Who pays the price? Socio-ecological controversies regarding the energy transition in South America

Quem paga o preço? Controvérsias socioecológicas associadas à transição energética na América do Sul

Axel Bastián Poque González [1]

[1] *Master of Science in Engineering. Doctoral student, Environment and society program, Center for Environmental Studies and Research (Nepam), State University of Campinas (Unicamp). Campinas, SP, Brazil*
E-mail: axel.poque@usach.cl

doi:10.18472/SustDeb.v13n3.2022.44799

Received: 26/08/2022
Accepted: 19/11/2022

ARTICLE- VARIA

ABSTRACT

Transformations linked to more sustainable energy and economic systems may have societal and ecological costs, which some people and territories must assume. Controversies might emerge associated with developing new productive chains, e.g., transition mineral activity. This study examines the relations among energy transition, society, and the environment, focusing on copper as a high-tech mineral and considering Bolivia, Chile, and Peru, three countries with mining-dependent economies. This work tries to see if countries are becoming more renewable, efficient, and modern and if this correlates with copper activity and societal factors. As a result, Bolivia has pending tasks on both the energy demand and production sides. Despite presenting good performance on renewables and efficiency, Chile and Peru have pending tasks associated with the ecological distribution regarding mining and energy sectors. Mining-based economies might expose the fragility of green transitions in meeting sustainable goals considering equality, justice, and ecosystem care.

Keywords: Energy transition. Extractivism. Just transitions. Natural boundaries. Societal boundaries. South America.

RESUMO

As transformações ligadas à busca por sistemas energéticos e econômicos mais sustentáveis poderiam trazer custos sociais e ecológicos que algumas comunidades e territórios devem suportar. Além disso, podem surgir controvérsias relacionadas com o desenvolvimento de novas cadeias de produção, por exemplo, a atividade industrial associada à exploração e produção dos minerais de transição. Este estudo examina as relações entre transição energética, sociedade e o meio ambiente, focando o cobre como mineral de alta tecnologia, e considerando como casos de estudo a Bolívia, o Chile e o Peru, três países com economias dependentes da mineração. Tenta-se explorar se os países estão se tornando mais renováveis, eficientes e modernos, e se isso está correlacionado com a produção de cobre e fatores sociais. Como resultado, a Bolívia tem pendências tanto na demanda quanto na produção de energia. Apesar do bom desempenho histórico das energias renováveis e da eficiência energética, o Chile e o Peru têm questões a serem resolvidas relacionadas à distribuição ecológica, concernente aos setores *de mineração e energia. As economias baseadas na mineração poderiam evidenciar a fragilidade das transições verdes para alcançar objetivos transversalmente sustentáveis, levando em conta a equidade, a justiça e o cuidado com os ecossistemas.*

Palavras-chave: *Transição energética. Extrativismo. Transições justas. Limites naturais. Limites sociais. América do Sul.*

1 INTRODUCTION

The sustainable energy transition has become pivotal in the current decarbonization of economies to face and mitigate climate change. Regarding energy production, matrices have begun to include increasingly low-carbon sources to substitute fossil fuels. On the other hand, according to the Intergovernmental Panel on Climate Change (IPCC), electricity is raising its share of end-use energy – the electrification of the economy (IPCC, 2022). According to the International Energy Agency (IEA), clean electricity and electrification are central to reaching a net zero emissions global system (IEA, 2022a). This implies developing new clean technology and production chains. Critical commodities to the development of technology for sustainable transitions are called "high-tech" metals or "transition minerals" (VOSKOBOYNIK; ANDREUCCI, 2022). Calvo and Valero (2021) found 13 prospectively critical elements to sustainable energy technology: tellurium (Te), silver (Ag), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), gallium (Ga), indium (In), lithium (Li), manganese (Mn), nickel (Ni), tin (Sn), and zinc (Zn). The countries with the highest production of these minerals are the People's Republic of China (Zn, Te, Sn, In, Ga, Cd), Indonesia (Ni), South Africa (Cr, Mn), Australia (Li), the Democratic Republic of the Congo (Co), Chile (Cu), and Mexico (Ag).

Latin America and the Caribbean (LAC) play a crucial role in the global sustainable energy transition since countries such as Chile and Peru are global leaders in copper production. Mexico leads in silver production, and Bolivia, Argentina, and Chile share one of the most extensive lithium reserves in the world (the lithium triangle). In addition, Brazil and Mexico remain economically dependent on hydrocarbons since they are among the most prominent producers in the world. However, the energy and mining industries historically have stimulated socio-ecological conflicts, whereas profits and benefits have failed to benefit everyone equally (BORDERA et al., 2022; POQUE GONZÁLEZ; SILVA; MACIA, 2022).

LAC energy and mining cases expose a critical paradigm. Nature limits the economy! As Meadows *et al.* (1972) advertised, unsatisfied human necessities exist, and nonrenewable natural resources – such as fossil fuels and minerals – are finite. As Nicholas Georgescu-Roegen claims, following the second thermodynamic law, industrial economic growth, as known today, presupposes a growing use of mass and energy. Moreover, economic activity spreads waste into the environment (Figure 1). Some (not all) of the used materials (inputs) can be recycled (CECHIN, 2010), but energy cannot, as it is dissipated (MARTINEZ-ALIER *et al.*, 2016).

In summary, global industrial economic activity inevitably needs matter and/or energy, and as described by Max-Neef (2010), "the economy is a subsystem of a larger and finite system, the biosphere" (Figure 1). Then, we might presuppose that energy transition inevitably needs materials to be carried out. Later, what is the relation between energy transition and society, the economy, and the environment? What are the natural limitations outlining sustainable energy transitions?

This study assesses the relations and controversies among sustainable energy transition, society, and the environment. As a critical transition mineral, copper is chosen to explore these relations. The focus is on LAC copper-producing countries – Bolivia, Chile, and Peru – as the objects of study. The structure of this work comprises Section 2, which focuses on integrating concepts; Section 3 shows the methodology used; and Section 4 exposes our main results. Finally, Section 5 articulates an interdisciplinary discussion, and Section 6 concludes and stimulates new research on this topic.

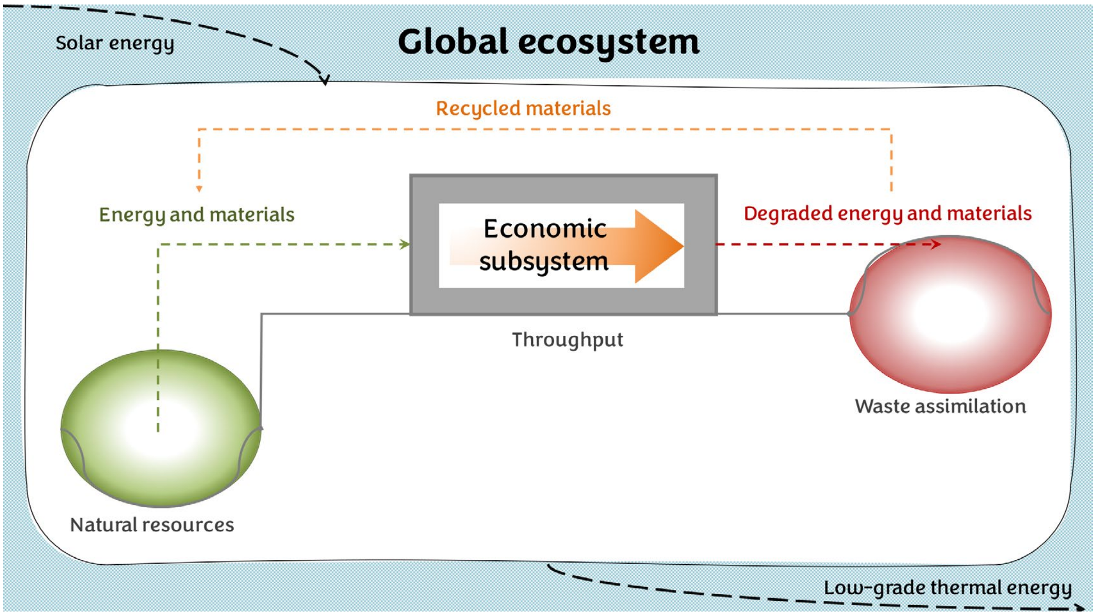

Figure 1 | Nicholas Georgescu-Roegen's economy model

Source: Created by the author based on Cavalcanti (2012) and Cleveland & Ruth (1997).

2 CONTEXTUALIZATION – CRISIS TIME AND THE FRONTIERS OF THE ENVIRONMENT

Governmental efforts to face and mitigate climate change in the last three decades have not been sufficient (DUNLAP, 2023)socio-ecological problems are nothing new. Despite all efforts to resolve environmental dilemmas, socio-ecological catastrophe has only intensified. Governments, in response, have unveiled the green economy to confront ecological and climate catastrophe. The green economy, however, has worsened socio-ecological conditions, invigorating the present trajectory of (techno. The IPCC claims that meeting the temperature goals of the Paris Agreement (1.5 - 2°C) implies intense efforts toward a net-zero economy (IPCC, 2022). In 2022, considering what governments are doing to reach the targets and objectives they have set out, the IEA (2022a) estimates a trend for the rise in average temperatures to be approximately 2.5°C in 2100 (with a 50% probability).

The world economy recently suffered the effects of the Covid-19 pandemic, triggering a complex context that changed the patterns of connectedness and causality among several financial and commodity markets. Later, in 2022, the Ukrainian–Russian Federation conflict stimulated a new overlapped stage of uncertainty and volatility in global commodity markets (ADEKOYA et al., 2022; ALI et al., 2022; BORDERA et al., 2022; IGLESIAS; RIVERA-ALONSO, 2022). To the IEA (2022a), "the crisis has stoked inflationary pressures and created a looming risk of recession."

The desperation to improve socioeconomic conditions and overcome financial crises can often encourage forgetfulness about the boundaries of Nature[1] (CAVALCANTI, 2012), mainly in commodity-dependent economies. Encouraged by the attempt to drive short-term political plans toward an economic recovery in line with industrial economic growth, countries could abandon the low-carbon pathways, threatening the biophysical limits of the Earth (AVIS, 2022). As described by Martinez-Alier (2022), the industrial economy is entropic, and therefore, it goes to the frontiers of commodity extraction and waste disposal, causing damages and conflicts. Recall that energy dissipates; meanwhile, only some materials can be recycled (Figure 1).

ISSN-e 2179-9067

2.1 A JUST ENERGY TRANSITION AND ECOLOGICAL DISTRIBUTION

"Just as addressing climate change is a prerequisite for redressing global injustice, delivering climate action in an equitable and just way is a prerequisite for the success of the transition" (CRONIN *et al*., 2021). According to the IPCC, this just transition would guarantee a set of principles, processes, and practices to include all people, workers, places, sectors, countries, or regions in moving from a high- to a low-carbon economy. Social protection, democracy, dialogue, well-being, equity, and justice are critical. Additionally, processes must respect vulnerable groups and their dignity (IPCC, 2022).

Energy systems and economic configurations often spread inequalities and injustice among societies. For instance, some net fuel exporting countries have high levels of energy poverty (KNOX *et al*., 2022) a growing body of literature has started to examine the (in. Currently, between 35 and 40 million people in LAC lack access to essential energy services, such as electricity and modern fuels (GUZOWSKI; MARTIN; ZABALOY, 2021). The *energy justice* concept emerged as a framework to discuss local and global issues of fairness among people concerning energy supply, production, and consumption (IWIŃSKA; LIS; MĄCZKA, 2021).

Environmental justice emerges from the debate about *ecological distribution*. It refers to the unequal repartition of the environmental costs and potentials resulting from economic activity. Furthermore, it points to social, spatial, and temporal asymmetries in using environmental resources and services. Currently, it is associated with decreased natural resources, biodiversity loss, pollution, scarcity, degradation, and the quest for a sustainable future (LEFF, 2013).

2.2 EXTRACTIVISMS

Following Gudynas (2017), "extractivism" is extracting natural resources in high intensity or volumes and exporting at least half of the extracted resources to global markets as commodities or raw materials. Since the 2000s, the expression "neo-extractivism" has become linked to progressive LAC governments. In neo-extractivism (also called 21st-century extractivisms), states play a decisive role in fostering extractive activities. The political establishment argued the legitimacy of their involvement by promoting progressive social development via the profits from extractive activities. Nevertheless, extractive activities stimulated socio-ecological conflicts, evincing the inequitable ecological distribution in LAC (SVAMPA, 2021; VILLALBA-EGUILUZ; ETXANO, 2017).

2.3 A BRIEF INTRODUCTION TO THE LAC ENERGY TRANSITION

According to the Latin American Energy Organization (Olade), in 2020, 36.3% of LAC electricity was produced by fossil fuels. Moreover, 20% of LAC end-use energy came from electricity, whereas 50% came from oil and its derivatives (OLADE, 2022b). In addition, subregions such as Central America or the Caribbean import more than 70% of the total oil used and its derivatives (OLADE, 2022a), making them vulnerable to the volatility of global markets (GROTTERA, 2022). Some LAC countries have recently transitioned to nonconventional renewable energies (NCRE)[2]. In 2005, Belize, Costa Rica, El Salvador, Guatemala, and Nicaragua generated more than 10% of their national annual electricity from solar, wind, geothermal, and renewable thermal sources. In 2020, this list also included Uruguay, Brazil, Chile, Honduras, and Mexico. Costa Rica and Uruguay practically decarbonized their power production, and Paraguay is almost entirely hydroelectric-dependent (POQUE GONZÁLEZ; SILVA; MACIA, 2022).

2.4 TRANSITION MINERALS – THE COPPER CASE

According to the IEA, the demand for transition minerals might rise twofold to fourfold by 2030 due to the expanding deployment of renewables, electric vehicles (EVs), battery storage, and electricity networks. Thus, copper use might increase meaningfully in terms of absolute volumes. The current demand of approximately 6 million tons (Mt) per year might increase to 11 Mt to 16 Mt by 2030. On the other hand, the recycling of transition minerals is underutilized, considering that 95% of solar panel components by mass are recyclable, similar to wind turbines (IEA, 2022a).

3 THEORY, MATERIALS, AND METHODS

This study focuses on copper, considering its role as one of the most prospective critical transition minerals (CALVO; VALERO, 2021; IEA, 2022a). Furthermore, it contemplates the Andean countries Bolivia, Chile, and Peru, which have highly mining-dependent economies (ERICSSON; LÖF, 2019) with copper production. From these cases, the study explores the relationship between energy transition, the environment, society, and the exploitation of copper. Then, this section shows some characteristics of the countries studied and, after, the methodological course.

3.1 CASE STUDIES

Chile had the most extensive copper reserves worldwide in 2020, with 200 million tons, or 23% of the world's total, whereas Peru had 11% (CANADA, 2022). Concerning energy, Bolivia has a relatively inefficient economy since it needs more energy to produce one gross domestic product (GDP) unit. Bolivia also uses small shares of electricity as final-use energy. Table 1 introduces these neighbouring countries.

Table 1 | National profiles

Parameter	*Bolivia*	*Chile*	*Peru*
2020 GDP per capita (constant 2015 USD)	2,986.0	12,890.3	5,807.1
2020 mining GDP (% of GDP)	7.1	6.1	3.9
2019 renewable supply of primary energy (%)	11.2	33.8	25.1
2019 energy intensity[a]	1.65	0.74	0.73
2020 electrification of the economy (% electricity in final use)	12.0	22.0	20.9
2020 access to electricity (%)	93.7	99.7	97.0
2018 GHG per capita (tCO_{2e} per capita)	5.0	5.9	3.0

a| Final energy consumption (in thousands of barrels of oil equivalent)/GDP in USD millions (at constant 2010 prices).

Source: Data from Olade (2022a), United Nations (2021) and World Bank (2022).

3.2 METHODOLOGICAL COURSE

This study looks for tendencies toward low-carbon energy systems, contrasting them with societal lacks, ecological threats, and socioenvironmental conflicts associated with the power and copper mining sectors. The behaviour and relationships of each country over time were evaluated by four qualitative and quantitative stages, namely:

i. Three data series were used to comparatively analyze shifts in energy source use and energy consumption, namely, the share of primary renewable energy (1970-2019), the share of electricity as end-use energy (1970-2020), and the share of renewable sources to produce power (2000-2020). Data is from the UN (2021) and Olade (2022a). This stage explores how renewable and efficient (or not) countries have become over time. Renewable shares in all the energy the country has at its disposal yearly show if fossil fuels are phasing out. The proportion of electricity in all final-use energy every year indicates that countries are participating in the electrification of economies' global process. Finally, the introduction of NCRE in power generation since the 2000s reveals whether countries are more modern, clean, and efficient.

ii. The socioeconomic evaluation contrasted copper mining activity indicators with national social conditions. It considers copper production (1990-2020), copper price (1990-2020), and national GDP per capita (1970-2020). This stage searched national (such as public ministerial information) and global databases (such as the World Bank). The primary purpose of this stage is to explore the benefits of mining in economies and societies.

iii. A qualitative assessment explores the relationship among energy and copper mining sectors, the environment, and society from the emergence of socio-ecological conflicts documented in the Atlas of Environmental Justice (EJAtlas) (MARTÍNEZ-ALIER, 2020; TEMPER; BENE; MARTINEZ-ALIER, 2015). It aims to map and understand the socio-ecological dimensions of copper mining and power sector development.

iv. The information shown in the three previous stages was cross-checked, seeking interrelations via Pearson's correlations among energy transition, societal variables, and copper mining activity over the 21st-century window (2000-2019). Nine variables describe the behaviour of these study fields over time in every country (Table 2). Pearson's correlation coefficient looks for correspondences, contradictions, or controversies in Bolivia, Chile, and Peru regarding the relation between the transformation of energy sources, socioeconomic attributes, and copper production. Finally, a matrix containing Pearson's coefficients for every relation among variables is elaborated for each country.

Note that Pearson's correlation coefficient assumes a value between −1 and 1, in which 0 refers to no correlation, 1 is an entirely positive correlation, and −1 is an utterly negative correlation. Additionally, a 0.7 correlation value between two variables indicates a significant positive relationship. A positive correlation means that as variable A increases, so will variable B, whereas if the correlation value is negative, B will decrease as A does (NETTLETON, 2014). Then, from the nine variables, this work explores if, since the 2000s, countries are turning more renewable, clean, modern, and efficient and if this correlates with population growth, national incomes, copper production, or copper prices.

This work uses mainly secondary data, which are duly referenced. Consequently, there are no ethical compromises or transgressions.

Table 2 | Data series

Variable	*Code*	*Unit*	*Source*
Access to electricity	EA	% of population	Olade (2022a)
Electrification of the economy	EE	% of final energy	Olade (2022a)
Renewable primary energy	RPE	% of energy	UN (2021)
Renewable-produced electricity[a]	REWH	% of electricity	Olade (2022a)
Final energy consumption	EC	1012 Cal	Olade (2022a)
Population	PO	Thousands of people	UN (2021)
GDP	GDP	Constant 2015 USD	World Bank (2022)

Variable		*Code*	*Unit*	*Source*
Copper production	Bolivia	CUT	Metric tons	INE (2022)
	Chile			Cochilco (2022)
	Peru			Ministerio de Energía y Minas (2022)
Copper price[b]		CUUSD	USD per pound	Macrotrends (2022)

a | Without hydropower. b | Year-end closing price.

Source: Elaborated by the author.

4 INTO THE ENERGY – SOCIETY – ENVIRONMENT TRIAD IN BOLIVIA, CHILE, AND PERU

4.1 WHAT ABOUT ENERGY SOURCES?

Figure 2 shows that Bolivia and Peru's primary energy increased their shares of nonrenewable sources. Only 11 of every 100 units of primary energy in Bolivia came from renewable sources in 2019; meanwhile, Chile maintained a mixed matrix over time. According to the 2020 energy balance, Bolivia exports approximately 74% of its natural gas production. On the other hand, Chile imports 98% of its oil, 80% of its natural gas, and 89% of its mineral coal. Peru is an intermediate case since it exports 31% of its produced natural gas while importing 28% of its oil and 62% of its coal (OLADE, 2022a). In other words, Chile is highly vulnerable to international fossil fuel markets.

Regarding the electrification of their economies, Chile and Peru increased electricity as end-use energy between 1970 and 2020 (Figure 3). On the other hand, although Bolivia shows a smooth tendency to raise electricity as an end-use, only 12 of every 100 units of energy it consumed came from electricity in 2020. Note that the world is at approximately 20% today, and if current tendencies continue, this will increase to 22% by 2030 and 28% by 2050 (IEA, 2022a). In sum, Bolivia needs technological improvements on the demand side.

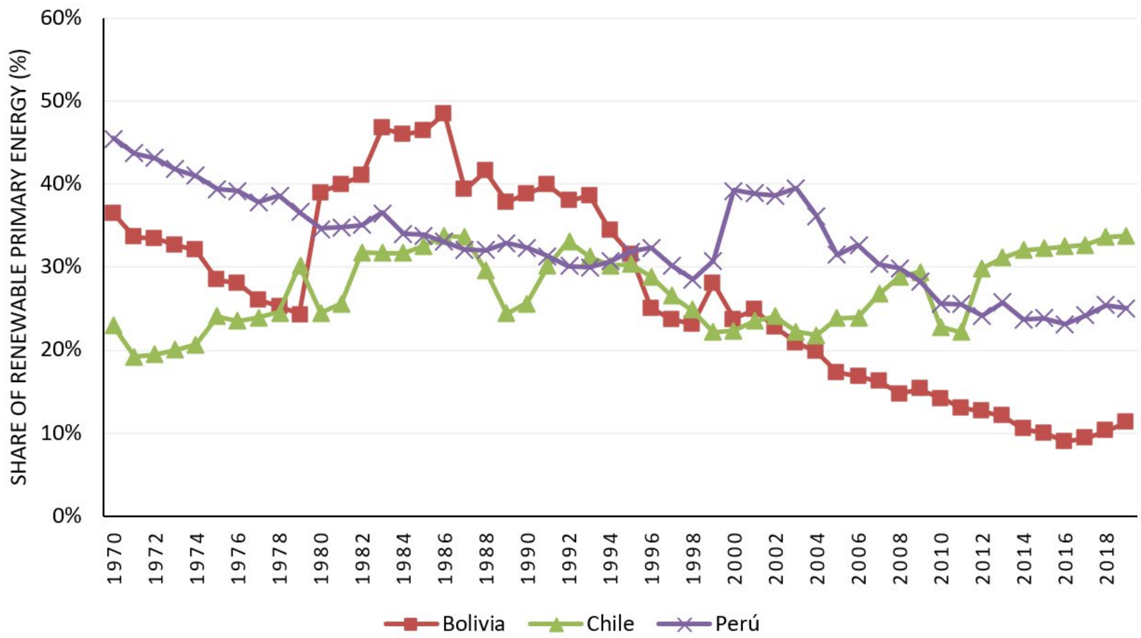

Figure 2 | Share of renewable sources in primary energy (1970-2019)

Source: UN (2021).

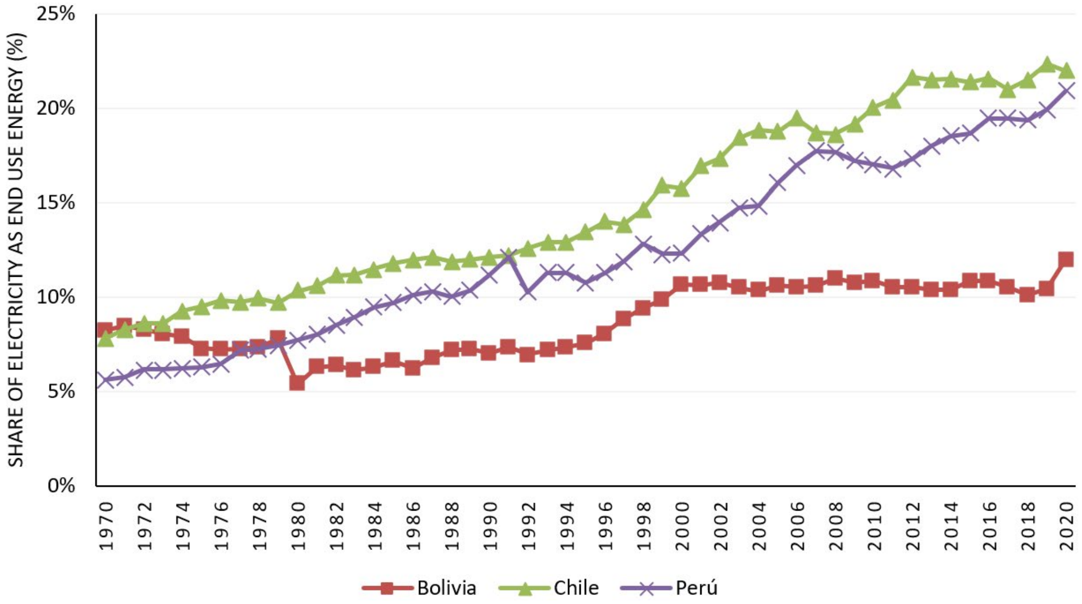

Figure 3 | Share of electricity as end-use energy (1970-2020)

Source: Olade (2022a).

Power generation introduced NCREs in the 21st century (Figure 4). If we consider hydroelectricity (strong colour series in Figure 4), Chile has maintained approximately 50% of its production by renewable sources during the 21st century. Nevertheless, Bolivia and Peru reduced their share of renewable power production over time, reaching 64% and 35% in 2020, in contrast to 81% and 54% in 2000, respectively. If we disregard hydroelectricity (and consider only solar, wind, geothermal, and biomass sources), only Chile progressed markedly in this transition, reaching 22% of its share of produced electricity in 2020 (Figure 4). Bolivia and Peru generated only approximately 6% from solar, wind, geothermal, and biomass sources (OLADE, 2022a). There is a lack of NCRE implementation in both Bolivia and Peru.

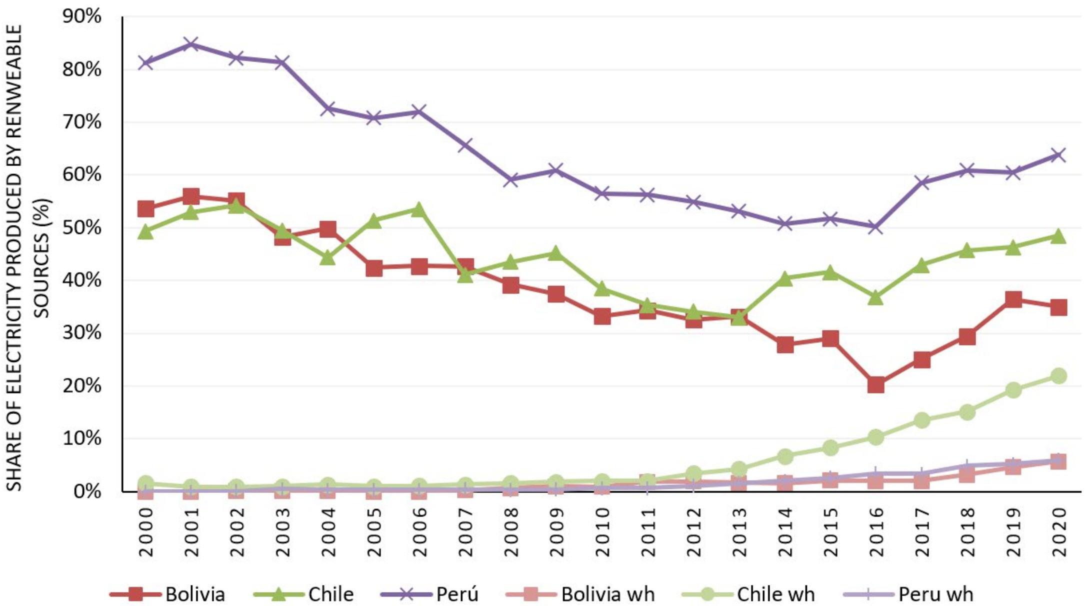

Figure 4 | Share of yearly power production by renewable sources (2000-2020)

Note: To distinguish the importance of hydroelectricity, the strong colour series consider hydroelectricity, renewable thermoelectricity, and solar, wind, and geothermal sources. The light colour series (using the "wh" mark = without hydro) show the data ignoring hydroelectricity.

Source: Olade (2022a).

4.2 A BRIEF POINT ON SOCIOECONOMIC ISSUES

Copper production has been a critical player in Andean South American economies. Figure 5 shows that Chile and Peru drastically increased copper production between the 1990s and 2020 (COCHILCO, 2022; MINISTERIO DE ENERGÍA Y MINAS, 2022). According to the National Institute of Statistics, Bolivia jumped to over 2,000 metric tons of produced copper in the 2010s (INE, 2022). In parallel, international copper prices climbed in the 2000s (MACROTRENDS, 2022). According to the World Bank (2022), between 2006 and 2011, more than 10% of the Chilean and Peruvian GDP came from mining. In 2020, Chile and Peru had the world's largest and second-largest copper production, whereas China held the third position, with 28.5%, 10.9%, and 8.4%, respectively. In 2020, 50% of Chilean exports were copper, representing 85.5% of all Chilean mining exports (SERNAGEOMIN, 2021).

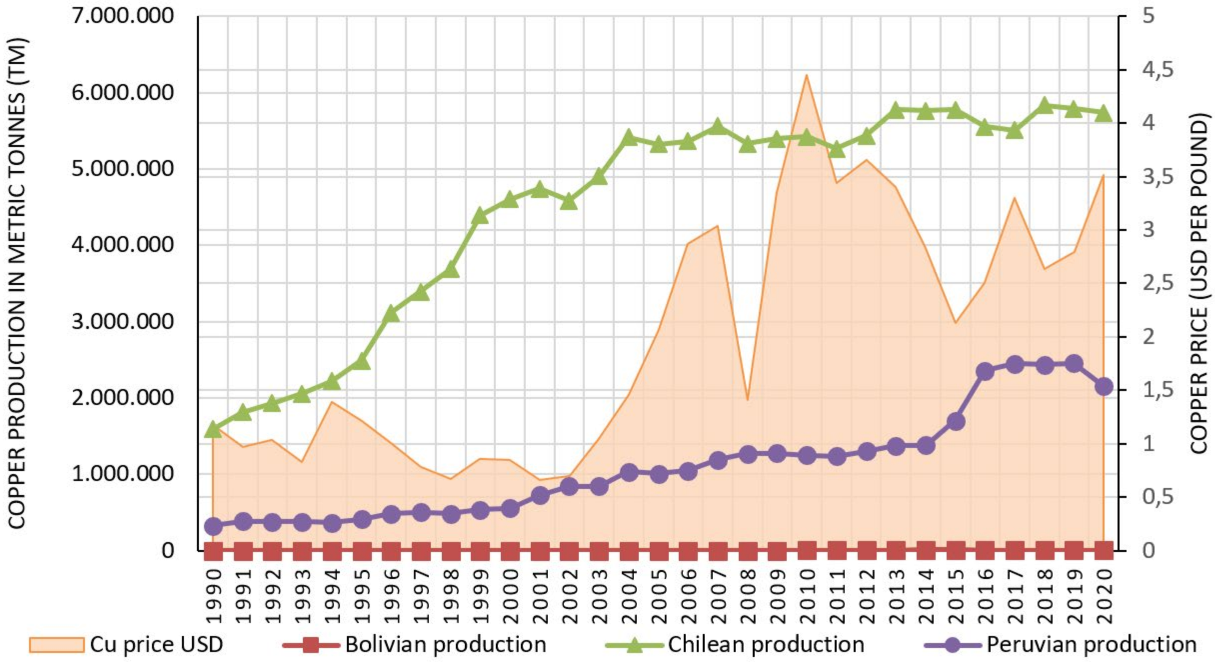

Figure 5 | Copper production (in metric tons) by country and price (USD per pound)

Source: Cochilco (2022); INE (2022); Macrotrends (2022); and, Ministerio de Energía y Minas (2022).

Despite their long-term increase in GDP per capita over time (Figure 6), these three countries face equity and poverty challenges. In 2020, the Chilean GINI[3] indicator was 0.475, above the Latin American average (0.464), consequently showing its pending task of distributing wealth. Conversely, Bolivia went from 0.635 in 2000 to 0.449 in 2020, showing an evolution regarding this task. In 2020, the Peruvian GINI indicator was 0.464. In 2020, Bolivia, Chile, and Peru had 32.3%, 14.2%, and 28.4% of their population living in poverty, respectively; the Latin American average was 33% (UN, 2021). If we consider the UN Sustainable Development Goals (SDG), Bolivia and Peru face challenges regarding SDG 7 – ensure access to affordable, reliable, sustainable, and modern energy for all – since a considerable part of their population lacks access to electricity (Table 1) (OLADE, 2022a; POQUE GONZÁLEZ; SILVA; MACIA, 2022). It also reveals the lack of energy justice in those countries because they are fossil fuel exporters.

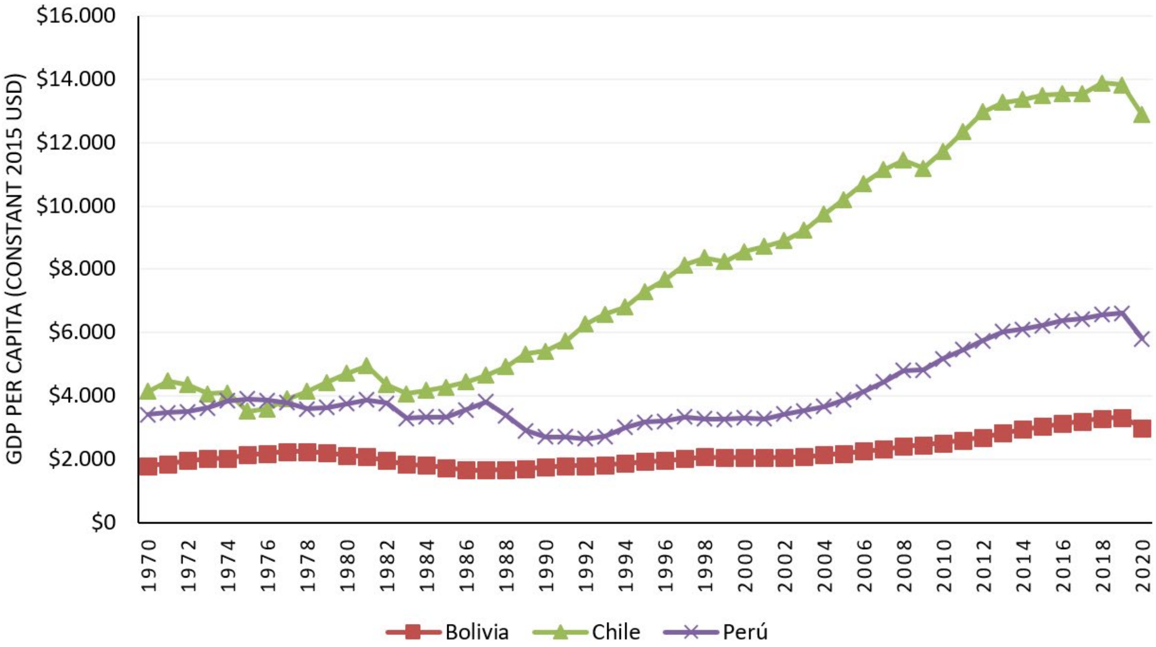

Figure 6 | GDP per capita (constant 2015 USD)

Source: World Bank (2022).

4.3 SOCIO-ECOLOGICAL ISSUES

According to the EJAtlas, copper mining is historically associated with the emergence of socio-ecological conflicts in Andean South America (Figure 7 shows a concentration of conflicting cases in the region). Bolivia has three conflicting cases associated with copper activity emerging in the 2010s, whereas Peru shows 29 cases, some of which have long-term origins. Both countries also face issues regarding silver, gold, and lithium extraction. Chile showed 21 conflicting copper mining issues, especially in its northern region.

In Chile, private companies are generally involved in the socio-ecological conflicts around the copper. Nevertheless, projects such as Dominga[4] were associated with corruption cases involving public government actors ignoring the environmental impacts of the activity. As transversal issues in all three countries, Indigenous people, peasants, and farmers are the main groups resisting critical mining projects. Additionally, water is a directly or indirectly disputed essential resource that opposes company interests against human necessities, social, cultural, and ecological heritage, and ecosystem preservation. Remarkably, the private figure of water rights in Chile, set by its 1981 Water Code, became a political issue driving disagreement (BUDDS, 2004).

Figure 7 | Socio-ecological conflicts around copper

Note: Colours identify the main type of conflict registered in the EJAtlas. Then, orange is: mineral ores and building materials extraction; cyan is: water management; red is: industrial and utility conflicts; light brown is: waste management.

Source: Temper, Bene, and Martinez-Alier (2015).

In addition to the disputes associated with copper mining, Bolivia and Peru face socio-ecological conflicts related to natural gas and oil extraction and processing. At the same time, Chile mainly shows conflicts associated with renewable and nonrenewable power-producing industries (Figure 8). Regarding fossil fuel activity, Bolivia has faced nine controversial oil and natural gas projects, whereas Peru showed 11 acute episodes and associated conflicts. Additionally, the local population has confronted two hydropower projects in Bolivia and eight in Peru.

Regarding fossil fuel exploitation, southern Chile has shown three controversial coal mining projects. Concerning power production, the EJAtlas reported four controversial projects associated with thermoelectrical power generation in central and northern Chile. Additionally, its population has faced 16 hydropower projects in its southern region. Finally, regarding NCRE, one geothermal project and two wind power production plants have triggered socio-ecological conflicts.

Figure 8 | Socio-ecological conflicts triggered by power projects

Note: Colours identify the main type of conflict registered in the EJAtlas. Then, orange is: mineral ores and building materials extraction; cyan is: water management; red is: industrial and utility conflicts; light brown is: waste management; yellow is: nuclear; black is: fossil fuels and climate/energy justice; grey is: infrastructure and built environment; green is: biodiversity and conservation conflicts; and, dark brown is: biomass and land conflicts.

Source: Temper, Bene and Martinez-Alier (2015).

4.4 CROSSING

As with the Pearson correlation, this item explores interrelations among energy transition, societal variables, and copper mining activity over the 21st century. In Bolivia, total energy consumption increased directly with its population, GDP, and copper production. In addition, access to electricity and the introduction of NCRE in power generation are positively correlated. As previously stated, the electrification of its economy and the share of primary renewable energy are pending tasks since they are not correlated with the economy's evolution, energy consumption, and demography. The renewable shares in primary energy are negatively correlated with all variables except electrification. Electrification does not correlate with any variable (Table 3).

Table 3 | Pearson matrix for the Bolivian series

Bolivia	*EA*	*EE*	*RPE*	*REWH*	*EC*	*PO*	*GDP*	*CUT*	*CUUSD*
EA		-0.186	-0.936	0.916	0.996	0.992	0.990	0.806	0.623
EE	-0.186		0.108	-0.283	-0.237	-0.215	-0.238	-0.166	-0.123
RPE	-0.936	0.108		-0.769	-0.934	-0.956	-0.914	-0.806	-0.713
REWH	0.916	-0.283	-0.769		0.915	0.907	0.926	0.659	0.4608
EC	0.996	-0.237	-0.934	0.915		0.993	0.996	0.823	0.5946
PO	0.992	-0.215	-0.956	0.907	0.993		0.988	0.796	0.6372

Bolivia	EA	EE	RPE	REWH	EC	PO	GDP	CUT	CUUSD
GDP	0.990	-0.238	-0.914	0.926	0.996	0.988		0.798	0.5415
CUT	0.806	-0.166	-0.806	0.659	0.823	0.796	0.798		0.4608
CUUSD	0.623	-0.123	-0.713	0.461	0.595	0.637	0.541	0.461	

Source: Elaborated by the author.

In Chile, total energy consumption is directly correlated with all variables except copper price, which has a smooth correlation. Copper price has no strong correlation with any variable. The stronger correlation is among total energy consumption, population, and GDP (Table 4).

Table 4 | Pearson matrix for the Chilean series

Chile	EA	EE	RPE	REWH	EC	PO	GDP	CUT	CUUSD
EA		0.922	0.763	0.627	0.909	0.892	0.926	0.927	0.713
EE	0.922		0.756	0.697	0.881	0.924	0.947	0.877	0.698
RPE	0.763	0.756		0.800	0.903	0.868	0.867	0.733	0.362
REWH	0.627	0.697	0.800		0.846	0.877	0.809	0.600	0.260
EC	0.909	0.881	0.903	0.846		0.980	0.978	0.857	0.576
PO	0.892	0.924	0.868	0.877	0.980		0.988	0.832	0.607
GDP	0.926	0.947	0.867	0.809	0.978	0.988		0.866	0.650
CUT	0.927	0.877	0.733	0.600	0.857	0.832	0.866		0.672
CUUSD	0.713	0.698	0.362	0.260	0.576	0.607	0.650	0.672	

Source: Elaborated by the author.

In Peru, total energy consumption directly increased in strong association with copper production, population, and GDP. The electrification of its economy correlated with this. Nevertheless, as in Bolivia, renewable levels of primary energy are not correlated with any variable (Table 4). As in Chile, copper prices do not correlate with any variable.

Table 5 | Pearson matrix for the Peruvian series

Peru	EA	EE	RPE	REWH	EC	PO	GDP	CUT	CUUSD
EA		0.873	-0.892	0.884	0.991	0.967	0.991	0.895	0.577
EE	0.873		-0.903	0.770	0.844	0.923	0.917	0.873	0.664
RPE	-0.892	-0.903		-0.643	-0.877	-0.859	-0.918	-0.748	-0.797
REWH	0.884	0.770	-0.643		0.886	0.934	0.876	0.942	0.301
EC	0.991	0.844	-0.877	0.886		0.963	0.986	0.895	0.565
PO	0.967	0.923	-0.859	0.934	0.963		0.980	0.956	0.568
GDP	0.991	0.917	-0.918	0.876	0.986	0.980		0.907	0.619
CUT	0.895	0.873	-0.748	0.942	0.895	0.956	0.907		0.437
CUUSD	0.577	0.664	-0.797	0.301	0.565	0.568	0.619	0.437	

Source: Elaborated by the author.

5 DISCUSSION – A GROUNDWORK FOR AN INTEGRAL ANALYSIS

This section looks for lessons learned from the previous sections and introduces new components to a critical analysis contrasting transition mineral production with the energy transition in LAC.

5.1 CONTROVERSIES FROM THE LATIN AMERICAN ENERGY TRANSITION

LAC countries (especially Bolivia and Peru, among those studied) could question the idea of a just sustainable energy transition. According to Figure 2, the shares of renewables in primary energy have decreased over time (1970-2019) in those countries. This contrasts with their increasing copper production and GDP. In other words, since the 2000s, economic growth and copper production have failed to correlate with a cleaner energy primary matrix (Tables 3 and 5). The NCRE (excluding hydropower) registered a smooth and limited rise in both countries since the 2000s, sharing approximately 6% of the generated electric power in 2020 (Figure 4). Although increasing GDP levels correlate with electricity access, universalizing access to electricity is still an unresolved task, questioning compliance with SDG 7. Moreover, regarding the analyzed qualitative information, Bolivia and Peru show intensive fossil fuel exploitation activity, which stimulated the emergence of several socio-ecological conflicts in critical localities.

It is worth noting that according to the IEA, the world share of electricity as an end-use is approximately 20%, and the world share of primary renewables is approximately 14% (IEA, 2022a, 2022b). Evaluating the Bolivian, Chilean, and Peruvian performances in both variables, Bolivia is under the global levels in both. On the other hand, Chile and Peru are over the global levels in both (Figure 9). Nevertheless, Peru has presented backtracking over the years in the share of renewables in primary energy. The question to further study is, why are Bolivia and Peru deploying fewer (proportionally) renewables? Is that sustainable? Is it equitable? If not, how can this tendency be broken?

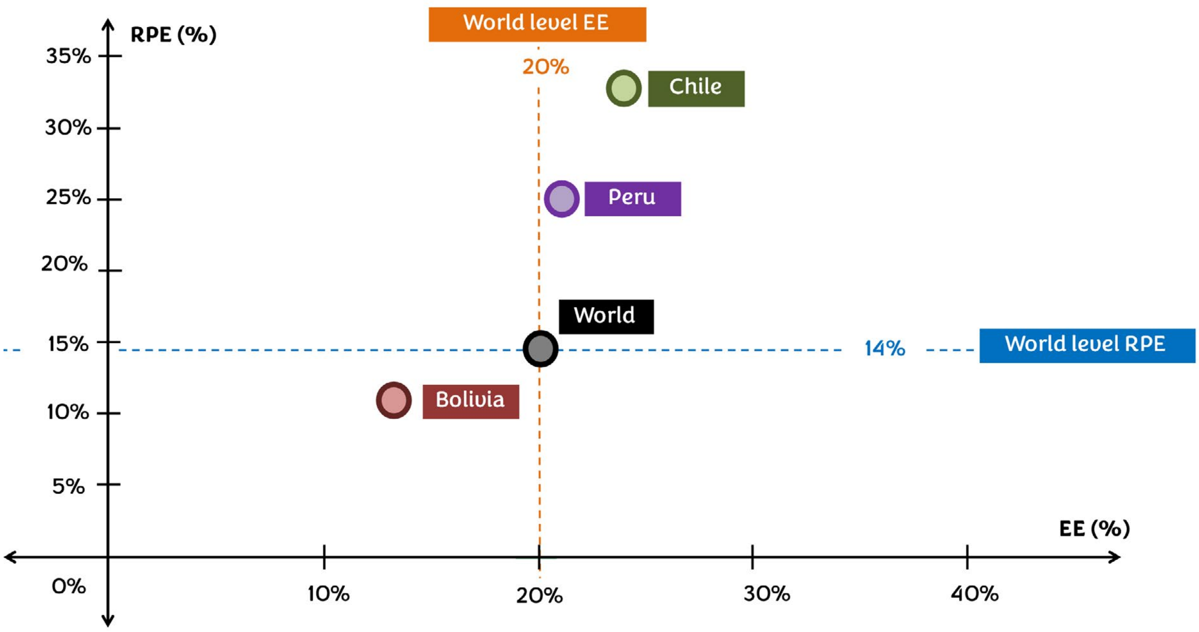

Figure 9 | Compared to world levels, renewable primary energy (RPE) and electrification of the economy (EE)

Source: Elaborated by the author.

Hydropower played a critical historical role in the studied countries because, at least until the 2000s (when NCREs were yet to spread), it constituted a significant part of the produced low-carbon power (see Figure 4). It is a critical issue in the middle of the debate on sustainable energy transition. The three analyzed countries face socio-ecological conflicts associated with constructing these infrastructures. NCRE projects also have stimulated socio-ecological conflicts. Finally, fossil fuel imports (especially in Chile) might stimulate intricate socioeconomic scenarios and vulnerability due to the volatility of global energy prices.

Regarding copper exploitation, in the Chilean and Peruvian cases, the main task might be associated with the emergence of socio-ecological conflicts in the territory since both present more than twenty cases of environmental injustices related to copper activities. Looking at the EJAtlas data, socio-ecological conflicts seem inherent to copper exploitation since all South American Pacific coastal areas register associated disputes. What are the pending tasks of the copper sector with societies and the environment? The next item gives some clues to discuss this.

5.2 EXTRACTIVISM IN LAC – ECONOMY AND POLICY VIEWS

5.2.1 HISTORICAL TRENDS

The Latin American insertion into the global market in the 20th century and the beginning of the 21st century intensified its commodity activity. Nevertheless, this trend started some time ago, when Latin America became a peripheral supplier of low-processing materials to the Global North (CALDERÓN; PRIETO, 2020). In an exciting scientific debate, Jason Hickel recently pointed to the colonial dimensions of the ecological crisis, highlighting the excesses of the Global North via its large net appropriation of resources from the Global South (HICKEL; HALLEGATTE, 2022). Moreover, most spaces used for extractive activities correspond to rural areas inhabited by peasant and salaried populations, many of Indigenous origin (CALDERÓN; PRIETO, 2020).

Neoliberalism, as a hegemonic force dominating recent decades, has tended to change the socioeconomic valuation of shared spaces toward a capital-dependent path, more so if we consider the prevalent historical extractivism in the region (VERGARA-PERUCICH; BOANO, 2021). Svampa (2021) argued that, in the 21st century, extractivisms are the result of an accelerated increase in social metabolism within the framework of neoliberal capitalism with intensive consumption. This implies a greater pressure on commons, which are transformed into commodities, consequently aggravating the climate crisis and the destruction of local ecosystems.

5.2.2 UNEQUAL CONDITIONS

With extractive industries emerged the notion of unequal income distribution concerning spaces (or geography) and societal strata. Irarrazaval (2020) studied the Bolivian and Peruvian natural gas sectors, concluding that sometimes inequality is grounded in the local geography of class relations, marginalizing social groups in weaker political and economic positions. The Puchuncaví township in Chile has had both energy-intensive and polluting industries since at least 1967 and a marginal evolution in social equality compared with national levels (GAYO *et al.*, 2022).

Since both mining and energy industries focus on specific areas due to the location of potentials or the location of resources, specific social sectors and ecosystems are particularly affected. With this, an uneven ecological distribution also emerged. Then, environmental and energy injustices are reproduced.

5.2.3 CONTEMPORARY POLICY DISCOURSES ABOUT CRITICAL RESOURCES

A new progressive political wave has recently emerged in LAC. Among its foremost voices, a contemporary discourse grew regarding transition minerals. Álvaro García Linera called for state control over commodities (LINERA, 2022). At the same time, Maristella Svampa pointed to private and state corporations and their articulations to neglect public assets within the commodities consensus stage. Thus, an ecoterritorial stamp has dominated the new social collectives facing extractivism in recent years (SVAMPA, 2021).

We find a long-term unresolved ontological discussion about extractivism and development conceptions in LAC. Paradoxically, the emergence of an Indigenous president (Evo Morales, 2006-2019) in Bolivia showed a confrontation of different worldviews. On the one hand, the Bolivian plurinational state reinforced institutions to preserve its cultural and ecological heritage and reinforce the rights of nature. On the other hand, it recuperated the public control of national resource exploitation. Then, a wave of neo-extractivisms paid the price of social equity and progressive reforms (HOPE, 2022).

As lithium has emerged as a critical transition mineral, states might reinforce their pivotal management role. For instance, Mexico reformed its Mining Law, situating the state as the only entity authorized to explore, exploit, use, and benefit from lithium (ESTADOS UNIDOS MEXICANOS, 2022). Likewise, the Chilean president, Gabriel Boric, recently announced the creation of a national lithium company (BORIC, 2022). Since Morales' government, the Bolivian state has prioritized lithium-driven industrialization, fostering this sector and arranging several strategic joint partnerships with foreign companies (VOSKOBOYNIK; ANDREUCCI, 2022).

5.3 SOCIO-ECOLOGICAL ISSUES IN CONTRAST TO A "MODERN" PARADIGM

The ecological economy focuses on the environmental conditions limiting economic activity (CECHIN, 2010). Some researchers who have taken this approach offer some narratives that highlight issues related to the biophysical boundaries of Earth, its entropic death, and its system collapse triggered by unsustainable development or the current growth-oriented economy (CLEVELAND; RUTH, 1997; HICKEL; HALLEGATTE, 2022; MARQUES, 2022; MAX-NEEF, 2010).

Political ecology analyzes power relations and political conflicts over the environment. Consequently, it explores social struggles that have emerged since the appropriation of nature (LEFF, 2013). At the start of the 21st century, Enrique Leff stimulated the field to move further:

> The environmental crisis questions the ontological, epistemological and ethical premises on which modernity has been founded, denying the limiting laws and potentials of nature and culture; environmental degradation is the product of a globalizing and homogenizing societal paradigm that has denied the power of the heterogeneous and the value of diversity. (LEFF, 2000)

The ecological economy and political ecology are helpful tools to explore the relationships between the mining and energy sectors and society, the environment, and the economy, considering that we are facing an ecological crisis. As Meyer and Vilsmaier (2020) described, ontological, epistemological, and ethical foundations should be considered concerning the study of sustainable futures and the search for alternative theories of transformations in the human – nature coexistence.

5.3.1 CONFLICTS AND SACRIFICE ZONES

Earth is a single, complex, integrated system. Nevertheless, biophysical imbalances resulting from anthropogenic activity might be critical at different levels (STEFFEN *et al.*, 2015). The three analyzed countries showed localities agglutinating more than one intensively polluting company (for instance, mining, energy, and chemical companies). These are called sacrifice zones, and continuing risks from chronic environmental impacts on health and livelihoods and ongoing epistemic violence lead to social resistance (ANBLEYTH-EVANS *et al.*, 2022). Sacrifice zones check for unbalanced ecological distribution since local populations and ecosystems shoulder disproportionate and unequal pollution burdens over time (GAYO et al., 2022).

For example, the neighbouring townships of Puchuncaví and Quintero in Chile have a total area of 448 km^2, with a population of ~50,500 people and concentrating more than 17 polluting companies, including thermoelectric plants, a refinery, and a copper smelter, which relate to hydrocarbon distribution, chemical storage, and gas distribution companies (ANBLEYTH-EVANS *et al.*, 2022; TAPIA-GATICA et al., 2020). Recently, the Chilean president, Gabriel Boric, expressed concern about them and announced the progressive end of operations of the copper smelter, attempting to reduce pollution in the zone after several critical health events in recent years (DIARIOUCHILE, 2022).

5.3.2 WATER: AN ESSENTIAL RESOURCE

Satoh *et al.* (2022) concluded that, due to climate change, even in a low-emission scenario, Andean South America (especially Chile) could experience an unprecedented critical drought in the upcoming years and decades. The surface areas of Andean lakes in central Chile tended to diminish during the 2010s. These declines coincided with decreasing precipitation and increasing regional temperatures (FUENTEALBA *et al.*, 2021). Recently, Cereceda-Balic *et al.* (2022) showed how open-pit copper mining influenced the reduction of a few Chilean Andean glaciers.

5.4 INTERSECTION POINTS – BETWEEN ENERGY TRANSITION, EARTH BOUNDARIES, AND A SOCIO-ECOLOGICAL CRISIS

Rockström *et al*. (2009) defined boundaries to the safe operating space for humanity concerning the Earth system and its biophysical subsystems or processes. Currently, based on the idea of a future "good life for all," Brand *et al*. (2021) proposed "societal boundaries" as a form to self-limit socio-ecological transformations and cope with the deepening ecological crisis and its devastating socioeconomic impacts. These limits pertain to poverty, inequality, ecological destruction, injustices, subordination, exploitation, consumption, and the defence of the commons, among others. Societal boundaries are structural issues set by political rules that secure material and energy conditions to guarantee a good life. They also involve relational, spiritual, and affective dimensions of well-being rooted in equity, solidarity, cooperation, participation, redistribution capability, and cohabitation of diverse modes of living.

5.5 A NEW GEOPOLITICAL CONFIGURATION

An exciting discussion emerges from the following questions: Where, how, by whom, for whom, and toward whom should mass and energy flow in energy transition times? In our intricate world context, geopolitics could contribute to resolving these questions as the field that studies the international scene, underlining power (un)balances, spatial relations, historical causation, and national interests (CAIRO CAROU, 1993; SLOAN; GRAY, 1999). It applies now more than ever. The world economy is experiencing dynamic shifts, and states are pivotal in reinforcing their control over strategic fields (such as mineral and energy sources) as power unbalances emerge, reconfiguring geographic and virtual frontiers and political structures.

A new global power configuration is growing since critical actors emerged in parallel with sustainable transitions. China, for example, became pivotal in the global and LAC scenarios. Calvo and Valero (2021) pointed out that China possesses essential mineral reserves to fabricate clean energy technology. Moreover, the Indo-Pacific region – led by China – has secured a pivotal position in the global supply of materials and components, which are critical if the world follows the net-zero 2050 path (IEA, 2022c).

Overall, 79.5% of Chilean copper rents came from Asia in 2020 (80.6% of its copper shipments), 55.1% of which came from China (SERNAGEOMIN, 2021).

After the Washington consensus, LAC suffered a strong wave of economic neo-liberalization and reprimarization. Meanwhile, the explosive economic growth of China demanded growing quantities of commodities from LAC (COONEY, 2016). Energy and mining extractive industries became pivotal. From 2009 to 2013, commodities comprised four of China's most significant LAC exports (ABDENUR, 2017). This could mean reproducing and reinforcing Theotonio dos Santos's dependence theory, which postulates that some countries expand their economies to become self-sustaining. In contrast, on the other side of the system, dependent countries could boost their economies depending on the pace of the former. Thus, following dos Santos, financial and technological dependence could be in force (SANTOS, 2011).

China also expanded its economic influence over LAC – with private and state capital – via mergers, acquisitions, joint ventures, and greenfield projects in critical economic sectors. Generally, extractive industries were associated with mergers and acquisitions. Chinalco (the Aluminum Corporation of China) is one such example, becoming the operator of one of the world's largest copper and molybdenum deposits, the Toromocho mine, in central Peru (ABDENUR, 2017).

6 FINAL CONSIDERATIONS

LAC cases evince Georgescu-Roegen's claim of mass and energy flows confronting nature's limits. Fossil fuel and critical mineral extractive activities (in both carbon-based and low-carbon eras) have threatened social structures, local livelihoods, and ecological balances over time. Additionally, LAC has a long-term historical economic configuration based on exploiting commodities, which has emerged since the instauration of the modern world-system paradigm (DELGADO, 2016; LEFF, 2013; MARTÍNEZ-ALIER, 2015; ULLOA, 2017). Currently, it seems that "green growth" narratives around energy transitions may be camouflaging an old (capital-based) way of responding to emerging, more complex contemporary challenges such as climate change (BROWN; SPIEGEL, 2019).

If we consider our just and equitable energy transition definition, Bolivia and Peru face critical challenges. LAC has suffered – and could continue to – the impacts of the complex global economic and ecological scenario. The region had a 7.7% GDP economic contraction in 2020. Moreover, poverty grew, showing the sensitivity of the population to economic growth (GROTTERA, 2022). With unmet human necessities, such as access to affordable, reliable, sustainable, and modern energy, it is imperative to go to new socioeconomic configurations that establish economic and ecological equity. As we described, guaranteeing a just energy transition and redefining the role of extractive industries within national economies is critical and requires political definitions, mainly in the Global South. We know that "natural resources" have a political dimension (HUBER, 2019), but we strongly perceive it within the complex current ecological crisis.

Nonrenewable resource exploitation and indiscriminate use have become shreds of evidence of the boundaries of Earth. Although Chilean socio-ecological conflicts are mainly associated with mining and Bolivia faces conflicts with fossil fuels, they are two sides of the same coin. They locally, subnationally, nationally, and regionally show unequal ecological distributions. As Martinez-Alier sentenced, "unfair ecological distribution is inherent to capitalism" (MARTÍNEZ-ALIER, 2020).

As Zografos and Robbins (2020) claimed, planning a sustainable future and transition and a green transformation has social and ecological costs that some people and territories must assume! In this case, sacrifice zones in the periphery of the global economy have shouldered it. Addressing sustainable transitions under the current socioeconomic model could reproduce green sacrifice zones arising from the transition from mineral exploitation.

In Hickel and Hallegatte (2022), Hickel hits the nail on the head when he says, "more growth means more energy demand, and rising energy demand will make it more challenging to decarbonize the economy in the short time we have left." Additionally, Hallegatte highlighted that the wealthiest countries and societal strata must stop reproducing unsustainable (energetically intensive) behaviour! The Chilean case illustrates wealth concentration as unresolved trouble despite greater per capita incomes. As Hickel (2019) reinforced, redistribution is pivotal, especially when countries reach an income that can satisfy their citizens' needs. Max-Neef (2010) suggested moving toward efficiency, sufficiency, and well-being.

Could it be possible to meet human priorities and environmental goals at the same time? Considering social and ecological justice and equity, the relevant questions are "What are the economic growth boundaries in the Global South?" and "How many times can the Global South depend on commodity exploitation?" Studying these issues in the Global South requires reviewing new dimensions. We suggest at least three: deconstruction, decolonization, and dependence.

DECLARATION OF CONFLICTING INTERESTS

The author declared no potential conflicts of interest concerning this study's research, authorship, and/or publication.

NOTES

1| For example, as this article is being written, Germany has stated that it will reactivate coal-fired plants to replace the lack of Russian gas (SEVILLANO, 2022).

2 | According to the International Renewable Energy Agency (IRENA, 2022), bioenergy, geothermal, hydropower, ocean, solar, and aeolian sources are examples of renewable energy. Nonconventional renewable energy sources (NCRE) generally include bioenergy, geothermal, ocean, solar, aeolian, and small hydropower plants. Sometimes, national definitions (considered in regulations and policies) vary due to interpretations regarding small hydropower plants. For instance, NCRE considers small hydropower plants in Chile those with a capacity below 20 MW (POQUE GONZÁLEZ, 2021)adopting an interdisciplinary perspective, the influence of Covid19 pandemic on the Chilean and Brazilian energy transition towards sustainability of 21st century. Subsequently, there are presented the main opportunities and challenges of social, environmental, and technical nature that might determine the development of the electricity systems of both countries after the current crisis will be overcome. The strong positive correlation between the Gross Domestic Product (GDP.

3 | The GINI indicator ranges from 0 to 1, in which values near 1 maximize inequality, and values near 0 tend to perfect equality.

4 | Placed on the Coquimbo Region cost, the Dominga project comprises two open pit mines for iron ore and copper extraction, a harbour to load the mineral, a desalination plant, and a processing plant (TEMPER; BENE; MARTINEZ-ALIER, 2015).

REFERENCES

ABDENUR, A. E. ¿Eludiendo o cortejando la controversia? La inversión extranjera directa (IED) china en las industrias extractivas de América Latina. **Revue Internationale de Politique de Développement**, n. 9, 10 out. 2017.

ADEKOYA, O. B. *et al*. Does oil connect differently with prominent assets during war? Analysis of intra-day data during the Russia-Ukraine saga. **Resources Policy**, v. 77, p. 102728, ago. 2022.

ALI, S. R. M. *et al*. The impacts of Covid-19 crisis on spillovers between the oil and stock markets: evidence from the largest oil importers and exporters. **Economic Analysis and Policy**, v. 73, p. 345–372, mar. 2022.

ANBLEYTH-EVANS, J. *et al*. Toxic violence in marine sacrificial zones: developing blue justice through marine democracy in Chile. **Environment and Planning C:** politics and space, p. 239965442210841, 16 maio 2022.

AVIS, W. **Ukraine Crisis and Climate and Environment Commitments**: K4D Helpdesk Report. Birmingham: Institute of Development Studies, 9 mar. 2022. Available at: https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/17419. Access in: 27 jun. 2022.

BOOKCHIN, M. **Toward an ecological society**. 1980.

BORDERA, J. *et al*. **El efecto dominó.** Guerra en Ucrania y extractivismos en América latina. 1. ed. Cochabamba, Bolivia: LALIBRE Proyecto Editorial, 2022.

BORIC, G. **Presidente de la República rinde la primera Cuenta Pública de su mandato**. Gobierno de Chile. Available at: http://prensa.presidencia.cl/discurso.aspx?id=195328. Access in: 29 jun. 2022.

BRAND, U. *et al*. From planetary to societal boundaries: an argument for collectively defined self-limitation. **Sustainability:** science, practice and policy, v. 17, n. 1, p. 264–291, 1 jan. 2021.

BROWN, B.; SPIEGEL, S. J. Coal, Climate Justice, and the Cultural Politics of Energy Transition. **Global Environmental Politics**, v. 19, n. 2, p. 149–168, maio 2019.

BUDDS, J. Power, nature and neoliberalism: the political ecology of water in Chile. **Singapore Journal of Tropical Geography**, v. 25, n. 3, p. 322–342, 26 nov. 2004.

CAIRO CAROU, H. Elementos para una geopolítica crítica: tradición y cambio en una disciplina maldita. **Ería**, n. 32, p. 195–213, 1993.

CALDERÓN, M.; PRIETO, M. La Cuestión agraria y el cobre en la Provincia de El Loa (1929/30 – 2006/07). Andes centro-sur, norte de Chile. **Estudios Atacameños**, 18 nov. 2020.

CALVO, G.; VALERO, A. Strategic mineral resources: availability and future estimations for the renewable energy sector. **Environmental Development**, p. 100640, abr. 2021.

CANADA. **Copper facts**. Government of Canada. Available at: https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/copper-facts/20506. Access in: 22 jul. 2022.

CAVALCANTI, C. Sustentabilidade: mantra ou escolha moral? Uma abordagem ecológico-econômica. **Estudos Avançados**, v. 26, n. 74, p. 35–50, 2012.

CECHIN, A. **A natureza como limite da economia.** A contribuição de Nicholas Georgescu-Rogen. 1. ed. São Paulo: Senac São Paulo, 2010.

CERECEDA-BALIC, F. *et al*. Understanding the role of anthropogenic emissions in glaciers retreat in the central Andes of Chile. **Environmental Research**, v. 214, p. 113756, nov. 2022.

CLEVELAND, C. J.; RUTH, M. When, where, and by how much do biophysical limits constrain the economic process? A survey of Nicholas Georgescu-Roegen’s contribution to ecological economics. **Ecological Economics**, v. 22, n. 3, p. 203–223, set. 1997.

COCHILCO. **Producción Minera | Cochilco**. Available at: https://www.cochilco.cl/Paginas/Estadisticas/Bases%20de%20Datos/Producci%C3%B3n-Minera.aspx. Access in: 13 jul. 2022.

COONEY, P. Reprimarization: implications for the Environment and Development in Latin America. The cases of Argentina and Brazil <sup/>. **Review of Radical Political Economics**, v. 48, n. 4, p. 553–561, dez. 2016.

CRONIN, J. *et al*. Embedding justice in the 1.5°C transition: a transdisciplinary research agenda. **Renewable and Sustainable Energy Transition**, v. 1, p. 100001, ago. 2021.

DELGADO, J. O. Sociedades posneoliberales en América Latina y persistencia del extractivismo. **Economía Informa**, v. 396, p. 84–95, jan. 2016.

DIARIOUCHILE. **Presidente Gabriel Boric anuncia cierre de Planta Ventanas de Codelco:** "No queremos más zonas de sacrificio". Diario y Radio Universidad Chile. Available at: https://radio.uchile.cl/2022/06/17/presidente-gabriel-boric-anuncia-cierre-de-planta-ventanas-de-codelco-no-queremos-mas-zonas-de-sacrificio/. Access in: 21 jul. 2022.

DUNLAP, A. The green economy as counterinsurgency, or the ontological power affirming permanent ecological catastrophe. **Environmental Science & Policy**, v. 139, p. 39–50, jan. 2023.

ERICSSON, M.; LÖF, O. Mining's contribution to national economies between 1996 and 2016. **Mineral Economics**, v. 32, n. 2, p. 223–250, jul. 2019.

ESTADOS UNIDOS MEXICANOS. **Ley Minera.** Nueva Ley publicada en el Diario Oficial de la Federación el 26 de junio de 1992. 20 abr. 2022. Available at: https://www.diputados.gob.mx/LeyesBiblio/pdf/LMin.pdf.

FUENTEALBA, M. *et al.* The 2010–2020 "megadrought" drives reduction in lake surface area in the Andes of central Chile (32° - 36°S). **Journal of Hydrology: Regional Studie**s, v. 38, p. 100952, dez. 2021.

GAYO, E. M. et al. A Cross-Cutting Approach for Relating Anthropocene, Environmental Injustice and Sacrifice Zones. **Earth's Future**, v. 10, n. 4, p. 1–21, abr. 2022.

GROTTERA, C. **Reducing emissions from the energy sector for a more resilient and low-carbon post-pandemic recovery in Latin America and the Caribbean**. Economic Commission for Latin America and the Caribbean (Eclac), 2022. Available at: https://www.cepal.org/pt-br/node/56102.

GUDYNAS, E. **Extractivismos** y **corrupción**: anatomía de una íntima relación. 1. ed. Lima, Perú. Montevideo, Uruguay: CooperAcción: Red GE, Red Peruana por una Globalizacíon con Equidad; Claes, Centro Latino Americano de Ecología Social, 2017.

GUZOWSKI, C.; MARTIN, M. M. I.; ZABALOY, M. F. Energy poverty: conceptualization and its link to exclusion. Brief review for Latin America. **Ambiente & Sociedade**, v. 24, p. e00272, 2021.

HICKEL, J. The contradiction of the sustainable development goals: growth versus ecology on a finite planet. **Sustainable Development**, v. 27, n. 5, p. 873–884, set. 2019.

HICKEL, J.; HALLEGATTE, S. Can we live within environmental limits and still reduce poverty? Degrowth or decoupling? **Development Policy Review**, v. 40, n. 1, jan. 2022.

HOPE, J. Driving development in the Amazon: extending infrastructural citizenship with political ecology in Bolivia. **Environment and Planning E**: nature and space, v. 5, n. 2, p. 520–542, jun. 2022.

HUBER, M. Resource geography II: what makes resources political? **Progress in Human Geography**, v. 43, n. 3, p. 553–564, jun. 2019.

IEA. **World Energy Outlook 2022**. International Energy Agency, 2022a. Available at: www.iea.org. Access in: 1 nov. 2022

IEA. **World – World Energy Balances**: overview – analysis. Available at: https://www.iea.org/reports/world-energy-balances-overview/world. Access in: 3 nov. 2022b.

IEA. **Securing Clean Energy Technology Supply Chains**. Australia: International Energy Agency, 2022c. Available at: https://iea.blob.core.windows.net/assets/ac24282b-c3d6-4b0e-a0c3-de948a0af104/SecuringCleanEnergyTechnologySupplyChains.pdf.

IGLESIAS, E. M.; RIVERA-ALONSO, D. Brent and WTI oil prices volatility during major crises and Covid-19. **Journal of Petroleum Science and Engineering**, v. 211, p. 110182, 1 abr. 2022.

INE. **Producción de minerales por tipo de mineral según año y mes 1990-2022**. Instituto Nacional de Estadística, 2022. Available at: https://www.ine.gob.bo/index.php/estadisticas-economicas/hidrocarburos-mineria/mineria-cuadros-estadisticos/.

IPCC. **Climate Change 2022**: mitigation of climate change. Intergovernmental Panel on Climate Change, 2022. Available at: https://www.ipcc.ch/report/ar6/wg3/. Access in: 14 abr. 2022

IRARRAZAVAL, F. Contesting uneven development: the political geography of natural gas rents in Peru and Bolivia. **Political Geography**, v. 79, p. 102161, maio 2020.

IRENA. **IRENA – International Renewable Energy Agency**. Available at: https://www.irena.org/. Access in: 30 jul. 2022.

IWIŃSKA, K.; LIS, A.; MĄCZKA, K. From framework to boundary object? Reviewing gaps and critical trends in global energy justice research. **Energy Research & Social Science**, v. 79, p. 102191, set. 2021.

KNOX, S. *et al*. The (in)justices of smart local energy systems: a systematic review, integrated framework, and future research agenda. **Energy Research & Social Science**, v. 83, p. 102333, jan. 2022.

LEFF, E. Tiempo de sustentabilidad. **Ambiente & Sociedade**, n. 6, p. 10, 2000.

LEFF, E. Ecologia Política: uma perspectiva latino-americana. **Desenvolvimento e Meio Ambiente**, v. 27, n. 0, 28 jun. 2013.

LINERA, Á. G. **La política como disputa de las esperanzas**. 1. ed. Buenos Aires, Argentina: Clacso, 2022.

MACROTRENDS. **Copper Prices – 45 Year Historical Chart**. Macrotrends, 2022. Available at: https://www.macrotrends.net/1476/copper-prices-historical-chart-data.

MARQUES, L. O Antropoceno como aceleração do aquecimento global. **Liinc em Revista**, v. 18, n. 1, p. e5968, 4 abr. 2022.

MARTÍNEZ-ALIER, J. Ecología política del extractivismo y justicia socio-ambiental. **INTERdisciplina**, v. 3, n. 7, 20 set. 2015.

MARTÍNEZ-ALIER, J. A global environmental justice movement: mapping ecological distribution conflicts. **Disjuntiva. Crítica de les Ciències Socials**, v. 1, n. 2, p. 83, 2 jul. 2020.

MARTINEZ-ALIER, J. *et al*. Is there a global environmental justice movement? **The Journal of Peasant Studies**, v. 43, n. 3, p. 731–755, 3 maio 2016.

MARTINEZ-ALIER, J. Circularity, entropy, ecological conflicts and LFFU. **Local Environment**, v. 27, n. 10–11, p. 1182–1207, 2 nov. 2022.

MAX-NEEF, M. The World on a Collision Course and the Need for a New Economy: contribution to the 2009 Royal Colloquium. **Ambio**, v. 39, n. 3, p. 200–210, maio 2010.

MEADOWS, D. H. *et al*. **The limits to growth.** A report for the Club of Rome's project on the Predicament of Mankind. New York: Universe Books, 1972.

MEYER, E.; VILSMAIER, U. Economistic discourses of sustainability: determining moments and the question of alternatives. **Sustentabilidade em Debate**, v. 11, n. 1, p. 98–124, 30 abr. 2020.

MINISTERIO DE ENERGÍA Y MINAS. **Producción minera metálica, por principales metales 1980-2020**. Ministerio de Energía y Minas. Dirección General de Promoción y Sostenibilidad Minera, 2022. Available at: https://www.inei.gob.pe/estadisticas/indice-tematico/economia/.

NETTLETON, D. Chapter 6 – Selection of Variables and Factor Derivation. *In*: NETTLETON, D. (Ed.). **Commercial Data Mining**. Boston: Morgan Kaufmann, 2014. p. 79–104.

OLADE. **Sielac** – **Sistema de Información Energética de Latinoamérica y el Caribe**. Available at: http://sier.olade.org. Access in: 3 jun. 2021a.

OLADE. **Panorama Energético de América Latina y el Caribe 2021**. 2. ed. Quito, Ecuador: Olade, 2022b.

POQUE GONZÁLEZ, A. B. Transição energética para a sustentabilidade no Chile e no Brasil: oportunidades e desafios decorrentes da pandemia por Covid-19. **Latin American Journal of Energy Research**, v. 8, n. 1, p. 1–21, 11 jul. 2021.

POQUE GONZÁLEZ, A. B.; SILVA, B. D. J.; MACIA, Y. M. Transición energética en América Latina y el Caribe: diálogos inter y transdisciplinarios en tiempos de pandemia por Covid-19. **Lider**, v. 39, p. 33–61, 15 mar. 2022.

ROCKSTRÖM, J. *et al*. A safe operating space for humanity. **Nature**, v. 461, n. 7263, p. 472–475, set. 2009.

SANTOS, T. DOS. A estrutura da dependência. **Revista da Sociedade Brasileira de Economia Política**, v. 1, n. 30, 2011.

SATOH, Y. *et al*. The timing of unprecedented hydrological drought under climate change. **Nature Communications**, v. 13, n. 1, p. 3287, dez. 2022.

SERNAGEOMIN. **Anuario de la mineria de Chile 2020**. Chile: Servicio Nacional de Geología y Minería, 2021.

SEVILLANO, E. G. **Alemania anuncia que recurrirá al carbón ante el recorte de suministro de gas ruso**. Available at: https://elpais.com/economia/2022-06-19/alemania-recurrira-al-carbon-ante-el-recorte-de-suministro-de-gas-ruso.html. Access in: 29 jun. 2022.

SLOAN, G.; GRAY, C. S. Why geopolitics? **Journal of Strategic Studies**, v. 22, n. 2–3, p. 1–11, jun. 1999.

STEFFEN, W. *et al*. Planetary boundaries: guiding human development on a changing planet. **Science**, v. 347, n. 6223, p. 1259855, 13 fev. 2015.

SVAMPA, M. **Feminismos ecoterritoriales en América Latina.** Entre la violencia patriarcal y extractivista y la interconexión con la naturaleza. Madrid, España: Fundación Carolina, out. 2021. Available at: https://www.fundacioncarolina.es/dt_fc_59/. Access in: 3 dez. 2021.

TAPIA-GATICA, J. *et al*. Advanced determination of the spatial gradient of human health risk and ecological risk from exposure to As, Cu, Pb, and Zn in soils near the Ventanas Industrial Complex (Puchuncaví, Chile). **Environmental Pollution**, v. 258, p. 113488, mar. 2020.

TEMPER, L.; BENE, D. DEL; MARTINEZ-ALIER, J. Mapping the frontiers and front lines of global environmental justice: the EJAtlas. **Journal of Political Ecology**, v. 22, n. 1, p. 255–278, 30 nov. 2015.

ULLOA, A. Dinámicas ambientales y extractivas en el siglo XXI: ¿es la época del Antropoceno o del Capitaloceno en Latinoamérica? **Desacatos. Revista de Ciencias Sociales**, n. 54, p. 58, 16 maio 2017.

UN. **Cepalstat – Bases de Datos y Publicaciones Estadísticas**. Available at: https://statistics.cepal.org/portal/cepalstat/dashboard.html?theme=2&lang=es. Access in: 3 dez. 2021.

VERGARA-PERUCICH, F.; BOANO, C. The big bang of neoliberal urbanism: the gigantomachy of Santiago's urban development. **Environment and Planning C:** politics and space, v. 39, n. 1, p. 184–203, fev. 2021.

VILLALBA-EGUILUZ, C. U.; ETXANO, I. Buen Vivir vs Development (II): the limits of (Neo-) extractivism. **Ecological Economics**, v. 138, p. 1–11, ago. 2017.

VOSKOBOYNIK, D. M.; ANDREUCCI, D. Greening extractivism: environmental discourses and resource governance in the 'Lithium Triangle'. **Environment and Planning E:** nature and space, v. 5, n. 2, p. 787–809, jun. 2022.

WORLD BANK. **World Development Indicators – DataBank**. Available at: https://databank.worldbank.org/indicator/NY.GDP.PCAP.CD/1ff4a498/Popular-Indicators#. Access in: 13 jul. 2022.

ZOGRAFOS, C.; ROBBINS, P. Green Sacrifice Zones, or Why a Green New Deal Cannot Ignore the Cost Shifts of Just Transitions. **One Earth**, v. 3, n. 5, p. 543–546, nov. 2020.