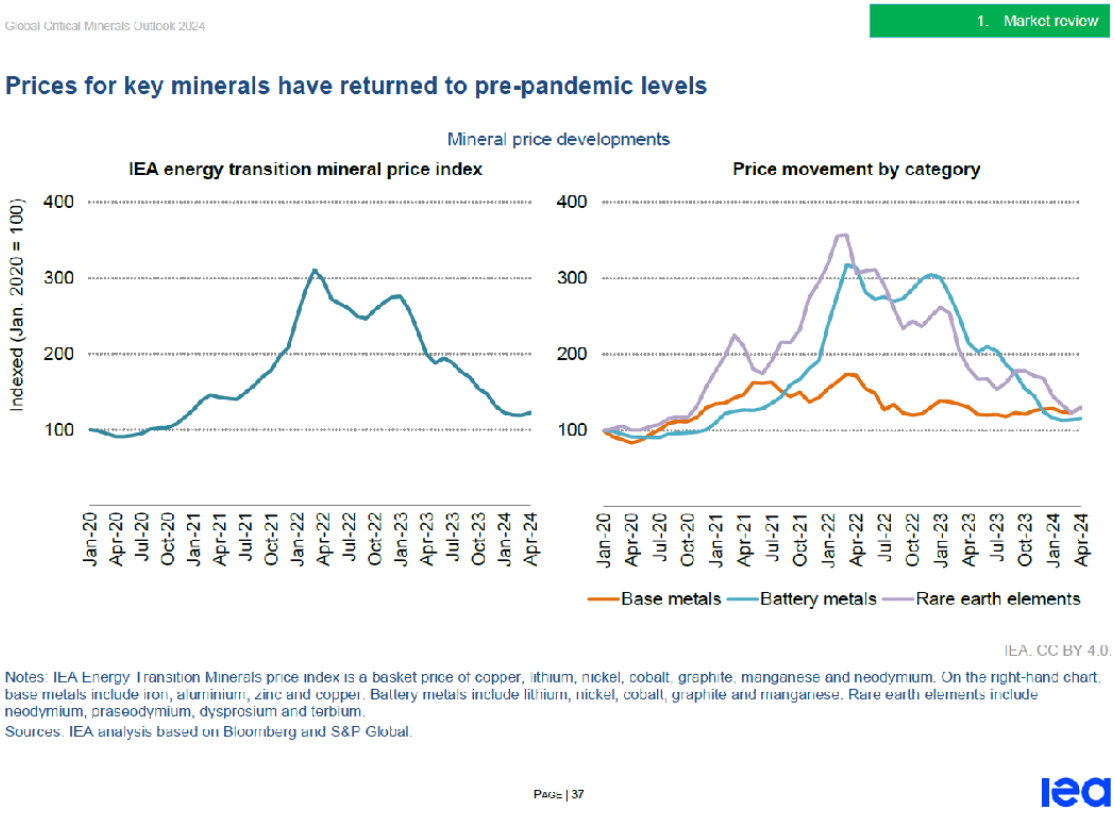
The energy transition technology trends in Figure 1, have amplified demand for critical minerals, have rendered prices volatile, have surfaced potential or existing supply chain bottlenecks and have generated geopolitical concerns (IEA 2024). The Outlook also presents the results of three modelled scenarios to help communicate the likely paths ahead for critical minerals. The three scenarios are (a) Stated Policies Scenario (STEPS) – which reflects today's existing policy settings, (b) Announced Pledges Scenario (APS) – which reflects meeting all national energy and climate goals, and (c) Net Zero Emissions by 2050 (NZE) – which as the name suggests

[4] For example, consider that in the year 2010, 7000 Battery Electric Cars were sold globally. That number was 11 million in 2024. Whereas a negligible number of Plug-in Hybrid Electric Cars were sold in 2010, in 2024, 6.5 million were sold. In the case of two and three-wheeler Battery Electric Vehicles the numbers grew from 41,000 to 10 million during the same period. Battery demand for cars has grown from less than 1 GWh to 840 GWh during this time, and for two and three wheelers, it has grown from 0.1 GWh to 32 GWh in this period. These statistics do not include vans, buses and trucks, which will only increase these numbers further (Source: IEA Global EV Data Explorer, https://www.iea.org/data-and-statistics/data-tools/global-ev-data-explorer)

achieves net-zero emissions by 2050. The STEPS realizes a doubling of critical mineral demand by 2030. The APS realizes slightly more than a doubling in this time frame. Under NZE demand for critical minerals nearly triples by 2030 and quadruples by 2040. Under this scenario, lithium has the most rapid rate of growth of nine times by 2040. On the other hand, copper, witnesses the largest growth by volume by 2040. Graphite is seen to quadruple, while nickel, cobalt and rare earth elements double by 2040.

Another important trend in critical minerals value chains is the geographical distribution of the resources, their processing and the impact of prices on these dynamics. As seen in Figure 2, the prices for critical minerals witnessed a sharp increase during the COVID-19 pandemic and immediate post-pandemic years and was followed by a return in 2024 to pre-pandemic price levels. Such a drastic reduction has had two important consequences. First, lower mineral prices were a boon to consumers with battery prices witnessing a 14% reduction in 2023. Second, one with important consequences for future reliability and diversity of supplies, is for private sector investments. Investors rely on price signals to make investment decisions. Low prices generally elicit lower confidence for embarking on large investments and undermines prospects for checking the geographic concentration in the value chain.

Figure 2: Price trends for key critical minerals (IEA 2024, 37)



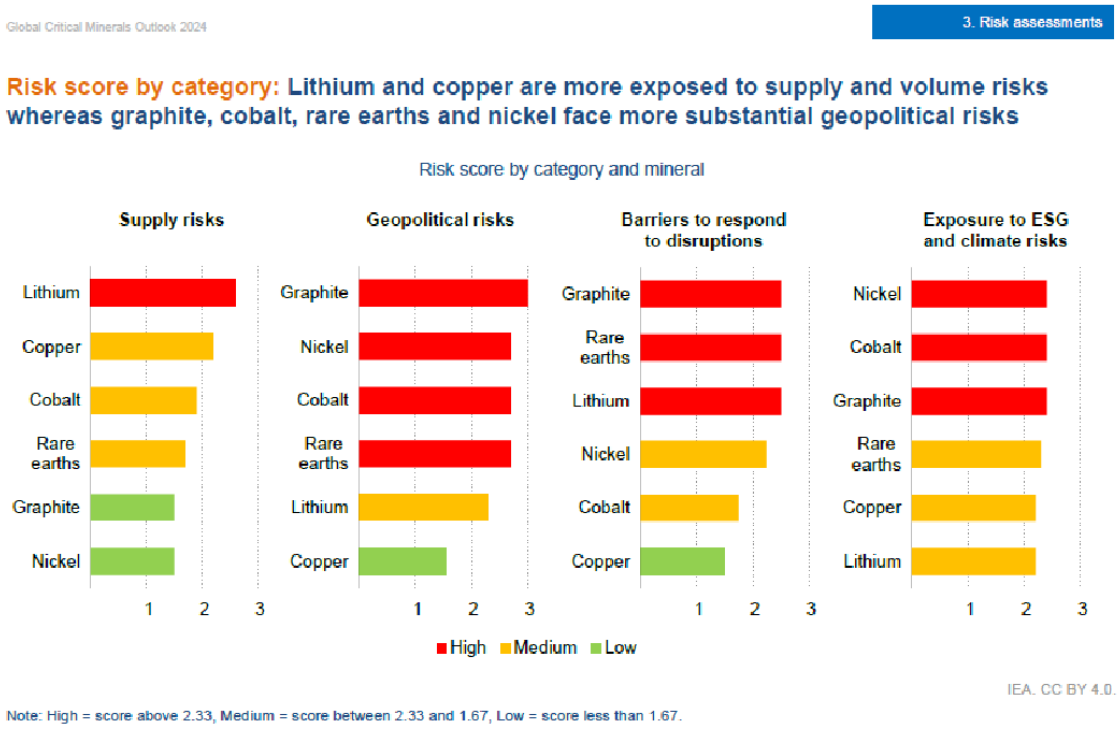
To explore future supply-demand balances, the IEA (2024) developed "base case" and "high production case" scenarios. The former was based on existing projects, those under construction and those with a "high chance" of being completed. The high production case adds projects at a "reasonably advanced stage of development" and awaiting financing or permits. Using the demand projections generated by the APS

as a comparison, the situation in 2035 for various minerals was as follows: the supply of copper and lithium meet only 70% and 50%, respectively, of modelled demand. The shortfall is starker if the NEZ scenario was used as a benchmark. For nickel and cobalt, the base case would produce a tight demand-supply balance, which could be eased in a high production case. The situation with graphite and rare earth elements is less a concern about volumes of production, but their geographic concentration. China is expected to supply 90% of battery grade graphite and 77% of refined rare earth elements in 2030.

The question of source diversification and thereby mitigation of geopolitical risk does not seem to have an easy answer. For example, 70-75% of the supply growth for refined nickel, lithium, cobalt and rare earth elements until 2030 will be met by the top three producers. In the case of battery grade graphite dependence on China alone could be 95% (IEA 2024, p. 105). Low prices while beneficial for consumers, can discourage private investors pursuing profits and could pose a challenge to diversify production. This inability to diversify production is a considerable limitation that has important consequences for risks.

The IEA (2024)'s Risk Assessment Framework evaluated key critical minerals against the following risks: (a) supply risk, (b) geopolitical risk, (c) barriers to respond to supply disruptions, and (d) environmental, social, governance and climate risks. It found that lithium and graphite had the highest risk scores. For lithium and copper, it was high supply volume risk. While, for graphite, cobalt, nickel and rare earth elements were higher for geopolitical risk. Most of the minerals scored high on Environment, Social and Governance (ESG) and climate risks.

Figure 3: Risk assessment of important critical minerals (IEA 2024, 213).



An evaluation of the global context of a range of critical mineral value chains is beyond the scope of this project. We have been selective due to time and resource constraints. Based on this assessment of risk (Figure 3), we narrowed down to lithium (high on supply risk) as the illustrative mineral for our exploration. Leading scenarios suggest that Australia, China and Latin America (some combination of Chile, Argentina and Bolivia) will dominate lithium supply into the foreseeable future. Africa too will make an appearance, but at a smaller scale (IEA 2024). We therefore mainly focus on the first three regions for insights into how sustainability as justice has been encountered in the emerging lithium value chain.

3. Methodology: Sustainability as Justice

This section presents the theoretical orientation and the methodological approach for this study. Drawing from the ecological economics, development studies, political ecology and sustainable production-consumption systems literatures, we propose that sustainability is best understood as justice. The analytical framework and research methods, therefore, are aimed at discerning if the emerging discourse on critical mineral value chains prioritizes and enables justice. We use a narrative literature review for this purpose and work with lithium value chains as our illustrative case.

i. A Theoretical Framework

The starting premise of this paper is that functional and desirable social and political arrangements must successfully and continuously navigate between two equally essential, non-negotiable conditions. First, useful (i.e. “low-entropy”) matter and energy available on earth – the basis of all value created by production-consumption systems – are finite. This insight is borrowed from the field of Ecological Economics. Herman Daly called these the “ultimate means” in his ends-means spectrum (see, Daly 1993). This we regard as a biophysical reality. This insight was articulated originally in the 1970s as a corrective to the dominant neo-classical view of biophysical limits as categorically external to the production-consumption of economic value. The second condition that needs to be realized is justice. There are two qualifiers here. First, hardly any political arrangements appear viable without the realization or at least the promised realization of justice (Sen 1992). Second, the problem of justice that informs this paper also derives from the condition of biophysical finitude presented above. Given the limited low-entropy matter and energy available on earth, their use to produce economic value and the ensuing impacts of such production-consumption (e.g. land degradation and pollution) must be allocated fairly.

These conditions invite us to acknowledge that values and their associated actions by individuals and groups will necessarily impact – mediated by the modification of biophysical conditions they engender – the life-chances, or opportunities, or

capabilities of other individuals and groups, and vice versa. The idea of entirely independent values and actions in the production-consumption of economic value is hard to sustain given these inevitable interconnections, that *is* the social-ecological system within which all human life and economic activity transpire. This necessary, inescapable dependence of normative social goals (i.e. "intermediate" and "ultimate ends" in Daly's end-means spectrum) on finite low-entropy biophysical inputs, sets up the problem of sustainability as justice. The challenge for policy and governance therefore is to navigate this essential tension, at the foundation of all production-consumption systems. The successful navigation between these two necessary constraints is referred to here as *social-ecological justice or sustainability*.

The experience of social-ecological injustice occurs at various levels. For example, at the macro level the disproportionate burden of climate change on countries that have contributed negligibly to the problem is obvious. Consider the impacts of climate change on Bangladesh or other parts of the less-industrialized world (e.g. Oladipo 2025; Byrne et al. 2002). Or at the micro level, consider the disproportionate burden of pollution on individuals and groups belonging to marginalized socio-economic classes (e.g. Agyeman 2016). Their consequences are widely recorded (e.g. Fuller et al. 2022) and such harms often form the basis of environmental debates, including political mobilisation. These consequences are manifest in visible and less visible health impacts, and/or political, social and cultural dysfunction that may even be exacerbated by experiences of colonialism, racism, casteism and "classism" (entrenched and excessive wealth inequality). Recent work also documents differential impacts between workers from the same socio-economic class but working in different industries of the production-consumption system (Satheesh 2025).

In addition to levels, and more importantly, we suggest there is the matter of degree. There are the evident morbidity and mortality associated with the degradation and destruction of individuals' and communities' ecological contexts. However, *before* social-ecological injustice becomes tangible in formal data and datasets, it emerges first and perhaps even lingers for a long time, as daily, routine, sub-critical violations of health and dignity. These are the daily deprivations of the freedom to breathe clean air, to drink clean water and to eat food without chemical residues. The deprivation of the ability to sleep soundly at night on account of noise pollution. The deprivation of the ability to move freely for fear of bodily injury or even death from degraded landscapes or speeding vehicles. We propose that this **daily, persistent, sapping of valuable freedoms, of dignity, and their eventual measurable manifestations, that are mediated via biophysical degradation, constitutes social-ecological finitude**[5]. These

[5] We acknowledge two other forms of "finitude", mostly because they tend to dominate environmental policy and governance discussions. First, is finitude, that is contingent on the economic price of the commodity. For example, at the end of 2023, the estimated global reserves of Bauxite, the precursor to alumina and then aluminium, a critical mineral listed by the US government, according to the United States Geological Survey (USGS) , was 30 billion metric tons. The corresponding annual global production of bauxite was 400 million metric tons, which means about 75 years of available reserves under current economic conditions. The USGS further notes in this same report that "…the United States and most other major aluminium-producing countries have essentially inexhaustible subeconomic resources of aluminium in materials other than bauxite." If the economic price is right, Aluminium production could be continued for centuries to come. There does not appear to be a finitude in the limited sense of the

are limits to the deprivation of human freedoms that individuals and collectives can tolerate, before the promise and desire for human dignity is blighted.

Fundamentally, below these limits are unfree lives and violated dignity. Social-ecological finitude, therefore, is the discernible but less easily measurable line between viable and dysfunctional social arrangements. It is important to recognize it as the line that is breached before quantified manifestations of local environmental degradation are recorded by bureaucrats; and long before earth systems tip over the 'safe operating spaces' prescribed by scientists. It is a line that is perceived subtly but persistently by all people living their daily lives. It is for this reason that we argue that framing sustainability *as* justice, offers great purchase. It invites us to understand sustainability ***as living well, together, on a shared and finite planet***. Social-ecological injustice begins when dignity is violated. When we are not living well, together.

Justice is clearly about living well, together. And this brings our attention now to the mechanics of living together. We borrow a useful explanation of justice that acknowledges this challenge. It does so by seeing the essential diversity of those living together, and hints at the necessary mechanics – the procedural, institutional, political and cultural resources – needed as a result to bring justice to fruition. We take this elaboration from the field of Development Studies (the Human Development and Capability Approach, in particular) which offers that equality in some preferred normative dimension, is a prerequisite for all frames that undergird viable social arrangements. Amartya Sen (1992:ix) eloquently argues, and I quote at length:

> …The central question in the analysis and assessment of equality is, I argue here, 'equality of what?' I also argue that a common characteristic of virtually all the approaches to the ethics of social arrangements that have stood the test of time is to want equality of some-thing—something that has an important place in the particular theory. Not only do income-egalitarians (if I may call them that) demand equal incomes, and welfare-egalitarians ask for equal welfare levels, but also classical utilitarians insist on equal weights on the utilities of all, and pure libertarians demand equality with respect to an entire class of rights and liberties. They are all 'egalitarians' in some essential way—arguing resolutely for equality of something which everyone should have and which is quite crucial to their own particular approach. To see the battle as one between those 'in favour of' and those 'against' equality (as the problem is often posed in the literature) is to miss something central to the subject (emphasis in the original).

Social-ecological finitude needs to be discerned in manifestations of the denial of such varied possibilities expressed by diverse individuals and communities. It can be

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quantity of these elements found in the earth's crust in relation to their immediate and foreseeable demand.

The second type of material finitude is biophysical finitude independent of economic prices. The ability of the earth's atmosphere to absorb greenhouse gas emissions and simultaneously maintain stable rates of "radiative forcing" – and by extension global average temperatures— at levels that characterized the Holocene, is one such illustration. No economic price or anything else society can construct, will change the biophysical coefficients for radiative forcing caused by greenhouse gases. Biophysical finitude is a fact based on the known laws of physics. It is not socially constructed. We could in theory use social institutions like prices and markets to reduce GHG emissions. But that does not change the rate of radiative forcing per unit of GHG added to the atmosphere. It simply tries to reduce the number of units of GHG added to the atmosphere.

seen, as Amartya Sen, might point out, as the denial of the "freedom" "to do and to be" as diverse individuals or communities have reasons to value (Sen 1992).

This approach to justice has conceptual and practical implications for us. Conceptually, while it can be applied to group based (e.g. caste and class) analysis of injustice it also invites us to consider the diversity of human beings and complexity of human societies (e.g. values toward the use of low-entropy biophysical resources espoused by factory workers that perhaps contradict those of farm worker or miners). For example, as revealed recently by Satheesh (2025: 3): "existing theoretical explanations, solely rooted in class, fall short in accounting for conflicts between trade unions and environmental movements, particularly in the context of countries in the Global South, where working-class participants mainly constitute both movements." In other words, being attentive to complexity of human societies and some scepticism about the analytical comfort provided by pre-existing categories is called for.

This line of thinking about justice sees just arrangements as the outcome of public reasoning (Sen 2010) and not of prescriptions based on binary categories, and neither of depoliticised, techno-managerial control[6]. Such choices often entail realities where an approach to "advancing rather than perfecting" justice (Sen 2010, xiii) is better suited. This paper agrees that the idea that there awaits a preexisting off-the-shelf transcendental idea of justice waiting to be bought and installed, is mistaken. Injustice manifests as subtle and overt violations of the freedoms that diverse groups and individuals have varying reasons to value. Therefore, in practical terms ***a culture and politics of governance attuned to take cognizance of such nuance, and to test these claims through reasoned, democratic scrutiny, is needed to make them known to policy and governance choices***. The search for justice, if it is to be a commitment of the emerging critical mineral value chains, must ensure this cultural, political, procedural and discursive context for public reasoning – reasoned, democratic, and inclusive scrutiny – of social-ecological finitude in decision making.

This approximates what Polanyi offered as socialism, "essentially, the tendency inherent in an industrial civilization to transcend the self-regulating market by *consciously subordinating* it to a *democratic society*. It is the solution natural to industrial workers who see no reason why production should not be regulated directly and why markets should be more than a useful but *subordinate trait* in a free society" (Polanyi 2001, 242; emphasis added). The field of Development Studies has long championed the merits of democracy and democratic decision making (e.g. Sen 1999a; 1999b). The field of Science, Technology and Society studies, too, has long

[6] The reliance on "narrow techno-economic mindsets and ideologies of control" for addressing environmental problems not only kicks in only after substantial harm has already been done – once injustice is recorded in a database – but it has also proven to be limited (Stoddard, Isak, Anderson, Capstick et al. 2021). For example, the Chief Economist of the bp Energy Outlook, 2024 underscored the limited effectiveness of the managerial approach to climate change: "Despite marked increases in government climate ambitions and actions, and rapid growth in investment in low carbon energy, carbon emissions continue to rise. Indeed, other than the Covid-induced fall of 2020, carbon emissions have risen every year since the Paris climate goals were agreed in 2015. The carbon budget is running out." See "Introduction to Energy Outlook 2024." Retrieve online on 10th January 2025 from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2024.pdf

championed the need for democratic scrutiny of technological change, i.e. arranging production-consumption systems (e.g. Feenberg 1991; Noble 1983, among many others). The principle of subsidiarity, and the ensuing idea of participatory planning and decentralization have also over the decades informed and challenged political and economic arrangement (e.g. Chambers 1997) and prominently so in the context of Sustainable Development (WCED 1987). Referring to sustainability as the common interest, this report notes:

> …The law alone cannot enforce the common interest. It principally needs community knowledge and support, which entails greater public participation in the decisions that affect the environment. This is best secured by decentralizing the management of resources upon which local communities depend, and giving these communities an effective say over the use of these resources. It will also require promoting citizens' initiatives, empowering people's organizations, and strengthening local democracy (p. 63).

These acknowledgments of the necessity for democratic decision making in the context of political and economic Development are fundamentally Social Ecological, as Murray Bookchin framed it (e.g. Bookchin 2006). They acknowledge that excessive power, its centralization, the exclusion of citizens and the lack of transparency are woefully insufficient arrangements for political and economic well-being, and for Sustainable Development in particular. At their core they regard *sustainability as justice*. The question, we ask, therefore, is does the ongoing discursive construction of critical mineral value chains create the space for public reasoning?

ii. Mining Injustice?

Modern mining is the archetypical extractive industry. Almost a century ago Lewis Mumford (1934), provoked us to think of modern civilization as one founded on mining. Virtually every facet of modern life depends on it. Even modern agriculture depends on the availability of "cheap" fossil fuels for energy, for nitrogen fertilizers and a plethora of other agrichemicals. It may not be the dependence that is of concern, but the form that mining has come to take – the mechanics that render these resources "cheap" (see, Moore 2015). The process appears to stand on the denial, and even the violent denial (e.g. Butt et al. 2019), of public reasoning.

An early assault on a humane form and pace of commerce, and the first step in creating "cheap" nature, was the dehumanisation of miners. Mumford (1934) traces this evolution to sixteenth century Germany when mining transformed from an occupation of "owner-workers" to mere wage workers. In this transformation, the forms of control and sources of motivation in the industry turned away from the necessaries of a livelihood for owner-workers, to speculative profits for investors, the "absentee owners" (pp. 74-75). No doubt that absentee owners made substantial capital investments needed for the technological innovations and transformation of the industry, but they also transformed the culture of mining and thereby the rest of modern industry. Such changes were evident by the nineteenth and early twentieth centuries. Mumford (1934) reports, and we quote at length:

> … Now, the sudden accession of capital in the form these vast coal fields put mankind in a fever of exploitation: coal and iron were the pivots upon which the other functions of society revolved. The activities of the nineteenth century were consumed by a series of rushes – the gold rushes, the iron rushes, the copper rushes, the petroleum rushes, the diamond rushes. The animus of mining affected the entire economic and social organism: this dominant mode of exploitation became the pattern for subordinate industry. The reckless, get-rich-quick, devil-take-the-hindmost attitude of the mining rushes spread everywhere: the bonanza farms of the Middle West in the United States were exploited as if they were mines, and the forests were gutted out and mined in the same fashion as the minerals that lay in their hills. Mankind behaved like a drunken heir on a spree. And the damage to form and civilization through the prevalence of these new habits of disorderly exploitation and wasteful expenditure remained, whether or not the source of energy itself disappeared. The psychological results of carboniferous capitalism – the lowered morale, the expectation of getting something for nothing, the disregard for a balanced mode of production and consumption, the habituation to wreckage and debris as part of the normal human environment – all these results were plainly mischievous (pp. 157-158).

Mumford presciently captured here what contemporary scholarship (see Chagnon et al. 2022) recognizes as extractivism. Mining was the first industry for which "extractivism" was conceptualized in scholarship, but its application has expanded, just as Mumford noted, to now also include agriculture and even the digital, intellectual and financial services (Chagnon et al. 2022).

Methodologically, extractivism is a powerful concept. We understand extractivism as an approach to commerce emerging from an "ensemble of self-reinforcing practices, mentalities" (Chagnon et al. 2022, p. 760) when high demand for commodities or the commercial potential of unexplored commodities intersects with social-ecological finitude under conditions of unequal *and* unethical power. It signifies that mining guided entirely by the competitive drive to maximize the efficiency of capital accumulation devoid of moderation by values such as aesthetics, autonomy, liberty, livelihoods and dignity, through public reasoning, will necessarily produce exploitation.

Scholars Kramarz, Park, and Johnson (2021) offer a typology of the dynamics that constitute what they refer to as the "dark side" of renewable energy. They identify, "(1) processes of dispossession that displace local populations and communities from land and livelihood through processes of expropriation and resource exploitation; (2) the pollution and degradation of local and global ecosystems at the extraction, production, transportation, and disposal/recycling points of the RE supply chain; and (3) systemic patterns of unequal environmental exchange that lock regional and national economies into destructive development dependencies of primary extraction, land expropriation, elite capture, and unsafe disposal of toxic and hazardous waste" (Kramarz, Park, and Johnson 2021, 2). Embedded in each of these types of relationships are elements of extractivism -- "*subjugation, violence, depletion and non-reciprocity*" – identified by Chagnon et al. (2022).

Looking for these elements of extractivism allows clearer analytical purchase. We use the academic and grey literature on lithium value chains to detail the discourse shaping critical mineral value chains, and its intersection with social-ecological

finitude. Such an analysis can tell us whether the emerging discourse organizing critical mineral value chains are cognizant of extractivism and seek to avert its production and reproduction, or not. As discussed in Section 5 below, the three elements of the discourse we identify are urgency, energy security and geopolitics. The overall analytical frame that guides this paper is represented in Table 1.

Table 1: Analytical Framework

	Elements of the Discourse		
	Urgency	Energy Security	Great power rivalry
Social-ecological finitude	?	?	?

iii. Research Methods

The language and practice of government, industry and civil society is the empirical basis for this study. We explore this through academic writing and media coverage of principles as well as practices such as bi-lateral and multi-lateral trade, investments and the actual production and consumption of critical minerals. To this end the paper applies a narrative review method (Sovacool, Axsen, and Sorrell 2018). Such a method is suitable for deriving insights from diverse perspectives. In our case these include the energy transition, national security and geo-strategy, commodity value chains, ecological economics, material flow analysis, political economy, ecological justice, international trade and international relations. A systematic review of each of these domains, separately, is not suitable for the goals of this study. A narrative review allows the author to draw on and synthesize a position on this multi-causal, multi-dimensional and rapidly evolving phenomena. Such an approach is indeed informed, to a larger extent than say a systematic review, by the author's judgement and choices. The best way to mitigate the downsides of this fact is to be transparent about the criteria for the choice of literature this analysis relies on. One of which is that this study only uses publications in English. This means that perspectives and insights only published in say Mandarin or Spanish and other languages are overlooked here, as are confidential and proprietary material.

We relied on EBSCOhost and set the search window for 10 years – 2014 to the present (end of April 2025) and used the following search strings. Our search using "Lithium AND Australia AND Mining" in the abstracts yielded 26 academic journal articles. Scanning the title clarified that all but two of them focused on issues related to life-cycle assessment, environmental impacts (greenhouse gas emissions), geochemistry of deposits, recycling, security of value chains and the competition from China. Notably, we did not apply "Justice" or "Communit*" or "Worker*" to create our list, because when we tried them, it reduced the hits significantly. Justice retrieved zero,

Worker* retrieved one (Gbondo et al. 2024), and Communit* retrieved one (Graham, Rupp, and Brungard 2021).

We ran the same keywords for China (of course with China, instead of Australia!) and hit 83 academic journal articles. A scan of the titles revealed that all but 11 of them pertained to question of mining techniques, risk mitigation and supply chain security, geochemistry and greenhouse gas emissions (which was the variable in more than one instance for sustainability). Again, we did not apply "Justice" or "Communit*" or "Worker*" to create our list, because when we tried them, it reduced the hits significantly. Justice retrieved zero, Worker* retrieved zero, and Communit* retrieved two (Graham, Rupp, and Brungard 2021; Boafo et al. 2024).

This picture changes a little when we move our attention to Latin America's so called "Lithium Triangle", i.e. Chile, Argentina and Bolivia. The keywords "AB Lithium AND AB Mining AND AB Chile/Argentina/Bolivia" generated 46, 30 and 14 hits respectively. Here too, the use of the words justice and worker* generated zero hits. However, notably, the use of Communit* generated eight, six and five hits respectively. We reviewed the titles of these papers and removed those that dealt with faunal diversity and biophysical variables and were left with seven unique papers that focused on the social-ecological dimensions of lithium mining.

To probe the role of civil society in the lithium value chain, we queried EBSCOHost with the following search string AB (Lithium) AND AB (worker cooperative*) AND AB (trade union*). It returned zero papers. We then queried the free version of Elicit.ai, with "Find research papers that mention worker cooperatives, and trade unions in the lithium value chain." Elicit.ai came back with one paper (Bell 2024) and it concluded that the literature lacks attention to worker cooperatives and unions. This gap needs to be redressed if the kind of democratic scrutiny this paper argues for is to be realized. We also queried Elicit.ai with the following prompt: "What are the occupational health, livelihood, and safety risks associated with the lithium value chain for communities and workers?" Several relevant papers were identified reporting consequences widely associated with mining in general, such as media (water, air and land) pollution, and related health issues, but it concluded that "no studies specifically addressed lithium mining toxicity". This lack of attention must be read alongside the fact that projections under the Net Zero Emissions scenario (see Section 3 above) indicate that the demand for lithium could grow nine times by 2040.

iv. A Brief on the Use of Discourse Analysis

The definition of discourse adopted here is a "specific ensemble of ideas, concepts and categorizations that are produced, reproduced and transformed in a particular set of practices through which meaning is given to physical and social realities" (Hajer 1995: 44). While reflections on the power of storytelling can even be traced back to Plato, the popular writings of the historian Yuval Noah Harari (e.g. Harari 2018) have now made popular the understanding that human beings are distinct from other species, not necessarily in tool use or ability to manufacture, but in the ability to tell stories about the past, the present and the future. And even more importantly, to share these stories so that we and others begin to live within them, by shaping our thoughts and actions in extremely powerful ways.

There is long standing academic reflection on the power of storytelling, which we refer to as discourse, more formally here, in the context of environmental and development policy. While discourse analysis has a broad disciplinary provenance and application, ranging from linguistics to artificial intelligence, critical theorists, i.e. those most closely interested in studying power and social change, think of discourse as "a broad conglomeration of linguistic and non-linguistic social practices that together construct power…" (Schiffrin, Tannen, and Hamilton 2005, 1). Similarly, explaining the importance of discourse analysis to understand and explain history, Escobar (1995, 5), notes that "a certain order of discourse produces permissible modes of being and thinking while disqualifying and even making others impossible". Given this role in shaping or reshaping the world of meaning and the material world, discourse becomes crucial as an object of study. Unpacking it allows us to ask about the possibilities of justice or lack thereof, in the "stories" and thereby the resulting modes of "being and thinking". In other words, by unpacking the emerging discourse on critical mineral value chains, we can usefully interrogate how likely a creative engagement with social-ecology finitude is in these newly emerging forms of meaning and being.

4. Typology of Discourses Shaping Critical Minerals Value chains

This section details the discursive typology comprising Urgency, Energy security and Great power rivalry that are shaping the construction of critical mineral value chains today.

a. Urgency

The language from the recent climate change COP meetings acknowledges that the global community has fallen below the expectations of the Paris Agreement and signals an intent therefore to dramatically accelerate action. The COP 28 talked about the need to reduce greenhouse gas (GHG) emission by 43% below 2019 levels. And the concomitant need to "triple renewable energy and double energy efficiency by 2030". It called for "a swift, just and equitable transition" ("COP28 Agreement Signals 'Beginning of the End' of the Fossil Fuel Era | UNFCCC" 2025). Similarly, COP 29, has significantly raised the financial ambitions to triple finance to USD 300 billion annually by 2035, and USD 1.3 trillion annually from "all actors" and "public and private sources" by 2035 ("COP29 UN Climate Conference Agrees to Triple Finance to Developing Countries, Protecting Lives and Livelihoods | UNFCCC" 2025). The IEA reported that "from 2017 to 2022, the energy sector was the main factor behind a tripling in overall demand for lithium, a 70% jump in demand for cobalt, and a 40% rise in demand for nickel." And this was *before* these recent COP meetings. In 2022, the market for critical minerals touched USD 320 billion, and it "is set for continued rapid growth, moving it increasingly to centre stage for the global mining industry" (IEA, 2023: 5; PWC 2023). The political, economic, and geopolitical significance of this scale of resource flow is hard to miss.

As witnessed in this language, an important discursive element in our typology is urgency (Hine, Gibson, and Mayes 2023). This need for a rapid or urgent transformation of the energy system is produced as a "permissible mode of being and thinking while disqualifying and even making others impossible."[7] In its turn, *urgency* is rationalized by a discourse of ecological modernization – the idea that the answer to the social and ecological costs engendered by modernity, is more modernity (Hajer 1995). Better tools, better data, better protocols, better regulations, better economics and eventually better management. The effectiveness of this approach and efforts expended over decades in its pursuit, are empirically questionable (Richardson et al. 2024) and the discourse has been usefully interrogated (Stoddard et al. 2021; Bäckstrand and Lövbrand 2006; York and Rosa 2003). Yet it prevails in energy policy

[7] The deployment of urgency is also reported in Dünhaupt et al. (2025a), who study the 2020 Draft Just Transition Policy developed by the government of Trinidad and Tobago. They find that policy "amounts to a "structural adjustment program," packaged with ecological concerns, particularly the urgent need to address climate change. It used this sense of urgency to advance further privatization, commodification and liberalization of key sectors of the economy, but also to exclude workers and their organisations from a critical policy debate that has enormous impact on them and the society as a whole."

making, as seen for example, in the COP statements sampled above and it underwrites the current discourse of *urgency* shaping critical mineral value chains. The point here is not that anthropogenic climate change is not real, or that the atmosphere isn't warming. Instead, it is that urgency risks sacrificing democracy, the space for public reasoning. It can override democratic imperatives to "enrich reasoned engagement through enhancing informational availability and feasibility of interactive discussions" … and ensuring that "different voices from diverse sections of the people can actually be heard" (Sen 2010, xiii). Urgency risks a rapid apolitical or techno-managerial 'solution' that might 'fix' the wrong problem (Swyngedouw 2010).

b. Energy Security

The second key discursive element is that of resource nationalism – "the tendency of resource rich countries to control their mineral resources and use them for economic and political gain" (Dou et al. 2023) and the resulting securitization of energy. This turn is traced back to the early 1970s and some regard it as the birth of the field of International Political Economy (e.g. Hancock and Vivoda 2014). The Arab oil embargo of the West in 1973 in the context of the Arab-Israeli war, turned then conventional liberal assumptions about the role of energy commodities in international relations, on its head. The embargo was simply a demonstration that conventional measures of state power, such as the size of the economy or the military were not adequate to maintain and assert power in international relations. Disrupting the value chains of energy commodities – oil in that instance – had demonstrably caused severe economic and social disruption for economies that were regarded hitherto to have their way in international affairs. This experience is regarded to have transitioned energy policy from the purview of economic issues (concerned with markets and efficiencies of allocation) to a national security challenge (Hancock and Vivoda 2014).

Chairman Mao is reported to have stated, "while the Middle East has oil, China dominates rare earths" (quoted in Zhang, Han & Jurisoo 2014). Speaking about the embargo, at a special session of the United Nations General Assembly on resources and developing, in 1974, Deng Xioping, then as chairman of the delegation, noted that "If imperialist monopolies can gang up to manipulate the markets at will, to the great detriment of the vital interests of the developing countries, why can't developing countries unite to break imperialist monopoly and defend their own economic rights and interests? The oil battle has broadened people's vision. What was done in the oil battle should and can be done in the case of other raw materials" (Xioping 1974). These discursive elements are indicative of how control over resources (and critical mineral among them) may be used to advance national economic and even national security interests. In 2010 China temporarily banned the export of rare earth elements to Japan against the backdrop of the long-standing conflict between the two countries over the Senkako/Daioyu islands, that had flared up at that time. The Chinese government then said that this was part of a larger effort to better manage the domestic rare earth element resources that had witnessed explosive growth and

exploitation since the 1990s. In addition to these domestic environmental and economic considerations that may have precipitated it, that ban continues to be seen as an illustration of using an advantageous position in rare earth elements for pursuing a strategic goal in an international altercation, in that case, with Japan (Zhang, Han, and Jürisoo 2014; Park, Tracy, and Ewing 2023).

The US dominated the global value chains of rare earth elements from the 1950s until the 1980s, when the US accounted for 99% of the production of the world's heavy rare earth elements (Park, Tracy, and Ewing 2023). The US approach, adopting what international relations scholars may regard as a "liberal" orientation, oversaw an industry largely driven by the private sector, but given the strategic value for weapons systems[8] in the competition with the Soviet Union, being also supported by the Federal Government in upstream R&D. With the demise of the strategic threat of the Cold War and the rise of environmental regulation, the viability of the US rare earth elements industry was undermined. With growing environmental scrutiny and compliance issues, and resulting rising costs, Edward Nixon, a brother of President Richard Nixon's, proposed the transfer of the beneficiation technology to China and the import of processed rare earth elements. This held the advantage for the US of displacing the environmental costs to China and accessing cheaper low-cost processed rare earth elements reimported for further value addition (Park, Tracy, and Ewing 2023). The plan succeeded from an economic efficiency lens but was disastrous from an environmental lens. Scholars record that according to the Chinese media "environmental contamination caused by REE {rare earth elements} mining and refining devastated Jiangxi and Guangdong provinces' ecology" (Park, Tracy, and Ewing 2023, 5). However, the US's complacency, given Deng Xiaoping's warning, cited in the previous paragraph, is striking. Consider the state of play in 2025 (*From Rock to Rocket: Critical Minerals and the Trade War for National Security*. 2025, Swanson 2025) to get a measure of the current strategic consequences of the US position in the 1970s on critical minerals.

The rare earth elements industry in China was developed by state owned enterprises, and the industry has always remained under state control. By the 1980s, the state's commitment to developing this supply chain produced a dedicated ministry, considerable R&D investments and growing market share. By the 1990s the government declared rare earth elements as protected strategy minerals, restricted foreign investments, and suspended permits for foreign firms. By the end of the decade export quotas were initiated, and by 2006 production quotas were also in place. By this time, Chinese production of rare earth oxides (the beneficiated form) topped 120,000 metric tonnes per year, while the US production was near zero, even as some of private firms that led the US industry for decades were declaring bankruptcy (Park, Tracy, and Ewing 2023).

Considering these trends and the behaviour of both these countries that have dominated rare earth value chains over the past seven decades, it appears that the US position started off with a "liberal" orientation while the Chinese industry was

[8] Note that this was a period long before the explosion of demand for rare earth elements for consumer electronics such as LCDs and smart phones, renewable energy technologies that are rapidly growing today.

guided by a long-term "realist" predisposition (Park, Tracy, and Ewing 2023). The year 2025 has witnessed a dramatic recentring of critical minerals within global security and political discussions. It started with President Trump's claim that the USA should take control of Greenland, either through economic means or even militarily. The claim generated useful commentary recounting the history of US interests in Greenland and the legality or lack thereof, of Trump's current proposal (Rothwell 2025). While US's decades old strategic interests continue, given the location of Greenland at the gateway between the Arctic and Atlantic, the current recent claim had the additional resource dimension to it. Greenland is rich in critical minerals and even oil and ironically, with climate change making the arctic more accessible, exploiting these resources is gradually becoming realistic (*The Economist* 2025a).

If the Arctic is warming up (pun intended) in 2025 so too is the long festering conflict in the mineral rich eastern Democratic Republic of Congo (DRC) near the Equator. Even as the Trump-Greenland shock reverberates, the city of Goma, capital of North Kivu province of the DRC, fell to M23 rebels allegedly backed by Rwanda. The Tutsi-Hutu ethnic tensions dating back to the Rwandan genocide underlie this conflict in eastern DRC that borders Rwanda. The control of Goma is however significant since it is the gateway to international markets for the mineral wealth that is mined in eastern DRC. Over 100 militia groups reportedly fight for control over this wealth. The M23, the largest among them, now claims control over this city and with that the ability to profit richly from the rising trade in these minerals (*The Economist* 2025b; "Rwandan Backed Rebels 'seize' Goma in Mineral-Rich Eastern Congo" 2025).

The pace of changes is so rapid that it outpaces the efforts of this paper to record them! As of this writing, (April 2025), the world economy is grappling with the disruptions engendered by President Trump's "Liberation Day" (April 2nd, 2025) tariff policies. On April 4th, 2025, China, which was visibly singled out by this new tariff regime, placed six heavy rare earth elements[9] mined entirely in China and rare earth magnets, 90% of which are manufactured in China, under export restrictions. A "special export license" is now needed for exporting these commodities. And the system to issue such licenses does not yet exist. This export suspension will affect a wide range of manufacturing industries across the world (Bradsher 2025).

The powerful rare earth-based magnets are essential components of electric motors which are used in everything from cars (including electric vehicles) and drones to robots and even missiles – not to mention wind turbines. The rare earth metals are also essential ingredients into manufacturing semiconductors essential for computing and consumer electronics. While the US government weaponized tariffs in its ongoing geopolitical competition with China, the latter has responded by raising tariffs as well as weaponizing the supply of certain critical minerals. In announcing these immediate restrictions, the Ministry of Commerce and the General Administration of Customs called out the dual-use character of these metals and said the "said the move aligns

[9] Western sources list Dysprosium, Terbium, Neodymium, Praseodymium, Europium and Yttrium as the six heavy earth elements covered under the new export restrictions ("China's Rare Earth Export Ban: Global Impact and Alternatives" 2025). Chinese sources list a slightly different list of seven medium-to-heavy rare earth elements, samarium, gadolinium, terbium, dysprosium, lutetium, scandium and yttrium (刘小卓 2025).

with global norms and is necessary to protect national security" (刘小卓 2025). The influence of the discourse of resource nationalism – i.e. 'the control of mineral resources and using them for economic and political gain' – on shaping critical mineral value chains, is clear and strident.

c. Great Power Rivalry

The third discursive element is more a corollary to the energy security discourse that is shaping critical mineral value chains today amidst the flux in international relations and changing geopolitics. It is cliché by now to start a discussion on contemporary international relations by acknowledging the error of western liberal scholars who, after the Cold War ended in 1989, declared the "end of history." It hadn't. This is now self-evident. But the contours of this return to history, as it were, are less clear. And international relations scholars argue widely on possible explanatory models to understand the behaviour of states and of peoples. In the West, the realist, liberal and historical structural paradigms in international relations offer diverging explanatory lenses, i.e. respectively, the power of the state, the freedom and quality of life of the individual and the role of institutions, and the importance of structures of power – political, economic and social, e.g. class that shape international relations (Hancock and Vivoda 2014).

Beyond the dominant western frameworks for understanding international relations is the *re*assertion that culture, long dismissed in western IR scholarship, is also a critical element to understand the behaviour of nations. While sympathetic to some elements of the critiques directed at the "clash of civilizations" thesis, Milner (2024), points out that there remain elements to Samuel Huntington's argument that need attention. Milner notes, a "second dimension of culture which received less attention in Huntington's writing was culture as the "meaningful structures" or categories of understanding and experience which shape human behaviour." However, the exploration and integration of this domain of "cultural specificities" within international relations is significantly underdeveloped. In the realm of practice, this also explains the deep uncertainties as the United States recedes in relative power from a world order that it was chiefly responsible for creating and enforcing after World War II. Will a newly ascendent China that has gained in relative terms, behave in similarly expansionist ways as the West? Will the Chinese, follow Kenneth Waltz's proposition that "states similarly placed behave similarly despite their internal differences"? Or is Wang Gungwu's challenge (see Milner 2024) to this thesis, emphasizing the role of cultural specificities of states in shaping international relations, more relevant?

On this question, we return to Deng Xioping's comments at the UNGA referenced earlier. He concluded that speech by noting "China is not a superpower, nor will she ever seek to be one. What is a superpower? A superpower is an imperialist country which everywhere subjects other countries to its aggression, interference, control, subversion or plunder and strives for world hegemony. If capitalism is restored in a

big socialist country, it will inevitably become a superpower" (Xioping 1974). The world has transformed since 1974 and China with it. The scholarship on international relations has not yet provided clarity on whether the views of Waltz or Gungwu have the upper hand at this juncture. But it does seem to be the case that states that are great powers, appear to have assumed a competitive, nationalist posture toward these minerals. As Dou et al. (2023) suggest, the "geopolitics of global fossil energy will shift to critical minerals geopolitics". In other words, critical minerals could be the new oil. Whether or not it has yet become the new oil, the beginning of 2025, clarifies that it has fully surfaced as a dominant theme in geopolitics, notwithstanding theoretical differences about the behaviour of states in transacting international relations.

It is against the backdrop of the three discourses discussed in this section that we place the current negotiations of critical mineral value chains. The three discursive frames illustrate three different but intertwined intentional loci or systems of agency and their potentials to shape the practices of the energy transition, the role of critical minerals in this transition and the arrangements to securely procure these minerals. To what extent do the critical mineral value chains that these discourses are actively shaping, align with or contradict the imperative to live well together, or, to live within social-ecological limits?

5. Justice in Emerging Critical Mineral Value Chains?

This section applies the framework developed in Sections 4 and 5 (see Table 1) to examine the transforming global value chains of Lithium. It presents the impact of the three discourses, i.e. urgency, energy security and great power rivalry, discussed above, on shaping these value chains and their relationship with social-ecological finitude. It focuses on lithium as the illustrative case, for reasons discussed in Section 3. Picking one mineral is necessarily incomplete, since the material and political specificities of each mineral will influence its emerging value chain. In other words, applying this framework to assess the large number critical minerals identified by different countries and their emerging value chains should be a future task. However, even this limited engagement with one mineral generates important insights, even if they may not be generalizable to all critical minerals.

a. Trends and Projections of Lithium (Li) Demand and Supply

Every element in the periodic table is unique. Lithium is perhaps more so. It is the lightest metallic and first solid element in the periodic table, preceded only by two gases in atomic mass, i.e., Hydrogen (H) and Helium (He) – the lightest elements in the known Universe. This attribute, and its electrochemical characteristics makes Li an ideal element to build batteries, a business where engineers tussle with the laws of

physics to store the highest possible amount of electricity in batteries that are as light as possible.

The commercial sale of Li-ion batteries was started by Sony and Asahi Kasei in 1991. The following decades, that also overlapped with the period of neo-liberal economic globalization, witnessed dramatic reductions in price and growth in utilization of the technology in the thriving consumer electronics segment[10]. These trends however pale in comparison to what is projected. For example, the IEA's Advanced Policy Scenario (APS) suggests a growth in demand for Li driven by "clean tech" applications (that is, batteries for Electric Vehicles (EVs)) from 38 kt[11] in 2021 to 1203 kt by 2040. Available supply of Lithium from recycling and reuse is expected to contribute about 154 kt by 2040 (IEA 2024). In other words, the bulk of the demand over the next decade and a half is expected to be met by mining of new lithium.

b. The Lithium Value Chain

The lithium value chain for batteries is regarded as three stages, *i.e.* the Upstream mining and extraction stage; the Midstream, that includes additional processing to make cell grade material as well as the manufacturing of electrodes and cells; and the Downstream stage that includes manufacturing the battery pack and end of life and recycling (FCAB 2021). The intersection of the differential distribution of lithium ores in the Earth's crust along with the country specific evolution of each of the three stages of the value chain, their state of technological innovation, and the state of international relations, make these value chains an important variable for the overall prospects of sustainability as justice in this century.

Lithium ores are of three broad types, i.e. hard rock ores, brines and clays. Of the 190 kt of lithium raw material produced in 2023, 120 kt came from hard rocks while 70 kt came from brines. Of this, Australia dominated the production from hard rock with 84 kt in the form of spodumene concentrate, and almost all of it was exported to China for midstream and downstream processing. China is also emerging as a player in the upstream stage with production from the hard rock ore lepidolite reaching 12 kt in 2023. This however was engendered by high prices in 2021-23 (IEA 2024). The other notable country in the upstream of hard rock lithium production is Zimbabwe with 9 kt supplied annually in recent years. Lithium hard rock production also came from informal artisanal and small-scale mining (ASM) in Nigeria. This is unusual for lithium, but quite common and widely reported for other metals like cobalt, goal, tin, tungsten and tantalum (IEA 2024) – and is widely known for employing people and children living in desperate poverty, extremely dangerous working conditions, severe health and environmental impacts, as well as poverty alleviation opportunities (e.g. Omotehinse and Ogunlade 2022).

[10] Between 1992 and 2016 the price per kWh of Li-ion battery storage decreased from US$ 6,035 to US$ 244. The corresponding growth in Li-ion storage capacity was from 1.55 MWh to 78,000 MWh (constant USD) ("History of the Lithium-Ion Battery" 2025).
[11] "kt" is kilo tonnes, or 1000 tonnes.

Lithium production from brines is dominated by two of the three countries whose common border region is called the Lithium Triangle of Latin America. Chile dominates this part of the upstream stage with 46 kt in 2023 and Argentina contributed 9 kt. China too is a notable player in this form of production with a supply growing to 14 kt from its western plateau. Bolivia, the third corner of the triangle, reported to have a quarter of the world's known lithium resources, has not yet managed to commercialize its production (IEA 2024).

In the midstream stage, refining of lithium into carbonate or hydroxide forms is dominated by China and Latin America, with hard rock refining in the former and production from brine in the latter. This picture is not expected to change soon. Even in 2030, 98% of the refining is expected to remain concentrated in three countries, with Argentina and Chile dominating the refining of domestic brines, and China continuing to dominate refining of domestic and imported hard rock ores (IEA 2024).

Taking the announced projects into account indicates that production of lithium raw material is expected to reach 450 to 520 kt by 2030 and over 1200 kt by 2040 (from 190 kt in 2023). The three dominant regions will continue to lead this rapid growth with Australia expected to remain the leading producer. It is expected that China in addition to being the largest consumer and refiner of lithium will overtake Latin America to become the second largest lithium producer this decade. Leading scenarios also suggest that in addition to Zimbabwe, Ethiopia, Mali, Namibia, the Democratic Republic of Congo and Ghana could enter the upstream hard rock stage of lithium production, with some base case projections suggesting that by 2030 Africa's production could reach 53 kt by 2030 (IEA 2024).

Lithium reserves in relation to production of lithium is an interesting picture. In 2024 the world produced 240 kt of lithium raw material, when the global reserves were estimated at over 30 million tonnes (mt) (USGS 2025). This translates to about 120 years of reserves. However, if we assume expected 2040 levels of production, i.e. 1200 kt, the current reserves will last 25 years. If we shift attention from proven reserves and look at "measured and indicated resources"[12] the picture changes again. Such resources are estimated currently at 115 million tons (USGS 2025). These estimates remain dynamic given the significant attention to lithium in recent years and the resulting exploration. For example, in January 2025, China's Ministry of Natural Resources announced that it has overtaken Australia, as the country with the second largest (after Chile) lithium reserves. The new findings, that include both hard rock ores as well as high altitude brines, place China's estimated reserves at 6.5 to 30 mt (Brown 2025).

Despite rapid growth in demand for lithium, there does not appear to be imminent absolute finitude (i.e. finitude that is not contingent on economic prices, see footnote 5). There is however the possibility of economic finitude, i.e. when prices fall reserves become unprofitable to exploit. This can constrain supply in the short run and

[12] These terms specify the degree of confidence about the nature and confidence of identified resources. "Measured resources" suggests the quantity and quality of the resource is well established. "Indicated resource" many of the criteria used to ascribe "measured resource" to geological deposit, but with a slightly lower degree of assurance. See, *Principles of a Resource/Reserve Classification for Minerals*.

investment in new mines in the longer term. The 2023 crash in prices (see, Figure 2) resulted from an oversupply of lithium due to slowing sales of electric vehicles. Periods of such low prices and price volatility in the value chain can dampen longer term availability of lithium (IEA 2024). A finitude linked to economic price trends is observable (Biesheuvel 2024). Yet, these tend to be responsive to price changes, leading some studies to suggest that in general, "growing mine production" when prices go up, is followed by "growing reserves and resources" (Mudd 2021). But, it is the question of social-ecological finitude that is important to engage, to which we turn to in the next section.

c. Towards Social-Ecological Justice in Lithium Value chains? Negotiated, Unnegotiated and Aborted Extraction.

It appears that absolute finitude of lithium in the earth's crust is not an immediate concern for the energy transition, even if the unevenness of the value chain is. And similarly, the availability of lithium for the market appears responsive to its economic price. The two forms of finitude (see footnote 5) may be set aside by policy makers. What cannot be, but often is, is the third form – social-ecological finitude – ***the experience of daily, constant, sapping of valuable freedoms, of dignity, and their eventual measurable manifestations*** (see Section 4(i) above) attributed to extractivism in the landscapes where people and communities live and work.

Scholarly evidence of "social-environmental harms" has been documented and reviewed in the recent literature. The impact on workers largely results from the exposure to air and water borne pollution. Brown et al. (2024) carried out a systematic review of the PubMed database, taking the lithium-ion battery value chain (that includes, cobalt, manganese, nickel *and* lithium) as the boundary. They identified 183 relevant papers, of which 110 reported results of toxicological hazards related to the above metals' value chains. Cobalt and nickel mining were found to be associated with respiratory toxicity, while for association with manganese neurological toxicity was strong. Notably none of these papers assessed lithium toxicity associated with mining. This is evidently a serious gap in the knowledge about the health of workers in the lithium value chain.

At the opposite methodological end, Yang et al. (2024) take the case of one river, the Jinjiang river basin that straddles the largest brine-based lithium production area in China. They characterize the pollution, its sources, exposure levels, and associated human health risks. Their findings indicate significant downstream concentrations of lithium attributable to lithium mining, and high concentrations in aquatic plants and animals. This contamination of water and vegetables is likely behind the chronic, but non-carcinogenic health risks observed among residents – who likely include both workers and local community members. Such localized studies underscore the seriousness of the gap in toxicity studies associated with lithium highlighted above by Brown et al. (2024).

The Lithium Triangle – the trijunction of Chile, Argentina and Bolivia – accounts for a disproportionate number of studies. The impacts of the lithium value chain include depletion of the water table that undermines agricultural production, pastoralism and cultural solidarity, the contamination of air and the land with airborne dust from the evaporation ponds that eventually settles, deposition of waste that alters the spatial arrangement of the land, among others. The prioritization of lithium mining has resulted in health impacts on workers and communities, the eviction of communities, forcefully gained mining concessions (i.e. without free, prior and informed consent), ambiguity around legal frameworks (e.g. Chile's legal classification of brine as a mineral and not as water), and the loss of biodiversity. Higher order political dysfunction like elite involvement in rent seeking and corruption, clientism, and even the active exclusion of civil society from decision making have been documented by a wide range of studies (Chaudary 2025; Orujela 2024; Marconi, Arengo, and Clark 2022; Liu and Agusdinata 2020). Some studies (e.g. Slattery 2023) point to the worry that promises of work made to frontline communities need to be monitored to ensure that they are not broken.

These diverse trends can be typologized as three displacements, i.e., displacement by dispossession, displacement by degeneration and displacement by lock-in into dependency (or dependent development) (Kramarz, Park, and Johnson 2021). The example of indigenous communities in the Jujuy and Salta provinces, where the Salinas Grandes (salt flat) of Argentina is located is instructive. Their effort to resist and or negotiate the penetration of lithium mining in their territories, as described by (Orujela 2024), captures these displacements. The Jujuy indigenous communities have used varied forms of protest to express disapproval of the "deterioration and the invasion of their lands". Their strategies spread across the province include "daily demonstrations" and "over a dozen roadblocks across the region". The government's response to these forms of political expression has been to "crack down…on demonstrators", to "carry out widespread arrests" and "perform illegal raids on homes". The allied approach used by the government is to contest the narrative of the three displacements utilized by the Jujuy communities, and instead, formulating the expansion of lithium mining as an "obligation to the 40,000 people of Argentina in need of development projects". Finally, the government has "invited lithium mining companies, who have openly disregarded or denied the environmental deterioration associated with their conduct, to initiate mining operations". Taking all of this into consideration, Orujela (2024) concludes that the communities' efforts to negotiate or resist is "not going to deter it [the government] from heavily investing the expansion of lithium mining" (Orujela 2024).

The Jujuy indigenous communities have taken cognizance of and articulated the varied violations of their social-ecological finitude. And they have used social mobilization and protest seeking an opportunity to publicly reason with the state. Yet latest media reports (Gabay 2025) confirm that mining activities have advanced from permits granted by the state to exploration and even production in a few of the identified locations in the province. Media reports also hint at a complex impact on the nature of work and on workers in these communities engendered by the arrival of lithium mining. The president of the El Angosto indigenous community in the Jujuy province told Mongabay, "The mentality towards livestock production has changed.

Ten years ago, the number of cattle was significantly higher than it is today. Now, young people are more dedicated to working for a company, for the state, or a specific job where they receive a salary" (Gabay 2025). This is a change in the attitude toward work among the young from a pastoral livelihood, mainly in subsistence mode, to the commodified form of wage labour. The changing attitudes appear as subtle inter-generational divisions within these communities.

This complexity of the attitudinal and material change, conflict and negotiation can find a generalized structure through a framework offered by González and Snyder (2023) with three "modes of extraction" practiced by transnational mining companies. By studying five mining projects, across three sub-national regions of Argentina, they frame extraction in three modes, i.e., unnegotiated, negotiated and aborted.

Unnegotiated extraction represents projects where companies offer little if any concessions to local stakeholders. For example, this is captured by the experience of some of the Jujuy communities recorded above by Orujela (2024). The large-scale violence in the mineral rich eastern DRC, recorded at the beginning of this paper, could be seen as another example, (albeit not a Lithium one) more so perhaps given that it had long suffered a history of brutal colonial rule and genocide, week state capacities, ethnic violence and numerous rebel factions, all overlaid onto its enormous mineral and other natural resource wealth that states and corporations from around the world prize. Such a context makes unnegotiated investments in extraction almost the norm. In general terms, we see the unnegotiated mode in records of violent dispossession, displacement and degradation embedded in mineral and other commodity value chains (Butt et al. 2019). Such violence often takes macabre form, as seen in data on the murder or disappearance of environmental defenders maintained by Global Witness.[13] Of the 146 murders and disappearances recorded in 2024, 29 were attributed to the "minerals and extractives" driver by Global Witness (2025, p. 16).

Negotiated extraction represents situations where local stakeholders can influence the terms of the extraction in the form of say, jobs, investments to create local public goods or even just monetary payments. The employment of indigenous peoples in the mining industry has received recent scholarly attention that records their demand for dignified work and inclusion in the mining economy as a strategy for their economic advancement. This was recorded by Caron et al. (2020) from Canada and Parmenter et al. (2024) from Australia. They are not mineral specific studies. Instead, they focus on the mining industry in general, in these contexts. In both situations it appears dignity, inclusion and work in the mining sector are actively being sought by women and men from indigenous communities.

It appears in these contexts that communities, mining companies and regulators are actively probing the boundaries of social-ecological limits to identify a line where indigenous communities feel their biophysical habitats are adequately protected – from 'daily, persistent, sapping of valuable freedoms, of dignity, and their eventual measurable manifestations, that are mediated via biophysical degradation' – and,

[13] "Land and Environmental Defenders Report Archive." Global Witness. Accessed October 10, 2025. https://globalwitness.org/en/topics/land-and-environmental-defenders-report-archive/.

they can also benefit economically from the commodification of their work. Of course, such outcomes are not guaranteed against the historical and ongoing backdrop of competitive accumulation, supplemented by discourses of urgency, energy security and geopolitical rivalry. Negotiated extraction is contingent on the strength of 'the procedural, institutional, political and cultural resources' required for such negotiations. It is useful to note here that Australia and Canada are among a few countries categorized as "full democracies" according to the Economist Intelligence Unit.[14]

Recall that the third type of displacement characterizing extractivism was 'systemic patterns of unequal environmental exchange that lock regional and national economies into destructive development dependencies of primary extraction, land expropriation, elite capture, and unsafe disposal of toxic and hazardous waste' (see Section 4). Basically, such displacement locks-in economies at the low value-added end of the global value chain. As reported above, Chile is the largest producer of lithium raw material and expected to be so for the foreseeable future. As widely observed and recorded in the development studies literature, avoiding the predicament of a primary commodity supplier requires creative and targeted industrial policies. In this context, the trade regime of the WTO and of bilateral Free Trade Agreements have been compared to "kicking away the ladder" (Chang 2002). While they provide increased market access, they limit the industrial policy space that less developed countries need to protect and grow domestic value-added industrialization.

The 2023 modified EU-Chile Free Trade Agreement (FTA) and its novel Energy and Raw Material (ERM) chapter is a case study, developed by Dünhaupt et al. (2025b). It effectively explores the ability of nation states to mitigate such displacement. Europe remains a small player in the lithium battery value chain and depends on Chinese imports for li-ion cells, if not batteries. Given the intersection of urgency, security and great power rivalry, Europe seeks to reduce this dependence through the European Battery Alliance. The case study reports that "various interviewees corroborated that the EU's concerns regarding China have been a driving force during the ERM negotiations" (Dünhaupt et al. 2025b, 15–16). These concerns took the form of two interventions that may reduce the industrial policy space available to Chile, a periphery in relations to the European core, with regards to lithium.

The first is a prohibition of import and export monopolies for the trade in commodities. Given that Chile does not currently have such monopolies, nor does it seem to want to create them, this was a relatively easy win for the EU negotiation team. The latter however were motivated not by present concerns but keen to "make sure that in the future there cannot be a legal way to favour exports to China in discrimination of the EU" (Dünhaupt et al. 2025b, 15).

It is the second concession that the EU won that raised concerns. This pertained to the policy of preferential pricing, where raw materials are provided at lower prices to incentivize investments in domestic value-adding industrialization. On the face of it,

[14] That remain in 2024. "The Global Democracy Index: How Did Countries Perform in 2024?" Accessed October 10, 2025. https://www.economist.com/interactive/democracy-index-2024.

an EU committed to progressive values and non-exploitative international relations might not be expected to press for curbing this option in Chile's lithium industrial policy. Article 8.5 of the ERM however is a complex negotiation of progressive intent, and perceived reality. The first paragraph removes Chile's preferential pricing option. But it proceeds then to offer a partial opening of this policy option. It offers four conditions under which lower prices may be offered to domestic value-adding investments. First, it should not amount to "export restriction on exports to the [EU]"; second, it should not "adversely affect the capacity of the [EU] to source raw materials from Chile". Third, tellingly, the clause states that if an "economic operator in a third country" received primary commodities at a lower price, the same price should be offered to "economic operators in like situations in the [EU]". Lastly, there is a clause about pegging the lowest price to the lowest prices in the preceding twelve months. According to interviewees, this restriction on preferential pricing arose given China's dominance across the lithium value chain and to guard against potential Chinese Foreign Direct Investment (FDI) in the lithium value chain in Chile (Dünhaupt et al. 2025b).

Future studies will have to determine if the tight constraints on Chile's preferential pricing policy is a win for the country. Currently, we can say that it signals what can be achieved by concerted and diligent trade negotiators and clear government strategies. But it also signals the opening of a new phase of industrial policy and trade negotiations, where the preferential pricing policy comes with constraints. Whether Chile succeeds in breaking free of its primary commodity supplier status regarding lithium is not only a function of this pricing policy. It also remains tied to Chile's own lack of national consensus on industrial policy, the limited state capacity, its absent car production industry, low domestic demand for EVs, and its current position in the lithium value chain (Dünhaupt et al. 2025b).

Future studies will also need to engage civil society actors like community (peasants and other indigenous livelihood workers) movements, or workers' cooperatives (such as those in mining) and of course the traditional trade unions from the lithium mining provinces. It appears from Appendix A1 in Dünhaupt et al. (2025b) that they had access only to bodies of the state on the Chilean side, while developing their case study. On the EU side however, it appears that an EU trade union(s) were interviewed, as was a trade policy NGO located in the EU. While Chile is more centralized, than say Argentina, the absence of the views of actors other than the state and representatives of the mining industry, suggests important perspectives may be missing. For example, Bell (2024) notes, transnational workers solidarity now appears to be needed to advance social justice struggles. Studying the emerging lithium value chain between Mexico and the UK, she arrives at this conclusion by acknowledging the possibility of green extractivism in this value chain – where the dispossession, degradation and dependency are concentrated in the global south while the value-added stages and the transitioning of the energy system are realized in the global north. Even if FDI is part of these deals, the pre-existing unequal global division of labour – of workers and of community livelihoods – are unlikely to be changed without focused effort. The call for transnational workers solidarity is a proposal to redress this colonial relationship being reproduced (Bell 2024). Such solidarity needs to be interpreted broadly to also include the social-ecological finitude of workers and communities, both inside and

outside unionised work, affected by lithium value chains. Even as this section is being finalized, in October 2025, media reports that IndustriALL Global Union convened a seminar to strengthen unions in the lithium sector in Argentina and Chile. The seminar was supported by Friedrich Ebert Foundation (IndustriALL 2025).

Lastly, aborted extraction is when companies stop after an initial investment because the costs of overcoming opposition, or of the terms for the negotiated extraction are too high, or external conditions such as falling demand in international markets, change (González and Snyder 2023). There are, however, few examples of clearly aborted extraction in lithium projects. Projects in Australia are regarded to proceed with the least opposition. Instances of aborted on delayed mining do not seem to be reported from the continent. One hypothesis is that environmentalist and communities in sparsely populated Western Australia support mining development for the economic progress it generates in the region. The state is also actively pursuing movement up the lithium value chain (Graham et al. 2021). Academic research, while not conclusive, suggests that environmental and community concerns have not aborted projects in China, the other big producer. In some cases, they have been met with state crack down on protesting communities, i.e. unnegotiated extraction discussed above (Graham et al. 2021). However, media reports indicate that lithium mining is being suspended in some of the largest mines in China due to concerns about overcapacity (Chatterjee et al. 2025). Although Chile is the largest producer in the world, further expansion appears to be hindered by lawsuits between the two largest miners. The two companies envisioned expansion, to supply Samsung, which in turn promised to produce lithium-ion batteries for electric vehicles in Chile, a significant step up in the value chain ladder. The deal was aborted given the government's growing concerns about water use and environmental concerns and presumably the political system wasn't conducive to negotiating (Graham et al. 2021).

Other parts of the world, particularly in Europe, the media and academic reports indicate more effective protests and community opposition to lithium mining projects on the continent utilizing the rhetoric of "colonialism", "sacrifice zones" and "attacks on democracy". These have delayed (not clear if aborted, yet) projects going beyond prospecting (see, e.g. Niranjan 2025). The US, once dominant (1960s to 1980s) in lithium mining, is seeking to revive the industry driven by geopolitical reasons. Notable mining projects in North Carolina and Nevada have faced opposition from conservation groups and communities as well as downward commodity price pressures. While these have not resulted in these projects being aborted, they have delayed production. They appear to have set aside community and conservation concerns (Graham et al. 2021, Burritt 2025, Solis 2025). More so than in Europe, so far at least, lithium extraction in the US has received a fillip from the discourse around energy security and great power rivalry. This has engendered direct federal investments in some projects and references by industry officials and politicians to US energy dominance and countering China's dominance of lithium value chain (Solis 2025).

What emerges from these case studies is that the path to recognizing social-ecological finitude, in lithium mining communities, is complex. The discourses of urgency, energy security and great power rivalry intersect in varying and complicated

ways with state and transnational corporate stakeholders, at the national, regional and local levels. The role of local structural factors like economic diversification, division of labour and national and local democratic resources are extremely critical as well. The EUs approach, we suggest, is an effort to uphold the ideals of progressive intent in international relations and being forced almost to acknowledge the reality of the new discursive environment of urgency, security and great power rivalry that is now upon it. While the EU-Chile trade agreement may be argued by some as not undermining Chile's industrial policy space, it certainly did not expand it. And when viewed against the extant reality of extractivism, we come away with a picture that stops short of an unambiguously more just reordering of north-south divisions of labour in lithium value chains.

The experiences sampled above suggest that the new discursive environment of urgency, energy security and great power rivalry, can further exacerbate the mining sectors age old displacements via dispossession, degradation and dependency even via lock-in – even in the case of lithium, a core mineral required for the purportedly progressive ambitions of transitioning to a clean and green energy system. There are no grounds to assume that social-ecological limits will be respected by the energy transition's demand for lithium. Such an outcome will require a lot more by way of vigilance to build on past normative victories (e.g. the advance of the sustainable development discourse) and to keep the powerful forces generated by competitive accumulation and the new discursive confluence of urgency, security and rivalry, in check.

This assessment of lithium value chains parallels that of researchers studying a different industry – AI – but also part of the same purportedly progressive politics of technological progress as social and ecological redemption, now confronted by competitive accumulation and by the discourses of urgency, security and rivalry. I quote an opinion writer from The New York Times (Witt 2025) who pondered this moment:

> …A.I. moves fast. Two years ago, Elon Musk signed an open letter calling for a "pause" in A.I. Today, he is spending tens of billions of dollars on Grok and removing safety guardrails that other developers insist on. The economic and geopolitical pressures make slowing down appear impossible, and this has Ms. Von Arx (an AI capabilities researcher profiled in the piece) concerned. "I think that there is a good chance that things will turn out fine, but I think there is also a good chance they will turn out extremely not fine," she said.

Clean energy and the demand for lithium, and other critical minerals, are also "moving fast." In precisely the same way.

6. Conclusion

The still dominant fossil-fuel based energy system (it accounted for about 87% of total global energy demand, in 2024) (Energy Institute 2025) is characterized by "cheap"[15] and abundant energy. It is the foundation on which the modern, urban-industrial world, since the industrial revolution, stands. Every dimension of modern economic, political, social, and cultural life – modern civilization in its entirety – stands on this foundation furnished by the fossil-fuel based energy system. This abundance has no doubt produced the great achievements of modernity, but it has not come without stupendous costs. The resulting contemporary environmental moment is characterized by interlocking social-ecological crises. These include climate change, biodiversity loss, land degradation, and the pollution of the air, freshwater and the oceans with varied pollutants in vast quantities – and their commensurate and diverse consequences for workers and communities across the world – the violation of their social-ecological limits, the undermining of their dignity.

Early observers on the course of political and economic affairs predicted such a turn. They instead argued for cautious reflective progress and even proposed alternatives (e.g. Mill 1848; Gandhi 1928; Mumford 1934) for this purpose. These early intuitions and analyses have informed a vast body of scholarship and innovations in development studies critiquing the dominant development model (its division of labour, its undemocratic tendencies and its obsessive faith in GDP growth and technological progress) and offered alternatives (see for example, Martinez-Alier 2023; Mathai et al. 2021; Brand and Wissen 2021; Govindu and Malghan 2016; Dale, Mathai, and Puppim de Oliveira 2016; Moore 2015; Mathai 2013; Guha 2006; Byrne, Toly, and Glover 2006; Martinez-Alier 2002; Smil 2000; Sachs 1999; Sen 1999; Daly 1993; Sachs 1992, among many others). Transitioning modern society away from its now foundational relationship with cheap and abundant energy is obviously a consequential and complex endeavour with multiple dimensions. In its essence however, it has been argued that it is about "transforming power" (Byrne, Toly, and Glover 2006).

Despite being faced with these debates and insights, the mainstream energy and environmental policy prescriptions have been strikingly unreflective. They remain determined to pursue more modernity, more efficient accumulation, more GDP growth, more technological innovation and more expert driven administrative or regulatory options. The context of critical mineral value chains and the case of lithium, in this paper, are an example of this inheritance. It is the belief that exponential growth in renewable energy deployment will redeem the present social-ecological crisis. It seems casually oblivious of the novel social-ecological crises that these new value chains will also engender. Just as the older value chains of the fossil fuel

[15] See the discussion on the construction of "cheap" nature in Moore (2015). The key point here is that resources are actively rendered cheap through deliberate historical processes such as medieval enclosures, colonialism and their contemporary manifestations (e.g. subtle and even violent violation of the rights of frontline communities, the rejection of progressive legislation and the dominance of corporate control over policy making in many states) that perpetuate enforced inequality and injustice vis-à-vis people and nature.

economy did. But more importantly, constrained by competitive accumulation and the new discursive frames of urgency, energy security and great power rivalry, the energy transition struggles to take a reflective and democratic path. It may be aware of the opportunity for justice that the current social-ecological impasse presents, but it appears incapable to pause, to reason and to seize it.

This paper framed "sustainability as justice" as the guiding orientation to determine whether the emerging clean energy value chains can overcome extractivism, understood as three displacements, i.e., displacement via dispossession, degradation and lock-in. Using lithium as an illustrative case, we find that justice is not guaranteed. The ongoing energy transition is not quite a "clean energy transition". There is no evidence that the lithium value chain is unambiguously just, as seen in the examples above. There are also large knowledge gaps for example, about the health impacts of the lithium value chain, even when the toxicity of mining, in general, is widely documented. At the same time, the new discursive confluence is real and is actively shaping industrial policy and investments in lithium value chains. The extent to which these arrangements can enable justice (i.e. overcome the three displacements) will depend on the character[16] and capacity of the state, civil society[17] and a supportive international order[18] – resources that are in short supply even if lithium is not.

The role of transnational workers' solidarity and the progressive politics represented by workers and trade unions in South Africa (Zulu 2025) and Trinadad and Tobago (Dünhaupt et al. 2025) find special mention as the kinds of democratic interrogation and oversight of clean energy policies and investments that are urgently needed. Both cases endorse public ownership of energy assets as a prerequisite for a more just energy transition. Ownership of production and distribution in these emerging value chains can of course take a range of forms. They could see public ownership, or state ownership, or even ownership by private enterprises. However, irrespective of which of these forms, or a combination of them, shape these emerging value chains, we argue that it is critical that they interrogate concentrated, opaque and unaccountable power, be it in the state or in the business corporation or even in cooperatives. All forms of organizing production-consumption can be at risk of excessive concentration of power and corruption.

Therefore, we broadly align with the view that as part of the emerging industrial policy to guide lithium value chains, the market must be 'consciously subordinated to a democratic society' (Polanyi 2001 [1944]). Part of this entails more attention from civil society to the impacts of these value chains on community solidarity and livelihood security, especially in the global south, given the relatively more effective democratic oversight in parts of the north. Equally it entails transnational workers' solidarity suggested by Bell (2024), and as seen recently in Chile (IndustriALL 2025), or public ownership in Trinidad and Tobago, and South Africa. It must also ask how

[16] A commitment to democratic values and practice, and the welfare of its citizens.
[17] Civil society indicates the broad swath of actors that constitute the public square, including social movements, political parties, community organizations, workers cooperatives, trade unions and policy research and advocacy organizations.
[18] One oriented to living well-together, different from today's emphasis on competition even slipping into violent conflict.

indigenous and non-indigenous frontline workers and communities in these value chains, and in civil society more broadly, define and nurture livelihoods, dignity and community? What modalities of democracy and solidarity can enable these outcomes?

Finally, the disproportionate academic attention to the Lithium Triangle needs to be corrected. More studies from China and Africa, and other regions that may soon become important in this value chain, are needed. In the absence of more even scrutiny of justice in the lithium value chain, and given the discursive confluence of urgency, security and great power rivalry, there is a risk of a competitive downward spiral in the race for critical minerals. There is also a wide variation in the capacity of states and national civil societies (see footnote 17) in the countries that are being looped into these emerging value chains. There is a risk, under such circumstances, that the pace of investments will outrun the social, political and cultural resources to guide them toward justice.

Will the energy transition advance sustainability as justice? The possibility that it won't, is real.

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