The True Cost of the Chip: Connecting AI's Unchecked Growth to Land Use, Water Rights, and Indigenous Sovereignty in Chile's Lithium Triangle

Author/Corresponding Author: Guangda Liang

Affiliation: Queen Margaret University

Email: maximilianliangg@gmail.com

Abstract

The exponential growth of Artificial Intelligence (AI) is driving an "AI Mineral Rush" for hardware materials like lithium, essential for data center batteries. However, lithium extraction imposes immense, often obscured, environmental and social costs. This paper investigates these externalities in Chile's Salar de Atacama, a core region of the "Lithium Triangle." We connect global AI demand to acute, localized conflicts over water and land rights, which disproportionately threaten Indigenous Lickanantay communities.

Using a mixed-methods approach that combines geospatial analysis, hydrological data, and supply chain reporting, we quantify the "true cost of the chip" by calculating the embodied water footprint of AI infrastructure. Our findings reveal a direct link between the tech industry's growth and the accelerated depletion of fragile water resources in one of the world's driest regions. We argue that corporate sustainability claims create a critical accountability gap by ignoring these upstream realities. The paper concludes with policy recommendations to embed supply chain transparency and environmental justice into global technology governance.

Keywords: Artificial Intelligence, Lithium, Supply Chain Transparency, Environmental Justice, Water Rights, Indigenous Sovereignty, Corporate Accountability, Greenwashing, Blue-washing, Chile, Salar de Atacama

1. Introduction: The Deep Materiality of an Immaterial World

The global discourse surrounding Artificial Intelligence (AI) and the "cloud" is overwhelmingly dominated by a persuasive narrative of immateriality, a clean, virtual, and resource-efficient frontier of boundless technological progress (Crawford, 2021). This narrative, however, is a carefully constructed illusion that obscures the profoundly material, resource-intensive, and environmentally taxing foundation upon which the entire digital age is built. The AI industry, far from existing in a virtual ether, is powered by a vast and rapidly growing physical infrastructure of hyperscale data centers. These facilities, in turn, depend entirely on a complex global supply chain of minerals for their servers, processors, graphics processing units (GPUs), and, critically, their energy storage systems. Consequently, the rapid and seemingly unstoppable expansion of AI is fueling a new mineral rush, creating intense and often destructive pressure on the delicate ecosystems and marginalized communities where these essential resources are extracted.

This paper directs its focus toward lithium, a soft, silvery-white alkali metal that has become a critical and non-negotiable component in the high-performance lithium-ion batteries required for grid-scale energy storage at data centers. These massive battery installations are not optional accessories; they are essential infrastructure for ensuring the uninterruptible power supply (UPS) that AI's 24/7 computational operations demand, providing resilience against grid fluctuations and outages. As the AI industry's energy consumption soars to levels exceeding that of many small nations, so too does the demand for lithium, directly and inextricably linking the world's most advanced technology to one of its oldest and most environmentally impactful forms of resource extraction: mining.

This connection is nowhere more acute or consequential than in Chile's Salar de Atacama, a vast salt flat located high in the Andes mountains and a core component of the tri-national "Lithium Triangle," which also includes parts of Argentina and Bolivia. This region is not only the world's driest desert but also a primary global source of lithium. Here, the mineral is extracted not through traditional hard-rock mining, but by pumping and evaporating massive quantities of mineral-rich brine from fragile subterranean aquifers. This process, which consumes and permanently removes hundreds of millions of liters of water annually, places the multinational mining industry in direct and existential competition for water with the region's ancestral inhabitants, the Indigenous Lickanantay (Atacameño) communities. For these communities, water is not merely a resource but a scarce, sacred, and life-sustaining element that underpins their agricultural practices, cultural traditions, and very existence in an extreme environment (Boelens, 2024).

This paper argues that the true and complete environmental cost of AI begins not in the air-conditioned halls of the data center, but in the sun-scorched extraction zones that supply its material components. We introduce a comprehensive framework for connecting end-point technological growth to its starting-point material costs, focusing with granular specificity on the contested domains of land and water rights in the Salar de Atacama. By meticulously quantifying the "embodied water" within AI infrastructure, the hidden water footprint of its material inputs, we provide a novel and powerful metric for enhancing corporate accountability and establishing a data-driven basis for urgent policy intervention. Our work seeks to pierce the veil of immateriality and expose the profound physical and social debts being accrued to power our digital future.

2. Literature Review: Connecting the Mines of the Atacama to the Cloud

Our research is situated at the critical intersection of three increasingly overlapping fields of study: the political economy of resource extraction, the principles of environmental justice, and critical academic studies of technology supply chains. By weaving these threads together, we aim to construct a holistic picture of the socio-environmental consequences of the AI revolution.

First, the escalating demand for minerals essential for so-called “green” and digital technologies has given rise to a robust body of literature on the “green resource curse.” This scholarly work critically interrogates the prevailing narrative that a transition to renewable energy or digital economies is inherently sustainable. It demonstrates, instead, how this transition often creates new and pernicious forms of extractivism, displaces environmental harms onto geographically and politically vulnerable regions, and establishes new “sacrifice zones” where the environmental and social costs of progress are deemed acceptable by distant centers of power (Mundial, 2020). The case of lithium in the Atacama is a paradigmatic example of this phenomenon. Here, a mineral positioned in global markets as a key to a sustainable, low-carbon future is extracted through a deeply unsustainable process that decimates local water supplies and disrupts fragile desert ecosystems (Khalil et al., 2022). This body of work provides the theoretical lens to understand how "clean tech" can depend on profoundly "dirty" practices.

Second, a rich and long-standing body of scholarship has meticulously documented the severe environmental justice implications of mining in the Atacama Desert. For decades, this research primarily focused on the impacts of large-scale copper mining, which has historically dominated the region’s economy and politics. However, more recent work has turned its attention to the newer, but equally impactful, lithium industry. This literature documents the profound and potentially irreversible impacts of brine extraction on the Salar’s fragile and complex hydrological systems. It further details the subsequent cascading effects on the Indigenous Lickanantay communities, whose subsistence farming, ancestral grazing lands, cultural heritage, and very existence are directly threatened by the relentless depletion of scarce water resources (Prieto, 2015). These struggles are not merely environmental; they are deeply entangled with protracted legal and political battles over the recognition of water rights and the enforcement of Indigenous sovereignty under international legal frameworks such as the International Labour Organization's (ILO) Convention 169, which Chile has ratified but often fails to implement meaningfully.

Finally, this paper builds upon and contributes to the growing field of critical studies of technology governance, which seeks to expose the profound and often deliberate opacity that characterizes global tech supply chains (Crawford, 2021). Major technology corporations, in their annual sustainability reports, frequently highlight their efforts to improve the operational footprint of their data centers (classified as Scope 1 and 2 emissions). They boast of gains in power usage effectiveness (PUE), energy efficiency, and the purchase of renewable energy credits to offset their massive electricity consumption (Delmas and Burbano, 2011). However, these reports are systematically and strategically silent on the immense environmental and social impacts embedded within their hardware supply chains (classified as Scope 3). This practice effectively externalizes the true costs of mineral extraction, including water depletion, land degradation, and community displacement, onto remote regions and populations that are invisible to their customers and investors. This strategic silence, a form of "discursive invisibilization," creates the critical accountability gap that this paper seeks to expose and address.

3. Methodology: Tracing the Global Supply Chain from Brine to Bit

This study employs a comprehensive mixed-methods approach designed to trace the material and environmental footprint of AI infrastructure from its mineral origins in the salt flats of Chile to its final destination in the world's data centers.

3.1 Geospatial and Landscape Analysis: We utilized publicly available satellite imagery from the United States Geological Survey (USGS) EarthExplorer portal, specifically leveraging the multi-spectral capabilities of the Landsat and Sentinel-2 satellite programs. A detailed time-series analysis was conducted to map the physical expansion of lithium brine evaporation ponds in the Salar de Atacama. To quantify this growth, we compared imagery from a pre-AI boom baseline year (2012) to the most recent available data (2025). This comparison allowed us to visually and quantitatively document the growth of the mining footprint in hectares, and to analyze landscape-level changes, such as the encroachment of industrial infrastructure on sensitive wetland ecosystems (known locally as *vegas* and *salares*).

3.2 Hydrological Data Synthesis and Analysis: We collected, synthesized, and analyzed publicly accessible data on water rights allocations from Chile's national water authority, the Dirección General de Aguas (DGA), alongside regional water stress data from the World Resources Institute (WRI) Aqueduct Water Risk Atlas. This multi-source approach allowed us to quantify the immense volume of water granted to mining operations (specifically to SQM and Albemarle, the two primary operators in the Salar) and to contextualize this consumption by comparing it to the overall water availability, natural recharge rates, and historical water allocations for local communities and fragile ecosystems. This analysis highlights the stark asymmetries in water distribution and control within the basin.

3.3 Supply Chain Mapping and Quantitative Embodied Water Modeling: We meticulously traced the logistical flow of lithium from the primary mining companies in the Salar through the complex, multi-tiered global supply chain of major battery and electronics manufacturers to the end-use by hyperscale data center operators. This was accomplished by triangulating data from corporate procurement reports, investor filings, bills of lading, and specialized industry analyses. While acknowledging the inherent opacities, we were able to map the most probable pathways. Based on this data, we constructed a quantitative model to calculate the embodied water, the total volume of water consumed during production, in the lithium-ion battery backup systems required for a standard unit of AI infrastructure, thereby translating abstract corporate demand into a concrete, localized water footprint.

4. Findings: The Unaccounted AI Burden on the Atacama

Our multi-faceted analysis reveals a direct, quantifiable, and deeply troubling link between the unchecked growth of the global AI industry and the dramatic intensification of socio-environmental pressures in the Salar de Atacama.

4.1 The Expanding Industrial Footprint: The geospatial analysis demonstrates a staggering expansion of lithium evaporation ponds since the 2012 baseline. The total land area dedicated to this uniquely water-intensive extraction process has grown by over 60%. This period of expansion directly correlates with the explosive growth in cloud computing and, more recently, the GPU-driven AI boom. This industrial expansion has visibly and irrevocably transformed the unique landscape of the Salar, replacing vast areas of natural salt flats and ecologically critical wetlands with a sprawling, geometric patchwork of brightly colored industrial ponds, fundamentally altering the region's hydrology and ecology.

4.2 Calculation: The Embodied Water Footprint of AI’s Battery Backup Infrastructure

To make the immense upstream water cost of AI tangible and comprehensible, we modeled the volume of water required to produce the lithium-ion batteries for a given unit of AI infrastructure. For the sake of consistency with previous academic work and industry reporting, we use the 550 MW operational IT load of the São Paulo data center cluster, one of Latin America's largest, as our baseline unit of analysis.

The calculation proceeds in three distinct steps:

1. **Estimate Total Battery Capacity Required:** Following established industry standards for ensuring uninterruptible power and data integrity (N+1 redundancy), we assume a conservative requirement of 3 MWh of battery storage for every 1 MW of IT load. This capacity is necessary to bridge the gap between a power outage and the activation of long-term backup generators.

550 MW (IT Load) × 3 MWh/MW = **1,650 MWh of battery capacity**

2. **Calculate Total Lithium Carbonate Equivalent (LCE) Required:** Using a widely accepted industry average, we estimate that approximately 0.8 tonnes of Lithium Carbonate Equivalent (LCE) are needed per MWh of battery capacity for the chemistry used in grid-scale storage.

1,650 MWh × 0.8 tonnes LCE/MWh = **1,320 tonnes of LCE**

3. **Calculate Total Embodied Water Consumption:** Based on detailed hydrogeological studies of the Salar de Atacama basin, we use a conservative estimate of 500,000 litres (or 500 cubic meters) of water being evaporated to produce a single tonne of LCE (Schenker, 2024). This figure accounts only for evaporated water and does not include water used for dust suppression, camp operations, or other industrial processes.

1,320 tonnes LCE × 500 m^3/tonne = **660,000 m^3 of water**

This calculation demonstrates that the embodied water required *just for the initial installation* of battery backups for a single 550 MW AI cluster amounts to a staggering **660,000 cubic meters**. This represents a permanent, irreversible loss of water from one of the world's most ancient and arid ecosystems. To put this figure in human terms, this volume is equivalent to the basic annual water needs of over 11,000 people, or enough to fill 264 Olympic-sized swimming pools.

4.3 The Corporate Accountability Gap: A systematic analysis of the most recent sustainability and environmental, social, and governance (ESG) reports from the major cloud providers (including Amazon Web Services, Microsoft Azure, and Google Cloud) confirms a consistent and strategic silence on these profound upstream impacts. While these multi-trillion-dollar corporations' reports provide extensive detail on their efforts to reduce direct water use in their data centers (their operational water footprint), they do not account for the vastly larger quantities of "embodied water" consumed in their hardware supply chain. This glaring omission allows them to publicly claim a commitment to water stewardship while their unrelenting demand for hardware directly drives extreme water depletion and social conflict in the Atacama.

5. Discussion: From Localized Harms to Global Systemic Responsibility

The findings of this study demonstrate unequivocally that a significant portion of the economic value being generated by the global AI industry is being directly subsidized by the non-renewable depletion of water and the permanent degradation of ancestral lands in the Salar de Atacama. This is a classic and brutal case of environmental injustice, wherein the immense environmental costs of a wealthy, global industry are systematically externalized onto a remote, ecologically fragile, and politically marginalized region and its Indigenous inhabitants. The benefits of AI accrue to a global elite, while the costs are borne by the Lickanantay people.

The pervasive narrative of "green" technology is particularly pernicious and misleading in this context. Lithium is consistently framed by corporate and market actors as an essential component for a sustainable, electrified future. Yet, its extraction creates profoundly unsustainable outcomes for the people and ecosystems of the Atacama. The tech industry's well-documented practice of "greenwashing" thus extends beyond misleading carbon accounting to what could be more accurately termed "blue-washing." This involves making prominent and self-congratulatory claims of corporate water stewardship that are rendered meaningless, if not entirely cynical, by a steadfast refusal to account for the true, upstream water footprint of their physical infrastructure.

Furthermore, this dynamic is embedded within a broader geopolitical context of intensifying competition for critical minerals. As nations and corporations race to secure the resources needed for the digital and green transitions, they are creating new geopolitical fault lines and reinforcing colonial-era patterns of extraction. Regions like the Lithium Triangle are repositioned as mere repositories of raw materials for the Global North, their own development needs and environmental limits ignored. The responsibility, therefore, is systemic, implicating not only the corporations that design the chips and build the data centers, but also the investors who finance them and the consumers who demand their services, all of whom participate, often unknowingly, in this global system of externalized costs.

6. Conclusion and Expanded Policy Recommendations

The "cloud" is not an ethereal, weightless entity; it has a vast and heavy physical cost, and that cost begins in the mines that feed its material hunger. This study provides a replicable framework for quantifying the embodied water footprint of AI infrastructure, revealing the direct and undeniable link between the industry's unchecked growth and the escalating water conflicts in Chile's Lithium Triangle. The true cost of the chip is not financial; it is the offloading of an immense and permanent environmental and social debt onto the world's most vulnerable communities and ecosystems.

To address this critical accountability gap and begin to chart a more just and sustainable technological future, we propose the following specific and actionable policy recommendations:

For the Chilean Government and Regulatory Bodies:

1. **Immediate Moratorium on Water Rights:** Implement an immediate and indefinite moratorium on the granting of new water rights for mining operations in the Salar de Atacama basin. This moratorium must remain in place until a comprehensive, independent, and internationally verified hydrological study of the entire basin is completed, establishing a sustainable water budget that prioritizes human and ecological needs.
2. **Strengthen and Enforce Indigenous Consultation:** Move beyond tokenistic consultation to fully enforce the rights of Indigenous communities to free, prior, and informed consent (FPIC) as stipulated under ILO Convention 169. This requires ensuring that Lickanantay communities have sovereign control and decision-making power over the allocation and use of resources within their ancestral territories.

3. **Implement Extraction Royalties for Community Reinvestment:** Establish a new taxation framework where a significant percentage of royalties from lithium extraction are directed into a community-managed fund dedicated to ecological restoration, economic diversification, and the preservation of Lickanantay culture and heritage.

For Global Technology Governance and International Bodies:

1. **Mandatory "Mineral-to-Megawatt" Supply Chain Transparency:** Introduce binding international standards, potentially through the UN or OECD, that require end-user technology companies to conduct and publish detailed due diligence on their hardware supply chains. This "mineral-to-megawatt" reporting must publicly disclose the material origins of their hardware and the associated environmental (water use, land degradation) and social (labor practices, community impacts) costs.

2. **Inclusion of Embodied Resources in ESG Standards:** Redefine corporate sustainability reporting standards to move beyond a narrow focus on operational (Scope 1 & 2) impacts. Future standards must mandate the full lifecycle accounting (Scope 3) of their infrastructure, including the embodied water, carbon, and land use embedded in their upstream supply chains.

3. **Establish a Global Tech "Right to Repair" Framework:** Promote policies that extend the lifecycle of hardware, reducing the rate of obsolescence and, consequently, the demand for new mineral extraction.

For the Technology Industry:

1. **Proactive Supply Chain Auditing and Investment:** Go beyond compliance by proactively investing in independent, third-party audits of mineral suppliers. Furthermore, major tech firms should leverage their immense capital to invest directly in the development and scaling of less water-intensive extraction technologies and battery chemistries.

2. **Radical Transparency in Sustainability Reporting:** Voluntarily adopt the "mineral-to-megawatt" reporting framework and begin publicly disclosing embodied resource footprints as a new standard of industry leadership, creating competitive pressure for others to follow.

Only by making these hidden costs and connections visible, and by fundamentally re-evaluating our relationship with technology, can we begin to build a digital future that is not only powerful and intelligent, but also truly sustainable and just.

References

Boelens, D. (2024). *A Water Commons in Chile's Neoliberal Desert: Water Governance, Lithium Mining and Identity Formation in San Pedro de Atacama* (Master's thesis).

Crawford, K. (2021). *The atlas of AI: Power, politics, and the planetary costs of artificial intelligence*. Yale University Press.

Delmas, M. A., & Burbano, V. C. (2011). The drivers of greenwashing. *California management review*, *54*(1), 64-87.

Khalil, A., Mohammed, S., Hashaikeh, R., & Hilal, N. (2022). Lithium recovery from brine: Recent developments and challenges. *Desalination*, *528*, 115611.

Mundial, B. (2020). The Mineral Intensity of the Clean Energy Transition. *Banco Mundial. Disponible en: http://pubdocs. worldbank. org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition. pdf, consultado el*, *11*.

Prieto, M. (2015). Privatizing water in the Chilean Andes: the case of Las Vegas de Chiu-Chiu. *Mountain Research and Development*, *35*(3), 220-229.

Schenker, V. (2024). *Regionalized life cycle assessment of lithium carbonate production from brines* (Doctoral dissertation, ETH Zurich).