Lithium supply chain metabolism, a conflict-based analysis

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Abstract

This article examines the impacts of the energy transition industry from an environmental justice perspective, proposing to understand supply chain metabolism through environmental conflicts and enhancing socio-metabolic analysis. By revisiting the concept of social metabolism, we explore its evolution and relevance in the current context of global supply chains analysis. Historically, this approach provides tools to understand the flow of energy and materials sustaining societies. We argue that, within the context of the contemporary energy transition in the Global North, our challenge as critical scholars is to examine whether and how the supply chain, as a capitalist *dispositif*, exacerbates environmental and social injustices across multi-scalar geographies. Situating our research within the emerging political ecology scholarship on supply chain metabolism and its links to global power dynamics, our empirical contribution focuses on the lithium supply chain, a critical component of the energy transition sector. While metabolic analysis primarily focuses on the flow of energy and materials, we use data from the Environmental Justice Atlas (EJAtlas) to trace the dynamics of resistance and conflict along the supply chain, uncovering the socio-environmental injustices embedded within it. We employ a hybrid methodology (using qualitative data for quantitative description) to analyze the structural mechanisms of exclusion that underpin injustice along lithium supply chains.

Keywords: Social metabolism, supply chain, lithium, environmental struggles, socio-environmental justice

Résumé

Cet article examine les impacts de l'industrie de la transition énergétique sous l'angle de la justice environnementale, en se concentrant sur le métabolisme de la chaîne d'approvisionnement du lithium. Nous soutenons que, dans le contexte de la transition énergétique contemporaine au Nord Global, l'un des enjeux majeurs pour les chercheurs critiques est d'examiner si et comment les chaînes d'approvisionnement, en tant que dispositif capitaliste, exacerbent les injustices environnementales et sociales à travers des géographies multi-scalaires. Alors que l'analyse métabolique utilise principalement des données quantitatives sur les flux d'énergie et de matériaux, nous nous appuyons plutôt sur les données de l'Environmental Justice Atlas (EJAtlas), une source particulièrement adaptée pour retracer les dynamiques de résistance et de conflit le long des chaînes d'approvisionnement. Par

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conséquent, nous adoptons une méthodologie hybride — utilisant des données qualitatives pour produire une description quantitative — afin d'analyser les mécanismes structurels d'exclusion qui sous-tendent l'injustice le long des chaînes d'approvisionnement du lithium

Mots-clés: Métabolisme social, chaîne d'approvisionnement, lithium, luttes environnementales, justice socio-environnementale

Resumen

Este artículo examina los impactos de la industria de la transición energética desde una perspectiva de justicia ambiental, centrándose en el metabolismo de la cadena de suministro del litio. Argumentamos que, en el contexto de la actual transición energética en el Norte Global, un desafío clave para los académicos críticos es examinar si las cadenas de suministro, entendidas como un dispositivo capitalista, exacerban las injusticias ambientales y sociales a través de geografías multiescalares, y de qué manera lo hacen. Mientras qu'el análisis metabólico emplea principalmente datos cuantitativos sobre los flujos de energía y materiales, nosotros nos basamos en datos del Atlas de Justicia Ambiental (EJAtlas), una fuente especialmente adecuada para rastrear las dinámicas de resistencia y conflicto a lo largo de las cadenas de suministro. Por lo tanto, adoptamos una metodología híbrida —utilizando datos cualitativos para producir una descripción cuantitativa— con el fin de analizar los mecanismos estructurales de exclusión que sustentan la injusticia a lo largo de las cadenas de suministro de litio.

Palabras clave: Metabolismo social, cadena de suministro, litio, luchas ambientales, justicia socioambiental

1. Introduction

The energy transition has been hailed as the ecological imperative of our time, yet, in its practical manifestations, it is becoming one of the new battlegrounds of environmental justice. Over the past decade, scholarship linking environmental injustices to the energy industry and its supply chains has expanded significantly. The international structure of these commodity flows facilitates the externalization of environmental burdens and socio-political costs onto specific territories and communities, rendering these effects largely invisible and making urgent the need to foreground 'supply chain justice' (Mastini *et al*. 2021). This article enhances efforts to understand and advance supply chain justice by offering a conflict-based analysis of the supply chain metabolism. To address this, we propose an empirical study to understand supply chain metabolism through the lens of conflicts, aiming to enrich socio-metabolic analysis through a conflict-based approach.

The concept of social metabolism is a theoretical framework for understanding socio-environmental transformations (Fischer-Kowalski & Haberl 1997, 2007; Sieferle 2011; González de Molina & Toledo 2014; Schaffartzik *et al.* 2021) and as a set of methodological tools for analyzing the biophysical behaviors of economies (Weisz 2007). Social metabolism provides a perspective for examining the intricate interplay between society and nature, focusing on the flow of energy and materials—an analogy drawn from biological metabolism. Social metabolism analysis underscores the critical role of these flows in sustaining and reproducing societies (Pichler 2023). The intensification of material and energy flows—central to social metabolism—began increasing significantly with industrialization.

Supply chain systems are designed to maximize profits, often at the expense of communities, workers, and the environment, thereby generating multi-scalar impacts. While supply chains generate value and profits along their pathways, they simultaneously obscure responsibility and accountability by masking the flows of power and capital that structure supply chain metabolism. To fully understand the unjust configurations arising along these chains, it is essential to study them from a multi-local perspective.

Although some authors have suggested that supply chains, particularly when associated with sustainability agendas, may benefit marginalized communities (Hall & Matos 2010, Xing *et al*. 2017), we align with scholars who have highlighted the global inequalities and injustices these networks generate (Dicken 1986). By employing a conflict-based perspective, we can see how power relations shape supply chains at both local and global levels, influencing socio-political and economic decisions. This approach challenges mainstream discourses on supply chains (for a critique, see Braucher & Armiero 2023), which often frame them solely in terms of the geographical and financial distribution of raw materials (Singh Garha *et al.* 2022). Our empirical contribution to the debate on social metabolism involves a comprehensive survey of conflicts surrounding the lithium supply chain. Using data collected from the Environmental Justice Atlas (EJAtlas), we construct a featured map of the lithium supply chain struggles to better understand its dynamics.[2] These sources enable us to approach supply chains through the lens of environmental conflicts, integrating perspectives from political ecology. By studying supply chain metabolism through the lens of conflict, we aim to understand how struggles and power relations affect the flow of commodities, their local impacts and conflicts, and their broader global interconnections. By combining an analysis of conflicts with a global perspective, a multi-local approach makes unjust conditions unfolding along supply chains visible. Meanwhile, it helps to interconnect these local conflicts, tracing a common thread across global supply chains.

In the article, we first revisit the concept of social metabolism, examining its evolution in the current context while stressing the potential to think in terms of supply chain metabolism. Subsequently, we propose employing a political ecology lens to study metabolism along energy transition supply chains. This approach aligns with the call made a decade ago by González de Molina and Toledo (2015) and Madrid-Lopez and Giampietro (2015) for a metabolic analysis that better incorporates social dynamics.

From an empirical standpoint, we utilize data from the EJAtlas to produce lithium supply chain maps, revealing the global interconnectedness of struggles and the associated impacts. Given that the EJAtlas systematizes a large amount of qualitative data—though with the limitations we will discuss below—we aim to contribute to social metabolism studies by adopting a qualitative–quantitative approach, complementing the predominantly quantitative methods that have long dominated the field.

2. Social metabolism to analyze supply chains

The concept of social metabolism encompasses historical and contemporary dimensions. It refers to the metabolic relationships that shape the exchanges of energy and materials in all productive and reproductive activities of societies and their environment. The expansion of capitalism has radically intensified these metabolic flows, resulting in a significant increase in metabolic processes and the demand for materials and energy over the past two centuries (Clark & Foster, 2021).

The term "social metabolism" has a rich and extensive history, rooted in the fundamental biological concept of metabolism. It has been applied to various contexts, with diverse interpretations developed by social scientists over centuries. Karl Marx employed the term "Stoffwechsel" (metabolism) to illustrate the flow of commodities and, more broadly, to describe the exchanges

[2] The EJAtlas (https://ejatlas.org) is the largest open-access database on environmental conflicts. As of March 2026, it includes more than 4,500 cases. On its methodologies and theoretical background see Leah Temper, Daniela del Bene and Joan Martinez-Alier (2015). We will expand on the limitations of this dataset below.

between society and nature. In this article we will not delve into the genealogy of the social metabolism concept, but we will provide a short introduction.

After the pioneering use of the term in the 1960s by Boulding (1966), it was in the 1990s that Fischer-Kowalski and Haberl (1997) proposed the concept of social metabolism for analyzing the flow and exchange of materials. Fischer-Kowalski and Haberl (1997) and Martinez-Alier (2009) define social metabolism as the way societies organize and develop their growing exchanges of energy and materials with the environment. Given the significance of this theoretical framework, many related concepts have emerged over the years, including industrial metabolism (Ayres 1989), urban metabolism (Wolman 1965), agrarian metabolism, rural metabolism (Tello *et al*. 2008), and water metabolism (Cabello *et al*. 2015; Madrid-Lopez & Giampietro 2015).

We focus particularly on the spatial features of social metabolism, as the concept of scale is crucial. The choice of scale in studying metabolism is not neutral and significantly influences methodologies, results, and their political implications. Indeed, metabolism can be studied from a local to a global scale (Baccini & Brunner 1991; Matthews *et al*. 2000; González de Molina & Toledo 2014). The interconnections between different scales, also a key feature of political ecology, underscore the need for integrated approaches to understand metabolism as a complex phenomenon. Furthermore, scales shape the methodological and epistemological tools employed in such analyses. The concept of metabolism, along with the analytical methods used to study it, is strongly influenced by the scale and the object of study.

Recently, research on social metabolism has seen significant effort to move beyond a mainly biophysical approach by integrating socio-political and economic perspectives (Schaffartzik *et al*. 2021; Haberl *et al*. 2025). This approach goes beyond the study of the flow of materials, focusing instead on the structural configuration of the systems that provide for fundamental human needs through interconnected metabolic, economic, and political-institutional dimensions (Schaffartzik *et al*. 2021). This integrated framework explicitly acknowledges that socio-ecological transformations are fundamentally shaped by power relations, governance regimes, and political processes (Pichler 2023).

Building upon the work of scholars who have analyzed injustices in energy transitions—particularly in identifying the phenomenon of green extractivism and green colonialism (Dorn 2022; Dunlap *et al*. 2024; Riofrancos 2020)—we analyze injustices along the lithium supply chain to understand the multi-local fallouts of commodity flows metabolism. This allows us to analyze on a multi-local dimension how environmental conflicts manifest and are redistributed along the supply chain phases—Extraction, Transformation, Consumption, and Disposal (Schaffartzik *et al*. 2021). This lens is particularly effective for tracing the specific injustices generated by green extractivism, green transition and for connecting Global North demand with on-the-ground impacts.

3. Social metabolism, conflicts and political ecology perspectives

Analyzing conflict dynamics through a case study approach is central to political ecology and can provide valuable insights into human and non-human interactions (DeLoughrey *et al*. 2015), as well as into how these relationships shape both nature and society. Studies on resource extraction, land use, pollution levels, and biodiversity loss aim to identify who holds decision-making power and who benefits from the exploitation of territories and communities (Martinez-Alier 2002; Robbins 2019).

Environmental conflicts often arise from issues related to the access, management, and distribution of natural resources and services essential for human reproduction (Martinez-Alier *et al*. 2011). These conflicts also stem from the beneficial or harmful effects that these issues have for humanity. Specifically, conflicts emerge from the unequal distribution of energy and material flows, as well as the waste generated by their use.

Martinez-Alier and Walter (2016) establish a clear link between the increase in social metabolism and the rise in conflicts over resource extraction and waste disposal. These conflicts, particularly those stemming from the extraction of materials and the subsequent disposal of wastes, are strongly associated with socio-metabolic effects (González de Molina & Toledo 2014). Martinez-Alier and Walter (2016) note that alongside the boom in extractive activities, there has been a corresponding rise in conflicts. The discussion of ecological distribution conflicts is rooted in the structural asymmetries of pollution, environmental impacts, and access to natural resources, shaped by unequal distributions of power and wealth, as well as social inequalities related to ethnicity, caste, class, and gender (Martinez-Alier *et al*. 2011).

Martinez-Alier and Walter (2016) identified four key stages in social metabolism: extraction, transport, processing, and disposal. However, they primarily focused on extractivism and disposal as sites of environmental conflict. We build on this perspective while emphasizing the need for an interconnected understanding of all phases of the supply chain. This approach allows us to uncover the environmental and social pressures that emerge along the entire chain, beyond the initial phases of extraction, through an analysis of conflicts across its different phases.

Furthermore, the global structure of these chains is not merely a logistical pathway, but an intrinsic mechanism for the displacement of socio-environmental burdens (Cederlöf 2021; Ajl 2023). This study contributes to the analysis of supply chain impacts enabling high-consumption regions in the Global North to internalize economic value while externalizing ecological degradation along the supply chain. The approach draws on the idea that environmental conflicts are one of the most evident expressions of the structural asymmetries and stratification of injustices embedded within global production networks.

Coming from a background in environmental history, Armiero (2008) also argues for using conflicts as key elements in the analysis of socio ecological processes. In an essay published in the radical journal *Left History*, Armiero stated that "we can better see and understand the environment if we look at it through the lens of conflict" because, according to him, a conflict-based approach can reveal aspects of social metabolism that might otherwise remain hidden. Environmental conflicts, Armiero suggests, serve as a litmus test, revealing what is typically obscured in the landscape. However, by exposing power dynamics within nature, conflicts are not merely passive indicators; they actively produce new landscapes and socio-ecological relationships. Peluso and Watts (2001) presented a similar perspective, arguing that political ecology examines conflicts and struggles over control and access to resources. Political ecology consistently illustrates how the rise in socio-ecological conflicts is driven, among other factors, by the intensifying capitalist exploitation of nature. They also highlighted the unequal distribution of risks through a broader analysis of capitalism's uneven development (see Heynen 2003).

We observe a division of labor between scholars of social metabolism, who mostly use quantitative, statistical approaches, and those studying environmental conflicts on the ground, who rely on qualitative field data such as impacts, types of mobilization, and outcomes. This division of labor between quantitative and qualitative approaches raises methodological challenges. Our proposed methodology recognizes that while the study of social metabolism often relies on statistical metrics, the use of a conflict-based perspective requires qualitative data sourced from the field (Armiero 2008). The EJAtlas offers a unique opportunity since its raw data, collected through collaborative and citizen-science approaches, are fundamentally qualitative, yet standardized into categories and data points that enable quantitative analysis. The EJAtlas' dual nature allows us to analyze supply chain conflicts descriptively while accessing global socio-economic, health, and environmental data, offering a complement to quantitative metabolic studies and moving beyond traditional indexes like EROI or MUSIASEM.[3] Through the EJAtlas we gain access to global data on environmental conflicts and the socio-economic, health, and environmental impacts of the lithium supply chain. The analysis we propose in the following paragraphs aims to contribute to the social metabolism literature on energy transition.

4. Methodology

From an empirical perspective, our contribution to the debate on social metabolism involves conducting a comprehensive analysis of conflicts related to the lithium supply chain, drawing on data collected in the EJAtlas. The EJAtlas includes a variety of featured maps, categories, and keywords. Our analysis builds on existing EJAtlas categories while introducing new ones to represent lithium supply chain struggles as an important part of the energy transition supply chain (see Table 1, 2 & 3).

As noted, the EJAtlas is the largest inventory of socio-environmental conflicts (4,500 entries in 2026). Temper and colleagues (2015) describe the process of co-designing and developing the Atlas and assess its initial outcome as a tool for activism, advocacy, and scientific knowledge. Nearly a decade later, the EJAtlas remains a collaborative project involving academics, activists, and organizations contributing verifiable information for each case (Scheidel *et al*. 2011; Temper *et al*. 2018). This enables a comparative multi-case approach, transcending the single-case studies that dominate much of the political ecology literature (Temper *et al*. 2015; Martínez-Alier *et al*. 2016). The EJAtlas aims to make these conflicts visible. The base unit of the EJAtlas is a record describing a specific place-based struggle. According to Temper *et al.* (2015), these records focus on struggles mobilizing against the distribution of costs and benefits, or the lack of representation in decision-making. The record description includes a wide range of actions in its inventory, such as legal cases, campaigns, petitions, meetings, demonstrations, boycotts, strikes, threats, civil disobedience, collective violence, and more (Tilly, 1993). Among other elements the EJAtlas categorizes—after a large amount of general information on the struggles (place, intensity, context)—the type of impacts, the outputs, and the status of the struggles.

From its inception, the EJAtlas has aimed to involve communities directly, representing a form of citizen science developed through participatory action and collaborative research (Bacon *et al*. 2013). These methodologies engage communities in the production of knowledge, recognizing them as knowledge producers.

However, as with any data source, it is essential to consider potential biases and limitations. The geographical coverage of the EJAtlas is uneven. Some countries have more conflicts listed than others, not due to a higher number of conflicts but because of better data availability and collaborations. Additionally, the political situation in each country affects the presence of conflicts in the EJAtlas, as the ability to mobilize often depends on levels of democracy and violence. Limited freedom for social mobilization in certain countries may result in underrepresentation of conflicts. Taking all factors into account, these limitations must inform the interpretation of quantitative trends, particularly regarding the comparison of conflict across countries and phases. Despite these constraints, the EJAtlas remains the largest database on environmental conflicts worldwide. We argue

[3] Several methods analyze social metabolism. HANPP quantifies human appropriation of biomass but simplifies ecological interactions (Haberl *et al*., 2007). EFA and MFA examine energy and material flows, respectively, but overlook qualitative and social impacts (Gonzalez-Martinez & Schandl, 2008). MEFA integrates them but struggles to incorporate social dynamics. EROI assesses energy efficiency without considering socio-environmental implications (Martinez-Alier, 2011). MUSIASEM applies a multi-scale analysis of energy, water, and land use but faces challenges in data integration (Giampietro, 2003).

that it should be used with an awareness of its limitations, employing caution akin to the assessment of any other primary data source.

The first study using a global dataset of 1,357 EJAtlas cases was published by Martinez-Alier *et al*. (2016), providing insights into the actors involved and forms of mobilization. A special journal issue published in 2018 further strengthened the role of the EJAtlas in comparative political ecology research (Temper *et al*. 2018). These studies examined hundreds of cases, focusing on regional trends, such as environmental conflicts in Andean countries (Pérez-Rincón *et al*. 2019), sectoral dynamics—including disputes over wind energy (Pérez-Rincón *et al*. 2019), hydropower and dams (Del Bene *et al*. 2018), and mining (Aydin *et al*. 2017)—as well as specific thematic concerns, such as multidimensional violence in Central American conflicts (Navas *et al*. 2018). In an article published in 2023, Martinez-Alier highlighted the significant contributions of the EJAtlas, both in terms of the number of cases included in the database and the papers published. He argued that this tool has been instrumental in advancing research in comparative statistical political ecology, though they have yet to explicitly define this approach.

In this article, we employ EJAtlas data to examine the lithium supply chain. Lithium was chosen due to its growing importance in the energy transition industry. Our analysis seeks to address injustices and impacts within the context of this supply chain, amidst the ongoing transformation of demand and global social metabolism driven by the transition industry (Sneddon *et al*. 2006, Gerber *et al*. 2009). We have analyzed the struggles happening along the supply chain from mines to disposal locations. In this way we have shifted the focus from the material objects (lithium, battery, solar panels, etc.) to the socio-ecological relationships produced within the commodity flow. By analyzing the struggle, we were able to develop the dataset and map the lithium supply chain struggles, highlighting its global dimension and interconnected processes. Building upon Armiero (2008), we argue that conflict-based research contributes not only to the study of social movements but uncovers the mutual constituency of power and ecologies through a global-local perspective.

While lithium and its role in the energy transition industry serve as the *fil rouge* of our research, we argue for the heuristic potential of studying struggles to reveal the complex socio-ecologies embedded in any supply chain. Our research remains deeply rooted in materiality, even as we focus on the struggles surrounding the commodity rather than solely on the thing itself—lithium, in this case. We argue that these struggles are deeply embedded, intricately connected to broader socio-ecological relationships.

5. Data and sources

A sample of 148 conflicts on a global scale were analyzed, covering various phases of the lithium supply chain, from extraction to struggles over e-waste. The dataset was compiled using multiple criteria, including a map of critical raw materials developed by the EJAtlas team, the search category "conflict type", and keywords such as "lithium," "battery," "EV," "electric vehicle," and "e-waste" in the search bar. The subsequent filtering and categorization of cases showed that struggles in the consumption phase were overwhelmingly concentrated in renewable energy infrastructure, resulting in very few cases linked to vehicle manufacturing sites and directly analyzed.

The data cleaning process began with the definition of four categories to classify the 148 records:[4] extraction, processing, consumption, and disposal phases (Table 1). This categorization,

[4] Total = 253 records (up to 12 January 2024) – cleaned = 150 records (2 not analyzable due to system issues) – final dataset = 148 records. Through the cleaning process, we lost more than one third of the records. This was due to the keyword section analysis.

while at a global scale, incorporated local and specific details for each conflict to maintain a global-local perspective through a zoom-in, zoom-out approach.

Phase	N° of conflicts
(1) Extraction phase – Mining phase	25
(2) Processing/Production phase – batteries production	12
(3) Consumption phase – Renewable energy installation and electric vehicles production	85
(4) Disposal phase – E-waste	26
Total	**148**

Table 1: Supply chain phases used for the analysis.

The categorization in phases allowed us to identify the number of conflicts at each stage and begin mapping the lithium struggle supply chain. EJAtlas entries provide a wealth of information, including a summary of the conflict, the location, the intensity, the type of conflict, the commodity involved, the impacts, and the outputs.[5] In some cases, they also report the number of people involved in the struggle, the actors involved and the size or scope of the exploited area.

The data collected by EJAtlas is qualitative, reflecting human perspectives and positionalities. However, because it standardizes and repeats similar categories across records, it also offers a quantitative dimension.

6. Struggles along the lithium supply chain: A metabolic analysis

An analysis of the multi-local features of the conflicts along the lithium supply chain highlights how socio-environmental issues affect different parts of the world over time, and how they are all interconnected through the same material flow. This section examines the interconnected conflicts and proposes a perspective on the metabolic processes arising along lithium supply chain struggles through five steps:

1. Conducting a multi-local analysis and producing a featured map
2. Proposing an overview of the impact produced by the lithium supply chain
3. Contributing to a metabolic analysis of supply chains
4. Redefining socio-metabolic variables for lithium supply chain
5. Analyzing struggles dynamics and institutional responses

[5] The EJAtlas records provide this and other information for each struggle.

Multi–local analysis: from lithium extraction to the energy industry supply chain. A feature map

To develop a multi-local analysis of the supply chain we constructed a map of the lithium supply chain along the four identified phases: extraction, production, consumption and disposal (Figure 1). From a geographical perspective, many of the conflicts reported by the EJAtlas are concentrated in the Americas, with high occurrences in Mexico. This means that Mexico has the highest number of conflicts recorded in the EJAtlas related to the lithium supply chain. This reflects strong local activism and civil society networks that contribute significantly to the database, but it must be interpreted with caution, as it does not necessarily mirror the actual number of lithium-related conflicts occurring in the country, nor Mexico's position in relation to lithium conflicts worldwide. In Mexico and the USA, struggles primarily revolve around the construction of mega-plants for renewable energy production, corresponding to Phase three—the consumption phase of the lithium supply chain. Meanwhile, in Argentina, communities face conflicts primarily in the extraction phase. In China, the diverse range of activities associated with lithium has resulted in a variety of conflict types, spanning all four phases of the supply chain, with particular prominence in the production phase.

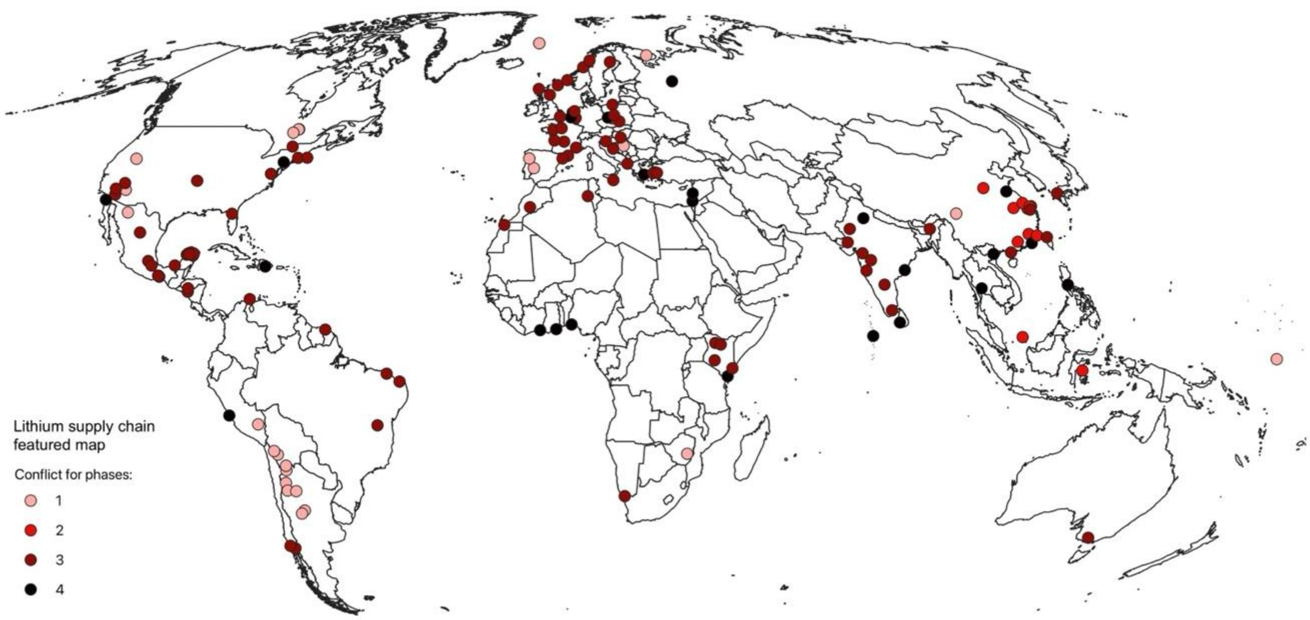

Figure 1: Feature map of the lithium supply chain phases elaborated by the authors.

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The map can help to visualize the data provided by the EJAtlas regarding the distribution of conflicts in the diverse phases of the lithium supply chain. Although acknowledging its limitations, this is the most comprehensive map that can be produced employing environmental conflicts as the unit of analysis. The map offers for a multiscale analysis of the lithium supply chain, allowing for a further multi-local study while not abandoning our global perspective.

Analyzing the broader context of the lithium supply chain, merging data on conflicts with per-capita income reveals that wealthy countries, such as the USA, Canada, and Northern European nations, and middle/low-income countries, such as India, China, Argentina, and Poland are heavily investing in the renewable energy market.[6]

The conflicts analyzed show an asymmetric distribution relative to traditional extractive patterns (Martinez-Alier & Walter, 2016), with the highest number of recorded struggles occurring in Phase 3 (the consumption phase). The limitations of our dataset must be foregrounded. As we have already emphasized, the uneven geographical distribution of cases—due to the availability of collaborators and differing socio-political contexts—is a structural limitation of the EJAtlas and must be taken into account in any analysis of conflict numbers. Nonetheless, making visible the remarkable presence of environmental conflicts along the supply chain beyond extraction and disposal provides an interconnected representation of supply chain metabolic processes. The diffusion of conflicts across Phase 3 (consumption) for example can be explained with the increasing number of locations affected by invasive projects, such as those related to the implementation of renewable energy mega-projects. While the extraction phase remains geographically confined, these mega-projects can be established almost anywhere (Figure 1). Furthermore, the over-representation of conflicts in areas of lithium use—in comparison with areas of lithium extraction, for instance—can also be explained by the geopolitics of academic research, with a concentration of researchers working in those areas and thereby recording entries for the EJAtlas. The high number of conflicts in the use phase may result from several factors, including the strong interest of researchers in studying conflicts related to renewable energy, the prevailing green transition narrative, and efforts to expose its colonial underpinnings. Additionally, these conflicts often arise from the numerous challenges associated with top-down mega-projects and decision-making processes, which are frequently linked to justice issues (Mulvey 2022; Dunlap & Tornel 2023). The sheer number of conflicts in this phase is evidence of the displacement mechanism, demonstrating how the rush to secure green technology supplies leads to pervasive and visible conflicts over land and infrastructure implementation across consuming and manufacturing contexts.

Impacts overview of the lithium supply chain

The observed impacts, from water pollution to land dispossession, are conceptualized here as outcomes of mechanisms of socio-metabolic exclusion (Pichler *et al*. 2022). These mechanisms systematically deny communities the capacity to choose how to use their land and vital resources, transforming the material flow of lithium once again into a driver in a context of injustice. This lens allows us to move beyond mere impact registration to analyze the structural deprivation resulting from the global supply chains. By observing the impact trends across different phases, we can identify differences and common patterns among the recorded struggles at each phase. Providing an analysis of the environmental impacts emerging from the EJAtlas records, water and land are recognized as heavily affected and polluted across all four phases of the supply chain (Adeel *et al*. 2023). Phase 4 (disposal) interacts with numerous sectors—disposal and industrial processes—showing heavier impacts on different commodities. Environmental impacts are severe across all phases, but the extraction and disposal phases stand out because of their significant consequences (Martinez-Alier 2002, Martinez-Alier & Walter 2016).

[6] The EJAtlas reports lithium supply chain conflicts in a total of 51 countries Albania, Argentina, Australia, Belgium, Bolivia, Brazil, Canada, Chile, China, Colombia, Croatia, Dominican Republic, France, Ghana, Greece, Honduras, Hungary, India, Indonesia, Italy, Ivory Coast, Japan, Kenya, Lebanon, the Maldives, Morocco, Mexico, Nauru, the Netherlands, Nigeria, Norway, Palestine, Peru, Philippines, Poland, Portugal, Russian Federation, Serbia, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Taiwan, Thailand, Tunisia, Turkey, UK, USA, Vietnam, and Zimbabwe.

Impacts related to air, soil, water, and groundwater contamination are most recorded in phases 1, 2 and 4. In contrast, in Phase 3, the recorded impacts are associated with biodiversity loss and deforestation, driven by increasing anthropization processes often linked to development projects.

What emerges is that nearly all impacts are visible in contexts of resource extraction. These locations, according to the EJAtlas data, are the most heavily affected from an environmental perspective. The most intense impacts fall into two main categories: deforestation, biodiversity loss, and landscape degradation; and severe environmental pollution affecting air, water, and soil.

From a human health perspective, Phases 2 (processing) and 4 (disposal) are the most detrimental. The data that emerges from health impacts analysis suggests a general path where accidents, work issues, mental problems, and occupational disease produce impacts for the second and third phase. Phases 1 and 3 do not seem to have specific and frequent health impacts, at least not according to the EJAtlas records.

One of the most pressing issues is exposure to unknown or uncertain risks, such as radiation, pollutants, hazards, or toxic and radioactive substances in the air, soil, or water. These risks are linked to the fallout of environmental pollution and are often poorly understood, with insufficient knowledge about their effects on human and ecosystem health in the short, medium, and long term, as they are difficult to assess and quantify.

The analysis of socio-economic impacts is complex due to the multiple interconnections and issues it reveals. Loss of landscape and cultural traditions, along with land dispossession and displacement, are highlighted in records from Phases 1 and 3, where land use changes emerge as a central concern. Work and labor-related issues, which are included among the socio-economic impacts, follow a similar trend, with a higher percentage affecting Phases 2 and 4.

From the analysis of socio-economic impacts, it becomes evident that human rights violations and the loss of livelihoods are two critical issues that impact all phases of the supply chain.

A contribution to the metabolic analysis of the lithium supply chain

We analyze metabolic processes along the lithium supply chain by combining the distribution of conflicts over the phases with the number of impacts reported in the EJAtlas, understanding the supply chain through the struggles produced by its underlying power dynamics. This analysis allows us to visualize how many impacts are recorded over each phase of the supply chain. In this context, the number of impacts refers to the cumulative sum of specific socio-environmental burdens—such as water contamination, health issues, or loss of livelihoods—reported within each individual conflict, which are divided by phase. Since every record considered has associated environmental, health, and socio-economic burdens, it is possible to count the total incidence of these specific effects recorded for each phase (Figure 2).

To contribute to the analysis of the metabolic processes along the lithium supply chain, we analyze the number of conflicts and the recorded impacts over the four phases. We developed a visual representation that allows us to understand the relation between the number of conflicts in each phase of the chain and the corresponding impacts observed in our analysis. Figure 2 is a heuristic visualization: the base of the triangle represents the number of conflicts in a phase (a measure of visibility and ubiquity), and the apex represents the total number of recorded impacts (a measure of the density of socio-metabolic fallout). The sharper the triangle, the higher the number of registered impacts for that phase. Conversely, the wider the triangle, the lower the proportion of recognized impacts relative to the number of conflicts.

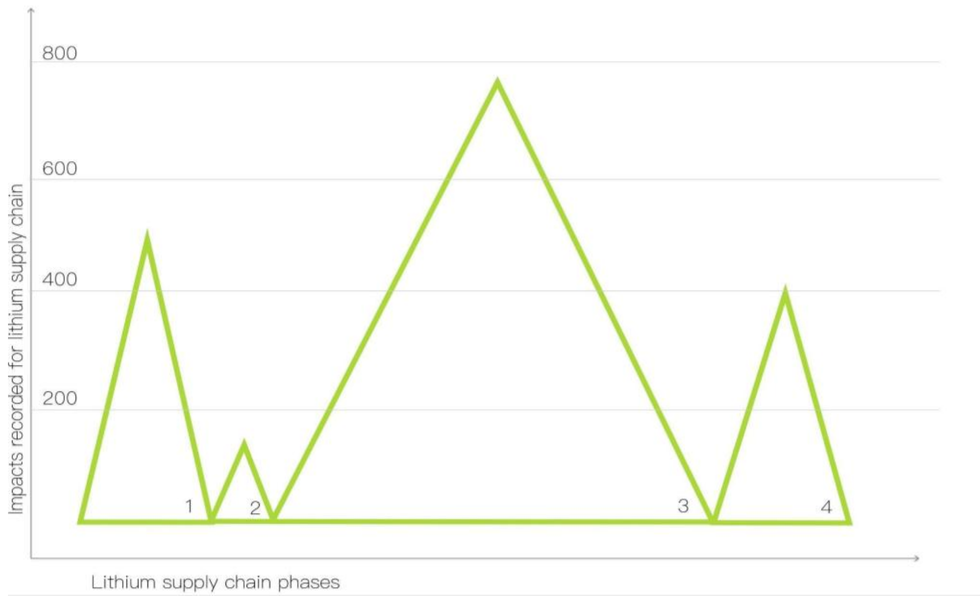

Figure 2: Relation between the distribution of conflicts and the impacts for the four phases (1 extraction, 2 production, 3 consumption, 4 disposal).

This visual representation can help to understand supply chain metabolism across different phases and how these activities linked to each phase are perceived, while emphasizing the significance of both the number of conflicts and their impacts in understanding social metabolism within supply chains. Confirming the insights of recent literature (Levanda *et al.* 2021), it emerges that Phase 3 (the consumption phase) occurs in various geographical contexts, as we saw on the map (Figure 1). There are a high number of struggles even globally. Figure 2 visually suggests that while the extraction and disposal phases (1 and 4) generate a high number of impacts (the sharp apex) relative to the number of recorded conflicts, the consumption phase (3) shows a high number of conflicts (wide base) but a lower number of impacts.

This supports findings in the literature emphasizing the heavier burdens associated with the extraction and disposal phases (Martínez-Alier & Walter 2016). It also aligns with broader scholarship on green extractivism and green colonialism (Dunlap *et al*. 2024; Dorn 2022), which shows how rich countries transfer the costs of their ecological transitions onto communities in the Global South. However, the remarkable number of conflicts arising in Phase 3 must be considered in relation to renewable energy projects (Levenda *et al*. 2021). We should reiterate that we consider the data collected in the EJAtlas as indicators of possible trends rather than quantitative values.

Redefinition of socio-metabolic variables of lithium supply chain by phase

Considering the most recurrent impacts in the lithium supply chain—defined as those appearing in at least 10% of the analyzed conflict records—and their trends across the different phases, we propose a reclassification of the impacts recorded in the EJAtlas (Table 2). Here, the trends refer to the shifting prevalence of specific impact categories as the commodity moves through the supply chain. This reclassification is designed to identify variables capable of capturing socio-metabolic mechanisms. Specifically, we group impacts based on how they undermine a community's capacity to access the essential socio-ecological conditions necessary for their health and well-being (e.g., contamination removes access to water, criminalization removes access to political participation). We develop this reclassification by analyzing the specific trends of each impact recorded within the EJAtlas across the four phases. This reclassification (Table 2) allows us to understand how different types of impacts characterize each stage of the supply chain.

Authors' reclassification	**Environmental, health and socio-economic impacts recorded by EJAtlas**
Contamination and pollution	Air pollution; soil contamination; surface water pollution and decreasing water quality; groundwater pollution
Landscape, biodiversity and cultural loss	Biodiversity loss; deforestation; desertification; disturbance to hydro-geo systems; landscape degradation; noise pollution; reduction of ecological or hydrological connectivity; displacement; land dispossession; loss of knowledge; loss of landscape
Psychosocial and occupational burdens	Waste overflow; accidents; mental problems including stress, depression and suicide; occupational disease and accidents; exposure to unknown or uncertain complex risks (radiation, etc…); mortality; lack of work security, unemployment
Rights and security loss	Food insecurity; militarization and police presence; violations of human rights; loss of livelihood; violence and crime; global warming; soil erosion; impacts on women; increase in corruption; alcoholism, prostitution, etc.

Table 2: Reclassification of lithium supply chain impacts.

We focus on the most recurring impacts and their trends across the different phases of the supply chain. Following this criteria, we exclude those impacts that are recorded in less than 10% of conflicts across the entire dataset, as well as those appearing in a highly asymmetric manner -meaning they are strictly localized in only one phase, such as the incidence of fires in Phase 4 (disposal) or mine tailing spills exclusive to Phase 1 (extraction).

The reclassification of impacts in Figure 3 allows some considerations on the socio-metabolic impact of the lithium supply chain. The data in this analysis are expressed as percentages to ensure that the specificities of each phase are clearly visible. Instead of using absolute numbers, we calculated the percentage of conflicts within each specific phase that reported a particular impact. This normalization is essential because the number of recorded conflicts varies greatly between phases (e.g., Phase 3, consumption, has many more records than Phase 2, production). Without this adjustment, the impacts of phases with fewer conflicts would be overshadowed and disappear from the analysis. This allows us to visualize each stage on equal terms. This figure represents the distribution of the reclassified categories (Table 2) based on the percentage of conflicts within each phase that reported those specific impacts. Phases 1, 2 and 4 are recognized as having the highest impact prevalence, measured as the percentage of struggles within each specific phase that reported at least one impact category; however, the impacts on landscape and biodiversity and cultural loss are found to be stronger in Phase 1 (extraction) and 3 (consumption). This resonates with the fact that mining projects and renewable energy projects are implemented primarily, almost 80%, in rural areas, where biodiversity, landscapes, and land-use traditions still are preserved. This suggests that while Phase 1 (extraction) is marked by acute contamination, the transition to the consumption phase (Phase 3) triggers a resurgence of territorial pressure through landscape degradation and biodiversity loss. This resonates with the analysis on green infrastructure implementation—often requiring extensive land use—replicates extractive dynamics by compromising territorial integrity.

The impact we define as human 'Psychosocial and Occupational Burdens' mainly affects the second and fourth phases. The significant peak of these burdens in the production phase (Phase 2) underscores the specific metabolic pressure on labor and industrial health. This is a distinctive form of socio-metabolic violence occurring in the processing stage where the systemic exposure to industrial hazards and psychological strain becomes a structural cost of the supply chain.

Impacts related to pollution and contamination processes are primarily observed in Phases 1, 2 and 4. The trend of contamination impacts follows a "U-shape," concentrated at the extremes of the chain (extraction and disposal), while mostly bypassing the consumption phase. The section we have defined as "rights and security loss" experiences the most diverse range of impacts. These impacts tend to have an almost transversal presence across the various phases, though some are more concentrated in the first and last phases.

This reclassification allows us to analyze the impacts (Figure 3) of the different phases of the supply chain, proposing variables useful for a socio-metabolic analysis based on the study of conflicts and recorded impacts. What emerges is a fragmented geography of exclusion: while territorial integrity is most threatened during the mining and infrastructure stages (Phase 1 and 3), the metabolic pressure shifts toward occupational risks and contamination at the processing and waste extremes (Phase 2 and 4) of the global production network.

The dynamics of struggle, and institutional responses

The records of the EJAtlas provide one section that addresses the outcomes of environmental struggles. It covers issues such as the criminalization of activists, displacement and migration, repression, corruption, and processes of negotiation and compensation. Additionally, it includes instances of successful mobilizations, such as project cancellations or temporary suspensions, environmental improvements, rehabilitation or restoration of affected areas, and the strengthening of participation and civic activism.

Analyzing the outcome of each record allows us to understand the power dynamics that characterize each phase. We propose to analyze outcomes through three lenses:

1. Resistance and transformation (reflecting transformative shifts or direct opposition)
2. Participation, negotiation, and corruption (reflecting attempts at institutionalization or capture of the struggle)
3. Legal and court-related decisions (reflecting reliance on formal legal mechanisms).

These typologies were developed following the same methodological approach used in the previous section—calculating the percentage of outcomes within each phase to ensure that every stage is analyzed on equal terms, regardless of the number of records.

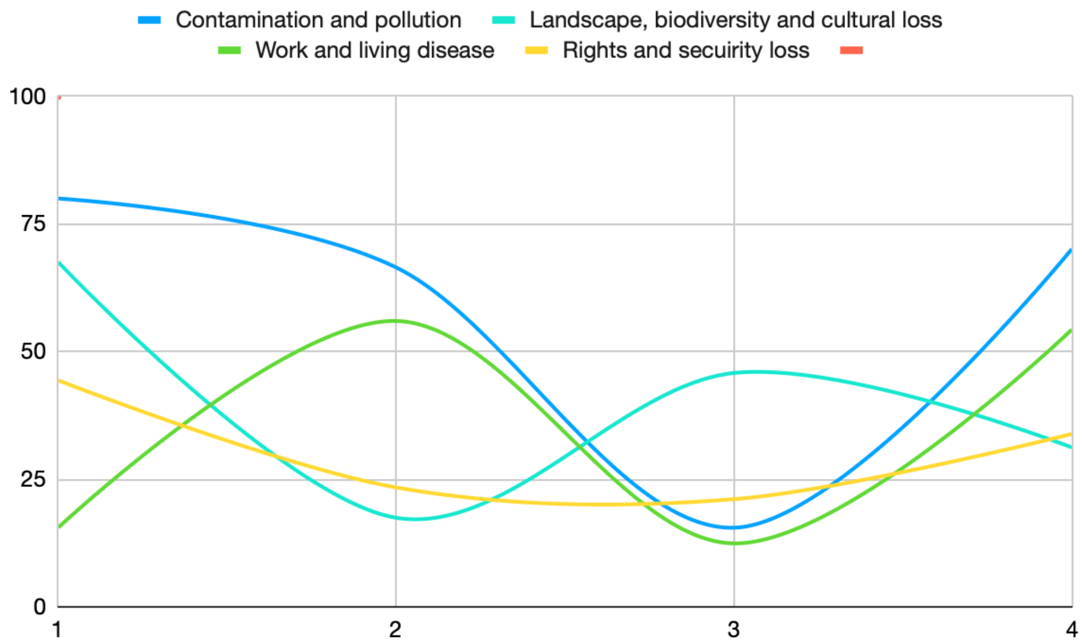

Figure 3: The percentage of impact categories among phases.

To complement the socio-metabolic analysis, we examine how outcomes are distributed by phase, as shown in Figure 4. This graph reflects the reclassification of outcomes developed in Table 3. Consistent with our previous analysis of impacts, the data are presented as percentages within each phase rather than as absolute numbers. This approach ensures that the specific outcome of every stage—even those with fewer recorded conflicts—remain clearly visible and can be compared on equal terms.

In Table 3 and Figure 4, we observe that outcomes related to Resistance and Transformation—which include both successes for the communities (e.g., project cancellation) and violent responses (e.g., repression, deaths)—tend to follow a similar trend. They peak during production (Phase 2) and extraction (Phase 1). This convergence suggests that the metabolic pressure in the early stages of the chain triggers the most acute forms of territorial defense, which in turn provoke a wide spectrum of responses from powerful actors—ranging from violent repression to the eventual withdrawal of investment. This indicates that these are not immediate reactions but rather emerge through long-lasting conflict processes.

Authors' Reclassification	Outcomes
Resistance and Transformation	Project cancelled; Environmental improvements, rehabilitation/restoration of area; Compensation; Project temporarily suspended; Withdrawal of company/investment; Deaths, Assassinations, Murders; Repression; Migration/displacement.
Participation, negotiation and corruption	Strengthening of participation; Under negotiation; Negotiated alternative solution; Corruption.
Legal and court decision outcome	Court decision (victory for environmental justice); Negotiated alternative solution; Application of existing regulations; Court decision (failure for environmental justice); Criminalization of activists.

Table 3: Recategorization of outcome function of trends and effects recorded by phase.

Figure 4: The percentage of outcome categories among phases.

A distinct group of outcomes—namely increased participation, negotiation, and corruption—follows a different trend. These appear early in the life cycle of conflicts and are processes of transformation still in progress. Notably, negotiation seems to operate as a pivotal moment: it can reinforce participatory mechanisms, but it can also create openings for corrupt practices or the co-optation of dissent. In the case of the lithium supply chain, outcomes related to negotiation are present across all phases, indicating that many recorded struggles are in an active or formative stage.

Legal and court-related outcomes, by contrast, are more prominent in the first and third phases. This suggests that while extraction (Phase 1 – extraction) triggers defensive litigation, the consumption and infrastructure implementation (Phase 3 – extraction) is increasingly being fought within institutional and legal arenas. This mirrors a shift in how green projects are contested in the Global North where environmental justice is frequently sought through the judicialization of ecological disputes.

The study of the selected records in the EJAtlas—that is, those on the lithium supply chain—allows us to better understand and visualize the fallout produced by the supply chain and the differences as the similarities along each phase, highlighting the injustices imposed on territories (see Figure 4). As shown in the map (Figure 1) and the analysis of distribution conflicts and impacts along the lithium supply chain, we propose a dual shift in social metabolism research. On one hand, we aim to complement analyses of social metabolism by shifting the focus from the object (lithium) to the subjects of struggle. This first shift is closely linked to the second: the use of qualitative data for quantitative description. Our decision to use the EJAtlas dataset reflects this shift, enabling the integration of a conflict-based approach into social metabolism analysis.

This approach allows us to examine metabolic processes from a multi-local and conflict-based perspective, avoiding an overly data-intensive process while highlighting affected communities and the interconnections among global struggles related to supply chains.

7. Discussion

This article analyzed the impacts of unjust configurations that develop along the lithium supply chain by combining a conflict-based approach with social metabolism literature. We aimed to interpret the dislocation of socio-metabolic burdens generated by the energy transition industry, which are structured by underlying flows of power and capital. To contribute to the understanding of unjust configurations that emerge along the lithium supply chain, we employed a multi-scalar and multi-local perspective.

Furthermore, we developed a conflict-based approach to understand supply chain metabolism. We utilized data from the EJAtlas, which supported us in contributing to the understanding of the metabolism of the supply chain through a conflict-based approach. Additionally, the EJAtlas's focus on community perspectives ensures that local voices are included, making the analysis more representative of real-world supply chain impacts. This empirical analysis, rooted in both qualitative and quantitative perspectives, can complement other approaches to social metabolism and contribute to analyzing commodity chains through a political ecology perspective.

The analysis was developed in four steps, encompassing a multi-local analysis of the supply chain, an analysis of the impacts along the four phases, a global assessment of the lithium supply chain's impacts, and a recategorization of impacts on lithium supply chain phases including power relations. Each of these components provides insights into the socio-metabolic dynamics that shape the supply chain. The multi-local analysis highlighted geographical dimensions through mapping the lithium supply chain and the energy transition. Mapping conflicts across supply chain phases visualizes the reach and complexity of the 'green transition' and its impacts. Our map applies distinct criteria based on the different phases of commodity flows.

The study revealed that conflicts are not confined to the extraction and disposal phases, as commonly expected, but also emerge significantly during production and consumption of lithium. The high number of conflicts recorded in the consumption phase (Phase 3) is evidence of dislocation mechanisms inherent to the energy transition industries, suggesting that socio-metabolic burdens are geographically dispersed during the implementation of green infrastructure.

The phase approach we propose enhances clarity, enabling the identification of key socio-environmental issues such as pollution, health risks, and socio-economic pressures at each stage. While Phase 3 (consumption) shows the highest number of struggles, our metabolic analysis (Figure 4) confirms that the extraction (Phase 1) and disposal (Phase 4) phases still bear the highest ratio between impacts and the number of conflicts, aligning with established political ecology literature (Martinez-Alier & Walter 2016). Our global analysis examines the socio-metabolic impact of the supply chain phases by linking the number of conflicts with the number of impacts recorded for each phase, allowing for a systemic view of the fallout from energy transition infrastructures.

Our analysis reclassified impacts based on how they affect different phases of the supply chain. These reclassified categories (Contamination, Landscape Loss, Psychosocial Burdens, Rights Loss) were designed to capture the structural mechanisms of exclusion that deny communities the capacity to derive benefits from their territories and resources. This reclassification organizes the observed impacts according to their relative distribution across the four phases, offering a clearer framework to understand how the burden of the energy transition is qualitatively different in each territory.

Finally, we proposed an analysis of conflict outcomes, which, consistent with the previous sections, was based on the percentage of outcomes relative to the total number of records in each phase. By focusing on this proportional distribution rather than absolute counts, the outcomes of every stage were represented on equal terms, regardless of the sample size of each phase. We analyzed the distribution of outcomes related to Resistance and Transformation, Negotiation, and Legal Decisions across each phase. The coexistence of contradictory outcomes (e.g., repression happening alongside project cancellation) within the same struggle suggests that the trajectories of environmental conflicts can change over time depending on the strategies, actors, and conditions at play. Power is dynamic.

8. Conclusion

We aim to contribute to a deeper understanding of socio-metabolic processes in global supply chains by proposing this analytical lens, which is linked to political ecology and grounded in a conflict-based approach. It has helped to illuminate the unjust configurations that emerge along supply chains because of power asymmetries and unevenly distributed impacts. We looked at the struggles unfolding along a lithium supply chain, which allowed us to rethink how different phases of the same network are affected in distinct ways by shared extractive and socio-environmental impacts.

The approach demonstrates that, although diverse, these impacts are inherently interconnected, as they are all tied to the same exchange of matter and energy that sustains the overall process. Even considering the inherent biases of the EJAtlas, as we have done in this article, it provides the opportunity to incorporate local experiences of exposure and struggles and into the analysis of supply chain metabolism. Our analysis contributes to socio-metabolic studies by framing ecological distribution conflicts not as consequences of socio-metabolic processes, but as a phenomenon central to understanding the multi-local effects of material flows and the metabolism of supply chains.

While our analysis focuses specifically on the lithium supply chain—as a key segment of the broader energy and technological transition—it is important to recognize that different supply chains possess unique characteristics. Nevertheless, they might share fundamental structural affinities that can be brought to light through this type of analytical framework. Our approach can support a radical critique of the green transition, suggesting that any *genuine* transition must necessarily involve a deep democratization of decision-making processes, respect for territorial rights, and the recognition of the subjectivities resisting these transformations worldwide.

Bibliography

Adeel, M., Zain, M., Shakoor, N., Ahmad, M. A., Azeem, I., Aziz, M. A., ... & Yukui, R. (2023). Global navigation of lithium in water bodies and emerging human health crisis. *NPJ Clean Water*, *6*(1), 33. https://doi.org/10.1038/s41545-023-00238-w

Ajl, M. (2023). Theories of political ecology: Monopoly capital against people and the planet. *Agrarian South: Journal of Political Economy*, *12*(1), 12-50. https://doi.org/10.1177/22779760221145232

Armiero, M. (2008). Seeing like a protester: Nature, power, and environmental struggles. *Left History: An Interdisciplinary Journal of Historical Inquiry and Debate*, *13*(1), 59-76. https://doi.org/10.25071/1913-9632.24610

Aydin, C. I., Ozkaynak, B., Rodríguez-Labajos, B., & Yenilmez, T. (2017). Network effects in environmental justice struggles: An investigation of conflicts between mining companies and civil society organizations from a network perspective. *PloS One*, *12*(7), e0180494. https://doi.org/10.1371/journal.pone.0180494

Ayres, R. U. (1989). Industrial metabolism. In J. Ausubel, & H. E. Sladovich (eds.), *Technology & environment*. National Academy Press.

Baccini, P., & Brunner, P. H. (1991). *Metabolism of the anthroposphere*. (2nd ed. 2012). Springer.

Bacon, C., deVuono-Powell, S., Frampton, M. L., LoPresti, T., & Pannu, C. (2013). Introduction to empowered partnerships: Community-based participatory action research for environmental justice. *Environmental Justice*, *6*(1), 1-8. https://doi.org/10.1089/env.2012.0019

Boulding, K. E. (1966). The economics of knowledge and the knowledge of economics. *The American Economic Review*, *56*(1/2), 1-13.

Braucher, C., & Armiero, M. (2023). The dark side of the white Alps: Guerrilla narratives in the marble landscape of Tuscany. *Resistance: A Journal of Radical Environmental Humanities*, *11*(1), 105-123. https://doi.org/10.1353/res.2023.a931668

Cabello, V., Willaarts, B. A., Aguilar, M., & del Moral Ituarte, L. (2015). River basins as social-ecological systems: Linking levels of societal and ecosystem water metabolism in a semiarid watershed. *Ecology and Society*, *20*(3), art. 20. http://dx.doi.org/10.5751/ES-07778-200320

Cederlöf, G. (2021). Out of steam: Energy, materiality, and political ecology. *Progress in Human Geography*, *45*(1), 70-87. https://doi.org/10.1177/0309132519884622.

Clark, B., & Foster, J. B. (2021). Marx's ecology and metabolic analysis. In L. Brownhill, S. Engel-Di Mauro, T. Giacomini, A. Isla, M. Löwy, & T. E. Turner (Eds.), *The Routledge handbook of ecosocialism.* (pp. 52–63). Routledge.

Del Bene, D., Scheidel, A., & Temper, L. (2018). More dams, more violence? A global analysis on resistances and repression around conflictive dams through co-produced knowledge. *Sustainability Science*, *13*(3), 617-633. https://doi.org/10.1007/s11625-018-0558-1

DeLoughrey, E., Didur, J., & Carrigan, A. (Eds.). (2015). *Global ecologies and the environmental humanities: Postcolonial approaches*. Routledge.

De Molina, M. G., & Toledo, V. M. (2014). *Social metabolism: A socio-ecological theory of historical change*. Springer.

Dickens, W. (1986). Wages, employment and the threat of collective action by workers. NBER Working Paper Series, No. 1856.

Dorn, F. M. (2022). Green colonialism in Latin America? Towards a new research agenda for the global energy transition. *European Review of Latin American and Caribbean Studies/Revista Europea de Estudios Latinoamericanos y Del Caribe*, *114*, 137-146. http://doi.org/10.32992/erlacs.10939

Dunlap, A., & Tornel, C. (2023). Pluralizing energy justice? Towards cultivating an unruly, autonomous and insurrectionary research agenda. *Energy Research & Social Science*, *103*, 103217. https://doi.org/10.1016/j.erss.2023.103217

Dunlap, A., Verweijen, J., & Tornel, C. (2024). The political ecologies of "green" extractivism(s): An introduction. *Journal of Political Ecology*, *31*(1), 436-463. https://doi.org/10.2458/jpe.6131

Fischer-Kowalski, M., & Haberl, H. (1997). Tons, joules, and money: Modes of production and their sustainability problems. *Society & Natural Resources*, *10*(1), 61-85. https://doi.org/10.1080/08941929709381009

Gerber, J. F., Veuthey, S., & Martínez-Alier, J. (2009). Linking political ecology with ecological economics in tree plantation conflicts in Cameroon and Ecuador. *Ecological Economics*, *68*(12), 2885-2889. https://doi.org/10.1016/j.ecolecon.2009.06.029

Giampietro, M. (2003). *Multi-scale integrated analysis of agroecosystems*. CRC Press.

Gonzalez-Martinez, A. C., & Schandl, H. (2008). The biophysical perspective of a middle-income economy: Material flows in Mexico. *Ecological Economics*, *68*(1-2), 317-327. https://doi.org/10.1016/j.ecolecon.2008.03.013

Hall, J. & Matos, S. (2010). Incorporating impoverished communities in sustainable supply chains. *International Journal of Physical Distribution & Logistics Management, 40*(1-2), 124-147. https://doi.org/10.1108/09600031011020368

Heynen, N. C. (2003). The scalar production of injustice within the urban forest. *Antipode*, *35*(5), 980-998. https://doi.org/10.1111/j.1467-8330.2003.00367.x

Levenda, A. M., Behrsin, I., & Disano, F. (2021). Renewable energy for whom? A global systematic review of the environmental justice implications of renewable energy technologies. *Energy Research & Social Science*, *71*, 101837. https://doi.org/10.1016/j.erss.2020.101837

Madrid-López, C., & Giampietro, M. (2015). The water metabolism of socio-ecological systems: Reflections and a conceptual framework. *Journal of Industrial Ecology*, *19*(5), 853-865 https://doi.org/10.1111/jiec.12340

Martinez-Alier, J. (2002). *The environmentalism of the poor: A study of ecological conflicts and valuation*. Edward Elgar.

Martinez-Alier, J. (2009). Socially sustainable economic de-growth. *Development and Change*, *40*(6), 1099-1119. https://doi.org/10.1111/j.1467-7660.2009.01618.x

Martinez-Alier, J. (2011). The EROI of agriculture and its use by the Via Campesina. *The Journal of Peasant Studies*, *38*(1), 145-160. https://doi.org/10.1080/03066150.2010.538582

Martinez-Alier, J. (2023). Environmental conflicts and the making of world movements for environmental justice. *Economia Politica*, *40*(3), 765-779. https://doi.org/10.1007/s40888-023-00306-x

Martínez-Alier, J., Healy, H., Temper, L., Walter, M., Rodriguez-Labajos, B., Gerber, J. F., & Conde, M. (2011). Between science and activism: Learning and teaching ecological economics with environmental justice organisations. *Local Environment*, *16*(1), 17-36. https://doi.org/10.1080/13549839.2010.544297

Martinez-Alier, J., Temper, L., & Demaria, F. (2016). Social metabolism and environmental conflicts in India. In Ghosh, N., Mukhopadhyay, P., Shah, A., & M. Panda, (Eds). *Nature, economy and society*. (pp. 19-49). Springer. https://doi.org/10.1007/978-81-322-2404-4_3

Martinez-Alier, J., & Walter, M. (2016). Social metabolism and conflicts over extractivism. In de Castro, F., Hogenboom, B., & Baud, M. (Eds.). *Environmental governance in Latin America*. (pp. 58-85). Palgrave. https://doi.org/10.1007/978-1-137-50572-9_3

Mastini, R., Kallis, G., & Hickel, J. (2021). A green new deal without growth? *Ecological Economics*, *179*, 106832. https://doi.org/10.1016/j.ecolecon.2020.106832

Matthews, E., Amann, C., Bringezu, S., Fischer-Kowalski, M., Hüttler, W., Kleijn, R., ... & Weisz, H. (2000). *The weight of nations: Material outflows from industrial economies*. World Resources Institute. http://pdf.wri.org/weight_of_nations.pdf

Mulvey, B. (2022). Participatory parity as a way forward for critical internationalisation studies. *Studies in Higher Education*, *47*(12), 2417-2429. https://doi.org/10.1080/03075079.2022.2072481

Navas, G., Mingorria, S., & Aguilar-González, B. (2018). Violence in environmental conflicts: The need for a multidimensional approach. *Sustainability Science*, *13*(3), 649-660. https://doi.org/10.1007/s11625-018-0551-8

Peluso, N. L., & Watts, M. J. (Eds.). (2001). *Violent environments*. Cornell University Press.

Pérez-Rincón, M., Vargas-Morales, J., & Martinez-Alier, J. (2019). Mapping and analyzing ecological distribution conflicts in Andean countries. *Ecological Economics*, *157*, 80-91. https://doi.org/10.1016/j.ecolecon.2018.11.004

Pichler, M. (2023). Political dimensions of social-ecological transformations: Polity, politics, policy. *Sustainability: Science, Practice and Policy*, *19*(1), 2222612. https://doi.org/10.1080/15487733.2023.2222612

Pichler, M., Schmid, M., & Gingrich, S. (2022). Mechanisms to exclude local people from forests: Shifting power relations in forest transitions. *Ambio*, *51*(4), 849-862. https://doi.org/10.1007/s13280-021-01613-y

Riofrancos, T. (2020). Extractivism and *extractivismo*. *Global South Studies: A collective publication with the Global South*, 11. Available at https://commodityfrontiers.com/wp-content/uploads/2022/07/riofrancos-thea_extractivism-and-extractivismo-1.pdf (accessed 7 January 2026).

Robbins, P. (2019). *Political ecology: A critical introduction*. Wiley.

Schaffartzik, A., Pichler, M., Pineault, E., Wiedenhofer, D., Gross, R., & Haberl, H. (2021). The transformation of provisioning systems from an integrated perspective of social metabolism and political economy: a conceptual framework. *Sustainability Science*, *16*(5), 1405-1421. https://doi.org/10.1007/s11625-021-00952-9

Scheidel, A., Del Bene, D., Liu, J, Navas, G., Mingorría, S., Demaria, F., Avila, S., Roy, B., Ertör, I., Temper, L. &, Martínez-Alier, J. (2020). Environmental conflicts and defenders: A global overview. *Global Environmental Change*, *63*, 102104. https://doi.org/10.1016/j.gloenvcha.2020.102104

Sieferle, R. P. (2011). Cultural evolution and social metabolism. *Geografiska Annaler: Series B, Human Geography*, *93*(4), 315-324. https://doi.org/10.1111/j.1468-0467.2011.00385.x

Singh Garha, N., Garcia Mira, R., & González-Laxe, F. (2022). Energy transition narratives in Spain: A case study of As Pontes. *Sustainability*, *14*(18), 11177. https://doi.org/10.3390/su141811177

Sneddon, C., Howarth, R. B., & Norgaard, R. B. (2006). Sustainable development in a post-Brundtland world. *Ecological Economics*, *57*(2), 253-268. https://doi.org/10.1016/j.ecolecon.2005.04.013

Tello, E., Garrabou, R., Cussó, X., & Olarieta, J. R. (2008). Una interpretación de los cambios de uso del suelo desde el punto de vista del metabolismo social agrario. La comarca catalana del Vallès, 1853-2004. *REVIBEC-Revista Iberoamericana de Economía Ecológica*, *7*, 97-115. https://raco.cat/index.php/Revibec/article/view/87201

Temper, L., Del Bene, D., & Martinez-Alier, J. (2015). Mapping the frontiers and front lines of global environmental justice: the EJAtlas. *Journal of Political Ecology*, *22*(1), 255-278. https://doi.org/10.2458/v22i1.21108

Temper, L., Demaria, F., Scheidel, A., Del Bene, D., & Martinez-Alier, J. (2018). The Global Environmental Justice Atlas (EJAtlas): Ecological distribution conflicts as forces for sustainability. *Sustainability Science*, *13*(3), 573-584. https://doi.org/10.1007/s11625-018-0563-4

Tilly, C. (1993). Contentious repertoires in Great Britain, 1758–1834. *Social Science History*, *17*(2), 253-280. https://doi.org/10.2307/1171282

Weisz, H. (2007). Combining social metabolism and input-output analyses to account for ecologically unequal trade. In Hornborg, A., J. R. McNeill, & J. Martínez-Alier, (Eds.). *Rethinking environmental history: World-system history and global environmental change* (pp. 289–306). AltaMira Press.

Wolman, A. (1965). The metabolism of cities. *Scientific American*, *213*(3), 178-193. https://doi.org/10.1038/scientificamerican0965-178

Xing, M. *et al*. (2017). The effect of local supply chain on regional economic impacts of mining. *The Extractive Industries and Society, 4*(3), 622-629. https://doi.org/10.1016/j.exis.2017.05.005