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The coloniality of green extractivism: Unearthing decarbonisation by dispossession through the case of nickel

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ABSTRACT

This article elaborates on the notion of "decarbonisation by dispossession" in order to shed light on the contradictory character of capital-driven energy transitions. First, we suggest conceptualising "decarbonisation" as a "socio-ecological fix" to intersecting, climate-induced crises of accumulation and hegemony, aimed at saving capital rather than the planet. Second, reflecting on the mineral intensity of "low carbon" technologies such as industrial-scale solar and wind farms, we approach ongoing transitions as a form of "extractivism": a form of predatory appropriation of land and resources, embedded in global geographies of unequal ecological and value exchange. Third, examining the case of nickel, we argue that, despite elements that complicate a clear North-South binary, capital-driven transitions are ultimately reinforcing the colonial character of energy provision; they are causing an expansion of "transition mineral" frontiers and associated dispossession effects, and creating sacrifice zones of extraction and processing concentrated in formerly colonised countries. Considering also the contradictory outcomes of mineral-intensive transitions in terms of CO^2 emissions reduction, our findings point to a structural inability of capital to solve its ecological contradiction. We conclude that radical proposals for a genuinely "just" transition, including those that mobilise a Green New Deal framework, should aim to decouple energy provision (and the reproduction of life more generally) from the material and epistemic violence of colonial-extractive capitalism.

1. Introduction

The climate crisis is deepening and accelerating, highlighting the urgent need to reduce anthropogenic greenhouse gas emissions. As a response, ambitious political and economic programmes for transitioning away from fossil fuels are being proposed, largely aimed at expanding investments in renewable energy generation and electric transport.[1] The most prominent among these programmes refer explicitly to the framework of the Green New Deal, which has re-emerged in public debate in recent years. For instance, in late 2019, the European Union adopted the European Green Deal (European Commission, 2019); and, in the US, the climate and recovery plans of the Biden administration draw on the Green New Deal bill sponsored by Representative Ocasio Cortez in 2019 (Milman, 2021). Yet, as mainstream and critical analyses have highlighted (Hund et al., 2020; Mastini et al., 2021), plans to "decarbonise" energy and transport systems will require substantial amounts of raw materials, whose extraction and processing are themselves carbon intensive, environmentally destructive and socially damaging.

The socio-environmental implications of expanding renewable energy frontiers are becoming central to research and debate in critical geography and political ecology (Sovacool, 2021). There is increasing attention, for instance, to the "greening" of large hydropower projects (Atkins, 2020; Del Bene et al., 2018); the land grabbing and conflicts associated with wind energy generation (Alonso Serna, 2021; Avila, 2017; Siamanta & Dunlap, 2019); the expansion of photovoltaics and

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[1] In this article we use the terms "renewable energy" or "renewables" primarily to refer to industrial-scale wind and solar power plants. We are aware that the "renewability" of such energy technologies is contested by political ecologists (e.g., Dunlap, 2018) because, as this article will also show, they are often associated with dispossession, ecological destruction and energy intensive mineral extractivism.

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"solar colonialism" (Allan et al., 2021; Brock et al., 2021); or the use of climate mitigation funds to promote biofuel and timber plantations, and fortress-style conservation (Alonso-Fradejas, 2021; Camargo & Ojeda, 2017; Devine & Baca, 2020; Lyons & Westoby, 2014).

Although these literatures highlight the extractivist and colonial character of industrial-scale renewable energy projects, the focus on "transition minerals" is still incipient. Recent political ecology research has paid particular attention to lithium, due to its primary use in "low-carbon" technologies, notably batteries, as well as its unique materiality and extraction process (Bustos-Gallardo et al., 2021; Jerez et al., 2021). "Green conflict minerals" (Church & Crawford, 2018, p. 56), among which cobalt and rare earths feature most prominently, have been another focus of research (Phua & Barraclough, 2016; Sovacool, 2019). However, base metals such as nickel – common metals already widely employed in conventional technologies, and not so closely associated with low-carbon "socio-technical imaginaries" (cf. Barandiarán, 2019) – are equally important or critical for renewable technologies, despite having received much less attention.

In this article, we argue that the energy intensity and socio-environmental impacts of transition minerals can help us reflect on the contradictions of capital-driven decarbonisation plans, including mainstream versions of the Green New Deal. We address two empirical objectives: *1)* to outline how the global geography of energy and extraction is being reconfigured in response to the climate crisis; and *2)* to detail the socio-environmental implications of transition mineral extraction and processing. This exploration offers a theoretical entry point for arguing that the ongoing energy transition is premised upon an extractivist logic, linked to neo-colonial patterns of uneven development and the creation of sacrifice zones of mineral extraction in the global South.[2] We adopt the concept of "decarbonisation by dispossession" to underscore the centrality of these patterns to current energy transition plans (cf. Ojeda, 2014; Sovacool et al., 2021).

The empirical arguments presented in this paper are primarily based on the analysis of press reports and grey literature focused on nickel and other transition minerals, their significance for energy transitions, and their socio-environmental challenges. Sources analysed include environmental and development agency reports; documents published by the nickel and associated industries and consultants; and reports by civil society movements and organisations. The identification of case studies and relevant sources was supported by consulting on-line archives such as the Business & Human Rights Resource Centre (https://www.business-humanrights.org) and the Environmental Justice Atlas (https://ejatlas.org; Temper et al., 2018). Research for one of the cases analysed—the Cerro Matoso nickel mining project in Colombia—was based on fieldwork conducted by one of the authors in 2016, including observation of socio-ecological impacts associated with the mine and 20 formal and informal interviews with representatives of affected communities. The positionality of the authors is at the interface of academic and advocacy-oriented work on extractivism and climate justice. Our shared experiences of researching (with) socio-environmental movements, including indigenous organisations, motivate our goal to render visible the neo-colonial character of mainstream climate policies.

The article is structured as follows. In the next section, we present our analytical framework for approaching decarbonisation by dispossession. By bringing the concept of "socio-ecological fix" into dialogue with the notion of (green) extractivism, we posit that a capital-driven shift to low-carbon technologies, primarily in the North, is organically linked with the production of sacrifice zones of extraction and dispossession, concentrated in the South. Section 3 argues that a sharp expansion of renewable technologies entails changes in the socio-ecological production of space, whereby the historical association of capitalism with the *intensive* spatial logic of fossil fuels is increasingly compounded by an *extensive* and more diffused geography of energy and extractive conflicts. In section 4, we direct attention to the case of nickel. We detail the severe socio-environmental impacts resulting from nickel production in extractive peripheries, and argue that these exemplify the type of geographically uneven dispossession which is likely to be increased by capital-driven energy transitions. Before concluding, in section 5, we present some reflections on political action, and in particular on how to imagine a "just transition" beyond colonial-extractive capitalism.

2. Unpacking decarbonisation by dispossession

This section elaborates on the idea of decarbonisation by dispossession, which refers to how mainstream efforts to mitigate climate change go hand in hand with a new wave of dispossession resulting from expanding energy and extractive projects. In order to unpack this dialectic of decarbonisation and dispossession, we draw on and bring into dialogue two critical conceptual perspectives. First, the notion of the "socio-ecological fix" helps us to see that, as envisioned by dominant capitalist institutions, *decarbonisation* plans are centrally concerned with saving capital rather than the climate. Second, we characterise mineral-intensive energy transitions as extractivism, so as to highlight their predatory and colonial character, predicated on uneven geographies of *dispossession*.

2.1. Decarbonisation as a socio-ecological fix

The notion of the "socio-ecological fix" was introduced by critical geographers in recent years, to refer to any intervention or strategy that "directly engages with and resolves, mitigates, or postpones a structural impediment—including any environmental one—to sustained capital accumulation" (McCarthy, 2015, p. 2495). The socio-ecological fix approach, as outlined by McCarthy (2015) and others (e.g. Ekers & Prudham, 2015), places emphasis on how capitalism responds to crises through socio-ecological and spatial reconfigurations. Specifically, climate change is associated with interlocking crises of accumulation and hegemony. First, the ongoing climate and ecological catastrophe, as well as reduced access to easily available resources such as fossil fuels, present short-term challenges and aggravate structural impediments to sustained capital accumulation. Second, this is linked with an increasingly visible crisis of hegemony or legitimacy of global capital (Fraser, 2022; Mann & Wainwright, 2018), to the extent that the association of capitalism with fossil fuels is leading more and more people to identify capitalism as the main culprit of climate change.

Following McCarthy (2015), we suggest considering mainstream energy transition plans, including versions of the Green New Deal, as attempts to fix such interlocked crises. This expands on Harvey's concept of the "spatial fix", by placing additional emphasis on how nature is appropriated and "produced" in the process in new ways (McCarthy, 2015, p. 2489). Fixing is meant here in a double sense: as solving or staving off accumulation crises, at least partly and temporarily; and of doing so by "fixing" capital into the built environment in ways that give rise to novel socio-ecological arrangements (Ekers & Prudham, 2017). This also resonates with the idea and critique of a depoliticising "techno-fix" to socio-environmental issues (Clark & York,

[2] We use the term "neo-colonial" to reflect the continuation of colonial relations today. The concept of neo-colonialism was coined by anti-colonial freedom fighters such as Kwame Nkrumah and Walter Rodney to refer to the European political economic domination and extractivism that prevailed in Africa after independence. The term coloniality is also often used to refer to this, particularly in the Latin American tradition of political ecology (see Alimonda, 2011) – though "coloniality" tends to emphasise the epistemological realm (the way social and racial hierarchies, cultures and knowledge systems are colonial) rather than the material one (unequal patterns of socio-ecological extraction, exchange, or development). For a discussion of the wide array of terms used to capture different aspects of neo-colonialism/coloniality in relation to socio-environmental dynamics – including eco-imperialism, environmental colonialism, and toxic/energy/fossil/carbon colonialism – see García López and Navas (2019).

2012).

The current demand boom for renewables and associated technologies may provide new outlets for investing over-accumulated capital, pushing new rounds of primitive accumulation. All the while, it helps to address the crisis of legitimacy by presenting capital not as the cause of global heating but as the way out of it: energy, extractive, and financial capital, as well as neoliberal governments and international institutions, refashion themselves from villains to global saviours of both climate and economy, shifting blame unto the depoliticised materiality of fossil fuels or CO^2, and to individualized citizen-consumers (Supran & Oreskes, 2021; Swyngedouw, 2010).

Thinking of decarbonisation plans as a globally operating socio-ecological fix suggests that what they aim to save is not so much the climate, but capital (McCarthy, 2015). This is only an ambition and future potentiality. There is no evidence that capital is being saved by increasing investment in green technologies, nor are there guarantees that this will happen in the coming years and decades. However, this framing allows us to stress that the core logic or concern of the (uneven and contradictory) global effort to transition away from fossil fuels through private investment in renewables is to leave dominant power relations and political economic arrangements intact, while staving off accumulation crises associated with capital-induced climate disruptions (Mann & Wainwright, 2018).

2.2. *The "green energy-extractivism nexus" and its colonial character*

A central, conceptually under-appreciated aspect of the current low-carbon transition is the corresponding expansion in transition minerals, and how this connects to long-standing colonial-extractive dynamics of capitalism. Producing electricity from renewable energies is currently ten times more mineral intensive than doing so from fossil fuels (Mastini et al., 2021, p. 5), and there is a clear consensus in policy and industry literature that a shift to renewables will entail an unprecedented increase in mineral mining (e.g., Barbesgaard & Whitmore, 2022; Hund et al., 2020, p. 11). Therefore, we argue that expanding industrial-scale renewables and transition mineral extraction should be considered part of the same emergent regime, what we call the "green energy–extractivism nexus".

This concept is informed by, but also moves beyond, Bainton and co-authors' (2021) formulation of the "energy-extractives nexus". Defining capital-driven energy transitions as a form of *extractivism* highlights not only the mineral intensity of such transitions, but also how they follow a predatory logic of land and natural resource appropriation. Moreover, seeing the socio-ecological fix as extractivist points to the ways that it (re)produces uneven geographical relations globally (Acosta, 2013; Vela Almeida, 2020). From the point of view of the countries where extraction takes place, extractivism may be understood as a national, resource-based development or accumulation strategy (Brand et al., 2016; Gudynas, 2016). However, from the perspective of its political economy, it should be approached as a structural necessity of capital, inherently global in character, and linked with neo-colonial processes of commodity frontier expansion and reconfiguration (Arboleda, 2020; Moore, 2015).

The historico-geographical dynamic of extractivism has been intimately imbricated with colonialism (Machado Aráoz, 2014). As Luis Tapia (2014) argues in the case of Bolivia, the systematic conversion of peasant economies into extractivist ones is a core defining feature (a "constitutive moment") of colonialism, establishing a hierarchical relation whereby one society is made to work for another and is partly disarticulated in the process. Today, extractivist expansion continues to insert indigenous and peasant territories and economies into complex global production networks and circuits of capital valorisation (Arboleda, 2020; Dorn & Huber, 2020). Even though such uneven geographical patterns are not unchangeable and do not always conform to a clear North-South or core-periphery binary—as the rise of China as the epicentre of raw material demand and industrialisation demonstrates (Arboleda, 2020)—overall, they tend to reproduce and reinforce spatial and power relations formed since colonial times.

2.3. *Green extractivism, dispossession and sacrifice*

In recent years, the term "green extractivism" (Dunlap & Jakobsen, 2020; Voskoboynik & Andreucci, 2022) has been introduced in political ecology research to refer to the paradox whereby an environmentally destructive mode of extraction and accumulation loaded with colonial legacies is being promoted as a solution to the ecological and climate crisis (cf. Sultana, 2022).[3] Mining extractivism has long been presented as a vehicle of modernisation, development and progress (Machado Aráoz, 2014). Since the 1990s, the mining industry and institutions like the World Bank have dedicated increasing effort to framing mining as key to sustainable and inclusive development (e.g., World Bank, 1996; Andreucci & Kallis, 2017). And, increasingly, resource extractivism is being repackaged not only as compatible with planetary sustainability, but indeed as essential for urgent and effective climate action (Hund et al., 2020). Researchers working on lithium in South America, for instance, have shown how transition minerals are imbued with novel imaginaries of clean, high-tech development and industrialisation, capable of saving the climate while ushering in an era of unprecedented prosperity and geopolitical power for southern countries (Barandiarán, 2019; Voskoboynik & Andreucci, 2022).

These techno-optimistic discourses find a counterpoint in accounts, increasingly present in popular media, of the "dark side" of electric batteries, the most infamous case being that of cobalt mining in the Democratic Republic of Congo (Sovacool, 2019). Overall, however, there is a clear tendency on the part of mainstream development institutions to present transition mineral extraction as necessary for reducing emissions globally, endorsing the World Bank's mantra that, if done correctly, mineral extraction contributes to sustainable and "climate-smart" development (Hund et al., 2020). This strategy is accompanied by a discourse of universal salvation from climate change via the greening of the global economy, which obscures the uneven, (neo-)colonial geographies of sacrifice upon which such greening is predicated (Zografos & Robbins, 2020).

There is broad evidence that extractivism is associated with ecological destruction, dispossession and violence (Menton & Billon, 2021). The systematic creation of sacrifice zones of industrial pollution and waste has long been denounced by environmental justice movements (Lerner, 2012). Zografos and Robbins' (2020) notion of "green sacrifice zones" expands on this idea: by adding the label "green", not only does it signal the contradictory dialectics between greening and sacrificing, but it also *spatializes* this dialectic by signalling the divide between territories or populations that are greened, and others that are sacrificed (cf. Sovacool et al., 2020). It highlights the spatial injustices traversed by neo-colonial hierarchies and racialization of populations connected to global resource and energy provision and use (Andreucci & Zografos, 2022).

Decarbonisation plans based on expanding industrial-scale renewable and electric technologies are giving shape to these injustices, whereby cities and industries in the North are increasingly striving to achieve the status of low-carbon or "zero-emissions"; while peripheries, primarily in the South (but also in economically and politically marginalized spaces in the global North), are being assigned the role of extraction areas, waste or carbon dumps. As such, decarbonisation is becoming a widespread means of "accumulation by dispossession", embedded in neo-colonial patterns of extractive capitalism (Bumpus & Liverman, 2008; Ojeda, 2014; Siamanta & Dunlap, 2019; Sovacool et al.,

[3] In this sense, the idea of green extractivism builds on related conversations in critical geography around "green neoliberalism", "green grabbing", and the "green economy" (Cavanagh & Benjaminsen, 2017; Devine & Baca, 2020; Fairhead et al., 2012).

2021; Yenneti et al., 2016).

3. Changing geographies of energy and extraction

In this section, we argue that a sharp expansion of low-carbon technologies entails changes in the socio-ecological production of space; and that this complicates predictions for a relatively smooth low-carbon transition. First, we provide some evidence on the current and projected expansion in renewables and electric automotion globally. Second, we show that such expansion is changing the geography of energy production and provision, whereby the historical association of capitalism with the *intensive* spatial logic of fossil fuels is increasingly compounded by an *extensive* and more diffused geography of energy and associated conflicts. Third, we argue that considering the extractivist character of energy transitions helps us to highlight their impacts in terms of socio-ecological destructiveness, carbon emissions, and spatial injustice.

3.1. Decarbonisation in energy and transport

Energy decarbonisation is a central goal of mainstream climate action. The consensus is that achieving "net zero" emissions by 2050, required to keep temperature rise within the 1.5 °C threshold (IPCC, 2018), would involve an unprecedented increase in renewable energy generation and a rapid electrification of transport globally (IEA, 2021b). Energy generation from renewables has already been increasing sharply in the last decades, particularly in solar photovoltaic and wind, and this trend is projected to continue in the near future (IEA, 2021b). This will require an unprecedented redirection of capital into new energy infrastructure (IEA, 2021b, p. 22), related to a concomitant (though partial and uneven) "phasing out" of fossil fuels (Furnaro, 2021). Transportation is also at the threshold of a systemic shift away from fossil fuels. The automotive sector is investing heavily in a reconversion to electric vehicles (EVs), in order to respond to actual and predicted regulatory and reputational pressures. Forecasts by the International Energy Agency (2021b, p. 134) estimate that, in order to achieve net-zero, 60% of car sales would need to be electric by 2030, reaching 100% by 2050. This would entail a rather spectacular increase in the total number of light-duty EVs on the road globally, from 11 million in 2020 to approximately 2 billion in 2050.

As with renewables, this would imply a significant expansion of resource extraction and production networks. Electric automotion is also becoming exemplary of the uneven geographical dynamics inherent to energy transitions (Bonelli et al., 2022; Brand & Wissen, 2021; Jerez et al., 2021): sales of electric cars are strongly correlated with consumer purchasing power as well as state subsidies and investments in charging infrastructure, and therefore concentrated (in *per capita* terms) in wealthy, northern countries like Norway, Sweden and the Netherlands (IEA, 2021a). Meanwhile, as we will discuss in the next section, the extraction of minerals for the components of those cars takes place predominantly in global South regions. Again these patterns are complicated by the growing centrality of China as the main consumer and industrial processor of raw materials, but by no means reversed by it.

3.2. Renewables and the socio-ecological production of space

The expansion of renewables is part of a fundamental change in the geography of energy (Avila et al., 2021; Bridge et al., 2013). For Huber and McCarthy (2017, p. 658), a shift to renewables marks a historic break with the "subterranean energy regime" of fossil-fuelled capitalism, whose spatiality is "structured by an overall 'vertical' reliance upon the underground stocks of energy and minerals", concentrated around more or less fixed points in space. Historically, the rise of this energy regime reduced the relative significance of land compared to that of productivity-enhancing machines and technologies enabled by fossil energy, and to access to the fuels themselves. The spatial implications of this are extremely significant: subterranean fossil fuels were much less space extensive than organic fuels such as wood, thereby reducing the land footprint of energy generation and, indirectly, changing the organisation of production and (geo)politics of energy access. In sum, the materiality of fossil fuels had the effect of freeing up land for other uses, and reduced the relative social power attached to control over land (Huber & McCarthy, 2017).

A transition to renewables represents a partial return to a more spatially extensive mode of energy production and provision. The spatial or land footprint of renewable energy provision is several times greater than that of fossil fuels (and nuclear). This is particularly true for biofuels, but applies also to wind and solar. For instance, producing one unit of energy from wind farms requires up to 600 times more land than from coal (from solar panels, 60 times more).[4]

The increased land footprint of renewables has a disproportionate impact on marginalized rural areas, which have lower population densities and land prices (McCarthy, 2015). This could lead to an unprecedented wave of agrarian enclosures; the industrialisation of large areas; and other forms of dispossessions resulting from the construction of energy transmission grids and infrastructures (Dunlap, 2020). Such new enclosures are already being denounced by critical agrarian scholars, under the label of "green grabbing" (Fairhead et al., 2012). These are primarily associated with biofuels (Franco & Borras, 2019); yet increasingly land grabs and other forms of dispossession are being found by political ecologists to result from wind and solar projects (Franquesa, 2018; Siamanta & Dunlap, 2019; Stock & Birkenholtz, 2019; Yenneti et al., 2016).

These dynamics are advancing "energy colonialism" in rural peripheries in the North and South (Batel & Devine-Wright, 2017; Dunlap, 2020), with regions such as the Isthmus of Tehuantepec in Oaxaca, Mexico emerging as global hotspots of renewable energy contestation and conflicts (Alonso Serna, 2021; Avila, 2017; Avila et al., 2021; Ramirez & Böhm, 2021). Such projects are also increasingly inserted into fraudulent climate mitigation schemes whereby northern countries and corporations are granted emissions offsets for investing in renewable projects in the global South (Bachram, 2004; Lyons & Westoby, 2014). Indeed, we see a continuity in these dynamics with the ways that fossil fuels have been intertwined with colonialism (Smith-Nonini, 2020). These are emerging and consolidating features of decarbonisation by dispossession.

3.3. The impacts of extractivism compound those of energy infrastructure

These trends signal that, as Huber and McCarthy (2017, p. 666) argue: "far from being inherently progressive or environmentally benign, the geographies of industrial-scale renewable energy production might involve just as many 'extractive peripheries' or 'sacrifice zones' as current geographies of fossil fuel extraction" (see also Brock et al., 2021). However, considering the raw material intensity of renewable energy transitions, as part of what we called the green energy-extractivism nexus, the argument can be pushed further: land-based forms of energy production and provision are not simply *replacing* a regime of intensive verticality, but *adding* to it. In other words, the horizontal and extensive installation of industrial-scale renewable energy is compounded by the intensive and vertical extraction of minerals, which in turn results (as we will show later) in localised increases in fossil fuel extraction and energy generation. Moreover, given the slow pace (at best) of fossil fuel phase out (Furnaro, 2021; Roy & Schaffartzik, 2021; Sweeney et al., 2021), increased land based

[4] We calculate this on the basis of data about the respective "power density per unit area" of these technologies, cited in Huber and McCarthy (2017, p. 665): 2–3 W/m^2 (Watts per square meter) for wind, 20 W/m^2 for solar, 1200 W/m^2 for coal.

conflicts could coexist, for decades to come, with growing struggles over the extraction and processing of *both* fossil fuels and transition minerals.

Thinking of renewables as part of the same complex as fossil fuels and mineral extractivism means that not only rural areas in general, but primarily extractive peripheries in the global South are likely to be disproportionately affected by dispossession. This is not to deny that the increase in mining will also affect marginalized populations in the peripheries of capitalist cores (del Mármol & Vaccaro, 2020; Lassila, 2018). Yet, the geography of transition mineral deposits shows a clear prominence of resource-rich, colonized or formerly colonized countries (World Bank, 2017). Therefore, renewable energy expansion will reinforce rather than challenge the extractivist dynamics of global dependent peripheries. The next section will detail some of the socio-environmental implications of such expansion in the case of a key transition mineral, nickel.

4. Transition minerals and dispossession: the case of nickel

In this section we present the case of nickel in order to illustrate some of the socio-ecological implications of a mineral-intensive decarbonisation. First, we observe that growing demand for nickel is causing a shift to lower grade ore deposits and an expansion of mining frontiers in formerly colonised countries, centred on Southeast Asia. Second, we show that, in places where nickel extractivism is growing, this is driving a paradoxical increase in carbon intensive, fossil-fuelled energy production, due to the high energy intensity of mineral production. Finally, we detail the impacts of nickel extraction and processing on affected territories and populations in different countries—including deforestation, land dispossession, soil, water and air-borne contamination, indigenous rights violations, and violence against environmental defenders.[5] Taken together, these impacts give a clear indication of the type of sacrifice and dispossession that sustain decarbonisation.

4.1. Reconfiguration and expansion of the nickel frontier

Nickel is a key material for low-carbon technologies. It is used primarily in energy storage, particularly rechargeable batteries for electric vehicles (Hund et al., 2020, p. 61). Nickel is also employed in thermal solar plants, concentrated solar power, geothermal energy production, generators for wind energy, and for protecting energy infrastructure in corrosive marine settings (Church & Crawford, 2018, p. 56; Henckens & Worrell, 2020; Hund et al., 2020; IEA, 2021c; Månberger & Stenqvist, 2018). Currently, nickel used in green technology still represents only a fraction of the global market (Azevedo et al., 2020). Yet, demand for nickel is set to grow sharply over the coming decades. For instance, a recent report by the International Energy Agency (IEA, 2021c, p. 8) estimates that (in an optimistic decarbonisation scenario) overall nickel demand could increase 19 times by 2040.

Growing demand is causing nickel mining to shift towards lower grade ores. Nickel is largely found in two types of deposits: sulphide ores (found in the subsoil, generally a product of volcanic or geothermal activity), and laterite ores (abundant in the topsoil in tropical regions). Historically, sulphide ores mining was more commonplace, due to higher ore grade. However, production is increasingly shifting towards lower grade, laterite ores, which are more abundant (60% of global reserves) (U.S. Geological Survey, 2020).[6] The processing of laterites is more complex: while sulphide extraction is done through conventional underground mining techniques, laterite extraction tends to require open-pit mines or strip-mining of topsoil. This requires more energy and is generally more impactful on surrounding ecosystems (Smith, 2018).

This shift from sulphide to laterite ore deposits is reconfiguring and expanding the geography of nickel extraction. Most sulphide nickel extraction took place from deposits in Australia, Canada and Russia. The move towards laterites has shifted the epicentre of nickel mining towards Southeast Asia: in 2017, the top two nickel producers were Indonesia and the Philippines, concentrating 41% of global production (Smith, 2018). In 2019, they each exported over 1.2 billion US dollars in nickel ores, adding up to 58% of global exports (Atlas of Economic Complexity, 2021a). In the coming decade, it is predicted that Indonesia will be responsible for most growth in nickel extraction and processing (Sanderson, 2020). Most of this production is routed through China, which is the world's largest purchaser of nickel ore (73% of imports) (Atlas of Economic Complexity, 2021b), being the main producer and exporter of batteries and other nickel-based low carbon technologies globally.

4.2. The paradox of "decarbonising" through energy intensive extraction

Considering the overall life-cycle, the CO_2 emissions of renewables are significantly lower than those fossil fuels (Hund et al., 2020, p. 87). However, at the point of extraction and production, renewable technologies generate more emissions than fossil fuels. This has relevance for energy and carbon colonialism, to the extent that such emissions (and associated socio-ecological impacts of fossil energy generation) are largely concentrated in poorer countries where minerals are extracted and processed and renewable technologies assembled (cf. Lennon, 2021).

Paradoxically for a mineral expected to contribute to global decarbonisation, nickel production is remarkably carbon intensive, particularly in the smelting and refining stages (Eckelman, 2010), as it requires high temperatures in order to break down chemical bonds.[7] According to a World Bank report (Hund et al., 2020), nickel is the third most impactful transition mineral in terms of its "global warming potential" (GWP), after aluminium and graphite. Together, producing these three minerals to meet projected global demand increase would "account for a cumulative 1.4 Gt CO^2 up to 2050, nearly equivalent to the total 2018 CO^2 emissions from France, Germany, and the United Kingdom combined" (Hund et al., 2020, p. 90).[8] These figures may be optimistic, to the extent that, first, this report (unlike previous ones, e.g., World Bank, 2017) factors recycling and reuse in its growth estimates for transition minerals (Whitmore, 2021, p. 14); and second, it does not take into account decline in ore grades, which significantly increases energy and material expenditures for extracting the same amount of metal (Bainton et al., 2021, p. 6).

This high energy demand relies on burning significant amounts of fossil fuels for mineral production. For instance, in Sulawesi, Indonesia, the boom of nickel mining and smelting has tripled the electricity needs of the region (Harsono, 2020), and four new coal-fired power stations

[5] These cases were selected on the basis of their representativeness, showing the diversity of socio-ecological impacts associated with nickel extraction, processing, and associated infrastructures.

[6] Nickel is normally differentiated into classes of quality, which indicate what it can be used for. The highest-grade, or Class 1 nickel, is what is needed for lithium-ion batteries. This was typically extracted from sulphide mines. Of the two categories of laterites (saprolites and limonites), only limonites are of good enough quality to be used for battery production (Azevedo et al., 2020).

[7] Energy costs are often very high in nickel-processing facilities and can make up to half of operating costs (Tsang & Zhang, 2012). Moreover, high levels of carbon emissions are released when acid effluents are neutralised after acid leaching. Overall, the emissions of nickel extraction from laterite deposits are significantly higher than from sulphides extraction (Smith, 2018).

[8] The authors of the report obtained this figure by multiplying the estimated total demand in tons for each mineral, multiplied by its GWP per kilogram. Mineral demand estimates are derived from the 2017 IEA's "2DS" (two-degree scenario), defined as a scenario with at least a 50% chance of limiting the average global temperature increase to 2 °C by 2100. For nickel, the estimated global demand through 2050 is 20 million tons, assuming a 35% recycling rate (Hund et al., 2020, pp. 11, 82).

are being planned to meet the demand (Fikri et al., 2022; Global Energy Monitor, 2021). Indeed, some of the largest socio-ecological impacts of nickel mining and smelting have emerged from the energy apparatus required to sustain it. Norilsk Nickel is currently facing the largest environmental fine in Russian history (2.1 billion US dollars) for a massive spill which leaked over 150,000 barrels of diesel from a power plant owned by the company into the Ambarnaya River (Fedorinova, 2020). This is considered the worst ecological disaster to ever occur in the region.

Offsetting such emissions is also linked with environmental impacts and dispossession. The Cerro Matoso nickel project in Colombia is the fourth largest open-cast nickel mine in the world, owned by the Australian company South32 (formerly part of Anglo-Australian mining giant BHP Billiton) (El País Cali, 2018; Opray, 2017). Its processing facility is the most energy-intensive industrial project in the country (Arcila, 2020). In order to offset its emissions, the Cerro Matoso project has established a series of new palm oil and fast-growing teak plantations (Voskoboynik, 2016). This type of plantations has been associated with deforestation, pollution from agrochemicals, water scarcity, loss of livelihoods, and violent expulsions, land grabbing and murders of local residents (Ojeda, 2014).

4.3. Socio-environmental impacts of nickel production

Nickel extraction and processing are associated with severe impacts on ecologies and communities (EJAtlas, 2019). As with other metals, the dumping or leaking of toxic waste (acid mine drainage) is a main source of contamination (Müller & Reckordt, 2017). The nickel industry faces significant waste management challenges, given that often low-grade ores and rock materials extracted will only contain a sliver of nickel (around 1% or less) (Wollschlaeger, 2017). The significant amounts of remaining material (known as waste rock and tailings) are often inadequately stored or treated, causing contaminants such as heavy metals to affect adjacent soils and water bodies (Bartzas et al., 2021). Moreover, the disposal of tailings into the sea—known as sea waste disposal or deep sea tailings (DSTs)—is a growing practice in the nickel industry, and an increasing concern associated with nickel mining projects (Whitmore, 2021).

The smelting process of nickel is also linked with severe air- and water-borne pollution. The smelting of nickel from sulphide ore emits very high amounts of sulphur dioxide, which is a significant contributor to acid rain (Azevedo et al., 2020). Companies in the industry are among the largest global and historical emitters of sulphur dioxide.[9] Just one smelter facility, constructed in the Siberian city of Norilsk in 1942 and decommissioned in 2016, was responsible for 350,000 tonnes of annual emissions of sulphur dioxide (Luhn, 2016). Monchegorsk, home to the world's largest nickel refinery that was only recently closed, is one of the most polluted areas in Russia (Nilsen, 2021).

The socio-environmental impacts of nickel mining are worsened by the fact that 40 percent of global reserves (all of them laterite deposits), are located in high biodiversity areas, and 35 percent in areas with high water stress (Smith, 2018). Nickel mining expansion implies the clearance of territories and, in some cases, the eviction of communities reliant on them. In 2017, the government of the Philippines suspended 28 mining projects (half of its nickel producing capacity), citing concerns over their environmental damage (Almendral, 2017). In 2021, the government suspended nickel mining operations on Tumbagaan Island, over its "devastation". Cabinet secretary Karlo Nograles noted: "the island has, at this point, been mined out" (Jacinto, 2021).

4.4. Dispossession, health impacts and human rights violations

Nickel projects have been associated with dispossession effects on communities, particularly indigenous people and the rural poor (EJAtlas, 2015; 2022b). Contamination of soils and water bodies presents major threats to food sovereignty and security. An example of this can be found in Papua New Guinea, where fisher-folk communities have long challenged the Chinese-owned company Ramu NiCo over its dumping of millions of tons of mine waste into the ocean, affecting fisheries relied on by around half a million people (Morse, 2020; Mudd et al., 2020).

Populations affected by nickel mining (including mine workers) also suffer from grave health impacts (Genchi et al., 2020). For instance, indigenous Zenú, Afro-Colombian, and campesino communities living near the aforementioned Cerro Matoso nickel project in Colombia have denounced a significant rise in respiratory illnesses, congenital defects, and dermatological conditions linked to the heavy polluting generated by the mine and smelter (Idrovo, 2018). In 2018, the company was found guilty by the Colombian Constitutional Court for causing irreparable damages to residents and ecosystems' health through contamination (El País Cali, 2018; Heinz & Sydow, 2020). The court found that the company had violated numerous environmental regulations through its 30 years of operation, and in this lengthy period, had not once consulted the region's indigenous communities. However, due to the difficulty of specifying causal linkages and measuring impacts, the payment for damages to residents was later annulled.

Concessions for nickel mines often overlap with the ancestral lands of indigenous communities (Dominish et al., 2019; Horowitz et al., 2018; Whitmore, 2021), generating resistance and conflicts. For instance, the Aborigen Forum, a coalition of communities across the Russian Far East, North and Siberia have organised a concerted campaign against nickel mining in the region. In 2020, the forum called on car manufacturer Tesla to boycott any purchases of nickel from Nornickel, until the company conducts an independent assessment of the damage of its operations, compensates indigenous communities for the destruction of their way of life, implements plans for re-cultivating contaminated lands in both the Taymyr peninsula and Murmansk Oblast, and revises its policies on relationships with indigenous peoples (Indigenous Russia, 2020).

Multiple human rights violations have been documented across nickel extraction supply chains over the last decades (EJAtlas, 2022a). Colombia, the Philippines, Guatemala and Indonesia—where some of the world's largest nickel mining projects are located—are among the 10 deadliest countries for environmental defenders, according to Global Witness (2020).[10] In the Philippines, a well-known case is that of Gerry Ortega—a radio broadcaster, environmental activist and outspoken critic of nickel mines—who was murdered in January 2011, as he was preparing to launch a major campaign to ban mining operations in Palawan (Mariano, 2011).

Guatemala has been another hotspot of human rights abuse linked to nickel production. The Fenix mining project in El Estor, particularly, has long been a source of grave impacts affecting Q'eqchi' Maya indigenous communities (Rodríguez, 2021). Conflicts have reactivated particularly after 2004, when the mine was acquired by the Canadian company Skye Resources.[11] At least three people have been killed, and dozens injured, in protests by community members against the mine (Brigida, 2020). The project's activities have also been linked to a range of human rights abuses, including eviction, arson, unjust detention, forced displacement, and sexual violence (Church & Crawford, 2018, p. 56; Deonandan et al.,

[9] The world's main nickel companies by production are: Vale (Brazil), Norilsk (Russia), Jinchuan (China), Glencore (Switzerland) and BHP (UK-Australia) (NS Energy, 2020).

[10] Over half of all killings of environmental defenders reported in 2019 (107 out of 212) occurred in Colombia and The Philippines. Mining is the industry most directly associated with such killings (50 deaths) (Global Witness, 2020).

[11] In 2008, the project was acquired by another Canadian company, HudBay Minerals; and it has been owned since 2011 by the Swiss-based Solway Investment Group.

2017; Kassam, 2017). The mine, one of the largest nickel mines in Central America, has also faced legal disputes over its environmental impacts, and for denying indigenous communities the right to "free, prior and informed consent" (Rodríguez, 2021).

Colombia's Córdoba region, where the Cerro Matoso mine is located, has registered some of the worst human rights violations in recent years (Moreno Montenegro, 2016), with 37 activists murdered since the 2016 Peace Accords (Heinz & Sydow, 2020). Though not officially linked to the company, mining attracts paramilitary groups seeking to capture funds from local authorities, while the violence allows the company to perpetuate weak environmental governance.

To sum up, attention to these highly unequal geographies of sacrifice and dispossession casts serious doubts regarding the desirability of decarbonisation plans centred on the green energy-extractivism nexus. First, mineral extraction and processing are very energy intensive, and they become more so as the quality of mineral ores diminishes. Second, the dispossession effects of low carbon energy generation are further aggravated by the socio-environmental impacts of extracting and processing of minerals. Such impacts are concentrated primarily in the global South, and disproportionately affect indigenous peoples, reinforcing neo-colonial spatial relations and uneven geographies of sacrifice. Considering all this is fundamental for envisioning a genuinely just transition, to which the next section turns.

5. Envisioning a Green New Deal without extractivism

5.1. The limitations of "corporate-led governance"

In 2019, Amnesty International (2019) challenged electric vehicle manufacturers to commit to sourcing "ethical batteries". This is no easy feat. While there are various mining industry initiatives in this sense, these are voluntary: producers can unilaterally decide to comply (or not) with them. The same goes for other international reporting standards on sustainability and sourcing codes (Church & Crawford, 2018, p. 56; Whitmore, 2021).

Transparency is also a major challenge, given that the supply chains of transition minerals such as nickel are convoluted and murky (Church & Crawford, 2018, p. 56; Müller & Reckordt, 2017). From extraction, to processing and smelting, to incorporation into steel and alloys, to embedding in renewable technologies, the trajectory from mine to renewable technology involves a wide range of actors, across countries and industries. Various nickel mining operations are shrouded in opacity. The Solway Investment Group mentioned in the previous section (footnote 9), for instance, is a mining company headquartered in Switzerland, but operationalised through a network of subsidiaries and shell companies in Malta, the Virgin Islands, and St. Vincent and Grenadines (Garside, 2019). Understanding and unpacking these supply chains is an important challenge for activists wishing to tackle the social and environmental injustices that characterise the green energy-extractivism nexus, a challenge that future political ecology research could contribute to addressing.

Several organisations scrutinising transition mineral supply chains have called for a prioritisation of recycling and recovery processes to minimise the growth of new extractive frontiers (Bolger et al., 2021; Dominish et al., 2019; Whitmore, 2021). Additionally, they propose minimising the socio-ecological abuses described above as endemic to mineral supply chains through various measures: a strengthening of corporate accountability and due diligence legislation; more robust regulations for the import and export of metals; and the creation and protection of "no-go zones" for mining (Church & Crawford, 2018, p. 56; Müller & Reckordt, 2017). All this may help to reduce some of the socio-environmental burdens associated with transition mineral mining, and perhaps improve its development potential for affected populations and countries. Without dismissing such proposals, however, we suggest that a truly just transition would need to be placed in the context of a more radical socio-environmental transformation, whose main features we discuss in the rest of this section.

5.2. From post-extractivism to post-capitalism

Based on our findings, we argue that Green New Deals should envision transitions beyond the logic of a socio-ecological fix. This does not mean that renewable energy or even extraction itself are necessarily part of the problem (Lennon, 2021). What must be overcome is the system of extractive-colonial capitalism that currently governs the way energy is produced and materials are mined. Our exploration of the case of nickel is consistent with political ecology critiques reviewed above (section 2), which consider extractivism as a neo-colonial mode of accumulation predicated upon the devaluation of territories and racialised populations in extractive peripheries, primarily in the global South: one that results in ecological destruction, dispossession, severe health impacts, human and indigenous rights violations, and murderous violence against environmental defenders.

Extractivism, therefore, cannot be a part of a just solution to the ongoing climate crisis. A report on transition minerals published by War on Want and the London Mining Network argues that a just transition must be a "post-extractivist" transition (Hitchcock-Auciello, 2019). The report endorses Eduardo Gudynas's (2011) proposal for "indispensable extraction", according to which, in a transition scenario, the only extractive activities permitted would be those that are "genuinely necessary" (Gudynas, 2011, p. 200, our translation). Moving away from a commodity-driven and expansionary model of extractivism, "indispensable extraction" would require for Gudynas (2011, p. 200) a sharp reduction of material demand, a redefinition of needs centred on ensuring a good quality of life for all, and a vision of resource use focused on minimising pressure on ecosystems. This proposal is broadly consistent with post-development approaches and the recently emerged tradition of pluriverse (Kothari, Salleh, Escobar, Demaria, & Acosta, 2019), as well as with degrowth advocates' call for considerable reductions in material use and resource and energy consumption, particularly in global North economies (e.g. Hickel, 2020).

In endorsing such proposals, however, we also emphasise that, for a post-extractivist vision to materialise, control over the means of (re)production, including energy, land and subsoil resources, must be wrestled away from capital and the (trans)national institutional structures that sustain its dominance, and given back to indigenous, peasant and other dispossessed populations. A path to post-extractivism, therefore, must emerge out of the actually existing indigenous, peasant, working class, anti-racist and feminist-territorial struggles against the material and epistemic violence of colonial-extractive capitalism.

Grassroots initiatives engaging with the Green New Deal and related frameworks offer promising opportunities in this sense. For instance, the Ecosocial Pact of the South (*Pacto Ecosocial del Sur*), developed by a Latin American alliance of scholars and activists, puts forward a "radical socio-ecological transition" away from extractivism as one of its core proposals, together with a move towards "a renewable, decentralised, decommodified, and democratic energy matrix" (Pacto Ecosocial del Sur, n.d., our translation). Similarly, the US-based Climate Justice Alliance's proposal of a "Frontline Green New Deal'' is rooted in a just transition from an extractive to a regenerative economy (based on caring and sacredness, cooperation, social and ecological well-being, and deep democracy) (Climate Justice Alliance, 2019; Lennon, 2021). A post-extractive vision of Green New Deals also requires us to transcend the national imaginary in which such proposals have remained trapped, supplanting it with an internationalist framework that is cognisant of and seeks to counteract the (neo-)colonial and capitalist dynamics of unequal exchange between North and South (Kaur Paul and Gebrial, 2021). This implies making central considerations of reparations for colonial, ecological and climate debts (Ajl, 2021), and the dismantling of corporate monopolies and the forced trade of international financial institutions.

5.3. The socio-ecological fix as a "battlefield"

Before concluding, we want to briefly return to the notion of the socio-ecological fix, and the question of its implications for emancipatory politics. Informed by the Regulation approach, the main focus of the socio-ecological fix is, in a sense, conservative: it is "fundamentally concerned with how capitalism *survives,* not with how it might be '*dis-assembled*'" (Ekers & Prudham, 2015, p. 2442). Critics point out that this approach may be politically disempowering, to the extent that it posits capital and the capitalist state as more unitary, rational and able to overcome socio-environmental challenges than it actually is; and that it may divert attention from revolutionary strategy (Chambers, 2021). While mindful of this risk, we maintain that the notion of the socio-ecological fix could nonetheless be useful for understanding the profoundly contradictory, haphazard and irrational character of capitalist responses to the climate crisis, and the political opportunities that may emerge as a result.

Much like what Thea Riofrancos (2019) argues with regard to the Green New Deal framework, we suggest considering the ongoing socio-ecological fix as a "battlefield". Capital's efforts to adapt to a changing climate are no doubt politically regressive, and likely to reinforce socio-environmental injustice, colonialism, racism and, potentially, fascism (The Zetkin Collective, 2021). At the same time, however, the conjuncture of a profound political economic and geographical restructuring of capital's energy matrix, which the idea of the socio-ecological fix captures, also opens up spaces of political engagement and emancipatory possibilities.

As shown by the deeply contradictory and uneven character of global decarbonisation strategies, the capitalist class is extremely divided in its attitude towards climate change (think, for instance, of how the fossil fuel industry keeps trying to sabotage attempts to regulate the sector, or the rampant climate negationism of most far right parties). There is also a clear disconnection between the impressive projected expansion of technologies such as renewables and electric automotion, and its relative irrelevance in terms of global emissions reduction to date (Sweeney et al., 2021). The expansion of the green energy-extractivism nexus as the core strategy for global "decarbonisation" has so far failed to deliver in terms of emission reductions from energy. At the same time, as the findings of this article suggest, it is clearly aggravating the ongoing socioecological crisis, with particularly disastrous effects on extractive peripheries, primarily in the global South. This points to something of a structural inability of capital to stop digging its own grave—or, perhaps more precisely, an ingrained tendency to make the grave deeper through each attempt at getting out of it (Fraser, 2022).

In this sense, we are sceptical of the "cautiously hopeful" position of Castree and Christophers (2015) regarding the ability of capitalism in general, and of financial capital in particular, to lead a transition towards less environmentally harmful and more socially necessary infrastructures. Yet, we do see in capital's muddled response to the crisis opportunities for radical ruptures, and argue that the existence of a fix doesn't preclude pursuing such ruptures. This has implications for social movements concerned with climate justice. For instance, seeing energy transitions as a fix to a crisis of accumulation helps us to be more wary of how simply focusing on the negative impacts of fossil fuels, while losing track of the capitalist and colonial structures underpinning their production, may be insufficient: there is little reason to believe that the same, socio-ecologically destructive and unjust modes of energy production and provision will not continue even under optimistic renewable scenarios.

6. Conclusions

This article has contributed to ongoing research and conversations on extractivism and energy transitions, by highlighting the centrality of minerals for so-called low-carbon technologies such as renewables and electric automotion. We have shown that a focus on the role of transition minerals adds to critical geographical literatures that consider the expansion of industrial-scale renewables as a central feature of an ongoing socio-ecological fix to climate-induced crises of capitalism. These literatures contend that a shift toward wind and solar technologies is increasing the spatial requirements of energy generation, leading to new rounds of primitive accumulation, land enclosures and green grabbing. We have argued that considering the material intensity of industrial-scale renewables, as part of an expanding green energy-extractivism nexus, points to the likelihood that land-based conflicts will be increasingly compounded by the dispossession effects of extracting and processing transition minerals.

We have elaborated on the idea of decarbonisation by dispossession in order to direct attention to the grave socio-environmental implications of the ongoing, capital-led transition. Not only does renewable energy expansion tend to impact disproportionately rural populations who are often historically marginalized; it is also accompanied and sustained by an unprecedented expansion in mining, largely concentrated in extractive peripheries of the global South. As we detailed through the case of nickel, this expansion contributes to ecological destruction and territorial dispossession, propagating human rights abuses and direct as well as indirect violence. This contributes to the creation of green sacrifice zones, that is, territories and populations that are socio-ecologically debased for the sake of decarbonising economies in the imperial cores.

At the same time, our analysis casts serious doubts as to whether a shift to renewable energies and electric automotion will be enough to save capitalism from itself. Such a shift is unlikely to usher in more socially and environmentally just futures. Genuinely emancipatory ways of tackling the ongoing climate catastrophe, we have argued, must be pursued against and beyond the material and political infrastructures of colonial-extractive capitalism. It remains to be seen whether grassroots and radical reclamations of the Green New Deal will succeed in opening up opportunities for a post-extractivist (and hence anti-colonial and post-capitalist) transformation, capable of disconnecting decarbonisation from dispossession—or if this framework will remain trapped in the regressive logic of a socio-ecological fix.

Declaration of competing interest

None.

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