



extractive Alpine landscapes

**systemic territorial perspectives
and socio-ecological transition paradoxes**

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and socio-ecological transition paradoxes

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introduction

0.designing through contradiction: territories of extraction and transition

The intensification of ecological, economic, and geopolitical crises has made the question of resource use a central challenge of contemporary spatial practice. Within the European context, the ecological and digital transitions, often presented as irreversible and technologically driven processes, reveal instead a condition of structural instability and intrinsic paradox. This condition stems from the fact that the transition itself relies on an unprecedented demand for raw materials and energy, requiring the extraction of more resources to enable processes intended to reduce dependence on them.

These transitions must be understood not as linear trajectories but as temporary, reversible phases marked by uncertainty and conflicting temporalities. In this framework, the reconfiguration of production chains and territorial infrastructures is producing a profound transformation, exposing the contradictions between ecological ambitions and extractive realities. In this shifting scenario, the Alpine region emerges as a critical laboratory. Long considered a marginal and peripheral space, it now returns to the center of political and economic attention as Europe seeks to secure autonomy over critical raw materials and renewable resources. Transition appears as a condition of suspension, where multiple temporal and spatial regimes coexist: the remains of past industrial cycles, the infrastructures of the present, and the speculative projections of possible futures.

The research's theoretical framework builds on critical studies of extractivism and its development within modern capitalism. Rather than merely an economic model, extractivism is understood as a spatial and epistemic system—a way of organizing and governing territory through processes of abstraction, appropriation, and instrumentalization. From this perspective, mining becomes only one expression of a larger imperial system encompassing logistics, finance, and infrastructure: a planetary network that transforms environmental resources into economic value, covering entire regions of circulation and control. Europe's current attempt to internalize raw-material production, through policies such as the Critical Raw Materials Act, does not signify the overcoming of extractivism but its reconfiguration into new geopolitical forms. The supply chain becomes the contemporary frontier of extraction: a distributed and largely invisible geography that merges production, finance, and regulation into a continuous territorial machine. At the same time, a decolonial perspective is crucial to reveal the persistence of asymmetries

within these processes. Decolonial thought, therefore, offers not only a critique of historical relations but also a lens for exposing how modern territorial governance continues to rely on hierarchies of visibility and value. By linking these perspectives, the research proposes interpreting extractivism as a condition of territorial modernity—an enduring logic that structures both the material and the representational production of space. The extractive paradigm, in this sense, extends beyond the exploitation of resources. Understanding it as a spatial rationality allows for a critical examination of how design disciplines participate in or resist these processes. It also opens the possibility of reimagining the transition not as a definitive shift beyond extraction, but as an opportunity to rethink our relationship with matter, ecology, and territorial governance.

Paradox becomes a conceptual and interpretative lens for engaging with the complexity of contemporary territorial transformations. The multiple crises of our time expose a territory governed not by stable categories but by tensions, overlaps, and reversals. Rather than seeking resolution, it accepts simultaneity: extraction and regeneration, dependence and autonomy, conservation and transformation coexist within the same territorial field. Thinking through paradox means acknowledging that the dynamics shaping the territory are neither linear nor mutually exclusive. The infrastructures of sustainability often reproduce extractive patterns. Digital dematerialization generates new material dependencies. Protection policies may coincide with new forms of control. These contradictions are not anomalies but indicators of structural change. This operates as a method of reading and designing within conditions of uncertainty, revealing how conflict and coexistence can generate knowledge and form. This epistemological stance resists binary thinking, the separation between nature and culture, production and preservation, global and local, and instead embraces their entanglement. It recognizes that territorial processes unfold through differentiation and interdependence, where stability is temporary and transformation continuous. In this sense, paradox is not simply descriptive but generative: it opens space for alternative readings and for a design imagination capable of inhabiting ambiguity.

To engage with this unstable condition, design is approached as a critical and anticipatory practice. It does not aim to resolve contradictions but to operate within them, transforming tension into a productive field

of inquiry. It describes a search for alternative spatial logics capable of integrating material limits and collective agency. The transition is not a stable destination but a contingent and reversible process. It unfolds through cycles of experimentation and negotiation, producing new configurations of space that are always provisional.

Much of what is perceived as natural within the Alps can instead be considered human-made, shaped by centuries of technical intervention and material reconfiguration. Building on this premise, they emerge as a constructed field where natural formations and technological processes are inseparable. The mountain landscape becomes an archive of material operations, extraction, industrialization, and energy production that have redefined its morphology over time. These transformations reveal how the processes of modernization and territorial control are inscribed in the very structure of the Alps, turning them into a critical lens through which to understand the spatial and political consequences of Europe's long dependence on resource exploitation, and the enduring need to transform inherited structures without erasing their complexity—to construct futures conscious of their own impermanence. By reading these contradictions as evidence of systemic change, design becomes both a diagnostic and a transformative instrument. It reveals how ecological ambition can coexist with extractive persistence, and how new forms of spatial organization may emerge from this tension. The approach operates through a movement between interpretation and projection, constructing an analytical framework that interprets the Alps and other marginal territories as complex fields of interaction.

The prospect of returning to mining exposes the contradictions between the urgency of transition and the inertia of existing systems. Radical alternatives based on degrowth remain indispensable but demand long temporal horizons—political, economic, and cultural transformations that cannot materialize within immediate cycles of change. Within this transitional phase, the challenge lies in acting according to the logic of sufficiency, integrating the recognition of material agency and the multispecies dimension of territorial processes. Rather than seeking to mitigate or green unsustainable models, this perspective calls for the formulation of concrete utopias, conceived as operational frameworks that introduce a radical shift in the design process, opening the way to new modes of territorial transformation and governance. Understood as territorial liability, this principle redefines the relationship between

production and care, opening the way for new paradigms of intervention that move beyond remediation or adaptation, and instead conceive transformation itself as a form of collective stewardship.

Recycling, in this research, is conceived not as a metaphor for reuse but as a territorial strategy that operates within the specific material, infrastructural, and institutional systems shaped by extraction. It entails working within existing frameworks of exploitation, reactivating rather than erasing them, to test the limits and potential of transformation under conditions of scarcity and transition. It concerns infrastructures whose persistence defines both constraint and opportunity. Instead of viewing them as remnants of a concluded cycle, they are reconsidered as active spatial devices capable of supporting new forms of production, experimentation, and monitoring. It also involves reconfiguring productive ecologies by identifying intersections among technological systems, environmental processes, and economic practices that can generate new territorial rationalities. Through these synergies, the distinction between resource and residue becomes unstable. In this sense, recycling becomes an analytical and projective tool: it exposes how the same infrastructures that once sustained extractive economies can evolve into agents of transition, mediating between inherited structures and emerging forms of territorial organization. Extending this logic, re-establishing material and functional connections between highlands and lowlands becomes essential, particularly where the effects of extraction have been historically most uneven. The valleys, often sites of concentration for infrastructures, logistics, and industrial facilities, now contain extensive stocks of underused productive spaces. These residual systems represent a latent resource: they hold the physical capacity, accessibility, and spatial continuity necessary to support new cycles of experimentation. Through this lens, the valley floor becomes a strategic interface. In this zone, reorganizing existing stocks can generate new territorial synergies by redistributing energy flows, thereby aligning ecological transitions with renewed regional economies. Paradoxically, the emergence of new cycles could offer an opportunity to address the toxic legacies of previous ones, those currently suspended in a state of neglect precisely because they lie outside contemporary economic dynamism. Residues of past production persist as silent witnesses to extraction-driven modernity. Their remoteness, once a reason for marginalization, now allows them to become experimental grounds for remediation and transforma-

tion. By confronting rather than concealing these inherited conditions, recycling can turn obsolescence into agency, transforming forgotten territories into active laboratories for testing new forms of coexistence between ecological recovery and productive reconfiguration.

Regionalization extends this reasoning to the scale of interdependence between territories, addressing how processes of transition can be anchored locally rather than displaced elsewhere. It calls for compensation mechanisms that reinvest value within the same regions affected by extraction, transforming environmental and social costs into resources for ecological repair and collective benefit. Such an approach resists the logic of mono-functional territories, promoting coexistence with the slower, more resilient economies already present in the Alpine context. Instead of replacing these systems, regionalization seeks to align them with broader ecological objectives, fostering a balanced redistribution of functions and values across the mountain landscape.

Ultimately, this thesis positions the territorial project as a form of knowledge, a way of thinking through space that is speculative yet grounded, critical yet operative. By navigating the contradictions, it seeks to define a mode of territorial reasoning that accepts uncertainty as its starting point. What emerges is not a definitive model but an open framework: a way of seeing and designing through its paradoxes, where the possibility of transformation resides precisely in the awareness of its limits.

The thesis unfolds in three interrelated sections, each addressing a different scale and temporality of the extractive condition. The first investigates the renewed centrality of raw materials in the European transition, focusing on the spatial implications of recent policies aimed at reopening concessions for cobalt extraction in the Western Alps. The second reconstructs the palimpsest of Alpine transformation through three valleys in Piedmont, examining the relationship between technological innovation and spatial transformation, and tracing how productive cycles and territorial governance have co-evolved over time. This reading interprets the Alps not as a static natural domain but as an engineered, continuously negotiated landscape where infrastructures, industries, and environmental systems intersect. By examining the material and spatial imprints left by successive extraction regimes, mining, hydroelectric production, and manufacturing, it reveals how each phase has redefined both the ecological balance and the political imagination of the mountains. The analysis does not isolate individual sites but considers them as interconnected territories within a more expansive trans-scalar geography, in which local experimentation reflects broader European dynamics of resource use and transformation. The third develops a design framework grounded in territorial configurations conceived as possible conditions for testing critical hypotheses about the future of Alpine territories, presupposing forms of extended, multilevel governance articulated through intermediate plans, agreements, and pacts. These territories, locally marked by extractive concessions yet embedded within global supply dynamics, offer a multi-scalar field in which to question the implications of transition and to envision reversible forms of transformation.

l.



extraction cycles

**global flows and territorial paradoxes
in Europe's resource transition**

1. far from home extractivism and neoextractivism, beyond a decolonial perspective

The metaphor '*far from home*' underscores the unequal geography of resource extraction. Extractive activities often occur far from decision-making and industrial centers in peripheral regions of the world, characterized by a history of colonialism and economic dependency¹ structures. Outsourcing extractive processes not only shifts the environmental and social burden of production but also reinforces global hierarchies between the Global North and the Global South². These hierarchies, inherited from colonization, are reproduced through extractive practices that impoverish local communities, destroy ecosystems, and fuel territorial conflicts (Acosta and Martínez-Alier 2014). Indigenous and rural populations, in particular, are often the most affected by extractivism. They see their territories invaded by multinational companies that exploit resources without proper consultation and a fair redistribution of benefits. This highlights how, in this process, extraction sites become sacrifice zones, often invisible and distant from the final consumers of the goods produced from the extracted resources. This distance facilitates ethical indifference towards the devastating consequences of extractivism (Svampa 2019).

Decolonial perspectives on extractivism Adopting a decolonial perspective in the context of extractivism and neo-extractivism means questioning the historical and geopolitical structures that have sustained and legitimized these practices. Decolonialism, in this sense, is not just an invitation to overcome formal colonialism but a critique of how the global capitalist system continues to perpetuate the logic of appropriation and domination towards indigenous populations and their territories (Quijano 2000). This logic is both territorial and epistemic, entailing the devaluation of indigenous knowledge systems, land-based practices, and relational ontologies that diverge from extractivist rationalities. In this sense, the critique of extractivism cannot be separated from a broader epistemological challenge to Western universalism and its claims to neutrality, objectivity, and progress (Escobar 2006). A decolonial perspective requires recognizing that local populations have an intrinsic relationship with the land and natural resources,

¹ The phenomenon of extractivism and neo-extractivism has developed in parallel with economic globalization, mainly through outsourcing productive processes and expanding extractive industries into regions geographically and culturally distant from global economic and political power centers

² This dynamic highlights the disconnection between the beneficiaries of extractive profits and the populations that bear these activities' environmental, social, and cultural impacts.

grounded in worldviews often incompatible with capitalist extraction. This relationship is economic, cultural, spiritual, and political. It emerges through embodied, place-based knowledge, usually transmitted through oral histories, rituals, and communal governance practices. These systems reflect a deep ecological consciousness that contrasts with the instrumental logic of resource commodification³. By foregrounding interdependence and reciprocity, they propose modes of coexistence that resist the abstraction and detachment embedded in global supply chains and planning systems. It highlights how indigenous knowledge and resource management practices can offer sustainable and just alternatives to dominant extractive models (Coulthard 2014). Moreover, it suggests that environmental justice cannot be separated from social and epistemic justice. Recognizing Indigenous forms of life and knowledge as legitimate alternatives to dominant narratives of economic development is crucial in imagining a future beyond extractivism. Such recognition requires representational inclusion and structural transformation: shifting decision-making power, land rights, and resource governance towards community-led processes. Decolonial approaches align with calls for a pluriversal future, in which multiple worldviews can coexist without subsuming under a single development model (Mignolo and Walsh 2018).

Diagrams of power. Visualizing extractive geographies and invisible structures A significant contribution to this decolonial critique and understanding the power mechanisms underpinning global extractivism can be found in the work of artist Mark Lombardi. His detailed diagrams trace networks of power and connections between governments, banks, multinational corporations, and individuals involved in complex economic and political processes, often invisible to the general public. Through his works, Lombardi reveals how global invisible threads connect financial structures, corporations, and political elites, controlling not only markets but also natural resources, often located in regions far from centers of power (Lombardi 2003). This spatial disloca-

³ This form of ecological consciousness goes beyond conservationist or managerial approaches to nature. It is rooted in cosmologies that emphasize reciprocity, interdependence, and the agency of non-human entities. Such worldviews, often articulated through indigenous and land-based epistemologies, do not conceive of nature as a passive resource to be extracted, but as a living network of relations to be respected and maintained. This stands in contrast with extractivist paradigms grounded in anthropocentrism, where nature is reduced to a set of utilitarian inputs for economic growth (Shiva 1989, Kopenawa and Albert 2010).

tion recalls operational landscapes (Brenner and Katsikis, 2013), where resource territories are functionally essential yet politically peripheral, structured to remain invisible within dominant spatial narratives and economic flows.

Lombardi's work visually represents the physical and moral distance described by the *far from home* metaphor. His networks are not merely maps of economic connections but rather pathways of power relations that show how decisions made in distant places can devastate local communities in extractive areas⁴. These networks illustrate the interconnection between financial centers and extraction sites, underscoring the need for a decolonial perspective that exposes the ongoing colonial logic (Gudynas 2013a). It helps us see how global economic and political power is intrinsically linked to resource exploitation⁵. In this way, the work intersects with broader decolonial calls to reimagine sovereignty, not only as political autonomy but also as control over the flows of information, capital, and matter that shape territorial futures.

Just as the decolonial perspective invites us to challenge dominant narratives and recognize local and indigenous alternatives, Lombardi's work pushes us to visualize the invisible and trace the lines of connection that underpin the global extractive system.

The matter of extraction. Rendering the invisible Following upon the decolonial critique of extractivism, exploring how practices can render visible the spatial, legal, and epistemic architectures that sustain global resource exploitation becomes crucial. While Mark Lombardi's diagrams expose the entangled networks of power, capital, and decision-making that often remain invisible, other trajectories extend this critique by engaging directly with the materiality of extraction and its entanglement with forms of territorial governance. Among these, the work of Lara Almarcegui offers a particularly significant contribution by foregrounding the relationship between extraction, urban transformation, and legal apparatuses. Her projects do not represent extraction from afar, but rather intervene within their physical and symbolic mech-

⁴ These diagrams thus function as epistemic devices that challenge the fragmentation of knowledge typical of extractivist regimes, offering instead a systemic reading that links seemingly disconnected scales and actors.

⁵ His diagrams suggest that extractivism cannot be understood only at the local level but must be analyzed as part of a global network that connects multinational corporations, governments, and financial institutions in a system of capitalist accumulation. In this sense, Lombardi's art becomes a powerful critique of the structures of domination and reproducing inequalities between the Global North and South.

anisms.

Since the mid-1990s, she has worked on sites of urban marginality, addressing vacant lots, ruins, and materials in transit as unstable thresholds through which political, social, and economic transformations become legible. Her guides to urban wastelands, compiled during periods of intense regeneration across European cities, challenge the dominant logics of redevelopment and accumulation, seeking instead to register the presence of what has not yet been captured by formal planning systems. In recent years, her research has shifted increasingly toward the subterranean, where extraction and speculation intersect. In projects such as *Mineral Rights*, Almarcegui acquired ownership over specific mineral deposits, not to exploit them, but to prevent their future extraction. This gesture, at once legal and symbolic, reveals the contradictions inherent in ownership. By becoming the legal proprietor of an underground iron ore deposit, the artist reconfigures the logic of appropriation into a tool of resistance. These operations underscore the juridical foundations of extractivism and reveal how the territory itself is increasingly subjected to processes of abstraction and commodification. By confronting this dynamic at the level of matter, her work articulates a form of critique that operates not through representation, but through spatial and legal entanglement⁶. Rather than adopting a representational stance, she displaces the logic of visual spectacle to focus on what remains materially and perceptually invisible. Her interventions, such as the *Spanish Pavilion* at the *55th Venice Biennale*, where she exhibited the exact quantity of materials used in constructing the building itself, transform architectural space into an index of extraction. Exposing the origins of construction materials disassembles the apparent neutrality of built environments and draws attention to the planetary scale of resource mobilization involved in their making. She does not aestheticize ruin, or decay, or monumentalize absence. Instead, she maps the processes of becoming and unmaking that shape urban and geological strata.

In dialogue with Lombardi, who traces the abstract circulations of finance, policy, and elite networks, Almarcegui anchors her critique in the granular matter of earth, minerals, and the bureaucracies that enclose them. Together, their practices illuminate the relational field between extractivism, invisibility, and systems of control, suggesting that the coloniality of power persists not only through institutions and narratives

⁶ In this sense, her practice resonates with decolonial thought by refusing to separate environmental justice from questions of access and authority over land and resources.

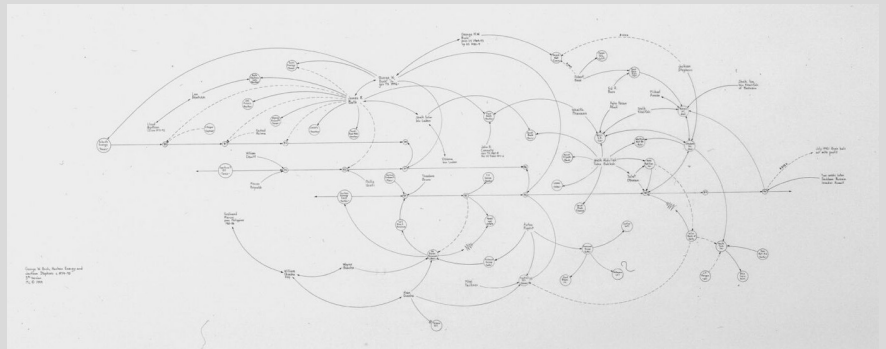
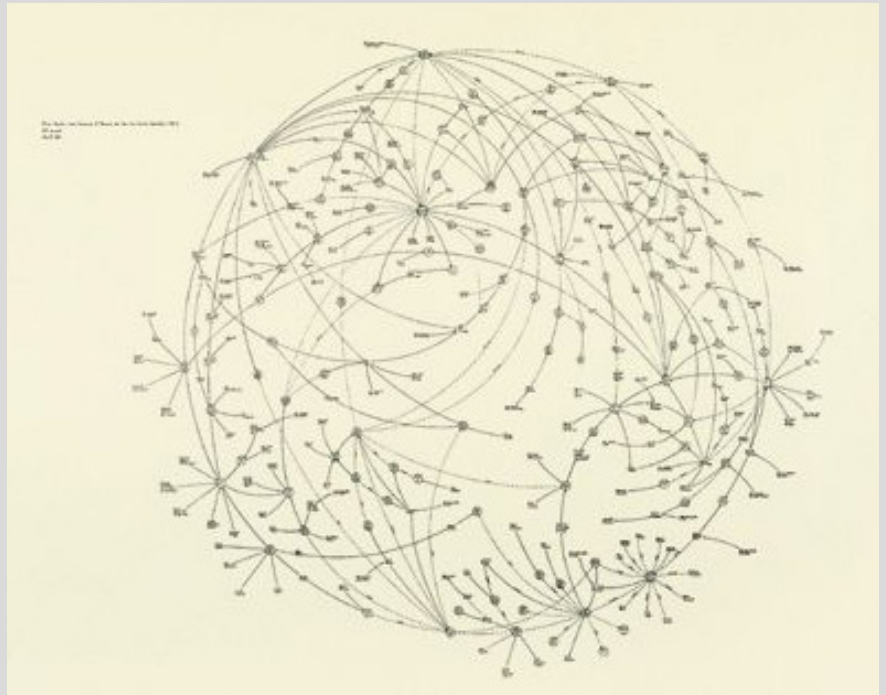


fig.1.1 Mark Lombardi, *Oliver North, Lake Resources of Panama, and the Iran-Contra Operation*, ca. 1984–86 (4th Version), 1999. Independent Curators International, New York.

fig.1.2 Mark Lombardi, *George W. Bush, Harken Energy, and Jackson Stephens*, c. 1979–90 (fifth version). Independent Curators International, New York.



fig.1.3, fig.1.4 Lara Almarcegui, *Construction Materials Main Hall*, 2010, Wien.
 Photos: Wolfgang Thailer

but also through the very substances and spatial configurations that organize the contemporary condition. Though methodologically distinct, these works invite a rethinking of visibility: what is seen, who sees, and what remains structurally obscured. In doing so, they expand the field of decolonial analysis to include artistic strategies as active components of territorial critique.

From backdrop of exploitation to medium of relation At the far edge of England, where the shingle plain of Dungeness stretches between the sea and a nuclear power station, Derek Jarman cultivated an improbable garden. This desolate landscape became, from 1986 onward, the site of a radical act of composition. Rather than escaping the devastation of his time, he confronted it through the slow labor of rearranging stones, driftwood, and wild plants. His gesture inverted the logic of extraction: instead of removing matter from the earth, he gathered what the tide had discarded, reassembling it into a fragile constellation of care. Dungeness thus transforms the notion of landscape from a backdrop of exploitation into a medium of relation. Every object placed bears the trace of previous cycles of use, waste, and erosion. By recomposing them without erasing their histories, the garden enacts a politics of attention that resists the abstraction of global systems⁷. The work reminds us that inhabiting a damaged habitat does not mean restoring it to purity, but instead learning to coexist with its scars. In this sense, the garden at Dungeness can be read as a form of counter-mapping, a situated response to the same processes of material displacement and epistemic control that this chapter has traced across extractive geographies. Where mining and logistics stretch connections across vast distances, they are compressed into a few square meters of shingle. Where industrial modernity seeks efficiency and scale, it cultivates slowness and contingency. The garden's cyclical temporality, its rhythms of erosion and growth, proposes an alternative to the linear time of exploitation. It embodies a different ecology of practice, grounded in proximity and reciprocity rather than appropriation.

Because it resists hierarchy and linear progression, the garden operates as a rhizome. A living network of connections where ideas, materials, and affects spread laterally rather than vertically, linking the aesthetic, the political, and the ecological in continuous transformation. Jarman's

⁷ What extraction externalizes and renders invisible, it returns to the surface, where decay, color, and light become tools for thinking through loss.

act of planting amid radiation and illness was not a nostalgic retreat but an experiment in endurance. The garden's vitality reconfigures the relation between matter and agency, human and nonhuman. In this sense, it resonates with the territorial questions raised throughout this research: how to act within landscapes already exhausted, how to transform residues into potential. Dungeness does not offer redemption; it offers method. Through gestures of gathering, recomposition, and care, he demonstrates that new forms of inhabitation can emerge even within the ruins of extraction. His garden, humble and exposed, becomes both a metaphor and a practice of transformation, an experiment in living with the remnants of a landscape continuously mined, dismantled, and reimagined.



fig.1.5 A view of Derek Jarman's garden at Prospect Cottage in Dungeness, featured in an article by Crowdy (2021) for *Architectural Review*. The image captures the Jarman's creation, set against the desolate shingle beach and the backdrop of the nuclear power station.

fig.1.6 Derek Jarman at Prospect Cottage.
Photo: Howard Sooley

1.1.globalization and planetary mining

Extractivism has gained significant traction in global economic practices, environmental degradation, and discussions on social justice. It refers to a financial model centered on the large-scale extraction of natural resources for export. The shift from industrial to financial accumulation⁸ has altered the logic of value extraction, prioritizing short-term returns over long-term sustainability⁹. Commodities, such as oil, minerals, and agricultural products, function as both physical goods and financial assets, with prices that fluctuate in response to market speculation rather than to changes in material supply and demand¹⁰. This dynamic aligns with the critique of the “*irresponsible enterprise*” (Gallino 2011), in which corporate strategies are designed to maximize shareholder value rather than to reinvest in productive or sustainable practices. The logic of short-term exploitation, driven by financial imperatives, exacerbates unsustainable resource extraction while undermining economic diversification in resource-rich regions. Financial actors increasingly dictate extraction conditions, often prioritizing speculative investments over sustainable development.

Extractivism and financial capitalism This perspective also illuminates the systemic nature of extractivism in contemporary capitalism. The metaphor of a “*mega-machine*” (Gallino 2011) offers a structural lens for analyzing extractive economies. Extractivism is not merely a localized phenomenon but a transnational system embedded within global production, finance, and governance circuits. The infrastructure supporting resource extraction, from transportation corridors to digital trading platforms, is an integral component of a broader apparatus that facilitates the uninterrupted flow of capital. A defining feature of this system is the increasing abstraction of value extraction, in which financial instruments such as futures contracts and derivatives set the pace and intensity of material exploitation¹¹. This financialization process in-

⁸ Theoretical contributions to financial capitalism offer a compelling framework for understanding its relationship with extractivism. This notion describes a system in which financial capital exerts dominance over productive capital, reshaping economic structures and subordinating labour, natural resources, and democratic institutions to the logic of speculative accumulation.

⁹ Extractive industries, historically tied to productive investment, have increasingly been integrated into speculative financial markets.

¹⁰ The financialization has intensified the volatility of resource-dependent economies, exposing them to global economic shocks while reinforcing patterns of dependency.

¹¹ This framework suggests that extractivism cannot be understood solely regarding its environmental consequences but must also be examined through its financial and logistical underpinnings.

roduces greater economic instability, exposing resource-dependent regions to the volatility of speculative markets. Labor precarity represents another dimension where this analysis intersects with extractivism. The critique of neoliberal globalization highlights the erosion of labor rights and the increasing precariousness of work as financial capitalism restructures labor markets. The extractive sector exemplifies these trends, as workers face exploitative conditions characterized by job insecurity, wage suppression, and exposure to hazardous environments. The flexibilization of labor, a hallmark of financial capitalism, has facilitated a shift toward subcontracting and informal employment in extractive industries, reducing corporate accountability for workers' rights¹². The emphasis on the structural mechanisms that devalue labor provides a theoretical foundation for analyzing the intersection of financialization and exploitation in extractive economies.

This model emphasizes commodities such as minerals, oil, gas, timber, and agricultural products, often with profound impacts on the environment and local communities. At its core, extractivism involves the removal of natural resources from their ecosystems and their transformation into raw materials for global markets. Massive operations often require significant infrastructure, capital investment, and technological inputs¹³. Examples include mining operations for precious metals, drilling for oil and gas, and large-scale logging and agricultural plantations (Gudynas 2013a). The mining industry's transformation into a global, interconnected system extends beyond the extraction site, encompassing an entire infrastructure network, including transportation, trade, logistics, and economic governance. The mine is no longer a static, geographically isolated place but a node within a transnational network linking extraction sites to production and consumption centers on a global scale (Arboleda 2020).

The extractivist model is heavily oriented towards export. The role of

¹² Automation and remote-controlled mining operations further exacerbate these trends, consolidating corporate power while reducing direct labor engagement.

¹³ This perspective reduces complex ecosystems and biodiversity to mere inputs in the production process, overlooking their intrinsic value and the services they provide to local communities and the environment (Acosta 2013a).

logistics as a “*science of systems*”¹⁴ underscores how the technological and organizational integration of the extractive industry has accelerated capital circulation. Extracted resources are typically shipped to global markets where they are processed and consumed, generating revenue for the extracting countries but often without fostering local economic diversification or technological advancement. This creates a dependency on volatile global commodity markets¹⁵. The externalization of extraction costs, wherein negative environmental and social consequences are displaced onto local populations, remains a fundamental characteristic of this model. These include pollution, deforestation, biodiversity loss, and the forced displacement of communities, disproportionately affecting marginalized and indigenous groups (Svampa 2019). The ecological crisis occupies a central place in the critique of financial capitalism, thereby reinforcing its relevance for studies of extractivism. The

¹⁴ Arboleda (2020) refers to the “*science of systems*” in the context of how modern scientific approaches have shaped economic and political governance, particularly in the extraction industries. He discusses how integrating systems theory into economic and industrial practices has led to the conception of society as a balanced, engineered whole, reinforcing the rationalization of extractive capitalism. He noted that the life sciences transitioned from physiology to systems theory in the 20th century (Haraway 1991), facilitating an approach that views society as an object of engineering. This shift enabled technocratic governance structures to implement extractive infrastructures as part of a broader logic of control and optimization. In this sense, engineering is no longer merely about machines; it extends to the rational placement and modification of human and natural resources to serve economic imperatives.

¹⁵ The dependence on volatile global commodity markets reflects what Arboleda describes as the “*fetishized autonomy*” of capital’s circulatory system, in which the value of extracted materials becomes subject to impersonal logics of global finance and logistics rather than to local productive or ecological conditions. Contemporary extractive industries are structurally tied to the speculative movements of capital through world markets: mineral prices fluctuate according to algorithmic trading, futures contracts, and shifting geopolitical demand, especially from industrial hubs in East Asia. This volatility is not accidental but constitutive of the capitalist mode of production, where the reproduction of mining economies depends on the acceleration and abstraction of value circulation rather than on stable, territorially grounded exchange. As a result, local economies become subordinated to a transnational infrastructure of extraction and circulation whose rhythms are dictated by distant centers of accumulation. The ensuing dependency exposes resource-producing regions to recurrent boom-and-bust cycles, undermining their capacity to pursue long-term social and ecological planning (Arboleda 2020).

concept of a “*double crisis*”¹⁶, encompassing both financial and ecological dimensions, underscores the inextricable link between economic instability and environmental degradation. The drive for capital accumulation accelerates ecological destruction as financial markets commodify natural resources without accounting for their regenerative capacities. The speculative logic governing financial capitalism encourages the expansion of extractive frontiers, disregarding ecological limits. This process manifests in the intensification of resource extraction in fragile ecosystems, where the imperative of profit overrides concerns for biodiversity loss, deforestation, and water contamination. This perspective suggests that extractivism is not simply a consequence of industrialization but a structural feature of a financialized economy that externalizes environmental costs onto marginalized communities.

Global extractivism. Infrastructures of accumulation and the logic of expansion Extractivism is a critical pillar of global capitalism, connecting territories across vast distances through resource flows that benefit global capital but perpetuate inequalities (Arboleda 2020). The extractive industry’s planetary reach is reshaping landscapes and societies globally, turning territories into *mines* for capitalist exploitation, where nature and people are subjugated to the relentless pursuit of profit. This resonates with broader critiques of extractivism that underscore the unequal power dynamics between the Global North, which consumes these resources, and the Global South, which bears the brunt of extraction’s negative consequences (Svampa 2019, Acosta 2013b). Within this system, the extraction infrastructures have expanded beyond traditional mining or drilling sites to include logistical corridors, ports, financial hubs, and digital platforms that facilitate the movement

¹⁶ The expression “*double crisis*” refers to the simultaneous financial and ecological collapse generated by the same systemic dynamics of global capitalism. Gallino (2011) uses it to describe how the mechanisms driving financial instability, speculation, deregulation, and the pursuit of unlimited growth, are inseparable from those that produce environmental degradation. Both crises stem from an economic order that treats nature as an inexhaustible reservoir of value and externalizes its social and ecological costs. In this sense, the “*double crisis*” reveals the internal contradiction of the capitalist system: the attempt to sustain accumulation on a finite planet whose regenerative capacities are continually undermined by the very processes that fuel economic expansion.

of commodities worldwide¹⁷. The increasing complexity of these networks shows how extractivism is no longer confined to a purely physical phenomenon but is deeply embedded in transnational circuits of finance and governance. The role of multinational corporations, hedge funds, and sovereign wealth funds in dictating the terms of resource extraction highlights how global capitalism has integrated extractive economies into larger financial frameworks that prioritize speculation over the well-being of affected populations. The logic of extractivism extends beyond material resources to incorporate data, labor, and even social infrastructures, reinforcing a model that systematically prioritizes profit over sustainability. In this light, extractivism can be understood as a material process and a broader strategy of capitalist expansion that appropriates and restructures territories for maximum economic gain¹⁸. As extraction intensifies, resistance movements that challenge its hegemonic logic also intensify, advocating for alternative models of economic development that prioritize ecological integrity and social justice. The shift towards an infrastructural understanding of extractivism has been accelerated by technological developments that enable seamless integration of mining operations with digital and financial networks¹⁹. These advancements have enabled corporations to control vast resource frontiers with minimal labor input, shifting the extraction burden from human workers to algorithmic governance. This has profound implications for labor markets in extraction-dependent economies, where job displacement due to automation intersects with ongoing environmental conflicts and social struggles.

This broader understanding of extractivism aligns with the analysis of resource imperialism, where extraction sites become nodes within a global infrastructure of accumulation rather than isolated points of economic activity. The *planetary mine* concept encapsulates the scale at which resource exploitation is reorganized, underscoring the systemic

¹⁷ Arboleda (2020) describes how extractive capitalism extends its reach through the construction of vast logistical networks that operate as material supports for global accumulation. These systems dissolve the spatial boundaries between extraction, circulation, and consumption, transforming the entire planet into a continuous operational field of resource mobilization.

¹⁸ According to Arboleda (2020), extractivism functions not only as a material practice but as a structural logic of capitalist expansion. It reorganizes territories by embedding them within planetary infrastructures of circulation and control, converting natural and social environments into components of a system oriented toward perpetual growth and accumulation.

¹⁹ The increasing role of automation, predictive analytics, and AI-driven resource management systems has fundamentally altered the traditional paradigms of extraction.

nature of the phenomenon and its inextricable link to global capital flows²⁰. Positioning extractivism within this expanded analytical frame enables tracing its connections to historical patterns of colonial exploitation while acknowledging its evolving role in contemporary capitalism. The fundamental contradiction remains: even as new technological advancements promise more efficient and sustainable extraction, the underlying logic of resource appropriation reinforces existing inequalities, ultimately shaping the economic and environmental futures of entire regions.

Green extractivism and its contradictions The contemporary capitalist system relies on a series of interdependent networks that blur traditional categories of *center* and *periphery*, making the spatial hierarchies of extraction increasingly fluid. This restructuring of global space reflects the imperatives of accumulation, shaping where resources are extracted and how these spaces are integrated into planetary circuits of production, finance, and trade.

This framework also extends to the political dimensions of financial capitalism, particularly in its impact on democratic processes. The analysis of the erosion of democratic institutions under neoliberal globalization (Gallino 2011) resonates with contemporary critiques of extractivism as a mode of governance. Resource-rich states often adopt authoritarian measures to facilitate extraction, suppress dissent, and prioritize corporate interests over community rights. The state's role in extractive economies reflects broader tensions between financial and political power as governments navigate conflicting pressures from multinational corporations, financial institutions, and civil society. Insights into the state's transition from an industrial to an economic regime of accumulation shed light on the governance structures that sustain extractivist policies. The contradictions of this evolving extractive economy are further magnified in the context of climate change and the so-called *green transition*. As nations seek to shift away from fossil fuel dependence, the demand for critical raw materials, including lithium, cobalt, and rare earth elements, has skyrocketed. This has led to an intensified scramble for resource security, with countries competing to secure exclusive access to

²⁰ The shift toward an infrastructural understanding of extractivism, Arboleda argues, stems from technological transformations that merge physical and digital systems of production. Automated logistics, algorithmic governance, and data-driven financial instruments integrate mining into a continuous network of extraction and exchange, where territorial boundaries blur and the flow of capital dictates spatial organization (Arboleda 2020).

mineral deposits essential for renewable energy technologies. Yet, this push for a low-carbon economy paradoxically reinforces the extractivist logic it claims to mitigate. The notion of sustainability within this framework remains deeply contested, as extractive operations marketed as *green* often replicate the same patterns of exploitation and environmental degradation that defined previous waves of resource extraction. The structural dependence on finite resources persists, highlighting the limitations of technological solutions that fail to address the deeper systemic drivers of the environmental crisis. The global extractive regime remains a dynamic and contested terrain, shaped by competing political, economic, and ecological imperatives. While corporations and states seek to expand resource frontiers in pursuit of profit and security, resistance movements, indigenous communities, and environmental advocates continue to challenge the hegemony of extractivist capitalism, advocating for post-extractive futures that prioritize local autonomy, ecological sustainability, and economic justice. This ongoing struggle underscores the need to critically examine the evolving configurations of extractivism and how its planetary logics continue to shape contemporary socio-environmental transformations.

1.2.about extractivism

In the previous chapter, we examined how global economic, social, and productive dynamics have driven the expansion of extractive phenomena far beyond the removal of natural resources. Extractivism is not solely about mining, machinery, and models of resource exploitation. It is embedded in the very structures of governance and territorial control. An insightful conceptualization of extraction was presented at the 2016 Venice Biennale by the Canadian Pavilion, titled “*EXTRACTION*”²¹, which framed extraction as a material process and a fundamental mechanism of state power. The pavilion argued that the state functions as an extractive technology, governing land through legal, administrative, and political instruments. Territory is not simply an extension of sovereign rule but a system actively shaped by bureaucratic control, regulatory frameworks, and economic imperatives. Extractivism, therefore, is a deeply rooted ideology that manifests in the direct exploitation of resources and the systematic separation of surface rights—property—from subsurface rights—minerals. The regulation of space through acts, statutes, and maps reinforces the dominance of state institutions and extractive industries, creating a framework in which mining corporations do not operate independently but as extensions of governmental policy and legal structures.

Cartographies of dispossession: Extending beyond the economic sphere, extraction actively reshapes borders, establishes new control jurisdictions, and produces hybrid territories between sovereign governance and privatized exploitation. While extractive economies generate economic growth and wealth for elites and global investors, they also reinforce exclusionary dynamics, turning extraction zones into spaces of control, dispossession, and ecological damage²². The decolonization of extraction is not simply a technical or regulatory issue but requires a fundamental rethinking of the ideologies that underpin territorial dispossession. Thus, reclaiming land and resources becomes central,

²¹ The Canadian Pavilion at the 2016 *Venice Architecture Biennale*, titled *Extraction Empire: A Report from the Edge of Empire (Outdoors, That Is)* and curated by Pierre Bélanger, critically addressed the theme of extractivism as a material and geopolitical foundation of the Canadian nation-state. The project explored the deep entanglement between landscape, natural resources, and national identity, highlighting the environmental, colonial, and systemic implications of a development model rooted in extraction. The installation aimed to expose the often invisible infrastructures of Canada’s extractive empire, situating it within a broader global context of territorial appropriation and environmental exploitation.

²² Rather than distributing resources equitably, extractivism exacerbates power asymmetries and access inequalities, consolidating corporate influence over land and governance.

demanding the recognition of territorial rights, the protection of ecological systems, and the restructuring of society's relationship with the environment.

As a spatial production mechanism, extractivism has deep historical roots and is closely tied to the dynamics of colonialism and imperialism. During the colonial period, European powers extracted vast resources from their colonies, fueling industrialization and economic growth in the metropole while often leaving the colonies impoverished and environmentally degraded (Acosta 2013a, Galeano 1971). In the contemporary era, extractivism plays a central role in the economies of many countries, particularly in the Global South. This model is often promoted as a pathway to development, providing governments with revenue and foreign exchange (Gudynas 2013b). However, it also perpetuates economic dependencies and inequalities, as resource-rich countries remain vulnerable to fluctuations in global commodity prices and rely on foreign corporations and investment (Bebbington 2018). Critics of extractivism highlight several significant issues associated with this economic model. These activities primarily drive environmental degradation (Bridge 2004a). The environmental impacts can be severe and long-lasting, disrupting ecosystems and threatening biodiversity. Additionally, the projects often displace communities, particularly indigenous peoples, who may have deep cultural and spiritual ties to the land (Escobar 2006). The loss of land, livelihoods, and territorial sovereignty can lead to social conflict, poverty, and erosion of cultural identities (Svampa 2019).

From another perspective, it can entrench economic dependency on a narrow range of exports, making countries vulnerable to global market volatility (Acosta 2013b). The influx of revenue from extractive industries can lead to corruption and governance challenges. Governments may prioritize the interests of extractive companies over those of their citizens²³, undermining democratic processes and accountability (Ross 2001).

Understanding and addressing the complexities of extractivism is crucial for fostering reform in the territorial design processes. From this perspective, extractivism can be read as a spatial and political project shaping the production of territory (Harvey 2003).

²³ The benefits of extraction are often concentrated in the hands of elites and foreign corporations, while local communities see little to no improvement in their standard of living.

Environmental and socio-political challenges of copper and lithium extraction

Chile represents a significant case study in extractive industries, particularly in the mining sector, due to its abundant reserves of copper and lithium, which are crucial for global technology and green energy transitions. The country's mining activities, especially in the Atacama Desert, have prompted various environmental and socio-political challenges, making it an exemplary model for understanding the benefits and complexities of modern extractive processes (Odell 2022). Copper mining, the backbone of Chile's economy, dominates the country's extractive sector. It is the world's leading copper producer, with large-scale operations such as the Escondida and Chuquibambilla mines. These mines have introduced substantial environmental challenges, including water scarcity and pollution. Water usage is a critical issue as copper extraction requires significant volumes of water, leading to conflicts over water rights, particularly in arid regions like the Atacama. Recent shifts in the industry have led to increased investment in desalination to address water shortages by using seawater rather than continental freshwater sources. However, this solution presents its own challenges. Desalination plants can create tensions with coastal communities, particularly among fishing industries concerned about the environmental impacts on marine ecosystems²⁴.

Lithium extraction, particularly in the Salar de Atacama, is a cornerstone of global supply chains for batteries used in electric vehicles and renewable energy systems. The country's vast lithium reserves have placed it at the forefront of the green energy revolution. However, the extraction methods and their environmental and social consequences have made Chile a significant case study in understanding the complexities of modern resource extraction. The predominant method of extraction involves brine evaporation, where lithium-rich brine is pumped from underground reservoirs beneath salt flats and left to evaporate. This process, although cost-effective, is highly water-intensive. In the arid Atacama region, this water use has exacerbated existing water

²⁴ Blair et al. (2023) discuss these tensions in relation to Chile's expanding desalination infrastructure, showing how coastal communities, especially small-scale fishing associations, contest the ecological risks posed by brine discharge, seabed disturbance, and altered marine circulation patterns. Their account draws on a wide body of ethnographic and environmental research, including work by Babidge, Yáñez, Prieto, and others, who have documented how desalination and mining-related water infrastructures reshape livelihoods along the Atacama coast. This literature highlights how the cumulative impacts of industrial extraction and seawater desalination intensify conflicts over territorial rights, ecological degradation, and the long-term viability of local fisheries.

scarcity, directly affecting fragile ecosystems and local Indigenous communities, including the Atacameño people (Blair et al. 2023). Many of these communities depend on the same water sources for agriculture and daily consumption, raising severe concerns about resource depletion and environmental degradation. Lithium extraction consumes large amounts of water, contributing to the depletion of aquifers in the Atacama Desert. This is particularly critical in one of the world's driest regions, where water is a precious and limited resource (Carrasco 2020). The process disrupts the area's hydrological balance, affecting local communities and ecosystems. Indigenous communities in the region have increasingly raised concerns about how lithium mining affects their water supply and traditional lands. While some benefit from employment opportunities in the mining industry, many feel the environmental costs outweigh the benefits. Protests and demands for greater involvement in decision-making have increased recently. In response to these concerns, efforts have been made to mitigate the environmental impacts of lithium extraction. Some companies are exploring alternative extraction methods that use less water, although these technologies are still in early development. Moreover, Chile's 2022 water code reform has aimed to prioritize human consumption and environmental protection over industrial water use, potentially reducing strain on water resources.



fig.1.8 Catherine Hyland, *Lithium Mining, Atacama Desert* 2019.
View of the infrastructural landscape connecting extraction
and mobility systems within the lithium mining complex.
www.catherinehyland.co.uk



fig.1.9 Catherine Hyland, *Lithium Mining, Atacama Desert*, 2019.
Detail of the water management infrastructure, revealing the
technical and ecological tensions underlying extractive opera-
tions in arid environments.
www.catherinehyland.co.uk

1.3.about neo-extractivism

The phenomenon of extractivism, marked by a heavy reliance on multinational corporations and devastating environmental and social impacts, has left a lasting legacy of inequality and economic dependence. In recent decades, however, many Latin American countries, especially under progressive governments, have sought to reshape this paradigm through what is called *neo-extractivism*. While retaining the centrality of resource extraction, this new model aims to integrate extractivism with redistributive policies and social justice objectives. However, neo-extractivism raises new challenges and concerns, proving to be an ambivalent solution to the region's economic and social problems.

Neo-extractivism and its contradictions Neo-extractivism has emerged as a significant economic and political model in many Latin American countries since the early 21st century. Neo-extractivism reconfigures traditional extractive models²⁵ within new political and economic frameworks, particularly under progressive or left-leaning regimes (Gudynas 2013c). It retains a focus on large-scale extraction while introducing new mechanisms of state involvement. Unlike traditional extractivism, typically dominated by private multinational corporations, neo-extractivism involves substantial state intervention and control. Governments seek to channel resource revenues into social programs and infrastructure as part of a broader agenda of redistribution and social equity²⁶ (Acosta 2013b).

A crucial distinction from traditional extractivism lies in the state's central role in shaping and directing the economy. As Dicken (2015) notes, globalization has not diminished the relevance of the nation-state. Although state autonomy has been constrained in certain areas, governments remain key actors in regulating markets, attracting foreign investment, and negotiating with multinational corporations. In neo-extractivist regimes, the state actively manages natural resource extraction, channels revenues toward developmental objectives, and serves as a mediator between global capital and domestic priorities. Despite progressive ambitions, neo-extractivism reproduces many of the structural and environmental problems of earlier extractive models (Bebbington 2018). In practice, many initiatives proceed without genuine community

²⁵ It represents a departure from traditional extractivism in its approach and ideological framing, but also raises critical concerns often referred to as its *dark side* (Svampa 2019).

²⁶ Revenues are directed toward welfare programs, infrastructure, and public services to ensure that the benefits of resource wealth are more broadly shared, particularly among marginalized communities.

consent, generating protests, social unrest, and human rights violations (Svampa 2019). These dynamics reinforce economic dependency and expose national economies to market volatility, limiting diversification and long-term resilience (Acosta 2013b, Ross 2001).

The concentration of state power over extractive industries also risks fostering authoritarian tendencies and democratic deficits. In the name of national development, governments may suppress dissent, curtail civil liberties, and weaken institutional accountability. This centralization of authority, combined with the pursuit of rapid economic growth, often conflicts with ecological conservation and the rights of local communities. These contradictions reveal the inherent tensions of the neo-extractivist project and its limits as a sustainable development strategy. Although it is often described as a developmental path intended to benefit local populations, extractive activities rarely lead to improved living conditions in practice. On the contrary, they often exacerbate inequality and environmental degradation, reinforcing forms of neo-colonial dependency rather than overcoming them.

Latin american neo-extractivism: between redistribution and dependency In the past two decades, countries like Venezuela, Bolivia, and Ecuador have become emblematic examples of neo-extractivism in Latin America²⁷. This economic model, adopted by progressive governments, aims to exploit natural resources to fund social programs and promote economic development. However, it has also drawn criticism for its environmental and social impacts. The declared goal of these governments has been to use the revenues from natural resource extraction, such as oil, natural gas, and minerals, to redistribute wealth, reduce poverty, and improve living conditions for the population. Despite some positive social outcomes, these countries face significant challenges regarding long-term sustainability and democratic resource management. In Venezuela, Bolivia, and Ecuador, neo-extractivism has

²⁷ This interpretation builds on the body of research discussed earlier in the chapter, which analyzes how neo-extractivist experiments in Venezuela, Bolivia, and Ecuador attempted to channel resource revenues into social investment and public welfare. These studies show that, while such policies produced visible improvements in areas like education, health, and poverty reduction, they also revealed structural constraints that remained largely intact: continued exposure to global commodity volatility, limited diversification of national economies, and growing pressures on ecologically fragile territories. Rather than replacing earlier extractive logics, these experiences illustrate the difficulty of transforming resource-based development models from within, as the dependence on natural resource rents continues to shape both political decision-making and territorial outcomes.

been an economic strategy to fund social programs and promote development. Still, it has raised complex issues regarding environmental sustainability and social justice. Despite progress in poverty reduction and wealth redistribution, these countries continue to grapple with the contradictions of an economic model heavily dependent on natural resource extraction, with negative impacts on fragile ecosystems and local communities. The inability to diversify their economies and the increasing centralization of power are some of the limitations neo-extractivism must address to evolve into a more sustainable development model.

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I. extraction cycles

2. material extraction and flows

EU's Critical Raw Materials and Strategic CRM

The extractive dynamics discussed in the previous section underscore that resource appropriation remains central to contemporary economic and political structures. The expansion of global supply chains and the financialization of raw materials have reinforced dependency and ecological degradation patterns, shaping the framework within which new policy responses emerge. The European Union's socio-ecological transition has been framed as a strategic response to the growing interdependence between resource extraction, environmental degradation, and global economic stability. Climate concerns do not merely dictate this shift but emerge from the structural need to secure critical raw materials while mitigating the socio-environmental contradictions of an extractive economic model. The European Green Deal, among the primary initiatives in this area, aims to make Europe the first climate-neutral continent by 2050 through a profound economic and social transformation. However, this ambitious goal raises questions beyond the mere technical dimension of reducing carbon emissions, embracing more profound reflections on humanity's role in planetary history, the dynamics of global capitalism, and the interconnection between energy and civilization.

One of the first critical considerations that emerges is the need to rethink the very temporality of the climate crisis. Ecological transformation cannot be viewed simply as a political or economic cycle. Instead, it is positioned on a temporal scale that exceeds the traditional historical framework. It requires a new approach to human history and its relationship with the Earth as a geological system (Chakrabarty 2021). This perspective introduces an awareness of the planet's vulnerability, which cannot be addressed merely as a problem to be solved within a legislative term or a ten-year economic plan. The EU's policies, though forward-looking, are often formulated according to short-term economic and political logic. However, to respond to the climate crisis, it is necessary to consider humanity's history, closely intertwined with that of the planetary system, and to intervene beyond the contingent dynamics of the capitalist cycle. In this direction, it has been emphasized that ecological political action must be radically rethought, considering ecology not only a scientific issue but also a global political and social problem (Latour 2017). Another crucial issue concerns the connection between the environmental crisis and the global economic system. Often, discussions of the Anthropocene present the ecological crisis as a universal phenomenon caused by humanity as a whole. However, this view tends

to obscure the specific role that capitalism has played in accelerating the processes of extraction and exploitation of natural resources (Moore 2016).

The economic model that has dominated the last century is intrinsically linked to an accumulation process that has exploited nature as an infinite resource, contributing to the destruction of ecosystems. While seeking to mitigate environmental impacts, EU policies often continue to operate within the confines of the capitalist system, promoting *green* economic growth that could remain trapped in the same exploitative logic that caused the crisis. In this sense, it has been highlighted that the climate crisis also represents a crisis of capitalism, which requires a radical transformation of our economic and social systems (Klein 2014). This dilemma is particularly evident in the context of energy. The history of human civilizations is inseparable from the control of energy resources, and every radical social transformation has been fueled by new forms of energy exploitation (Smil 2021). The energy transition to renewable sources, central to the European project, is not a mere technical issue: it requires a radical rethinking of how society produces and consumes energy. Replacing fossil fuels with renewable energy represents only part of the process. Still, the transition must be understood as a profound structural change that requires time, resources, and large-scale technological innovation. Some authors have pointed out that reducing consumption and decreasing energy dependency could be critical to a sustainable future (Latouche 2011).

However, the history of energy transitions²⁸ teaches us that these processes have never been quick or straightforward. Every time a civilization faces an energy transformation, it takes decades, if not centuries, and involves significant social and economic changes. The idea that a *green* transition can be achieved without radical transformations of the

²⁸ A valuable contribution to the reflection on energy transitions within urban and landscape studies is offered by the seminar cycle “*Per una storia ambientale applicata agli studi urbani e sul paesaggio*”, promoted by the *Environmental Humanities Cluster* at the Department of Architecture and Urban Studies, Politecnico di Milano (2022–2023). The initiative critically engaged with themes such as energy regimes, infrastructure, and extractive geographies. Particularly relevant were the sessions “*Il concetto di Antropocene: i vestiti nuovi della teleologia*” (*The concept of the Anthropocene: the new clothes of teleology*), “*Il mito della transizione energetica: un'altra fine del mondo è possibile?*” (*The myth of the energy transition: another end of the world is possible?*), “*La produzione del rischio 'naturale'*” (*The production of natural risk*), and “*La contaminazione del mondo*” (*The contamination of the world*).

economic and social system might prove overly optimistic²⁹. Furthermore, although renewable energy represents a crucial solution for the future, its development and large-scale implementation require complex infrastructure and investments beyond mere technological replacement. The effectiveness of European policies will depend on the ability to recognize and address the complexity of these challenges. The EU's socio-ecological transition policies are at a crucial crossroads in this context. On the one hand, they represent an innovative attempt to address an unprecedented crisis, aiming to promote sustainable economic growth compatible with the planet's limits. On the other hand, they risk underestimating the depth of the necessary transformations, limiting themselves to a superficial reconfiguration of current economic and social models (Moore 2016). The success of these policies will depend on integrating a broader, more radical vision of the climate crisis that takes into account the historical relationships between humanity and the environment, the dynamics of global capitalism, and the centrality of energy to civilizations. In this context, it has been observed that the relationship between capitalism and fossil fuels is so tight that an ecological transition is impossible without a radical break with capitalist logic (Malm 2016).

The socio-ecological transition cannot be achieved solely through policies aimed at decarbonization or technological modernization. It requires a profound rethinking of our relationships with the planet and the economic and social structures that govern our way of life (Chakrabarty 2021). Only a structural change that addresses the root causes of the ecological crisis can ensure a sustainable future (Klein 2014, Latouche 2011).

²⁹ Smil's historical analysis shows that every major energy transition has unfolded through long, uneven, and path-dependent processes. It emphasizes that energy systems possess a structural inertia rooted in their material complexity: extraction sites, transport networks, conversion technologies, and consumption practices co-evolve over centuries, creating locked-in arrangements that cannot be rapidly displaced. He also notes that contemporary fossil-fuel dependence is the cumulative result of this long historical layering. This is why, the transition to renewables cannot be understood as a simple substitution of one energy source with another: it requires transforming the entire metabolic structure of society. This reconstruction, therefore, challenges optimistic narratives of a rapid green transition. It demonstrates that historical transitions have always been slow, contested, and materially demanding, and that the current shift away from fossil fuels faces even greater hurdles: unprecedented global energy demand, deep interdependence between energy and economic growth, and the massive scale of existing fossil infrastructure. In this view, the European socio-ecological transition must reckon with these structural constraints, recognizing that energy transitions are not only technological but also civilizational scope (Smil 2021).

2.1.material flows and the socio-ecological transition: reconfiguring resource extraction in europe

Following the discussion on extractive dynamics and their entanglement with political and economic systems, the European socio-ecological transition can be understood as both a response to and an extension of these processes. While extraction has long underpinned Europe's industrial and economic expansion, it now lies at the core of renewed debates over autonomy, resilience, and the reconfiguration of material relations amid global environmental crises.

Europe's socio-ecological transition Europe's current environmental and social transformations reveal a redefinition³⁰ of the relationship between economy, ecology, and governance. These changes stem from an increasing awareness that ecological and social risks are interconnected and require a collective response at both political and economic levels (Beck 1992, Giddens 2009). Material resources are not passive elements but active agents (Bennett 2010) shaping socio-ecological systems. This perspective challenges the traditional view of resources as inanimate objects to be extracted and utilized. It introduces the idea that materials actively shape social and ecological systems. In this sense, resource extraction is not merely a question of appropriation but of interaction between human society and non-human matter. From a historical perspective, Europe has long been at the forefront of extractive industrialization, which marked the beginning of an era of intensive exploitation of natural resources, including coal, minerals, and oil. This development model led to unprecedented economic growth and devastating environmental impacts (Fischer-Kowalski and Haberl 2007). Europe is trying to reform its relationship with natural resources, promoting sustainability policies and energy transitions. However, the increasing scarcity of resources and environmental pressures have pushed Europe to rethink this model³¹. In the context of the socio-ecological transition, attention has shifted towards using renewable resources and reducing the environmental impact of extractive activities. Recent EU frameworks, including the Green Deal and Circular Economy Action Plan, aim to reduce dependence on non-renewable resources and en-

³⁰ A series of structural and systemic changes.

³¹ Resource extraction has been a mainstay of the European economy since the Industrial Revolution. Economic growth in the 19th and 20th centuries was mainly based on the intensive exploitation of natural resources such as coal, oil, and natural gas and raw materials such as iron and other minerals. This model led to unprecedented economic development but with severe environmental consequences, including ecosystem degradation, pollution, and climate change (Steffen et al. 2015).

courage the recycling and reuse of materials³². Yet the technologies enabling the green transition depend on critical minerals whose extraction reproduces ecological and social contradictions.. Still, their extraction is often associated with significant environmental and social impacts.

Matter, agency, and environmental justice Understanding matter as active rather than inert clarifies how extraction shapes socio-ecological processes. Material objects, such as minerals, are not mere passive resources to be exploited. They actively participate in environmental and social dynamics. This means that the ecological transition cannot be viewed solely as a matter of efficient resource management but must also involve restructuring human-nonhuman relationships. Europe must consider its relationship with natural resources not merely in economic or utilitarian terms, but also recognize their ecological and political complexity. This could lead to greater attention towards development models that integrate respect for ecological limits and a more equitable use of resources. While Europe seeks to reduce its environmental impact, it must also address justice issues, particularly concerning communities that bear the adverse effects of extractive activities, often outside Europe. The dynamics of the energy transition must also be considered in terms of social justice (Bouw 2023). This issue is particularly relevant in Europe, where reliance on critical resources extracted elsewhere often leaves local communities excluded from economic benefits and exposed to environmental and health impacts. A just socio-ecological transition must therefore integrate environmental justice as a structural dimension, not as a corrective afterthought.

The socio-ecological transition and resource extraction are closely interconnected, and this relationship must be understood in light of the complex dynamics between human societies, natural resources, and

³² In the 2019 *European Green Deal*, resource efficiency is framed as a structural pillar of the Union's long-term strategy. Rather than focusing solely on decarbonization, it places equal emphasis on reducing material throughput, strengthening circular-economy mechanisms, and reorienting production systems toward lower-intensity resource use. It situates recycling, reuse, and waste minimization as systemic interventions intended to reshape industrial processes and consumption patterns across member states. The *Green Deal* calls for harmonized waste-classification methods, improved traceability of secondary materials, and the development of EU-wide standards for recycled content, alongside investments in sorting technologies, advanced material recovery, and digital product passports designed to track components across their entire life cycle (European Commission 2019).

environmental justice³³. While Europe seeks to reduce its dependence on non-renewable resources and promote sustainable development through policies such as the Green Deal and circular economy, it faces significant challenges, including equity in resource distribution and the environmental impacts of extractive activities.

³³ Bennett's (2010) ideas on the vitality of matter and Bouw's (2023) environmental justice analysis in the context of energy transitions offer valuable critical perspectives. These theoretical contributions push us to rethink natural resources' role as objects to be exploited and as active agents in socio-ecological processes.

2.2.the Critical Raw Materials act

As Europe undergoes a broad socio-ecological transition—encompassing shifts in energy production, mobility, digital infrastructure, and industrial policy—the European Union is reconfiguring its mining strategy to reduce dependency on external sources and re-integrate raw material extraction within its borders (Mathis and Burkhardt 2021). This shift marks a break from the decades-long reliance on outsourced extraction, which had allowed European industries to benefit from global supply chains while externalizing the environmental and social costs of mining. However, as demand for critical raw materials intensifies due to the electrification of transport, the expansion of digital economies, and the push for renewable energy technologies, the EU faces the challenge of securing a stable supply while aligning with its sustainability commitments. The EU's Critical Raw Materials (CRM) Report serves as a legislative framework designed to ensure the supply of critical raw materials within the EU and address their strategic importance³⁴. This framework identifies a list of strategic raw materials essential for technologies that underpin Europe's green and digital transition while also considering potential future supply risks (Blengini et al. 2020). According to the report, by 2030, the EU must produce at least 65% of each strategic raw material's annual domestic consumption. Specific benchmarks have been set: at least 10% of yearly consumption must be extracted, 40% processed, and 15% recycled³⁵ (Mathis and Burkhardt 2021). In addition, member states are required to develop national programs to explore geological resources. However, this socio-ecological transition is expected to increase raw material consumption, particularly of lithium, cobalt, and rare earth elements, which are crucial to the energy transition and digitalization (Jowitt et al. 2020). This section investigates

³⁴ The European Commission's document *Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability* (2020) defines the institutional mandate through which the EU has begun to formalize its approach to critical raw materials. Rather than presenting a sectoral analysis, the report establishes a procedural framework: identifying priority materials, clarifying the criteria for 'criticality', and outlining the mechanisms through which the Union intends to coordinate actions among member states. It also sets the administrative architecture for future policy measures, specifying how monitoring, reporting, and strategic planning should operate at the European level. In this sense, the report functions primarily as an institutional baseline that organizes responsibilities and frames subsequent initiatives, rather than prescribing specific interventions or technical solutions.

³⁵ These targets were formalized within the EU's framework for critical raw materials, which defines the thresholds for extraction, processing, and recycling as part of its internal coordination mechanisms. Rather than prescribing specific interventions, the framework establishes the quantitative criteria through which future policy actions will be monitored and evaluated.

the spatial implications of these trends by analyzing the distribution of CRMs in Europe, the prospects for extraction, and their relationship to global extraction, distribution, and processing networks (European Environment Agency 2021).

Critical raw materials and global value chains The EU's attempt to localize resource extraction must contend with the realities of global value chains (*GVCs*), fragmented yet integrated networks of production and distribution (Gereffi 2018). Over the past decades, these chains have allowed companies to capitalize on the comparative advantages of different regions, outsourcing the extraction, processing, and manufacturing of raw materials to lower-cost locations (Baldwin and Lopez-Gonzalez 2015). Advances in shipping logistics and containerization have reduced transportation costs to historically low levels, enabling materials to be extracted in one part of the world, processed elsewhere, and manufactured in another (Hummels 2007). This economic efficiency challenge undermines the economic case for localizing CRM extraction, as importing raw materials from lower-cost regions remains an attractive option for many industries. The low cost of transporting raw materials also complicates Europe's socio-ecological transition. Even with ambitious targets for local extraction, processing, and recycling, the comparative advantage of importing CRMs from regions with abundant resources and less stringent environmental regulations could undermine these efforts. This raises the question of whether Europe can incentivize domestic industries to source CRMs locally when cheaper foreign alternatives are available (Jowitt et al. 2020).

Furthermore, compared to countries with less developed regulatory frameworks, the environmental and social costs of mining within Europe complicate the picture. Even if Europe increases domestic extraction, processing, and manufacturing, these activities will often remain part of global networks³⁶. Given these complexities, Europe's CRM strategy must balance local extraction efforts with remaining competitive in a global economy with minimal transportation costs. The strategy's success will depend not only on achieving domestic extraction, processing, and recycling targets but also on navigating the broader geopolitical and economic environment, which often favors global sourcing due to the

³⁶ For example, much of the processing of rare earth elements still occurs in countries like China, which dominates the market due to specialized infrastructure and knowledge (Blengini et al. 2020)

efficiency of GVCs. Additionally, Europe must address the sustainability of resource extraction within its borders and globally, promoting higher ecological and labor standards in the countries where it imports raw materials. As Europe advances its socio-ecological and digital transitions, the interplay between local resource extraction and global value chains reveals profound challenges³⁷. Europe's strategy to secure CRMs aims to reduce dependency on external sources, but its continued integration into GVCs makes complete self-sufficiency difficult. The tension between striving for resource sovereignty and remaining embedded in a global system incentivizes long-distance transport of materials (Blengini et al. 2020). The hidden costs of the green and digital transitions are the demand for rare metals like cobalt, lithium, and rare earth elements, crucial for clean technologies, often come at a high environmental and social price (Pitron 2020). These metals are primarily sourced from regions with less stringent protections, where extraction can cause significant environmental damage and human rights violations³⁸. The rare metals required for technologies like wind turbines, solar panels, and electric vehicles are often extracted in ways that contradict the sustainability principles they are meant to support. This tension exemplifies the complexity of Europe's transition, which must reconcile local ambitions with global realities. A more holistic approach is necessary—one that increases local extraction and processing capacities and critically engages with the ethical and environmental consequences of continued reliance on global raw materials. This rethinking of energy landscapes demands a systemic view integrating spatial, political, and ecological dimensions (Ghosn 2010). Europe's green transition will require more than technological innovation³⁹. It will demand reconfiguring the relationships between resources, landscapes, and societies. Europe must also ensure its green and digital transitions do not come at the expense of communities and ecosystems in other parts of the world. Stricter regulations on raw

³⁷ The tension between achieving resource sovereignty and maintaining global economic integration underscores the challenges ahead.

³⁸ Europe to promote higher environmental and social standards throughout its global supply chains (Pitron 2020).

³⁹ This becomes even more pronounced when viewed through the lens of the landscapes of energy. As the energy infrastructure and resource networks that fuel industrial societies are not simply isolated systems but embedded within vast and complex geographical, political, and ecological contexts (Ghosn 2010). For example, Europe's push for local extraction of CRMs will reshape its ecological and social landscapes. These changes will require a careful balance between minimizing environmental degradation from mining activities and ensuring that the impacts of resource extraction do not disproportionately burden local communities.

material imports, greater transparency in supply chains, and support for global initiatives that promote fair labor practices and sustainable mining are essential.

The hidden costs of transition While the EU's CRM strategy marks an essential step toward securing the raw materials needed for its green and digital transitions, the continued integration of Europe into global value chains, along with the hidden environmental and social costs of rare metal extraction, pose significant challenges. The success of Europe's transition will depend on how effectively it can navigate these tensions, promoting sustainability within its borders and across the global landscape of resource extraction.

The lists of Critical Raw Materials (CRM) and Strategic Raw Materials (SCRM) established by the European Union are continuously updated to reflect shifting industrial needs, geopolitical tensions, and supply chain vulnerabilities⁴⁰. These materials are central to sectors such as renewable energy, defense, and digital infrastructure, reinforcing their strategic importance in the socio-ecological transition. Among these, materials essential to lithium-ion battery production are particularly relevant, not only for their economic and geopolitical significance but also for their spatial footprint, environmental impact, and role in shaping industrial dependencies. Within the battery supply chain, lithium and cobalt are the most structurally pivotal elements⁴¹, primarily because of their influence on energy storage capacity, system stability, and thermal management.

⁴⁰ As of the latest revision in March 2023, the EU has identified 34 CRMs, among which 16 are designated as Strategic Raw Materials due to their fundamental role in ensuring technological and economic resilience (European Commission 2023).

⁴¹ Cobalt, in particular, deserves further examination, as its supply is concentrated in a few global production hubs, raising concerns about accessibility, sustainability, and the socio-political dimensions of its extraction.

2.3.raw materials for the digital transition the case of lithium-ion batteries

Lithium-ion batteries are often viewed as a key enabler of the energy transition, yet they present a paradox due to their environmental and social impacts⁴². While they are essential for storing renewable energy and electrifying transportation, their production and disposal involve significant ecological and ethical challenges. As a result, the socio-political consequences of these technologies remain obscured from the end-user, who sees only the final product—clean energy from lithium-ion batteries—without recognizing the trade-offs involved in their production (Latour 1987). The paradox arises⁴³ because while lithium-ion batteries help reduce carbon emissions by enabling renewable energy storage, mining lithium contributes to environmental degradation. Another significant issue is the social impact of mining, particularly in developing countries. Mining activities often lead to the displacement of local communities and the degradation of Indigenous lands, raising serious concerns about human rights and environmental justice (Voskoboynik and Andreucci 2022). This is especially critical because the shift to renewable energy is framed as a path toward a more sustainable and equitable future. Yet, it can exacerbate inequalities in resource-rich but economically disadvantaged regions. Lithium-ion batteries also pose recycling challenges, further underscoring their paradoxical role. While battery recycling technologies are advancing, most lithium-ion batteries are still not properly recycled at the end of their life cycle, resulting in hazardous waste (Harper et al. 2019). This highlights another tension: despite their role in advancing a cleaner energy system, the life cycle of lithium-ion batteries can contribute to environmental harm if recycling systems are improved.

The battery paradox Lithium-ion batteries rely on lithium and other critical raw materials, such as cobalt, nickel, and graphite, which compound these technologies' paradoxical role in the energy transition. Cobalt is a crucial component in the cathodes of many

⁴² Bruno Latour's theory of the "*black box*" offers a valuable lens through which to analyze the paradoxical role of lithium-ion batteries in the energy transition. In this framework, technological objects become *black boxes* when they function smoothly, effectively hiding the complex social, environmental, and material processes that make their operation possible.

⁴³ The paradox of lithium-ion batteries is that while they are indispensable for a sustainable energy transition, their environmental and social costs are significant. Addressing these issues requires advancements in battery technologies and recycling and more sustainable and equitable extraction and production methods.

lithium-ion batteries, especially those used in electric vehicles (EVs) and portable electronics. However, like lithium⁴⁴, cobalt mining has significant environmental and social implications⁴⁵. This presents a striking paradox: cobalt is essential for producing the batteries that power *clean* energy technologies, yet its extraction raises ethical concerns and contributes to social inequities. The environmental impact of cobalt mining is similarly troubling. Mining activities lead to habitat destruction, water contamination, and soil degradation, particularly in areas with weak regulatory oversight (Haque et al. 2014). As a result, while batteries reduce emissions from fossil fuels, their production generates new environmental harms, particularly in regions already vulnerable to ecological degradation. In addition to the ethical and environmental issues, reliance on critical raw materials like cobalt creates supply chain vulnerabilities that complicate the energy transition. Cobalt and nickel, for instance, are concentrated in a few countries, making supply chains susceptible to geopolitical tensions, market volatility, and resource nationalism (Binnemans et al. 2013). This reliance on a limited number of suppliers raises concerns about the sustainability of scaling up battery production to meet growing global demand.

Unboxing the battery The actor-network theory (*ANT*) provides a valuable perspective for understanding these paradoxes. Technologies like lithium-ion batteries result from interactions among a wide range of human and non-human actors, from miners and local communities to the global supply chains that facilitate resource extraction (Latour 2005). The battery’s reliance on critical materials like lithium, cobalt, and nickel shows how interconnected and vulnerable these networks are. When any part of this network is destabilized by environmental degradation or social unrest, the black box opens, revealing the hidden costs. For instance, growing concerns about unethical mining practices and environmental impacts have begun to expose these hidden dy-

⁴⁴ i.e., “*Environmental and socio-political challenges of copper and lithium extraction in Chile*”.

⁴⁵ Mining is often linked to severe human rights violations, including child labor and unsafe working conditions. See Amnesty International (2016) *This is what we die for. Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt*.

namics, leading to calls for alternative battery technologies⁴⁶ and better governance of critical raw material supply chains (Tarascon 2020). To address these paradoxes, Latour's theory invites reflection on how to *unbox* lithium-ion batteries and expose the full range of material, environmental, and social costs involved in their production. By revealing these hidden consequences, stakeholders can advocate for technological innovations, such as the development of solid-state or lithium iron phosphate (LFP) batteries, and push for more responsible and equitable governance of resource extraction (Voskoboynik and Andreucci 2022). This *unboxing* process could lead to more transparent and sustainable practices, helping to align the energy transition with broader environmental and social justice goals (Klein 2014).

The *black box* theory illuminates how lithium-ion batteries, celebrated for their role in the clean energy transition, obscure the complex resource extraction networks and environmental degradation underpinning their production. By applying this theoretical framework, we can better understand the paradoxes inherent in the reliance on these technologies and the importance of making these hidden dynamics visible to ensure a more sustainable and just energy transition. As the world increasingly shifts towards renewable energy and electric vehicles to reduce dependence on fossil fuels, it becomes heavily dependent on a few critical minerals, many of which are sourced from politically unstable or environmentally sensitive regions. This creates new forms of dependency that, in some cases, may mirror the geopolitics of oil. Using critical raw materials such as cobalt in lithium-ion batteries exemplifies the complex and often paradoxical energy transition. While these materials are indispensable for reducing greenhouse gas emissions and transitioning away from fossil fuels, their extraction and use raise significant environmental, social, and geopolitical concerns. Addressing these issues requires technological advancements and a broader, more equitable approach to resource governance and supply chain management.

⁴⁶ Efforts to mitigate the impacts of using critical materials like cobalt include research into alternative battery chemistries and materials, such as solid-state batteries or lithium iron phosphate (LFP) batteries, which reduce or eliminate the need for cobalt and nickel (Tarascon 2020). Additionally, there is a growing focus on improving the recycling of these materials to reduce the demand for virgin extraction. However, the recycling rates for these critical raw materials remain low, significantly limiting their potential to offset the market for newly mined resources (Harper et al. 2019).

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3.new cycles the cobalt mining

Cobalt has become one of the most emblematic materials of the transition. Once a marginal by-product of copper and nickel extraction, it now lies at the center of planetary debates on sustainability, energy sovereignty, and technological innovation. Its growing relevance does not stem solely from its chemical properties or its indispensable role in lithium-ion batteries, but from the way its circulation reveals the contradictions of the global economy that claims to move *beyond* fossil fuels while reproducing extractive dependencies on a new scale. In the post-carbon imagination, cobalt functions as both solution and symptom: a resource that enables decarbonization yet perpetuates the same geopolitical hierarchies and ecological asymmetries that have historically structured the world economy⁴⁷. The bulk of the world's cobalt still originates in the DRC, which accounts for more than two-thirds of global output. Extraction is embedded in a landscape of extreme inequality: artisanal miners working under precarious conditions coexist with large-scale industrial concessions controlled by multinational or state-backed corporations. China, in turn, dominates the refining stage, processing over 60 percent of the world's cobalt and securing strategic control over battery manufacturing. Together, the DRC and China form an axis of dependency that defines the current global supply chain, a structure as politically fragile as it is economically efficient. This configuration exposes a fundamental paradox of the so-called green transition. While framed as a shift towards sustainability, it depends on a material infrastructure that remains deeply extractive. The clean-energy economy relies heavily on the intensive mining of critical minerals, whose environmental and social impacts are often externalized to peripheral regions. The promise of decarbonization thus reproduces, under a new technological guise, the colonial division of labor between centers of consumption and zones of sacrifice (Svampa 2019).

In response to the volatility and moral scrutiny of this system, new players such as Canada and Australia have positioned themselves as *responsible* suppliers of critical minerals. Both countries are promoting large-scale mining projects framed within discourses of environmental governance and social accountability. Canada, with deposits concentrated in Ontario and Quebec, emphasizes ethical extraction practices and engagement with Indigenous communities, though these claims are contested by ongoing disputes over land rights and pollution (Angus 2022). Aus-

⁴⁷ As discussed in *Chapter 01*, the geography of cobalt mirrors the broader dynamics of global extractivism, where extraction, logistics, and manufacturing operate as a single, interdependent system of resource circulation.

tralia, similarly, markets its cobalt, often produced as a by-product of nickel mining in Western Australia, as ethically superior, leveraging its stringent regulatory frameworks to attract Western investment. Yet, despite the rhetoric of sustainability, these operations remain embedded in the same global commodity circuits that drive over-production and resource exhaustion. The multiplication of *green mining* frontiers, therefore, represents not a rupture with extractivism but its geographical redistribution under new legitimating narratives. From a geopolitical perspective, the rise of cobalt underscores the reconfiguration of global power around technological minerals. Control over their extraction, refining, and trade has become a new arena of strategic competition, shaping alliances and dependencies much as oil did in the twentieth century. The “*geopolitics of batteries*” now defines relations between industrial powers, linking raw-material supply to questions of energy security, innovation, and military capability. In this context, the DRC–China nexus challenges Western dominance, prompting the United States and the European Union to pursue diversification strategies to secure supply chains through investment, diplomatic partnerships, and the reactivation of domestic mining capacity. However, these initiatives often replicate the same extractive logic they claim to transcend: rather than reducing pressure on resource frontiers, they extend them across new territories. Beyond its geopolitical implications, cobalt also crystallizes a deeper epistemic tension within contemporary environmental discourse. The transition from a fossil to a mineral energy regime does not necessarily imply a transformation of the underlying economic model. Instead, it risks substituting one form of dependency for another, replacing carbon with a new material substratum of global production. The growing reliance on metals such as cobalt, lithium, and rare earth elements underscores the continuity of a world ecology structured around the endless appropriation of cheap nature (Moore 2016). In this sense, cobalt becomes both a literal and symbolic medium through which the contradictions of sustainable capitalism materialize. It embodies the promise of clean technology while concealing the extractive relations that sustain it. At the planetary scale, the expansion of cobalt extraction also foregrounds the temporal dimension of resource politics. Unlike fossil fuels, whose reserves accumulate over geological timescales, critical minerals are finite and dispersed, requiring increasingly invasive forms of exploration and processing. The life cycle of these materials reveals how the transition extends the extractive frontier into new ecological

and technological domains. Recycling initiatives and circular-economy models have been promoted as possible solutions, yet current recycling rates for cobalt remain marginal compared to projected demand (Harper et al. 2019). The temporal mismatch between extraction, consumption, and regeneration underscores the unsustainability of a system that seeks perpetual growth within finite planetary boundaries.

Finally, the global trajectory of cobalt invites reflection on the spatial consequences of these processes within Europe itself. As external dependencies become politically and ethically untenable, attention turns toward the continent's own geological potential. What was once relegated to distant colonial or post-colonial territories now returns to the European landscape, demanding a re-evaluation of extraction not as a remote activity but as an internal territorial question. This marks the transition from a planetary to a regional perspective—from global flows to the reactivation of local extraction sites. The following sections trace this shift, examining how the European search for resource sovereignty and sustainable mining reconfigures the geography of cobalt across multiple scales. Within this continental framework, the Alpine arc emerges as one of the most revealing territories for observing the reconfiguration of extraction in Europe. Historically, the Alps have operated as both barrier and hinge. Their geological complexity conceals significant deposits of nickel, copper, and cobalt. Once exploited and later abandoned, these deposits now return to strategic relevance, positioning the mountains at the intersection of resource politics, environmental policy, and regional development.

The renewed attention to Alpine mineral resources must be understood as part of a broader shift in how Europe conceives the role of its internal peripheries. In contrast to the colonial logic that externalized extraction to distant territories, the new European strategy re-inscribes resource production within its own landscapes. This movement redefines the Alps not as untouched natural heritage but as an infrastructural and ecological frontier where the material conditions of the energy transition are negotiated. The region's high environmental value and historical layering make it a particularly delicate context, one that may serve as a testing ground for how extraction might be redefined under contemporary environmental and social conditions. The Alps combine fragile ecosystems, tourism economies, and strong local governance structures, creating a context in which the reactivation of extraction inevitably takes on a social and cultural dimension. Mining debates thus transcend

the technical sphere, touching on questions of landscape identity, ecological ethics, and territorial autonomy.

In the western sector, particularly in Piedmont, exploration activities have identified cobalt- and nickel-bearing formations associated with ophiolitic complexes. Although still in preliminary phases, these projects indicate how mining, once external to the European imagination, is being re-inscribed into its mountainous heart. The Alps thus function as a laboratory of cohabitation between environmental regulation, industrial resurgence, and community resistance, a field where the contradictions of the green transition become visible and negotiable. Seen from this perspective, the return of extraction is not merely an episode in Europe's material policy but a critical experiment in spatial governance. It challenges inherited distinctions between natural and industrial landscapes, between conservation and production, between center and periphery. The mountains, long romanticized as repositories of purity and stability, are now reimagined as dynamic infrastructures of transition, mediating between the continent's ecological aspirations and its material dependencies. As such, the Alpine arc stands as both a microcosm and a test site: a place where the global circuits of cobalt and the local politics of territory converge, shaping a new geography of European extraction that will be explored in the following sections.

3.1.global scale, an overview

Building on the discussion of Critical Raw Materials (CRM) and lithium-ion batteries, cobalt emerges as a key element in Europe's strategy to secure essential resources. As the European Union aims to reduce its reliance on external suppliers, cobalt has attracted attention for its functional properties and the geopolitical, environmental, and economic challenges associated with its extraction and trade. Cobalt extraction is critical in several global industries, particularly rechargeable batteries, catalysts, and superalloys. The demand for cobalt has grown substantially due to the increasing use of electric vehicles and the expansion of high-tech industries, as cobalt is essential to improving the performance of lithium-ion batteries⁴⁸. Its ability to improve battery efficiency, extend lifespan, and enhance energy storage makes it indispensable in energy transitions and digitalization efforts.

Cobalt geographies On a global scale, cobalt production has risen steadily over the past few years, with an estimated total output of around 170,000 tons in 2022. However, the cobalt supply chain is characterized by high concentration in raw material extraction and refining capabilities. The Democratic Republic of Congo (DRC), Canada, and Australia⁴⁹ are the leading contributors to this industry, with the DRC alone supplying over 70% of global cobalt production (Sun et al. 2019). Meanwhile, China dominates the refined cobalt market, accounting for over 60% of global refining capacity. This high concentration level raises concerns about supply chain vulnerabilities, particularly for regions like Europe that depend on stable access to cobalt for clean energy technologies. The cobalt market is shaped by several key players, with geopolitical and economic factors heavily influencing production and trade flows. While the DRC dominates cobalt mining, China's refining monopoly gives it an outsized influence over global cobalt supply chains. Countries like Canada and Australia position themselves as ethical alternatives, offering cobalt produced under stricter environmental and social regulations. These nations are increasingly seen as stable cobalt

⁴⁸ The broader significance of cobalt within the energy transition becomes clearer when framed against global spatial patterns of extraction and human pressure. The accompanying maps show how the mining footprint, the distribution of transition minerals, and the overlap between resource frontiers and densely impacted territories reveal a highly uneven geography of material dependencies. They underscore that Europe's demand for battery-related minerals is embedded in these global dynamics, where critical raw materials are concentrated in regions facing the greatest ecological and socio-environmental vulnerabilities (fig.3.1–5).

⁴⁹ Where cobalt is mainly produced as a by-product of nickel mining.

sources for industries seeking to diversify away from the DRC and China, particularly amid geopolitical tensions and ethical concerns regarding supply chain transparency (Brierley et al. 2022).

From a trade perspective, cobalt has evolved into a globally integrated commodity, with extraction, refining, and manufacturing often occurring in different locations. The study by Sun et al. (2019) traces global cobalt flows from 1995 to 2015, highlighting shifts in extraction hubs and market dynamics. During this period, the cobalt in-use stock reached 220 kilotons, with significant portions embodied in consumer electronics and rechargeable batteries. Secondary cobalt recovery is increasingly seen as a crucial strategy to improve resource utilization efficiency, particularly given the finite nature of cobalt reserves and the environmental impact of primary extraction.

Supply chains, ethics, and future perspectives Despite efforts to diversify supply chains, cobalt remains a mineral with a high geopolitical risk. The DRC's dominance in mining is coupled with serious concerns over human rights violations, including child labor and hazardous working conditions in artisanal mines. These ethical considerations have led to growing calls for supply chain transparency, responsible sourcing initiatives, and increased investments in battery recycling and alternative chemistries that reduce cobalt dependence. Looking ahead, the future of cobalt mining and supply will be shaped by several key trends, including technological advancements in battery chemistry that may reduce cobalt content in lithium-ion batteries. Improvements in recycling infrastructure to recover cobalt from end-of-life batteries and ongoing geopolitical shifts that may impact the stability of major cobalt-producing regions. While cobalt will remain essential in the foreseeable future, achieving a sustainable, ethically responsible supply chain will require coordinated efforts by governments, industry stakeholders, and international organizations.

Cobalt dominance The Democratic Republic's overwhelming share solidifies its position as the most critical node in the global cobalt supply chain, linking mineral extraction to high-tech industries dependent on lithium-ion batteries. The DRC's cobalt reserves are primarily extracted as a byproduct of copper mining, with vast deposits in the Katanga region, a mining hub attracting significant international interest. However, extraction is marked by stark contrasts between large-scale industrial

operations and small-scale artisanal mining, each with distinct economic, environmental, and social implications. Most of the country's cobalt production stems from artisanal and small-scale mining (ASM). This decentralized sector employs hundreds of thousands of workers under precarious and often dangerous conditions. ASM mining accounts for an estimated 15-30% of total cobalt production in the DRC (Haque et al. 2020). Artisanal miners, known as '*creuseurs*', typically operate informally, extracting cobalt-rich ores using rudimentary tools with minimal safety measures⁵⁰.

Despite these challenges, ASM plays a crucial socio-economic role, providing livelihoods to local communities where formal employment opportunities are scarce. Efforts to regulate and formalize ASM mining in the DRC have faced structural barriers, including weak governance, corruption, and the influence of powerful mining interests. Initiatives such as traceability programs and ethical sourcing certification schemes have attempted to mitigate these risks, yet implementation remains inconsistent across different mining regions. Beyond ASM, large-scale mining (LSM) in the DRC is dominated by multinational corporations and, increasingly, Chinese firms that have consolidated control over vast mining concessions. Chinese investment has been a defining force in the Congolese mining sector, with state-backed enterprises securing long-term mining contracts and infrastructure deals reinforcing Beijing's influence over global cobalt flows. The acquisition of significant mining operations by Chinese conglomerates⁵¹, exemplifies the deep entrenchment of Chinese capital in the country's mineral economy. These investments not only shape the DRC's economic and political landscape but also extend China's reach across the entire cobalt value chain, from extraction to processing and battery manufacturing. While the DRC leads in raw cobalt extraction, China dominates the global market for refined cobalt, accounting for over 60% of the world's total refined co-

⁵⁰ The lack of regulation has led to frequent reports of hazardous working conditions, child labor, and exploitative labor arrangements. Amnesty International (2016) and other advocacy groups have repeatedly documented cases of human rights abuses, highlighting the sector's vulnerability to forced labor, extreme poverty, and health risks due to prolonged exposure to toxic materials.

⁵¹ Such as China Molybdenum's control of the Tenke Fungurume Mine.

balt production in 2018⁵². This concentration of refining power in China has raised concerns among Western nations regarding supply chain security and ethical sourcing. The heavy reliance on a single processing hub introduces vulnerabilities in the case of geopolitical disputes, trade restrictions, or supply disruptions. Countries like the United States and European Union members are actively exploring ways to reduce dependency on Chinese refining, investing in alternative processing facilities, and fostering partnerships with resource-rich countries outside China's direct sphere of influence. Efforts to diversify cobalt supply chains have increased interest in alternative sources, particularly in Canada, Australia, and emerging European deposits. These regions are positioning themselves as sustainable and ethical suppliers, promoting high environmental and labor standards in mining operations. However, challenges remain in scaling up production to levels that could significantly reduce dependence on the DRC and China. The cost of extraction, regulatory barriers, and the need for extensive infrastructure investments slow down efforts to create independent cobalt supply chains outside traditional hubs.

Looking ahead, several interrelated trends will shape the future of cobalt mining and supply. Advances in battery chemistry, particularly the development of lithium-iron-phosphate (LFP) and solid-state batteries, could reduce or eliminate cobalt use in energy storage applications. Improvements in recycling infrastructure aim to recover cobalt from spent batteries, reducing the need for primary extraction and contributing to a more circular economy. However, these innovations are still in their early stages and require further technological advancements and policy support to become scalable alternatives. As the global demand for cobalt continues to rise, the trade-offs between supply chain security, ethical sourcing, and sustainability will define the strategies adopted by major economies. The geopolitical significance of cobalt will remain high, reinforcing its role not only as a key industrial commodity but also as a critical element in shaping global power dynamics in the 21st century.

⁵² Unlike Western nations, which rely on imported raw materials for processing, China has built an integrated supply chain that ensures its dominance in the cobalt sector. This includes overseas mining assets and domestic refining capabilities, allowing Chinese firms to exert significant leverage over global cobalt distribution. China's control over refining also gives it pricing power, as companies processing cobalt into battery-grade materials depend heavily on supply chains.

Emerging cobalt suppliers for Western markets Canada is an emerging player in the global cobalt market, with production levels well below those of the DRC but steadily increasing. Here, cobalt is typically extracted as a byproduct of nickel and copper mining, primarily in Ontario and Quebec⁵³. Canadian cobalt is positioned as a strategic resource for Western industries looking to reduce their reliance on cobalt from conflict zones⁵⁴. Additionally, the government has launched initiatives to promote the domestic production of critical minerals, including cobalt, as part of a broader strategy to support clean energy and electric vehicle industries⁵⁵. However, despite Canada's reputation for ethical mining, challenges and complexities within the country's cobalt industry mirror broader issues in global extractivism. The extraction has been critiqued for its environmental impact and its ties to broader patterns of exploitation in the mining sector⁵⁶ (Angus 2022). These environmental consequences, although regulated, still pose long-term risks to local environments and Indigenous communities living near mining sites. While the law requires consultations with Indigenous communities, there have been instances in which these consultations have been criticized as insufficient or perfunctory. Many Indigenous groups argue that they face disproportionate environmental and social impacts from mining operations, yet they receive limited economic benefits. This tension highlights a persistent challenge in the Canadian mining industry: balancing economic growth with the rights and well-being of Indigenous peoples (Brierley et al. 2022).

The history of Canada's cobalt industry dates back to the early 20th century, particularly in Cobalt, Ontario, which became famous for its mining boom. Although primarily a silver mining town, Cobalt also played a crucial role in developing the national mining sector, as it was one of the first sites where cobalt was discovered as a byproduct. The industrial significance was not fully recognized at the time, and the town focused mainly on silver extraction. However, the legacy of environmental degradation left behind by early mining operations, including soil and water contamination, still affects the region today. Furthermore, this example

⁵³ See *Natural Resources Canada 2020*

⁵⁴ Mining practices adhere to higher social and environmental standards, making the country an attractive alternative to cobalt sources like the DRC.

⁵⁵ See also *NRC (2020)*

⁵⁶ As highlighted by Angus (2022), the mining industry in Canada, despite its positive image, has a dark side often overlooked by mainstream narratives. Nickel-cobalt mining operations in Ontario and Quebec have been linked to significant ecological damage due to the release of toxic byproducts into nearby water systems.

highlights the often-overlooked costs of resource extraction, particularly its long-lasting effects on local ecosystems and communities.

Australia is the third-largest cobalt producer globally, with production concentrated in Western Australia. Like in Canada, cobalt is primarily extracted as a byproduct of nickel mining. The investments in clean energy and high environmental standards make it a favored supplier for Western markets seeking to reduce their dependence on cobalt from regions with significant ethical and ecological challenges. As in Canada, Australia's mining sector also reveals a lesser-known *dark side* that raises concerns about the environmental and social impacts of large-scale extraction. While Australia has a solid regulatory framework to manage impacts, mining activities, particularly in remote regions of Western Australia, have disrupted ecosystems and contaminated water sources by releasing mining byproducts, including heavy metals and chemicals. The extraction generates significant waste, and despite adopting modern environmental practices, the scale of operations often leads to long-term ecological risks, including soil and water degradation.

Similarly, recurring tensions emerge around Indigenous land rights and environmental justice⁵⁷. Many mining operations in Australia are located on or near traditional lands, creating ongoing tensions between economic development and the protection of local cultural and environmental heritage. While legal frameworks mandate consultations with affected communities, the effectiveness of these processes varies widely. In some cases, communities have expressed concerns that they are not meaningfully included in negotiations and that their objections to projects carry little weight in final decisions. Some communities argue that they bear a disproportionate share of the environmental consequences of large-scale mining while receiving limited economic benefits. In particular, land degradation caused by mining can have profound effects on communities that rely on their ancestral territories for livelihoods, spiritual practices, and cultural identity. The challenges faced by these groups in Australia mirror those seen in Canada, where similar tensions have arisen over the impacts of mining on traditional territories and the extent to which local landholders can exert influence over extractive

⁵⁷ Both countries face challenges related to mining on Indigenous lands. However, in Canada, the conversation around Indigenous land rights has been particularly prominent, with ongoing legal disputes and more organized resistance from Indigenous groups. Australia's system of land consultations is also robust, but there is criticism that Indigenous voices are sometimes marginalized in decision-making processes, particularly in remote areas where economic pressures can dominate.

projects (Angus 2022). These issues highlight broader patterns within resource extraction industries, where legal recognition of land rights does not always translate into genuine decision-making power, reinforcing structural inequalities in mining governance.

Despite their differences in scale and geography, both Canada and Australia illustrate how Western cobalt suppliers navigate the tension between ethical aspirations and extractive realities. Their experience underscores that even within regulated contexts, the environmental and social contradictions of resource extraction persist. These cases mark a broader shift in the geography of cobalt supply—one that extends beyond traditional mining frontiers and sets the stage for Europe's renewed engagement with its own mineral resources.

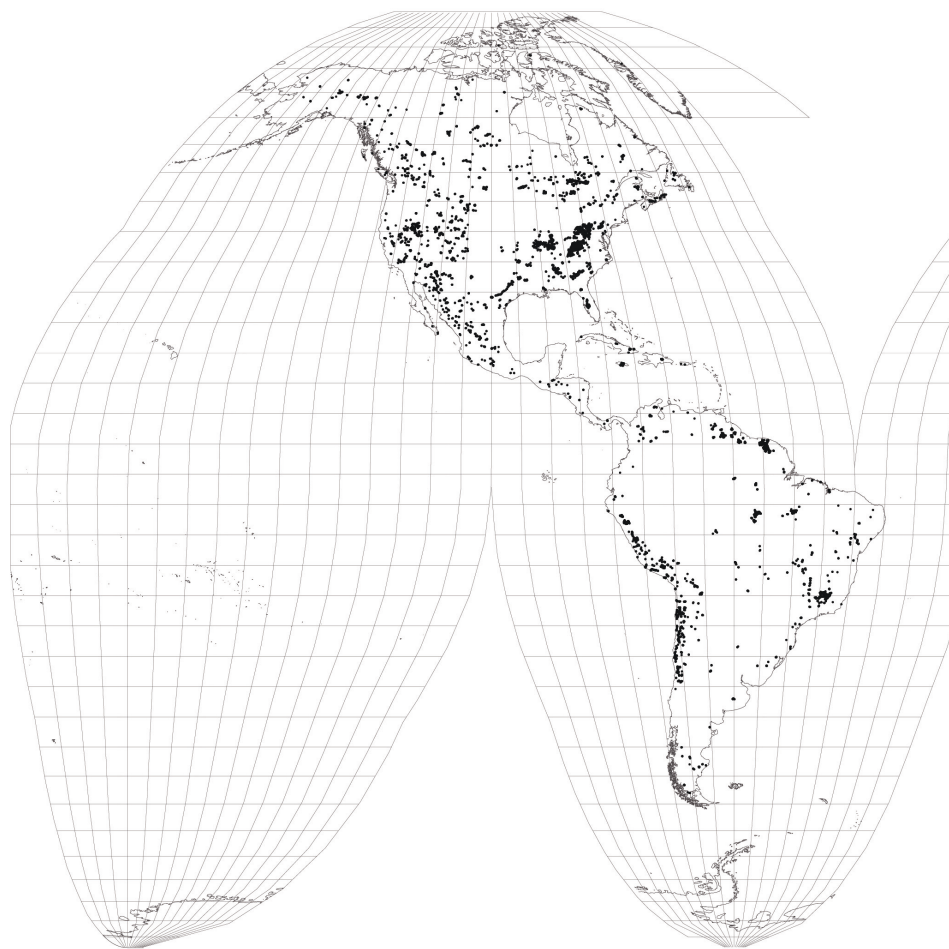


fig.3.1 Global mining footprint

Politecnico di Milano, AUIC School, MSc Landscape Architecture. Land Landscape Heritage, Master's Thesis, *The landscape of Lithium extraction: a Blue Water Scarcity assessment on United States territories*, Marco Gentile.

Supervisor: Davide Chiarelli. Co-supervisors: Marc Müller, Mattia Tettoni.

Academic Year 2025–2026.

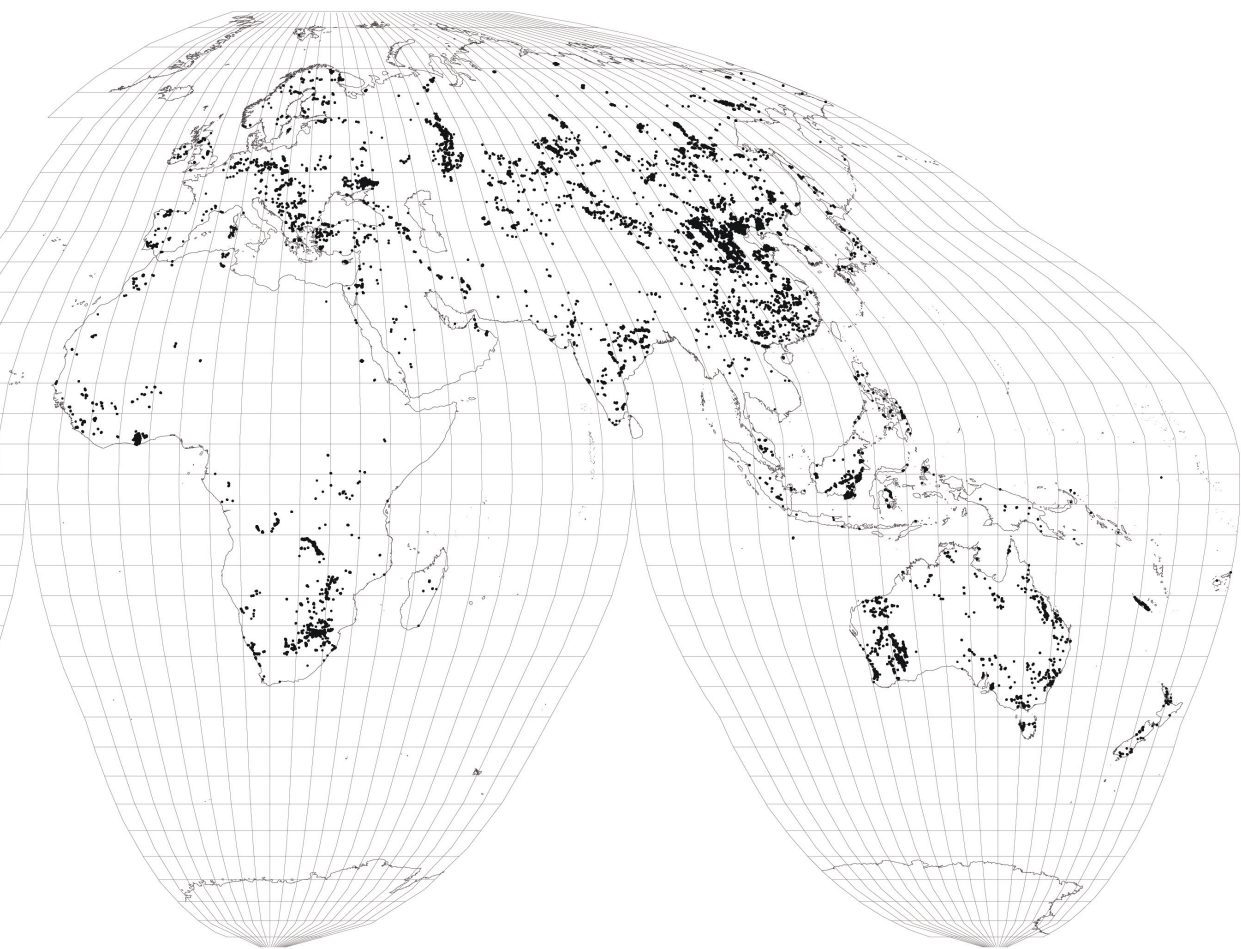


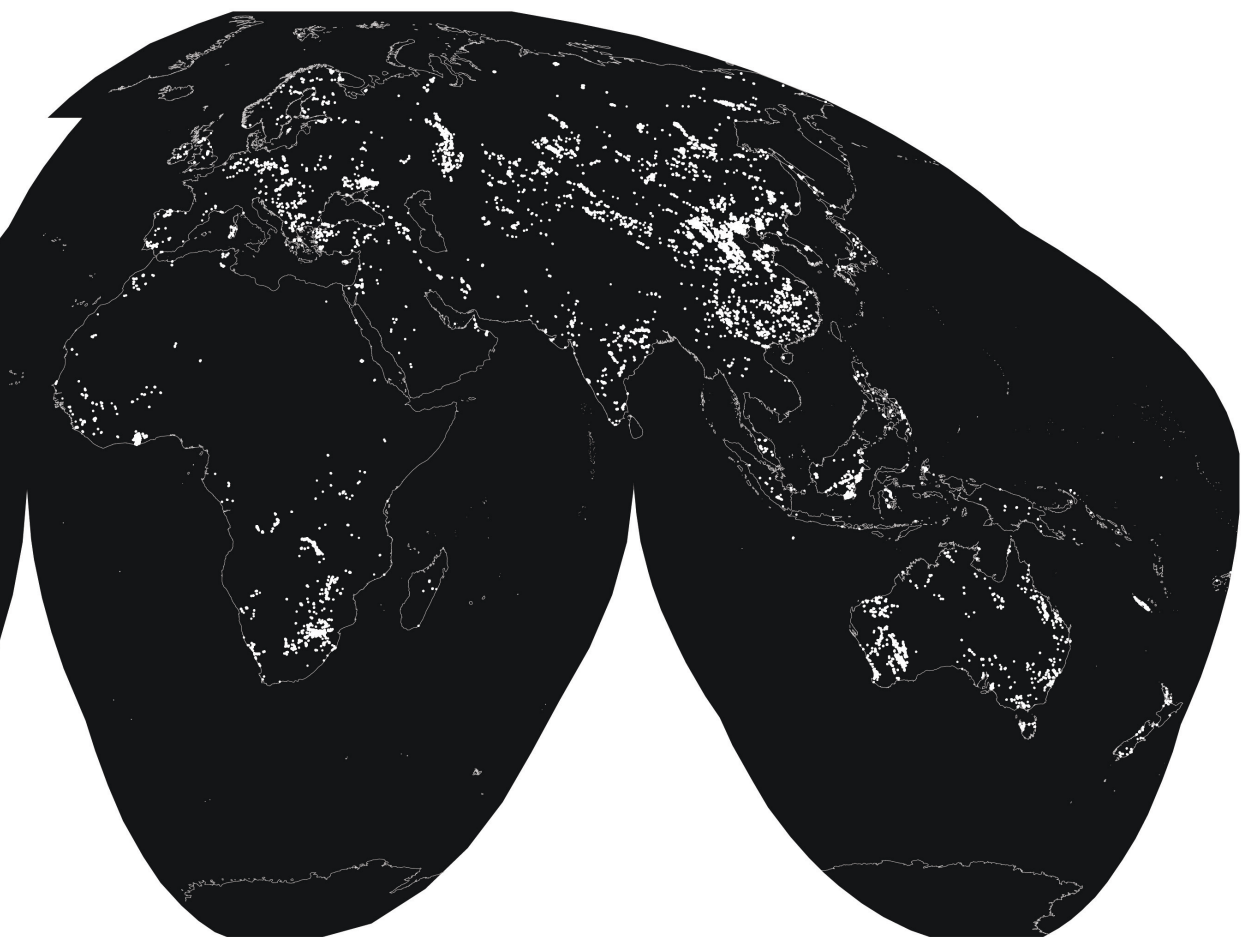


fig.3.2 Global mining footprint.

Politecnico di Milano, AUIC School, MSc Landscape Architecture. Land Landscape Heritage, Master's Thesis, *The landscape of Lithium extraction: a Blue Water Scarcity assessment on United States territories*, Marco Gentile.

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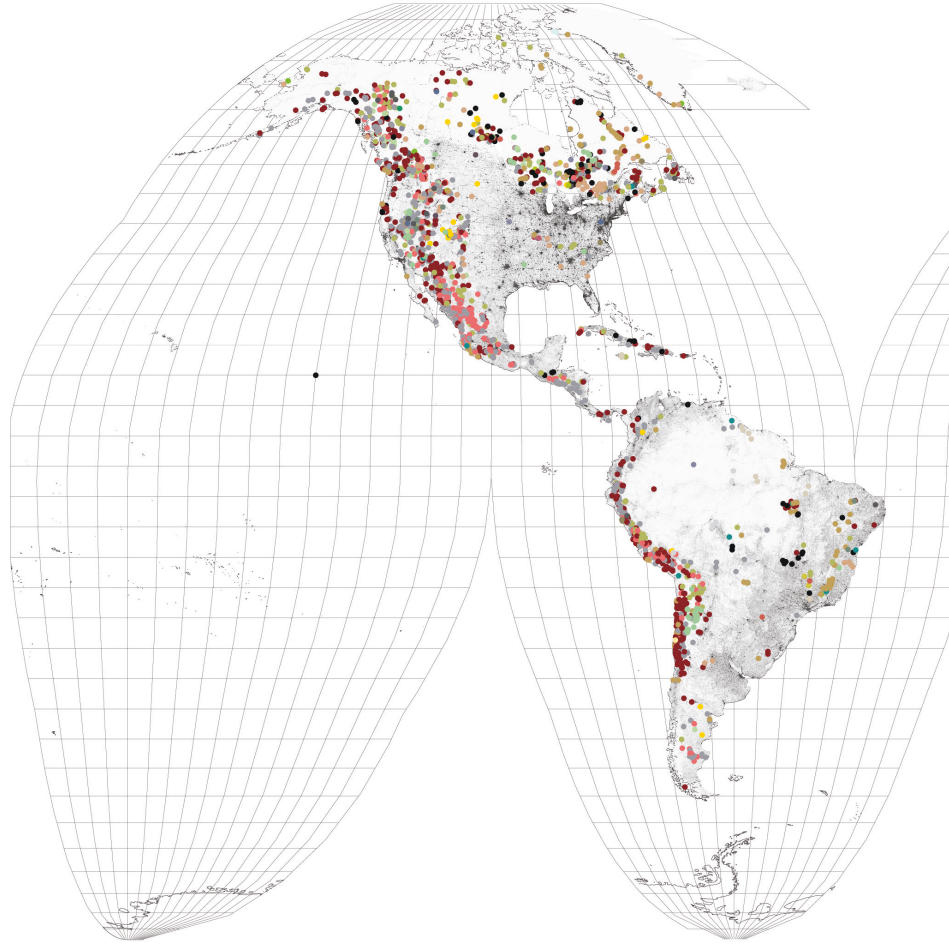
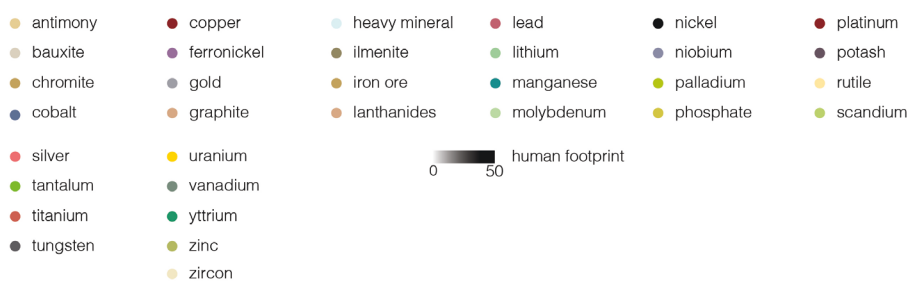
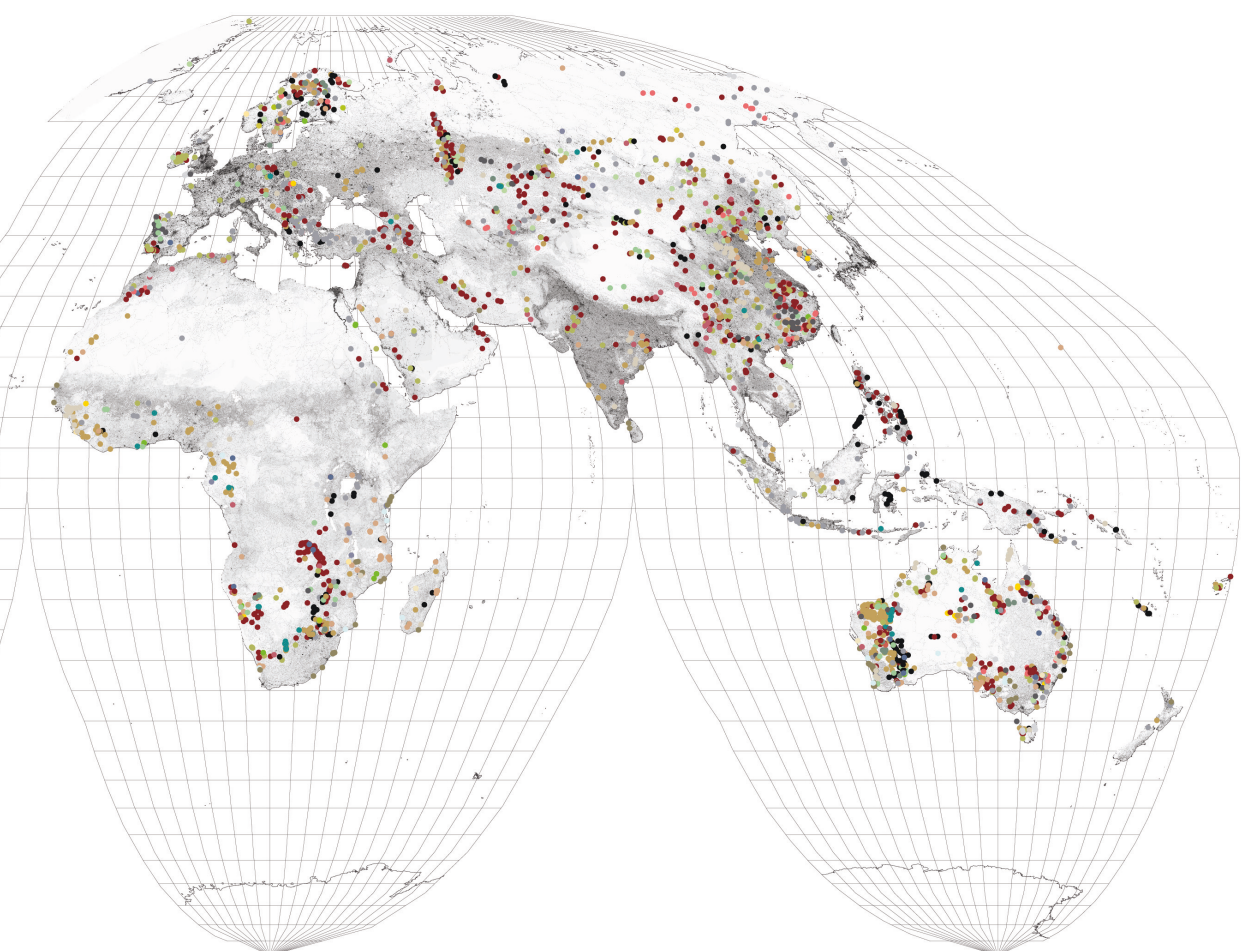


fig.3.3 Global overlap of energy transition mineral and the human footprint.
Politecnico di Milano, AUIC School, MSc Landscape Architecture. Land Landscape Heritage, Master's Thesis, *The landscape of Lithium extraction: a Blue Water Scarcity assessment on United States territories*, Marco Gentile.
Supervisor: Davide Chiarelli. Co-supervisors: Marc Müller, Mattia Tettoni.
Academic Year 2025–2026.



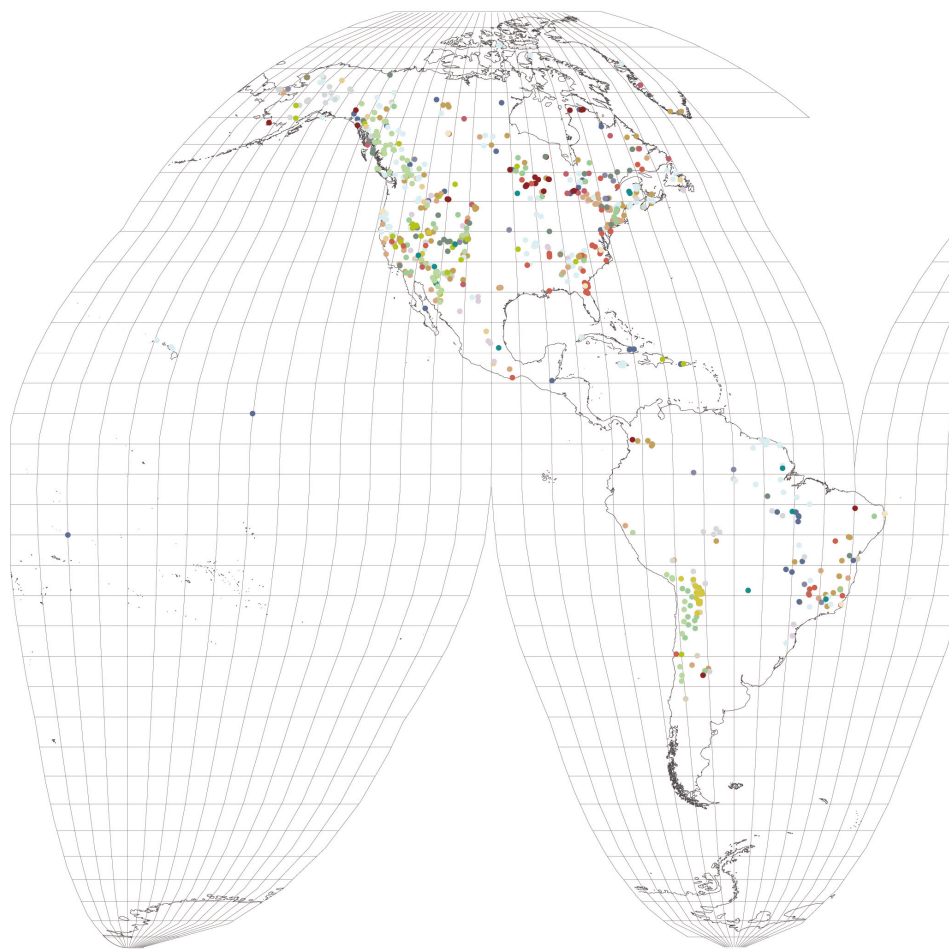
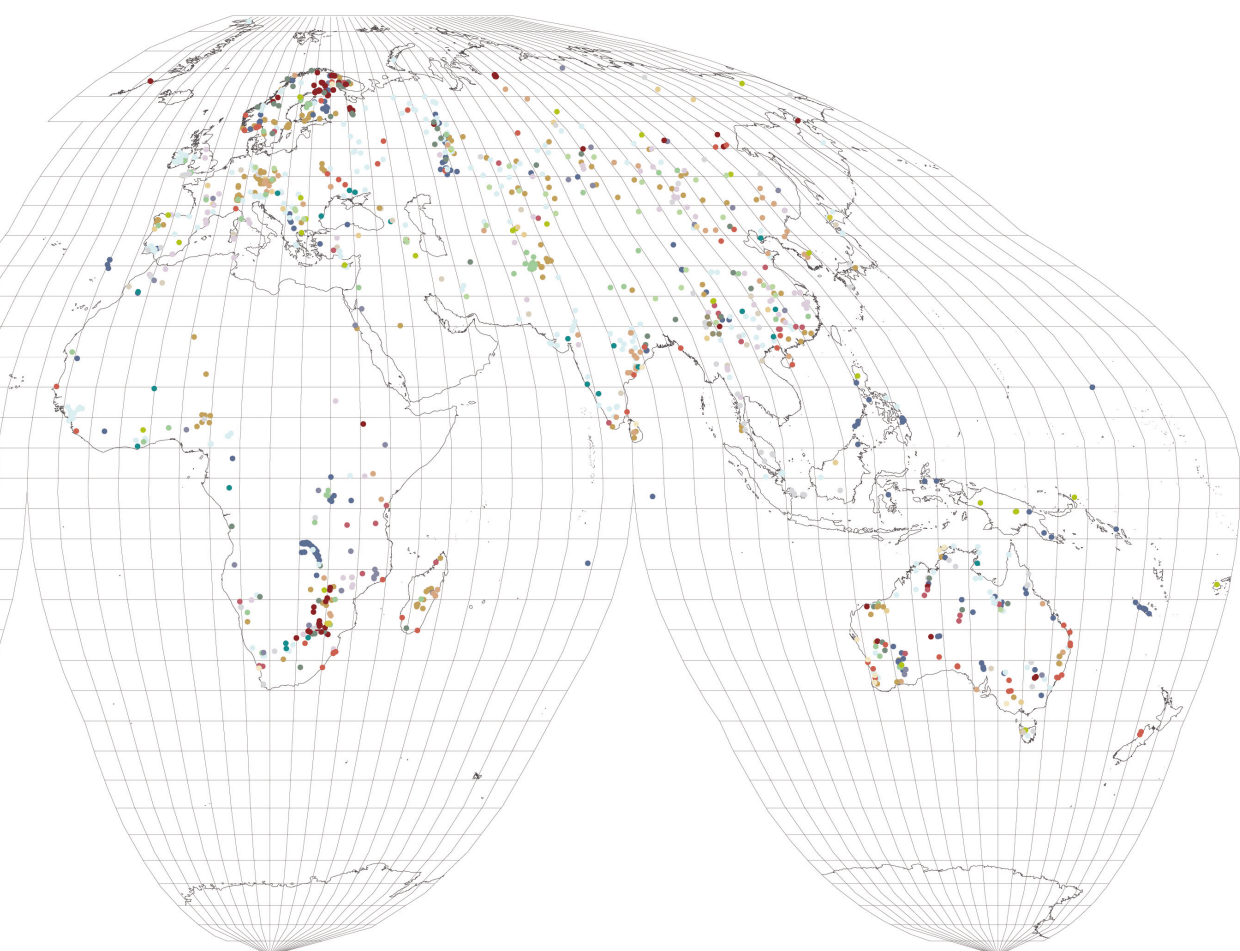


fig.3.4 Global spatial distribution of Critical Minerals.

Politecnico di Milano, AUIC School, MSc Landscape Architecture. Land Landscape Heritage, Master's Thesis, *The landscape of Lithium extraction: a Blue Water Scarcity assessment on United States territories*, Marco Gentile

Supervisor: Davide Chiarelli. Co-supervisors: Marc Müller, Mattia Tettoni.

Academic Year 2025–2026.



- | | | | | |
|-------------|-------------|--------------------|----------------------|---------------------|
| ● antimony | ● fluorite | ● indium | ● platinum-gr. elem. | ● tin |
| ● barite | ● gallium | ● lithium | ● rare-earth elem. | ● titanium |
| ● beryllium | ● germanium | ● manganese | ● rhenium | ● vanadium |
| ● cobalt | ● graphite | ● niobium-tantalum | ● tellurium | ● zirconium-hafnium |

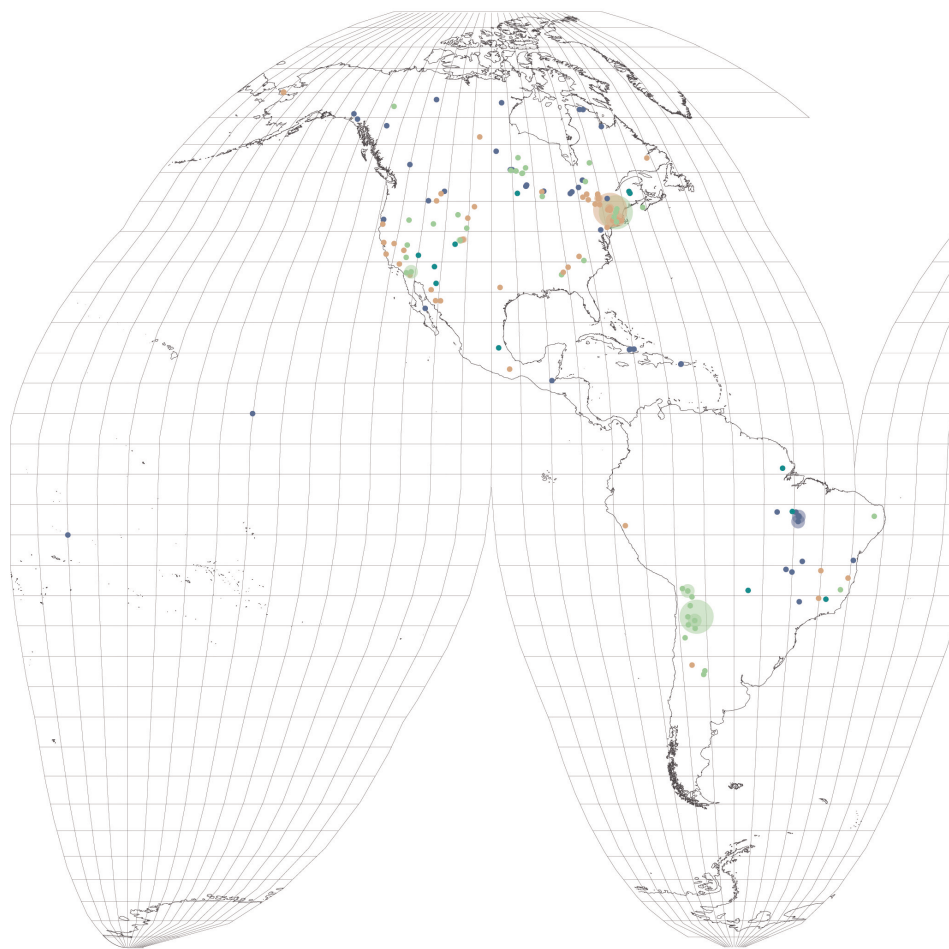
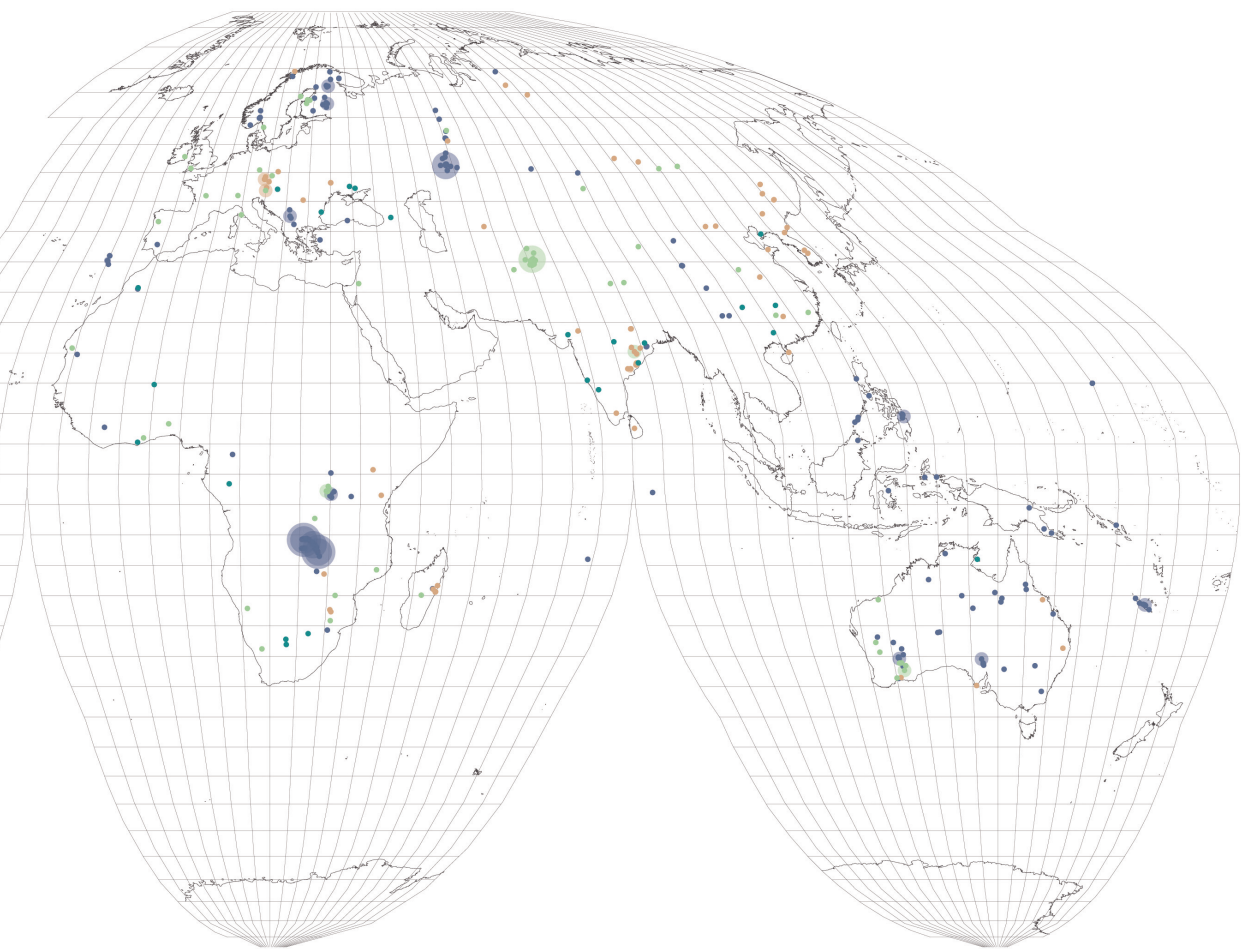


fig.3.5 Global spatial distribution of Critical Minerals essential for electric vehicle batteries. Politecnico di Milano, AUIC School, MSc Landscape Architecture. Land Landscape Heritage, Master's Thesis, *The landscape of Lithium extraction: a Blue Water Scarcity assessment on United States territories*, Marco Gentile. Supervisor: Davide Chiarelli. Co-supervisors: Marc Müller, Mattia Tettoni. Academic Year 2025–2026.



- cobalt
- graphite
- lithium
- manganese

3.2.regional scale contrast and paradoxes

While Europe has historically played a limited role in global cobalt production, recent studies suggest the continent holds significant untapped potential for resource development (Horn et al. 2021). In particular, Finland, Norway, and Sweden have emerged as critical regions with established cobalt extraction projects, while other areas offer prospects for discoveries. This marks a significant shift as Europe aims to reduce its dependence on cobalt imports (Hao et al. 2019).

Toward resource sovereignty: Europe's cobalt turn Europe's cobalt resources are mainly magmatic nickel-copper sulfide deposits, volcanogenic massive sulfide deposits, and sediment-hosted copper-cobalt deposits (Horn et al. 2021). Finland leads cobalt production in Europe, mainly through the Kevitsa and Talvivaara mines, which extract cobalt as a byproduct of nickel and copper mining. Norway and Sweden also contribute, but these countries are still in earlier stages of development, exploring their potential for large-scale production. Despite these advancements, Europe's contribution to global cobalt production still needs to grow, necessitating further exploration and investment to unlock greater resources. European policymakers and industries have recognized the need for a secure and sustainable cobalt supply chain within Europe⁵⁸. The European Union's emphasis on the circular economy and sustainable resource management further drives the push for domestic cobalt extraction, aligning with broader goals outlined in initiatives like the European Green Deal (Horn et al. 2021).

Advancements in exploration technologies and a deeper understanding of geological settings conducive to cobalt mineralization support the potential for new cobalt discoveries in Europe. Northern Europe, especially the Fennoscandian Shield, has shown considerable promise, with emerging projects in Finland and Sweden exploring greenfield and brownfield sites. Moreover, regions with historically lower levels of exploration, such as southern Europe, could yield new deposits as exploration activity intensifies (Horn et al. 2021). Sustainability remains a critical consideration in future cobalt extraction. Europe's approach to mining is increasingly focused on reducing environmental impacts and promoting responsible resource management. The incorporation of advanced technologies in mining, combined with stringent environmental

⁵⁸ According to van den Brink et al. (2020), the cobalt supply chain is vulnerable to disruptions due to the concentration of production in a few regions and the growing geopolitical risks associated with cobalt-exporting countries.

regulations, positions Europe as a leader in sustainable cobalt production. This shift aligns with efforts to reduce the ecological footprint of cobalt mining globally, which has been a significant concern due to the social and environmental challenges associated with cobalt extraction in other parts of the world (van den Brink et al. 2020).

Critical minerals in the Alpine belt The Alpine orogenic belt, which spans several European countries, including France, Switzerland, Italy, Austria, and Slovenia, is increasingly recognized as a strategically important region for extracting CRM, including cobalt. This geological region is characterized by complex tectonic processes that have formed diverse mineral deposits, making it a promising area for exploration and extraction of valuable resources. One of the key reasons it is considered strategic for CRM extraction is its geological diversity. The region hosts a range of mineral deposit types, including magmatic, hydrothermal, and sedimentary deposits, which are known to contain cobalt and other critical metals such as nickel, copper⁵⁹, and rare-earth elements. This geological richness provides a basis for further exploration and potential resource development. The Alpine region's proximity to key industrial centers in Europe enhances its strategic importance. The demand for cobalt and other critical raw materials is closely tied to the European Union's industrial strategy, particularly for sectors such as electric vehicle manufacturing, renewable energy, and advanced battery production. By increasing domestic supply from regions such as the Alpine orogenic belt, Europe could reduce its reliance on cobalt imports, which are currently dominated by non-EU countries, thereby enhancing its resource security and resilience⁶⁰. Moreover, projects within the Alpine belt can be designed to meet stringent European Union social and ecological standards, thereby contributing to the EU's goals⁶¹.

⁵⁹ Cobalt is often associated with these deposits, particularly in copper-cobalt and nickel-cobalt ore bodies

⁶⁰ In the 2020 Communication, the European Commission identifies geologically favorable regions as strategic zones where coordinated exploration could help clarify the EU's actual resource base. The document stresses the need for improved geological knowledge and shared data infrastructures across member states, noting that the lack of updated subsurface information constitutes a structural vulnerability in the Union's approach to critical raw materials. (European Commission 2020).

⁶¹ As the demand for cobalt continues to rise, the Alpine region could play a crucial role in securing the EU's supply of critical raw materials. The region's advanced infrastructure, strong regulatory framework, and emphasis on minimizing environmental impacts make it an attractive location for responsible mining.

Strategic cobalt extraction in the Alps: opportunities and geopolitical relevance.

In this context, the Alps represent a paradigmatic European territory—a laboratory—where local and global phenomena can be studied, capable of revealing and anticipating processes and dynamics of the near future. The Alpine orogenic belt, resulting from the collision of the African and Eurasian tectonic plates, has created diverse geological environments rich in mineral deposits. These processes have generated significant mineralization zones, particularly in magmatic, sedimentary, and hydrothermal settings, which are conducive to the formation of sulfide deposits containing cobalt, nickel, copper, and other base metals. The unique environmental and geological dynamics of the Alps are continuously evolving (Kissling 2019), revealing the region’s potential as a *natural* laboratory for studying both ecological processes and the resources beneath the surface. These transformations highlight the Alps’ role in providing insights into environmental change and underscore the strategic importance of understanding their subsoil wealth, including critical raw materials. (fig.3.6–12) Additionally, they are characterized by a variety of geological formations, ranging from ophiolitic complexes to metamorphic rocks, which are particularly favorable for the occurrence of cobalt and other critical minerals. Alpine regions could be considered spaces for ecological and infrastructural development, highlighting their dual challenges and opportunities (Schmid 2009). Identifying cobalt and other CRM in this context aligns with broader European strategies to reduce reliance on imports and secure local sources of essential materials⁶²

Potential areas for cobalt extraction in the Alps are mainly concentrated in regions where magmatic and sedimentary rocks rich in sulfides are found, often associated with copper and nickel deposits. Across the Alpine belt, some of the most promising sites are in Switzerland, Austria, Italy, and Slovenia. Notably, the northern and eastern Alpine sectors have seen growing interest due to mineralized copper-cobalt and nickel-cobalt deposits (Horn et al. 2021). These regions are now being closely examined for their potential to contribute to Europe’s demand for critical raw materials⁶³. In the Italian Alps, exploration activities have intensified in recent years as awareness of the need to develop domestic

⁶² Geological potential is presented as a starting point for rebuilding integrated industrial value chains, linking mineral identification to processing capacities, manufacturing, and broader forms of strategic autonomy (European Commission 2020).

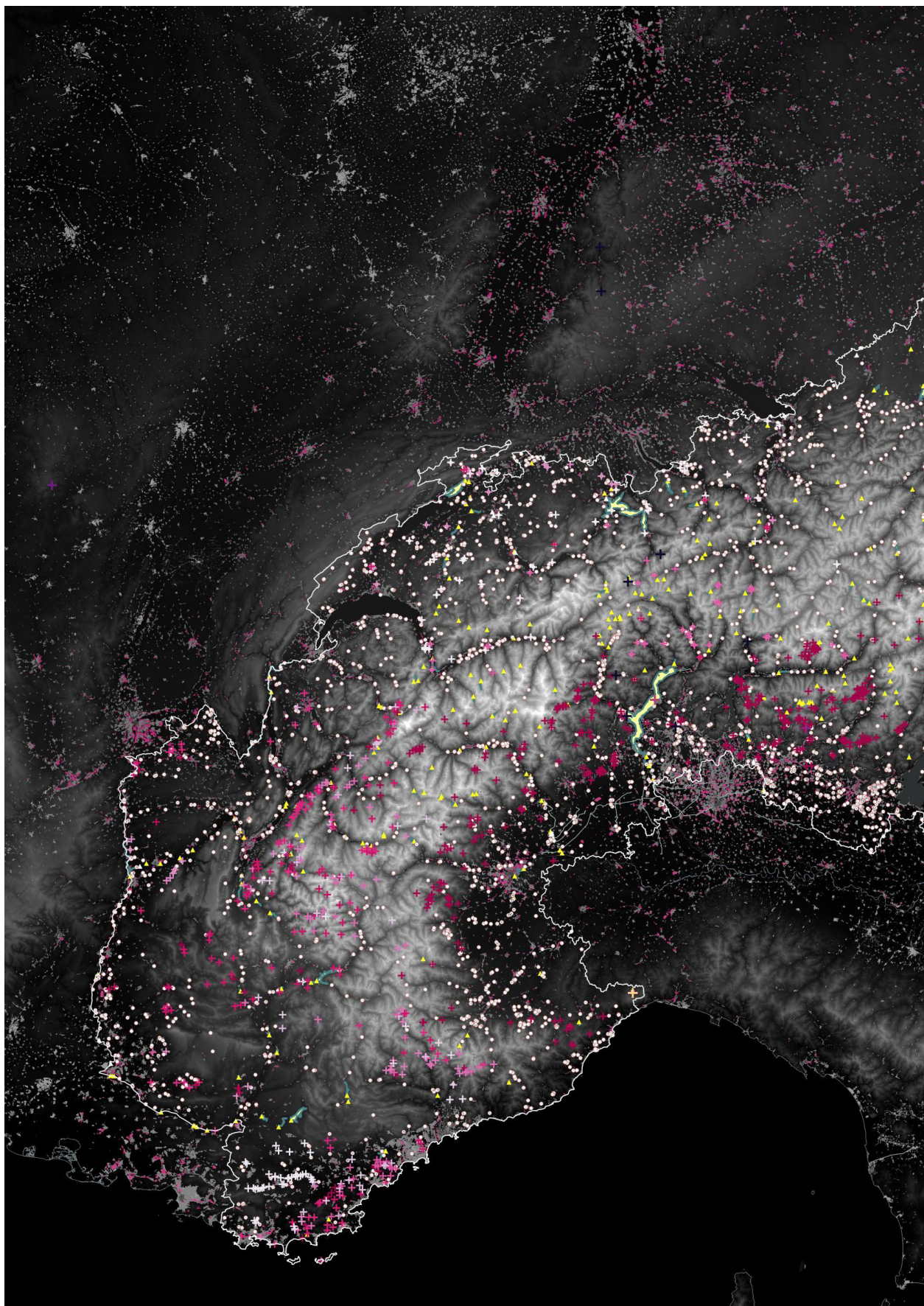
⁶³ The mountainous areas host various geological formations conducive to cobalt mineralization, particularly in association with sulfide deposits.

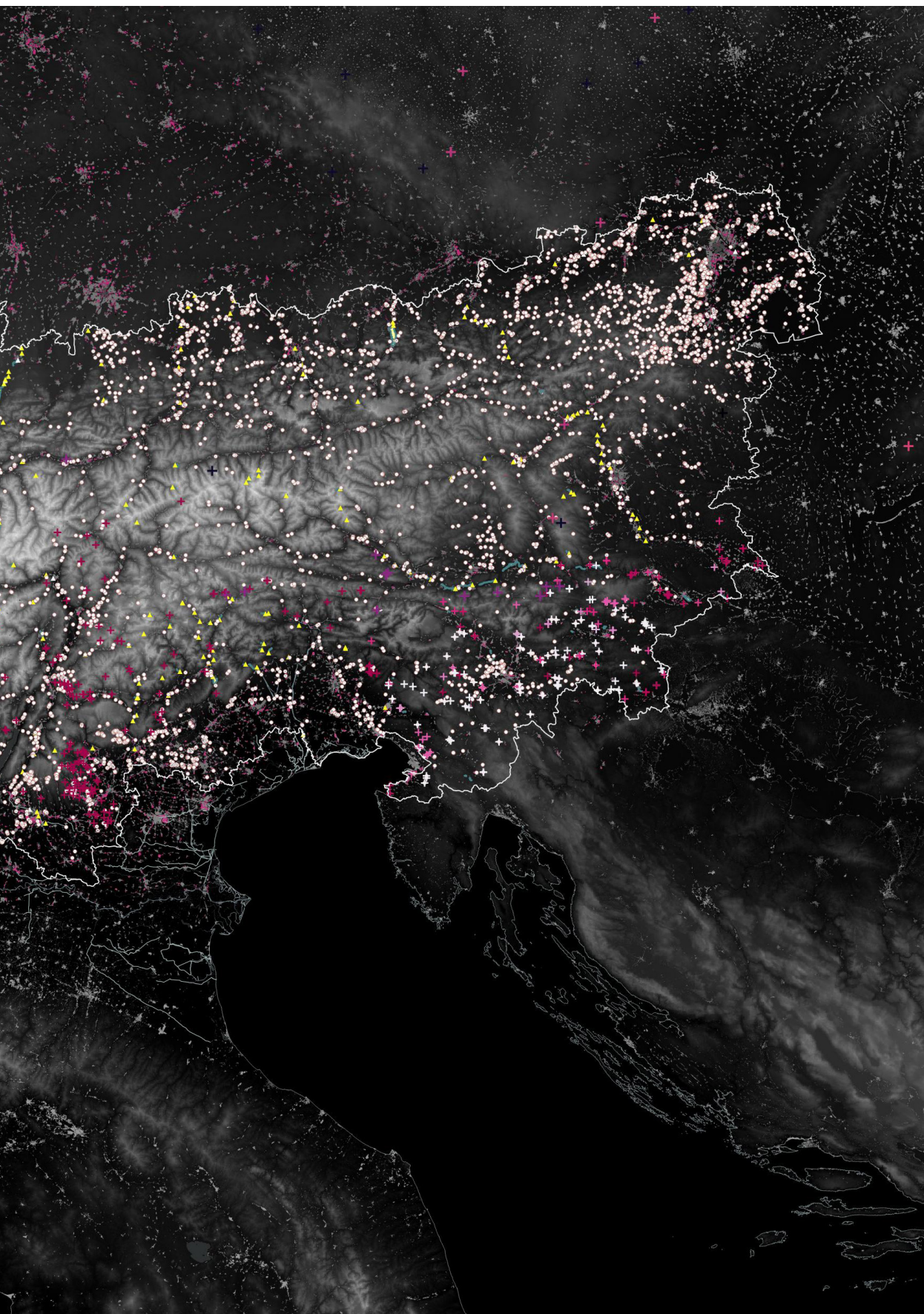
sources of cobalt and other critical materials has grown. With their long mining history dating back centuries, they offer substantial potential for discoveries.

A particular focus should be placed on the Piedmont Alps, which are emerging as a growing focus for cobalt extraction. Piedmont has a long-standing mining tradition, with historical activities centered around copper, gold, and other metals. Recent studies have highlighted the presence of mineralized deposits that could contain significant amounts of cobalt, particularly in the border areas between Piedmont and the Aosta Valley. The geological formations in this region, characterized by ophiolitic rocks and hydrothermal deposits, provide a favorable environment for the concentration of base metals, including cobalt. Moreover, the northern Piedmont has been identified as a potential site for cobalt exploration. These deposits are part of a larger geological structure that crosses the western Alps and has attracted attention from geologists and explorers for its potential to host critical raw materials. Surrounding areas, such as Val di Susa and Canavese, may also be strategic for future cobalt extraction operations, contributing to the security of critical material supplies for the European industry (van den Brink et al. 2020). The attention on the Piedmont Alps is particularly significant due to their favorable geology and proximity to major Italian and European industrial hubs and infrastructures, which could benefit from a local cobalt supply chain⁶⁴.

⁶⁴ The strategic relevance of regions like the Piedmont Alps is linked to the possibility of anchoring extraction to nearby processing and manufacturing capacities, reinforcing integrated value chains and reducing external dependencies (European Commission 2020)

fig.3.6 The diagram synthesizes the multiple layers of resource exploitation that structure Alpine territories today—ranging from historical and contemporary mineral extraction to open-pit inert-material quarries and the extensive hydroelectric infrastructures embedded in the landscape. Seen together, these strata reveal how different forms of appropriation, abandonment, and reactivation intersect within the same spatial frame, offering a composite reading of the Alps as a palimpsest of extractive processes





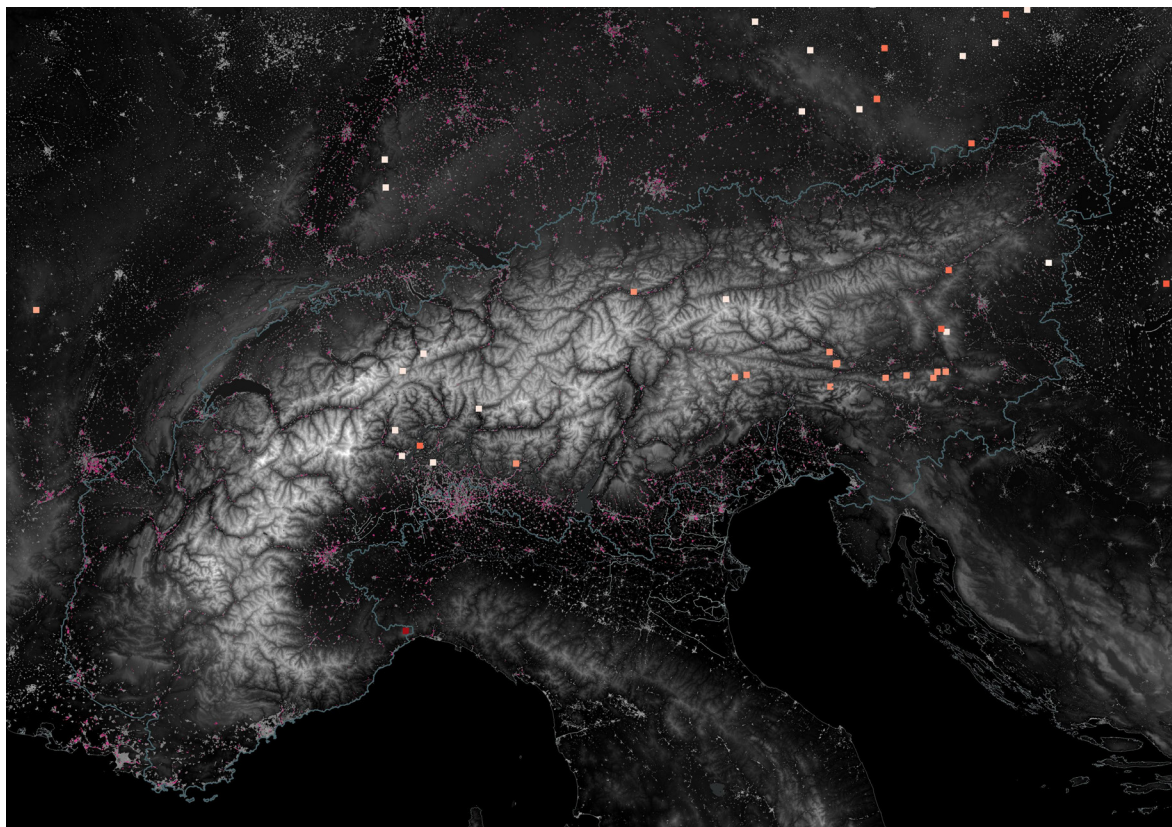


fig.3.7 Mineral extraction.

Current sites of mineral extraction across Europe, including locations potentially relevant for future CRM exploitation.

Database: *European Commission RMIS–Raw Materials Information System.*

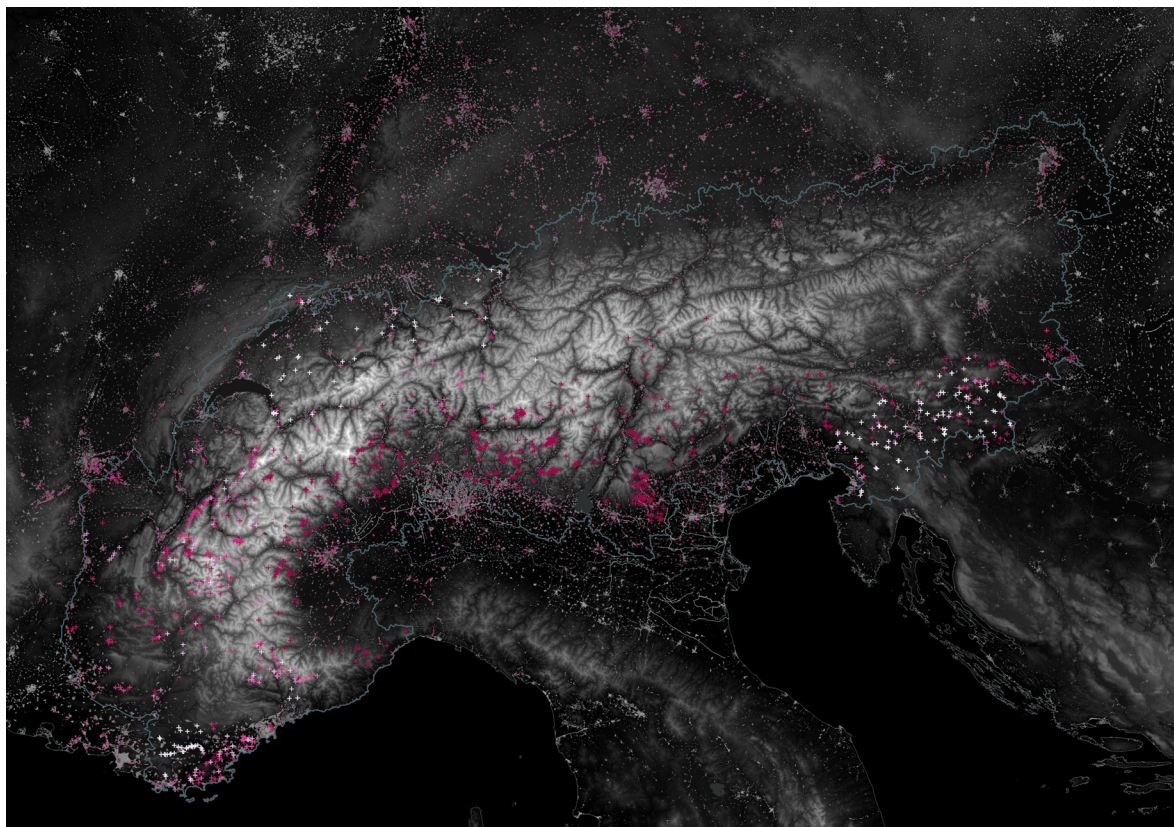


fig.3.8 Mineral extraction, Alps: abandoned sites.
Abandoned extraction sites across European territories, reflecting the historical legacy and uneven geography of mining.
Database: *European Commission RMIS–Raw Materials Information System*.

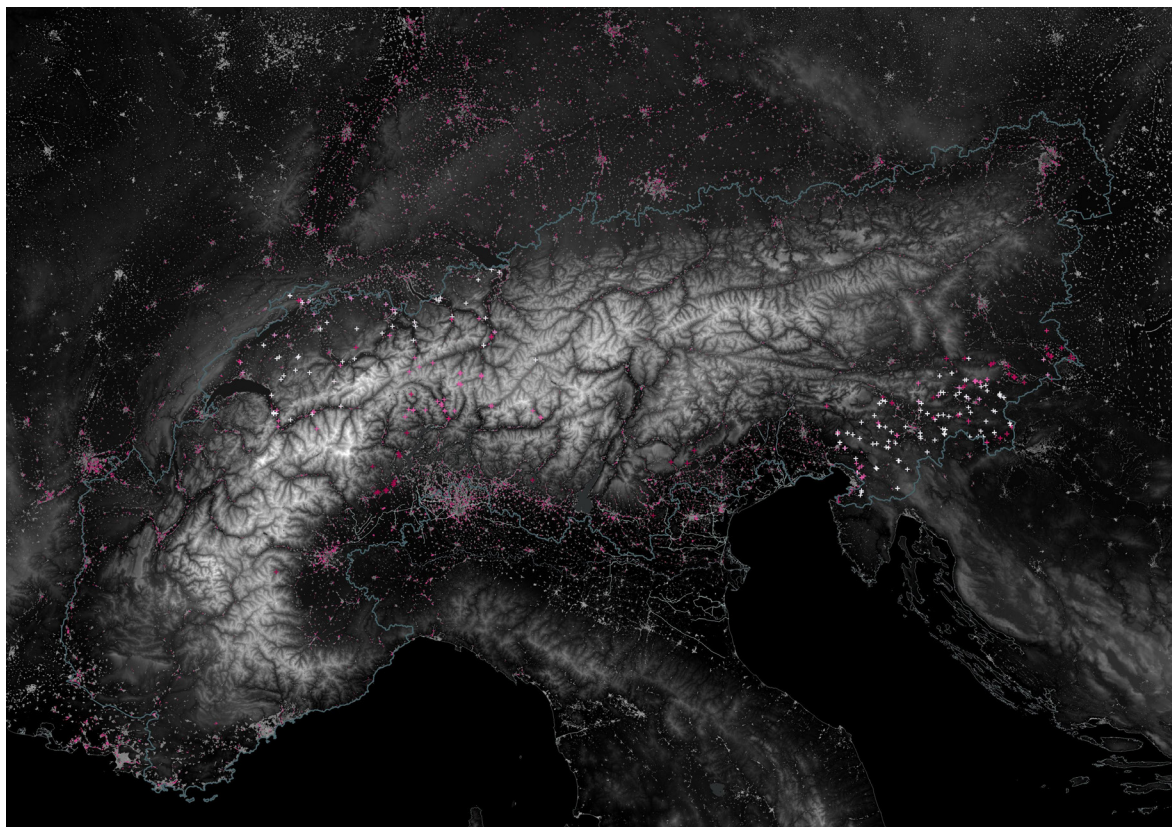


fig.3.11 Mineral extraction, Alps: active sites.

Active mineral extraction sites in Europe, including those connected to CRM strategies under EU policy frameworks.

Database: *European Commission RMIS–Raw Materials Information System.*

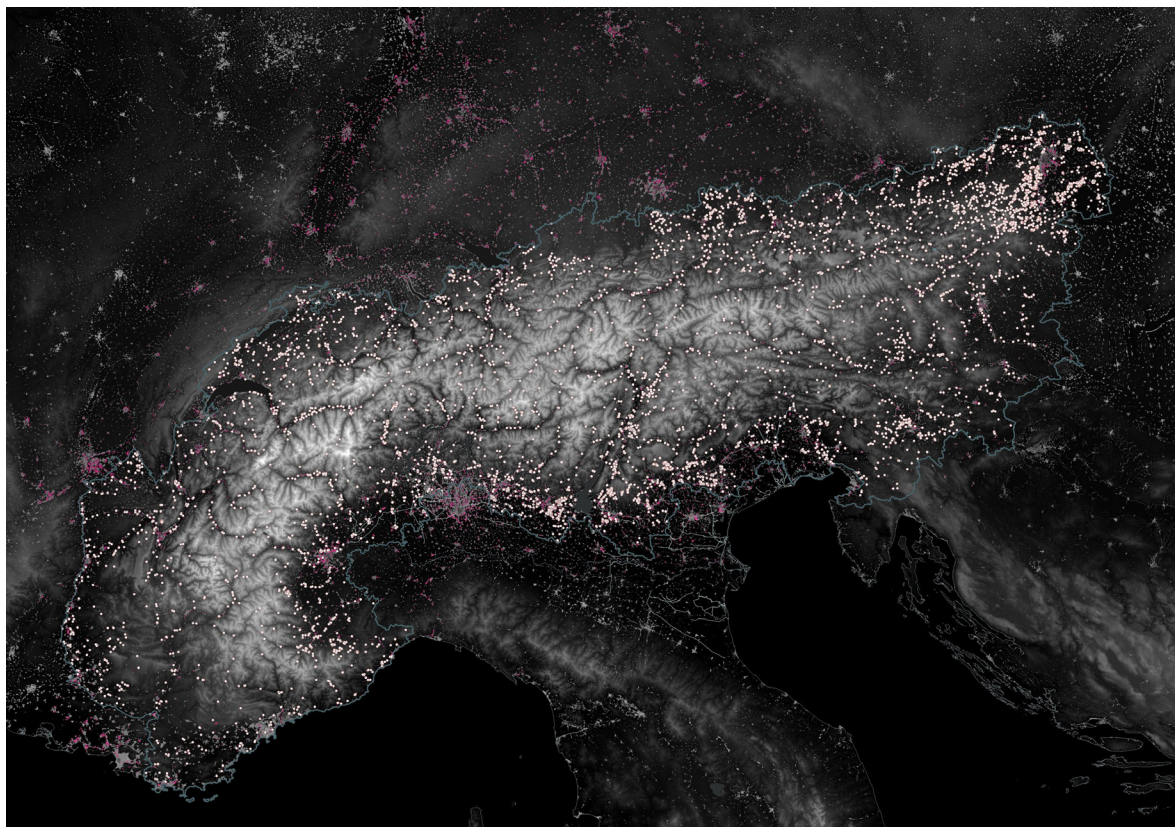


fig.3.10 Open-pit mining of inert materials.
Distribution of active open-pit mines (sand, gravel, stone) across the Alpine arc, revealing the spatial imprint of low-intensity, yet extensive, extractive operations.

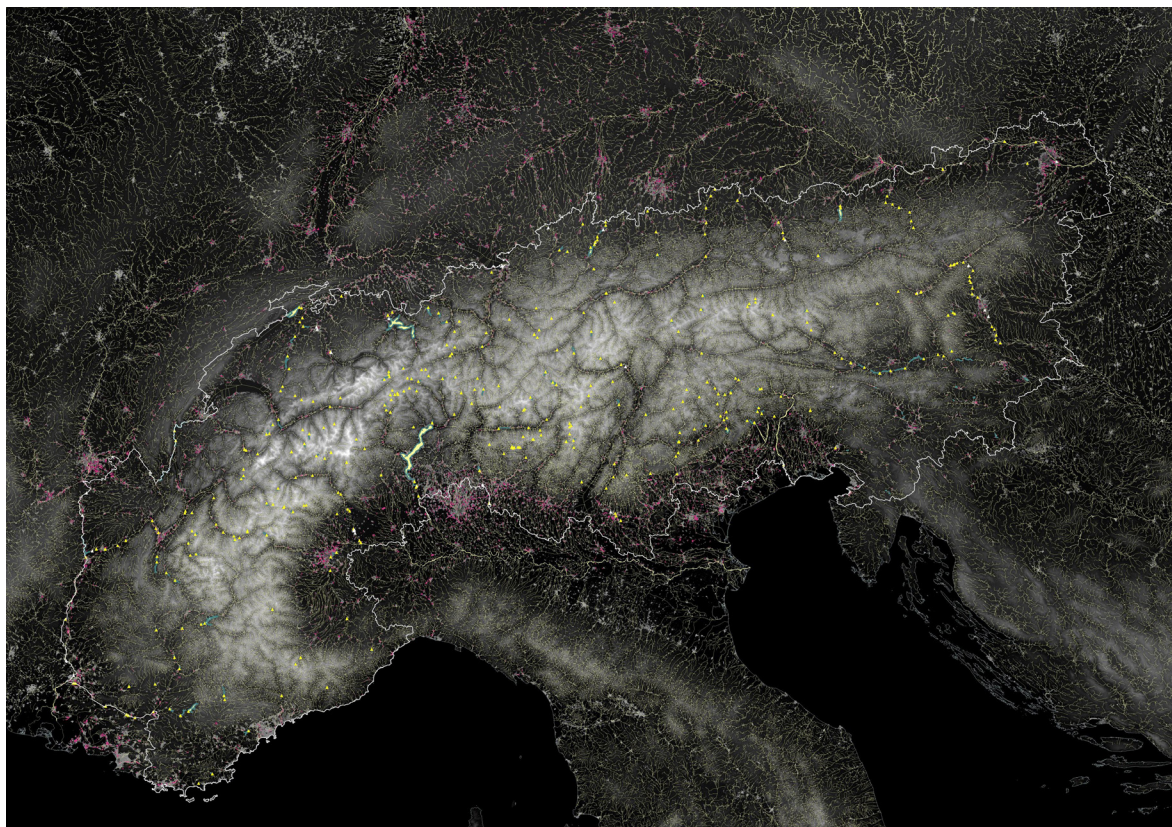


fig.3.11 Hydroelectric energy exploitation.

Main hydroelectric dams located within the Alpine region, indicating the historical inter-connection between energy infrastructure and territorial transformation. Hydroelectric power, though often framed as renewable, is also a form of extraction—it transforms landscapes and appropriates the energetic potential of water to generate value. This infrastructural capture of hydrological cycles reflects an extractive logic, wherein natural processes are harnessed, redirected, and commodified, often with significant ecological and social consequences in mountain territories.

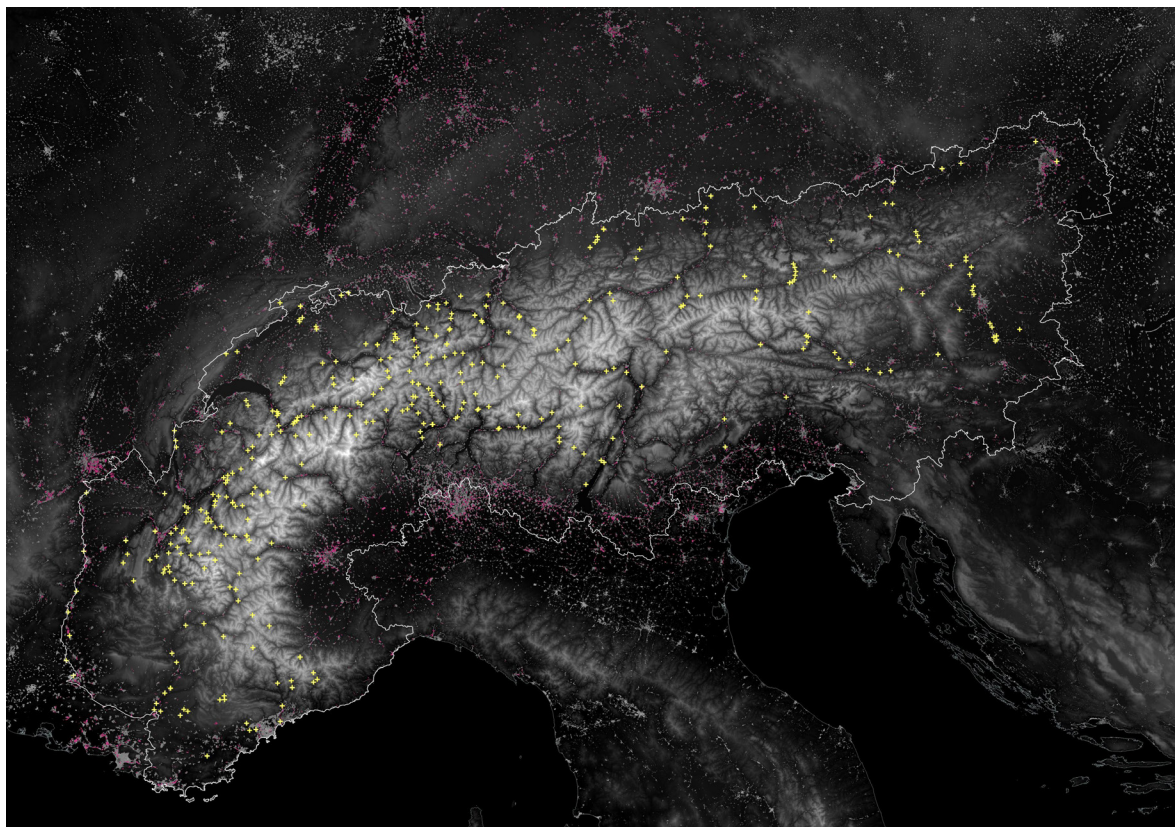


fig.3.12 Hydroelectric energy exploitation.
Hydroelectric power plants distributed across the Alpine orogenic belt, revealing the energetic dimension of Alpine territorial transformation.

3.3.local scale-the case of Piemonte

In 2019, the Piedmont Region granted an Australian mining company a license to explore cobalt, nickel, copper, silver, and associated minerals in the Punta Corna area, located in the Alps near Turin. This marked a renewed interest in the region's long-dormant mineral wealth. In 2021, another Australian company secured a similar license to explore resources in an area straddling Valsesia and Val d'Ossola. These developments highlight a broader trend of renewed mineral extraction in Northern Italy, tied to the global energy transition (fig.3.13–15).

New frontiers of extraction

In the upper Lanzo Valleys, an Australian company has been conducting geological assessments in the Punta Corna area since 2019⁶⁵. The company successfully renewed its exploration license in 2022, underscoring its ongoing interest in the site's potential. In 2021, a second Australian company began exploration activities across Valsesia and the eastern Val d'Ossola⁶⁶ (fig.3.16).

Despite their substantial natural resources, these regions paradoxically find themselves at the margins of economic and social development. Although rising demand positions these areas as key nodes in global supply chains, the economic benefits remain largely external. As mining activities in Piedmont accelerate, the challenge remains to ensure that local communities see tangible socio-economic gains from these developments. The ongoing exploration efforts in Piedmont are part of a

⁶⁵ Usseglio is located at the end of the Viù Valley, the southernmost of the three Lanzo Valleys, while Balme is the highest municipality in the Val d'Ala. In the Punta Corna area, which lies between these two municipalities, *Altamin Limited* has held a mining concession since 2019 and has been conducting geological assessments to evaluate cobalt extraction potential.

⁶⁶ *Alligator Energy*, starting in 2021, initiated similar exploratory operations in a broader area encompassing Valsesia, which stretches from hamlets above Varallo Sesia to the northern and northwestern sections of the valley and extends into the eastern zones of Val d'Ossola, which align with the Anzasca and Antrona Valleys.

broadier reconfiguration of the global extractive industry⁶⁷ driven by rising demand for CRM. As East Asia solidifies its role as a global economic powerhouse, particularly in green technology production, European mining regions like Piedmont are being drawn into new global supply chains⁶⁸. This dynamic is not without its contradictions. The European Union has set ambitious sustainability targets in its 2030 Agenda to reduce reliance on raw material imports and promote the circular economy. Yet, global market pressures, driven by demand, are drawing European regions back into extractive dependence. The resurgence of mining in Piedmont thus poses a complex challenge: balancing the need for critical materials with the EU's broader environmental and economic objectives.

Mining operations in Piedmont reveal an intricate spatial, social, and political landscape of resource extraction. Their integration into global logistical networks reveals how Alpine regions are being reintegrated into planetary supply chains. At the same time, these developments reflect the ongoing eastward shift in global industrial and technological production. This ongoing tension between local sustainability goals and global capitalist demands will continue to shape the future of mining in the Alps and similar regions worldwide.

⁶⁷ The transition towards the extraction of Critical Raw Materials (CRM) can be framed through some of the dynamics that characterized the oil industry in the 20th century, particularly in the context of the reorganization of the global extractive industry (Bridge 2004b). The geography of extractive investments has been profoundly influenced by neoliberal reforms, which facilitated access to natural resources in previously less economically active regions. This pattern has resurfaced in the modern CRM industry, where the increasing demand for critical resources such as cobalt, lithium, and nickel, mainly from East Asian economies, has stimulated renewed interest in regions that were not historically central to the global extractive economy. In the case of oil, the neoliberal reforms of the 1980s and 1990s led to market liberalization and a rush of investments in oil-rich areas, such as Africa and the Middle East, which major multinational corporations had primarily overlooked. Similarly, the growing demand for CRM is driving companies to invest in regions like Piedmont, which, though peripheral, possess significant mining potential. The oil and mining sectors reflect a global capitalist structure, where the center of economic power is often far from the extraction sites. In the case of oil, developed economies have benefited enormously from resources extracted in developing countries, often without these countries seeing significant economic or social improvements. Similarly, current extraction operations risk repeating this model, with capital and profits flowing to Asian and European economies while local communities remain marginalized.

⁶⁸ As indicated in the public communications released by the two Australian companies operating in the region, which outline their exploration plans, permit status, and projected integration into emerging supply chains (Altamin 2022, Alligator 2021).

Bridging extractive cycles and territorial transformations

Cobalt extraction and its global supply chain reveal how resource flows shape economies, power structures, and landscapes across multiple scales. The cobalt economy highlights the entanglement of resource governance with ethical concerns and the paradoxes of the energy transition. However, as seen in these cases, even in nations with high environmental and labor standards, extractive industries remain embedded in broader socio-political challenges, including Indigenous land rights, environmental degradation, and the long-term consequences of mineral dependency.

Europe's role in these dynamics, particularly through its efforts to secure domestic sources of cobalt and other critical raw materials, reflects a larger shift in the geography of extraction.

The Alps, and specifically the Piedmont region, are increasingly at the center of this transformation. No longer peripheral to extractive logics, these territories are being drawn into new supply chain configurations in which local resource extraction intersects with global demand for strategic minerals. The revival of mining activities in the Alps must be understood not only as an economic or industrial shift but also as a spatial reconfiguration of resource frontiers, in which landscapes are altered, infrastructures are reactivated, and governance structures are renegotiated⁶⁹.

⁶⁹ This transition leads directly into the next section, 'Manufactured Altered Alps', which will investigate how extractive processes and material cycles shape landscapes, economies, and territorial configurations. By examining the interplay between specific technologies, their required materials, and supporting infrastructures, this section highlights how extractive industries integrate into material infrastructures and industrial landscapes.

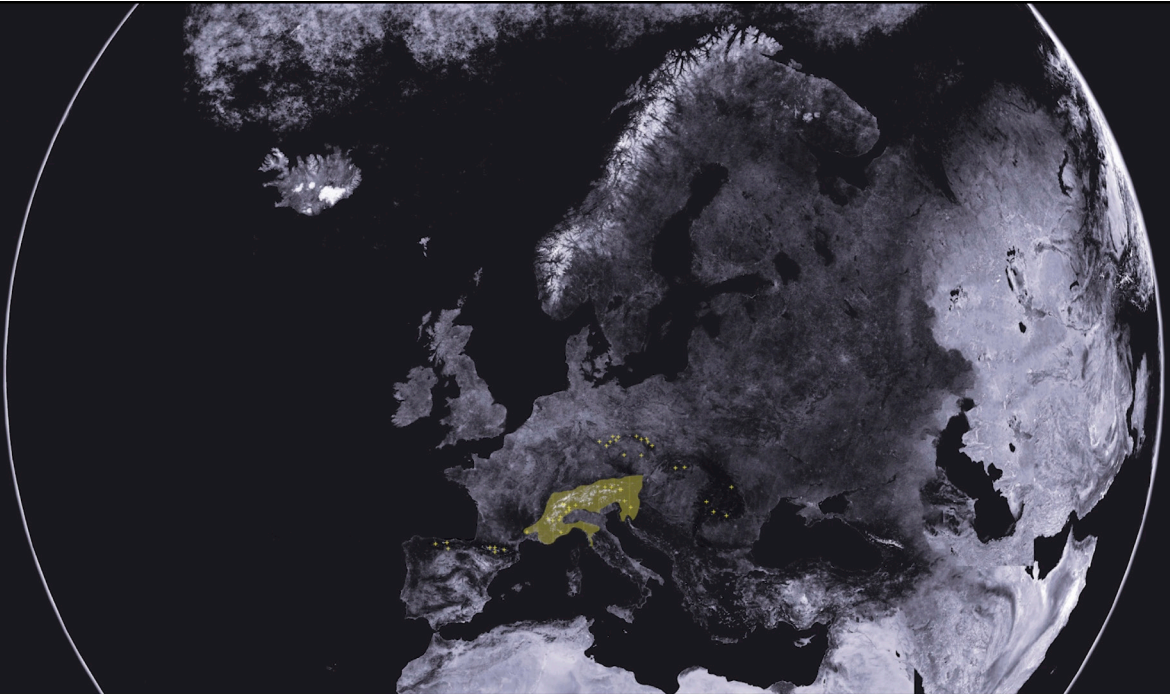
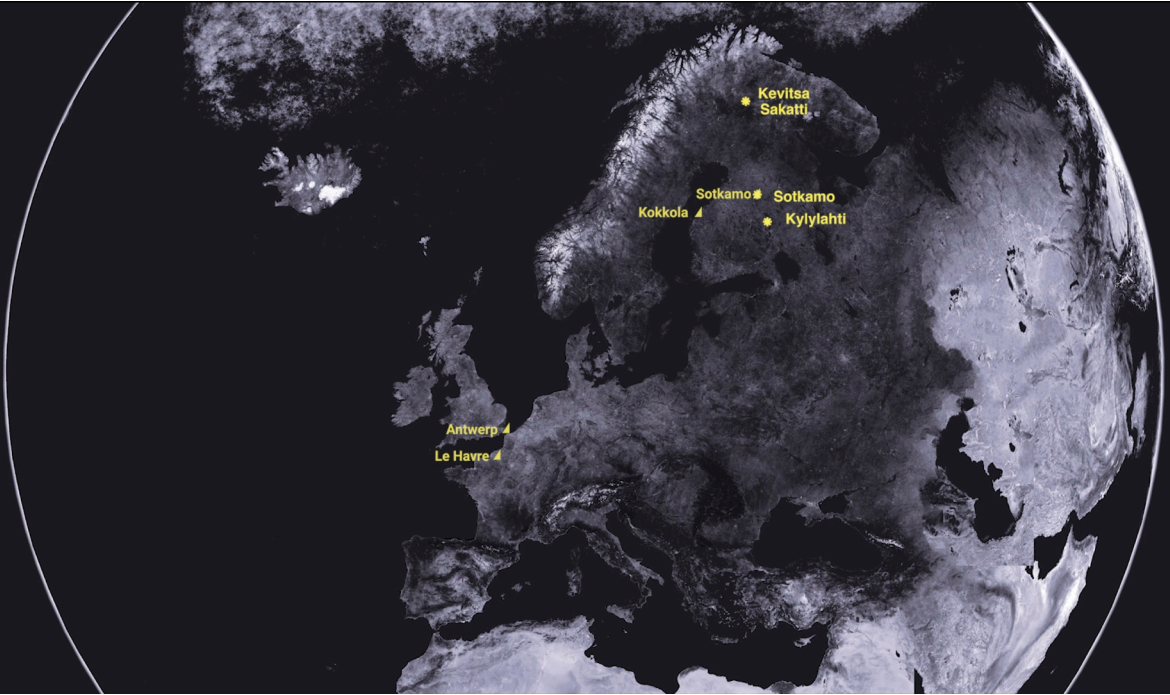


fig.3.13, fig.3.14, fig.3.15 Extract from the video-essay by Erpinio Labrozzi, Federico Godino, Mattia Tettoni – *Blue Cobalt, Geographies of the new extractive era*. *Climate Wunderkammer 2023, La Biennale di Venezia*.
 The video-essay investigates trans-scalar relationships and the environmental and social impacts embedded in consumer electronics and automotive. Screenshots visualize the European scale of extraction and processing sites, and frame the Alpine orogenic belt as a potential new resource frontier. A 3D animation and data visualizations trace global cobalt flows, with the DRC and China as, respectively, the main exporter and importer of the mineral.
 (animations: Alessandro De Vita, Filippo Tartaglia; data mining: Luigi Tredicine–Università di Ferrara)



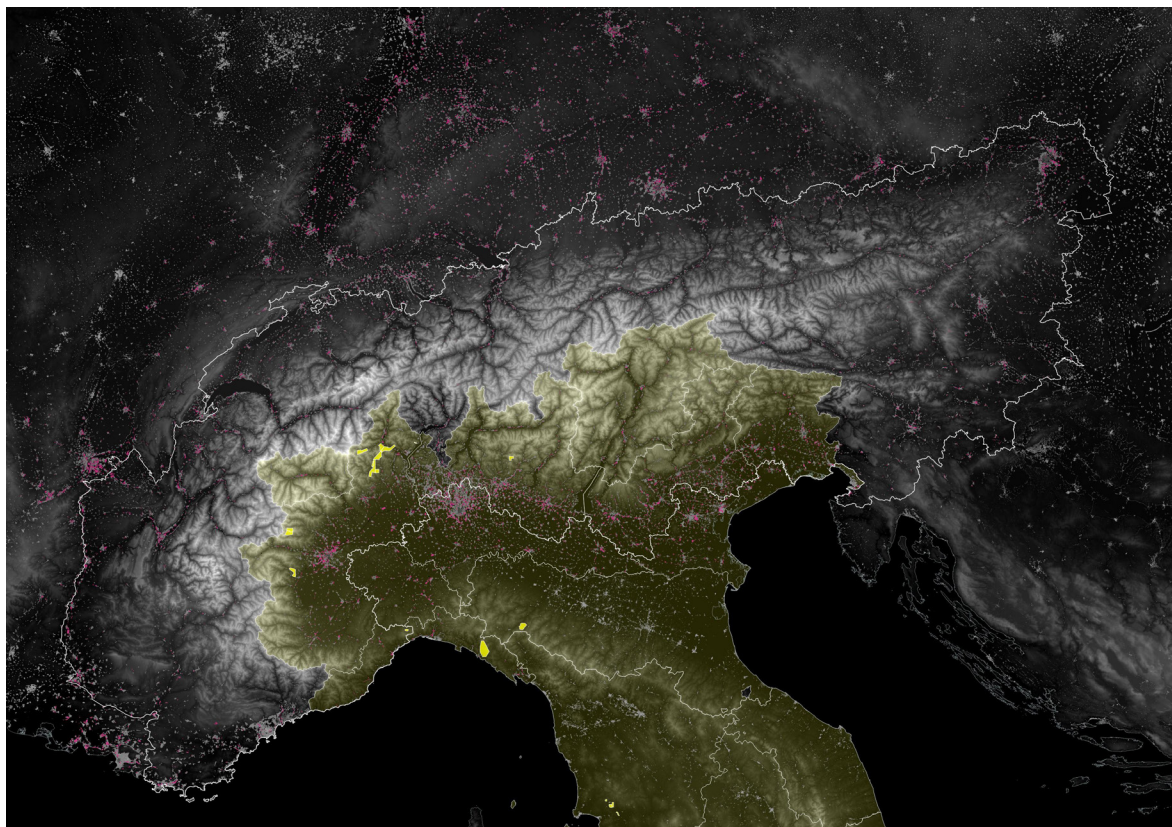


fig.3.16 National-level map of active exploration permits and mining concessions for critical raw materials across the Italian Alps, including Piedmont.
Database: *ISPRA-GeoDatabase GeMMA*.

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3.new cycles

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manufactured altered alps

an alpine palimpsest

4.the Alps as a reservoir of resources extractive economies and early mining infrastructures

Since the first half of the nineteenth century, the Alps have been progressively incorporated into Europe's industrial metabolism, functioning as a vast reservoir of organic and inorganic resources. Long regarded as the continent's natural bastion, these mountain territories entered modernity not as isolated refuges but as active frontiers where extraction, circulation, and transformation converged. While mining in the Alpine region dates back to antiquity, industrialization endowed it with a new strategic significance: the intensification of material demand tethered high-altitude valleys to continental trade networks and to the infrastructures of an expanding capitalist economy. This shift represented more than an economic integration; it produced a profound reorganization of territorial hierarchies. Peripheral valleys that had long relied on subsistence economies were re-coded as productive hinterlands, their rivers, forests, and subsoil incorporated into the infrastructural logics of modern industry. Extraction thus operated simultaneously as a material practice and a spatial instrument, translating political and economic ambitions into a new geography of resource management. The Alps became a field where modernization was not only built but also measured, administered, and imagined. Understanding this transformation requires looking beyond the chronology of technological innovation to the epistemic and administrative structures that enabled extraction. Long before the arrival of mechanized mining in the nineteenth century, pre-industrial regimes had already developed powerful tools to render mountain environments legible, calculable, and governable. Among these, cartography stands out as both representation and instrument. An anticipatory technology that preceded the machines of industry by installing a framework of knowledge through which resources could be classified and controlled.

Long before industrial mining reshaped the Alpine valleys, the logic of extraction had already begun to operate through acts of representation. Mapping, measurement, and classification were not neutral techniques of knowledge; they were tools through which mountains were reimagined as calculable and exploitable terrains. In the eighteenth century, cartographic practices such as those developed in the Piedmontese valleys translated the opacity of the Alpine landscape into a legible surface, a grid of value and potential. In this sense, the representation of Valsesia in mid-eighteenth-century surveys constitutes more than a historical curiosity. It marks the moment when the mountain ceased to be a symbolic or lived space and became a speculative object. Through mea-

surement, the landscape was abstracted into data: forests into inventories, slopes into resources, rivers into lines of circulation. This epistemic transformation preceded the mechanical one. The very act of making the territory visible and comparable was already an operation of extraction—an anticipation of value before any material was removed from the ground. What we call the pre-industrial phase of Alpine exploitation is therefore less about technology than about imagination. The state's speculative gaze, encoded in maps and tables, produced the conceptual infrastructure that later enabled industrial modernization. By turning knowledge into an instrument of control, cartography inaugurated a form of governance in which the territory itself became a project—a field of future operations. The Alps were no longer distant or self-contained: they were drawn into the administrative and economic circuits that would soon translate representation into intervention. The nineteenth century brought the transition from speculative to material extraction. What had been imagined through representation now took tangible form through machines, infrastructures, and institutions. Mechanization did not simply deepen existing mines: it materialized a new alliance between knowledge and technology, turning the mountain into an operative device.

In the Alpine context, the introduction of mechanical ventilation, steam-powered machinery, and new mining laws marked the consolidation of an extractive rationality that had been gestating for decades. The Alps became laboratories of technical innovation, where geological constraint and engineering ingenuity met. Yet this transformation was not merely technological; it redrew the social and territorial order. Mining colonies, transport routes, and hydropower installations reorganized settlement patterns and economic dependencies. Valleys once marginal became nodes of continental circulation, their infrastructures embodying the industrial metabolism of Europe. Mechanization thus stands as a second layer of extraction—not the exploitation of minerals alone, but of landscape, labor, and time. The machine extended the map's reach. It translated speculative potential into measurable productivity, fixing the rhythm of Alpine modernity within the temporal logic of industry. The mountain, once resistant and opaque, became porous: penetrated by tunnels, ventilated by machines, and governed by data. Among the many sites that illustrate this passage, the gold and silver mines of Alagna Valsesia and Macugnaga at the foot of Monte Rosa exemplify the encounter between extraction and urbanization. Here, the convergence

of state ambition, technical expertise, and mobile labor produced one of the first Alpine proto-industrial landscapes. The mining settlements that emerged in the eighteenth and nineteenth centuries were not isolated enclaves but embryonic urban forms. Their organization—housing for workers and soldiers, workshops, roads, storage facilities—anticipated the spatial logic of the industrial city. They condensed in miniature the dual nature of modernity: progress founded on exhaustion. Economic growth and environmental degradation advanced together, forging a social fabric marked by inequality and dependency. These proto-urban centers also reveal the contradictory temporality of extraction. They flourished rapidly around cycles of demand, then declined with equal speed, leaving behind infrastructures too solid to disappear yet too obsolete to reuse. The Alps thus became a terrain of repetition and erasure, where each phase of development layered over the previous one without fully replacing it. The urbanization of the mountain was less a process of expansion than of inscription: a writing of industry onto geology. In this light, Monte Rosa stands not as an isolated case but as a paradigm of Alpine modernity. It materializes the moment when extraction ceased to be only a practice of removal and became a project of construction—of territories, institutions, and imaginaries.

The mechanized and proto-urban Alps of the nineteenth century must be understood within a wider economic geography. The integration of mountain regions into industrial capitalism did not homogenize them; it differentiated them. Resource-rich valleys like Valsesia were drawn into asymmetric exchanges, exporting raw materials and energy while importing dependency. The infrastructures that connected them to the plains also codified new forms of peripheralization. This transformation redefined the meaning of the mountain in Europe's collective imagination. No longer a distant wilderness or romantic refuge, it became a productive landscape, a space of circulation and experimentation. Hydropower, transport, and metallurgy replaced pastoral economies, but they did so by inheriting the same extractive logic: the conversion of ecological complexity into measurable output. The Alps were industrialized through a process that conflated progress with depletion, sustainability with control. What emerges from this historical arc is the idea of the Alpine palimpsest: a layered territory where successive regimes of extraction—have overwritten one another without erasure. Each phase has left traces that remain active, shaping contemporary debates on resource management and ecological transition. To read the Alps through

this lens is to recognize that their current environmental and economic conditions are not the residue of the past but the continuation of a long cycle. The same valleys once surveyed for timber and ore are now measured for CRM, tourism, or renewable energy. The vocabulary has changed, the logic has not. The challenge lies in understanding how these inherited structures can be reimagined, not as instruments of depletion but as frameworks for regeneration

4.1. Grande Carta Della Valle Di Sesia (1759) cartographic extraction and forest exploitation before industrial mining

From the early modern period through the nineteenth century, mining and related extractive activities progressively reshaped the Alpine landscape, long before the onset of full industrialization. Rather than a sudden nineteenth-century transformation, these developments reveal a deeper continuity in which extraction-oriented territorial logics had already been consolidated during the seventeenth and eighteenth centuries. Among the most striking examples is the 1759 *Carta Topografica in Misura della Valle di Sesia*, produced under the auspices of the Savoy administration. Far from being a mere geographic document, the Valsesia Map is a pre-industrial articulation of extractive rationality—an act of knowledge production closely tied to resource governance, environmental control, and infrastructural planning¹. It provides critical insight into how the Alps, even before mechanization and large-scale industrial exploitation, were already seen as a reservoir of material value to be measured, ordered, and managed from the outside. While the authorship and methods of the Valsesia Map are well documented in historical accounts, its relevance to territorial history lies less in biographical detail than in its function as an early apparatus of spatial abstraction² (Peco 1988).

Cartographic rationalities and pre-industrial extractive logics in the alps The map's technical rigor and holistic spatial coverage anticipate modern infrastructural and cadastral surveys. Yet, unlike later efforts driven by industrial logic, this early representation blends topographic observation with administrative intent: forests, rivers, mining sites, and roads are not just described, they are categorized and counted, becoming legible for state intervention. The map was not an abstract or disinterested exercise. It was commissioned as part of the Savoyard state's broader strategy to consolidate control over its peripheral valleys by mapping their productive potential. In this sense, the map becomes

¹ This section partially draws on Peco's study *La grande carta della "Valle di Sesia" del 1759: miniere e boschi nel primo rilevamento topografico della valle* (1988). The document served as a supporting reference in the reconstruction of pre-industrial land use and resource mapping practices in the Valsesia region. Peco's detailed commentary on the 1759 map highlights the early integration of mineral extraction and forest exploitation within a coordinated territorial vision. While the present analysis introduces a broader interpretive framework, especially regarding the notion of *cartographic extraction*, the work was instrumental in identifying key spatial and infrastructural logics at play in the map's production and its role in orienting proto-industrial resource management in the Western Alps.

² Despite being produced in the era of pre-geodetic cartography, the map employed elementary triangulation techniques to deliver a surprisingly accurate rendering of the valley at a scale of 1:23,900.





fig.4.1 The 1759 Carta Topografica in Misura della Valle di Sesia — Eight Quadrants (Source: unionemontanavalsesia.it).
Overall view of the complete map divided into eight sections, showing the extent and compositional structure of the survey.

fig.4.2 Enlarged portion of the map highlighting the density and accuracy of the graphic representation.

a proto-statistical device. It identifies and localizes active and potential mining sites, many of which were exploited directly by the state rather than through private concession—a policy reflecting the economic priorities of the Piedmontese administration in the mid-eighteenth century. Equally significant is the detailed census of the region's forests, which occupied a prominent role in the lower register of the map. This was more than an ecological survey. Forests were measured regarding tree species, trunk diameter, and estimated harvestable timber or charcoal volume³—resources essential to sustaining mining operations. It allowed state officials to align economic ambitions with precise territorial data by spatializing extraction zones and potential yields. In this sense, it foreshadows modern technocratic planning and environmental commodification. It can, therefore, be read as a hinge between extractive epistemologies and emerging rationales of statecraft. Rendering the mountains legible is not a cultural or symbolic space but an operable resource platform. The logic is extractive in content and form: mountains and valleys become flattened into comparable, quantifiable value units. Measuring and visualizing territory, down to the scale of a single stream or wooded slope, constitutes a powerful gesture of control.

As the landscape was increasingly absorbed into industrial logic during the nineteenth century, the case of Valsesia illustrates how extractive pressures on mountain territories had already taken root in earlier governance regimes. In the mid-eighteenth century, this Piedmontese valley was the object of a far-reaching territorial intervention that did not rely on machines yet already framed the environment through extractive, administrative, and infrastructural lenses. The valley was not merely observed; it was measured, categorized, and mobilized, inscribed into a political vision that saw forests and minerals as elements of a territorial economy. In this context, forest resources became a central concern. The abundance of timber in Valsesia was not seen as an ecological richness to be preserved but as a strategic material asset tied to mining operations. Smelting processes, in particular, required vast quantities of wood, both as fuel and charcoal, leading to rapid deforestation and the risk of long-term environmental degradation.

The translation of landscape into inventory had direct political implica-

³ Each forest parcel was numbered and described in extensive marginal tables, reflecting botanical knowledge and a calculated anticipation of resource yield.

tions⁴. The systematic documentation of forest assets became the foundation for regulatory initiatives to secure sustainable timber access. In 1760, a year after the comprehensive survey of the valley was completed, the administration proposed a *Progetto d'Editto per la Conservazione de' Boschi in Valsesia*. This proto-environmental edict sought to rationalize extraction practices. Although framed within the logic of state productivity, the proposal reveals an early awareness of ecological thresholds and foreshadows the regulatory infrastructures of modern environmental governance. In this case, conservation was not driven by aesthetic or moral arguments but by the need to safeguard the productive function of forested land. This transformation of the territory into a governed resource zone was not limited to forests. At that moment, investments in basic infrastructures were renewed, particularly the reconstruction of the valley's main road, which the floods had partially destroyed. Here, again, the landscape crisis became the occasion for territorial reorganization. The road was not only a logistical asset; it served as the circulatory system that enabled the transport of mineral and timber resources from the high valleys to the state's administrative and economic centers. Territorial modernization thus emerged from the dual pressures of extraction and disruption, as well as the need to manage resources and respond to environmental volatility. The reordering of ecological functions went hand in hand with a broader recalibration of territorial authority.

The politics of extraction These changes were not purely technocratic. They were mediated through the political relationship between Valsesia and the central government in Turin. Although nominally under the Savoyards' control, the valley retained some administrative autonomy rooted in its communal structures and geographic remoteness. The intervention of state surveyors, engineers, and administrators was therefore experienced locally as an incursion (Peco 1988). Communities were compelled to provide lodging, food, and logistical support to the teams operating in their territories. The extractive regime thus operated on natural resources and social and institutional arrangements, reconfiguring the balance between local agency and centralized authority. The tension between peripherality and strategic value becomes espe-

⁴ The landscape was therefore assessed quantitatively. This environmental accounting allowed the Savoyard administration to estimate what existed in the territory and what could be extracted from it—an anticipatory gesture that framed nature as a ledger of potential outputs (Peco 1988).

cially evident in how the administration framed Valsesia. Although geographically marginal, the valley was understood as a node of extractive potential—a space rich in materials necessary to the state’s economic ambitions. This duality recurs throughout Alpine history: mountain regions often escape infrastructural integration and political investment, only to be drawn selectively when their resources become desirable. In this sense, Valsesia was not an exception but an early articulation of a recurring spatial pattern, wherein the periphery becomes legible only when aligned with metropolitan needs. The broader implication is that Alpine territories were already being transformed by extractive epistemologies well before the rise of industrial mining. These pre-industrial processes may have lacked the mechanical force of nineteenth-century operations, but they relied on equally powerful techniques of abstraction and control. These early interventions established a framework for administering, optimizing, and instrumentalizing the territory by converting forests into statistical tables and river valleys into strategic corridors. A portrait of the Alps emerges as a space of latent productivity, as an environment whose value was to be unlocked through state knowledge and infrastructural extension. This reading destabilizes the notion that extractive modernity arrived suddenly or uniformly; instead, it reveals a *longue durée* of territorial transformation, beginning not with steam engines or dynamite but with maps, measurements, and forest censuses. In this light, the Alpine landscape becomes a site of early resource governance, where environmental management and infrastructural vision intersected well before the industrial age.

As seen in the previous sections, the transformation of Valsesia in the eighteenth century represents more than a technical or administrative episode. It reveals the emergence of a specific territorial rationality that anticipated industrial modernity not through machines but through measurements, classifications, and a profound reordering of land for extraction. The 1759 survey of the valley may have culminated in a map, but its true legacy lies in how it restructured the relationship between territory, resources, and political authority. It redefined the mountain not as wilderness or cultural enclave but as an incipient field of oper-

ations: a place to be known, optimized, and managed at scale⁵. Such reframing had material consequences. The calculability of the Valsesian landscape enabled state actors to direct regulatory action, particularly in forest governance. The 1760 draft edict on woodland conservation illustrates this well: it emerged directly from cartographic knowledge and sought to impose order on a resource system increasingly understood as finite. Forests, once communal and cyclical in use, were reconceived as strategic reserves. This transition from subsistence to regulation marks a key moment in the emergence of a state form premised on infrastructural extraction (Mitchell 2011), where control is exercised not through overt coercion but through the mediation of environmental systems⁶. The logic underpinning this transformation is extractive in form, even if the mechanisms were not yet industrial. The mapping of the territory, the inventorying of its forest biomass, and the prioritization of its mineral seams constituted a strategy of anticipation. This is what gives the Valsesia case its broader significance. It invites us to recognize modern extractivism is a technological or economic phenomenon and a spatial and epistemic enclosure that begins with acts of representation. Once the landscape had been abstracted into measurable units, the territory could be reconfigured according to the future-oriented logic of planning and control. By translating terrain into data and forests into resource flows, the administration enabled decisions yet to be taken, investments yet to be made, and transformations yet to be enacted. This speculative character of territorial knowledge, its ability to shape the future by stabilizing the present, aligns it closely with modern forms of environmental planning and spatial governance. The fact that it emerged in the absence of industrial capital or modern machinery underscores how deeply extractive rationalities are embedded in the structures of territorial modernity. The landscape, at this moment, ceases to be inert.

⁵ This shift signals more than a technical exercise; it signals a political redefinition of space. Forests became quantifiable stocks, slopes became movement corridors, and mineral seams were inscribed as future sites of value extraction. Territory itself was transformed into a medium of action, shaped not only by physical interventions but by the conceptual tools that rendered it visible and actionable. Representation operates not merely as reflection but as intervention—a framing device enabling specific spatial practices (Cosgrove 2008).

⁶ In this sense, the Alpine landscape was not waiting to be transformed by industrialization; it was already undergoing a slower but no less consequential shift in its ontological status. It was becoming legible, not merely visible. This shift is epistemological: what was once experienced through seasonal rhythms, communal use, and vernacular knowledge was now rendered through quantitative abstraction. The result was a new spatial regime in which value could be projected in advance, ecological functions could be translated into fiscal terms, and local autonomy could be replaced by centralized oversight.

It becomes anticipatory—subject to projection, budget, and redesign. Its transformation is enacted not only in physical space but in epistemic space. Data precedes action. Tables precede saws. And knowledge becomes a condition for intervention. The Alps, in this configuration, are no longer distant or peripheral. They are strategically recoded into the circuits of early modern governance, even when they retain their geographical remoteness.

Mapping as an instrument of territorial control Significantly, the case complicates a binary view between pre-industrial *stasis* and industrial transformation. Instead, it proposes a continuum in which territories are gradually reconfigured through layered interventions—some material, others discursive; some disruptive, others administrative. The early survey work in the valley laid the infrastructural groundwork for future transformation, but it also installed a new way of thinking about the territory itself. Mountains, forests, and streams were no longer just natural features. They became indices of productivity, risk, and logistical feasibility. This redefinition of Alpine space resonates beyond the valley. It invites reflection on how peripheral landscapes are incorporated into broader systems of power and economy, not always through immediate exploitation but often through preparatory acts of classification, codification, and infrastructural potentiality⁷. In other words, the marginality of mountain regions is not absolute. It is frequently a function of timing, visibility, and strategic interest. When these landscapes become legible to central administrations—as Valsesia did to Turin—they enter a new phase of political life, one defined by surveillance, calculation, and structural asymmetry⁸. Crucially, this does not imply a uniform or unidirectional process. The legacy of extractive mapping in Valsesia is ambivalent. On the one hand, it enabled a more integrated approach

⁷ The landscape ceases to be inert. It becomes anticipatory—subject to projection, budgeting, and redesign. Its transformation is enacted not only in physical space but in epistemic space. Data precedes action. Tables precede saws. Knowledge becomes a condition for intervention. The Alps, in this configuration, are no longer distant or peripheral. They are strategically recoded into the circuits of early modern governance, even as they retain their geographical remoteness.

⁸ Such recoding challenges the binary of center and periphery. Valsesia was peripheral in location but central in value. This paradox is not incidental; it is structural. Peripheral territories often emerge as strategic nodes once their extractive capacity is rendered legible to distant administrations. Similar dynamic [...] in colonial cartographies, where peripheral environments become operationalized through visual and textual order regimes. In Valsesia, the same logic applies: surveyors did not just measure the land—they recalibrated its position within the state.

to territorial planning and resource management. On the other hand, it marked the beginning of a long history of appropriation, in which local communities were increasingly subordinated to external logic. The provision of accommodation and labor to survey teams, the implementation of distant regulations on forest use, and the reshaping of infrastructure to serve extractive routes—all these processes reflect a redistribution of power through territorial means. This recalibration was not only political but also profoundly spatial. It introduced new geometries of intervention: roads to be rebuilt, forests to be managed, and labor to be mobilized. These were not gestures of modernization per se, but instead of integration, folding the mountain into a broader diagram of productivity and control. What had been a largely autonomous valley with communal governance structures became increasingly dependent on centralized decisions emanating from Turin. The Alps, while not colonized in the imperial sense, were nonetheless subjected to internal frontiers of control, where knowledge, rather than conquest, marked the terrain of power. What is at stake here is not simply the history of a valley but the genealogy of a spatial *dispositif* that would become dominant in Alpine modernization. Later developments—mechanized mining, hydropower infrastructure, electrification, and tourism—would build upon this foundational reconfiguration. They would expand the logic of abstraction and projection, integrating more mountain space dimensions into utility and profitability grids. In this context, the 1759 intervention appears not as a precursor but as an operative moment in a *longue durée* of spatial extraction. One key insight from this historical reading is the importance of considering cartographic and territorial technologies as forms of soft infrastructure. Unlike dams, tunnels, or railways, these tools do not leave visible scars in the landscape. Yet they precondition how that landscape is understood, approached, and transformed. They authorize interventions by inscribing territories within broader epistemic and administrative networks. In doing so, they make certain futures imaginable—and others obsolete. This observation is particularly relevant for contemporary urbanism and landscape studies, which increasingly grapple with the residues and legacies of extractive pasts. As contemporary debates shift toward degrowth, ecological repair, and post-extractive futures, there is a need to understand how past territorial regimes continue to shape possibilities in the present. Valsesia offers a compelling case study in this regard—not because of its transformations but because of the subtle, anticipatory logic through which

it was first rendered governable.

From representation to governance: the Valsesia map as extractive paradigm In conclusion, the map does not merely document a region. It materializes a paradigm. It shows how, even without machines, landscapes can be reshaped by vision, measurement, and projection techniques. It reveals how extractive modernity begins not in the mine but in the map, not with the pickaxe but with the pen. Most importantly, it reminds us that the history of territorial transformation in the Alps—and elsewhere—is as much a question of knowledge production as it is of material intervention. This perspective opens a crucial bridge to the following sections, which examine how mechanization and electrification intensified and extended the spatial rationalities first articulated in this proto-industrial phase⁹. While the actors, technologies, and scales would change dramatically, the underlying principles of visibility, calculability, and instrumentalization remained consistent. In tracing this continuity, this case allows us to situate the origins of modern Alpine transformation within a broader history of extractive imagination—one that began not in the factory or the turbine but in the administrative imagination of the land itself. The concept of extractivism must, therefore, be broadened beyond its material footprint. It includes the preparatory epistemologies that make extraction possible, the representational grammars that convert the landscape into logistics, and the institutional logic that assigns a value before any resource is physically touched. In this sense, the transformation of Valsesia was not about what was removed from the earth but about what was inscribed onto the territory—a process of inscription that continues to inform how the Alps are seen, governed, and imagined today.

⁹ In reflecting on this moment, it becomes clear that the legacy of the 1759 operations does not rest in their completeness, but in their orientation. They signal a way of thinking about territory that persists through subsequent phases of Alpine modernization. Later chapters of this thesis will examine how mechanization, hydropower, and metropolitan planning inherited and expanded these same rationalities—amplifying the calculative, anticipatory, and extractive dimensions already latent in the pre-industrial moment.

4.2.the mining activities mechanization

The transformation of Alpine mining in the nineteenth century must be read as a continuation, rather than a rupture, of earlier territorial regimes shaped by extraction, environmental management, and infrastructural anticipation. Building on earlier forms of resource governance, the mechanization of Alpine mining consolidated a pre-existing logic of control and productivity inscribed onto the mountain landscape. Although Alpine mining has deep historical roots, the introduction of mechanized systems marked a decisive change in scale, intensity, and territorial integration. Mechanical innovations, particularly in ventilation, enabled deeper extraction and redefined the technical and social organization of mining communities.¹⁰ This section explores the evolution of Alpine mining from pre-modern practices to its mechanized phase, examining how successive layers of technological development reshaped the Alps as an industrial frontier within the European resource economy.

The early modern specialization Early mining activities played a crucial role in shaping the Alpine socio-economic landscape, laying the foundations for later industrialization¹¹. Rich deposits of copper, iron, lead, and later silver and zinc sustained mining from prehistoric times onward, driving the growth of Alpine economies.

The earliest evidence of mining in the Alps dates back to the Bronze Age, when copper extraction became an essential activity in various Alpine valleys¹². Archeological findings suggest that Alpine communities smelted copper to produce bronze, a material used for tools and weapons. During the Roman era, mining in the Alpine region expanded significantly. Roman exploitation of iron and silver deposits¹³ expanded

¹⁰ See *Landscapes of Preindustrial Urbanism*, edited by Georges Farhat (2020), for a critical examination of how preindustrial landscapes functioned as structuring agents in the formation of urban systems. The volume reframes urbanism as a historically layered interaction between environmental manipulation, infrastructural practice, and spatial governance—offering valuable conceptual tools for interpreting long-term processes of territorial transformation beyond modern industrial paradigms.

¹¹ From prehistoric copper extraction to the advanced mining technologies of the early modern period, the Alpine mining industry evolved into a key driver of local and regional development.

¹² Sites such as Mitterberg in the Austrian Alps are particularly noteworthy for their extensive Bronze Age mining remains, indicating a sophisticated level of metal extraction and processing.

¹³ Evidence of Roman mining operations, including tools and infrastructure such as tunnels and smelting furnaces, has been found in several Alpine regions, notably in Switzerland and Italy.

the Alpine mining frontier and set the stage for the medieval boom¹⁴. The extraction of silver and lead became especially important for coinage and construction purposes¹⁵. The introduction of water-powered machinery increased efficiency and allowed access to deeper ore veins. This period also saw the establishment of mining laws, such as the *Schwaz mining code* of the 15th century, which formalized mining practices and labor relations in the region. The Renaissance brought new techniques, such as gunpowder blasting, which enabled access to previously unreachable ore deposits. This technological shift coincided with the rise of the Habsburg Empire, which heavily invested in mining across its Alpine territories, particularly in the Tyrol. At this time, mining also became more specialized, with the development of specific techniques for different types of ores¹⁶.

Mechanizing the mountain The mid-19th-century process of mechanizing ventilation in mine shafts marked a pivotal shift in the mining industry, particularly in the Alpine mines. Before mechanization, ventilation relied on inefficient natural drafts and chimneys, which were insufficient for deeper, more complex mines. From the mid-nineteenth century, the Industrial Revolution introduced mechanical ventilation systems. Among the first mechanical solutions were centrifugal and Guibal fans, powered by steam engines and widely used across Europe.¹⁷ ¹⁸, which was widely used in coal and metal mines throughout Europe. These devices improved airflow control, reducing the accumulation of harmful gases and improving safety. In the Alpine context, high altitude and limited air circulation made ventilation particularly difficult.¹⁹. Mines in this region, often located at high altitudes, suffered from even

¹⁴ The Middle Ages saw a resurgence in mining across the Alps, particularly from the 11th century onwards, spurred by the growing demand for metals in Europe.

¹⁵ Alpine mining towns such as Schwaz in Austria and Idrija in Slovenia became significant centers for mining during this period, contributing to the region's economic growth and the rise of local trade networks.

¹⁶ For instance, silver mining in Schwaz required more sophisticated refining methods to separate silver from lead. The region also saw an influx of skilled labor from other parts of Europe, bringing new expertise and further enhancing mining productivity.

¹⁷ Developed by George Stephenson.

¹⁸ Invented by Théophile Guibal in 1862.

¹⁹ The mechanization of ventilation in mining shafts, introduced in the mid-19th century, revolutionized the mining industry, especially in more complex and dangerous regions like the Alps. It improved safety, efficiency, and extraction depth, allowing for more intensive exploitation of mineral resources and contributing to the economic prosperity of Alpine mining regions.

more acute ventilation problems than lowland mines due to the limited air circulation in mountain valleys. With the increasing exploitation of iron, lead, zinc, and other metal deposits, the demand for more efficient systems to ensure miner safety became increasingly urgent. Mechanization increased productivity and strengthened the integration of Alpine mines within the European metals market. This technological advancement is a crucial example of how industrial innovation can positively affect traditional sectors, transforming labor practices and mining communities.



fig.4.3 Giovanni Zanolò, *Carta del Lago Maggiore, della Strada del Sempione e delle Valli di Sesia*, 1831. Milano, Civica Raccolta Stampe Bertarelli.

4.3.Monte Rosa-the Gold and Silver Mines of Alagna Valsesia and Macugnaga mechanization and urbanization in the Italian Alps

The formation of proto-urban centers around extraction sites reveals the multi-scalar spatial, economic, and social impacts of mining in the Alps. The spatial and economic impacts of mining in the Alps can be analyzed at multiple scales. Locally, mining generated specialized communities shaped by resource exploitation, external investment, and workforce migration. Mining infrastructure, including trade routes, linked Alpine production sites to European markets, reinforcing transregional integration.. Environmentally, mining led to landscape modifications that, although smaller in scale than modern industrial operations, had lasting effects on ecological balances and land-use patterns. This overview necessarily simplifies a complex, uneven process of urbanization across the Alpine arc²⁰. These settlements evolved beyond extraction hubs into administrative and infrastructural centers integrated into regional and transnational circuits.²¹.

Extraction and urbanization: resource-driven territorial transformations and demographic changes Mining spurred early urbanization in the Alps, as resource exploitation attracted labor and fostered towns like Schwaz, Hallstatt, and Chur—centers of extraction, trade, and governance.²². Through such institutional development, early Alpine mining settlements laid the groundwork for later industrial and urban modernization..

While proto-urban formations demonstrate that mineral extraction triggered urbanization in the central and eastern Alps, similar dynamics unfolded in the western Italian Alps, most notably in Alagna Valsesia at the foot of Monte Rosa²³. The turning point came after 1752, when the

²⁰ This provides a structured overview of how mining shaped the territories, but it remains a necessary simplification of a complex, long-term process. Urbanization did not follow a linear path or have an equal impact on all regions.

²¹ These mining towns were not only centers of economic activity but also served as important administrative, trade, and social hubs, laying the groundwork for modern Alpine cities.

²² The activities required skilled labor and technical knowledge, bringing craftsmen, engineers, and traders to these regions and creating the conditions for urban growth.

²³ Gold and silver mining development in the 18th century catalyzed a profound social and spatial transformation. Mining in Alagna had already begun in the early 16th century, initiated by local entrepreneurs such as the Scarognini family. These early operations were small-scale, privately managed, and intermittently productive. It was only after the annexation of the region by the House of Savoy in the early 18th century that mining activities were transformed into a coordinated and state-driven enterprise. The Savoyard administration introduced formal oversight, technical standardization, and public investment, integrating Alagna into broader territorial strategies aimed at exploiting mineral wealth to strengthen the state's economic base.

Savoyard government assumed direct control over mining operations²⁴ and assigned a specialized regiment of “*artiglieri minatori*”²⁵, trained in Turin, to manage and modernize the site²⁶. This intervention professionalized extraction, reinforced territorial oversight, and attracted skilled labor from distant regions²⁷. At its peak, Alagna counted more than 850 inhabitants, one-third of them foreigners²⁸. This demographic configuration, remarkable for such a remote Alpine location, paralleled the scale and complexity of mining settlements in Austria and Switzerland. Infrastructure²⁹ and social structures evolved rapidly, reflecting an extractive logic³⁰ that privileged technical elites while local miners remained among the lowest-paid workers. Social structures also shifted markedly: while foreign foremen and engineers received high wages and occupied privileged positions, local miners were among the lowest-paid

²⁴ The reorganization of mining operations under Savoyard rule brought not only technical modernization but also a profound institutional transformation of the Alpine territory. State control introduced new bureaucratic procedures, centralized concession systems, and external engineering oversight, often at odds with pre-existing local governance structures. These changes redefined the relationship between mountain communities and their environment, framing natural resources—especially forests and waterways—as assets to be inventoried, regulated, and exploited according to metropolitan priorities. The environmental repercussions of this shift were significant: intensive timber extraction, air pollution from smelting sites, and the militarization of infrastructure planning became persistent sources of tension (Cagna Pagnone et al 1990).

²⁵ Mining artillerymen.

²⁶ The “*artiglieri minatori*” were trained at a technical school in Turin and constituted a state-engineered military corps specializing in subterranean extraction and smelting operations.

²⁷ Such as Saxony, Bohemia, Flanders, and Denmark. The recruitment of foreign specialists responded to the need for advanced metallurgical, engineering, and surveying skills not yet widespread in the region.

²⁸ The arrival of foreign workers had not only demographic but also cultural implications, affecting local dialects, technical vocabulary, social customs, and labor organization. Recruitment extended beyond the Piedmontese Alps to include miners and technicians from Saxony, Flanders, Bohemia, and even Denmark—often veterans of other state-run mining operations in Europe.

²⁹ Including housing for soldiers, foundries, access roads, and support facilities.

³⁰ The extractive system in Alagna required a sophisticated spatial organization adapted to the challenging Alpine topography. Ore was transported along narrow mule tracks carved into steep slopes, connecting extraction points with smelting stations located at lower elevations. Water power, harnessed through a network of diverted alpine streams and rudimentary channels, drove bellows and hammers in the foundries, reflecting a locally engineered adaptation of hydraulic technology. Inflammable materials, particularly wood and charcoal essential for smelting, were stored in specially designated structures away from residential zones, both to ensure safety and to manage the constant risk of fire. These depots were often built in proximity to forested areas, integrating timber harvesting and fuel storage into the broader territorial economy of extraction. Together, these logistical components formed a decentralized yet highly coordinated infrastructure that enabled sustained mineral production in an otherwise remote and ecologically fragile environment.

workers, earning less than rural builders³¹.

In this light, Alagna Valsesia emerges as a paradigmatic case of proto-urbanization in the Alps, illustrating how extractive regimes could catalyze urban and infrastructural development in peripheral mountain territories well before industrial modernity. Its evolution reflects broader logics of resource-driven spatial transformation, visible across the Alpine arc.

Beyond the evident economic expansion enabled by new techniques and external investment, the mining boom in Alagna Valsesia had profound demographic and social consequences³² (Viazzo 1990, Zanini 2016). Labor organization remained highly stratified. Foremen, foundry specialists, and military engineers enjoyed relative privileges, whereas ordinary miners, often recruited from poorer segments of the local population, worked under difficult and hazardous conditions for modest pay³³. This social hierarchy mirrored patterns found in other Alpine mining settlements, yet the scale of inequality in Alagna was particularly acute due to its sudden and state-driven development. The intense interaction between locals and foreigners fostered collaboration and tensions. Still, archival records indicate the emergence of mixed households, intermarriage, and long-term settlement by several immigrant families³⁴. In some cases, these lineages maintained a distinct occupational identity as miners for generations, suggesting the formation of a semi-endogamic sub-community within the village structure³⁵. Even after the mining industry's decline in the late 1760s, many infrastructural and demograph-

³¹ Wages for ordinary miners were lower than those of day laborers in construction, and the risks associated with tunnel work made the occupation particularly strenuous and hazardous.

³² The rapid demographic increase, over 850 inhabitants at the peak, required significant adjustments in both the built environment and institutional organization of the village. Temporary shelters were no longer sufficient, leading to the construction of permanent dwellings to accommodate military personnel, foreign technicians, and seasonal laborers. The increased demand for food, tools, and materials stimulated the expansion of local supply chains, while the presence of non-local residents necessitated the regulation of lodging, property rights, and communal resources. In response, local authorities—often in coordination with regional administrators—had to implement new forms of governance to manage resource distribution, social order, and labor disputes. These adaptations contributed to a visible transformation of Alagna's spatial configuration, from a dispersed agricultural settlement to a more centralized and functionally diversified village aligned with extractive and administrative priorities.

³³ Wage records show that ordinary miners earned less than construction laborers, despite the greater risks and intensity of their work underground.

³⁴ Parish registers and civil archives document intermarriages between foreign miners and local women, as well as naming patterns that blend Germanic and Romance elements.

³⁵ This phenomenon is particularly notable in the persistence of *mining families* that retained their professional identity even after the decline of the sector.

ic legacies persisted³⁶. Alagna's built environment, population structure, and economic memory continued to bear the imprint of this extractive phase well into the 19th century³⁷. Foreign experts, particularly from Switzerland and Austria, introduced advanced mining techniques and machinery, linking local operations to wider European networks. The Walser settlers, experienced in high-altitude environments, further adapted extraction practices to Alpine conditions, integrating mining into the cultural and ecological fabric of the Monte Rosa valleys. As mining expanded, its economic impact was profound: local economies diversified beyond agriculture as extraction became the dominant industry. This shift attracted miners, traders, and craftsmen, developing markets and artisanal sectors catering to the growing population³⁸. Profits from gold and silver extraction were reinvested in infrastructure and public institutions, improving mobility, education, and community life. The influx of workers from across Italy and neighboring regions fostered structured, diverse communities and a new class of mine owners

³⁶ The long mining history of Alagna reveals the layered complexity of Alpine extractive systems, which combined seasonal labor patterns, military engineering expertise, religious patronage, and fluctuating external capital. Despite moments of intense activity, most mining phases were marked by instability, high operational costs, and administrative fragmentation. The legacy of these dynamics is still visible in the village's spatial organization: from the location of barracks and processing facilities to altered woodland structures and toponymic traces linked to extraction. Over time, these transformations contributed to reshaping the socio-territorial identity of Alagna, embedding the memory of mining into its material and cultural landscape (Cagna Pagnone et al. 1990).

³⁷ For instance, parts of the village layout, occupational surnames, and oral histories remained tied to the memory of mining as a foundational economic episode.

³⁸ For a detailed historical account of mining development in Valsesia, see Cerri and Tizzoni (1988). The work reconstructs multiple phases of metallurgical and extractive activity in the region, with particular attention to the late phases of operation during the early 20th century. A central figure was Don Giuseppe Teruggi, parish priest of Ferrera, who played a remarkable role in supporting the Gula mine—not for personal profit, but in pursuit of social solidarity and the economic survival of the community. His efforts led to the creation of the *SAMIL* company and to attempts at attracting investors from Turin and abroad, highlighting the persistence of local agency even during phases of industrial decline. The volume also documents the gradual dismantling of mining infrastructure, the decline of cooperative management, and the shift from extraction to passive conservation, revealing the deep entanglement between religious, economic, and environmental dynamics in Alpine mining territories.

and managers³⁹.

In Macugnaga, particularly the mining center of Pestarena, extraction evolved through a network of local entrepreneurs and transnational investors; by the mid-nineteenth century, British capital and management models dominated⁴⁰. Despite the significant growth and development that mining brought to the regions in the 18th century, the industry began to decline in the 19th century due to the depletion of the wealthiest ore veins and the increasing difficulty of deep mining. Furthermore, shifts in the European economy, such as the rise of industrial mining in other parts of the continent, made it harder for smaller Alpine mines to remain competitive. By the mid-19th century, many of the region's mines had been abandoned or drastically scaled back.

Mining legacies as drivers of territorial integration Nevertheless, the legacy of mining remains visible today. Both towns retain their historical architecture and visible traces of mining, now reinterpreted through tourism as a key component of local identity. Although the mining industry eventually declined, the legacy of this period remains evident in the town's architecture, culture, and economy.

³⁹ A valuable case study of this migration dynamic is provided by Cerri (1992), who traces the presence of miners and metalworkers from Postua in the Valli di Lanzo at the end of the 14th century. Using archival sources from the castellania of Lanzo, Cerri documents the arrival and gradual settlement of individuals identified as *de Valle Sexia* alongside Bergamasque specialists. These Valsesian migrants, often integrated into mixed communities, maintained distinct linguistic and professional traits while contributing to the development of early Alpine metallurgical hubs. The legal records reveal patterns of transalpine mobility, labor specialization, and even early signs of local integration through land ownership and intermarriage. This case underscores the long-standing mobility of skilled Alpine laborers and their capacity to shape the socio-economic landscapes of distant valleys well before industrial mining.

⁴⁰ One of the most emblematic local figures was Giovanni Battista Fantonetti, a physician from San Carlo who played a central role in the management and technical evolution of the Pestarena mines during the first half of the 19th century. Fantonetti personally oversaw operations on site, investing his own capital while also attending to the medical and social needs of the workforce (Cerri and Zanni 2009). His involvement reflects a transitional phase in Alpine mining history, where local expertise and personal commitment still shaped industrial ventures before the arrival of large-scale foreign capital. Fantonetti introduced new amalgamation techniques, documented working conditions, and sought investors in Turin and abroad, embodying the last attempt at maintaining a locally controlled mining economy. His story illustrates not only the technical challenges of high-altitude gold extraction but also the deep personal ties between Alpine professionals and their territory—a connection soon to be disrupted by the corporate logics of late-century globalization. For a first-hand contemporary perspective on these developments, see also Fantonetti's *Le miniere metalliche dell'Ossola in Piemonte* (1836), which combines technical analysis with reflections on the scientific, economic, and administrative dimensions of mining in the Alpine context, based on his decade-long direct involvement in the region.

The transformation of Alpine settlements stemmed not only from technological change but from the deep social and demographic shifts triggered by extractive activity. In Alagna, mining was not a transient phase but part of a long process of territorial reconfiguration that linked mountain communities to distant economic centers. It brought the periphery into dialogue with distant regions economically and socially, making mountain communities legible to central powers for the first time. This new legibility, expressed through labor records and population registers, enabled governance and integration while reinforcing dependencies and environmental pressures. The case of Monte Rosa thus exemplifies how extractive cycles in the Alps were not isolated technical episodes but part of a *longue durée* of transformation, in which landscape, labor, and livelihood were continuously renegotiated. Mining catalyzed urbanization and a new geography of Alpine modernity, marked by circulation, displacement, and enduring asymmetries in power and resource distribution.



fig.4.4 The Macugnaga mining basin on the *Carta di parte del territorio di Macugnaga in cui trovansi minere d'oro e d'argento, nella Valle d'Anzasca nell'Ossola Superiore, Alto Novarese*. The map was produced during the 1756 survey campaign (ASTo, Corte, *Carte topografiche e disegni*).

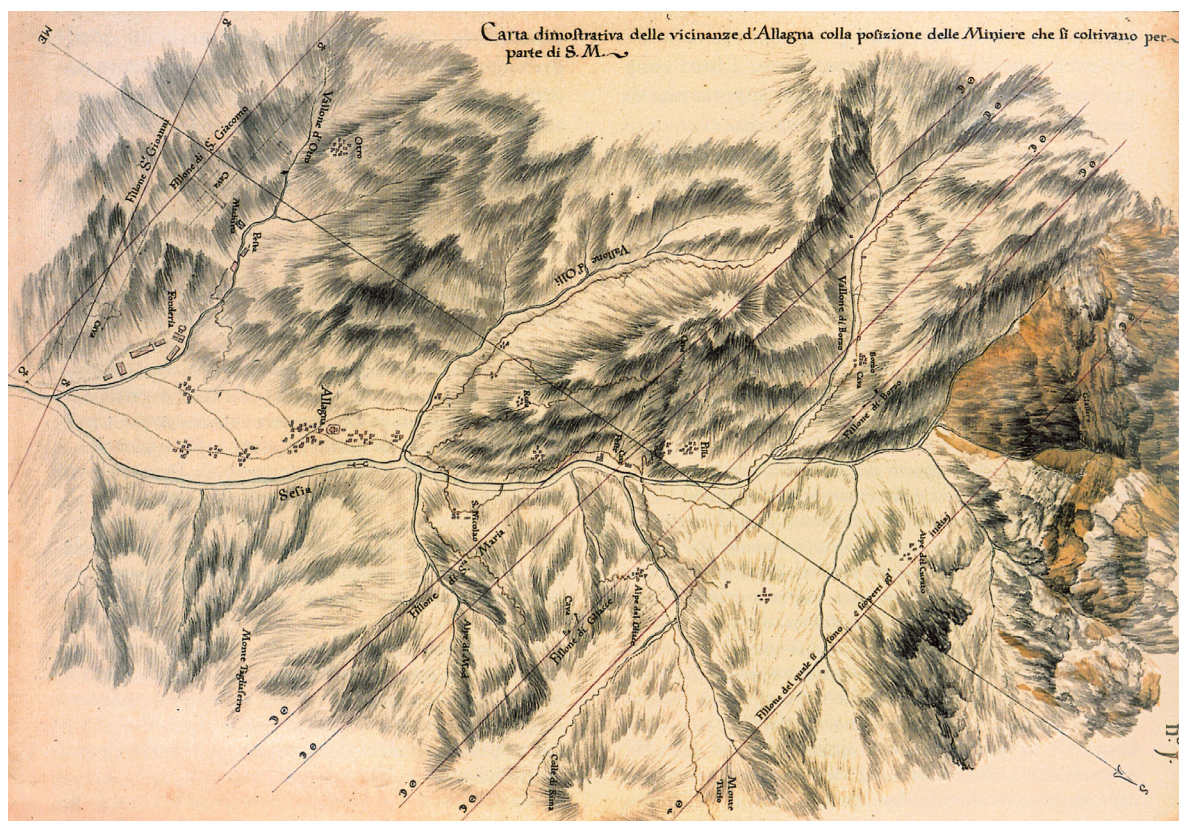
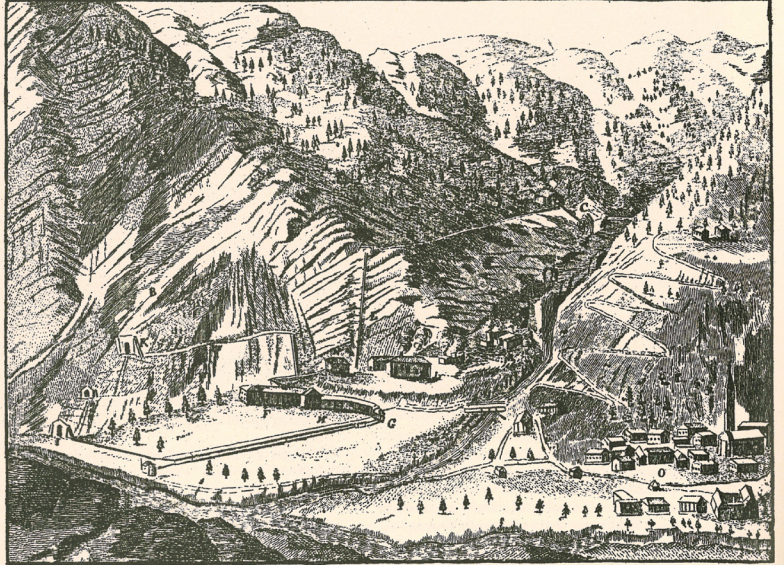


fig.4.5 The Alagna mines exploited in the eighteenth century under the Savoyard administration. *Carta dimostrativa delle vicinanze d'Allagna colla posizione delle Miniere che si coltivano per parte di S. M.* (ASTò, Corte, Carte topografiche e disegni).

fig.4.6, fig.4.7 *Perspective du departement du cuivre d Allagne dans la Vallée de sesia and Perspective des Environs de Scopel et de la Fonderie Royale.* From: S.B. Nicolis di Robilant, 'De l'utilité et de l'importance des voyages et des courses dans son propre pays).

Perspective du département du Cuivre d'Allagne dans la Vallée de Sesia



A Mine de Cuivre de S.^t Jacques B Mine de Cuivre de S.^t Jean C Machine pour l'extraction et l'équipement D Chemin pour le transport des minéraux
E Canal de roulement F Grand Bâtimens pour le pilage et lavage du Cuivre G Grilles de séparation H Machine élévatrice de Minéraux de S.^t
Jean I Galerie de S.^t Louis K Galerie de Charles Emmanuel qui ouvre le puits de S.^t Jacques L Fonderie pour les Matras M Recours N Magasin du
Charbon O Village d'Allagne P Vallée d'Otro

Perspective des Environs de Scopel et de la Fonderie Royale N.^o VIII



A Fonderie des Mines fines, et des Matras du Cuivre B Fonderie de Séparation C Logemens et magasins D Boccommes
E Canal des Fontes F Salle d'affinage G Magasin du Charbon pour les mines H Magasin de Charbon pour les sépara-
tions I K L Bâtimens pour les calcinations M Chaussée Canal N Porte d'entrée O Puits d'eau de la Sesia
P Avant Chaussée Q Paroisse de Scopel R Le Village S Chemin des mines d'Allagne T Lavage de la Bascarelle
aux mines de Sessera

Quar R. habitant inventé et pinxit

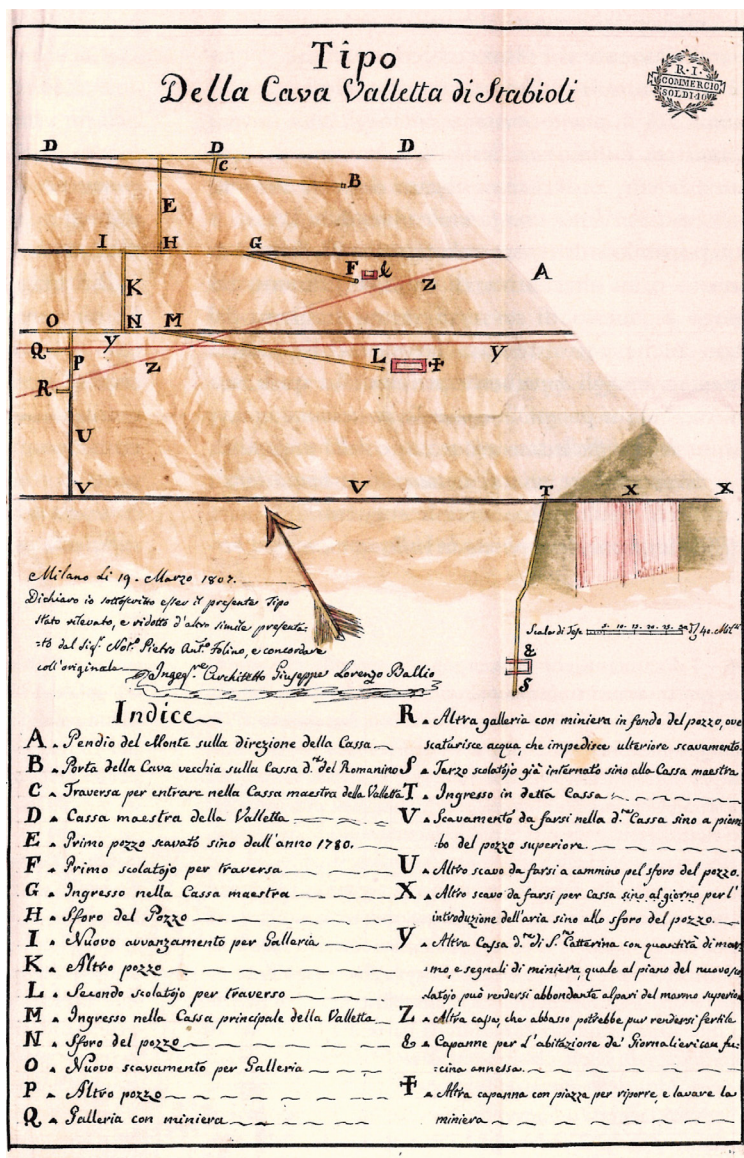


fig.4.8 Tipo della Cava Valletta di Stabioli (ASMi, Commercio)



fig.4.9 The settlement of Pestarena, the Pozzone mine, and the Alpetto mines.
Carta di parte del territorio di Macugnaga in cui trovansi miniere d'oro e d'argento, nella Valle d'Anzasca nell'Ossola Superiore, Alto Novarese. (ASTo, Corte, Carte topografiche e disegni).

4.4.the economic transformation of Alpine territories

By the late nineteenth century, Alpine mining entered a gradual structural decline driven by global market shifts, resource depletion, and changing labor dynamics, accelerating rural depopulation and weakening the region's traditional economic structures (Bätzing 2005). The mining industry in the Alps had historically been characterized by small-to medium-scale extraction, which, despite its strategic importance in earlier centuries, became increasingly uncompetitive in the face of emerging global markets. The rise of large-scale mining operations in the Americas, Australia, and Africa, driven by richer ore deposits and advanced mechanization, led to lower production costs and higher output. These developments placed European mining sites, particularly those in the Alps, at a structural disadvantage, as rugged terrain, fragmented ownership structures, and higher labor costs constrained them.

The decline of alpine mining and the collapse of rural economic systems Resource depletion was central to the decline, as centuries of extraction exhausted accessible deposits and raised operational costs. By the late 19th century, deeper mining shafts and more complex extraction methods were required, making many sites financially unsustainable. In parallel, the gradual industrialization of the Alpine valleys and the increasing availability of alternative employment in urban-based manufacturing and hydropower construction led to a shifting labor market, where mining was no longer the primary source of income for local communities. In addition to economic pressures, political and regulatory changes also contributed to the decline. Designed initially to support extraction through structured concessions, mining laws became increasingly restrictive, imposing higher costs and regulatory burdens on local operations. Consolidating national economies and prioritizing industrial development in major urban centers redirected state investments toward more productive sectors, leaving many Alpine mining operations without modernization or infrastructure support. As mining declined, Alpine communities faced economic instability and a shift from seasonal to permanent migration toward industrial centers. While temporary winter migration had long been a common strategy for Alpine laborers seeking employment in lowland industries, the closure of mines made it increasingly difficult for these workers to return, leading to a permanent demographic shift towards industrial centers in the valleys and beyond (Viazzo 1989). This demographic transformation further weakened local agricultural systems, as reduced labor in moun-

tain villages made traditional subsistence farming increasingly difficult to sustain⁴¹. In regions like Alagna, where mining had long provided supplementary income to agrarian households, the disappearance of extractive labor disrupted kinship systems and intergenerational livelihoods⁴². This loss of occupational diversity contributed to the erosion of adaptive strategies, such as seasonal migration and mixed subsistence, that had historically enabled mountain societies to navigate marginality⁴³. Moreover, the long-term effects of this transition extended beyond the workforce: depopulation, the abandonment of infrastructure, and the weakening of communal institutions⁴⁴ signaled a broader process of social and spatial disarticulation. Once structured around a functional integration between agriculture and mining, the Alps began to fragment both demographically and territorially. In this light, the decline of mining must be understood not only as a trigger for outmigration but also as a pivotal moment in the redefinition of Alpine modernity.

Post-Mining Landscapes The end of mining disrupted the balance between rural and industrial livelihoods; attempts to replace lost income through small manufacturing or tourism rarely succeeded. Still, these efforts were often insufficient to counterbalance the loss of mining-related employment. Mining infrastructure, including processing sites and worker settlements, was progressively abandoned or repurposed. Some former mining towns experienced post-industrial redevelopment, particularly in areas where rail infrastructure allowed for the establishment of new factories or hydropower plants. In many remote valleys, abandonment led to long-term economic stagnation, as neither agriculture nor emerging industries replaced mining incomes. While some

⁴¹ Viazzi (1989) describes the post-mining phase in Alagna as a period not simply of economic contraction, but of systemic social unraveling. With the disappearance of mining-related employment, many families lost access to the supplementary income that had sustained agricultural life during the most precarious months. This economic vacuum precipitated the dismantling of key communal institutions—including schools, parish structures, and irrigation consortia—which had historically underpinned the village's social cohesion. The loss of population, particularly among younger generations, accelerated a collapse in demographic resilience, leaving behind aging communities with limited reproductive and productive capacity. Rather than a return to a previous equilibrium, the post-mining era marked a profound rupture in the continuity of place-based knowledge, intergenerational transmission, and collective agency.

⁴² The gold mines of Alagna, for example, were tightly woven into the fabric of everyday life. From wage systems to family structures to local diets.

⁴³ The disappearance of extraction left a void that neither agriculture nor early tourism could immediately fill, leading to a loss of social versatility in many highland communities.

⁴⁴ Like schools, cooperatives, and irrigation consortia.

valleys successfully integrated into emerging industrial networks in the early 20th century, others faced prolonged economic marginalization, thereby reinforcing patterns of uneven regional development. This shift set the stage for the rise of hydropower, which channeled resources to lowland industries, reinforcing the mountains' economic subordination. This shift confirmed the economic subordination of the mountains to the plains and accelerated the demographic trends already set in motion by the mining decline. In this context, agriculture did not regain its former relevance but instead entered a phase of further contraction, reinforcing the Alps' transition from a productive landscape to a resource-extraction zone⁴⁵.

The agricultural decline and ecological reconfiguration By the early twentieth century, depopulation and integration into national markets undermined the viability of Alpine agriculture, which struggled to compete with modernized lowland systems. This shift intensified competition and diminished the economic viability of traditional Alpine farming, which relied on small-scale production and limited mechanization. While lowland agriculture modernized, increasing its efficiency and market reach, Alpine agriculture remained structurally disadvantaged, unable to compete in yield and cost (Bätzing 2005). The decline of agriculture had profound ecological effects, leading to the abandonment of terraces, pastures, and irrigation systems that had long stabilized the landscape⁴⁶ (Sereni 1961). These traditional agricultural forms have been essential in preventing soil erosion and managing

⁴⁵ The following section will examine how this crisis of traditional Alpine agriculture unfolded and how it intersected with the broader socio-economic transformations of the region.

⁴⁶ The transformation of agricultural structures and social and economic changes can be attributed to the penetration of capitalist logic into rural areas. Emilio Sereni (1968) focused on the transition from feudalism to capitalism in the countryside and the processes and dynamics that led to this transformation. By emphasizing profit and market-oriented production, he argues that capitalism profoundly affected rural societies with the rise of commercial agriculture and the commodification of land and labor. The emergence of agrarian capitalism has had social, economic, and political consequences on various groups, including small farmers, agricultural workers, and rural communities. Through this analysis, the tensions and contradictions inherent in the capitalist transformation of the countryside emerge. The state's role and policies—again exogenous processes—shaped the agrarian structure and how rural societies adapted to and resisted capitalist pressures. Starting in the second half of the 19th century, in the face of the growing environmental impact of industrialization processes and the tendency towards uncontrolled exploitation of resources, a greater interest in the rational use of natural resources and the protection of the environment began to develop.

water flows, creating a delicate balance between human activity and environmental stability.

As these landscapes were progressively abandoned, the natural process of forest recolonization accelerated, altering the ecological dynamics of entire regions. While forest expansion sometimes restored biodiversity, the absence of active management increased hydrogeological risks such as landslides and floods. The disappearance of grazing areas and decline of transhumance further weakened local economies; early twentieth-century subsidies and land-consolidation programs failed to reverse the trend. Early 20th-century agricultural policies aimed to support mountain farming through subsidies and incentives. However, these measures frequently fell short of addressing the structural disadvantages of Alpine agriculture. Initiatives such as land consolidation and irrigation projects were implemented in some regions, but they were insufficient to counterbalance the economic forces driving depopulation⁴⁷. Small textile, woodworking, and metalworking activities absorbed part of the displaced workforce but remained too localized to replace mining and agriculture.

⁴⁷ In response to the agriculture crisis, many Alpine communities sought alternative economic models. Tourism emerged as one of the most promising sectors, particularly in areas that could capitalize on scenic landscapes and cultural heritage. The late 19th and early 20th centuries saw the rise of Alpine tourism, initially promoted through elite mountaineering expeditions and spa resorts and later expanding into winter sports and mass tourism. However, tourism was highly uneven in its impact: while some valleys benefited from infrastructure investments, others remained disconnected from this new economy, further reinforcing regional disparities. Another alternative was small-scale industry and handicrafts, which developed in certain Alpine areas to diversify economically.

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4.the Alps as a reservoir of resources

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5.a place of experimentation hydroelectric modernization and territorial reconfiguration

Hydropower has been one of Europe's leading sources of energy production since the late 19th century⁴⁸. It emerged as the main engine of economic transformation in the Alpine region. The Alps have become a prime area for developing hydroelectric plants due to their morphology and abundant running water. European industrialization led to the need for new energy sources to meet the growing demands of industries and cities⁴⁹. The same valleys that once focused on mining and subsistence agriculture were repurposed as energy reservoirs for industrial expansion in the lowlands. Unlike mining, which historically fostered localized economic networks, hydropower was characterized by a highly centralized system of resource extraction. In 1882, the construction of the first hydroelectric power plant in Italy⁵⁰ marked the beginning of the exploitation of Alpine hydraulic energy. Similar plants began to emerge in Switzerland, France, and Austria, where the Alps provided the ideal geography for constructing power stations powered by rivers and glaciers. The first hydroelectric installations were relatively modest in terms of capacity. Still, starting in the 1890s, with the adoption of new technologies⁵¹, it became possible to increase the power of the plants and spread their use along the major Alpine waterways. In the 20th century, energy demand grew exponentially as industries expanded and urban and rural areas were electrified. Thanks to their topography, the Alps became a focal point for hydropower production. Dams and reservoirs were created at high altitudes, from which water could be released to generate electricity⁵².

The development initially followed a path of constructing small-scale power plants serving local industries, but quickly evolved into large-

⁴⁸ Switzerland, in particular, emerged as one of the world leaders in hydroelectric exploitation, with major plants built in the first half of the century, such as Grande Dixence, which at the time of its construction in the 1930s was the tallest dam in the world. Italy, too, with its Valtellina project and dam systems in Trentino-Alto Adige, Italy also made significant investments in this form of energy. In France, the Alpine region became crucial for the national energy development plan by constructing large hydroelectric plants, particularly in the Durance basin. The project, launched in the 1950s, represents one of Europe's most extensive hydraulic engineering works and profoundly impacted France's energy supply.

⁴⁹ Energy was produced in the Alps, but primarily consumed in urban and industrial centers.

⁵⁰ On the Serio River in Lombardy.

⁵¹ Such as *Pelton* and *Francis* turbines.

⁵² The exploitation of hydropower in the Alps has played a fundamental role in Europe's energy development, significantly contributing to the electrification of Alpine regions and surrounding nations. While it has provided a renewable energy source and promoted economic development, it has also presented considerable environmental and social challenges.

scale infrastructure projects requiring significant capital investment and labor migration. The construction of major dams and power stations briefly reversed migration trends, attracting workers to Alpine construction sites. However, the projects generated only temporary employment, unlike mining, which supported long-term settlement. Once the dams and power plants were completed, the workforce had little incentive to stay, and many left the mountains permanently. Instead of revitalizing Alpine communities, it reinforced existing patterns of depopulation, accelerating the transition that had begun with the decline of mining and the agricultural crisis⁵³. The structure management reinforced the asymmetry between resource production and economic redistribution. Concessions were granted to national and international companies, limiting the decision-making power of local actors. While extensive infrastructure development was designed primarily to support energy production rather than sustain local economic growth.

The region of Piedmont played a key role in the national development of hydroelectric power, particularly from the early 20th century onward. Due to its territorial features, including steep mountain slopes, abundant watercourses, and glacier-fed rivers, Piedmont became an ideal setting for the construction of hydroelectric plants. The hydropower development in this region followed a pattern similar to that seen across the wider Alpine arc, as described above, characterized by technological innovation, increasing energy demand, and significant socio-environmental impacts. As in other Alpine regions, the initial exploitation of hydroelectric resources in Piedmont began in the late 19th century, spurred by the region's growing industrial sector, particularly in cities such as Turin. The first hydroelectric plants were modest in capacity and designed to meet the energy needs of local industries and urban areas. However, the introduction of advanced turbine technologies and government incentives for renewable energy accelerated the construction of larger plants in the early 20th century. By the 1920s, Piedmont had become one of Italy's most hydroelectrically developed regions, with significant plants built on the Dora Baltea, Orco, Toce, and Sesia rivers. The Toce River was among the first watercourses in Piedmont to be identified for large-scale hydroelectric projects. As early as the late 19th

⁵³ Extractive transitions—whether based on minerals or energy—rarely replace lost social capital. While hydropower offered infrastructural renewal and temporary employment, it often failed to reintegrate local populations into the circuits of production and decision-making (Viazzo 1989). The result was a growing disconnection between resource flows and human settlement, reinforcing the structural marginalization of mountain communities.

century, engineers and industrialists recognized the Toce's potential to generate significant electricity for the rapidly industrializing areas of northern Italy⁵⁴. The construction of the first hydroelectric plant on the Toce began in the early 20th century, culminating in the completion of the iconic Verampio plant in 1906⁵⁵. The downstream plants⁵⁶ formed a complex system that maximized the river's hydroelectric potential⁵⁷. Such technological innovations were crucial for efficiently exploiting Toce's water resources, and they became a model for similar projects in other parts of the Alps. Exploiting the Toce River for hydroelectric purposes had considerable environmental and social consequences. The construction of large dams altered the river's natural flow, significantly impacting local ecosystems and reducing water availability downstream, particularly during dry seasons⁵⁸.

Furthermore, as with other Alpine hydroelectric projects, the creation of reservoirs and the construction of power plants involved the relocation of local populations. The displacement of communities, particularly in the high-altitude areas where dams and reservoirs were built, mirrored the broader trend seen across the Alps, where large-scale hydroelectric development often came at the expense of local livelihoods. The fascist regime in Italy, emphasizing industrialization and energy self-sufficiency, further promoted the development of hydroelectric plants in Piedmont⁵⁹. Large infrastructure projects were undertaken⁶⁰, technological marvels that symbolized the regime's energy independence and economic growth ambitions. During this period, state support and pub-

⁵⁴ The Toce River, located in the Ossola Valley in northern Piedmont, has been one of the most significant waterways in Italy for hydroelectric exploitation, particularly due to its steep descent from the high Alpine regions and its substantial flow throughout the year. The exploitation of the Toce mirrors the broader pattern of hydroelectric development in the Alps but holds specific historical and technical significance, given the large-scale infrastructure built in the early 20th century and its role in powering both local and national industries.

⁵⁵ This plant was one of the most advanced of its time, harnessing the river's steep gradient and strong flow to produce energy for the emerging industrial cities of Piedmont and Lombardy.

⁵⁶ Formazza, Verampio, and Crevola.

⁵⁷ This system was unique because it relied on high-altitude reservoirs that could store water during the wet season and release it during dry periods, ensuring a steady electricity supply throughout the year).

⁵⁸ Regulating the river's flow also affected agriculture and local communities, who depended on it for irrigation and daily needs..

⁵⁹ The dams and related facilities were a critical part of Italy's fascist-era push for energy independence and industrial growth.

⁶⁰ Such as constructing the Valle Orco system, which included the notable Telesio and Ceresole dams.

lic-private partnerships enabled Piedmont to make significant contributions to Italy's energy production. The expansion of hydroelectric power in Piedmont, as in the Alps, had profound environmental and social consequences. The construction of dams and reservoirs altered the landscape and river ecosystems, affecting local biodiversity. Additionally, creating large reservoirs often required displacing communities and losing agricultural land⁶¹. These impacts mirrored the broader trends observed in Alpine hydroelectric development, where the drive for energy production often conflicted with environmental preservation and local livelihoods.

In addition to hydroelectric projects, large-scale infrastructure works such as the construction of the *Traforo del Sempione* (Simplon Tunnel) had a significant impact on the Alpine landscape. The Simplon Tunnel, completed in 1906, was a monumental engineering achievement, at the time the longest railway tunnel in the world, spanning nearly 20 kilometers beneath the Alps and connecting Italy with Switzerland. The tunnel was built to facilitate trade and transport between northern Italy and central Europe, serving as a key artery for the movement of goods and people. The construction of the Simplon Tunnel required extensive tunneling through mountainous terrain, drastically altering the landscape. The environmental impact of this colossal project included deforestation of large areas, the excavation of massive amounts of rock, and the construction of new railways that cut through previously isolated valleys. Moreover, the influx of labor required for the project led to the establishment of temporary settlements and a shift in local economies from agriculture to construction-related activities. While the tunnel dramatically improved connectivity and economic integration for the region, it also significantly departed from the traditional, rural Alpine way of life. The combined impact of hydroelectric infrastructure and large-scale projects such as the Simplon Tunnel profoundly transformed the Alpine environment⁶². On the one hand, these projects contributed to Piedmont's modernization, enabling it to compete on the national and international stage by supplying power to burgeoning

⁶¹ The Ceresole Reale dam, for example, required the resettlement of local populations as the valley was flooded to create the artificial lake.

⁶² Despite the economic benefits and critical contribution to national energy independence, hydropower development in the Alps also had significant environmental and social consequences. Starting in the 1970s, ecological awareness increased, leading to the emergence of movements opposing the construction of new dams in the Alps, especially in Italy and Switzerland. This resulted in greater environmental regulation and the introduction of mitigation measures to reduce the impact of hydroelectric plants on river ecosystems.

industries and facilitating trade. On the other hand, the environmental costs were substantial. Entire ecosystems were reshaped to accommodate human activity, and the traditional relationship between Alpine communities and their natural surroundings was irrevocably altered. In addition to the physical alterations to the landscape, the socio-economic effects of these projects were far-reaching.

Once largely dependent on agriculture, livestock, and small-scale industry, local communities in the Alps were thrust into a new industrial and infrastructural economy. The labor demand for both the hydroelectric plants and the Simplon Tunnel attracted workers from other regions, resulting in population shifts and changes in the social structure of these mountainous areas. While developing hydroelectric power and significant infrastructure projects was crucial to Piedmont's industrial growth, they also posed challenges to environmental preservation. Today, there is a growing recognition of the need to balance economic development with the protection of the Alpine environment. Efforts to mitigate the impacts of hydroelectric projects, such as ecological compensation and modernized water management practices, are being implemented to preserve the region's natural heritage. However, the legacy of these early 20th-century projects remains visible in the altered landscapes of the Piedmontese Alps. The transformation of valleys and the construction of vast transportation networks stand as a testament to the tension between the drive for modernization and the preservation of natural environments in one of Europe's most iconic mountain regions⁶³.

⁶³ Like other Alpine regions, Piedmont saw a shift toward modernizing existing hydroelectric infrastructure rather than constructing new large-scale dams. This phase, beginning in the late 20th century, was marked by efforts to increase the efficiency of older plants and mitigate the environmental impacts of previous projects. Introducing mini-hydropower plants, particularly in less accessible valleys, allowed for more sustainable use of water resources, reducing the need for large-scale alterations to the landscape. Piedmont remains a leader in Italy's renewable energy sector, contributing significantly to the national grid through hydroelectric production.

5.1.the Alps as a Hub of Innovation and Infrastructure in Early 20th-Century Europe

From the mid-19th to the early 20th century, the Alps became a key territory for experimentation and technological transfer, where infrastructure, materials, and engineering practices were developed and tested in extreme environments. International Expositions accelerated this exchange, linking Alpine innovation with Europe's rapid industrialization in transport, communications, and energy.

The interaction between the city and the mountains fostered the development of new technologies specifically adapted to the harsh alpine conditions. Railroads connected remote and isolated valleys to cities. The Alps also became a testing ground for early hydroelectric power stations, which later became a vital energy source for industrial cities.

Industrial expositions, alpine modernity, and the symbolic power of infrastructure International Expositions in Paris, Vienna, and Milan offered platforms where engineers and entrepreneurs presented mountain-specific innovations and forged transnational collaborations. These events tied Alpine experimentation to the wider European process of industrial modernization and scientific exchange. The 1906 *Milan International Exposition* (fig.5.2) marked a decisive moment in the articulation of Alpine modernity within Europe's industrial imagination. Conceived to celebrate Italy's role in technological progress, the event positioned the Alps not as a natural periphery but as a core site of modern engineering. The completion of the Simplon Tunnel the previous year, at the time the world's longest, was central to this narrative. Cutting through the mountain to connect Italy and Switzerland, it materialized the rhetoric of international cooperation and the triumph of engineering over nature that animated the Exposition. Prominently featured in official posters and architectural displays, the tunnel became both infrastructure and icon⁶⁴. A representation of national ambition framed within a European project of connectivity⁶⁵ constructed its own geography of progress. The visual culture surrounding the Simplon technical achievement presented it as an image of civilization's advance, suggesting that mastery of the mountain was synonymous with entry

⁶⁴ It embodied the convergence of scientific expertise, transnational capital, and political symbolism through which industrial modernity.

⁶⁵ The tunnel's construction and enduring impact on European transportation reflect the late 19th and early 20th-century infrastructure development trend. Several other major Alpine tunnels were constructed, such as the Gotthard and Mont Cenis tunnels, each contributing to the creation of a comprehensive rail network that reshaped the European economy (Sharp 1979).

into modernity itself.

Its successful completion⁶⁶ (fig.5.3) profoundly impacted the economies of the regions it connected, significantly reducing travel times and facilitating the movement of goods and people between northern and southern Europe. It thus became a powerful symbol not just of progress in transportation but of the broader modernizing forces at work in Europe during this period of rapid industrialization. The tunnel was celebrated as a national and international symbol of progress at the exposition. Many promotional manifestos (fig.5.1) prominently displayed the tunnel as an icon of technological achievement, linking it to the broader themes of the Exposition: innovation, connectivity, and overcoming natural barriers. In particular, it became a symbol of the connectivity and economic integration that characterized Europe's industrial expansion in the early 20th century. These posters, often depicting the tunnel entrance framed by the majestic Alps, conveyed a narrative of conquering *nature* through engineering⁶⁷.

Once operational, the Simplon Tunnel not only reshaped the economic geography of the Alps but also altered their cultural perception. Historically regarded as an impassable natural barrier, the mountain range gradually came to be understood as a connective territory, an infrastructural corridor linking Europe's industrial centers. Additionally, it played a crucial role in stimulating the development of travel and leisure infrastructures across the transalpine corridor. Rather than fostering tourism in the high valleys themselves, it enhanced accessibility to the cities and lake districts, integrating these landscapes into the broader geography of European mobility and modern leisure.

Early territorial substitution: the social reconfiguration of Alpine space During the construction, large temporary settlements were established to house the thousands of workers and their families who migrated from various parts of Italy, mainly from central and southern

⁶⁶ Construction on the Simplon Tunnel was both a technical and logistical challenge. Engineers faced considerable obstacles, including extreme alpine weather conditions and the necessity to drill through solid rock over 20 kilometers beneath the mountains. The work required advanced tunneling techniques and innovative technology and took seven years to complete (Courthion et al. 1920).

⁶⁷ This motif resonated deeply with the Exposition's visitors and with the broader public at a time when industrial progress was equated with national pride and international prestige. Thus, the Milan Exposition served as a celebration of technological achievements such as the Simplon Tunnel and a platform for promoting the idea that these advancements were emblematic of a new era of industrial and scientific progress.

regions. One of the largest and most significant of these settlements was the village of Balmanolesca, which, at its peak, housed approximately 8,000 inhabitants. This village was not merely a collection of makeshift shelters but a fully functioning community with essential services and provisions for social and cultural life, reflecting the immense scale of the project and the human infrastructure needed to support it.

The village was built near the tunnel's entrance on the Italian side, strategically located to provide quick access to the worksite. It was a remarkable example of the social organization required for large-scale engineering projects at the turn of the 20th century. It included infrastructure typically associated with permanent communities, despite its temporary nature, which indicates that families were present, as workers often brought their families with them. The presence of a hospital was crucial, given the dangerous working conditions that characterized tunnel construction at the time⁶⁸. Its existence highlights the broader socio-economic context of significant infrastructure projects in the Alps at the time. Temporary worker settlements like this were essential to the success of such projects, offering a glimpse into the lives of the laborers who built the infrastructure that shaped modern Europe. Though transient, these villages played a crucial role in facilitating the construction of ambitious projects that would transform Alpine transportation and contribute to Europe's broader industrialization

However, while the village was relatively well equipped with essential services, it remained a temporary settlement, vulnerable to environmental factors. In 1920, a flood destroyed the village, underscoring the precariousness of life in such makeshift settlements, particularly those in mountainous or flood-prone areas. The brief existence of Balmanolesca exemplifies the transient yet transformative cycle of the great Alpine construction sites, whether infrastructural or extractive, which, despite their limited duration, profoundly reconfigured the spatial and social dynamics of mountain life. These temporary enterprises imposed new temporalities of labor, settlement, and mobility, often displacing the slower, adaptive rhythms that had governed Alpine communities for centuries.

⁶⁸ The establishment of such services also speaks to the long-term nature of the project, which required sustained labor over several years and necessitated stable living conditions for the workforce.



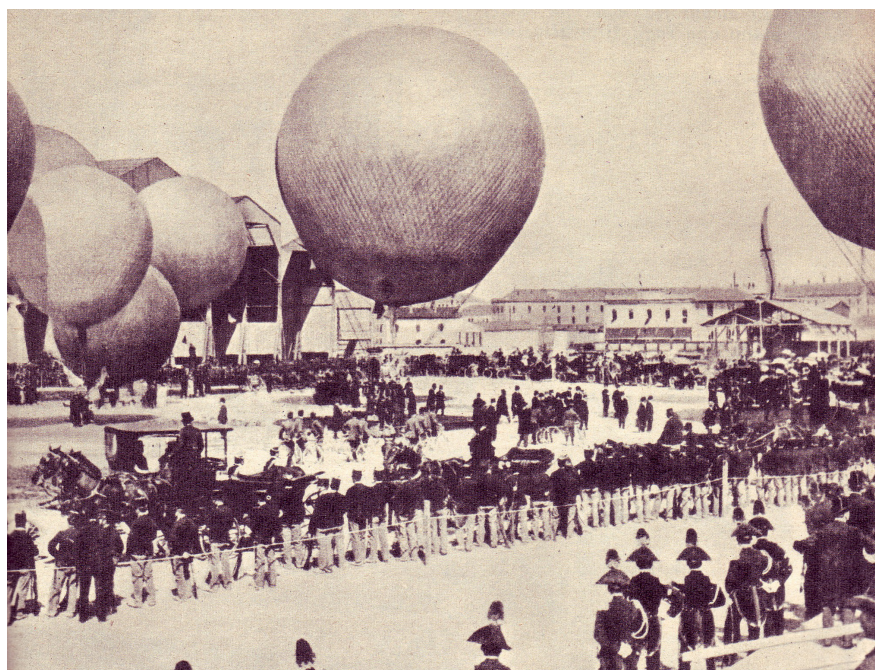


fig.5.1 Marcello Dudovich, Manifesto per l'Esposizione Internazionale di Milano (1906, *Marcello Dudovich Archive*).

fig.5.2 Exhibition view, Esposizione Internazionale di Milano (1906, *Archivio Fondazione Fiera Milano*).

fig.5.3 Inauguration of the Simplon Tunnel, (1906, *The Guardian*)

5.2.the white coal-the rise of the electrical industry

At the turn of the twentieth century, the emergence of electricity as a territorial infrastructure was still in its formative phase. Introduced for public lighting—first in New York in 1882, then in Milan and London in 1883 electricity remained a marginal utility, loosely integrated into the productive fabric of cities. In Italy, electrification progressed unevenly, primarily driven by municipal enterprises and initially limited to pilot plants or localized grids. By 1901, only 24 municipalities operated electric stations, and most installations were experimental or served only illumination needs. The concept of electricity as an integrated, multi-scalar energy system (Hughes 1993) was not fully formed. Illumination and traction operated on segregated circuits, while mechanical power remained dominated by steam

From illumination to power: the infrastructural consolidation of electric energy in early modern Italy. Only in the early 1900s did electricity begin to displace steam engines in manufacturing, marking a shift from service provision to industrial productivity⁶⁹. This transition was neither linear nor homogeneous. It depended on the technical unification of separate uses into a consolidated infrastructural model. The subsequent emergence of centralized power plants and interconnected transmission and distribution networks formalized electricity as an infrastructural product, capable of reorganizing territorial economies and shaping new patterns of spatial dependency.

The electrical industry in Piedmont began to take shape around 1885, largely spurred by the 1884 *Turin industrial exhibition*. During this event, an electric-powered public lighting demonstration captured the imagination of industrialists and the public alike, demonstrating the potential of electricity for urban illumination and a wide array of industrial applications. This marked a turning point, creating new market opportunities and setting the stage for the rapid development of the electrical industry in the region. Piedmont's geographical location, nestled at the foothills of the Alps, provided the area with abundant “white coal”, a

⁶⁹ For an in-depth institutional and technical history of the Italian electric industry, see *Storia dell'industria elettrica in Italia, Vol. 1: Le origini (1882–1914)*, which reconstructs the sector's early development through detailed analysis of policies, infrastructures, and corporate structures.

term for energy derived from watercourses fed by perennial glaciers⁷⁰. This natural resource became the backbone of the region's electrical industry.

Hydropower and the disruption of traditional economies in the Western Alps The harnessing of hydropower enabled the establishment of several large-scale electro-commercial companies. These companies were pivotal in developing energy infrastructure and facilitated regional industrial polarization. With the availability of cheap, renewable energy, production sites that relied on electricity became more accessible, particularly in areas close to water sources in the Alpine valleys. The development of hydroelectric power not only bolstered local industries but also enabled the region to supply energy to other parts of Italy⁷¹ (Caligaris 2004).

Large-scale hydroelectric projects, such as those along the Dora Baltea and Toce rivers, provided a crucial energy source for Turin and the surrounding industrial districts. These projects, undertaken by companies such as *Edison* and *Società Idroelettrica Piemontese (SIP)*, laid the foundation for Piedmont's leadership in the energy sector. The introduction of hydroelectric power in Piedmont had profound and far-reaching effects on the region's traditional economic and social structures, particularly in the western Alpine arc. Before electrification, these mountainous areas had maintained a fragile balance based on agriculture, forestry,

⁷⁰ The expression *white coal* (*houille blanche*) emerged in early 20th-century France to describe hydropower as a strategic industrial resource equivalent in value to fossil coal. First used in public discourse by economist Charles Gide in the early 1900s, the term gained traction through works such as Henri Cavaillès's *La Houille blanche* (1922), which framed hydropower as a central vector of regional modernization (fig.5.7). See: Gide C. (2008) 'La Houille Blanche' [Originally published 1902, *La Semaine littéraire, Genève*]. In Pénin M. (eds.) *Propos d'actualité et d'actualité, 1887–1931*. L'Harmattan. 59–66.

⁷¹ The analyses presented in these sections draw on Caligaris's essay (2004) *La valorizzazione della risorsa idrica sul versante alpino occidentale: l'avvento dell'industria elettrica*, in Bonoldi A. and Andrea Leonardi A. (eds.) *Energia e sviluppo in area alpina. Secoli XIX–XX*, pp. 49–66. This contribution offers a detailed reconstruction of the emergence and expansion of the electric power industry in the Piedmontese Alps, tracing the shift from traditional uses of hydraulic energy to its systematic exploitation for industrial purposes. Caligaris emphasizes how hydroelectric production not only influenced the spatial distribution of new manufacturing activities but also contributed to the broader reconfiguration of territorial and socio-economic dynamics in the western Alpine arc. The essay focuses particularly on case studies in the Susa Valley, Lanzo Valley, Biellese, and Ossola, showing how large electro-commercial companies actively reshaped regional hierarchies—often subordinating mountain economies to the priorities of urban and lowland industrial centers. The tensions between energy production and redistribution, and between local interests and national strategies, form a central theme in the analysis.

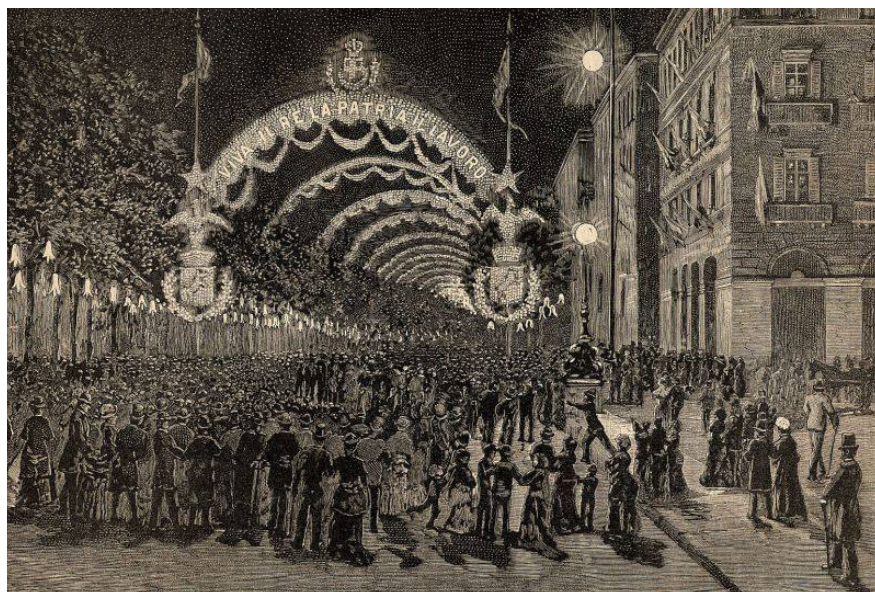


fig.5.4 *Veduta a volo d'uccello degli edifici dell'Esposizione* (1884, Antonio Bonamore).

fig.5.5 *L'illuminazione di Corso Vittorio Emanuele, la sera del 27 Aprile* (1884, Ettore Ximenes).

and small-scale manufacturing. The arrival of large-scale energy projects disrupted these longstanding economic practices. Hydroelectric plants and dams require vast land and water resources, often displacing local populations or repurposing land previously used for agriculture. Moreover, the energy produced in these remote areas was rarely used to benefit local communities. Instead, it was directed towards powering the growing industries in urban centers like Turin, widening the gap between the economically thriving plains and valleys and the increasingly marginalized mountainous areas. This imbalance exacerbated pre-existing economic disparities and led to what has been termed the *energy paradox*: the very regions that produced the energy were often those that benefited the least from it.

Electrification and industrial polarization in Piedmont The electrification process in Piedmont had the long-term effect of accentuating economic differences within the region. The areas that attracted industries powered by hydroelectric energy, such as the Turin, Novara, and Vercelli plains, became economic powerhouses. These regions experienced rapid industrial growth and urbanization, benefiting from abundant, relatively cheap energy supplies. On the other hand, despite being a major source of hydroelectric power, many mountainous areas in the western Alpine arc experienced economic decline. As industries and populations moved to the cities, these areas were increasingly left behind, with fewer employment opportunities and diminished agricultural productivity. The economic divergence created a spatial imbalance that persists today, as cities continue to thrive on the energy generated by hydroelectric plants in the Alps. At the same time, many rural communities remain economically vulnerable. This dynamic highlights the complex relationship between energy production and regional development in Piedmont, where the benefits of industrialization and modernization were unevenly distributed. As noted, the electrical industry emerged in Piedmont around 1885. By the end of the decade, small thermoelectric generating plants for public lighting (fig.5.5) had opened in Turin and other cities, initially using foreign patents, reflecting the region's early reliance on international technological innovations. The real leap in the scale of regional electricity production and distribution occurred in the second half of the 1890s, driven by the need to electrify urban transportation and accelerate the city's industrialization. These developments attracted the attention of the international electrome-

chanical industry, as Piedmont offered a fertile ground for research and innovation in electricity generation and distribution. Foreign companies such as *Siemens*, *Halske*, *AEG*, *Schuckert*, and *Brown Boveri* were drawn to Piedmont, competing to enter this burgeoning market for mass electrical production. This influx of foreign expertise and investment was instrumental in shaping Piedmont's industrial landscape. Turin, in particular, sought to pursue an energy policy aligned with its ambitious growth objectives, aiming to offset its political decline after the capital was moved to Rome by achieving national economic leadership.

Long-distance transmission and the origins of alpine electric modernity In 1884, public remote lighting, from Turin to Lanzo, was demonstrated during the 1884 industrial exhibition (fig.5.4). It was proposed by Gaulard and represented a solution to the problem of remote electricity transmission with limited dispersion, and anticipated the transformer⁷². The results won a special prize for the “*Best electric transmission in Turin of the motive power of our Alps*”, followed by a double appropriation from the government to establish “*An international grand prize*”. This has drawn foreign attention to the subalpine area's potential for water resources and the energy consumption associated with them. Lucien Gaulard, a French electrical engineer, is best known for pioneering the development of alternating current (AC) technology, particularly for long-distance electricity transmission. In 1884, along with his collaborator John Dixon Gibbs, he introduced a crucial innovation: the transformer, which would revolutionize the transmission of electricity. Before this innovation, direct current (DC) transmission faced severe limitations due to high energy losses over long distances, making it inefficient for widespread distribution. This transformer enabled efficient AC transmission by stepping up the voltage for long-distance transmission and then stepping it down for safe local use. His design consisted of an open-core transformer that could increase or decrease the voltage of alternating current, paving the way for a more efficient electrical grid. Gaulard's transformer was first demonstrated in London and later in Turin, drawing the attention of local engineers and industrialists. Though its design had limitations compared to later improvements, it

⁷² From this, Galileo Ferraris had the occasion for reflection to formulate the following year's fundamental theorems on alternating currents and arrive at the discovery of the rotating magnetic field, as well as the development of a prototype asynchronous motor capable of transforming electrical energy into mechanical energy, the final moment of the entire distribution system.

laid the foundation for the commercial use of transformers⁷³.

This innovation was crucial for electrifying cities like Turin, which sought to expand their industrial base. The system enabled electricity to be transported over long distances with minimal losses, making it feasible to harness hydroelectric power from remote locations in the Alps and transmit it to urban centers.

White coal and the energy logics of industrial localization In Piedmont, numerous areas offered the potential for developing processing activity, an essential attraction for electro-commercial companies. The interest of companies in producing and distributing electricity arose from the complementary relationship between energy demand for industrial uses and consumption for lighting and traction in urban centers. A degree of user concentration and diversification could be achieved to flatten the load diagram and thus maximize the company's efficiency. The market potential, moreover, lay in the fact that by the end of the 1880s, there still existed in Piedmont a clear preponderance of hydraulic plants over steam or gas machines for the production of mechanical power. The predominant use of hydropower at almost no cost raised high expectations among industrial users about its low cost. From the very origins of the electric industry, the energy price problem has been a crucial factor in determining the location and polarization of industrial activities, influencing local growth dynamics.

Turin City energy policies, at the turn of the 19th and 20th centuries In 1880, hydraulic power was enhanced with a project to divert water from the Po above Villafranca, the straightening of the Dora in Turin, and the construction of a dam to accumulate the waters of the Dora to ensure a greater flow to the Pellerina canal. By 1890, foreign business ventures intended to bring "*Power retraceable from our Alps*" to Turin through advances in the technology of remote electricity transmission. In 1910, direct intervention in the sector occurred with the construction of a municipal hydroelectric company aimed at reducing energy costs to levels conducive to industrial expansion, thereby counteracting the monopolistic position of *Società Alta Italia*⁷⁴. Between 1890 and 1900, the power of electrical plants built in Piedmont nearly quin-

⁷³ His work was instrumental in the eventual adoption of AC systems by major electrical companies, including those led by George Westinghouse and Nikola Tesla, who further developed and refined the technology (Gorman 2001).

⁷⁴ Established in 1896 by Siemens & Halske (Pavese 2007).

tupled from initial values, thanks to the arrival of prominent foreign electromechanical companies in the subalpine market. By the 1911 industrial census, 69% of the energy consumed by enterprises in Piedmont was supplied by electricity. However, the electrification process in Piedmont lagged behind neighboring regions such as Lombardy and Liguria, where only 1.4% of the population in Milan needed an electrical system. In Genoa, this figure was 10.5%.

In 1898, hydroelectric generation surpassed thermal generation, marking a pivotal moment as new power plants were constructed and existing ones expanded. Hydroelectricity accounted for 5% of the increase in plant potential during the decade. The most powerful plants and extensive networks were concentrated mainly in the provinces of Novara and Turin. Cuneo was only beginning to attract attention from larger companies operating in the sector. These provinces also housed self-generation plants and the largest electrified municipalities. Looking at the sector's development, however, the average installed power per 1,000 inhabitants grew unevenly across Piedmont's four provinces. Novara held 51% of the power per capita, Turin 28%, Cuneo 17%, and Alessandria 4%. The distribution of per capita consumption was also unequal, with 68% of the installed power per thousand inhabitants located in Novara and Cuneo. However, these provinces accounted for just 24% of the total consumption. In contrast, Turin and Alessandria, holding only 32% of the potential, consumed 76% of the energy produced in the region. These data illustrate the disruptive effects of large electro-commercial companies on local productivity and social balances, particularly in exploiting the critical catchment areas of the Ligurian-Piedmontese Alps.

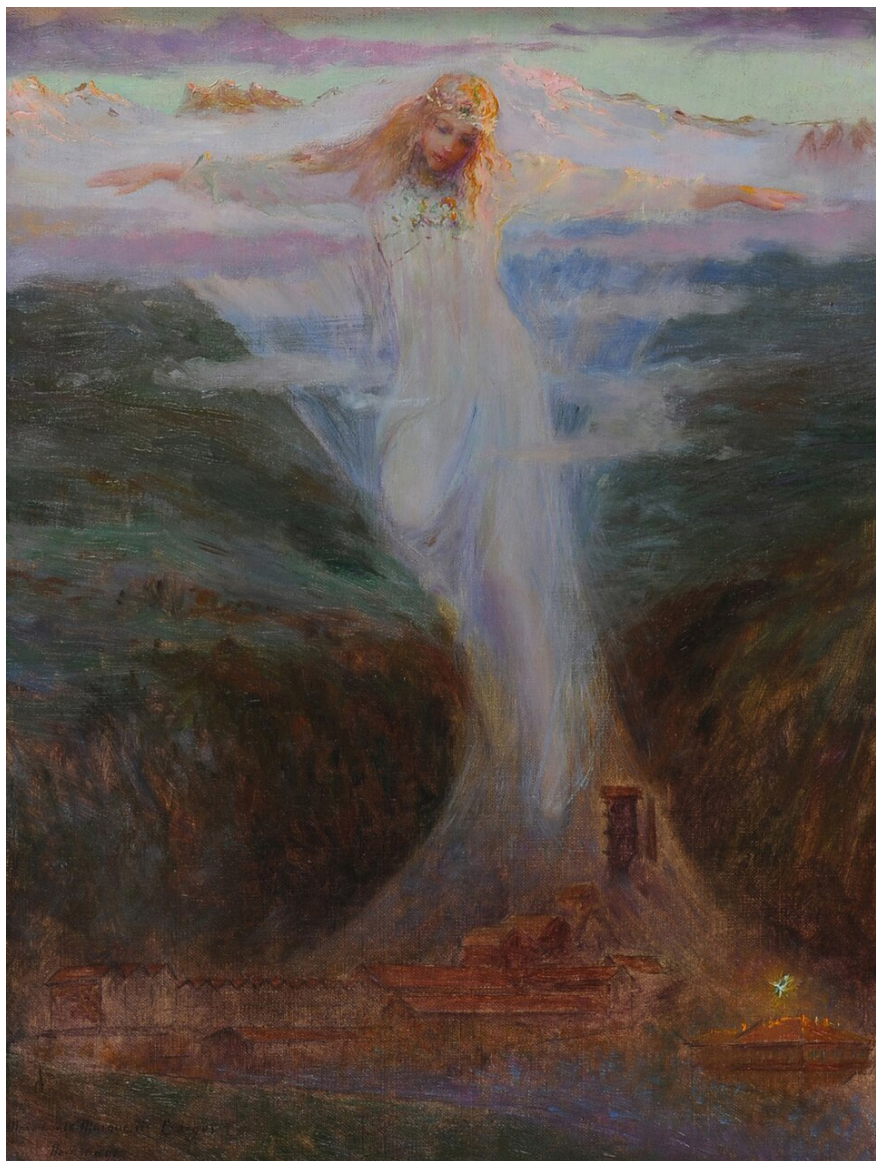


fig.5.6 La Houille blanche surplombant les papeteries Bergès, Combe de Lancey (*Gaston Bussière, 1902, Maison Bergès Collection*).



fig.5.7 Lake of Moncenisio and Mont Malamot, Cottian Alps (Photo: CC)

5.3.territorial imbalances

The drive towards electrification and the use of water resources from the Western Alps played a central role in Turin's modernization policies and directly influenced the urban fabric, infrastructures, and urban space organization. One of the most evident effects of hydroelectric power was the creation of new infrastructure for managing and distributing electricity⁷⁵. This included hydroelectric power plants, canals, and distribution systems that had to integrate with the city's urban expansion. For instance, the centralization of hydroelectric resources through projects such as the canalization of the Dora and Po rivers had profound implications for urban structure and the connections between industrial and residential areas.

Hydropower and the Social Restructuring of Turin. Hydroelectric plants acted as a catalyst for the Expansion of industrial regions, as Turin, with its established industrial tradition, experienced the establishment of new factories powered by locally generated electricity. The establishment of a municipal hydroelectric company in 1910 marked the city's direct control over energy resources, thereby supporting the development of industrial districts.⁷⁶ This also influenced the city's social and demographic structure. New factories required a large workforce, leading to significant residential expansion in the suburbs, where new working-class neighborhoods emerged to accommodate the influx of laborers⁷⁷. Turin became increasingly polarized between residential areas, primarily in the city center, and industrial zones on the peripheries. Hydroelectric power was a crucial factor in this urban dichotomy, allowing for the efficient and economical relocation of industrial activities away from the historical center. However, this also led to greater social segregation, with working-class districts often lacking the services and

⁷⁵ For comparative analyses of how electrification reshaped Alpine landscapes and regional geographies—often through the interplay of engineering ambition, aesthetic imagination, and industrial capital—see Gouy-Gilbert, Dalmaso, and Jakob's *Alpes électriques: : paysages de la houille blanche* (2011), which explores the visual and infrastructural transformations wrought by hydropower in the French, Swiss, and Italian Alps. A complementary perspective is offered by Foëx and Jakob's *Architecture et électricité: un siècle d'architecture électrique en Suisse* (2003), which documents a century of electrical infrastructure in Switzerland, highlighting the architectural, territorial, and cultural dimensions of electrification in mountainous regions. These works provide a broader context for understanding the Ossola case, situating it within pan-Alpine processes of technological modernization and spatial reconfiguration.

⁷⁶ Like Borgo San Paolo, which expanded significantly due to electrification.

⁷⁷ Areas such as Barriera di Milano—initially on the city's outskirts—proliferated following industrialization, with urban planning that considered proximity to new electrical and industrial facilities.

amenities found in the city's wealthier central areas.

Hydroelectric power similarly brought changes to the urban and suburban landscape. The canalization of the Dora and Po rivers and the construction of dams and plants altered the rivers' natural courses and created new areas for urban expansion. The establishment of hydroelectric plants not only contributed to the energy supply but also improved water regulation, helping to prevent floods and enhance sanitary conditions in certain parts of the city. The construction of hydroelectric plants was often accompanied by architectural and landscape design projects to integrate these new structures into the urban environment⁷⁸. The rise of hydroelectric power highlighted the issue of political and administrative control over energy. The interaction between large electromechanical companies and the city of Turin represented a central conflict in urban development. With its high prices, the private monopoly on electricity became an obstacle to balanced industrial and urban development, prompting the municipality to intervene directly in the sector to lower costs and attract new factories. This public intervention in the electrical industry was crucial for fostering more coherent and functional urbanization.

Power to the city: from energy source to periphery Between the end of the 19th century and 1906, the first power plants were built on the slopes with the easiest and most economical exploitation (Caligaris 1993). Those built by the *Società Alta Italia* were located on the Dora Riparia and the Stura di Lanzo, by the *Pont St. Martin Company* on the Dora Baltea, and by the *Società per le Forze idrauliche del Moncenisio* on the Cenischia stream in the Susa Valley (Caligaris 1986). The predominant presence of foreign capital in the first two companies created an initial competitive environment that pushed electro-commercial companies to secure concessions. The construction of plants was accelerated, leading to a potential that exceeded the local market's absorption capacity. The initial phase involved acquiring urban markets with more favorable load diagrams, where companies, thanks to developments in AC technology, competed in transferring upstream-generated power to the city. The systematic exploitation of the Stura di Lanzo catchment area by the *Società Alta Italia*, which continued in the following years, led to the

⁷⁸ For example, hydroelectric plants were frequently designed as monumental symbols of industrial progress and placed strategically within the urban landscape to showcase the city's modernization visibly.

construction of three power plants in a relatively short period, between 1900 and 1905, in the Ceres and Ala di Stura areas. The Lanzo Valley's economic impact was immediate, helping slow population outflow and even prompting temporary labor immigration from neighboring municipalities. It also stimulated the local real estate market by purchasing concentrated land and water rights from the public and private sectors. In the longer term, however, the hydroelectric industry could absorb very little labor, and harnessing the energy captured by the Stura jumps near Balme indirectly accentuated, rather than reduced, migration.

Hydropower expansion in the Greater Turin Area. From local networks to regional monopoly In the Maira Valley between 1913 and 1916, the power plants of Acceglio, Ponte Marmora, and San Damiano delivered over 50,000 kW. These installations were central in supplying electricity to the Piedmont and Ligurian regions. In contrast, only minor plants were present in the adjacent valleys of Varaita, Po, and Chisone. In the Susa Valley, the Chiomonte facility, operated by the *Azienda Elettrica Municipale (AEM)* of Turin, together with the plants in the Cenischia basin drawing from Lake Moncenisio, reached a combined capacity of approximately 30,000 kW. Despite their hydropower potential, the Lanzo and Orco valleys remained vastly underutilized⁷⁹ (De Rossi 2016). Only the lower areas of the Aosta Valley were harnessed, with the Montjoet and Pont-Saint-Martin plants representing the most significant infrastructure.

The post-World War I period marked the onset of large-scale hydroelectric transformation. A paradigmatic case of this new phase is the development of the Orco Valley by *AEM* on behalf of the City of Turin. Around 1915, the municipal administration began assessing the hydroelectric potential, a project that had also attracted the attention of provincial authorities⁸⁰. The City of Turin was ultimately granted the concession following an agreement with the Province, which was assured one-tenth of the generated energy at cost. However, the project provoked strong opposition from local communities, particularly over

⁷⁹ In the Formazza Valley, three early installations reached a total output of 35,000 kW. Meanwhile, in Lombardy, infrastructure in the Valtellina and Camonica valleys had already come to be regarded as strategically important.

⁸⁰ By the end of the war, six competing proposals had been submitted to the Ministry of Public Works, including plans from the City, the Province, the *Società Elettricità Alta Italia*, the *Società Forze Idrauliche del Moncenisio*, and two private actors. Many of these proposals were backed by banking capital

the expropriation of valley-floor land required for the new infrastructure⁸¹. The project entailed the construction of two high-altitude reservoirs, Lakes Agnel and Serrù, located at nearly 2,300 meters above sea level. These would feed a power station upstream of the newly created artificial basin at Ceresole Reale⁸². A subterranean channel directed water from the Ceresole basin to the Rosone plant, allowing a hydraulic head of over 800 meters. The Rosone plant was also designed to capture water from the adjacent Piantonetto Valley, where three additional dams were planned.

The 1929 global economic crisis left a significant portion of the energy generated by the Orco Valley system unused. AEM was compelled to raise its electricity tariffs and entered into a partnership with the *Società Idroelettrica Piemontese (SIP)*, which, by then, had consolidated control over much of the hydroelectric infrastructure in the Western Alps⁸³. The institutional history of SIP offers a critical lens for understanding the evolving territorial geographies of energy in the region⁸⁴. Founded in 1899 as the *Società Industriale Elettrochimica di Pont-Saint-Martin*, it served the Canavese and Biella areas, supporting early electrification in the Valle Mosso. That same year, the *Società Eletticità Alta Italia (EAI)* was established with predominantly foreign capital, to supply electricity first to Turin and later to the broader northwest Piedmont region. During the early 20th century, *EAI* constructed a transmission network connect-

⁸¹ This reconstruction of the spatial transformations, infrastructural development, and territorial dynamics associated with hydroelectric expansion in the Western Alps—particularly in the Lanzo and Orco valleys—relies primarily on the analysis presented in De Rossi (2016), whose work draws extensively on historical sources, institutional archives (such as those of *AEM* and *SIP*), and mid-20th-century technical publications produced by companies.

⁸² This large reservoir, approximately 1,600 meters, was formed by a gravity-arch dam with semicircular joints on the lake-facing side, collecting runoff from a 90 km² catchment area. The dam at Ceresole Reale was widely celebrated as a landmark of Italian engineering. It stood 54 meters tall, with a crest length of 270 meters and a foundation width of 45 meters. Construction required 188,000 cubic meters of concrete, resulting in a reservoir with a 35 million cubic meters storage capacity. The dam at Ceresole Reale was widely celebrated as a landmark of Italian engineering. It stood 54 meters tall, with a crest length of 270 meters and a foundation width of 45 meters. Construction required 188,000 cubic meters of concrete, resulting in a reservoir with a 35 million cubic meters storage capacity.

⁸³ To stimulate demand, *AEM* opened a showroom for electric appliances in its Turin headquarters—a model later adopted by *SIP*, which promoted “model electric homes” at industrial exhibitions to demonstrate American-style domestic technologies.

⁸⁴ On the institutional trajectory of *SIP* and its role in shaping the territorial organization of the electrical sector—particularly during the consolidation and crisis phases of the interwar period—see Castagnoli’s analysis of the company’s evolution and governance structures, with specific attention to its financial exposure and regional operations (Castagnoli 1976).

ing the hydroelectric plants in the Susa and Lanzo valleys to Turin. A secondary transmission line routed through the Canavese region linked the Turin grid to the Pont-Saint-Martin network, which connected with Ivrea and Biella. After the war, SIP was restructured and adopted an aggressive expansion strategy. It absorbed *EAI* and a constellation of smaller hydroelectric companies⁸⁵—extending its reach into Lombardy and Trentino.

SIP was pivotal in developing the telecommunications corridor between Turin, Milan, and the Lake District. At the national level, hydroelectricity increasingly displaced thermoelectric power. Between 1918 and 1928, the proportion of hydropower in total installed capacity rose from 70% to 82%, remaining stable until the 1962 nationalization. Around 1920, *SIP* expanded the Moncenisio reservoir by constructing three additional dams.

Turin's industrial growth: energy transfer and labor migration The emergence of the large-scale industrial sector coincided with a significant surge in industrial dynamism in the subalpine region, which favored the concentration of processing activity in a few districts rather than alleviating the existing imbalances between various economic areas. The accentuation of disharmonious development among Piedmont's four provinces can be directly related to the rise of the electrical industry. Thanks to this industry, energy ceased to be a constraint on the location of industrial activities. The mechanical industry favored clustered settlements in the urban center, which offered more significant incentives and external economies. The electrical sector initiated a process of polarization of transformation activities, benefiting from users' resulting concentration and diversification. The Lanzo Valley contributed to Turin's industrial takeoff at the turn of the century, providing a significant portion of the energy required and also flows of de-skilled labor to meet the growing demand for services in the expanding city. Although the power of the waters of the Stura was also captured by small hydroelectric plants for local use, the valley's economic structure largely retained its traditional agricultural-pastoral character, proving incapable of capitalizing on the opportunities offered by technological progress.

However, intense migratory flows did not lead to a real depopulation of the area because of its proximity to Turin, where many workers headed,

⁸⁵ Including *Evançon*, *Marmore*, *Forze Idrauliche del Moncenisio*, and *Idroelettrica Monviso*.

and because the substantial deskilling of the workforce favored seasonal transfers⁸⁶. From its origins, the industry that developed in Piedmont to produce and distribute electricity tended toward a monopolistic configuration. Entrepreneurial initiatives in the electrical sector shared the common goal of transferring all the energy produced in the valley to Turin to support the municipal administration's efforts to promote Turin's industrial concentration. The concentration of the electrical industry in the Susa Valley had short-term dynamic effects on the local economy during the construction phase of the plants. Later, Turin's industrial growth led to notable commuting patterns and the need to import labor. The depopulation that affected the Upper Valley manifested as a migration toward the plains, making low-lying municipalities more significant than those upstream, reversing a historical trend.

Territorial fragmentation and demographic regimes Towards the end of the first decade of the century, cartel agreements divided the Piedmontese territory into zones of influence. *Società Alta Italia*, with the Ponte Preti power plant on the Chiusella, a right-hand tributary of the Dora, began operations in 1897, and *Pont St. Martin* followed with the Carema power plant in 1901 and the Bard power plant in 1907. *Società Valle D'Aosta* established the Montjovet plant in 1914 and acquired two power plants on the Evançon: Ponte Lylla in 1910 and Verrés. The partial local exploitation of hydroelectric resources from the Dora Baltea's catchment area did not stop the migratory flows⁸⁷. In contrast, the Middle and Lower Valleys experienced a 7.1% population increase, driven by two sub-zones where industry grew: along the Dora in the municipality of Aosta, and the lower stretch between Donnaz and Châtillon, where companies clustered.

Alpine population migration toward the plains in response to large-scale industry settling in valley bottoms is a recurring phenomenon, especially with the rise of workers' villages. The systematic depopulation of the Upper Chisone Valley reached such levels that, during reforestation works, labor had to be sourced from other regions. However, in the Middle Susa Valley, population decline was related to migration and to a new demographic regime characterized by a falling birth rate aligned with trends in the city environment. The electrical industry, particularly

⁸⁶ The ease of connections allowed emigrants to maintain ties with their homeland, often renting their family homes to vacationers.

⁸⁷ Between 1871 and 1921, the Upper Aosta Valley population decreased by 14.09%, as recorded in census data (Caligaris 2004).

large-scale electric companies, directly influenced industrial development and polarization by enabling energy-accessible production locations in Piedmont. This disrupted the traditional economic and social balances carefully established over centuries in many regions of the western Alpine arc. In other parts of the interior mountain territory, however, the emergence of the electrical industry served as a confirming factor and an impetus for achieving new, more modern local economic balances.

5.4.replacing ecologies

In Ossola, the penetration of hydroelectric enterprises and the systematic exploitation of water power along the Toce and its tributaries triggered profound transformations in both the landscape and the social fabric. The construction of reservoirs, power stations, and transmission lines redefined access to land and resources, accelerating the displacement of traditional agricultural and pastoral economies and producing visible reconfigurations in settlement patterns and labor distribution.

In this context, a process of demographic lightening can be recognized, marking the outcome of long-term adjustments between environmental constraints, resource management, and industrial transformation. The progressive emigration of mountain populations, while symptomatic of crisis, also represented a reorganization of the territorial system. As agricultural and pastoral economies lost centrality, migratory flows redistributed labor toward valley floors and emerging industrial centers, aligning local dynamics with the broader modernization processes unfolding across Piedmont and northern Italy. This demographic contraction was therefore not merely a symptom of decline but a factor of adaptation and selective resilience: it enabled a more rational exploitation of environmental resources and the redefinition of productive relations between highland and lowland zones.

In the longer term, these adjustments would have contributed to stabilizing the remaining population, consolidating new forms of equilibrium between human settlement and the transformed energy landscape of the Alps (Calligaris 1993).

Hydropower and industrial expansion The capture of the Toce and its tributaries in the high Ossola valleys was undertaken by highly capitalized domestic and foreign companies. Among them, *Motor*, a financial holding of the Swiss firm Brown Boveri, which in 1907 established two subsidiaries for power generation and distribution: the *Società delle forze motrici dell'Anza*, with the Piedimulera power plant in Vallanzasca, and the *Società Dinamo*⁸⁸, with power plants built on two tributaries of the Toce, Cairasca and Diveria. Equally systematic was the program

⁸⁸ The volume, published by the Istituto Geografico De Agostini on the occasion of the 50th anniversary of Società Dinamo (1957), offers a detailed narrative and iconographic reconstruction of the company's foundational role in the hydroelectric development of the Ossola and Diveria valleys (fig.4.16–17).

led by *Società Conti*⁸⁹, Edison's partner in Milan, with plants at Goglio and Verampio. The potential was significantly increased between the two wars through the construction of large artificial regulating basins, a technical solution that was particularly successful in containing thermo-electric integration, which was particularly costly due to the almost total dependence on foreign coal.

Ettore Conti led one of the earliest and most comprehensive initiatives, which proposed a large-scale hydroelectric program for the Toce-Devero basin⁹⁰ (Cannata 2023). This entailed the construction of 10 artificial reservoirs and 14 power stations, capable of harnessing 80% of the catchment's hydroelectric potential. The project marked Europe's first example of a fully integrated basin-scale hydroelectric system. The penetration of the electrical industry into the valley, which operated on a large scale, played a decisive role in accelerating the structural transformation (Pavia 1998) that had already been initiated locally through the extension of the road and rail network. The importance and frequency of large-scale construction works (fig.5.8–15), especially with the appearance of storage reservoirs and high-voltage transmission lines, ended the agricultural-pastoral economy of Alta Ossola.

Grid construction and distributive fragmentation across northern Italy Between 1905 and 1908, *Società Conti* undertook a wide-ranging spatial and infrastructural expansion aimed at integrating future high-altitude hydroelectric production from the Toce and Devero basins with a broader distribution network. This necessitated the construction of the Novara steam plant in 1907, intended to offset seasonal hydro shortfalls, particularly during winter months when reservoir capacity remained limited.

To finance this infrastructural expansion⁹¹, *Conti* more than doubled its capital, with authorization for further increases. In parallel, he pursued

⁸⁹ The most comprehensive account of the hydroelectric program initiated by Ettore Conti and later integrated into the Edison group is provided by Andrea Cannata *Centomila cavalli per Milano. Storia idroelettrica dei bacini del Toce e del Devero da Ettore Conti alla nazionalizzazione* (2023). Drawing on extensive archival research, the book documents the technical, territorial, and institutional evolution of the Toce–Devero infrastructure, highlighting its integration into national energy systems and its environmental and social impact on the Ossola region.

⁹⁰ Cannata's reconstruction also draws on a close reading and interpretive use of Ettore Conti's autobiographical account (1986), which offers valuable insight into the entrepreneurial mentality, infrastructural vision, and political ambitions behind early large-scale hydroelectric development in the Ossola region.

⁹¹ Including the Adamello hydroelectric initiative and a network of regional distributors.

organizational decentralization while maintaining operational hegemony, creating or acquiring majority stakes in distribution companies across Novara, Vigevano, Pavia, Tortona, and Voghera. These firms operated under a unified managerial and technical framework, with *Conti*-appointed engineers at the helm, thereby enabling the standardization of energy transmission and operational logic across fragmented territorial units⁹². Yet this approach prioritized infrastructural readiness over immediate demand, confident in the inevitability of electrification. Financing remained structurally independent: rather than rely on bank intermediaries such as *Edison*-linked *COMITS*, *Conti* secured bond placements through transport-sector partners, reaffirming his strategic autonomy and resistance to financial entanglement.

These years crystallized a model of entrepreneurial territorialism, in which technical infrastructure, legal foresight, and regional energy geopolitics converged into a spatial strategy predicated on delayed but inevitable returns. This anticipatory posture, risky yet coherent, underwrote the eventual spatial reach and institutional durability of energy enterprise.

The Toce-Devero system and large-scale alpine basin integration Supported by increased revenue from operational power stations⁹³, interconnected transmission lines, and expanding distribution companies, the *Conti* now had the capital and infrastructure to execute larger, more technically demanding projects. The implementation of the remaining plants coincided with upgrades to transmission infrastructure and the strategic extension of power corridors toward Monza and the Milanese hinterland, reflecting a shift from local energy autonomy to regional integration. Capital expansion and bond issuance marked a transition to financial instruments aligned with national industrial growth⁹⁴. Although construction logistics had improved since earlier projects, le-

⁹² This distributed model of infrastructural control prefigured the eventual consolidation of regional grids but also exposed the firm to substantial legal and financial risk. Regulatory uncertainty, stemming from ill-adapted water laws, and industrial hesitation to adopt electricity over steam power added further complexity.

⁹³ Following the commissioning of the Rivasco and Goglio plants and the initial Codelago dam, the *Conti* enterprise proceeded to complete the Toce-Devero system with the construction of the Verampio and Crego hydroelectric facilities.

⁹⁴ The technical consolidation was matched by financial scaling. The capital increase and a new bond issue facilitated the mobilization of resources necessary for high-voltage transmission upgrade and the planned interregional connection between Novara and Monza.

gal and bureaucratic constraints persisted, yet the scale and coordination of the Verampio and Crego developments marked a turning point. These installations, significantly more complex than their predecessors, were supported by stable revenues, expanding transmission interconnections, and a network of affiliated distribution companies. The project thus moved from a territorial cluster to a regional energy system. Despite this, the development process remained burdened by administrative opposition and fragmented water legislation, particularly in the Ossola Valley⁹⁵. The design and construction of Verampio and Crego introduced a new architectural aspect⁹⁶ into hydroelectric infrastructure, fusing engineering functionality with a refined spatial language.

By the mid-1900s, as the Toce–Devero cascade was developing, preliminary studies began on a vast hydraulic system in the upper Formazza valley. Although initial concessions were held by the *Società Serbatoi Alpini* (SSA)⁹⁷, the entire planning and eventual rationalization fell under the expanding *Conti–Edison* framework. The proposed scheme envisioned a complex constellation of reservoirs and interconnected stations⁹⁸. Many of these projects were only partially realized or reconfigured due to technical constraints or shifting corporate priorities. However, they marked a conceptual shift toward a systemic, catchment-wide logic of hydroelectric exploitation. The scheme's key innovation was the envisioned cascading use of hydraulic head, consolidating water from glacial basins into large, regulated drops exceeding 1,000 m⁹⁹. The project remains a critical episode in the evolution of alpine hydroelectric territorialization. In the early 1920s, amidst postwar economic stagnation and labor unrest, the group launched a new phase of expansion. While wage parity and energy shortages had temporarily disrupted the sector, Ettore Conti responded with renewed infrastructural ambition, expanding generation capacity and transmission infrastructure under the aegis of the affiliated SSA.

⁹⁵ The organizational model, predicated on vertical integration and infrastructural redundancy, allowed for a level of resilience and adaptability rare at the time.

⁹⁶ This phase initiated a long-term collaboration with Piero Portaluppi. This not only transformed the built environment of the Ossola region but also articulated a novel vision of industrial architecture as a cultural and territorial agent.

⁹⁷ Which will be acquired by the *Conti* group in 1924.

⁹⁸ including Crampio, Buscagna, Agaro, Valdo, Laubach, and Crevoladossola, distributed across elevations ranging from 2,000 to 2,400 meters above sea level.

⁹⁹ Despite its partial implementation, the network prefigured later rationalizations by Edison in the 1930s–40s, with the construction of Ponte and Fondovalle compensating earlier inefficiencies.

The acquisition of *SSA* in 1924 and its subsequent absorption by *Edison* in 1926 marked a strategic consolidation of hydraulic concessions. This shift reflected a broader rationalization of alpine hydropower planning, transcending the earlier “*constellation*” model of independent reservoirs. Ultimately, the transition from *SSA* to *Edison* marked the end of *Conti*’s proprietary industrial phase and the beginning of a modernized territorial approach to high-altitude hydroelectric infrastructure.

By the mid-1920s, the hydropower network developed along the Toce and Devero basins had reached a near-completion stage. What had begun as an ambitious scheme of energy exploitation in alpine terrain had evolved into a coherent territorial infrastructure, characterized by distributed reservoirs, cascading catchments, and hierarchical production nodes. The system mirrored, in both spatial articulation and production capacity, the extent of operations of the major electricity company *Edison*. Its technical and logistical success rested on a dense configuration of high-altitude basins and interconnected plants and a political economy driven by urgency, improvisation, and strategic overreach. The final components, primarily the Cadarese and Crevoladossola plants, were still under construction, but the foundational hydraulic geometry had been defined. The basin’s logic was based on vertical integration, which involved controlling runoff from glaciers and high-elevation snowmelt through reservoirs and transmitting energy via high-voltage lines across regional and interregional networks¹⁰⁰.

This final phase also witnessed significant tensions between public regulatory frameworks and the *de facto* construction timelines of the energy sector. Infrastructure, often built before formal authorization, occupied physical and political space faster than institutional processes could keep pace. The institutionalization of this hydro-territorial regime, shaped by a rugged physical environment and rapid industrial demand, revealed the structural disjuncture between technical feasibility, administrative constraint, and spatial governance. While the completion of the program was grounded in engineering ambition and landscape transformation, it also marked a transition toward more consolidated capital structures and regional energy governance, positioning the Toce-Devero system as a prototype of hydroelectric regionalization in early 20th-century Europe.

¹⁰⁰ The spatial logic of the system demanded continual adaptation, such as the conversion of transmission infrastructure to 75 kV or the capital-intensive recalibration of older installations.

In the years preceding World War II, Fascist policies had already initiated the so-called “*Programmi di Realizzazioni Autarchiche*”, which included hydroelectric infrastructure. These measures ensured accelerated access to materials, especially for electromechanical construction. The regime’s autarchic drive shaped projects such as the Sabbione dam, designed in the early 1940s to minimize cement use in line with the goal of material self-sufficiency. While energy demand soared due to the conflict and the sharp decline in imported coal, the urgency of the country’s hydroelectric expansion increased. Shortages of labor and raw materials, alongside the strategic vulnerability of energy facilities, forced electric companies to prioritize rapidly deployable, less exposed installations. *Edison*, which in 1939 had spun off its electrical operations into the newly formed *Società Volta per Imprese Elettriche*, adopted this strategy by focusing on smaller plants at Devero and Fondovalle¹⁰¹. The hydro-climatic context worsened the situation: the years 1941–1943 were marked by unusually low water availability. Combined with severely limited thermal generation capacity, this led to a drop in hydroelectric production precisely when wartime industry demanded more energy than ever. The final stages of the war were the most devastating for *Edison*. Tariff freezes imposed by the state severely constrained revenues, while physical damage to infrastructure mounted rapidly, reaching its peak during the German retreat from northern Italy. Full repairs were not completed until 1947, when development plans could finally resume.

The socio-territorial effects of hydroelectric industrialization in the Ossola valleys Energy production from the exploitation of the Toce River and its tributaries on the border between the Pennine and Lepontine Alps led to local development, as well as fueling essential transfers to the Novarese and Milanese areas under the control of the *Edison-Conti* industrial group (fig.4.18). An intense migratory movement along internal and external routes crossed the Ossola Alps. Internally, migration from upper to central hamlets intensified depopulation, while externally, seasonal emigration toward France and Switzerland gave way to permanent relocation. In the context of coexisting population growth and depopulation, depopulation came to mean flight from the traditional pastoral-agricultural system, built on the systematic exploitation of productive fallow land. The crisis of the conventional agricultur-

¹⁰¹ Larger undertakings, such as expansions at Crego and Verampio, or the new Morasco–Sabbione complex, were put on hold.

al-pastoral system had manifested itself before the advent of the electric industry, with the gradual abolition of tax privileges¹⁰².

The advent of the electrical industry disrupted the economic and social balances achieved over centuries in the Ossola valleys. These are identifiable and can be isolated for analysis better than elsewhere, precisely because of the early and systematic exploitation of abundant water power, both for local industry and for exporting electricity beyond the production area's boundaries¹⁰³. Thus, the Ossola economy was characterized by marked dynamism, driven by the development of processing activities in which the electrical industry played a leading role. It revitalized the pre-existing productive fabric linked to the railroad and road network development, encouraging the location of new factories, from the widespread presence of the mining industry with quarries of *beola*, marble, and granite, to the appearance of chemical plants¹⁰⁴, metallurgical, and others of various kinds, which employed about 3,500 workers in centers along rail and road links¹⁰⁵.

¹⁰² The crisis, here as elsewhere, in the years of the electric sector's growth did not become an occasion for restructuring the local rural heritage but rather a phenomenon of abandonment.

¹⁰³ With their strategic value for the entire nation, industrial interests soon took a clear upper hand over those of Alpine pastoral agriculture.

¹⁰⁴ Such as *Rumianca*.

¹⁰⁵ Such as Domodossola, Villadossola, Varzo, and Vogogna.









fig.5.8-15 These photographs document the technical and material complexity of the early hydroelectric construction sites in the Ossola and Formazza valleys. They capture the provisional infrastructures, the organisation of labour, and the experimental character of high-altitude engineering, revealing the extent to which dams, conduits, and power stations were embedded in—and transformed—the mountain environment long before their completion. The images foreground the often invisible operations that structured these large worksites: excavation, transport systems, temporary housing, and the choreography of machines and workers across challenging terrain. Similar visual insights into the formation of these ‘technical landscapes’ are offered by Ermanno Olmi’s film *La diga del ghiacciaio*, which observes the temporal and human dimensions of Alpine hydroelectric construction. Archivio Enel.

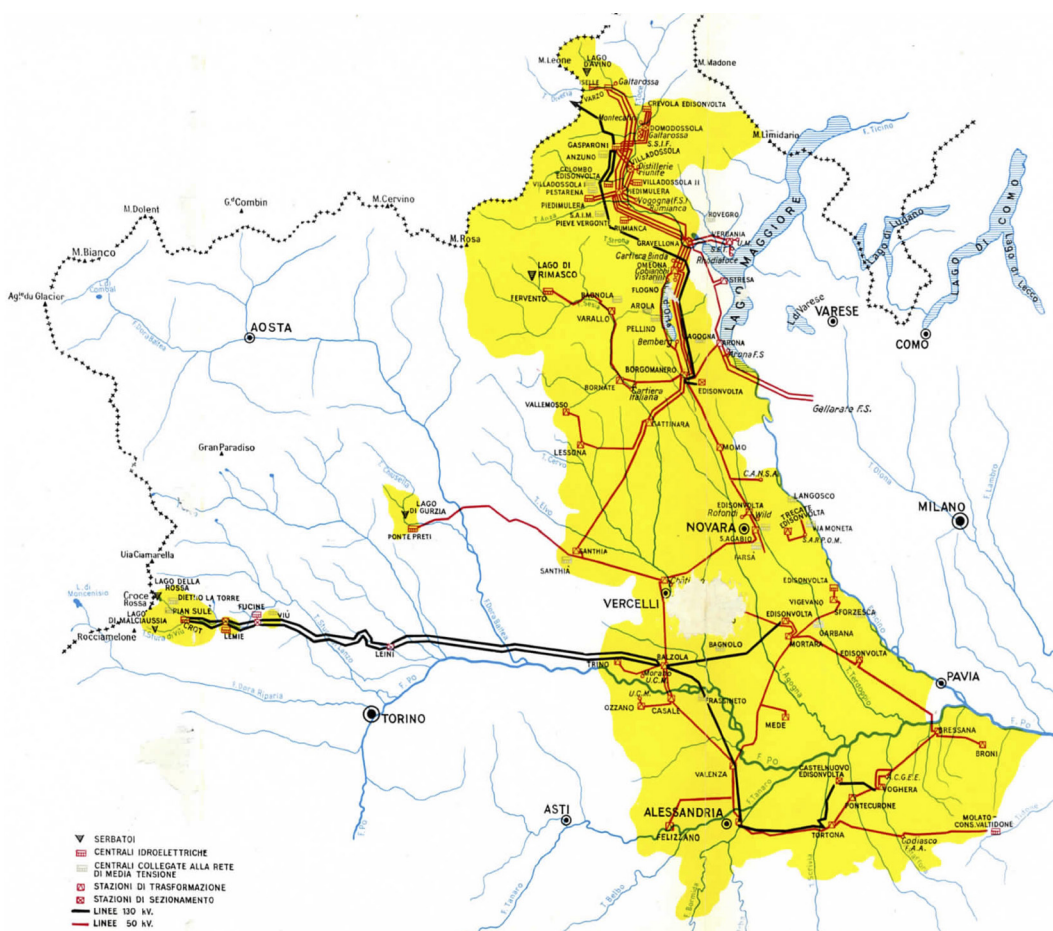


fig.4.16, fig.4.17 Established in Milan in 1907, the Società Dinamo emerged as a key actor in the hydroelectric transformation of the Ossola region and northern Piedmont. Initially capitalized at five million lire, the company rapidly pursued water concessions along the Diveria and Cairasca streams, completing its first alpine installations in Varzo and initiating the construction of the Lago d'Avino reservoir. By 1912, Dinamo's grid extended to support early railway electrification between Milan, Gallarate, and Varese, positioning the firm at the intersection of energy innovation and infrastructural modernization.

Over the next decades, Dinamo absorbed and consolidated numerous smaller operators—including the Società Forze Motrici dell'Anza and the Società Elettrica Ossolana—gradually expanding its catchment through an interlinked network of reservoirs, power plants, and high-voltage lines. Its operations extended across key valleys (Varzo, Iselle,



Vallemosso), supported by large-scale dam construction and storage basins that enabled year-round energy production and long-distance transmission. By the 1930s, Dinamo had transformed into a vertically integrated energy enterprise, managing nearly 1,200 km of transmission lines and producing upwards of 200 million kWh annually. Its infrastructural footprint reshaped the spatial hierarchy of Ossola, establishing energy corridors that connected high-altitude production sites with emerging industrial nodes in Novara, Domodossola, and along the western shore of Lake Maggiore. The 1940s and 1950s marked a phase of further rationalization and scale, including mergers with regional distributors such as Ovesticino and the acquisition of strategic sites like Pieve Vergonte. This consolidation reinforced Dinamo's territorial presence across Piedmont and Lombardy, enabling the company to serve over 250 municipalities and over 260,000 users. At the same time,

the integration of border-crossing lines into the Swiss grid exemplified the increasing regionalization of alpine hydroelectric production. Dinamo's trajectory illustrates how a single corporate actor catalyzed the infrastructural and territorial modernization of alpine valleys through hydropower. The resulting spatial regime was characterized by extensive reconfiguration of watercourses, electrified mobility infrastructures, and energy-exporting landscapes. While its operations remained deeply tied to the geographies of water and altitude, Dinamo's logic of accumulation and coordination foreshadowed postwar models of regional energy governance.

*(Both drawings are reproduced from the publication *La Società Dinamo 1907–1957*)*

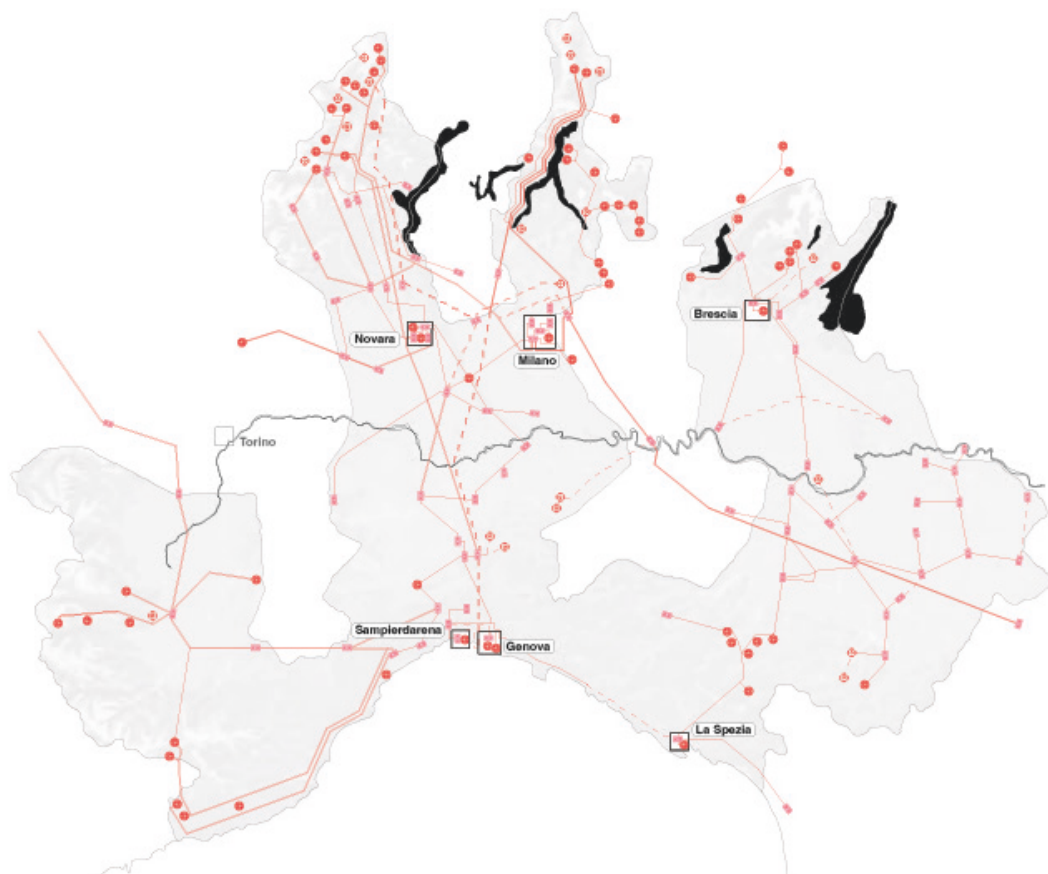
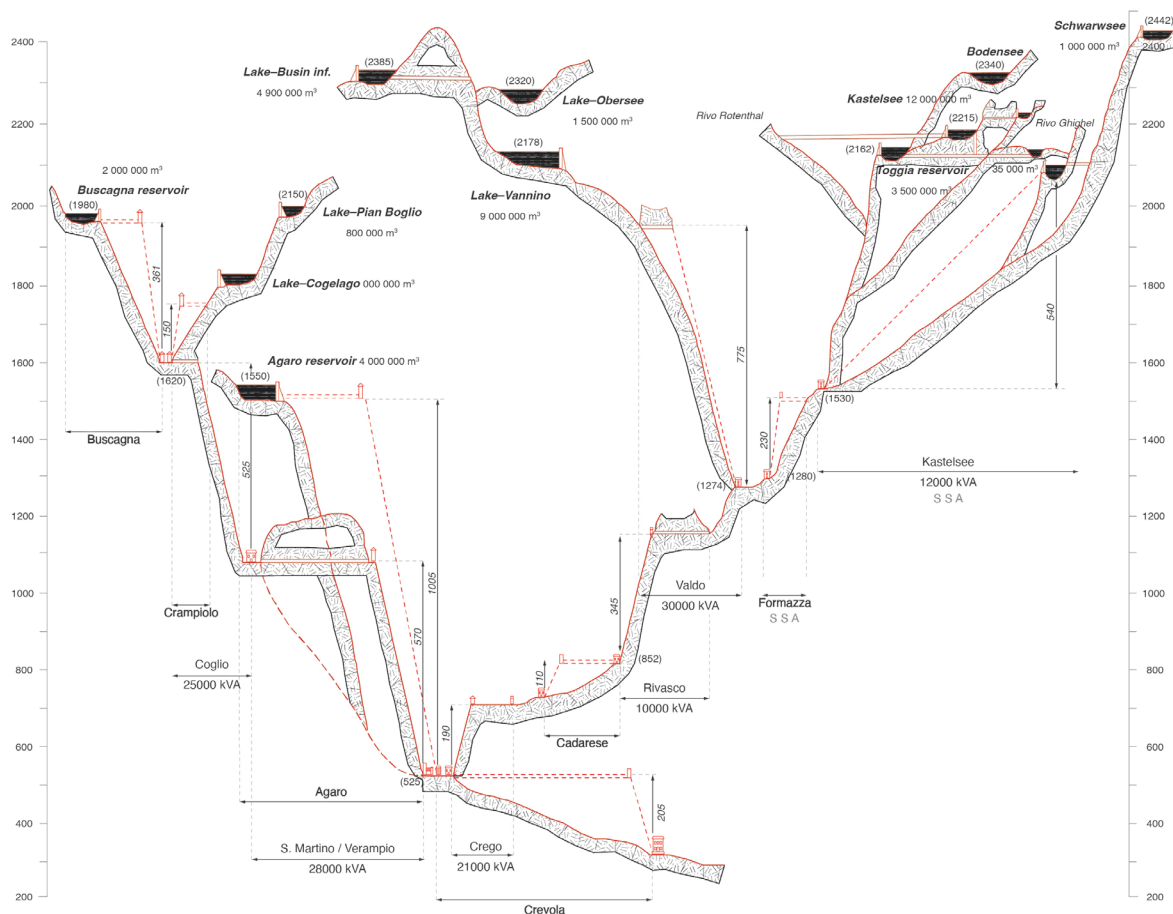


fig.4.18-19 Hydroelectric plants grew in size and numbers in the Anzasca, Antrona, Divedro, Antigorio, Formazza, Vigizzo, and Bognanco valleys. The transfer of power outside the valleys of production was essentially due to the companies Dinamo, Anza, and Conti. Dinamo, in particular, activated the Varzo power plant in 1912 and began using Lake Avino as a seasonal storage reservoir the following year. Starting in 1911, the company began distributing in the Val D'Ossola energy supplied by Anza, which owned the Pie di Mulera plant, and the Novara thermal power plant, which produced energy for electric traction. With the Varzo-Gallarate line in operation in 1912, it supplied the energy needed for the Milan-Gallarate-Varese line, one of the first railway lines to be electrified in Italy. It linked up with Edison to sell power to it. It also sold electricity to the Ferrovie dello Stato for the Simplon line. The Società Anza, having built a storage reservoir on the

stream of the same name, pushed its lines to the extreme boundaries of its influence, which had been drawn in the agreements made with the electro-commercial companies operating in Piedmont. The Anza's network, starting from Piedimulera, reached Gravellona Toce and Intra to the east, where it delivered power for distribution to Unes and the Società Elettrica Ossolana, respectively, to the south as far as Novara, where it delivered most of its output to Conti. From Borgomanero, branches departed southwesterly to the Bornate, Lessona, and Santhià areas, defined as neutral in the above conventions. Conti entered the valley by building the first plant at Foppiano in 1909, followed by the one at Goglio and Verampio. In addition, the Codelago storage reservoir was created to supplement the Devero lean water. The energy produced by these power plants was transported to the Novara power plant, from where it was radiated into the province and neighboring



provinces of Alessandria, Milan, and Pavia. Since Conti had come permanently under the control of Edison since 1912, the latter's area of influence had extended from the Lower Novarese area to Vercelli and Alessandria. Good relations with the Società sviluppo per le imprese elettriche in Italia, which distributed in central-eastern Piedmont, and with the Società elettrica Riviera di Ponente ing. Rinaldo Negri fostered a growing integration of plants in the subalpine region with those in the Milanese industrial hub. This resulted in the long-distance consumption of the energy produced in the Ossola Valleys to support the development of outside economies unrelated to that of the mountains that had generated it. At the end of WWI, Edison also acquired control of Dinamo. At the same time, Conti extended its influence in the Novarese, Vercelli, and as far as Santhià in the Monferrato area. In 1918, the Comit, which had taken control of the Società di Pont St. Martin, quickly brought

this company to the top of the subalpine electric industry. To protect the industrial interests of the region—particularly the Turin hub—this company implemented an active policy to curb and hinder energy transfer to competing centers in Milan and Genoa.

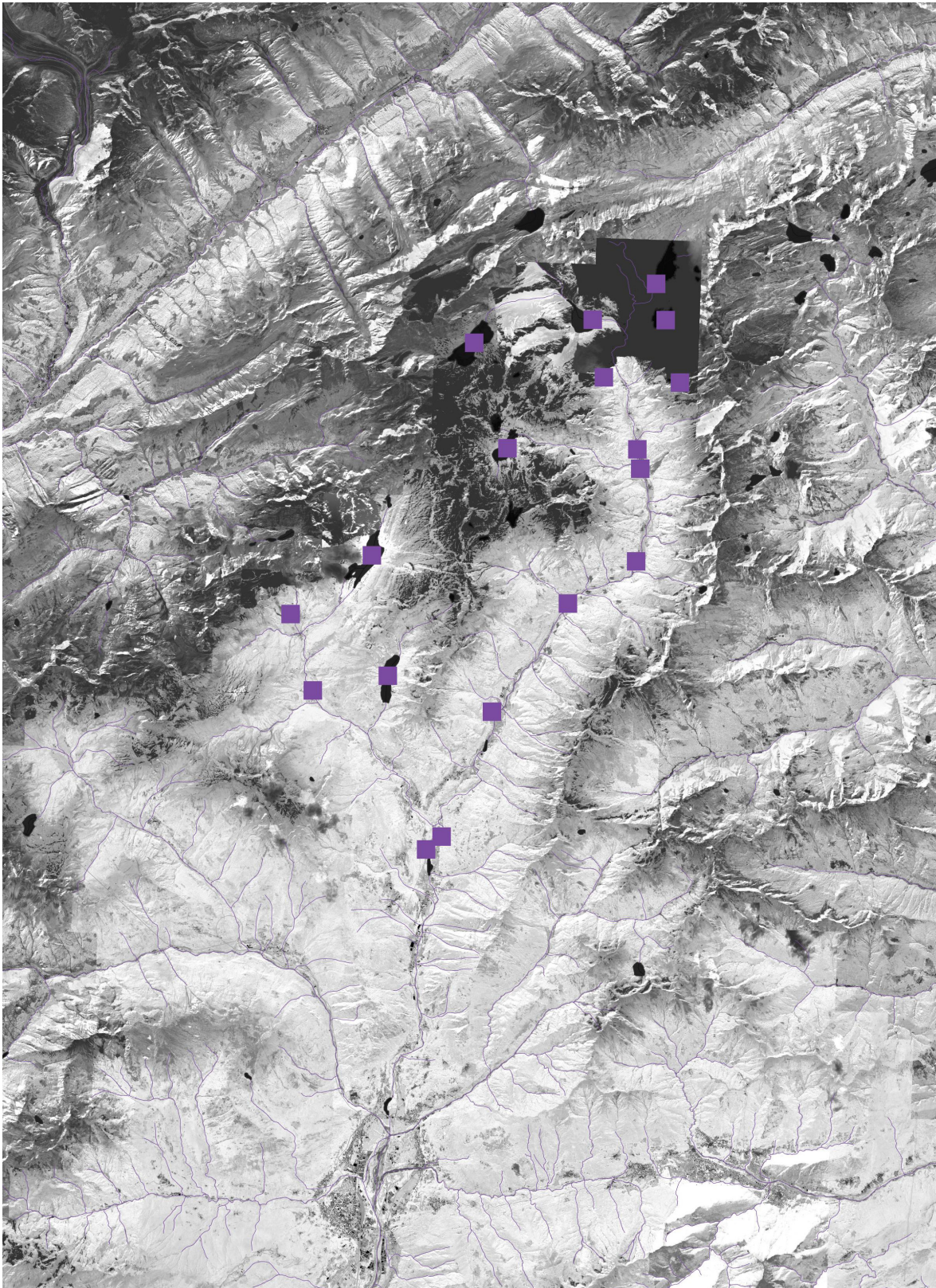
(both diagrams are author's elaborations.)



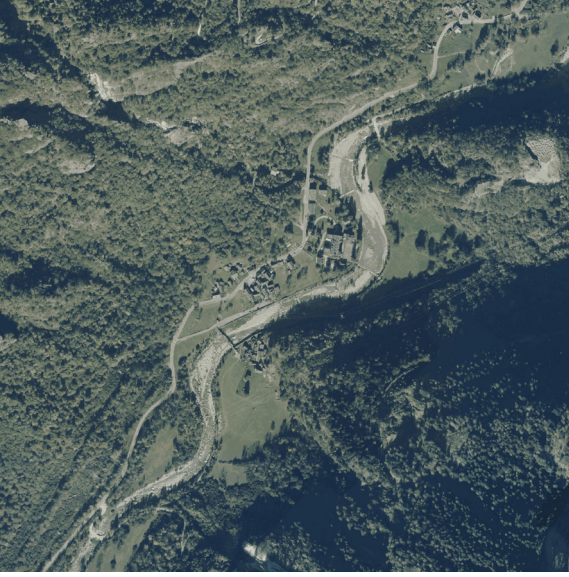
fig.4.20 Artificial reservoirs, originally conceived as purely technical infrastructures, have progressively become part of the collective imagery and visual clichés of Alpine landscapes. Once symbols of engineering control and energy production, these hydroelectric basins are now perceived as integral landscape features, their presence absorbed into representations of natural beauty and regional identity. Alpe Devero (*photograph by the author, 2023*).

territorial snapshots.1 The following section comprises twenty-five analytical case studies that examine the technical and territorial decisions underlying the construction of the Toce–Devero hydroelectric system. Together, these investigations trace how engineering, geography, and capital converged to produce a landscape shaped by infrastructural, productive, and institutional logics. Conceived as a territorial machine (Bélanger 2016; Longhin 2021), the project reconfigured Ossola’s spatial logic and institutional geography. Rather than addressing the broader and more fragmented constellation of hydroelectric developments across the valley’s tributaries—including the Anzasca, operated by the Società Anza; the Antrona, by the Società per le Forze Idrauliche della Valle Antrona; and the Diveria, by the Società Dinamo—this section focuses exclusively on the Toce–Devero network, leaving aside the many minor companies active in adjacent basins. Viewed in this light, it serves as a paradigmatic case of Alpine hydroelectric transformation, providing a lens through which to understand the interplay of technology, territory, and capital in a context of accelerated modernization.

territorial snapshots.1



S.1.1 The Rivasco hydroelectric plant and the emergence of landscape conflict



1908–1909 The construction of the Rivasco hydroelectric plant revealed early tensions between industrial hydropower development and the preservation of the landscape's integrity. Situated in a highly fragmented valley, where land expropriation required protracted negotiations, the facility represented one of the first spatial deployments of the Toce basin's hydraulic potential. The plant entered full operation, supplying energy to Novara and its surrounding areas. The facility's implementation underscored the physical vulnerabilities of early hydroelectric systems. A rupture in the penstock during commissioning tests resulted in significant delays, highlighting the challenges of infrastructural reliability in alpine conditions.

More significantly, the excavation of a pressure tunnel beneath the Antillone lake triggered subsurface drainage, accelerating its desiccation and generating one of the earliest recorded conflicts between hydropower infrastructure and natural heritage in the region. The episode prompted public criticism and formal correspondence between the munici-

pality of Formazza and the company, fueling the emerging debate on landscape protection among local elites. While the Conti attempted partial mitigation through compensatory infrastructural works, such as constructing new roads to replace mule tracks, its intervention catalyzed a broader awareness of the territorial footprint of hydroelectricity. Alterations to both ecological assets and historical landmarks marked a turning point in the cultural reception of energy infrastructure. Though eventually decommissioned in 1928 and later repurposed as a summer camp by Edison, the Rivasco facility constitutes a critical site in the genealogy of Italian hydroelectric spatial politics: a moment where technical ambition began to collide with incipient notions of environmental and cultural stewardship.

S.1.2 The Goglio vecchia hydroelectric plant



1910–1912 The facility’s hydraulic architecture reflected typical early-century alpine strategies: water was impounded upstream in the Codelago and Pianboglio reservoirs and then conveyed to the Goglio powerhouse via a diversion intake at “*Ai Ponti*”, with discharge directed either to the Devero stream or to the future Verampio system. However, this layout entailed a notable hydraulic inefficiency: rather than exploiting the full elevation drop from dam to turbine, intake points were positioned substantially lower, resulting in a loss of potential energy and, at times, volumetric dispersions. This apparent sub-optimization was rooted in the prevailing industrial rhythm of the time. Power demand followed factory schedules, with daytime peaks and nocturnal shutdowns, and civil consumption remained negligible, allowing for longer flow times and less reactive system architectures. This temporally segmented mode of production, coupled with prohibitive costs of high-altitude tunneling in rugged terrain, constrained the technical rationalization of early alpine hydroelectric infrastructure.

The Goglio system thus exemplifies a transitional moment in the evolution of hydroelectric planning, in which engineering choices reflected both the operational rhythms of nascent electrification and the financial limitations of a still-consolidating industrial sector. The spatial inefficiencies of the site would only be addressed decades later, once the economic surplus generated by these first-generation plants enabled the construction of more integrated and technically optimized systems.

S1.3 The Codelago dam system and staged hydraulic consolidation



1908–1921 The Codelago dam represents a pioneering instance in European dam typology, introducing the technique of dry masonry fill combined with an impermeable facing. The design responded to the site's asymmetry, solid bedrock on one flank and detrital deposits on the other, by adopting a hybrid structure: a dry-laid stone mass enclosed by outer retaining walls and an interior watertight lining. This inner face was built atop a concrete foundation, sealed with layers of mortar, asphalt, and a granite cobble veneer, exhibiting a level of constructional precision that drew critical acclaim for its structural integrity and aesthetic refinement. The auxiliary dam at Forcoletta enabled lateral water retention that fed into the central Codelago basin. By 1921, both structures had been raised to a maximum elevation of 1,867 meters above sea level, increasing the total storage capacity to 16 million cubic meters. The raising was executed through downstream buttressing in dry masonry and the reinforcement of horizontal planes with concrete, keyed into the original fabric. Despite a temporal lag of

nearly a decade, the upgrades retained complete typological continuity with the initial structure. Functionally, the dam supplied water to the Devero intake and onward to the Goglio powerhouse, via twin bottom-discharge pipes controlled by surface-accessible butterfly valves. The multi-stage development and long-term operational stability of the Codelago system underscore early 20th-century attempts to reconcile structural innovation, alpine topography, and hydroelectric demand within a still-nascent energy regime.

S1.4 The Pianboglio earth dam and wartime hydroelectric provisioning



1917–1926 Located at approximately 2,000 meters above sea level in the Arbola basin, the Pianboglio dam was conceived as an emergency reservoir during the First World War to increase winter electricity output for the Goglio powerhouse. Executed under severe wartime constraints, the project proceeded with minimal topographic or geological preparation. Geotechnical challenges rapidly emerged. Preliminary surveys revealed loose terrain, micaceous sands, and fine clay deposits at shallow depths across the planned site, making standard masonry or concrete solutions unfeasible. In response, the project team opted for an earthfill dam with dry-stone retaining walls, adapting to local materials and construction capabilities under pressure. Work began in July 1917 with the highly unusual choice, dictated by urgency, of leaving a central trench open through the dam body to allow continued stream discharge while construction advanced. This was necessary as the headrace tunnel, though simultaneously attacked from both ends, could not be completed before late August. The initial construction

phase focused on the lateral dry-stone walls, the excavation of dual clay cores, and the establishment of local clay quarries. Despite the improvised conditions, the Pianboglio dam exemplifies a typology shaped less by engineering orthodoxy than by logistical improvisation and temporal urgency. It remains a paradigmatic case of early 20th-century alpine infrastructure responding to the dual imperatives of energy security and environmental constraint.

S.1.5 Verampio. Architectural centrality and wartime acceleration



1912–1914 The Verampio plant represented a technical and spatial leap in the Conti company's hydroelectric program. Designed on an unprecedented scale, it was envisioned as the central node of the entire Toce-Devero network. Its architectural identity, developed in collaboration with Piero Portaluppi, marked the beginning of an integrated approach to industrial construction, where formal expression and site specificity were instrumentalized as markers of both permanence and territorial embeddedness. Construction, initiated in 1912, progressed across multiple fronts despite logistical and environmental challenges. A technical anomaly—interference with long-distance telephone lines due to harmonic distortion from 60 kV transmission—highlighted the growing complexity of managing high-voltage networks within shared infrastructural systems. The plant was completed and put into operation by late 1914, underscoring the company's capacity to maintain infrastructural momentum even under acute external pressures. Verampio thus emerged as both a material and symbolic consolidation of Conti's early hydroelectric expansion.

S.1.6 Valdo. Multiplicity of reservoirs and infrastructural extensions



1916–1924 The Valdo hydroelectric plant integrated a network of four alpine reservoirs situated between 2,000 and 2,400 meters above sea level. The system marked a substantial escalation in both elevation management and technical sophistication. The project necessitated overcoming significant territorial constraints—most notably, the construction of a new road segment overcoming the Casse escarpment—to enable the transport of heavy machinery to the otherwise inaccessible Formazza basin. The scheme’s complexity lay in its staged water storage and conveyance system: the Vannino and Busin reservoirs were hydraulically interconnected via a tunnel beneath the Busin Pass, while the Obersee basin, integrated only in 1922, augmented the volumetric capacity. A fourth basin, the Miryam reservoir, functioned as a regulatory forebay for daily operations. Water from the upper catchments was routed entirely through tunnels, bypassing surface streams prone to avalanches and flash floods caused by blockages. The Valdo powerhouse operated two generating units, and it was decommissioned in 1936 following the opening of the Ponte station.

S.1.7 Crego. Wartime construction and network integration across the Ossola basin (1923)



1916–1923 The Crego power station was constructed under severe wartime constraints, including material shortages, labor scarcity, and rising construction costs. Its architectural form, symmetrical, axial, and hieratic, reflected the emerging model of monumental hydroelectric design. The station utilized a 190 m head and delivered electricity via direct 60 kV lines to Novara and Villadossola, bypassing the Verampio substation. Technical features included a defrosting circuit, designed to melt ice on high-voltage lines using controlled short circuits at distal substations. The original Poirée dam at Piedilago illustrates early concessions to the need for rapid deployment and operational fragility. As a whole, the plant embodied a pivotal phase in the Toce system’s expansion: integrating decentralized hydraulic inputs into a coordinated, high-capacity transmission network.

S.1.8 Vannino. Structural adaptation and dry masonry experimentation



1917–1921 The Vannino dam exemplifies the adaptive strategies employed in alpine dam construction during the early 20th century. Designed initially as a cement-mortar masonry structure, the dam underwent a mid-construction redesign after excavation revealed the absence of bedrock at the expected depth. Opted instead for a dry masonry configuration, replicating the model successfully implemented at Codelago. The resulting gravity dam—measuring 40 m in height and 120 m in crest length—enabled the impoundment of approximately 10 million cubic meters of water. The project illustrates both the technical uncertainties associated with high-altitude hydraulic infrastructure and the need for robust, locally validated construction methodologies in response to unforeseen subsoil conditions.

S.1.9 Obersee. High-altitude water recovery and adaptive reservoir design



1921–1925 Initially excluded from the Valdo system, the Obersee dam was incorporated during the final construction phase in response to the exceptional drought of 1921, which underscored the strategic necessity of maximizing alpine water retention. In 1922, the Conti commissioned a permanent dry masonry structure with a cement-mortar upstream face, completed in 1925. Its construction illustrates the increasing sensitivity of hydroelectric planning to climatic variability and the opportunistic integration of marginal basins into broader production schemes.

S.1.10 Miryam Dam. Remote-controlled terminal basin for the Valdo plant



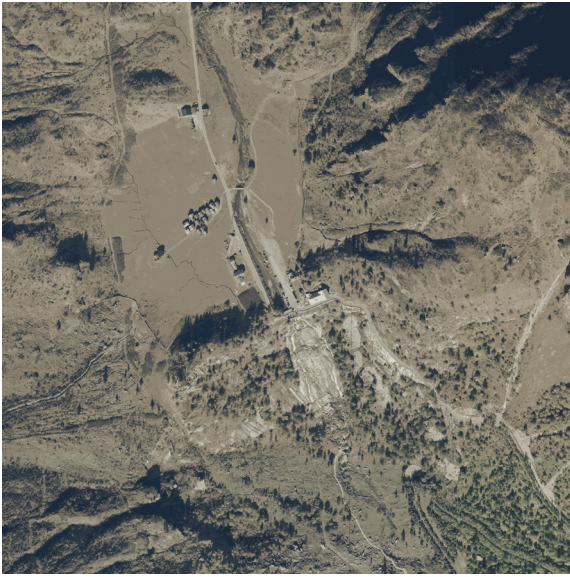
1920–1924 Constructed as the final regulating reservoir for the Valdo power station, the Miryam dam collected outflow from the Vannino basin via a short derivation gallery. She transferred it to the pressure shaft feeding Valdo’s twin penstocks. Notably, it marked the first installation within the Conti network to forgo on-site personnel at the intake, employing remotely operated sluice gates powered by direct current from the plant. The structure featured a 300-meter curved crest and stood 15 meters high. Executed in rubble masonry with lime mortar, it raised the natural lake at the foot of the Clogstafel moraine. Decommissioned in 1936 following the commissioning of the Ponte plant, the Miryam basin exemplifies early 20th-century remote-controlled hydraulic infrastructure in alpine conditions.

S.1.11 The Riale Project (Fisch–Kastelsee)



In early 1919, the *Società Serbatoi Alpini* (SSA) applied to the *Genio Civile* of Novara for a concession to build a high-altitude hydroelectric reservoir above the Formazza Valley, capturing runoff from the basins of Lake Fisch and the Kastel area. The planned 8-million-cubic-meter reservoir was meant to ensure ten days of continuous production during seasonal shortages, offsetting the winter energy deficits of Lombardy and Piedmont’s industries. The site exploited the glacial morphology of the valley, its terraces and hanging basins, allowing for intermediate reservoirs and high-head installations. Although technically feasible, the Riale configuration was soon abandoned in favor of the Sottofrua scheme, which offered a greater head and more efficient hydraulic integration within an increasingly advanced infrastructural framework.

S.1.12 Sottofrua Hydropower Plant

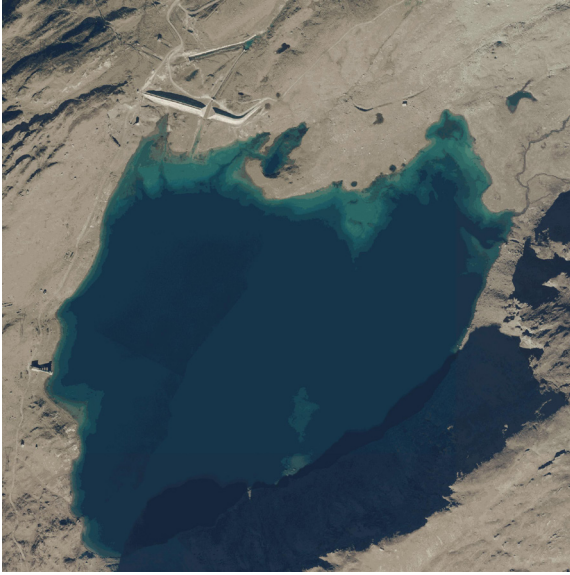


1919–1924 Initially conceived as a reworking of the unbuilt Riale project, the Sottofrua plant marked a technical shift in the exploitation of the Kastel and Toggia reservoirs. Whereas the earlier project had envisaged separate derivations to a single powerhouse at Riale, the revised solution centralized intake via an expanded system converging at a new regulating basin near Scelp and discharging at the base of the Toce Falls. This enabled a higher hydraulic head and more efficient seasonal regulation.

Construction activities began in 1919 but proceeded slowly due to topographical constraints, adverse climatic conditions, and three significant disruptions: public opposition to the potential aesthetic loss of the Toce Falls, and the partial collapse of the Kastel dam during construction. Concerns about the landscape's impact, particularly on the visibility and volume of the Toce Falls, drew national attention and sparked parliamentary debate. Despite reassurances that the derivations would not materially reduce peak seasonal flows, fed mainly by glacial sources, debate delayed final ap-

proval. The conclusion of the administrative review in early 1923 effectively cleared the project of further legal or conservation barriers. The topographical isolation of the site necessitated substantial preparatory investment in access infrastructure. The alignment largely followed an existing mule track to minimize land acquisition costs and ecological disruption. Works were coordinated to ensure rapid deployment across multiple segments, and the route was opened by mid-1923 in time for autumn delivery of turbine and generator parts. The decision by the *Società Serbatoi Alpini* to cede all concessions to *Società Conti* in 1924 followed the compounded delays and additional cost pressures. The plant ultimately served as a transitional model for higher-capacity alpine systems, integrating catchment reconfiguration, remote-regulation systems, and large-scale penstocks across a fragmented but increasingly rationalized energy landscape.

S.1.13 The Kastel Dam



1921–1924 To use the natural lake as a reservoir, the water level was raised by building a dam and lowered through a drainage gallery at a lower elevation. A lateral conduit with sluice gates connected Lake Kastel to the channel from Lake Toggia, which fed the Scelp compensation basin. On 12 December 1922, the final rock diaphragm was blasted to allow controlled discharge serving the Rivasco and Crego stations downstream in the Antigorio Valley. Following the spring snowmelt of 1923, the basin refilled and reached its operational level by mid-September, and the Sottofrua plant officially entered service. Geological surveys confirmed a predominantly impermeable rock substratum overlain by 1–2 m of silt, except for a clay sector near the outlet and calcareous formations on the eastern shore, where groundwater inflows suggested a possible subsurface connection with a nearby glacial stream. To increase storage, the Società Serbatoi Alpini built a provisional 5.5-m-high earth-fill dam in 1921, initially without authorization. Constructed from compacted clay mixed with stones, it was

intended for gradual elevation. Work, suspended in winter 1923, was interrupted when heavy rainfall raised the lake by 2.6 m above its limit, causing a central failure of the dam. No fatalities occurred, and remedial works were completed by mid-1924. After the incident, the Società Conti took over the concession and, in 1925, erected a dry-stone masonry dam nine meters above the natural level on the same site. Despite the addition of a ten-meter-deep concrete footing, structural deficiencies persisted, leading to its decommissioning in 1976 after a partial breach. Today, Lake Kastel remains regulated below its original level, using the early-twentieth-century control shaft.

S.1.14 Toggia Dam with multiple arcs



The Toggia basin, a broad glacial plain surrounded by alpine pastures and traversed by the Röni stream, was identified as a suitable site for a high-altitude hydraulic reservoir. Its geomorphological configuration—a narrow constriction within an expansive, level plateau—naturally suggested a dam placement. The selected typology was a multiple-arch dam, a choice driven by both economic and material considerations. The proposed structure, composed of semicircular arches supported by regularly spaced buttresses, was designed to impound up to eight million cubic meters of water. However, the increase in planned height to 32 meters introduced significant engineering complications, particularly regarding foundation stability in a high-alpine environment characterized by intense freeze-thaw cycles and limited access to sound bedrock. Following the catastrophic failure of a similar structure elsewhere in the Alps, national scrutiny over dam typologies intensified. The severe climatic exposure, susceptibility to ice pressure, and thin structural design inherent to multiple-arch dams

led to a nationwide reassessment of their suitability. In the case of Toggia, the project was halted and ultimately cancelled. The site was later repurposed for a more robust gravity dam design, integrated into a reconfigured hydropower scheme developed a decade later. This episode underscores the sensitivity of large-scale alpine infrastructures to both geomorphological context and structural typology. It further illustrates the evolving relationship between hydropower ambitions and environmental constraints in early 20th-century high-mountain landscapes.

S.1.15 The Lago Nero Dam and the Scelp Dam



1922–1923/4 The Lago Nero and Scelp dam projects illustrate the challenges of hydraulic infrastructure in extreme alpine environments. The former, positioned at nearly 2,700 meters above sea level, was intended to transform a natural lake into a regulated reservoir through the construction of a gravity dam approximately 80 meters in length and 15 meters in height. However, construction was halted due to technical objections regarding structural integrity under ice pressure and foundation weakening caused by design features. Despite revisions that aligned with regulatory recommendations, the project was scaled back significantly. Nonetheless, a small diversion system was successfully implemented to redirect runoff from minor tributaries toward the Schwarzsee basin, overcoming considerable logistical difficulties related to altitude and material supply. The Scelp basin was the terminus of a high-altitude derivation system integral to the Sottofrua power station. This system originated near the provisional intake at the Toggia basin and incorporated water flows from multiple sub-catchments,

including Kastel and Ghighele. Excavated almost entirely through bedrock, the derivation tunnel was constructed under difficult topographical and climatic conditions, with several tunnel access points requiring vertical climbing routes. Its completion enabled the regulation and transfer of water to a newly built load-balancing basin at Scelp, which served as the upper reservoir for the Sottofrua installation. The Scelp dam, built in masonry and completed in 1924, formed a modest reservoir of 35,000 cubic meters. It was a critical component in modulating alpine runoff for high-efficiency hydroelectric production. Both projects exemplify the spatial and technical complexities of early 20th-century hydropower expansion in high-mountain landscapes, particularly in managing water resources across distinct elevation gradients and geologically heterogeneous terrains.

S.1.16 The Crevoladossola Power Plant



1924–1925 Located downstream along the Toce River, the Crevoladossola power station was designed to operate as autonomously as possible from upstream installations. Given the considerable delay in water transfer—four hours from Valdo and Sottofrua, and approximately two hours from Goglio—the plant faced inherent limitations in responding to peak energy demand in real-time. To decouple its operations from the hydraulic inertia of upstream systems, the solution lay in constructing a large-scale compensating reservoir, known as the Braccio barrage. This intervention was not solely a matter of energy optimization but also one of territorial hydrology. The reservoir would serve not only as a buffer for electricity production but also as a regulatory device for downstream flow modulation, mitigating flood risks and minimizing wetland formation in the Verampio plain. A system of movable dams was proposed, designed to maintain the natural dynamics of flooding while increasing the river’s transverse discharge capacity. This solution enhanced the stability of the channel and flood-

plain management by doubling the regulated section of the river to 50 meters and implementing a Swiss-designed self-regulating lock mechanism known as “Dach Vehr.” This hydraulic infrastructure featured two interlocking wooden flap gates, pivot-mounted and capable of opening or closing autonomously based on upstream pressure. Although functionally innovative—allowing passive flood control without human intervention—the wooden construction proved structurally fragile, leading to its replacement in the 1950s with more conventional sector gates. The Crevoladossola plant remains operational today, integrated within the larger hydroelectric cascade of the Toce-Devero system. It serves as a spatial and hydraulic hinge between upper-basin energy production and lowland power distribution, its reservoir mediating between alpine runoff variability and the temporal logic of industrial energy consumption.

S.1.17 The Cadarese Power Plant



1925–1928 The Cadarese hydroelectric plant was initially conceived to exploit the residual hydraulic head between the tailrace of the Rivasco plant and the intake at Piedilago for the Crego station. Initially deemed a minor installation, its strategic role was later reconsidered in light of significant developments across the upper Formazza basin. The construction of large upstream reservoirs and the commissioning of new plants at Valdo and Sottofrua rendered Rivasco inadequate to handle peak flows, prompting a complete redesign of the Cadarese system. In its revised configuration, it would bypass the now-obsolete Rivasco and instead draw directly from the Fondovalle weir. These figures positioned Cadarese as the most powerful installation within the Conti network. As an infrastructural node, it represents a pivotal moment in the evolution of the Ossola hydroelectric system. Architecturally, it was the final contribution by Piero Portaluppi to the Conti portfolio before the company's merger with Edison, thus marking the end of a prolific collaboration that had significantly shaped the

region's industrial landscape. Although the design included provisions for a third penstock and turbine group, these were never implemented. In territorial and hydraulic terms, Cadarese consolidated and rationalized water usage from the Toce basin, achieving a highly efficient conversion of alpine hydraulic energy into power while simultaneously formalizing the transition from fragmented systems to an integrated, high-performance regional infrastructure.

S.1.18 The Ponte Hydroelectric Plant



1929–1941 Initially conceived as a modest installation designed to exploit the hydraulic head between Sottorua and Ponte—recovering both the discharge from the upstream power station and part of the Toce Falls’ flow—the Ponte plant underwent significant revision under Edison’s rationalization program. This led to a major reconfiguration and amplification of its role within the Ossola hydroelectric network. The redefined project consolidated three distinct hydraulic systems—Toggia, Vannino, and Morasco—into a single, multi-input plant, maximizing energy output while minimizing infrastructure fragmentation. An innovative interconnection among these systems permitted operational flexibility. Owing to the 10-metre elevation difference between the Toggia and Vannino reservoirs, water could be transferred between them through a sophisticated system of valves linking their respective penstocks. From a territorial and engineering perspective, the Ponte facility exemplifies a decisive shift toward integrated hydropower systems, characterized by the rationalization of reservoirs, centralization of generation, and interconnectivity between hydraulic circuits, which enables both spatial efficiency and dynamic regulation of water resources. Still operational today, the plant connects to the national grid at 132 and 220 kV, retaining its original hydraulic versatility.

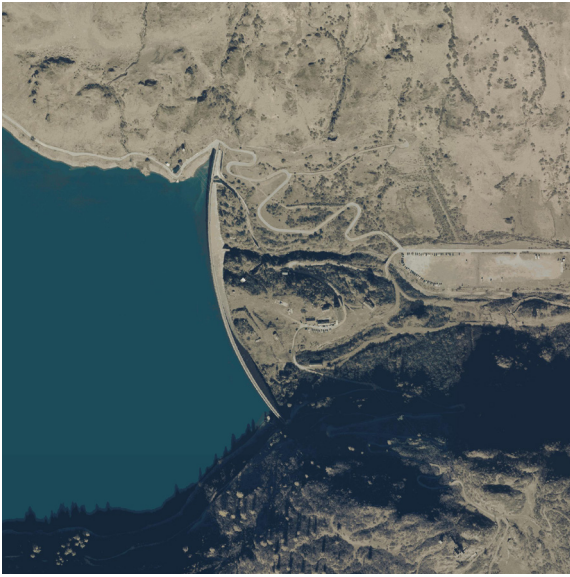
S.1.19 The Toggia Dam



1929–1932 Following the Gleno dam disaster, the construction of multiple-arch dams was formally prohibited. To provisionally operate the Sottofrua power plant and include the Röni basin, Conti implemented only a basic intake weir, setting aside a previous design for a 30-metre-high stone masonry dam that included problematic features, such as a keeper's dwelling integrated into the dam itself. With the arrival of Società Edison and the redesign of the Ponte power station, the Toggia system assumed new strategic significance. This shift culminated in the construction of a gravity dam built from rubble masonry, bonded with cement mortar and anchored to concrete foundations along a gently curving alignment. Yet before the dam could rise, the terrain itself had to be transformed. Access to this high-altitude site required the extension of an existing road—an intervention as essential as the dam itself. In 1928, a multi-party agreement involving the local municipality, a hotel consortium, the contractor Girola, and eventually Edison, along with the Italian military, set the stage for the construction of the so-called *Autostrada del Passo San Giacomo*. This alpine carriage road climbed from Sottofrua, passed the Cascata hotel, and wound its way to the dam site and beyond, connecting infrastructure that would otherwise remain isolated by terrain. Though primarily used for personnel and lighter transport, the road formed only part of the logistical chain. Heavier materials—cement, in particular—were trucked to Sottof-

rua and then transferred to the dam site by cableway. The stone cladding was similarly shuttled from the Riale basin, while aggregates were quarried and crushed near the Boden lakes and hauled up by narrow-gauge wagons and incline lifts to the batching plant. The construction process reflected a high degree of organization and spatial choreography. A metal trestle—engineered to mirror the dam's curvature—spanned the site, carrying gantry cranes and track-bound carts that distributed materials. Concrete was poured through sloped chutes, a method later replicated at the dams of Agaro and Morasco. In this remote alpine setting, the Toggia dam thus came into being not only as a feat of engineering but as a coordinated transformation of landscape, logistics, and access. From a territorial and logistical standpoint, the Toggia project exemplifies the evolution from localized interventions to a coordinated alpine infrastructure network. It integrates road, aerial, and material transport systems into high-altitude dam construction, reinforcing the spatial coherence and operational efficiency of the Formazza hydroelectric system.

S.1.20 The Morasco Dam



1936–1938 The Morasco Dam marked a decisive turning point in the environmental transformation of the Formazza Valley. While previous hydroelectric interventions had preserved the iconic Cascata del Toce, the construction of this large concrete structure permanently disrupted the natural flow of the Gries stream and, with it, the cascade's wild character. Unlike earlier masonry works, Morasco was entirely built in concrete, indicating both a technological shift and a more radical imprint on the alpine landscape. The construction of the dam submerged the hamlet of Morasco, erasing its buildings. The logistics of the project were monumental, shaped by the need to pour an extraordinary volume of 260,000 cubic meters of concrete in just three short alpine seasons, each lasting only four months at an altitude of 1,800 meters above sea level. The aggregate was sourced from a gneiss outcrop located three kilometers away on the Furkulti slope. Two 80-meter-deep vertical shafts, connected to an underground gallery, enabled the continuous loading of small electric trains onto narrow-gauge tracks. These brought materials to the crushing plant, perched dramatically on the slope and designed for maximum efficiency. Cement was delivered by truck from Domodossola and transported to the site by a dedicated aerial cableway. A storage depot allowed for two full days of uninterrupted work. The concrete distribution system was carefully adapted to the site's morphology and represent-

ed a highly refined logistical solution. The left side of the construction area, which extended over the Gries streambed, was served by two blondins anchored to the rock face and two mobile towers installed on a steel truss bridge. On the right side, where the terrain was more regular, inclined gantry cranes operated along parabolic tracks supported by timber trestles. Together, these systems formed an integrated network of suspended carts with a capacity of 0.8 cubic meters, ensuring the accurate and continuous placement of concrete across the entire construction front. The Morasco Dam stands as a synthesis of territorial transformation, industrial scale, and modern engineering. It completed the hydraulic rationalization of the upper Formazza basin, but at the cost of erasing both cultural and natural landmarks, marking a turning point in the reshaping of Alpine space for energy production.

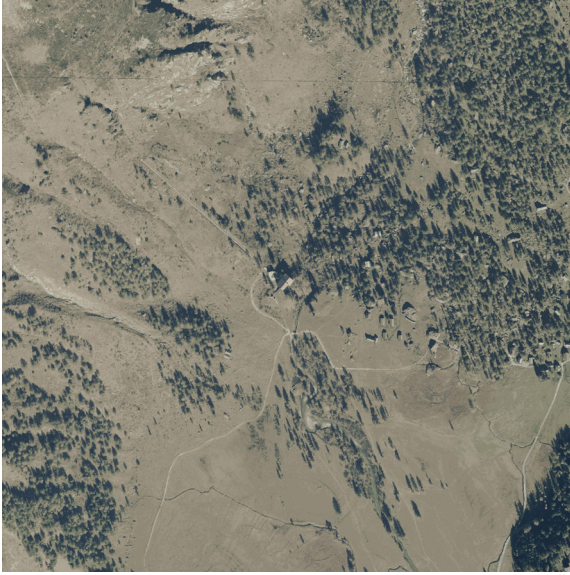
S.1.21 The Agaro Dam



1935–1939 The construction of the Agaro Dam exemplifies the environmental and social implications of hydroelectric development in the Ossola Valley. The alpine village of Agaro, continuously inhabited for over six centuries by Walser communities, was ultimately displaced by the expansion of industrial infrastructure. In 1930, the Edison Company secured a concession to inundate the high-altitude plateau of Agaro, creating a reservoir with a capacity of 20 million cubic meters. In the subsequent years, Edison exacerbated the process of displacement by leasing communal pastures from the municipality. Although nominally framed as a measure to benefit the local population, this action effectively undermined the community's subsistence economy and accelerated the abandonment of the settlement. Dwellings were gradually dismantled for salvageable materials, and the land was submerged beneath the new artificial lake. The transformation of this alpine landscape was irreversible: a formerly inhabited plain at 1,550 meters above sea level was replaced by a large impoundment. From a technical perspective, the construction of the Agaro Dam was a complex logistical undertaking, marked by a high degree of efficiency. Built of rubble masonry, the structure required approximately 150,000 cubic meters of stone and 50,000 cubic meters of excavation, which were completed over three alpine construction seasons. Two principal quarries—located on opposing sides of the valley—supplied up

to 1,000 cubic meters of material per day. Narrow-gauge rail systems and cranes facilitated transportation, while distribution across the structure was achieved through the use of derricks and overhead gantries. Construction proceeded in two main stages, with adjustments to the layout and equipment as the dam rose. Despite the brief seasonal windows imposed by the high-altitude context, the project was completed within the planned timeframe. While Edison engineers later presented the project as a model of construction efficiency, the rapidity of execution must be understood in light of its broader consequences: the displacement of a historical community and the permanent alteration of a high-mountain landscape. The Agaro Dam represents both the apogee of interwar hydroelectric ambition and a sobering case of territorial sacrifice, where infrastructure triumphed over human continuity and mountain ecology.

S.1.22 The Devero Hydropower Plant



1942–1947 The “old” and “new” Goglio installations initially captured water discharged from the Codelago dam at the Devero plain, leaving roughly 200 meters of hydraulic head between the dam’s base and the intake point unused. A 1928 project aimed to capitalize on this potential, proposing the construction of a compensation reservoir at Crampio and a generating station at Cantoni to harness both the outflows from Codelago and several springs in the Crampio area . The facility, designed to host two horizontal-axis Francis turbines, was ultimately not built. Instead, a more efficient solution was adopted: a direct intake from the base of the Codelago dam, which eliminated the Crampio reservoir but gained additional static head, albeit at the expense of the lower springs. This revised project, still in operation today, involves a 2,700-metre-long pressurized tunnel branching from the dam’s bottom outlet. Along this path, the canal also intercepts flows and, just before the surge tank, receives water from the Buscagna basin via a short diversion, thereby eliminating the need for both the Buscagna dam and its corresponding power station.

S.1.23 The Fondovalle Hydropower Plant



1938–1940 The installation was designed to recover the residual head of about 90 m between the outlet of the Ponte station and the intake of the Cadarese plant. Still in operation, it channels water discharged from the Vannino, Morasco, and Toggia reservoirs, supplemented by a small Toce weir and an intermediate intake on the Rio Vannino. The plant intended to exploit the Agaro reservoir was not realized as Conti had planned—his scheme envisioned diverting water along the left flank of the Devero Valley to the Toce level—but was instead built at Goglio, effectively doubling the discharge to Verampio.

This technical simplification reflected a broader post-war shift in the perception of hydroelectric infrastructure: once celebrated as monumental symbols of national modernity, such plants became utilitarian facilities marked by efficiency, standardization, and architectural anonymity.

S.1.24 The Morasco–Sabbione Hydropower Plant (1948–1953)



1948–1953

Initially conceived in the 1920s by the Serbatoi Alpini and Conti companies, the exploitation of the Rio Hosand and surrounding glacial streams in Upper Formazza did not materialize until decades later. Early hydrographic surveys and glacier measurements laid the groundwork, while more precise studies, including a topographical survey and the installation of a flow recorder, were completed by the late 1930s. A preliminary design submitted in 1941 envisioned a dual-reservoir system with a secondary basin at Piano dei Camosci. This concept was later abandoned in favor of a simplified system involving three intake structures and a single, more sophisticated main dam at Sabbione. The final configuration featured a lightened gravity dam and a central hydraulic derivation system. Water from the Sabbione reservoir is directed through a nearly 2.5 km long, pressurized tunnel, fully excavated in rock and lined with concrete, delivering over 8 m³/s to the head of the steel penstock. This penstock descends nearly 640 meters to the underground Morasco power station. The water discharged from the plant flows into the Morasco reservoir downstream, effectively closing the hydraulic circuit. Constructed in just four calendar years, of which only two were viable work seasons due to high-altitude snowfall, the plant's realization stands as a testament to Edison's integrated engineering model. Commissioned in 1953, the Morasco–Sabbione installation symbolically marked the culmination of an era: the end of large-scale hydroelectric development in the Toce and Devero valleys, which had begun in 1908 with Ettore Conti's pioneering work at Rivasco.

S.1.25 Sabbione Dam



1951–1953

Located at an elevation of 2,460 meters above sea level, the Sabbione Dam intercepts the waters of the Hosand and Sabbione, contributing a catchment area of nearly 20 km². This is augmented by the left-bank tributaries (Sidel and Camosci) and the right-bank intakes (Ban and Nefelgiù), which add just over 4 km². The resulting reservoir has a storage capacity of 42 million cubic meters. In its early years, however, the usable volume was significantly reduced due to the presence of the Arbola Glacier, whose tongue extended directly into the lake and periodically released icebergs at an altitude of 2,500 m. Initial impoundments were allowed for only around 26 million cubic meters, about 40% less than today's capacity. Retrospectively, the glacier retreat was advantageous, but at the time, concerns were focused on the opposite possibility: glacial advance. The dam is of the hollow gravity type and consists of eleven sections: nine central hollow units and two solid abutments. Each hollow block shares the same geometric profile, scaled to fit its specific position within the valley. Designed during a period of material scarcity, the structure maximized efficiency by minimizing concrete use—a key autarchic goal, given the high energy costs of cement production. The seventh block, the largest, has a base width of 55 meters and a height of 64 meters; all blocks are 22 meters wide, and the dam measures 279 meters along its crest. The upstream face is clad in dressed stone to ensure watertightness. Due to its remote

and high-altitude location, as well as the decision to use road access instead of aerial transport, the construction site required extensive preparatory work. Initial setup—including the camp at Morasco, three cableways, and the operations building at Sabbione (which later became the caretaker's residence)—began three years before actual dam construction. The worker accommodations, capable of housing up to 700 people, included dormitories, a canteen, a bakery, workshops, medical and religious facilities, and offices. The batching plant was fully equipped with crushers, conveyors, cement dispensers, and two “blondins” to place concrete. The system enabled an extraordinary construction speed: the first pour occurred in September 1951, and the final one in October 1953.

5.5.the unequal electrification of the Western Alps

Between the late nineteenth century and the early 1930s, the most significant efforts to develop the electrical supply chain on the western Alpine slope to valorize local water resources ultimately failed. Despite isolated efforts to integrate hydropower generation with small-scale manufacturing or municipal electrification, these initiatives were largely unsuccessful in altering the dominant flows of capital, technology, and energy distribution. At the same time, the strength of the interests at stake in electro-commercial and electromechanical activity, especially international ones, as well as the strategic value hydroelectric energy production had assumed at the national level, was enough to justify liquidating the traditional Alpine economy based on agriculture and pastoralism. The centuries-old balances established between the upland and the lowland, which involved both sides, broke down irreversibly. Plain agriculture dispensed with mountain agriculture, while the fiscal regime, exacerbated by state policies such as the introduction of an unpopular goat tax, the fragmentation and dispersion of property, and restrictive emigration laws during Fascism, contributed to making the exodus definitive that, in the traditional system, had retained a predominantly seasonal character. What had once been a dynamic of temporary winter migration evolved into structural depopulation, transforming the social and economic landscape of high-altitude communities.

The advent of the electrical industry in a defined regional area, such as the western Alpine arc, was uniform in appearance but with distinct characteristics in the various realities that composed it. It produced different results depending on the greater or lesser dynamism of local economies and, thus, on the more or less marked ability to seize the opportunities offered by a new energy paradigm¹⁰⁶. From 1910 onward, cartel agreements were signed among the leading electro-commercial companies in Piedmont to partition zones of influence. These arrangements anticipated the processes of industrial concentration that would dominate the early postwar period and were pivotal in shaping uneven development across the region. The boundaries drawn on the region's map by these agreements divided the territory into zones that were electrified at times and in the ways freely chosen by each group to which they belonged¹⁰⁷. The resulting fragmentation was reflected in energy prices

¹⁰⁶ In zones like Formazza and Toce, systematic investment and early coordination enabled basin-wide integration, while in peripheral or less connected valleys, fragmentation and disarticulation prevailed.

¹⁰⁷ These artificial partitions often ignored both topographic logic and local needs, prioritizing proprietary control over infrastructural efficiency.

and the amounts offered across different areas, creating uneven conditions that favored industrial localization in select regions, depending on the case. Moreover, no real integration existed between the companies' plants that had historically shared the subalpine market, as alternating current was transmitted at different frequencies in the various provinces, further impeding interconnectivity¹⁰⁸.

The process of electrification of the region, thus, in the long run, accentuated the economic differences already visible before the significant energy transition. Strong areas emerged, anchored around urban-industrial poles such as Turin and Novara. While peripheral mountain areas grew increasingly weaker, excluded from the direct benefits of electricity and the indirect returns associated with industrial concentration. This uneven geography was reinforced by the logic of capital accumulation, which channeled investments toward lowland nodes of transformation and consumption rather than the highland production zones. Despite producing the energy needed for regional and national development, the western Alpine arc mountains mostly fell into this second category. Their marginalization varied in intensity depending on local configurations¹⁰⁹. Still, it occurred under the combined pressure of structural constraints and the irrepressible attraction of the growing income differential perceptible in both internal and external areas of industrialization¹¹⁰. Infrastructure such as high-voltage lines and transformer stations physically bypassed local communities, reinforcing the condition of being both "within" and "outside" the electrical modernization project. Local opposition to expropriations or land use changes, where it existed, was largely ineffective in altering this trajectory. Even where municipalities received compensation or partial access to cheap energy, this rarely translated into autonomous industrialization or demographic stabilization.

In this sense, electrification in the western Alps can be understood less as a process of integration than of territorial substitution—where pre-exist-

¹⁰⁸ In some instances, local grids were physically incompatible with one another, preventing mutual support or redistribution of surplus energy.

¹⁰⁹ Some of the reflections on the territorialization dynamics of electrical infrastructure, and on the spatial effects of productive regionalization, engage with the critical readings proposed by Lanzani, Bolocan, and Zanfi (2015)—particularly in the sections addressing the unevenness of development models and the fragmentation of the national territorial project.

¹¹⁰ Indeed, as companies like Edison and SIP expanded their territorial reach, they did so by optimizing for transmission length and urban market absorption, rarely reinvesting in the very valleys from which hydropower originated.

ing socio-economic structures were displaced rather than transformed. Local economies, shaped over centuries by seasonal rhythms and ecological balance, were systematically reconfigured to serve the needs of distant markets and metropolitan growth. While often framed in terms of modernization and national development, this dynamic concealed a deep asymmetry: the energy harvested from glaciers and torrents was monetized elsewhere, while mountain regions bore the costs of ecological disruption, labor displacement, and infrastructural fragmentation. Ultimately, the legacy of early hydroelectric development in the western Alpine arc is not merely one of technological innovation or industrial growth. It is equally a story of territorial disparity, where infrastructure functioned as both a tool of connection and an instrument of exclusion. This paradox—of producing energy without reaping its benefits—remains a central element in the region's spatial history, shaping debates around energy justice and territorial cohesion well into the 20th century and beyond.

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5.a place of experimentation

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6.parallel processes industrial interdependencies

Electrification of the Alps, primarily driven by hydropower, reshaped both industrial development and territorial configurations. While energy extraction from Alpine rivers and reservoirs fueled the industrial expansion of lowland cities, it also set into motion a series of interconnected transformations that altered landscapes far beyond the mountain valleys. These processes, coinciding across multiple geographies, reflect what Jane Hutton (2020) defines as reciprocal landscapes, materially, ecologically, and economically linked territories through the movement and exchange of resources¹¹¹. Hydropower infrastructure in the Alps was never an isolated project. It was part of a broader material flow system connecting distant landscapes in a reciprocal yet asymmetrical manner¹¹². The construction of dams, reservoirs, and power stations in mountain valleys enabled the accumulation of electrical energy, which was primarily directed toward industrial centers in the plains. Cities like Turin, Milan, and Genoa became the main beneficiaries of Alpine hydropower, which powers manufacturing sectors such as metallurgy, textiles, and the chemical industry. This dynamic reinforced the economic subordination of mountain territories, which remained largely peripheral in their distribution of benefits despite producing a vital resource. The logic of reciprocal landscapes extends beyond energy

¹¹¹ The concept of reciprocal landscapes challenges the perception of materials as static commodities by emphasizing their continuous interactions with land, labor, and ecological systems. Hutton (2020) argues that materials are never inert but rather exist within a dynamic cycle of extraction, transformation, and redistribution that connects distant geographies in often asymmetrical ways. The movement of materials is not merely a logistical process but an active force that reshapes both source and destination landscapes. She notes that “tracing each material, examining the unequal dynamics of exchange along its path, and probing a project’s ideological agendas alongside these material relations, these cases offer a set of points from which more lines can be drawn”.

¹¹² Understanding reciprocal landscapes requires recognizing the interdependencies between production sites and consumption sites, not as discrete or isolated entities but as relational spaces shaped by historical and economic forces. Hutton describes how “contemporary urbanization through globalized capitalism is anything but reciprocal”, highlighting how resource extraction often benefits one landscape at the expense of another. These material exchanges reinforce economic imbalances, as resource-rich regions are integrated into industrial supply chains without necessarily reaping the benefits of their own contributions

alone¹¹³. The infrastructure¹¹⁴ supporting hydropower interconnected Alpine valleys to expanding urban economies while altering local environments. Forests were logged to clear land for reservoirs, river courses were modified to regulate water flow, and entire villages were displaced to accommodate energy infrastructure (Hutton 2020). Though framed as necessary for modernization, these interventions deepened territorial disparities, reinforcing patterns of uneven development between production sites and consumption site centers. Parallel to this transformation, new industries emerged in Alpine and peri-Alpine valleys, directly leveraging the availability of hydroelectric power. Textile mills, metal refineries, and electrochemical plants clustered in areas where concessions for energy supply had been secured, demonstrating how industrial geography was shaped by proximity to raw materials and access to reliable power sources. In many cases, these industries were financed by external capital, with foreign investors recognizing the economic potential of cheap hydroelectricity for energy-intensive production. The establishment of these industries further integrated Alpine territories into global economic circuits, transforming them into sites of industrial experimentation that mirrored broader trends in resource-based urbanization. Yet, while the Alps supplied the energy necessary for industrial expansion, their socio-economic fabric underwent profound change. The shift from a mixed economy of agriculture, seasonal migration, and mining toward industrial production was neither uniform nor universally beneficial. Many Alpine communities faced structural challenges as traditional livelihoods collapsed in the face of modern-

113 By situating hydropower within the framework of reciprocal landscapes, it becomes possible to reassess the role of infrastructure as more than a technical system. The construction of hydroelectric facilities was not merely an engineering feat but a political and economic intervention that redefined territorial relationships. The restructuring of land and labor associated with this transformation was not incidental but integral to the functioning of the system, demonstrating how infrastructure actively produces space rather than simply occupying it. Hutton's perspective urges a reconsideration of material movements as embedded within broader social and ecological entanglements, compelling us to think beyond the physical structures of energy production and towards the landscapes they shape and the communities they impact.

114 Hydropower exemplifies this model of reciprocal but unequal landscapes, where Alpine valleys became energy production sites for distant urban and industrial centers. The infrastructure required to generate and distribute electricity: dams, reservoirs, and transmission networks, imposed significant territorial transformations, often disrupting existing land uses and displacing local populations. While hydropower enabled industrial expansion, it also entrenched regional disparities by channeling resources away from the areas where they were extracted. This structural arrangement mirrors broader patterns of environmental load displacement, in which the ecological burdens of industrialization are borne disproportionately by certain landscapes while others accrue economic advantages.

ization. The long-standing cycles of transhumance and small-scale subsistence farming, which had shaped Alpine landscapes for centuries, eroded under the pressures of industrialization and labor migration. By viewing hydropower and its associated industries through the lens of reciprocal landscapes, it becomes evident that material exchange is not a neutral process. The landscapes of energy production and industrial consumption are fundamentally intertwined, yet they experience the consequences of resource extraction in vastly different ways. The Alps became a frontier of industrial energy supply, but the benefits of this transformation were disproportionately concentrated in urban manufacturing districts. Meanwhile, mountain communities primarily bore the environmental and social costs, ranging from land dispossession to ecological degradation. This section establishes the conceptual foundation for examining the following case studies, exploring how hydropower infrastructure shaped the Alps and the industrial landscapes dependent on its energy. Tracing these material movements and their territorial consequences makes it possible to reconstruct the broader reciprocal relationships that have defined the Alpine region's role in the modern industrial economy. Suppose the first section explored how the Strona Valley emerged as a layered industrial landscape—where artisanal hydraulics, textile manufacturing, and hydroelectric modernization coexisted within a complex palimpsest of productive regimes—and the second traced how design-driven industries reconfigured inherited infrastructures into global domestic economies. In that case, the third has extended this narrative into decline, remediation, and uncertain futures. Rather than interpreting energy infrastructure as a neutral enabler of development, this chapter has shown how electrification and hydropower consolidation acted as agents of spatial reconfiguration, first enabling industrial intensification, then leaving behind material legacies in the form of brownfields and contested terrains.

The analysis advances a framework for understanding Alpine modernity as inseparable from its infrastructural substrate by foregrounding the entanglement of material flows, labor regimes, and representational strategies. The Alps did not simply host industrial modernity, they structured it, redistributed its benefits and externalities, and continue to embody its unresolved tensions. The concept of reciprocal landscapes thus offers a critical tool for interpreting these spatial histories: not as linear narratives of progress or decline, but as recursive configurations of extraction, transformation, and redefinition. From the cascading

flows of water and aluminum to the sedimented residues of industrial architecture and chemical pollution, the Alpine valleys emerge not as passive backdrops but as infrastructural landscapes (Bélanger 2016) whose pasts remain operative in shaping their present and future trajectories.

6.1.threads of power energy and the territorial fabric of textile industrialization

This chapter examines the Strona Valley as a paradigmatic site of energy-driven industrial transformation within the Alpine context. Following the previous section's investigation into extractive landscapes and the material reconfiguration of mountain territories, the focus here shifts toward the entanglement of hydropower infrastructure and textile manufacturing. Rather than viewing energy as a neutral input to industrial development, the chapter considers it an active territorial agent that has shaped spatial logics, property regimes, and production cycles across multiple historical layers¹¹⁵ (Garuzzo 2000). The Strona Valley offers a dense palimpsest in which early artisanal hydraulics, proto-industrial arrangements, and twentieth-century modernization coexist. Situated between Lake Orta and the Ossola region, and historically connected to the Cusio district, the valley formed part of a broader territorial constellation in which water, forests, and mineral resources supported overlapping productive regimes. Unlike more centralized industrial regions, the valley's development relied on the adaptive reuse of existing energy regimes, legal water rights, and infrastructural fragments, allowing it to absorb and redirect successive waves of economic and technological change (Castronovo 1988). Its marginal geographic condition was counterbalanced by strategic connectivity to transalpine markets, making it a site of innovation and dependency.

The emergence of linear industrial urbanization, the persistence of domestic-scale hydraulic systems, and the articulation of company towns reveal the Strona Valley as a dynamic field in which energy, labor, and landscape were tightly interwoven. In this sense, the valley is not simply a container of industrial heritage but a critical lens to interrogate the spatial politics of hydraulic and institutional power within the broader evolution of Alpine productive geographies.

Mineral Extraction and Proto-Industrial Development in the Strona Valley The exploitation of mineral resources in the Strona Valley dates back to at least the late 15th century, representing one of the few viable alternatives to seasonal migration. Initially centered on

¹¹⁵ The reconstruction presented in this section draws primarily on the foundational work by Garuzzo (2000), which systematically assembled a wide range of archival sources, local histories, and oral accounts to trace the development of industrial activities in the Strona Valley. Building on this empirical groundwork, the present analysis integrates and spatializes those materials within a broader territorial framework, highlighting infrastructural configurations, hydrographic logics, and socio-economic patterns that connect local developments to regional processes of industrialization and energy transformation.

iron extraction in Luzzogno, where natural conditions provided proximity to waterpower and forest resources, the mining economy gradually increased. The sector remained fragmented and technically underdeveloped, with most mining plots operated by small-scale proprietors lacking the capital or expertise for sustained extraction. Attempts to systematize these activities were periodically advanced, including proposals for centralized state-operated processing plants. The uneven geography of investment and difficulty accessing deeper mineral deposits contributed to a cycle of premature exhaustion and abandonment. By the late 19th century, however, a more diversified mineral economy emerged. Copper, iron, and nickel were extracted from numerous scattered sites, including Balmela, Croso Monsone, and Campello¹¹⁶. These extractive practices contributed to the rise of mechanical workshops and metalware production in the valley, laying the groundwork for the precision metal industries that would later define the region's identity. Yet this trajectory remained vulnerable to global price competition, and most operations ceased by the mid-20th century, surviving briefly under autarkic policies during the Fascist regime.

Mapping Early Hydraulics and Proto-Industrial Systems Cadastral sources constitute a critical entry point for reconstructing the spatial articulation of early productive systems in the Strona Valley. The analysis of 17th- and 18th-century land registers, including narrative surveys and geometric maps, provides a valuable record of pre-industrial territorial configurations, many of which were later erased or overlaid by successive phases of mechanization and industrial development. The *Catasto Teresiano* (1723), commissioned under the Habsburg administration, is a foundational document. As the first geometric and systematic mapping of land use in the region, it not only provides spatial coordinates for mills, forges, and hydraulic structures but also reveals the relative density, size, and function of productive *nuclei* dispersed along the Strona River and its tributaries. The update to this cadaster in 1771 captures the proliferation of small-scale water-powered installations, including twenty permanent mills and several integrated facilities that combined grain processing, ironworking, and dye preparation. These mapped infrastructures are material evidence of a dispersed, domestic-oriented production economy, shaped by hydraulic availability, fiscal

¹¹⁶ Remnants of these operations remain visible today in the form of abandoned galleries and shafts across Alpe Collo, Alpe Cunetta, and Campello.

exemptions, and seasonal labor patterns¹¹⁷. The layout and ownership patterns they document illustrate the emergence of proto-industrial logics based on shared infrastructures and hybridized production cycles. Additionally, maps and descriptive surveys concerning paper mills reveal how productive practices were embedded in transregional trade networks, shaped by the availability of raw materials and, in turn, by taxation regimes and elite patronage. In this context, the maps do not merely document a landscape, they reveal a palimpsest of overlapping uses and social relations, many of which have left enduring imprints in the form of surviving hydraulic traces, residual architecture, and naming conventions. These documents thus provide both spatial data and a narrative framework to understand the *longue durée* of extractive and productive processes in Alpine valleys.

Textile Industry and the Spatial Logic of Industrial Urbanization and Infrastructural Reconfiguration During the second half of the 19th century, the Strona Valley became a strategic site for relocating and expanding industrial activities that could no longer be sustained in spatially constrained and hydraulically saturated valleys such as Intrasca. The development of mechanized facilities in the valley was closely linked to the evolution of regional transport infrastructure. Roads, telegraph networks, and eventually railways restructured access to raw materials and export channels, connecting it to Genoa, Venice, and the Swiss market. Hydropower remained the primary locational advantage through the 1880s, attracting Swiss and northern Italian industrialists who invested in sites with established water rights. Early industrialization often occurred through the adaptive reuse of existing pre-industrial facilities, many of which were upgraded into mechanical cotton-spinning factories, ironworks, or paper mills. This phase of industrial transition was characterized by significant capital mobility and frequent ownership changes, particularly in the cotton sector (Castronovo 1965), which was highly sensitive to international trade policies, raw material shortages, and the progressive restructuring of production

¹¹⁷ In cases like the Molineto and lower Strona clusters, reusing the same hydraulic drop for multiple alternating operations demonstrates an early rationalization of energy input, enabling a high degree of spatial layering. Beyond their technical function, these cadastral records afford insight into the socio-economic ecology of early industrialization.

phases. The liberalization policies promoted in the 1850s¹¹⁸, coupled with the decline of protectionist tariffs, led to capital concentration and vertical production. Small-scale and under-capitalized firms gave way to larger, better-financed enterprises capable of absorbing the volatility of raw material markets and machinery imports. These structural changes were inscribed spatially in the transformation of the built environment: pre-existing craft-based facilities were replaced by multi-story factory complexes designed to accommodate specialized machinery and dense labor concentrations. These new industrial architectures disrupted the traditional rural fabric, introducing verticality and formal differentiation in previously agrarian landscapes.

By the 1870s and 1880s, linear industrial urbanization had shaped along the Strona river, progressively filling the interstitial spaces between pre-existing productive settlements, and proto-urban agglomerations emerged¹¹⁹. The symbolic centrality of the factory was reinforced in the period's visual culture: company letterheads, postcards, and industrial panoramas prominently featured smoking chimneys, rail tracks, and mechanized conveyance systems as emblems of modernity and local pride. These representations underscored a cultural shift: nature was no longer the privileged image of the territory, but was replaced by the factory as the marker of progress and collective identity. The rise of vertically integrated textile complexes after 1887, enabled by renewed protectionist policies, marked a final phase of territorial reorganization, in which industrial activity became increasingly spatially concentrated and structurally specialized. These processes not only redrew the economic geography of the valley but redefined its visual and cultural identity¹²⁰, embedding industrial modernity in the very form and image of

¹¹⁸ The liberalization policies promoted in the 1850s refer to a set of reforms introduced in the Kingdom of Sardinia—later extended to unified Italy—including the abolition of internal customs barriers, the reduction of duties on imported machinery, and the dismantling of corporative restrictions that had regulated access to manufacturing activities. These measures, together with the progressive lowering of protectionist tariffs, encouraged the inflow of foreign capital, facilitated the acquisition of modern textile and mechanical equipment, and promoted the consolidation of industrial enterprises. In the western Alpine foothills, the effects were particularly visible in the transition from dispersed artisanal workshops to vertically integrated factories, where standardized production cycles could be organized around new steam- and water-powered machinery.

¹¹⁹ Complex, micro-urban systems organized around internal circulation paths, hierarchical zoning, and specialized structures such as warehouses, administrative buildings, and workers' housing.

¹²⁰ Thus, the Strona Valley became a productive landscape—a terrain where modern industrial aesthetics and economic functionality converged.

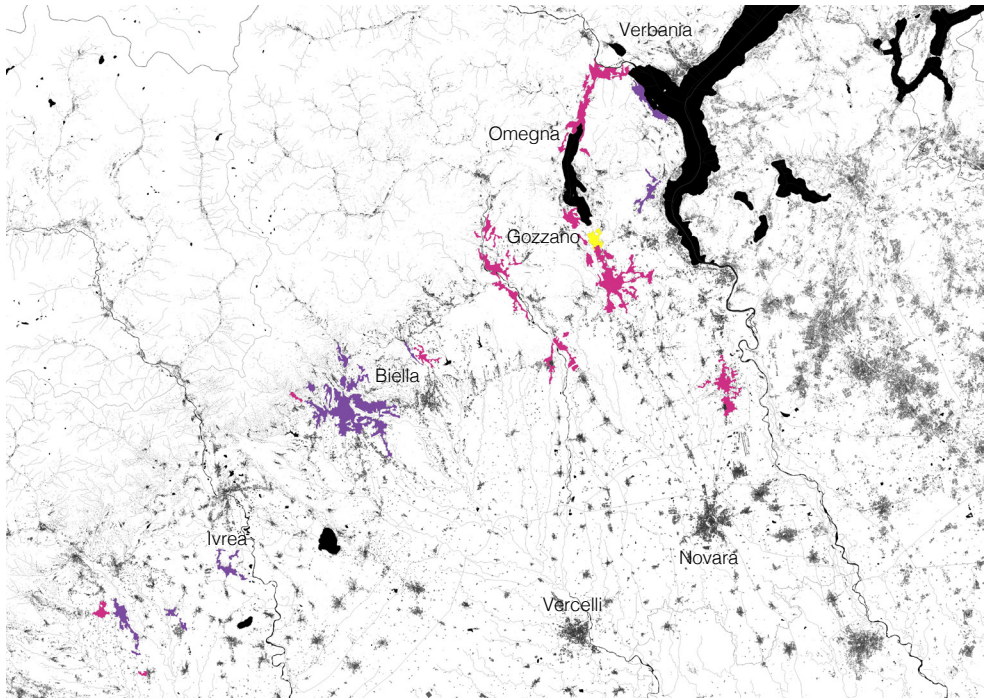


fig.6.1 The map illustrates the present distribution of productive areas in relation to the historical evolution of hydroelectric and manufacturing activities. The first cluster corresponds to the areas once occupied by cotton and wool mills that, since the late nineteenth century, had exploited the hydropower potential of the Dora Baltea catchment, particularly along its left-bank tributaries, and of the pre-Alpine valleys converging toward Lake Orta and the Toce basin. These industries operated as self-producers, installing small and medium hydroelectric plants to supply their own manufacturing complexes. Within this context, the early textile system structured the geography of industrial settlement: its distribution along the main hydrographic corridors determined the emergence of a dense network of productive nuclei linked by water supply and transport infrastructure. These manufacturing poles formed the spatial substrate from which subsequent waves of industrial diversification unfolded.

The second cluster identifies the areas where later industries expanded from this textile foundation, adapting to new technologies and materials while maintaining continuity with earlier productive patterns. Metalworking, mechanical, and electrotechnical firms emerged by reusing existing hydraulic infrastructures and converting mill sites into small factories. This gradual transformation, concentrated along the Strona Valley and the southern edge of Lake Orta,

produced a landscape of incremental industrialization where artisanal skill, hydropower, and technical innovation coexisted within a coherent territorial system.

The third and distinct pole is represented by the Bemberg complex in Gozzano, which introduced a structural discontinuity into this trajectory. While external investments had already entered the region, the establishment of the *viscose-rayon* plant marked a decisive rupture in scale, technology, and environmental impact. The choice of a lakeside location responded to the extraordinary water demand of the process. This spatial decision, however, generated paradoxical effects: by concentrating capital and labor within a single modernized enclave, Bemberg undermined the smaller textile industries that had previously defined the valley's productive balance. The resulting shift in the territorial economy transformed the lower basin into a polarized industrial landscape, simultaneously a factor in the decline of the traditional cotton and wool sectors.v.

the territory.

Energy Infrastructure and Hydroelectric Modernization

Along the Strona River, an industrial landscape of exceptional historical depth developed throughout the 19th century, consolidating rather than erasing earlier hydropower infrastructures through the transition from mechanical to electrical energy. A hybrid environment emerged where artisanal and proto-industrial water rights, initially conceived within an agrarian legal framework, were gradually subsumed under the demands of mechanized manufacturing. Conflicts between agricultural users and industrial entrepreneurs were frequent in the early phases, but industrial interests prevailed in a region where agriculture had never been dominant. The valley's historic network of canals (*rogge*), as documented in the *Catasto Teresiano*, was progressively adapted and unified into a continuous hydraulic system supporting a range of industries.

By the 1880s, major firms had replaced traditional water wheels with turbines, achieving higher energy yields while retaining the same hydraulic flows. Efforts to regulate seasonal flow fluctuations culminated in an ambitious hydraulic reconfiguration of Lake Orta, designed to store floodwater and release it during dry periods. Despite opposition from landowners and prominent engineers concerned about the impact on riparian properties, industrial actors pushed for the project, citing economic efficiency and social necessity. By the late 19th century, electrification extended the reach of energy infrastructure into the upper valley. Local industries became early adopters of hydroelectric self-production, building small-scale plants that powered factories and public lighting, often before larger cities like Milan and Turin. The textile sector, susceptible to lighting and fire safety concerns, was among the first to adopt electric illumination, followed quickly by metalworking and mechanical workshops¹²¹. These infrastructural transformations reshaped both productive and visual regimes. The upper valley, previously marginalized by its topography, became integrated into industrial circuits through the strategic siting of power stations. Electricity's symbolic and functional

¹²¹ On the early diffusion of electrification in the alpine and pre-alpine valleys, several studies highlight how small hydroelectric and thermoelectric plants were adopted by local textile manufacturers well before large urban systems were fully established. Cotton and wool mills in the Gressoney, Biella, and Canavese areas installed autonomous power stations for lighting and mechanical transmission in the mid-1880s, making these districts among the first in Piedmont to integrate electricity into production. This early uptake positioned the upper valleys as active components of the emerging regional energy network, anticipating the broader municipal electrification of Turin and Milan.

prominence catalyzed a shift in factory design: from vertical multi-story mills dependent on shaft transmission to horizontal layouts enabled by electric motors and modular flexibility.

By 1900, the Strona Valley had emerged as a paradigmatic site of hydroelectric capitalism. Its modernization was not linear but layered: new energy systems coexisted with older hydraulic channels, while aesthetic and spatial codes evolved in parallel with technological infrastructure. This stratification exemplifies how modernization in peripheral Alpine regions hinged on innovation and the capacity to reorganize inherited landscapes into dynamic production sites. Extending the railway network into the Strona Valley did not initiate industrialization but rather consolidated an existing, deeply rooted manufacturing tradition. The arrival of the railway reinforced the area's longstanding industrial vocation, strengthening its logistical and economic integration into national and transalpine markets. In the early 1850s, the line from Novara reached Arona, positioning the region within the primary corridor linking the port of Genoa to central Europe. This connection ensured the swift circulation of raw materials, particularly cotton, and facilitated access to Mediterranean and continental export routes¹²². Proposals were advanced for alternative routes through the Lake Orta region¹²³. Although many of these plans encountered delays or were abandoned, they underscore the pressing need to connect peripheral manufacturing sites with principal transportation axes. By the late 1880s, the completion of the Arona-Domodossola line, traversing the Strona Valley, marked a turning point. This infrastructure enabled industrial sites in the lower valley to access broader markets and supply chains. The construction itself entailed significant engineering efforts, including the erection of stone viaducts and metal truss bridges, utilizing locally sourced granite, demonstrating a synthesis of local knowledge, resource exploitation, and technological ambition. Despite the strategic importance of the new railway, direct industrial access remained limited¹²⁴. Others had to wait for the development of the electric tramway system, which enabled integration into the railway network while also serving as

¹²² Local demands for improved railway infrastructure were particularly strong in towns like Omegna and Gravellona, where industrial development was underway but still dependent on traditional, slower transport modes.

¹²³ Considered strategically safer and more efficient than those vulnerable to Austrian artillery or constrained by Alpine topography.

¹²⁴ Only a few factories, such as the Maffioletti paper mills, possessed dedicated freight and passenger stations.

a commuter line for workers and a vital artery for regional tourism. The tramway thus emerged as a flexible infrastructural solution, particularly suited to the fragmented and linear settlement patterns along the valley. In this context, rail and tram infrastructure served not only mobility. They redefined the territorial logic of industrial capitalism in the Alps, translating spatial proximity into economic potential and facilitating the clustering of production, labor, and logistics. This reinforced the valley's transformation into a continuous industrial landscape. What had once been discrete settlements evolved into interconnected nodes in a broader economic geography, with rail lines and tramways forming its circulatory system.

Expanding the frame: from local histories to regional patterns

While the previous section has traced a *microhistorical* reconstruction of hydroelectric and industrial transformations in the Strona Valley¹²⁵, it is crucial to emphasize that the dynamics observed there were not isolated. Instead, they formed part of a much broader territorial phenomenon across the western Alpine arc. The entanglement of hydropower infrastructure and textile manufacturing unfolded across multiple valleys, revealing recurring patterns of energy self-production, spatial organization, and industrial specialization. From the Biellese to the Canavese, and from the Valsesia to the Aosta Valley, dozens of cotton mills and wool factories integrated hydraulic energy into their production models, shaping local economies and landscapes in deeply interrelated ways (fig.6.1). This broader frame allows us to situate the Strona case within a regional constellation of hydroelectric-driven textile industrialization. The exploitation of the Dora Baltea catchment, particularly its left-bank tributaries, illustrates the broader regional dynamic wherein hydropower was primarily harnessed by industrial self-producers, es-

¹²⁵ The methodological approach adopted in the previous section draws on the tradition of *microstoria*, as elaborated by Carlo Ginzburg, which privileges dense, localized inquiries as a means to interrogate broader historical structures. By focusing on a restricted spatial and social context—the Strona Valley—it becomes possible to uncover the granular mechanics of industrialization, energy transformation, and territorial restructuring that would otherwise remain invisible in macro-level narratives. This microhistorical lens allows the historian to trace the uneven and contingent unfolding of modernization in peripheral areas, highlighting the ways in which local actors negotiated, resisted, or adapted to infrastructural and economic change. See: Ginzburg, C. (1993). *Microhistory: Two or Three Things That I Know About It*. *Critical Inquiry*, 20(1), 10–35.

pecially in the cotton and wool sectors¹²⁶. This pattern of distributed energy production reveals how Alpine valleys, despite their geographic marginality, played a pivotal role in the emergence of a decentralized yet highly productive industrial network¹²⁷.

Hydropower and the territorial production of the sub-alpine region A significant portion of hydropower generated in the Dora Baltea basin was utilized locally, especially in textile districts such as the Biellese, where energy-intensive manufacturing benefited from proximity to perennial alpine flows. These self-production strategies enabled firms to insulate themselves from fluctuating market rates, ensuring both energy stability and spatial autonomy. At the same time, they contributed to territorial differentiation: areas with access to hydraulic concessions and transmission capacity became industrial strongholds, while others remained locked in agricultural or extractive economies¹²⁸. The prevalence of hydro-powered textile sites across the northwestern Alpine region demonstrates how water, energy, and industrial modernization were co-constitutive forces. These interconnected processes did not simply overlay existing geographies—they redefined them. As the next section will show, the transformation of alpine energy regimes also entailed institutional reconfigurations and shifting relationships between municipal authorities, private actors, and state infrastructures.

¹²⁶ Rather than relying on centralized electricity suppliers, many textile manufacturers—such as the Manifattura Rossari & Varzi (with plants at Fontainemore and Lillianes), the Cotonificio Valle d'Aosta (Verrès), and others in Strambino, Baveno, Nebbiuno, and Biella—opted for hydroelectric self-sufficiency, directly capturing and converting local water resources into mechanical or electric energy.

¹²⁷ Beyond its technical dimensions, infrastructure operates as a spatial instrument of power. It organizes access, reconfigures hierarchies, and embeds asymmetries into the fabric of everyday life. In the case of hydroelectricity, the distribution of energy networks and the localization of production sites did not simply follow natural advantages—they produced new territorial orders, privileging certain areas while marginalizing others. Power, in this sense, is both energetic and political: it flows through conduits and cables, but also through laws, concessions, and institutional arrangements that shape who benefits and who is excluded.

¹²⁸ Throughout this chapter, the term power operates along a double semantic axis: as both physical energy—hydropower—and as a modality of spatial control and political-economic domination. This dual reading underscores how energy infrastructures are never neutral technological systems but active agents in the (re)production of spatial hierarchies. The selective allocation of hydraulic concessions, the establishment of monopolistic energy regimes, and the consolidation of self-producing industrial enclaves illustrate how hydropower shaped not only production regimes but also patterns of inclusion and marginalization across the Alpine landscape. This framework aligns with recent work in political ecology and critical infrastructure studies that examine energy not only as a technical resource but as a terrain of socio-spatial inequality and governance.



fig.6.2 The Strona Valley has historically been a site of mineral extraction, particularly for nickel, as well as copper, cobalt, gold, and manganese. The main center of mining activity was Campello Monti, where remnants of the mines and processing infrastructure are still visible. Due to the specific nature of these operations, the *Campello Monti abandoned mining site* has been included in a national environmental remediation program (*Accordo di Programma Quadro del 30/01/2004*).

Initial concessions for nickel prospecting date back to 1865. However, by 1878, the sector entered a period of crisis following the entry into production of the massive garnierite deposits in New Caledonia, which triggered a collapse in global nickel prices. This episode exemplifies how global market shifts were already shaping the trajectories of remote local economies, embedding Alpine mining sites, such as Campello Monti, into broader geoeconomic dynamics long before the onset of contemporary globalization.

Despite intermittent activity and recurring license suspensions, mining operations continued into the early 20th century. A renewed and intensive phase began in 1936 during Italy's Fascist-era autarky, when the concession was granted to the *Società Anonima Nichelio e Metalli Nobili* (S.A.N.M.N.), a state-linked company within the AMMI group. Campello was reorganized and modernized, becoming Italy's most important nickel mine until

production ceased definitively in 1945. The site comprised two main mining concessions—"Alvani" and "Pennino Grande"—developed across vertically stratified shafts and galleries, with ore transported via narrow-gauge rail to a centralized flotation plant. This facility, operational from 1940 to 1943, processed approximately 46,000 tons of ore, achieving a daily capacity of 75 tons. The extracted ore, primarily nickeliferous pyrrhotite, was enriched through a combination of mechanical and chemical treatments.

The environmental legacy of this activity remains significant. The flotation process generated large volumes of tailings, still present in surface deposits across the valley. These materials, which contain high concentrations of heavy metals such as nickel, iron, copper, cobalt, chromium, and selenium, have been subjected to prolonged atmospheric exposure, allowing contaminants to disperse into the surrounding environment. As a result, the site poses ongoing environmental and health risks, underscoring the need for continued containment and mitigation measures.

Campello Monti (photograph by the author, 2023).

territorial snapshots.2 This sequence examines the industrialization of the Strona Valley, where hydropower and craftsmanship converged to shape one of the most distinctive manufacturing landscapes of the Alpine foothills. The entries trace the evolution of textile, metallurgical, and mechanical production, which redefined settlements, infrastructure, and labor geographies along the valley. By reconstructing the material and infrastructural decisions behind these transformations, the section reveals how local ingenuity and resource availability fostered an enduring industrial ecology rooted in the geography of water and slope.

territorial snapshots.2



S.2.1 Cotonificio Guidotti e Pariani.

Typological and Technological Evolution of Hydraulic Infrastructure in Grav-

ellona Toce The industrial trajectory of Gravellona Toce in the nineteenth century offers a paradigmatic example of spatial continuity and technological transition within Alpine manufacturing territories. Situated at the confluence between the Ossola and Strona valleys, the town emerged as a hinge between the mountain's hydraulic economy and the industrial expansion of the Piedmontese plain. The repurposing of an old paper mill into a cotton-processing complex by *Guidotti e Pariani* in the 1840s exemplifies how pre-existing infrastructures, particularly canal systems and water rights, were strategically leveraged to accommodate new forms of mechanized production. The availability of the canal, combined with favorable climatic conditions for cotton spinning and finishing, made the site an ideal location for transformation. Its development reflected the broader capacity of Alpine valleys to absorb industrial modernity without erasing their pre-industrial frameworks. Architecturally, the complex was developed in successive phases that mirrored changing production logics. The typological evolution from compact vertical mills to horizontally articulated structures coincided with the diffusion of turbine-powered shaft systems and, later, with the adoption of reinforced concrete in the early twentieth century. Beyond its architectural form, the site illustrates the persistence of industrial palimpsests, where older construction logics, property regimes, and hydraulic infrastructures coexisted with emergent technologies and management systems. This overlap produced a distinctive kind of modernization: incremental rather than revolutionary, grounded in adaptation and continuity rather than rupture. Gravellona Toce thus stands as a key node in the geography of Alpine industrialization, a place where inherited infrastructures, technological innovation, and territorial conditions converged to generate one of the earliest hybrid landscapes of modern production.

S.2.2 Cotonificio Furter e Bebié

Spatial Hybridization and Transnational Logics Founded by the Swiss industrialist Federico Furter in the 1860s, the cotton mills of Ramate and Santa Maria introduced a new industrial presence into the Strona Valley, bridging rural production and early mechanization. Emerging from the conversion of existing water-powered mills, they reveal how Alpine valleys adapted pre-industrial infrastructures to the needs of modern manufacture. The two sites evolved in parallel with the regional spread of hydroelectric power, which gradually replaced mechanical transmission systems and tied the factories to the broader territorial network of energy and mobility. By the 1920s, both plants had undergone substantial expansion, supported by the construction of two small hydroelectric stations (1921–1923) that stabilized production and reinforced the valley's dependence on water as a source of industrial autonomy. Under Federico Rothpletz, the company entered a wider corporate constellation linking Piedmont and Lombardy, anticipating the multi-site strategies of twentieth-century textile capitalism. Around the factories grew an entire social landscape of worker housing, service buildings, and managerial residences, an industrial microcosm shaped by energy, hierarchy, and proximity. These complexes marked a turning point in the modernization of the Strona Valley: they consolidated external capital, technological innovation, and local labor into a single spatial and economic system, projecting the valley into the emerging map of Northern Italy's industrial regions.

S.2.3 Cotonificio De Angeli-Frua

The Company Town and the Architecture of Industrial Welfare The Omegna cotton factory, founded by Swiss entrepreneur Massimiliano Ackermann in the 1880s and later acquired by the *De Angeli-Frua* group, represents a seminal case of industrial acceleration and territorial transformation in the Strona Valley. Conceived as a vertically integrated manufacturing hub, the site evolved from a carefully planned investment in hydraulic infrastructure and land consolidation. An efficient canal system and rational industrial layout enabled the rapid establishment of a complete production cycle, from spinning to printing. Ackermann's early adoption of specialized design and engineering—evident in the use of cast iron and iron-brick vaulting—signaled a decisive technological shift away from timber-based construction. By the early 1890s, the factory had expanded significantly, forming a dense enclosure of two-story perimeter buildings surrounding large shed-roofed halls optimized for natural lighting. Multiple chimneys testified to its growing reliance on steam power, though hydraulic energy remained integral to its operation. At this stage, the complex employed over 700 workers, becoming a key node in the valley's emerging industrial system. The 1901 fire that destroyed the printing department marked a turning point. The subsequent acquisition by the *De Angeli-Frua* group, a major player in Italy's developing textile conglomerates, inaugurated a new phase of technical, organizational, and architectural innovation. The site was systematically rebuilt using reinforced concrete, enhancing fire resistance, structural integrity, and production efficiency. Electric power and modular shed construction allowed horizontal reorganization, while a direct railway link to the Simplon line completed its integration into national and international networks.



Equally transformative was the company's social project. The factory catalyzed the development of a company town that prefigured the later *villaggio operaio* at Piano Egro (1920s–1930s), designed by architect Luigi Bisi. Conceived as an integrated socio-spatial organism, the village reflected the ideals of enlightened industrial paternalism. It included a range of residential typologies—from dense worker housing to duplex villas for administrative staff, built with local materials such as Montorfano granite and prefabricated concrete. While workers' dwellings emphasized efficiency and shared facilities, the villas offered privacy and gardens, reinforcing the socio-spatial hierarchy. Extensive welfare infrastructures, schools, workshops, a theater, and recreational spaces extended corporate discipline into everyday life. By 1936, the *villaggio operaio* had become a fully articulated urban fragment: a planned community structured by the rhythms of industrial production and corporate governance. Its architectural language balanced modernist rationalism with regional idioms, producing a functional yet symbolically charged landscape. At its peak in the late 1930s, the Omegna complex employed around 1,600 workers, anchoring the valley's demographic and economic growth. Even after partial closure in the 1950s, its physical and institutional legacies persisted: housing and social buildings were repurposed, while the factory itself hosted new forms of light manufacturing. The De Angeli–Frua complex thus exemplifies how industrial architecture operated simultaneously as a productive apparatus and as a vehicle of territorial and social transformation. It reveals the convergence of technological modernization, corporate welfare, and urban planning in shaping a distinctly Alpine industrial landscape where production, habitation, and governance became deeply intertwined. Its enduring presence invites reflection on the spatial configurations of labor, modernity, and power.



6.2.mapping objects

material transitions and industrial reconfiguration

While the previous chapter reconstructed the long evolution of industrial settlements and hydropower infrastructures in the Strona Valley, this chapter traces a different trajectory that unfolds not across landscapes or infrastructures but through material regimes, economic shifts, and transformations in scale. It examines how energy, production, and design converged in the reconfiguration of local industries during the 20th century, often through crisis, adaptation, and reinvention processes. Rather than following a linear narrative of modernization, the focus here is on the discontinuities and repurposing that characterized the valley's energetic and industrial metamorphosis, from the hydroelectric intensification of the interwar period to the restructuring of manufacturing practices after WWII. The chapter explores how material technologies, coal, water, aluminum, and stainless steel interact with organizational forms such as company consortia, family workshops, and design-led firms. In doing so, it highlights the embeddedness of industrial transformation in territorial negotiations that are both spatial and symbolic. What emerges is not a story of substitution, but one of sedimentation: energy systems layered over one another, material cultures adapting to new imaginaries, and technical infrastructures reshaping the forms and meanings of everyday life. This is about what was produced and how production became a design site for space, labor, and identity.

Hydropower Consolidation, Energy Policy, and Interwar Infrastructure Projects The energy crisis triggered by the First World War accelerated the search for alternatives to coal, whose supply had become irregular and prohibitively expensive. Industrial actors in the Strona Valley, such as the *De Angeli-Frua* textile plant and the Crusinallo paper mills, actively petitioned for coal wagons as early as 1916, underscoring the situation's urgency. National policy, already favoring energy autarky, began promoting coordinated exploitation of alpine water resources, aiming to transform Italy's natural hydrography into a systematic energetic infrastructure.

As seen in the previous chapter, the hydroelectric infrastructure promoted by *Conti* was, by the late 1920s, channeling power directly to Gravello Toce, from where it was distributed to the industrial network of the Strona Valley. Unlike other regions, the electrification of the Strona Valley did not disrupt preexisting industrial geography. Instead, it reinforced it. The new energy grid consolidated earlier sites while enabling modest reconfiguration, particularly by acquiring defunct high-altitude

water rights previously used by artisanal woodturning workshops. In the 1920s and 1930s, numerous water rights transfers from small to large enterprises facilitated this redistribution of energetic capacity. By the 1940s, large industries in the valley began drafting even more ambitious energy schemes. The *Cobianchi* steelworks envisioned a diversion system that would redirect the Strona River into Lake Orta, then channel it via a pressure tunnel to a new power station in Gravellona. Another proposal by the *Rumianca* chemical group sought to lower Lake Orta by seven meters to enhance its utility as a reservoir for power plants in Megolo and Piedimulera. These schemes provoked public outcry and were ultimately blocked, especially after the 1939 law protecting natural landscapes was enacted¹²⁹. Still, variations of these proposals persisted. Some suggested a partial lowering of the lake by five meters, combined with additional inflows from the Agogna River. Even this reduced-impact plan was rejected¹³⁰. By the end of the 1950s, the stretch between Omegna and Gravellona was home to twelve hydroelectric installations, clustered along the left-bank canal. While many served small-scale industry upstream, most high-capacity plants lay downstream, powering metallurgy, mechanical works, and aluminum processing. This dense constellation of power infrastructure exemplified the material and spatial legacy of the valley's energetic modernization: ambitious, territorially embedded, and increasingly contested.

Sectoral Transition and Post-War Redeployment of Industrial Sites By the early 20th century, the cotton sector, still the most prominent branch of Italy's textile industry, showed signs of contraction, ultimately ceding its primacy to mechanical sectors during the 1930s. This shift, observed nationally, also manifested locally in the Strona Valley, where the early impulse of cotton-based industrialization gradually gave way to a prolonged decline. After WWII, all major cotton mills in the region ceased operations. Several structural causes underpinned this trajectory: international competition eroded traditional markets, especially from developing countries that replicated the British model by prioritizing cotton manufacturing. Equally significant was the rise of

¹²⁹ Public reactions to the Rumianca proposal, widely dismissed as implausible and environmentally detrimental, reflected a growing sensitivity toward landscape preservation and a nascent critique of unchecked industrial intervention in alpine ecosystems.

¹³⁰ Only a more cautious proposal advanced by an existing consortium of Strona-based industries, seeking to increase the dam height by 30 centimeters, was considered, although it was ultimately not approved.

synthetic fibers, which gained political backing in Italy and Germany through autarchic economic policies aimed at reducing dependence on imported raw cotton.

De Angeli-Frua's strategic pivot toward artificial fibers in the 1920s, marked by new dedicated facilities in Crusinallo, and the establishment of the *Bemberg* rayon plant in Gozzano (1926), testifies to this systemic shift. Nevertheless, tariff protectionism enabled the cotton sector to maintain relevance in the province of Novara through the interwar period¹³¹. Initially resisting the transfer of textile printing operations to Legnano¹³² foreshadowed an irreversible retraction. Despite subsequent organizational experiments, the Omegna plant entered a prolonged period of stagnation, culminating in its final closure in 1952. The wartime years further underscored the sector's vulnerability¹³³. Although post-war improvements in supply logistics brought temporary relief, the cotton industry's structural crisis persisted. Increasing consolidation, especially in textiles, induced widespread plant closures across the area from the 1950s through the 1970s. This deindustrialization was particularly acute in the Strona Valley, with only a few firms continuing to operate into the 1970s¹³⁴.

In contrast, metallurgy, particularly the *Cobianchi* steelworks, entered a period of expansion due to military demand.¹³⁵ Yet signs of crisis emerged soon after: acquired by the *Edison* group, the facility began downsizing in 1965, culminating in its final closure in 1981 under the stewardship of the *Pietra* group of Brescia. Decommissioning large industrial sites throughout the valley opened up new spatial opportunities. The disused *De Angeli-Frua* complex in Omegna, located on the urban fringe, became home to emerging metalware manufacturers, who relocated operations into the pre-existing sheds, benefiting from their spatial adaptability and proximity to labor markets. Conversely, the *Furter* facility was partially demolished for retail development, with only minor reuse. The former *Guidotti e Pariani* site largely fell into abandonment,

¹³¹ The complex employed 900 workers in 1927, rising to 1,600 by 1939. A peak that marked both the zenith of its productive capacity and the beginning of its institutional exhaustion

¹³² Plans for rationalization were already under discussion in the early 1930s, including the closure of the Omegna printing division.

¹³³ Chamber of Commerce reports from Novara described the situation in stark terms: the shortage of raw materials, particularly cotton, paralyzed production.

¹³⁴ Notable among them was *Guidotti e Pariani*, which shifted toward terry-cloth production, and *Furter* in Gravelona Toce, which closed in the late 1960s.

¹³⁵ With state contracts during the war and renewed investment in the postwar years, the plant peaked at 1,300 employees in 1960.

despite housing architecturally significant buildings, such as those featuring granite column structures and vaulted ceilings, which could warrant preservation initiatives. A small portion is still used for industrial purposes and by the *Istituto Geografico De Agostini*. Urban interventions in the post-industrial landscape favored redevelopment over conservation. In the case of the former *Cobianchi* steelworks, demolition was total. The urban strategy prioritized a new public park and a cultural hub. The *Binda* paper mill in Crusinallo modernized operations in 1931 and, after postwar difficulties, maintained its presence under the *Favini* group from 1999 onward. Despite fierce international competition, particularly in the 1930s, the firm regained profitability by mid-decade and continued to specialize in coated papers, a legacy that persists today.

From workshop to factory, material transitions in the Strona Valley

Between the late nineteenth and early twentieth centuries, the Strona Valley underwent a gradual yet profound transformation that redefined its economic and spatial identity. What had long been a marginal rural corridor became a dense constellation of small industries rooted in hydropower and local craftsmanship. The shift did not stem from a single industrial impulse but from a patient process of adaptation in which existing agrarian and artisanal infrastructures were reinterpreted as productive assets. This transformation marked the passage from dispersed domestic economies to a proto-industrial landscape. The reuse of rural buildings, powered by waterwheels and later by hydraulic turbines, enabled flexible and low-capital manufacturing. Family-run workshops evolved into small enterprises, orienting production toward regional and national markets. While modest in scale, these activities were decisive in generating a durable territorial economy capable of integrating global demand without losing its local base.

In this process, energy and geography functioned as primary design parameters: the linear sequence of workshops followed the morphology of the valley, creating a productive geography that extended from Omegna to Gravellona Toce and linked mountain and plain through a continuous chain of work, supply, and exchange. Rather than a story of industrial heroism, the Strona Valley exemplifies the territorial logic of incremental innovation. The persistence of artisanal techniques, such as metal turning, galvanic finishing, and small-scale casting, combined with selective mechanization, forms a hybrid system. By 1900, Italy entered the international aluminum oligopoly by leveraging its

hydropower resources. Lightweight, thermally conductive, and corrosion-resistant, aluminum rapidly replaced tinplate in many applications, consolidating the integration of Alpine energy into a global industrial cycle. Spatially, this network of small and medium enterprises generated a new territorial order. Industrial clusters concentrated near confluences and transport nodes, while residential areas extended along the same infrastructural spine.

The valley became a linear city of workshops, where domestic, productive, and ecological spaces interlaced. Hydropower channels, storage basins, and transport links were as much architectural as territorial devices, structures that rearticulated the landscape rather than merely occupying it. Despite the availability of new materials, traditional forming methods persisted into the 1930s, as metalware manufacturing remained largely bespoke and workshop-based in the valley. Production was oriented toward local and regional markets, with limited standardization. This contrasted with European developments, where mass production and component interchangeability had already become standard. The Strona Valley lagged in this industrial transformation, maintaining a hybrid mode of production between artisanal practice and emerging mechanization. By the early twentieth century, this system had established a distinctive Alpine modernity: decentralized, adaptive, and deeply embedded in the geography of water and slope. Its resilience stems from the ability to reuse existing resources, transforming residual rural economies into a coherent industrial ecology. Seen through this lens, the Strona Valley is not a minor episode of regional history but a microcosm of the broader European shift from extractive to manufacturing landscapes. It demonstrates how peripheral territories, through gradual reconfiguration, could translate their physical constraints into productive forms, anticipating contemporary notions of circularity and local resource valorization.

The adoption of stainless steel in the early 1950s marked a decisive shift in technical processes and product imaginaries. No longer confined to handmade teapots or kitchenware soldered and hammered into form, manufacturers now operated under the regime of the press and the mold, a transition from volume to surface, from gesture to geometry. The entrance of stainless steel into domestic manufacturing was not merely a technical substitution. It signaled the reconfiguration of the household object as a site of design, branding, and international competition. Composed of chromium and nickel, stainless steel embodied the

ideals of hygiene, durability, and modernity, attributes inextricably tied to consumer imaginaries and the gendered reconstruction of domestic labor. As the Alps became integrated into a global network of steel circulation, local manufacturers were compelled to recalibrate their entire production infrastructure. This infrastructural overhaul demanded not only capital but also a reorganization of labor. The designer emerged as a new figure¹³⁶ while the craftsman was repositioned as an operator within a mechanized workflow¹³⁷. Yet this transition was not absolute. These residues of manual labor inscribe a paradox within the object itself—neither entirely artisanal nor wholly industrial, but suspended between economies of scale and gestures of care. In parallel, a cultural transformation was underway. The influence of American consumer culture, particularly through advertising and cinematic imaginaries, re-framed the kitchen as a site of liberation and technological agency¹³⁸. The broader implication is that the post-war transformation of Alpine metalware manufacturing was not a marginal episode in European industrial history but a microcosm of more profound epistemic shifts. The material resource became a medium of meaning. As stainless steel re-structured the possibilities of form, it redefined the relationship among territory, labor, and objecthood¹³⁹. The Alpine valleys, once shaped by the flux of ore and timber, now mediated flows of design, technology, and symbolic capital. In this reading, the domestic object becomes a condensed site of territorial negotiation, at once infrastructural, aesthetic, and political.

Reciprocal Landscapes and Extractive Infrastructures: Transformation and Decline of *Distretto del Casalingo* Manufacturing If hydropower marked the Alps as a frontier for energy extraction in service of urban-industrial growth, the trajectory traced in this chapter suggests that such transformations could also incubate alternative industrial models—localized, design-driven, and territorially

¹³⁶ Translating functional requirements and aesthetic values into manufacturable forms.

¹³⁷ The aesthetics of uniqueness, previously associated with artisanal value, gave way to the perfection of seriality:

¹³⁸ The proliferation of electric juicers, blenders, and non-stick cookware in the 1950s and 1960s reflected not merely functional needs but ideological investments in modern living, gender roles, and domestic efficiency.

¹³⁹ Companies like Alessi, Lagostina, and Calderoni pioneered a new form of sub-Alpine modernity within this context. These firms operated as mediators between local manufacturing capabilities and international design culture, serving as a laboratory for design-driven industrial experimentation.

embedded.

The case of Omegna and its manufacturing district reveals how mountain territories, often perceived as passive peripheries within broader systems of resource extraction, could become active sites of material culture, design experimentation, and industrial innovation. Reframing this history through the lens of reciprocal landscapes¹⁴⁰ (Hutton 2020) allows us to trace the entangled movements of materials, energy, labor, and knowledge that linked local production networks to global economic and cultural systems¹⁴¹. Hydroelectric infrastructure, aluminum supply chains, and metallurgical expertise did not merely serve the urban core—they shaped, and were shaped by, the spatial and institutional logics of the Alpine interior. This reciprocity is not symbolic but operational: the same infrastructures originally built for extractive purposes were later reappropriated to sustain new economies centered on domestic objects, aesthetics, and design value¹⁴². The infrastructures that facilitate material extraction and circulation are not neutral but constitutive

¹⁴⁰ Hutton's concept of reciprocal landscapes emphasizes the interdependence of seemingly distant territories through the movement of materials and the infrastructures that sustain them. In her analysis, landscapes are not only shaped by local conditions but are constituted through flows of energy, labor, and matter that span global networks. This framework is particularly useful for understanding the industrial transformation of towns like Omegna, where hydropower infrastructure, aluminum processing, and manufacturing were embedded in broader material geographies. As Hutton illustrates through the example of New York's Central Park and the brownstone quarries of Portland, Connecticut, the construction of a place often relies on the extraction and displacement of resources from elsewhere. Similarly, the Moka's aluminum body, powered by hydroelectric energy from the Ossola valleys and cast in the Alpine foothills, must be read as the product of such spatial entanglements. The reciprocal landscape here is not just material but also cultural: while the Alps supplied the physical and energetic substrates, the symbolic capital—design innovation, national identity, and lifestyle branding—was articulated through urban consumption and global distribution. In this sense, the Moka is emblematic of a landscape constructed through asymmetrical reciprocity: a dense interplay of local extraction and metropolitan projection, of marginal labor and iconic form (Hutton 2020).

¹⁴¹ In this sense, the Moka can be read as an artifact of reciprocal landscapes. Its production and circulation depended on asymmetrical exchanges between mountain and metropolis, labor and capital, material and form.

¹⁴² Aldo Bonomi (1997) has emphasized the role of local production cultures, territorial capital, and artisan-industrial hybrids in shaping Italy's distinct model of economic development, which crystallized into the so-called Made in Italy economy. Far from being a merely commercial label, Made in Italy reflects a dense network of territorial economies where design, craftsmanship, and industrial processes co-evolved (Bonomi 1997). This model, often grounded in districts like those in Piedmont and Lombardy, has been characterized by a strong link between production and place—an instance of territorially embedded capitalism (Trigilia 2005). The household goods sector, with companies like Bialetti, Alessi, and Lagostina, played a key role in articulating this model through products that fused aesthetic innovation with regional identity.

of specific territorial relations. Each stage in production and dissemination reveals the layered reciprocity between the Alpine interior and external economic systems. This materializes a vision-driven landscape (Cosgrove 2008), in which cultural imaginaries and representational regimes actively shape geography.

However, as the 20th century progressed, this balance became increasingly fragile¹⁴³. Global competition, delocalization, and technological standardization gradually undermined the forces that enabled the Alpine manufacturing districts, affordable energy, skilled labor, and infrastructural redundancy. The territorial coherence that once defined the Strona Valley's productive system began to dissolve, giving way to fragmented redevelopment and cultural rebranding. Yet the implications of this history remain vital. The Alps, long treated as spaces of resource extraction, emerge here as active terrains of industrial and cultural production. The domestic object, far from being marginal to this story, offers a condensed site for reading the transformation of labor, landscape, and identity. In this sense, the industrial district of Omegna does not represent an exception, but a lens¹⁴⁴—a way of understanding how infrastructures, materials, and design co-construct territorial futures.

¹⁴³ A powerful account of this territorial and symbolic decline is offered by *Moka Noir: A Omegna non si beve più caffè* (2019), a documentary directed by Erik Bernasconi. Through interviews, archival footage, and poetic visual language, the film reconstructs the socioeconomic unravelling of Omegna, once a proud center of household design and aluminum manufacturing. It explores how the departure of key industries—most notably Bialetti—disrupted local economies, eroded community identity, and left behind a sense of cultural dislocation. The title itself—Moka Noir: in Omegna they don't drink coffee anymore—points to the loss of symbolic continuity between everyday practices and the industrial object that once defined them. Beyond its documentary scope, the film invites broader reflection on the fate of former design districts in post-industrial Europe, where innovation was once deeply embedded in local material cultures and territorial infrastructure. The Moka, in this context, becomes a lens through which to view the contradictions of modernization, the ambivalence of industrial memory, and the tensions between global markets and situated histories.

¹⁴⁴ This reciprocal relationship between material base and cultural superstructure offers a vital framework for reimagining Alpine territories in the context of sustainability, design heritage, and post-extractive transformation.

territorial snapshots.3 This sequence focuses on Omegna and the household industry district that took shape between the mid-twentieth century and the postwar decades. It explores how design culture, material experimentation, and serial production transformed the Alpine valleys into a laboratory of domestic modernity. The selected cases trace the convergence of manufacturing know-how and industrial design, showing how everyday objects became instruments through which the Alps entered the global circuits of production and imagination.

territorial snapshots.3



S.3.1 Fratelli Calderoni

From hydraulic craft to semi-industrial electrified manufacturing founded in 1851 by Carlo Calderoni, following artisanal training in Central Europe, the *Fratelli Calderoni* firm exemplifies the phased transition from small-scale craftsmanship to semi-industrial production rooted in local hydraulic infrastructures. Originating within a converted watermill in Casale Corte Cerro, the enterprise expanded during the 1870s by acquiring a second site in Crusinallo, enabling diversification into hardware manufacturing. Both sites leveraged hydropower, specifically the Valessa stream and other tributaries of the Strona Valley, to drive early mechanical systems. This hydraulic dependency shaped both architectural and territorial choices. New facilities incorporated steel-beam and brick-vaulted flooring systems, providing structural integrity for heavier machinery, yet retained conservative volumetric proportions and modest fenestration, mirroring vernacular construction norms. The turn of the century brought further spatial differentiation by introducing friction-powered drop hammers and presses. This prompted architectural hybrids: cast-iron columns, masonry piers, and timber-framed shed roofs coexisted within an expanding industrial compound. Despite never employing thermal energy, Calderoni visually aligned itself with dominant industrial aesthetics, depicting fictitious smoking chimneys in promotional illustrations to signal modernity. Electrical power, instead, was sourced from a privately commissioned hydroelectric plant in upper Val Strona, an infrastructural investment that reinforced the firm's territorial entrenchment. By the early 20th century, the company operated across two physically distinct yet operationally interlinked sites, necessitating logistical infrastructure such as distribution hubs in Novara and at the Sempione railway. Excluded from early military supply chains, the firm responded to the economic downturn of the 1930s by diversifying production and adopting new processes, including initial trials with stainless steel and galvanic finishing. The 1959 construction of a reinforced concrete press hall marked a decisive shift toward serial manufacturing and material innovation, without fully relinquishing the semi-artisanal model that had long structured its production logic.



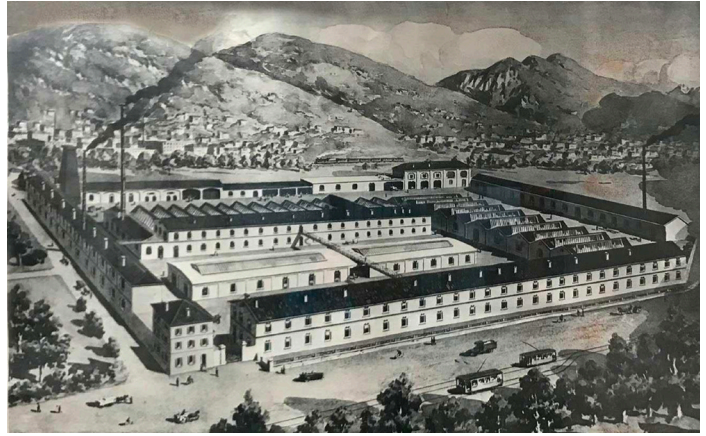




S.3.2 Agostino Cane

Agostino Cane (Omegna). Early aluminium processing and spatial adaptation around hydroelectric infrastructure

Founded in 1853 by Baldassarre Cane after his return from Paris, where he developed the prototype of the seltzer siphon, the Agostino Cane company initially operated as a small artisan workshop focused on white-metal alloys and shell-casting techniques. Under his son Agostino, the firm expanded significantly, relocating to Piano Egro at the urban edge of Omegna in response to late 19th-century economic growth. The new facility consisted of two-story perimeter blocks housing workshops, storage, and offices, constructed using iron-beam and brick-vaulted flooring, an intermediary system anticipating reinforced concrete frames. Production occurred in shed-roofed halls with cast-iron columns and timber trusses, typifying regional industrial forms. The plant was electrified via a proprietary hydroelectric station built in Quarna. However, internal power distribution relied on shaft-and-belt systems derived from earlier hydraulic models, constraining layout flexibility. A key technological milestone was the firm's 1897 patent for producing aluminum kitchenware—a hygienic, lightweight material then newly available at an industrial scale. This innovation allowed partial mechanization via early presses and positioned the company at the forefront of aluminum processing in Italy. During WWI, the firm supplied naval artillery components and lightweight field equipment, aligning with broader industrial autarky policies. Despite steady growth, spatial development remained fragmented. In the 1930s, the addition of a new reinforced-concrete wing and courtyard infills led to a congested, non-rationalized layout. By the mid-century, the firm had manufactured diverse products supported by a *fonderia* linked via underground tunnel and powered by electric and methane furnaces. The 1950s saw export-driven expansion, particularly in North America, and the introduction of Teflon cookware in the 1970s. However, the late adoption of stainless steel undermined long-term competitiveness. The company closed in the early 1990s, and the site was demolished in 1999.



Specialized metal fittings and early electrification within inherited hydraulic layouts Founded in 1860 by Costantino Cane, the Fratelli Cane company began as a small Milan-based workshop producing umbrella components—a niche sector heavily reliant on German imports at the time. Relocating to Crusinallo in 1888, the firm established itself in a repurposed watermill, employing just a few workers to fabricate tin and lead parts for agricultural umbrellas. By the 1890s, under the leadership of the second generation, the company diversified into precision fittings in brass, alpacca, and nickel-plated metals, prompting the construction of a new purpose-built plant at the edge of Omegna’s expanding Piano Egro district. The new facility adhered to the prevailing spatial model in the local metalware sector: perimeter masonry blocks coupled with timber-framed, cast-iron-supported shed-roof halls. In 1897, the company commissioned a hydroelectric station in Chesio, reflecting the regional trend toward localized electrification. While this new energy regime replaced earlier mechanical transmission, the factory’s internal organization continued to mimic hydraulic layouts, with centralized shafts and belts constraining spatial efficiency. By 1910, the firm employed around 150 workers and exported to markets across Europe and South America. Despite its technological modernization and skilled labor force, structural limitations persisted. The production process remained labor-intensive and reliant on imported steel rods, primarily from Switzerland and Germany. Processing stages—acid treatment, drawing, coiling, cutting, and assembly—were supported by specialized machinery but undermined by logistical challenges: the valley’s relative inaccessibility raised transport costs and eroded price competitiveness. These infrastructural disadvantages ultimately limited the firm’s ability to scale or consolidate its export advantages.

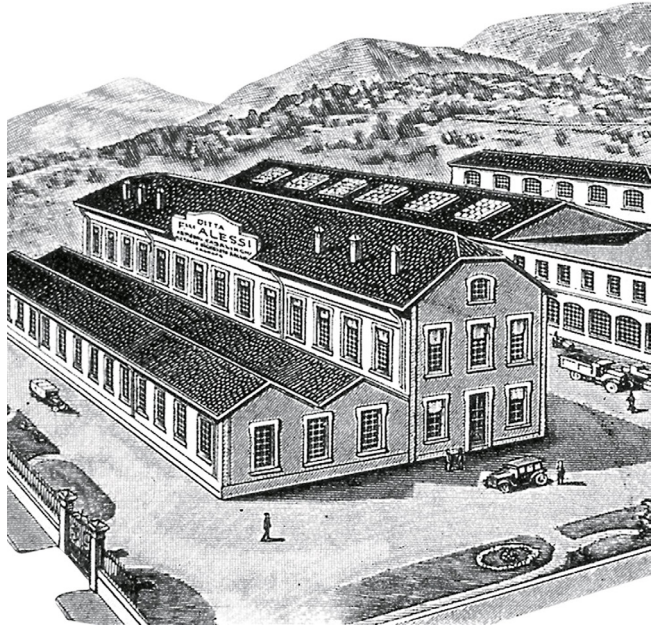
S.3.4 Lagostina

From artisanal tinplate cutlery to mechanized stainless steel cookware for domestic and institutional markets The Lagostina company's trajectory illustrates the evolution from artisanal cutlery production using recycled iron strap-ping to a fully mechanized industrial model centered on stainless steel cookware. Initially based in a small workshop repurposing cotton-mill waste into tinned iron utensils, the firm capitalized on low-cost materials to address the needs of lower-income consumers. WWI forced a shift toward military provisioning, prompting the installation of an in-house rolling mill to process metal scrap, reducing reliance on foreign suppliers and aligning with broader autarkic strategies during the interwar years. Massimo Lagostina initiated systematic experimentation with stainless steel after encountering the material at the Milan Trade Fair in 1933. Despite initial technical difficulties—due to inadequate machinery and undeveloped tooling—these trials marked the beginning of a long-term reorientation. The firm extended stainless applications from cutlery to kitchen and sanitary ware, installing specialized presses and adopting American-derived thermal diffusion techniques to enhance cookware performance. Spatially, this transformation coincided with the acquisition of a former textile mill in 1952, whose reinforced concrete structure was adapted to house new production lines. This appropriation of obsolete industrial architecture reflects a broader reconfiguration of territorial and material regimes in postwar Italy. By the 1960s, Lagostina operated four major departments—from tinplate to stainless steel—serving institutional and international markets. These developments consolidated the identity as a key player in the modernization of Italian domestic culture and its embedded industrial geographies.



From artisanal turned metal to modular stainless steel production integrated with industrial design

Founded in 1921 in Bagnella and relocated to Crusinallo in 1928, Alessi originated as a workshop producing turned metal objects in brass, alpacca, and tin-plated iron. Initially artisanal, the firm shifted toward serial production during the 1930s by introducing mechanical presses for tray stamping. This marked a foundational step in replacing lathe-based methods with mechanized workflows. Post-WWII expansion, catalyzed by U.S. demand and Marshall Plan capital, enabled the adoption of stainless steel in the early 1950s. Spatial upgrades followed: old buildings were replaced by modular, steel-framed structures optimized for assembly-line production. By 1964, stainless steel had supplanted all previous materials. Design assumed strategic relevance during this transformation. Carlo Alessi initially managed in-house product development but soon enlisted external designers. Integrating industrial design into metalware production responded to the expanding needs of institutional clients—airlines, canteens, hotels—and global export markets. Technological modernization mirrored this evolution: distributed electric drives replaced central transmission systems, and modular spatial arrangements facilitated scale and flexibility. By the 1970s, Alessi had aligned its organizational and architectural structures with principles of mass customization. Later collaborations with leading designers emphasized formal innovation as a means of generating added value—situating the firm at the intersection of industrial rationality and cultural production within the evolving material geography of the Strona Valley.



Centralized mass production of aluminum moka pots in a rationalist industrial complex

Founded in 1918 by Alfonso Bialetti, the firm initially focused on aluminum shell casting and artisanal metalwork. In 1933, it began producing the now-iconic “Moka Express” , a stovetop coffee maker that became the centerpiece of its output. While production remained modest through WWII, Renato Bialetti’s postwar strategy centered on mass-producing a single, standardized object. This required not only technical reorganization but also architectural redefinition. Between 1952 and the late 1950s, the company constructed a vertically organized factory explicitly designed around the moka’s manufacturing cycle. The foundry, located on the building’s top floor to manage thermal emissions, formed the start of a vertically cascading production process. Pneumatic waste extraction systems and specialized turning, assembly, and packaging automation reinforced mechanical precision. Ancillary infrastructure—including washrooms, lockers, and ventilation—reflected emerging models of industrial welfare, while the building’s formal language underscored its role as a corporate symbol. By the end of the 1950s, daily output exceeded 6,000 units. Bialetti’s site thus represented both an operationally optimized machine and a spatial embodiment of postwar industrial modernity—its architectural typology reflective of international currents yet territorially anchored within the Strona Valley.



S.3.6 Girmi

Domestic appliance production structured around thermoplastics Founded in 1919 as the Cooperativa Subalpina and restructured under Carlo Caldi in the postwar period, Girmi emerged as one of Italy's first manufacturers of small electric household appliances. Inspired by American consumer culture, Caldi introduced plastic casings to reduce cost and simplify assembly—pioneering a localized mass production of affordable coffee grinders and blenders. In 1963, Girmi commissioned a prefabricated, column-free industrial shed. Its lightweight reticulated structure allowed uninterrupted spatial organization of four core production lines: thermoplastic molding, metal stamping, electric motor assembly, and final product assembly. Adjacent prefab additions in the 1970s expanded warehousing and administrative capacity. Offices and technical divisions were housed in a suspended bridge-building and nearby villa, reflecting a distributed yet integrated operational model. Girmi's spatial configuration and use of thermoplastics marked a break from traditional metalworking paradigms, aligning instead with post-Fordist principles of flexibility and modularity. Marketing strategies—modeled after Bialetti's—helped democratize access to domestic appliances in Italy. At its peak in the 1980s, it embodied the hybrid character of postwar Italian industrial districts: technologically advanced, spatially rationalized, and attuned to international stylistic and organizational influences.

PIRELLA Puffatore elettrico, operante per "Pistone", sistema unico, acciaio, antiruggine, isolamento in perlon e teflon. Il Puffatore Pirella, grazie al sistema "Pistone" ed all'uso di teflon, evita ogni rischio di surriscaldamento e di incendio. Potenza 800 watt. Voltaggio a richiesta. 1.001.000.000.

PIRELLA in alluminio forato, con trattamento antiruggine, acciaio, a Pirella, sistema unico, acciaio, antiruggine, isolamento in perlon e teflon. Il Puffatore Pirella, grazie al sistema "Pistone" ed all'uso di teflon, evita ogni rischio di surriscaldamento e di incendio. Potenza 800 watt. Voltaggio a richiesta. 1.001.000.000.

PIRELLA Puffatore elettrico, operante per "Pistone", sistema unico, acciaio, antiruggine, isolamento in perlon e teflon. Il Puffatore Pirella, grazie al sistema "Pistone" ed all'uso di teflon, evita ogni rischio di surriscaldamento e di incendio. Potenza 800 watt. Voltaggio a richiesta. 1.001.000.000.

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6.3.productive habitat(s) energy landscapes and industrial decline

A combination of energy availability, infrastructure development, and external economic forces has historically shaped the industrialization of Alpine valley floors (Corrado and Segà 2019). The historical trajectory of industrialization in these regions reflects a succession of economic cycles, each leaving its mark on the built environment and settlement patterns (Lorenzetti and Valsangiacomo 2016). Unlike traditional urbanized areas, where industrial expansion followed a more linear urban growth model, Alpine industries were often developed as exogenous investments, driven by external capital, state policies, and market demands rather than endogenous economic evolution. The productive landscape that emerged was thus highly specialized and spatially selective, concentrated in corridors (Modica 2022). While some valleys became hubs of electrometallurgy and electrochemistry, others developed textile and mechanical industries that relied on water-driven energy production. However, the factors that enabled this growth later contributed to their vulnerability, as shifts in global industrial dynamics rendered many of these production models obsolete.

Energy, industry, and territorial cycles in the Alpine valley floor From the 1960s onwards, industrial decline became increasingly evident in Alpine valley floors¹⁴⁵. Several key factors drove this process: the rise of cheaper energy sources such as fossil fuels and nuclear power, advances in global logistics that favored large-scale industrial zones in lowland regions, and the increasing emphasis on knowledge-based economies that prioritized urban centers over peripheral manufacturing sites. The result was a landscape characterized by industrial obsolescence and fragmentation, where formerly productive sites became brownfields, abandoned or underutilized industrial spaces no longer fit

¹⁴⁵ The depopulation phenomenon occurs through the shift of the Alpine population toward the valley floor, where large-scale industry settled, such as in the case of hydroelectric plants and metallurgical complexes. This shift was further influenced by centralized industrial policies and the economic draw of lowland industries, reversing the traditional relationship between low-lying and upstream municipalities. (Raffestin and Crivelli 1988) This trend, particularly notable since the 1960s, is also linked to the broader processes of deindustrialization and urbanization that affected many mountain regions across Europe. The decline in population in the mountainous areas of the Alps reflects a broader pattern of abandonment in favor of low-lying valleys, as industrial opportunities and infrastructure developed primarily in these more accessible regions (Migliorati and Veronesi 2020).

into contemporary economic structures¹⁴⁶. A defining feature of this transition has been the emergence of large-scale abandoned industrial areas, particularly in regions that once hosted energy-intensive industries. These sites, often located in the Western Alps and across transnational corridors, represent the remnants of an economic paradigm that prioritized extraction and heavy industry over long-term territorial integration. While some sites have been repurposed, many remain stagnant, reflecting the broader challenge of Alpine industrial restructuring. Unlike traditional urban brownfields, which are often targeted for redevelopment due to land scarcity, Alpine industrial sites are often constrained by geographical isolation, accessibility challenges, and environmental contamination risks, making their reintegration into productive use a complex.

Despite these challenges, Alpine valley floors remain key to regional economic strategies, particularly for land-use optimization and sustainable redevelopment. The persistence of industrial infrastructure offers opportunities for adaptive reuse, turning former production sites into hubs for renewable energy, logistics, or niche manufacturing. However, this requires a shift in perspective, from viewing abandoned sites as economic failures to recognizing them as latent assets capable of supporting new economic and environmental functions. This transition aligns with broader European policies on the circular economy and the regeneration of post-industrial landscapes, emphasizing the potential of brownfield sites as an integral part of future territorial strategies.

Brownfields and the spatial legacies of Alpine deindustrialization

In examining the current condition of Alpine valley indus-

¹⁴⁶ The local development of these industries was primarily influenced by centralized industrial policies shared at the national level and by the rise of the electric sector linked to the exploitation of water resources. In the 1960s, deindustrialization and technological innovation made hydroelectric-based plants and large chemical and metallurgical complexes obsolete and unprofitable. Berger (2006) defines these portions of land as *drosscapes*, waste landscapes. These are suspended places still in a phase of difficult classification, something that rejects new stability and reintegration into the city, a space that remains on the margins waiting for a social desire to reconnect it within urban practices. Today, this results in a landscape composed of waste places, including significant industrial artifacts and connected residential buildings, characterized by a lack of public space typical of the expansive phase of diffuse urbanization. This built environment struggles to interact with the strong identity of the territory. The phenomenon of abandonment, therefore, does not concern isolated episodes but a complex network of elements, all affected by stagnation and no longer maintained (Berger 2006).

tries, it becomes clear that their transformation is not merely a question of economic restructuring but also a territorial and ecological challenge. The deindustrialization of the Alps has left behind a highly fragmented landscape, where industrial heritage coexists with environmental degradation and economic uncertainty. The management of these spaces will determine whether they remain disconnected remnants of a bygone industrial age or are actively reintegrated into a new vision of Alpine regional development, reconciling industrial legacies with emerging sustainability models, energy transition, and cultural landscape preservation. Today, the extensive infrastructure along the valley floor fosters an urban image of the Alps, contrasting sharply with the delicate local ecologies and potential hydrogeological hazards that characterize mountain territories (Bätzing et al. 1996). The emergence of the electric industry in the early 20th century played a pivotal role in shifting the local economy from self-sufficiency to industrialization, further altering the socio-economic balance in traditionally rural regions, such as the Western Alps (Modica 2019). The growing demand for energy and resources led to the abandonment of small-scale agricultural practices and the rise of large industrial operations, often on valley floors, for easier access to transportation and power. However, the Alpine region has undergone economic restructuring in recent decades, with traditional heavy industries and manufacturing sectors declining. Though evident in the surrounding lowlands, this process has been slower and less pronounced in the Alpine valleys, where the rugged terrain and remote location have delayed industrial decline. As a result, the sustainable management of brownfield sites, land previously used for industrial purposes but now abandoned, is becoming a critical issue for the future development of the Alpine region. Brownfield revitalization can help optimize land use, improve environmental sustainability, and foster economic recovery in Alpine areas. These areas experience stagnation and face lower economic growth pressures. However, they inherit high environmental and cultural quality, primarily due to the technical and industrial processes that shaped their development. They retain a deep-rooted identity that underpins a stable social and human capital base. Berger (2006) identifies these portions of the territory as *drosscaples*, landscapes of waste. These suspended spaces remain in a transitional phase, resisting new stability and integration into urban frameworks, remaining on the margins while awaiting social interest to reconnect them to urban practices. The socio-ecological transition of marginal spaces and

territories subject to exploitation, reflecting on the critical scenarios of post-extraction landscapes amid energy instability, resource contraction, landscape erosion, and climate urgency.

The Rise and Decline of Domodossola's Energy-Intensive Economy

The industrial history of Domodossola's valley floor is deeply tied to the rise and decline of hydropower-driven chemical industries, which played a crucial role in shaping the economic and territorial landscape of the Ossola Valley (Sega 2018). Located at the strategic crossroads of Alpine transit routes, Domodossola and its surrounding areas became key sites for industrial expansion in the early 20th century, particularly in the chemical and metallurgical sectors, which relied heavily on hydroelectric energy to sustain production. Abundant water resources drove the early industrialization of the Domodossola valley floor. A significant development in the area's industrialization was the establishment of large chemical plants, which utilized hydroelectric power to sustain energy-intensive production processes. The *Rumianca* chemical plant in Pieve Vergonte, one of the most significant industrial facilities in the area, became a key player in the chemical sector, producing a variety of industrial compounds¹⁴⁷. The extensive use of hydroelectricity in chemical production was a defining feature of these industries, enabling high-volume manufacturing of fertilizers, solvents, and synthetic materials but also leading to severe environmental consequences, as pollutants were discharged into local water bodies, particularly the Marmazza stream, a tributary of the Toce River.

The valley floor also hosted significant metallurgical industries, such as those concentrated in Villadossola, which became a steel and heavy metal production center. The *S.I.S.M.A.* plant, established in 1892, expanded its operations throughout the 20th century, reaching its peak employment in the 1970s before the effects of economic restructuring led to its gradual decline. This industrial landscape was shaped by the intense extraction and processing of local resources, with foundries and refining plants dependent on hydroelectric energy from the surrounding valleys. By the 1960s and 1970s, the industrial fabric of the Domodossola valley floor began to unravel due to technological advancements, global market shifts, and the declining competitiveness of hydroelec-

¹⁴⁷ Over time, the plant underwent multiple transformations, later becoming part of *EniChem Synthesis*, a company that continued operations for decades before facing the challenges of deindustrialization.

tric-based production. The introduction of alternative energy sources and the relocation of chemical and metallurgical industries to low-cost production centers led to the progressive abandonment of many industrial sites. This deindustrialization process resulted in the emergence of brownfield areas, where former production facilities were either repurposed or left to decay. Today, remnants of these once-thriving industries are scattered across the valley, with contaminated sites requiring extensive environmental remediation and infrastructure that remains underutilized.

The industrial history of the Pieve Vergonte chemical plant represents a significant chapter in the transformation of the Alpine valley floor into a center of energy-intensive production. Established between 1915 and 1920 in the former municipality of Rumianca, the plant was initially designed to exploit the region's hydroelectric potential to support large-scale chemical manufacturing. Over the decades, it became a significant hub for chlorine-soda production, sulfuric acid processing, and the synthesis of a range of chemical compounds, integrating itself into the broader industrial landscape of the Ossola Valley. The evolution of this facility reflects both the opportunities and constraints of hydroelectric-driven industrialization in the Alps, illustrating how the region's natural resources were leveraged for high-energy manufacturing while simultaneously generating significant environmental and socio-economic consequences. The industrial expansion of the Pieve Vergonte site followed the broader trajectory of Alpine electrification, where hydroelectric power facilitated the emergence of energy-intensive industries. Initially, the plant specialized in sulfuric acid production through pyrite roasting, capitalizing on local mineral resources and the availability of hydroelectric energy. As industrial demand grew, additional production lines were introduced, including chlorine-soda electrolysis, oleum, ammonia synthesis via methane cracking, carbon disulfide, chlorinated organic compounds, and various fertilizers. These expansions positioned the facility as a strategic site within the national chemical industry, reinforcing its role as a key producer of industrial inputs for agriculture, pharmaceuticals, and synthetic materials. By the mid-20th century, the plant was integrated into broader corporate structures¹⁴⁸ before being absorbed into the *ENI* group in 1981. The facility's transition through multiple ownership structures underscores its embeddedness within national industrial policies and corporate restructuring efforts, reflecting

¹⁴⁸ First under *Rumianca S.p.A.* and later as part of *SIR-Rumianca*.

broad shifts in the Italian chemical sector.

Post-industrial uncertainty and the future of alpine industrial Landscapes

The post-war period marked both the peak of production and the onset of structural transformations that would later lead to industrial decline. Technological advancements and shifts in regulatory frameworks prompted a gradual reconfiguration of production activities. By the 1960s and 1970s, several key operations were discontinued or replaced by newer, more efficient processes. The closure of carbon disulfide production in 1965, the discontinuation of ammonia synthesis and sulfate-based fertilizers in the 1970s, and the phase-out of tetrachloromethane production in 1990 illustrate the changing industrial landscape. While these adjustments aimed to maintain competitiveness, they also signaled the plant's growing vulnerability to global market pressures and environmental regulations. The decline of the Pieve Vergonte chemical plant aligns with broader patterns of deindustrialization and territorial restructuring observed in many hydroelectric-dependent industrial sites across the Alps. As alternative energy sources and shifts in production strategies rendered certain chemical processes obsolete, the facility faced mounting challenges in maintaining its industrial viability. By the late 20th century, the site had become emblematic of the tensions between industrial heritage, environmental remediation, and economic adaptation. The plant's environmental legacy, particularly concerning *DDT* contamination and the pollution of local water bodies, led to its designation as a nationally significant site for environmental remediation in 1998. The complexity of the contamination, stemming from decades of chemical discharges into the surrounding landscape, has necessitated extensive, ongoing efforts to manage soil and ground-water pollution.

Currently, portions of the Pieve Vergonte site remain operational under *Tessenderlo Italia*, while other sections are undergoing long-term remediation led by *ENP*'s environmental division. The site's dual status as both an active industrial facility and a landscape of remediation exemplifies Alpine valley floors' broader challenges in transitioning from high-energy industrial production to more sustainable economic models. While some segments of the facility continue to operate in the chemical sector, the surrounding landscape remains a contested space, caught between its historical role in industrial expansion and demands for environmental restoration. The future of such sites will largely depend on the ex-

tent to which industrial heritage, ecological sustainability, and economic restructuring can be reconciled within broader regional development strategies. This case provides a critical perspective on the intersections of hydroelectric infrastructure, industrialization, and post-industrial transition in the Alps, offering insights into the long-term implications of resource-based economic models. As Alpine territories navigate the complexities of post-industrial transformation, sites like Pieve Vergonte serve as key reference points for understanding the material, environmental, and socio-economic legacies of hydroelectric-driven manufacturing.

The industrial decline of Domodossola's valley floor reflects broader transformations affecting Alpine industrial regions. The infrastructure built to support energy-intensive manufacturing, hydropower stations, industrial rail links, and worker settlements has often outlived its original purpose, posing challenges for sustainable redevelopment. While some efforts have been made to reactivate these spaces, many sites remain uncertain, awaiting new forms of economic reintegration. Understanding the historical evolution of these industrial landscapes is crucial for envisioning future strategies that reconcile their industrial past with contemporary environmental and economic imperatives.

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6.parallel processes

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7.residual landscapes: reading the post-exploitation

This final section departs from the linear historical structure of the preceding chapters. Rather than tracing continuities or causal transitions, it assembles a series of contemporary visual fragments—photographic observations, archival juxtapositions, and spatial markers—that testify to the enduring presence of extractive and infrastructural pasts in the Alpine landscape. These images aim not to illustrate previous arguments but to complicate them, foregrounding the ambiguities, ruptures, and latencies that define post-industrial space. The selected sites—disused hydroelectric installations, reactivated mining villages, abandoned factories, repurposed dams—are not treated as case studies but as situated documents of a territorial condition where past and present remain materially entangled. Following a visual logic, this section invites the reader to consider how the Alps continue to act as repositories of industrial modernity, even in their apparent obsolescence. In this perspective, the Alps emerge not simply as the backdrop of modernity’s technical operations, but as a palimpsest, a multi-layered spatial construct in which past interventions persist, overlap, and sediment rather than disappear. Territory should be read “*comme un produit culturel*” (Corboz 1985), a cultural product continuously rewritten through the superimposition of infrastructures, economies, and imaginaries. The visual fragments presented here do not seek to resolve this layering but to render it visible: they disclose a landscape in which industrial residues, ecological transformations, and cultural inscriptions coexist without hierarchy, offering a non-linear entry into the post-exploitation condition of the Alpine region¹⁴⁹.

¹⁴⁹ All images in this section: *Aerial survey by Davide Simoni, elaboration by the author, 2023–2025.*

7.1.what remains today: a visual survey



fig.7.1 Detail of the former Bemberg industrial complex in Gozzano, looking toward San Maurizio d'Opaglio. The image frames the southern edge of the site, where industrial buildings, service structures, and later additions define the continuity between factory and settlement.

fig.7.2 Aerial view of Gozzano with the former Bemberg complex in the foreground and the Ortalion plant on the left. The proximity between factories, housing, and open land illustrates the compact morphology of the lower valley. Industrial wastewater once contributed to the degradation of Lake Orta's ecosystem, revealing the environmental dimension of the area's manufacturing history.





fig.7.3 Aerial view of the portion of the tap manufacturing district not directly aligned with the main road. The image captures the relationship between the industrial fabric and Lake Orta, visible in the background, while the disused Alzo quarry appears beyond the urban edge.

fig.7.4 Detail of a terrain behind the second industrial belt of San Maurizio d'Opaglio, showing residual deposits and traces of discarded materials along the edge of the productive area. The image documents the proximity between industrial operations and the surrounding vegetation, revealing the thin boundary between activity and abandonment.





fig.7.5, fig.7.6 The industrial areas of Crusinallo and Omegna today form a single continuous urbanized system. The images show the relationship between the household industry district and the residential fabric aligned along the linear road axis leading toward the Ossola Valley. The overlap of productive and inhabited spaces reveals how the territory evolved as a lived infrastructure where industry and city progressively merged.

fig.7.7 In the reverse view, the center of Omegna opens toward Lake Orta, where the Nigoglia Canal marks the natural and symbolic closure of the valley system. The transition from the industrial area to the lakeshore highlights the continuity between industrial and natural landscapes—an outcome of layered uses and long-term transformations.



fig.7.8, fig.7.9 The images show the relationship between the Strona River and the industrial compounds described in chapter 6.2. The sequence of factories, warehouses, and infrastructures follows the course of the river, illustrating how production was organized along its hydraulic axis. In the foreground appears the disused Bialetti site, a landmark of Omegna's manufacturing history. The river still defines the spatial order of the valley, mediating between the urban fabric, the productive landscape, and the mountain slopes that enclose them.







fig.7.10, fig.7.11 Two aerial images of the Calderoni factory in Casale Corte Cerro, decommissioned in 2012 and discussed in section S.3.1. The complex occupies a central position within the town, its disused structures marking the persistence of the household industry's spatial legacy.

fig.7.12 Detail of the Calderoni site, showing the cluster of buildings corresponding to the different phases and functions of production. The complex remains a large industrial void at the core of Casale Corte Cerro—a residual landscape shaped by successive cycles of growth and decline.

fig.7.13, fig.7.14, fig.7.15, fig.7.16 The images show the Valsesia landscape around Quarona, where the productive corridor extends along the main road connecting Valduggia and Borgosesia. Industrial buildings occupy the valley floor in a continuous sequence with the residential fabric, reflecting a mode of development driven by accessibility rather than spatial composition. This linear accumulation of factories and housing produces a fragmented condition, where open and collective spaces are residual, absorbed into the infrastructure of production and mobility.













fig.7.17, fig.7.18 Aerial views of the former *Cave di Corconio*, now reused by the company of the same name for the production of aggregates derived from crushed rock. The images show the relationship between the industrial site, the adjacent *Riserva naturale del Colle di Buccione*, and Lake Orta in the distance, revealing the coexistence of extractive and protected landscapes.

fig.7.19 Detail of the Corconio site and its proximity to the Novara–Domodossola railway line, near the disused Corconio–Ameno station. The view highlights the close interface between transport infrastructure and the productive reuse of former extraction areas.



fig.7.20, fig.7.22 Two aerial views of Campello Monti, showing the former nickel deposit already described in **fig.7.23** The images illustrate the relationship between the extraction area and the small Walser settlement, where mining activity and settlement patterns coexisted within the same confined valley basin. The proximity between the deposit and the village highlights the spatial interdependence of resource exploitation and mountain habitation.



fig.7.20, fig.7.22, fig.7.23 The three images depict the abandoned extraction site at Isola di Vocca, later analyzed in the following section. The photographs document the remains of mining activity and its integration within the surrounding landscape.





III.



new geographies

**toward situated transitions
and spatial practices**

8.back to mining?

This intentionally open and provocative question serves as the starting point for an inquiry that aims not to provide definitive answers or predetermined solutions. Instead, the objective is to build a framework of meaning and reflection, exploring a return to a practice that seems to belong to the past while outlining possible paths for the future. However, as the world faces the climate crisis, biodiversity loss, and resource depletion, the issue of mining is burdened with new complexities. Returning to mining is not merely a technical (Smil 2017) or economic (Harvey 2003) choice. It compels us to question which values, compromises, and responsibilities guide this practice in an era of profound change. *What kind of mining are we returning to?* The section outlines a scenario in which mining is reimagined as a *responsible* practice, potentially generating new contradictions and ethical dilemmas. The question ‘*back to mining?*’ thus opens a reflective space, a complex context, that explores the broader meaning of the term extraction.

The structural logic of hyperproduction: growth beyond ecological limits The pressure to extract more resources grows disproportionately in a world where production continually accelerates, often exceeding ecological limits. This dynamic threatens the planet’s finite reserves, as hyperproduction (Latouche 2009) overlooks natural limits, embedding a logic that values quantity over quality and immediacy over *sustainability*. It emphasizes production and consumption as ends, fostering an extractivist mentality that ultimately undermines long-term well-being. This relentless cycle creates a paradox: while technological progress promises efficiency, it often results in greater overall consumption, showing that returning to mining cannot rely solely on technological or *greener* practices. Instead, it demands a rethinking of production’s purpose and limits, questioning whether continuous resource extraction aligns with sustainable futures. Only by addressing the roots of hyperproduction can we envision scenarios in which the return to mining aligns with a balanced relationship among nature, the economy, and society, avoiding the pitfalls of excess and promoting a genuinely regenerative approach.

Destructive extraction and consumption habits follow the assumption of inevitable growth, driving societies to overlook environmental limits and perpetuating cycles of depletion. Economic and industrial structures rely heavily on constant expansion, which feeds into an extractivist mentality that reshapes ecosystems and human values, centering them

around production and accumulation. In this context, resources and energy are not viewed as finite but rather as inputs to be maximized in order to sustain ever-growing markets. Such a paradigm, however, neglects the irreversible damage inflicted on the environment and the growing disparity between resource exploitation and the planet's capacity for regeneration. The focus on growth at all costs disregards ecosystems' cyclical, interdependent nature, positioning extraction as a linear process in which resources flow out without meaningfully returning to support the natural balance. This paradigm is deeply linked to hyperproduction, where the imperative to produce more, faster, and cheaper drives increasingly aggressive resource extraction. Energy, minerals, and raw materials lose their inherent qualities and are viewed primarily for their ability to fuel an endless cycle of consumption. Each technological advancement aimed at more efficient extraction often leads to a paradoxical rebound effect, in which greater efficiency results in greater overall consumption rather than conservation. Thus, efforts to *green extraction* (Bruna 2023) practices or establish sustainable supply chains remain superficial if they do not question the overarching commitment to perpetual growth. Under this framework, reimagining a return to mining—or any form of resource extraction—calls for moving beyond mere technological fixes. It fundamentally requires re-evaluating the economic and social drivers and prioritizing growth over sustainability. Actual change would involve recognizing planetary boundaries, adopting practices that respect ecological limits, and fostering a cultural transformation that values regeneration and restraint over endless production and consumption.

Degrowth as a systemic alternative to the growth paradigm

In this context, the degrowth model is the radical alternative to the contemporary extractive and *hyperproductive* paradigm. Rather than merely reducing production or consumption, degrowth envisions a systemic transformation that decouples well-being from economic expansion. (Latouche 2009, Kallis 2018). The concept of degrowth fundamentally critiques the prevailing paradigm of limitless economic growth. It advocates a deliberate, strategic downsizing of economic activity, aiming for a more sustainable and equitable society that balances human needs with environmental limits (Latouche 2009). Degrowth is not about regression or austerity; it advocates a more conscious, simpler way of living that emphasizes waste reduction, the importance of recycling and

reusing materials, and the cultivation of social connections and leisure activities. The objective is to build a more resilient society capable of confronting ecological and social crises without relying on endless economic expansion¹ (D'Alisa et al. 2014).

Such a transformation entails complexity across economic, social, and technological dimensions: reallocating resources, reshaping consumption habits, and prioritizing innovations that favor resilience over efficiency². Transitioning toward a post-growth society challenges institutions, entrenched interests, and power dynamics that underpin the extractivist system. Implementing such radical changes requires a cultural and political transformation capable of redefining collective priorities, redistributing power, and imagining new forms of governance. In light of these challenges, transition scenarios are emerging as reversible and gradual solutions. These intermediary paths enable a progression towards a new equilibrium, offering compromise solutions that, although not radical, provide a feasible and adaptable approach to addressing the complexities of a change that, ultimately, is inevitable.

Degrowth in architecture emerges as an approach that transforms the relationship between architecture and resources. Recognizing its role at the intersection of economy, ecology, and society, architectural degrowth begins with a critique of excessive material extraction and production. Architecture operates in a reality in which geopolitical imbalances intensify resource extraction³.

Reconfiguring urban development through degrowth principles Architecture should be considered the construction of physical objects and a network of economic and political infrastructures that

¹ In this context, it presents a radical alternative to the current growth-centric model, calling for a redefinition of progress regarding human well-being and ecological balance rather than economic indicators like GDP. This transformation requires a profound shift that extends beyond economics to encompass politics, culture, and our relationship with nature, urging a move toward a sustainable and equitable development model.

² From an economic perspective, abandoning the constant-growth model necessitates a thorough reevaluation of resource allocation, labor distribution, and the value systems that define financial success. Socially, it calls for a radical shift in consumption habits, perceptions of well-being, and the very structure of communities. Technologically, it demands a pivot towards innovations prioritizing sustainability and resilience over efficiency-driven extraction. Above all, the political complexity of realizing a degrowth model represents the most significant challenge.

³ The raw materials required by the construction industry—such as cement, steel, and glass—demand enormous amounts of energy for production and transformation, generating devastating ecological impacts throughout their life cycle (Malterre-Barthes 2019, *Foster* 2108).

support unlimited growth and accumulation (Easterling 2014). Global infrastructure, transport networks, and material supply systems, among others, contribute to a cycle of hyperproduction that treats resource extraction and economic growth as ends in themselves, regardless of the real needs of the population or ecological impacts. In the architecture of degrowth, this network of interdependencies is questioned, proposing a radical revision of the very necessity to build (Heringer 2018). At the heart of degrowth in architecture lies a crucial question: How can habitable spaces be created without fueling the consumption of natural resources? Designers are called to confront their role in this exploitation process, challenging the idea that the value of a built space lies in its novelty rather than its durability and resilience. Degrowth represents an invitation to detach from the growth crisis model and question the profound meaning of building, reassessing its contribution to society in terms of balance and moderation rather than production. In this sense, the climate crisis makes this reflection all the more urgent. It represents a radical rethinking of urban expansion, land consumption, and the intensive resource use required to sustain contemporary cities. Instead of equating urban growth with progress, degrowth critiques the modern paradigm of continuous expansion that extracts resources far beyond the city, fueling global material and energy chains. (Wiesner 2018). This model implies extracting natural resources far beyond the city, fueling a global chain of materials and energy that strains the environment and depletes biodiversity. The city is not considered an ever-expanding entity but a closed system where the quantity of resources and land use is contained and limited. In this context, degrowth proposes halting the consumption of new land and limiting indiscriminate densification, advocating a more sustainable, mindful use of existing space.

Urban environments should be considered complex systems that respond to economic logic and support the well-being of both residents and local ecosystems (Bookchin 1982). Thus, degrowth promotes the creation of public spaces that reduce dependence on material and energy infrastructures, fostering deeper social cohesion and a relational approach to the territory. This implies that degrowth cities move away from centralized economic models and lean towards a polycentric organization, where neighborhoods can autonomously meet residents' needs, reducing the need for extensive transport infrastructure and energy consumption. In this approach, urban land becomes a resource to be safeguarded, a non-renewable asset that should not be compromised

to satisfy economic expansion. Rather than designing spaces for commercial purposes, degrowth reclaims disused areas as ecological and social assets and reconsiders time as a spatial and ecological variable shaping accessibility and energy use. It becomes a spatial and ecological variable, tied to the design of cities in which essential needs are accessible without reliance on extensive transportation systems or high energy consumption. This approach promotes an urban configuration that minimizes distances, reduces environmental pressure, and enhances the quality of everyday life. Within this framework, degrowth urban planning calls for a radical rethinking of land use and spatial organization⁴.

Mountain territories as commons: toward a degrowth-oriented governance In the Alps, the focus shifts from expansion to conservation, where Alpine urbanism becomes an exercise in de-design, reducing human impact and foregrounding the mountain as protagonist⁵. This perspective aligns with the idea of critical zones⁶, which suggests that certain areas, due to their ecological richness, should be protected from the pressures of consumption and exploitation (Latour 2018). Here, the concept of closure serves to limit human pressure and preserve the integrity of Alpine ecosystems, enabling them to regenerate naturally. Within this context, degrowth urbanism applied to the Alps does not involve expanding infrastructure or services but making choices that prioritize the conservation of natural and cultural heritage. This approach offers an opportunity to recognize the Alps as a common good: a vital ecosystem that, when managed carefully and respectfully, can contribute to the region's ecological resilience and, at the same time, offer a deeper, more authentic human experience⁷. This vision of

⁴ It aligns with the critique of urban models prioritizing horizontal expansion at the expense of urban quality and complexity (Jacobs 1961).

⁵ Following degrowth principles, imagining the Alps as a reservoir of biodiversity means promoting a vision of partial closure, in which the area is shielded from indiscriminate access, and human intervention is minimized.

⁶ This approach aligns with the vision that areas of high biodiversity and ecological significance should be protected and removed from the logic of consumption (Latour, 2018). Mountains are considered critical zones, meaning territories that have an essential function for the planet and therefore require governance aimed at stewardship rather than exploitation. Applying this idea to the Alps suggests adopting a policy of limited access and active conservation, where nature is left to regenerate without interventions that alter its ecological cycle.

⁷ Imagining the Alps as a unique reservoir of biodiversity to be preserved suggests rethinking these mountains as protected areas, limiting human expansion to favor the recovery and regeneration of alpine ecosystems.

a partial closure of the Alps implies redefining the boundaries of human access, balancing human presence with ecological conservation. Within a degrowth framework, this perspective views alpine urbanism as a discipline of land protection and stewardship rather than a vector of development and growth. Limiting access and urbanization in the Alpine region is essential to counter biodiversity loss, allowing ecosystems to regenerate and maintain their vital functions across the entire area. Degrowth urbanism in this context is less an act of design than de-designing, where the objective is not to build or modify but to return space to nature. The concept of a partial closure thus implies a paradigm shift, in which the Alps are no longer regarded as resources to be exploited but as a common good to be preserved. Nevertheless, defining the Alps as a common good introduces a tension that has been critically discussed concerning mountain regions: the so-called paradox of the commons, whereby framing a territory as common can, paradoxically, weaken local communities' autonomy and decision-making power, mainly when external actors impose top-down conservation or development agendas (Debarbieux and Price 2012).

This approach allows the Alps to function as a natural laboratory, where nature takes precedence and human intervention is subordinated to ecological dynamics⁸. The need to restore a balanced relationship between humanity and nature calls for managing territories as shared habitats rather than exclusively human domains (Bookchin 1982). Applying this principle to the Alps, the goal becomes creating a model of respectful coexistence where local communities can continue to live sustainably without compromising the area's ecological heritage. The partial closure of the Alps thus becomes a form of active protection, preserving the region's environmental value and restoring nature as the *protagonist*. Reframing the Alps as a space of ecological preservation rather than economic expansion reveals the contradictions embedded in contemporary development models and opens the possibility for an alternative territorial imaginary. Within this framework, degrowth urbanism does not propose withdrawal but a redefinition of spatial intervention—less centered on production and more attuned to environmental limits, resilience, and coexistence. This shift invites us to explore new principles for inhabiting and managing the territory, such as sufficiency, that acknowledge ecosystems' fragility and the materials' agency.

⁸ Degrowth urbanism in an Alpine context thus emerges as a practice of limitation and withdrawal.

8.1.the logic of sufficiency and the material agency

The principle of sufficiency could be considered a deliberate choice to limit resource use, challenging the prevailing logic of maximization and unchecked consumption (Princen 2005). This framework aligns with the principles of degrowth urbanism, which similarly questions the assumption that continuous growth equates to progress⁹. Applied to the degrowth perspective, sufficiency supports a reorientation of urban design toward “*enoughness*” rather than “*more*”¹⁰ and advocates for policies and designs that use resources wisely and respect the finite nature of ecological systems. It challenges designers and planners to ask not what can be built or extracted, but what is ecologically appropriate and socially beneficial, reducing speculative demand and resource use. A ‘*partial closure*’ of the Alps exemplifies sufficiency¹¹: limiting access and human activity to preserve biodiversity and ecological resilience, placing preservation over development gains¹². Here, sufficiency becomes a guiding principle, encouraging policies that maintain an *enough approach*, supporting only as much human presence as is compatible with ecological health. This approach not only safeguards the Alpine ecosystems but also fosters a model of coexistence in which local communities can thrive sustainably within these limits, aligning with a vision of a balanced, sufficient relationship with nature.

Redefining value through limits: from maximization to ecological compatibility In contrast to maximization, sufficiency repositions resources as partners in the human and ecological experience rather than as objects for extraction. Maximization often disregards environmental and social costs, relying on technology to surpass natu-

⁹ As discussed, rather than maximizing urban expansion and economic output, degrowth urbanism prioritizes ecological balance, social equity, and long-term sustainability by embracing limitations as a necessary response to environmental constraints.

¹⁰ Sufficiency is an ethical and practical principle that respects planetary limits, advancing sustainability by prioritizing *enough* over *more* (Princen 2005)

¹¹ Logic of sufficiency provides a framework for rethinking human activity in the Alps. Instead of focusing on growth and extraction, a sufficiency-based approach would redefine success as the capacity to maintain an ecological balance.

¹² This is a foundational challenge to the dominant paradigm of maximization, which underpins much of modern economic and consumer practices, a conscious decision to limit resource use grounded in recognizing ecological and social boundaries. This theoretical framework is not simply about reducing the volume of resources consumed but about shifting the perception and governance of these resources. Rather than imposing reduction for conservation alone, sufficiency promotes a balanced relationship in which resources are used judiciously and with awareness of their natural renewal limits. This philosophy calls for a shift in social values: success and well-being are no longer measured by the quantity of goods accumulated but by the capacity to live in harmony with ecological constraints.

ral thresholds. Sufficiency regards these limits as essential boundaries, safeguarding resources from depletion and ensuring their availability for future generations. This distinction redefines how society might view consumption and production, as each decision considers long-term ecological impacts over short-term gains. To ground this theoretical approach, it is necessary to illustrate how sufficiency can operate across different contexts, from daily life to global economic systems. A central example is his concept of a system operating at an appropriate level of activity that aligns with its surrounding ecosystem's regeneration capacity. Under this logic, a sufficient system is more sustainable and resilient, adapting to environmental fluctuations without exhausting its foundational resources. Applied to the Alpine region, the framework suggests an urban and environmental design model that limits resource use, development, and human impact to preserve the area's ecological resilience. The Alps are an ecosystem with distinct vulnerabilities, driven by their high biodiversity, unique climate, and geographic characteristics. The principle of sufficiency, in this setting, becomes a call to protect the natural balance by avoiding the pressures of over-development, mass tourism, and unsustainable resource extraction. Instead of viewing the Alps as a resource for unlimited economic growth, sufficiency reimagines them as a shared ecological reserve whose integrity must be preserved for the future. This means sustainability is not about expanding resources to meet growing demands but about fundamentally shifting our perspective—adapting social, economic, and spatial practices to operate within the thresholds set by ecological systems¹³. It implies a reversal of priorities: instead of bending the environment to accommodate consumption patterns, we must reshape those patterns to align with what ecosystems can realistically support, both now and in the long term.

Within this framework, sufficiency encourages a deeper, more respectful relationship with materials, not merely as resources to be restrained but as active agents in the design process and human interaction with the environment. This is where material agency (Bennett 2010) comes into play, enriching the perspective on sufficiency by acknowledging materi-

¹³ This approach would allow the Alps to serve as a model for regenerative land use, where human needs are met without compromising the environment's ability to sustain itself. The concept of *appropriate levels* of activity, systems operating within limits suited to their environments, finds a powerful application here. This implies that the scope of human activity in such a fragile area must be carefully managed to prevent environmental degradation.

als as active, rather than passive, participants in constructing sustainable environments. This implies that materials, such as stone, minerals, wood, and water in the Alps, are not simply inert objects to exploit or shape but agents with characteristics, limitations, and potentials that influence and shape human interaction and the landscape. This conceptual transition from sufficiency to material agency deepens our understanding of de-growth urbanism, extending reflection beyond consumption reduction to consider the intrinsic nature and autonomy of the materials themselves. Sufficiency becomes not only a limitation of use but an invitation to understand and respect the preferences and resistances of materials. In other words, this suggests that each resource has its own capacity for action, influencing design and shaping architectural and urban choices, guiding designers toward a more symbiotic and less imposing interaction with the environment. Applying these concepts to the Alps case allows us to regard the Alpine region not merely as a collection of passive resources but as a living, active entity that defines human spaces and practices. This approach paves the way for a type of land management that does not view wood, stone, or soil as mere building materials but as elements with which to collaborate, respecting regeneration cycles and the internal logic of each material.

Toward a relational approach to materials and landscapes

The transition from sufficiency to material agency marks a significant shift in how we engage with natural resources and the spaces they shape. This perspective moves beyond simply limiting resource use; it calls for recognizing their intrinsic autonomy, specific material characteristics, and ecological value. Materials are no longer understood as inert, passive elements at the disposal of human intention but as active participants in the construction of environments, agents with their rhythms, resistances, and capacities to influence design choices and territorial strategies (Ingold 2012). Such a shift invites a broader reconfiguration of urbanism and land management practices, fostering a model grounded in respect, responsiveness, and interdependence between human societies and the material world. It promotes an ethic of care in which design becomes a situated, ecological act that responds to the entanglement of human and non-human agencies in space-making (Frichot 2019). In this vision, designing with sufficiency and acknowledging material agency become acts of care, both ecological and cultural, that seek to rebuild the fabric of our relationship with the territory through restraint, atten-

tion, and long-term vision. Far from representing a return to austerity or a nostalgic attachment to pre-industrial simplicity, this framework opens the way for radically contemporary spatial imaginaries. It establishes the conceptual ground for more ambitious visions—capable of projecting alternative futures that are both realistic and transformative. From here, the question is no longer how to reduce impact but how to envision new forms of inhabiting space. This becomes the terrain where concrete utopias can take shape.

8.2.concrete utopias

The progression from degrowth in urbanism to sufficiency and then to material agency leads us toward an even more radical paradigm, one in which urban practices and theories not only limit human impact but also profoundly rethink the relationships among people, materials, and landscapes. Within this theoretical evolution, concrete utopias emerge as a powerful and necessary counterpoint to the dominant narratives of inevitability, scarcity, and resignation. It proposes a mode of imagining the future that is not detached from the constraints of the present. Instead, it uses ecological, social, and material constraints as the terrain to construct alternative, transformative scenarios. Concrete utopias are not projections of an abstract or idealized elsewhere but of historically situated hope grounded in collective desires and emergent possibilities (Bloch 1986). They are utopian in their refusal to accept the status quo as the only imaginable future, yet concrete in their commitment to what is materially and politically actionable. This dual character gives them a unique critical function: they do not escape reality but interrogate it, exposing its contradictions and allowing alternative spatial, economic, and ecological logics to emerge. In this sense, they can be understood as tools of resistance to dominant paradigms of urbanism that continue to reproduce extractivist, growth-oriented models under the guise of innovation or sustainability. Framing concrete utopias within the discourse of degrowth and material agency means recognizing their capacity to reconfigure the very idea of the project, not as the production of form but as the construction of meaning, care, and reciprocity. Urban and territorial space is no longer a blank surface for technical solutions or symbolic gestures but a contested field in which ethical choices, material conditions, and ecological limits must be negotiated. The utopia here is not the enemy of the real; it is the force that reveals what the real might become if guided by different values. In this context, the challenge is not to design a better version of what already exists but to render thinkable—and therefore possible—a reorientation of spatial practices toward coexistence, restraint, and regeneration. Concrete utopias do not promise harmony; they invite conflict, difference, and difficult transition work. They compel us to ask what kinds of futures are worth building, not in the abstract but through the specific, situated reimagination of territories such as the Alpine landscape, where competing pressures make the stakes of transformation visible and urgent.

Designing for coexistence: ethics, care, and material specificity

In an Alpine context, concrete utopias could form the foundation for an urbanism that reinvents life and construction in the mountains, not as an expansionist effort or an attempt to *green* existing paradigms, but as the co-creation of spaces where people, materials, and the landscape exist in dynamic equilibrium. This approach rejects the dominant logic of spatial optimization and productive intensification, proposing an ethic of restraint, coexistence, and mutual care instead. Within this vision, degrowth and sufficiency are no longer merely instruments of limitation or crisis management. They become enabling conditions for imagining radically different futures. The notion of material agency, which recognizes the active role of materials in shaping the built environment, adds another critical layer: it challenges the instrumental use of natural resources and embeds in the project a respect for material specificity, rhythm, and autonomy. In this framework, human intervention is not abolished but radically reframed—bounded by nature’s capacity to regenerate, adapt, and persist. Applied to the Alpine context, concrete utopias do not envision a future of minimalist survival or aestheticized green enclaves. Instead, they invite a fundamental redefinition of what it means to inhabit a place: one that is attentive to its intrinsic dynamics, temporalities, and vulnerabilities. This perspective aligns with the recognition that landscapes are shaped by assemblages of human and non-human actors entangled in fragile and provisional forms of cohabitation (Tsing 2015). Designing within this framework means cultivating attentiveness to these relational ecologies and embracing uncertainty as a condition of situated collective experimentation.

This approach insists that sustainability cannot be reduced to efficiency metrics or technological substitution. It requires a cultural and spatial shift that reorients the design imagination around limits as generative, not restrictive, forces. In this way, concrete utopias offer a path that begins with the real, present-day challenges of environmental degradation, excessive land consumption, and ecological fragmentation. However, they refuse to be constrained by them. Instead, they imagine a transformative convergence between material reality and anticipatory vision, expanding the conceptual space of degrowth and sufficiency toward projective urbanism that mitigates impact and articulates new, habitable horizons for mountainous territories.

The ecosystem is a complex web in which every element—from predator to prey to the soil itself—plays an essential role in maintaining

balance. “*Thinking like a mountain*” (Leopold 1949) invites a shift from anthropocentric perspectives to an ecological view that acknowledges the interdependence and embeddedness of human and non-human actors within shared environments. Such a vision calls for urbanism not shaped by control or extraction but by an ethic of attention, reciprocity, and long-term ecological awareness. Operating within this framework means understanding landscapes not as inert backgrounds for human intervention but as active fields of interaction, temporal and material constellations shaped by human and non-human agencies¹⁴. Recognizing the agency of ecological components reframes spatial intervention as a collaborative and situated practice grounded in interdependence and respect (Plumwood 2002). *Concrete utopias* intersect with this vision by positioning urban and territorial space as sites of interrelation, where futures are not imposed but co-emerge from within ecological limits and material specificities. Designing within this paradigm involves a form of ecological diplomacy that recognizes the multiplicity of agencies shaping the landscape and responds through adaptive, situated forms of spatial engagement (Morizot 2022). Such an approach demands more than technical knowledge. It calls for a profound shift in perception that reframes landscapes as dynamic, co-constitutive agents rather than passive surfaces to be optimized¹⁵.

From ecological awareness to deep ecology: shifting the ethical foundations of spatial practice Building on this relational understanding of landscapes and materials, a further conceptual step leads toward a deeper ecological perspective that challenges anthropocentric assumptions and redefines the ethical foundations of territorial and urban practice. The transition to deep ecology¹⁶ offers an even more radical perspective that recognizes the intrinsic value of all forms of life. This perspective promotes an environmental ethic that goes be-

¹⁴ This resonates with the notion of landscape as a *taskscape*, in which dwelling is understood as an ongoing negotiation with environmental dynamics (Ingold 2000, Rose 2004).

¹⁵ This lays the groundwork for a territorial ethic in which the flourishing of ecosystems and human culture are mutually reinforcing.

¹⁶ Deep Ecology, a term coined by Arne Næss (1973), represents a profound shift in how we perceive and interact with the natural world. Unlike the conventional anthropocentric approach to environmentalism, which prioritizes human needs and values, Deep Ecology advocates for a more holistic and eco-centric perspective that recognizes the intrinsic value of all living beings and their ecosystems. This contrasts sharply with the instrumentalist view that values nature primarily for the resources and services it provides to humans. It promotes more sustainable lifestyles, prioritizing ecological health over material accumulation.

yond mere conservation for human use. This approach holds that all life forms have inherent worth, independent of their utility to humanity, and that ecosystems should be respected as autonomous entities rather than as consumable resources. It surpasses the idea of designing sustainable spaces solely for human benefit, embracing instead the view that respecting and protecting ecosystems are ends in themselves. Where Leopold's "*thinking like a mountain*" encourages a broader understanding of the ecosystem, deep ecology calls for a complete reversal of the hierarchy between humans and nature. This vision reimagines urban and territorial projects to prioritize ecological balance over human functionality, creating spaces that reflect coexistence between humans and all other life forms. In a landscape like the Alps, this implies recognizing the environment as a complex network of interactions that is never just a human context. Designing Alpine territories within this framework requires minimizing human impact, allowing ecosystems to function autonomously as subjects. This broadens the concept of material agency by acknowledging that materials shape the project and the entire ecosystem, which acts as a co-agent—a living, interconnected reality of which humans are just a part¹⁷. Ultimately, introducing deep ecology into the theoretical framework enriches the vision of a degrowth urbanism that is not only restrictive but also profoundly respectful and interconnected with all life forms. Policies informed by deep ecology also tend to support degrowth-oriented strategies and alternative economic models that prioritize ecological integrity and collective well-being over perpetual economic expansion. These approaches advocate an intrinsic appreciation of all life forms, promoting holistic, *ecocentric* ethics that challenge prevailing notions of value, utility, and progress. Integrating such principles into planning and governance requires reconfiguring societal structures and encouraging shifts in behavior, institutional priorities, and cultural narratives. From conservation practices to models of sustainable living¹⁸, the implications of this ethical framework extend across multiple dimensions of daily life, fostering more equitable and

¹⁷ In an Alpine *concrete utopia*, the ethic of reverence and stewardship orient each decision toward minimizing interference and supporting biodiversity.

¹⁸ Deep ecology has given rise to a diverse body of environmental ethics that reject the prioritization of human needs as the sole basis for ecological decision-making. This ethical shift has informed various radical environmental thought strands, influencing ecofeminism, biocentrism, and post-human ecology discourses.

resilient forms of coexistence between humans and the biosphere¹⁹.

Mining as a transitional and regenerative tool In response to the initial question, *back to mining*, the conceptual path we have traced—from degrowth urbanism to sufficiency, material agency, and deep ecology—leads to a clear and increasingly radical answer: no. No to a return to an extractivist model that views the Alps as a resource to be exploited and no to a developmental paradigm that compromises biodiversity, ecological balance, and the cultural significance of the Alpine region. However, such a radical transition would require profound economic, social, and political transformations, making it highly challenging to implement. Adopting a model that entirely rejects mining and fully embraces a philosophy of respectful coexistence, as outlined by the principles of deep ecology, represents a shift far beyond what can be realistically achieved in the short term. This transition would necessitate rethinking the role of extractive economies, redefining the value of the territory, and fostering cultural awareness that respects and appreciates nature as an entity with intrinsic worth. Acknowledging these complexities, the *decision not* to return to mining does not preclude an intermediate phase in which limited, strictly regulated extraction practices could serve as a transitional step toward a different future for the Alpine region. This intermediate phase should not be viewed as a simple concession to the extractivist model, but rather as a reversible, controlled stage intended to reorient the Alpine region toward a new centrality. In this context, mining would become a temporary tool to economically and socially stabilize local communities while supporting a transition to more sustainable practices. In this framework, the answer of *no to mining* is not merely a rejection but a proposition for regeneration: a scenario in which the Alpine region reclaims a central role as a space for ecological, cultural, and social experimentation and innovation. This alternative future does not necessarily exclude short-term extraction. However, it reimagines it as an opportunity to transform the territory, making it resilient, self-sustaining, and aware of its value as a reservoir of biodiversity, culture, and irreplaceable natural resources.

¹⁹ This perspective's practical implications include bioregional frameworks, ecological restoration, rights-of-nature legislation, and emerging forms of Earth jurisprudence. These practices aim to realign institutional, legal, and spatial systems with the dynamics of ecological interdependence, challenging anthropocentric paradigms in territorial design and environmental governance.

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8.back to mining?

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9. beyond extraction reframing territorial ethics and transitions

In considering whether to resume mining in the Alps, we face complex, often conflicting perspectives on development, sustainability, and regional identity. The progressive exploration of concepts from *de-growth* to *sufficiency*, *material agency*, and *deep ecology* has established a clear stance: a radical *no* to unrestrained extractive activities. Nevertheless, as this theoretical journey reveals, such a decisive shift toward preservation and ecological respect requires a profound transformation in economic, social, and political structures. This aspiration remains challenging to realize practically. However, acknowledging the difficulty of such a radical transition opens a pathway to consider mining not as a fixed return to extractivism but as a reversible transitional stage. Rather than merely rejecting the prospect of extraction, this intermediate phase envisions a restructured mining approach that aligns with sustainable objectives. It would leverage extraction activities to support local communities economically and create new, context-sensitive frameworks that might ultimately foster greater autonomy and centrality for the Alpine region in the long term. This line of thought introduces the need for a deeper, more inclusive territorial consciousness that reflects these regions' complex socio-political dynamics. Rather than a fixed awareness of place, territorial consciousness must be understood as an active and contested terrain shaped by the interplay between political agendas, collective imaginaries, and ecological conditions. It emerges through spatial practices, discourses, and institutional arrangements that determine which territories are made visible, which are neglected, and under what terms they are governed. In this sense, it operates not only as a mode of recognition but as a form of territorial agency: an instrument through which communities and institutions negotiate power, memory, and futures. This aligns with critical geographies that interrogate the political construction of territory and its embedded hierarchies (Sack 1986, Elden 2013), as well as spatial imaginaries that challenge dominant representations and extractive paradigms from within marginal regions. For Alpine territories, cultivating this consciousness means reclaiming visibility and articulating new frameworks for autonomy and coexistence that resist the reductive logic of growth or abandonment.

Within this perspective, territorial consciousness becomes not only a theoretical lens but also a strategic horizon for action, foregrounding the political and ecological conditions under which Alpine communities may reclaim agency over their futures. This reframing invites us to move beyond the binaries that typically structure debates on develop-

ment and conservation, and to embrace more situated and negotiated approaches to inhabiting and transforming the territory. What follows is an exploration of how such consciousness can be cultivated and made operative through practices that rearticulate the meaning of territory and frameworks that rethink responsibility, reciprocity, and autonomy. From questions of recognition and visibility to those of redistribution and care, the challenge lies in constructing new imaginaries and tools that navigate the contradictions of extractive transitions while fostering more just and regenerative spatial futures.

9.1 territorial consciousness

Territorial consciousness refers to recognizing a region's material and ecological conditions and forming a shared spatial awareness shaped by political, historical, and symbolic forces. It is not a static identity but a dynamic, contested process through which communities articulate their relationship to land, resources, and memory. Such consciousness develops through narratives, cartographies, and practices, determining what is visible, valuable, and legitimate within a territory. It is, therefore, a field of struggle, where different visions of the future confront each other, between preservation and development, extraction and regeneration, autonomy and dependency (Raffestin 1980, Elden 2013). In the Alpine context, cultivating a territorial consciousness involves resisting extractive logic and reasserting the right to define the conditions of inhabitation, care, and governance from within. It implies the capacity to situate local needs and imaginaries within broader planetary frameworks without surrendering to external developmental imperatives.

Reclaiming alpine complexity: between resource centrality and peripheral governance Alpine territories are rich in natural resources, yet paradoxically marginalized in economic and social development today. Thus, shaping a narrative that captures their inherent complexity and potential, while navigating both preservation and controlled resource use, offers an opportunity to redefine these landscapes within a framework that acknowledges both local autonomy and global responsibilities. These territories have an immense wealth of natural resources, but paradoxically, they are at the margins of economic and social development today. In this sense, to define a narrative capable of interpreting the complexity of these territories, the scenario of a return to extraction is not only a response to the European Union's demands for the actions necessary for the ecological transition, but also works to restore political and economic centrality through a decolonial perspective. It thus assumes that these extractive activities occur within their borders and not in other parts of the world (Brenner and Katsikis 2020), which is considered inferior. This contrasts with an environmental awareness that might foresee a planned and controlled abandonment of the Alpine territory, recognizing an incredible *reservoir* of biodiversity²⁰, despite the knowledge that this is the result of human action over the years, exploiting and extracting its resources. This, while being aware that viewing

²⁰ <https://www.alpconv.org/en/home/topics/biodiversity-nature-conservation/>

the Alpine territory as a common good can trigger a series of narratives and practices that undermine local communities' right to exercise decision-making power over their territory (Debarbieux and Price 2012). However, it is necessary to consider some side effects related to ongoing phenomena, which operate within a climate change framework and the urgency of the consequent acceleration of processes. This includes reflections on migrant landscapes and the coexistence of neo-productive practices²¹ within the foothills and mountains.

The context of the socio-ecological transition calls for a profound reconsideration of production models and the sourcing of raw materials. As highlighted in *section 01*, a key aspect of this transition is the extraction of critical raw materials essential for developing advanced technologies that support renewable energy and sustainable solutions. However, mining operations cannot be disconnected from the environmental, social, and historical issues surrounding them, requiring careful resource management grounded in principles of equity and the deconstruction of colonial practices. The resumption of mining operations in Alpine regions, historically linked to natural resource exploitation, could present an opportunity for social and economic development. Still, it is accompanied by a range of paradoxes and complex problems. Space can be understood as collective capital (Viganò 2023) and as a social resource (Lefebvre 1991), suggesting that existing infrastructures and the material legacy accumulated in the Alps can be valued through a reactivation process, partial or complete. This approach would reduce the need for new construction, minimize environmental impacts, and promote more sustainable mining operations.

Extractive futures and contested development: toward situated territorial narratives The extraction of critical raw materials in economically depressed areas could represent a significant growth opportunity for local communities. Mining activities generate employment throughout the operations lifecycle and stimulate significant economic activity in the transportation, waste management, and infrastructure

²¹ The analysis highlights the crucial importance of symbols in the creation of both material and immaterial goods. Every perception passes through a filter and can be more or less shared. However, these perceptions act as powerful stimuli for projects aimed at giving meaning and shaping the productive future of these territories. When interpreting the phenomena of mountainous areas, it is essential to place the images within their temporal and spatial context to avoid generalizations that may overlook the specific peculiarities of each place (Ferrario and Marzo 2019).

sectors. Additionally, communities hosting these activities can benefit from essential services and communication infrastructure that would otherwise be difficult to obtain (Bryan et al. 2018). For these opportunities to become a tangible advantage for the local population, mining operations must be supported by public funds at both the European and national levels. Collaboration among different levels of governance, including municipal associations and regional and national authorities, is essential to ensure effective resource management and the equitable distribution of the economic benefits of extraction (Jones 2020). At the same time, it is necessary to assess the legislative framework governing such operations and the role of European and national directives in promoting the sustainable use of natural resources. One of the most controversial aspects concerns the need to extract new raw materials, such as cobalt. Although essential for many modern technologies, such as electric vehicle batteries, concerns about the environmental and social impacts of its extraction are growing²². Meanwhile, scientific research is exploring alternative solutions to cobalt use, such as developing technologies that reduce dependence on this material or using recycled components (Harper et al. 2019). Here, an evident paradox emerges: while there is a reflection on the need to extract new resources, efforts are being made to reduce demand through more sustainable solutions. The mining industry faces numerous socioeconomic challenges. Price fluctuations in raw materials can create significant instability in the sector, with periods of intense activity alternating with crises and plant closures (Blomberg et al., 2017). Additionally, introducing new technologies and an increasing reliance on automation progressively reduce the demand for low-skilled manual labor, thus eroding employment opportunities for local workers (Arndt et al., 2019). This phenomenon is particularly problematic in areas where the mining industry is the primary source of employment. Therefore, local and national governments should promote economic diversification strategies to ensure the long-term sustainability of communities and reduce their exclusive reliance on resource extraction. This final section will address various topics related to a possible return to extraction in the Alpine context. To study new extractive geographies, it is essential first to understand *the state of things*, including a thorough analysis of their physical structure, primary characteristics—

²² The cobalt supply chain is characterized by severe inequalities, especially in developing countries, where mining conditions are often dangerous and precarious (Amnesty International, 2016).

current and historical—and challenges. These regions, often shaped by natural resources and human activity, have unique topographies and evolved ecosystems.

Additionally, they share common *problems*, such as the impacts of climate change and depopulation, which threaten their environmental sustainability and socio-economic viability. Climate change is accelerating the retreat of glaciers, altering hydrological cycles, and increasing the frequency of extreme weather events, all of which profoundly affect extractive industries and local ecosystems. Depopulation, on the other hand, is a pressing issue in many resource-dependent areas, as younger generations migrate to urban centers, leaving aging populations and weakening local economies behind, making these areas vulnerable to external economic pressures. However, understanding these challenges also requires focusing on potential alternative development trajectories. While traditional extractive activities may have shaped these regions in the past, new patterns of sustainable development, such as eco-tourism, renewable energy, and the promotion of local products, offer promising alternatives. Innovative land-use and natural resource approaches can reshape extractive geographies by promoting social equity. If carefully managed, these strategies could provide paths for revitalization that balance economic growth with environmental conservation and cultural preservation, while fostering a more integrated understanding of extractive geographies that link local transformations to broader global processes. This approach emphasizes the need to analyze the immediate physical landscape and the larger socio-economic patterns that influence extraction and development. Thus, a comprehensive understanding of these geographies, grounded in a detailed knowledge of their physical and historical features, shared challenges, and opportunities for future development, is crucial for anyone seeking to engage with and influence the evolving dynamics of extraction in these regions. Territorial consciousness, in this sense, is not simply about recognizing the Alpine region's fragility or resource potential: it is about contesting the frameworks through which this fragility is governed, and this potential is mobilized. It invites a re-politicization of territorial narratives, challenging the binaries of conservation versus exploitation, center versus periphery, and local versus global. By reframing the Alpine territory as a site of situated knowledge, multi-scalar interdependence, and historical agency, this consciousness opens the possibility of counter-hegemonic spatial futures—futures in which extraction is neither romanticized nor

categorically rejected but situated within a broader ethical project of redistribution, autonomy, and ecological reciprocity. The Alpine territory is a palimpsest—a layered, evolving artifact shaped by successive interventions, meanings, and forms of inhabitation²³ (Corboz 1985). In this context, such a reading is not merely descriptive: it becomes an operative lens to interpret both the permanence and reversibility of spatial transformation. Positioned between the ecological urgencies of the present and the infrastructural legacies of the past, Alpine territories thus emerge as arenas of experimentation—spaces where the principles of post-extractive transition, territorial justice, and plural cohabitation can be simultaneously contested and enacted.

²³ Corboz's concept of the territory as a palimpsest goes beyond metaphor: it functions as an operational framework for understanding territorial design as a continuous act of reading and rewriting. In this view, each intervention engages with existing layers rather than erasing them, acknowledging landscape as a cultural and historical construction in perpetual transformation.

9.2.territorial liability

Territorial liability must be approached not merely as a technocratic response to the environmental consequences of extraction but as a fundamentally political concept that interrogates the spatial conditions of responsibility, reciprocity, and redistribution. In the context of the Alps, where historical processes of marginalization, resource appropriation, and infrastructural fragmentation have sedimented into the landscape, the idea of liability cannot be reduced to compensatory mechanisms or environmental mitigation strategies. Instead, it demands a shift in how territorial relationships are conceived and governed: from vertical logics of resource capture to horizontal networks of interdependence. This implies recognizing the uneven geography of extraction and actively contesting the narratives and systems that render certain territories visible as resourceful and others invisible as disposable. To reclaim liability as a spatial and political practice is to reframe the Alpine region as more than a site of impact. It becomes a site of negotiation, where new forms of territorial pact and cohabitation can be imagined. Such a reframing opens the possibility of articulating shared obligations across ecological gradients, institutional scales, and historical asymmetries—linking the right to remain with the right to decide and the right to inhabit with the project right²⁴.

Interdependence and reciprocity: highland–lowland dynamics and spatial responsibility Within this expanded framework, delving deeper into territorial consciousness, the need arises for a perspective recognizing territorial liability—a shared responsibility between highlands and lowlands. Rather than viewing the Alps and surrounding areas as distinct parts, this vision integrates them into a unified system in which ecological, economic, and social balances depend on ongoing

²⁴ This opening section serves as a methodological hinge within the chapter, repositioning territorial liability not as a procedural category but as a political condition. By framing it in terms of visibility, redistribution, and spatial justice, the text challenges managerial interpretations of environmental governance and opens the field to a situated, relational, and critical engagement with space. The passage highlights the Alps not as passive recipients of external decisions, but as contested arenas where extraction, inhabitation, and governance are negotiated. This shift is both epistemological and operational: it allows for a redefinition of agency across scalar and territorial gradients, while also substantiating the transition from abstract theoretical claims to grounded forms of territorial negotiation. Moreover, it foreshadows the argumentative arc of the section—reconnecting the right to territory with the right to project—thus establishing a bridge between spatial critique and design imaginaries. Methodologically, this approach aligns with critical urban theory practices and situated spatial analysis, rejecting universalizing assumptions and focusing instead on the co-constitution of ecological and political processes.

interaction and mutual support between the two. Building on the discussion in *section 02*, which highlighted how the Alps are a human-made territory shaped by centuries of human activity, it becomes evident that even artificial structures, such as terracing, roads, and villages, now help define what is perceived as the *authentic* Alpine landscape, a visual cliché yet rooted in human intervention (Debarbieux and Rudaz 2010). Within this framework, a return to mining can represent an opportunity to combine new economies with innovative protocols of control and responsibility. This approach aims to establish a balance in which extraction, rather than depleting local resources, becomes part of a regulated, sustainable system that integrates high and lowlands. Territorial liability requires moving beyond the isolated view of highlands as mere resource reserves, emphasizing instead the need to balance any activity's economic and environmental impacts with an approach that values the interdependence (Lefebvre 1991) of the integrated highland-lowland system. Territorial liability must, therefore, be reframed as more than a tool for environmental impact mitigation or resource compensation. It should be understood as a political and ethical condition that exposes the asymmetries in how benefits and burdens are distributed across spatial and socio-ecological gradients. Drawing from traditions of spatial justice and the right to territory (Harvey 1996), territorial liability becomes a lens through which to assess who decides, benefits, and bears the development costs. It introduces a redistributive imperative into the governance of extractive transitions: financial compensation, political inclusion, infrastructural reciprocity, and environmental repair. Within this frame, the Alpine context is no longer a periphery governed by external demands but a co-produced field of negotiation. The challenge becomes establishing situated, reversible intervention protocols, anchored not in extraction as an end but in the territory as a relational infrastructure shaped by common responsibilities and differentiated needs. Therefore, this notion of territorial liability must be understood not simply as an operational principle of environmental compensation but as a political concept that redefines the relationships between territories, institutions, and life forms. It articulates a shift from resource management to spatial justice, questioning who can decide over land use, who benefits from extraction, and who bears its costs. In this sense, it intersects with broader reflections on the right to the territory—an idea that expands upon the right to the city (Harvey 2008), insisting on the collective capacity to shape the socio-ecological conditions of

everyday life.

Territorial liability also resonates with critiques of systemic dependence on centralized infrastructures and extractive logic. Ivan Illich's notion of conviviality suggests an alternative model of territorial engagement: one that privileges autonomy, balance, and shared responsibility over top-down control and efficiency-driven development (Illich 1973). In the Alpine context, this implies moving beyond the compensation logic and toward the co-production of spatial arrangements rooted in reciprocity and restraint. Recognizing liability as a collective political act means establishing frameworks that mitigate damage and cultivate new forms of stewardship, relational equity, and ecological care. Building on this ethical and political reframing, territorial liability can be further deepened by recognizing the Alps not only as a socio-ecological system shaped by interdependencies but as a living territory inscribed with layers of exploitation, abandonment, care, and reappropriation. These layers do not simply accumulate linearly but interact as a palimpsest of extraction, where past and present forms of appropriation sediment into a spatial memory that structures future trajectories. While not exclusive to the Alpine context, this notion gains particular salience here due to the long-standing instrumentalization of these regions as supply zones: landscapes imagined and administered primarily as reserves of energy, labor, and scenic value. Far from being neutral, these representations shape both external perceptions and internal governance, producing a double bind in which the territory is simultaneously celebrated as pristine and mined as expendable.

From compensation to collective agency: design, governance, and the right to territory Reframing the Alps as such a palimpsest demands a different orientation in spatial practices that does not seek to erase prior traces or impose singular visions of development but rather engages with the complex interweaving of infrastructures, ecologies, and imaginaries. Territorial liability, in this sense, requires a projective and reparative gaze that sees in extraction the need for regulation or redistribution, as well as the possibility of radical empirical reconfigurations²⁵ (Viganò 2023). These are not utopias in the classical sense but grounded, situated experiments that acknowledge the asymmetries

²⁵ the notion of radical empirical scenarios (Viganò 2023) as speculative yet grounded instruments of territorial transformation. These scenarios emerge not from abstract ideals but from attentive observation of existing conditions and potentials—mobilizing them as the basis for alternative futures that are realistic, situated, and collectively negotiated.

of power and access inscribed in space while attempting to transform them through collective negotiation and design. In this light, the Alpine region becomes not simply a victim of external demands or a candidate for heritage preservation but an arena of plural cohabitation—where human and non-human agencies, institutional and informal actors, historical infrastructures, and future scenarios converge. Territorial liability thus moves beyond technocratic governance and enters the domain of spatial politics, calling for reversible, context-sensitive protocols and multi-voiced. These protocols should not merely compensate for damage but also redistribute spatial agency, allowing Alpine territories to reassert their capacity to define the terms of transition on their own terms. This leads to an expanded understanding of territorial rights—not only the right to remain or to benefit from resource redistribution but also the right to project. That is the collective capacity to generate spatial imaginaries, to experiment with new modes of inhabiting and organizing territory, and to intervene materially and politically in shaping its future. As an extension of the *right to the city* (Lefebvre 1996, Harvey 2008), the right to project reframes design as a democratic, territorial act: not the privilege of experts or institutions, but a shared and situated power to rearticulate what a territory is, does, and could become. In this regard, the Alpine context may be critically reinterpreted through the palimpsest of exploitation (Viganò 2023), a landscape deeply inscribed by historical extraction cycles, infrastructural control, and economic marginalization. This reading does not merely reveal past uses of the land but exposes the persistent spatial and symbolic patterns that shape its present condition. The Alpine territory is traversed by layered traces of environmental sacrifice, infrastructural domination, and social neglect—elements that challenge a simplistic binary between nature and infrastructure or exploitation and conservation. Territorial liability, in this light, must consider not only material impacts but also the imaginaries that legitimate specific uses over others, consolidating a territorial identity rooted in extraction and instrumentalization.

Against this backdrop, reframing territorial liability entails developing design and governance tools that can interrupt these inherited logics. It means proposing spatial practices that compensate for damage and rework the codes through which territories are valued, imagined, and inhabited. Like other marginal geographies, the Alpine region is a container of resources and a territory of political potential. New coexistence, situated autonomy, and interdependence forms may emerge on

this site. This shift from management to transformation requires long-term spatial imaginaries that can disarticulate the equivalence between resource richness and extractive destiny. It also requires the courage to envision infrastructural and territorial arrangements rooted in ecological reciprocity, polycentric responsibility, and radical empirical scenarios, speculative yet grounded visions that embrace uncertainty as a space for collective reinvention. Such a reframing calls for activating transitional figures: spatial, institutional, and symbolic. These may be temporary assemblies, adaptive infrastructures, or experimental governance models with space for negotiation, ambiguity, and situated learning. Rather than enforcing pre-defined outcomes, they function as threshold devices, enabling coexistence between conflicting temporalities, uses, and expectations. In the Alpine context, these figures become essential in resisting extraction as destiny, allowing the territory to articulate new roles for itself—beyond sacrifice, beyond marginality.

Redistributive frameworks and territorial regeneration beyond extraction To make this territorial responsibility effective, the study will continue by analyzing the various *layers* of complexity in the Alpine territory, from the physical configuration of the landscape to its network of systemic, visible, and invisible relationships linking the Alpine context to surrounding areas. This multi-layered approach will allow for identifying compensation and regionalization perspectives that can help equitably distribute the benefits and burdens of extractive activities. In this sense, territorial liability implies that extraction should not become a monocultural, all-encompassing activity, as could happen in an economic model based solely on intensive mining. Instead, it involves integrating extraction into a strategy that promotes economic diversification, preserves biodiversity, and supports a resilient ecological and social network (Latour 2018). In this framework, territorial responsibility between highlands and lowlands extends beyond impact mitigation. Still, it aims to create a system that accounts for all natural and human resources as part of a living, interconnected territory. The challenge lies in designing protocols and policies that preserve the Alpine landscape's authenticity and functionality, even amid new extractive economies. Territorial liability builds upon the concept of shared responsibility between highlands and lowlands, extending it to emphasize the dynamic interplay that sustains the broader Alpine region. This perspective reinforces the idea that the ecological and socio-economic stability of the

Alps depends on a system of mutual dependencies in which actions in one area resonate across the interconnected whole. As explored earlier, the Alpine region is a human-made landscape shaped by centuries of interaction—from resource extraction to infrastructure construction—defining its cultural and ecological identity (Debarbieux and Rudaz 2010). In this sense, the Alps can no longer be viewed as a detached geography: they are part of a networked territory continuously shaped by historical and contemporary flows of people, resources, and ideas. To illustrate this interplay, one might evoke a metaphorical comparison with the Mediterranean Sea—acknowledging its pretextual nature. Like the Mediterranean, the Alps serve as a space of crossings and encounters, a terrain where extraction, settlement, and regeneration dynamics converge. Just as the Mediterranean has historically been described as a *liquid continent* (Braudel, 1972), embodying the interconnectedness of its shores through trade, migration, and cultural exchange, the Alpine region functions as a *solid archipelago*. It is traversed by invisible currents of energy, labor, and material flows that bind its peaks and valleys to the lowlands and beyond. This underscores the Alps' role not as a static reserve but as a dynamic field of relationships, where local and global forces intersect to shape their physical and social fabric. Recognizing these dynamics necessitates a shift from purely extractive practices toward reciprocal relationships that balance extraction with regeneration²⁶. In practical terms, this means integrating extraction into a broader development strategy that prioritizes economic diversification, ecological preservation, and the empowerment of local communities. Moreover, adopting this integrated perspective involves recognizing the Alpine territory as a living system that requires constant negotiation to maintain balance. Territorial liability, in this context, goes beyond mitigating the immediate impacts of extractive activities. It calls for systemic policies and collaborative frameworks that ensure the benefits and burdens of resource use are equitably distributed. Drawing on the challenge, cultivating a terrestrial approach (Latour 2018) reimagines human engagement with the environment as a mutual, reciprocal relationship. This shift demands a new Alpine narrative that transcends traditional dichotomies between highlands and ends, or between conservation and

²⁶ This vision echoes Lefebvre's (1991) call to reframe space as a social product, where the landscape is shaped by and shapes human activities.

exploitation²⁷.

Highland and lowland areas function as co-dependent zones within a larger socio-ecological framework. For example, water resources originating in the Alps sustain agriculture, energy production, and urban centers in the plains. Conversely, economic investments and labor from the lowlands support activities in the highland areas. This reciprocity necessitates a governance model that aligns incentives and responsibilities across regions, fostering policies that reflect the shared stakes in preserving the Alpine landscape. One critical dimension of this interdependence is the management of natural resources. Highland regions often bear the ecological cost of extraction, while lowland areas reap the benefits through energy production, raw materials, or tourism revenue. This dynamic underscores the inequities embedded in resource geographies, which prioritize the needs of more developed areas at the expense of marginalized territories. Territorial liability proposes that these costs and benefits be redistributed through ecological compensation funds, in which revenues from resource exploitation are reinvested in local communities to enhance resilience and environmental stewardship. These funds could help address long-standing disparities by supporting restoration efforts and socioeconomic development programs tailored to Alpine communities' specific needs (Bryan et al., 2018). Territorial liability acknowledges the integrated nature of these territories and promotes equitable redistribution. It creates the conditions for sustainable interdependence that respects environmental limits and the rights of local populations.

Ultimately, territorial liability offers more than a framework for redistribution—it becomes a projective condition for transforming inherited geographies of dependence into sites of negotiated autonomy. In the Alpine context, this means confronting historical asymmetries through policy or compensation and cultivating territorial practices that acknowledge past violence, support plural forms of coexistence, and build infrastructures of care and ecological regeneration. The challenge is not simply to govern extraction but to displace its centrality by designing alternatives that emerge from within the territory. This opens the way toward a new phase that critically engages with the new extractive geographies and the contradictions they reveal at the intersection of ecological urgency, territorial justice, and the project of Europe.

²⁷ By viewing the Alps as part of an interconnected Mediterranean-like system of flows and exchanges, we can craft strategies that harmonize human activity with ecological imperatives, ensuring that this solid archipelago remains productive and resilient.

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9.beyond extraction

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10. strategic figures for a territorial and landscape design project: re-cycling and regionalization

Building on the reflections developed in the previous sections, this chapter returns to the Piedmontese Alps, specifically the Valli di Lanzo, Valsesia, and Val d'Ossola, as a critical terrain for testing how extractive processes can be reinterpreted within broader territorial logics. It is articulated around two key interpretative categories: re-cycling and regionalization, through which the following sections unfold.²⁸ The first cluster centers on the potential of territorial re-cycling: a critical approach that seeks to reinterpret disused infrastructures, abandoned mining sites, and underutilized valley floors as opportunities for spatial and material regeneration. From the reactivation of high-altitude mining infrastructures to the reuse of logistical and energy networks, this section investigates how latent assets can be mobilized without triggering new forms of land consumption. Re-cycling here is not merely technical but conceptual. It involves recognizing the active agency of landscapes and materials and constructing circular strategies that move away from the linear logic of depletion. The second cluster introduces the concepts of regionalization and diversification as conditions for integrating extractive activities into broader territorial systems. The idea of territorial liability emerges as a critical lens: extraction cannot be considered a closed-loop operation but rather as a process whose impacts and responsibilities reverberate across broader geographies. In regions marked by demographic decline and economic contraction, the challenge lies in ensuring that extraction coexists with slow economies, fragile ecologies, and diverse livelihoods rather than displacing them. Diversification becomes essential to avoid dependency on single-sector dynamics, while regionalization allows for embedding extractive activities into broader governance frameworks and infrastructural networks. Rather than offering a prescriptive model, the analysis works through layering territorial conditions, physical, ecological, infrastructural, and socio-political, revealing how past and present dynamics overlap. The Alpine territory is approached as a palimpsest, where former mining areas, residual infrastructures, terraced landscapes, and dispersed settlements intersect. These layers often reveal structural paradoxes rather than inconsistencies to be resolved: contradictions between abandon-

²⁸ This underscores the interconnectedness of its elements, warning against the risk of isolating individual layers from the broader system. Infrastructure initially developed for extractive purposes, for instance, often carries ecological implications or cultural significance that extend beyond its original function. While a detailed analysis of specific layers is essential, these must always be viewed within the larger framework of territorial complexity to avoid fragmentary solutions that fail to address systemic challenges.

ment and reactivation, isolation and connectivity, and extraction and regeneration²⁹. Addressing such tensions requires holding together detailed, site-specific analysis and a broader systemic vision capable of anticipating the long-term effects of new interventions. Ultimately, the section proposes reading the Alps not as peripheral or extractable spaces but as experimental grounds where the future of productive territories is being negotiated. Territories in which sufficiency, material agency, and spatial complexity shape the conditions for any possible reactivation. This layered reading of the Alpine territory foregrounds the importance of recognizing how ecological systems, infrastructures, and socio-economic structures are deeply interwoven. Attempting to isolate individual components risks producing fragmentary strategies that overlook systemic interdependencies. Infrastructures originally developed for extractive purposes, for example, often acquire ecological or cultural value over time, transcending their initial function. Therefore, any intervention within this context must engage not only with the specific characteristics of individual layers but with the broader territorial framework in which they operate. Only by holding together these interrelations is it possible to avoid reductive approaches and to imagine truly transformative and context-sensitive forms of reactivation.

²⁹ Combining a focus on individual layers with a holistic understanding of the palimpsest and critical awareness of paradoxes provides a framework for interpreting this territory as a dynamic, interconnected system. This approach allows for formulating strategies that address immediate challenges while aligning with the region's long-term complexities and interdependencies.

10.0.territorial frameworks-cobalt exploration and mining licenses in the western alps

To better reframe ongoing dynamics within a contemporary spatial perspective, the section turns to the renewed interest in Alpine territories as potential sites for critical raw material exploration. Recent concessions and prospecting activities in the Piedmontese Alps exemplify how extractive logics are re-emerging within regions historically marked by mining and industrial cycles. The municipality of Usseglio is located at the end of the Viù valley, the southernmost of the three Lanzo valleys, while Balme is the highest municipality in the Val d'Ala. In the Punta Corna area, which straddles the two towns, as of 2019, an Australian company has been granted the concession and is analyzing the presence of cobalt by exploring mining possibilities. The license granted has been renewed in 2022. Another company, established in 2021, is conducting similar operations across Valsesia, beginning in several hamlets above Varallo Sesia and extending to the northwestern part of the valley, as well as the Val d'Ossola in the eastern area, which corresponds to the Anzasca and Antrona Valleys.

Geographies of transition: three alpine valleys and territorial complexity Comprising Val Grande, Val d'Ala, and Val di Viù, the Valli di Lanzo form part of the Graian Alps in the Western Alps. Located within the Metropolitan City of Turin, these valleys stretch from the Susa Valley in the south to the Aosta Valley in the north, bordered by the watershed separating the Po River basin from the Arc River basin in France. This geographical position has historically given the region a dual role as a natural barrier and a communication route. The Stura di Lanzo River, fed by streams and alpine lakes³⁰, has long been a critical corridor for trade and travel between Italy and France³¹. As previously discussed in *section II*, these valleys were early integrated into the industrial metabolism of the Alps, where extraction, forestry, and proto-manufacturing coexisted with subsistence economies.. Tourism has become more prominent in recent decades, with visitors drawn to the area's natural beauty and outdoor recreational opportunities. However, this shift raises challenges related to balancing tourism-driven growth

³⁰ Such as Lago di Malciaussia and Lago di Monastero.

³¹ With mountain passes such as the Colle del Lys and the Colle dell'Autaret used for trade and migration since Roman and medieval times. The valleys also saw the passage of the Waldensians, a reformist religious movement that found refuge in these areas during periods of persecution.

with conserving fragile ecosystems³².

Valsesia, part of the Pennine Alps, lies between the Aosta Valley to the west, Val d'Ossola to the east, and Val Grande to the south. Stretching from the lower Sesia River to the Monte Rosa massif, the valley is defined by its river system, which has shaped the landscape and human settlements. Its cultural identity, shaped by Walser settlement and described in *section 4*, continues to inform regional planning and heritage conservation. Economically, it transitioned from a traditional reliance on agriculture, forestry, and artisanal production to a more diversified economy during the 19th and 20th centuries. Building on the processes traced previously, industrialization introduced small-scale manufacturing that coexisted with artisanal sectors, leaving a dispersed network of productive sites now subject to recycling and regeneration. In recent decades, tourism has become a central aspect of Valsesia's economy, with alpine sports and cultural tourism drawing visitors to the region. While economically significant, this shift poses a challenge in balancing economic development with the preservation of ecological systems and cultural landscapes. The impact of climate change—altered snow patterns and environmental fragility—further complicates this balance, calling for integrated spatial strategies addressed later in this section.

Val d'Ossola extends from the Swiss border in the north to the plains of the Po River basin in the south, within the province of Verbano-Cusio-Ossola. The valley encompasses the entire watershed of the Toce River and its tributaries, forming an ecologically and economically crucial complex hydrological system. Framed by the Lepontine and Pennine Alps, the Ossola valley, already analyzed in *05* through its hydropower and industrial evolution, remains a major ecological and infrastructural hinge between Italy and Switzerland. Hydroelectric power remains a key industry, though increasingly challenged by the need to address environmental pressures and the impacts of climate change on water availability. Its hybrid cultural identity, shaped by long-standing cross-border exchanges, as outlined earlier, continues to inform contemporary strategies for sustainable development. Today, the region faces complex challenges related to climate change, including glacial retreat, altered weather patterns, and more frequent extreme weather events. These changes impact agriculture, infrastructure, and tourism, particularly winter sports, while posing broader risks to local communities.

³² In particular, the development of winter sports, such as skiing at resorts like Pian della Mussa and Usseglio, and summer hiking has attracted an increasing number of visitors.

Demographic decline and the future of alpine cultural landscapes

Depopulation is not exclusive to the Valli di Lanzo, Valsesia, and Val d'Ossola. Instead, it mirrors a broader trend impacting large parts of the Alpine region for decades. Many mountain areas across the Alps have experienced significant depopulation due to the migration of younger generations to urban centers. This trend has been particularly pronounced in regions where traditional agricultural and pastoral economies have declined, leaving local communities vulnerable to demographic shifts and economic challenges (Bätzing 2003). The Valli di Lanzo, Valsesia, and Val d'Ossola have all experienced similar demographic pressures. Younger generations, faced with limited job opportunities in their home valleys, often seek better prospects in nearby cities like Turin or abroad. While this migration trend offers individuals new opportunities, it has left these valleys at risk of long-term population decline, echoing patterns in many other parts of the Alps. In the Valli di Lanzo, depopulation is particularly noticeable in the smaller, more isolated villages. As young people leave, local economies, once sustained by agriculture, livestock rearing, and small-scale mining, struggle to adapt. The traditional agricultural systems that shaped the landscape are in decline, leaving behind an aging population that finds it challenging to maintain the same activity level and community cohesion³³. In Valsesia, a similar story unfolds. As in many Alpine valleys, the younger generations have sought work outside the region, particularly in larger urban centers. This has weakened traditional economic activities, such as agriculture, forestry, and artisanal crafts. Alagna Valsesia, once a stronghold of Walser culture, now faces demographic challenges, with fewer young people staying to maintain the region's rich cultural heritage³⁴. Val d'Ossola has likewise seen a steady demographic decline. In many of the valley's smaller towns and villages, the migration of young people in search of better employment opportunities has weakened the local economy. Traditional activities, such as agriculture and pastoralism, along with some remnants of mineral extraction, have become less viable, resulting in the closure of farms and the abandonment of certain areas³⁵. In all three valleys, depopulation threatens the local economies and

³³ This trend mirrors the challenges described by Bätzing (2003), who emphasizes the difficulties in preserving cultural landscapes when rural populations shrink.

³⁴ Bätzing's (2003) analysis of Alpine depopulation also stresses the cultural impact, as the loss of inhabitants can lead to the erosion of traditional practices and languages.

³⁵ Efforts to revitalize these sectors through local products, such as cheese, wine, and chestnuts, are increasingly attempting to preserve the valley's cultural and economic vitality.

cultural landscapes, putting them increasingly at risk of abandonment. This demographic shift also complicates the provision of essential services, such as schools, healthcare, and transportation, in these isolated areas. At the same time, local governments and communities have recognized the urgency of addressing these issues. Initiatives to revitalize local economies through sustainable tourism and agriculture are gaining traction³⁶. These efforts, however, must carefully balance economic development with the need to preserve the natural environment, a key challenge in many Alpine regions. The difficulties of depopulation in the Valli di Lanzo, Valsesia, and Val d'Ossola reflect a larger pattern that affects much of the Alpine region. The decline in population poses risks to these valleys' economic sustainability and cultural heritage, but it also presents opportunities for innovation in sustainable development. By carefully managing their natural and cultural resources, these valleys may find a path to future prosperity that respects their past.

Framing extraction. Mining legacies and post-extractive landscapes In the northeastern part of Piedmont, between the provinces of Biella, Vercelli, and Verbania, lies the so-called *Ivrea-Verbania Zone*, a deep crustal unit composed of mafic rocks that exhibit a wide variety of igneous and metamorphic lithologies³⁷. This entire formation is characterized by various types of mineralization, including nickel-bearing pyrrhotite, copper-rich pyrrhotite, chalcopyrite, magnetite, sphalerite, and numerous secondary minerals. Mining activities have extensively exploited these deposits throughout the basic formation, with the most significant operations concentrated in the Valsesia and Valle Strona areas. Special focus and intensity were placed on nickel-bearing mineralizations³⁸.

The polymetallic gold deposits located in the headwaters of the southern valleys of Monte Rosa, Anzasca, Sesia, and Lys, represent a complex system of lode deposits embedded within the southwestern portion of the Monte Rosa nappe, part of the upper Penninic domain³⁹. The entire sequence has been overprinted by Alpine metamorphic events.

³⁶ Valsesia has capitalized on its heritage, while Val d'Ossola focuses on eco-tourism, leveraging its wilderness areas, such as the *Val Grande National Park*.

³⁷ Including melanocratic diorites, gabbros and metagabbros, norites, peridotites, and pyroxenites.

³⁸ Historically, mining activities began in the mid-1800s, although some deposits were known earlier, at the beginning of the century.

³⁹ This geological unit comprises polymetamorphic basement rocks intruded by late Hercynian granitoids, which are overlain by a Permo-Carboniferous sedimentary cover.

These lode systems include the *Cani-Val Bianca mine* and those in the Antrona Valley, which are structurally and geologically associated with the Penninic nappe, specifically the Camughera-Moncucco unit, Vanzone antiform, and the meta-ophiolite nappe of Antrona. Further south, minor gold-bearing lode occurrences are found in Val Toppa and upper Val Mastallone, located near the Canavese line, and hosted within mylonitic rocks derived from the Sesia-Lanzo and Ivrea-Verbano units⁴⁰. The territorial conditions outlined, marked by complex entanglements of abandonment, potential reactivation, and socio-economic fragility, point to the relevance of re-engaging with extractive geographies not as a desired outcome, but as a transitional scenario worth investigating⁴¹. While preceding chapters have explored post-extractive imaginaries grounded in degrowth, sufficiency, and ecological care, their implementation faces significant institutional, cultural, and structural barriers. In this context, extractive strategies, if critically reconfigured, may offer a temporary and reversible means to support territorial resilience, particularly in marginal and depopulated regions. The next sections, therefore, interrogate the operational and spatial logics of extraction not as a definitive model, but as a contingent response to the urgent need for territorial rebalancing. Framed in this way, mining becomes less a return to past paradigms and more a lens through which to explore how adaptation, regulation, and territorial consciousness might be activated in a time of uncertainty⁴².

⁴⁰ The central and most extensive lode systems, whether isolated or grouped in swarms of various sizes, are oriented according to a structural trend ranging *NW-SE* in the Anzasca Valley (Pestarena-Val Moriana, Borca, Val Quarazza) and *WNW-ESE* in Valsesia and Lys Valley (Mud-Jazza, Kreas-Solegna, Vallone delle Pisse, Vallone d'Indren). The paragenetic characteristics of these veins are relatively consistent across the region, featuring pyrite and arsenopyrite as dominant sulfides, with subordinate galena, sphalerite, pyrrhotite, and chalcopyrite, along with minor occurrences of copper, bismuth, antimony, silver, and mercury sulfides. The gangue minerals primarily include quartz and carbonates, with occasional scheelite. Gold is typically associated with sulfides and occurs in free form only in specific localized zones, with grades varying considerably, *from a few g/t to tens of g/t*. Historically, the average gold content in pyrite has ranged between 7-12 g/t. (Cerri et al. 2016).

⁴¹ The layered conditions described across these Alpine territories, ranging from renewed extractive interests to demographic fragility and infrastructural abandonment, underscore the urgent need to redefine territorial strategies.

⁴² This requires the articulation of situated strategies capable of engaging with each valley's material, cultural, and ecological specificity while opening paths for experimentation, reversibility, and systemic regeneration. Against this backdrop, the following chapters explore the conceptual and design-based tools through which a post-extractive Alpine future might begin to take form.

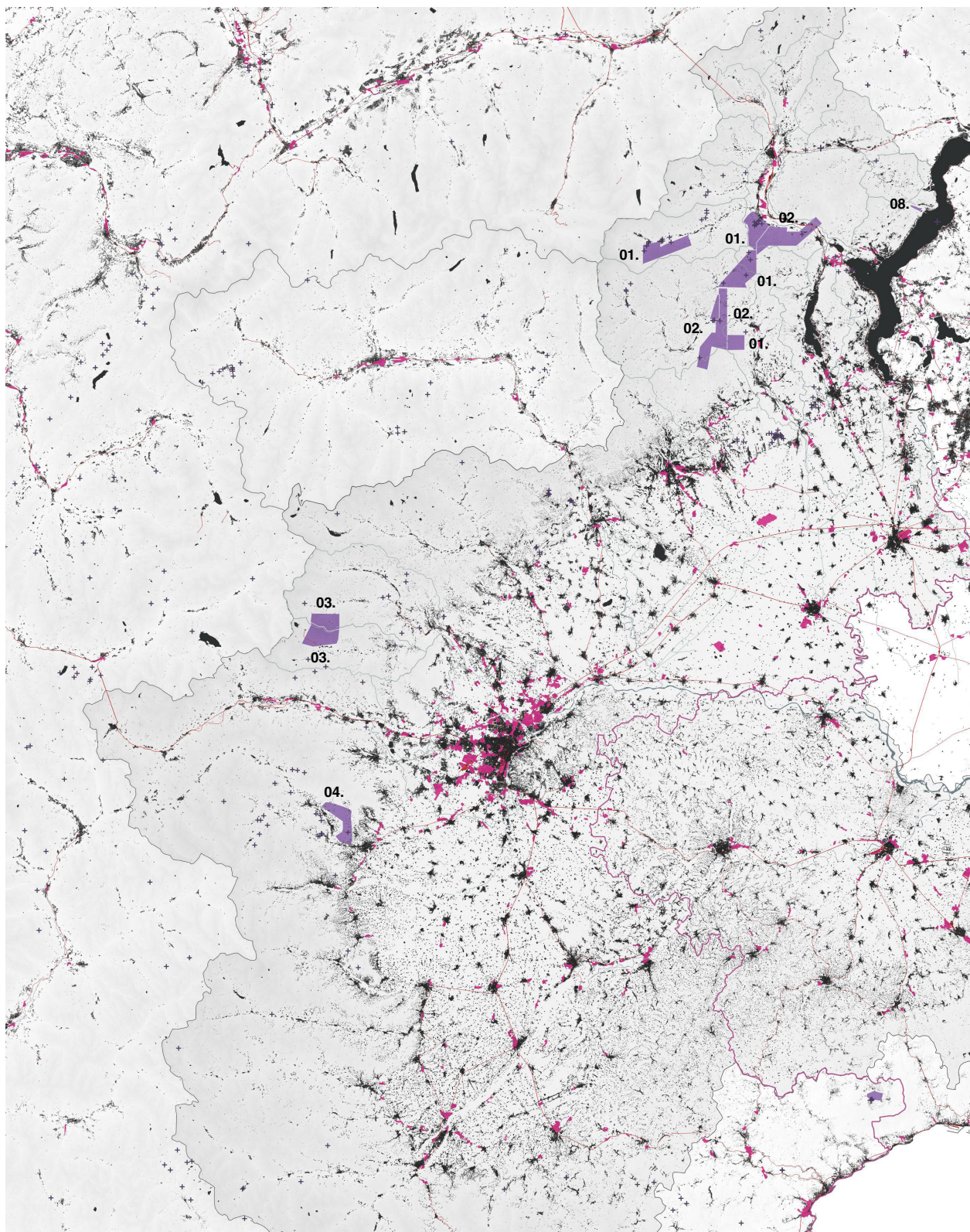


fig.10.1 Aerial view showing how the mining concessions extend over markedly different territories, many of high recognized landscape value, where former extractive areas have been fully reabsorbed into the landscape through processes of ecological and cultural reappropriation.
(Aerial survey by Davide Simoni, elaboration by the author, 2023)

fig.10.2 Map of active and requested mining concessions in Northwestern Italy (Source: *ISPRA – GeoDatabase GeMMA*). It spatializes the distribution of extractive concessions across the Alpine and sub-Alpine territories, illustrating their concentration in relation to other extractive activities and major industrial areas.

The codes identifies the types of minerals for which concessions have been requested:

- 1.** Ni, Cu, Pt, Au
- 2.** Ti, Cr, Co, Ni, Cu, Zn, Mo, Ag, Sb, N, Ac, Pb
- 3.** Co, Ag, Ni
- 4.** C
- 5.** Cu, Pb, Mn, Zn, Ag, Au, Co, Ni
- 6.** Cu, Pb, Zn, Ag, Au, Co, Ni
- 7.** Zn, Pb, Ag.
- 8.** Au, Ag, Co, Ni, W.



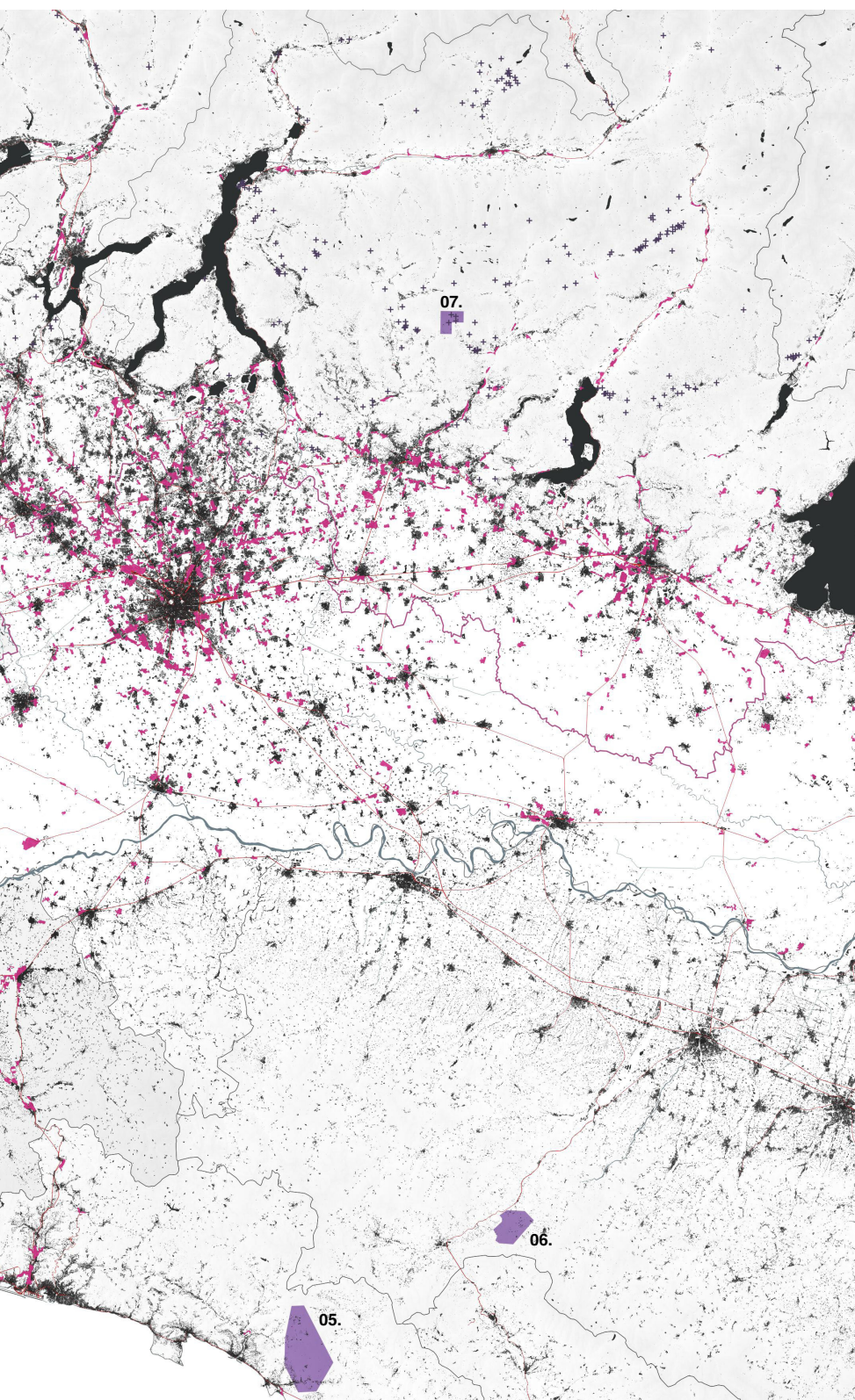


fig.10.3 The territorial section of the Val di Viù illustrates the valley's geomorphological structure and its relations with settlements and infrastructural systems.

fig.10.4 In the Val di Viù, the map highlights spatial connections between the Punta Corna concession, the hydrographic network, and the infrastructural framework, revealing the territorial coherence of the mining landscape.

fig.10.5 Series of territorial sections of the Val d'Ossola constructed at 2-kilometre intervals, illustrating the structural relationship between the valley floor and the surrounding highlands, and the position of the mining concessions within this system.

fig.10.6 In this case, the series of sections through the Valsesia, drawn at the same 2-kilometre frequency, reveals the morphological gradient between lowlands and uplands and the distribution of concessions along the longitudinal profile of the valley.

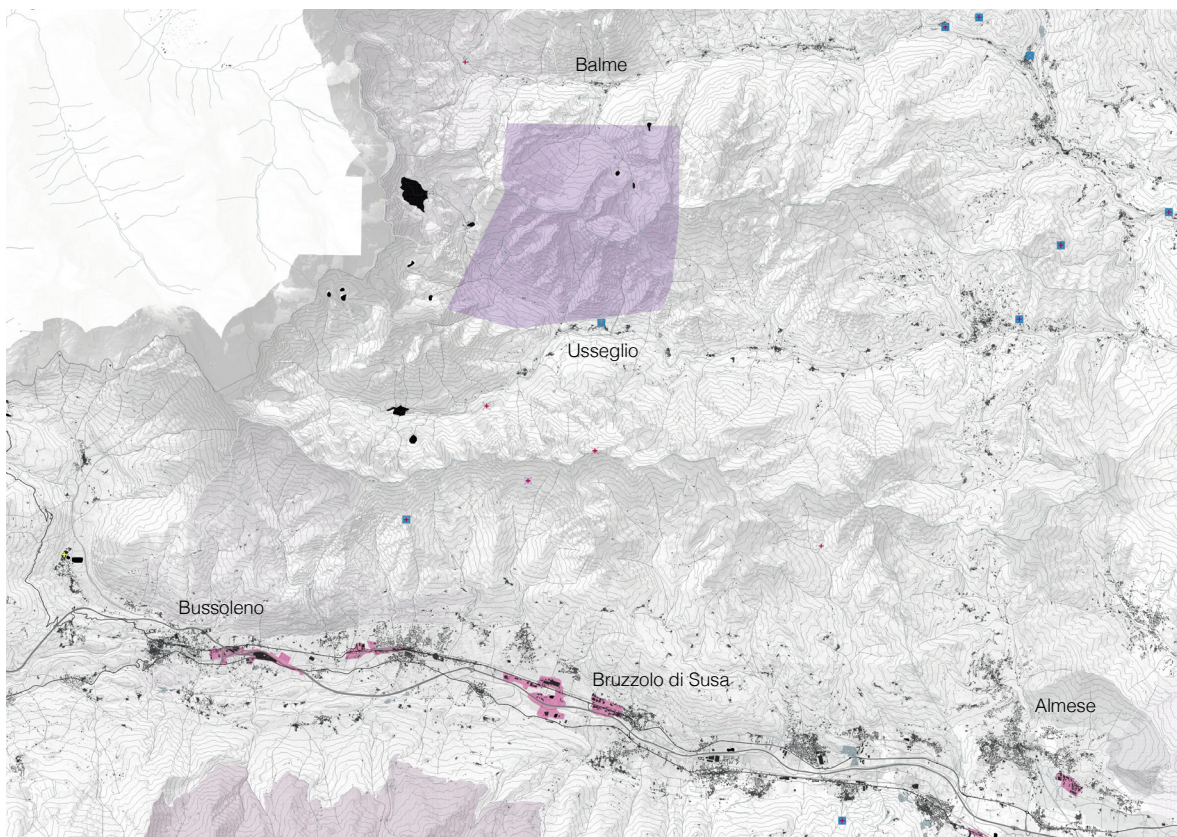
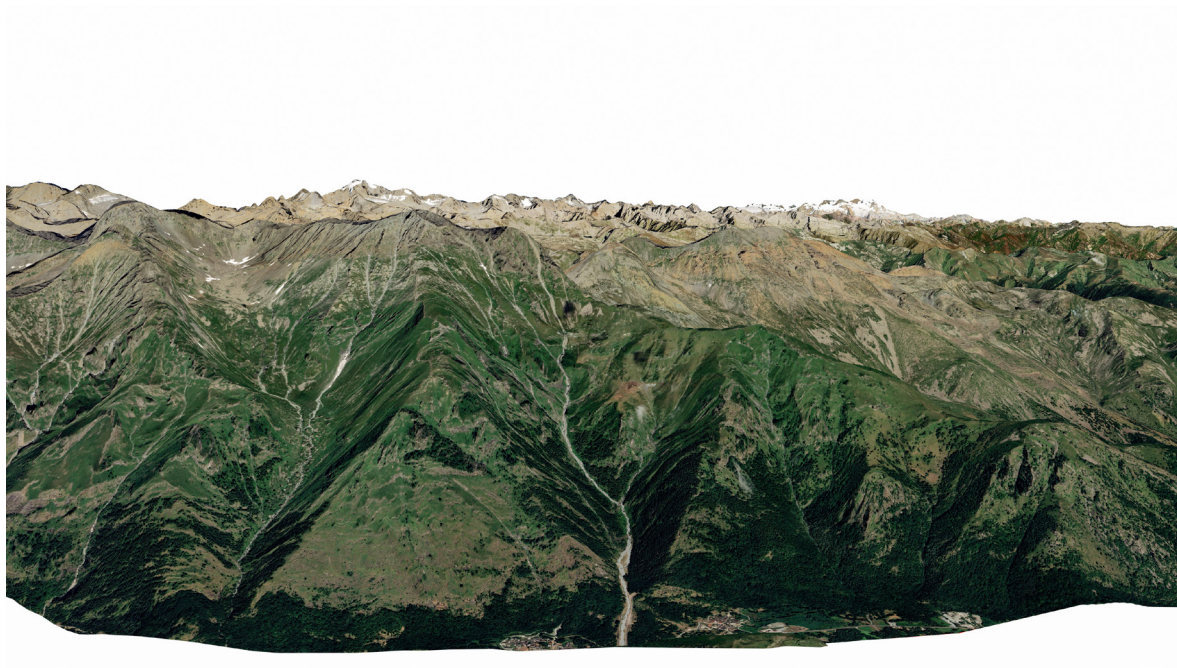
fig.10.7 In the Valsesia, the territorial section traces the morphology of the valley, revealing the connections between topography, settlement distribution, and infrastructural patterns.

fig.10.8 Mapping of the Valsesia shows the overlap between present mining concessions and historical extraction sites, in relation to industrial areas and the hydrographic system, extending the territorial conditions observed in the previous case.

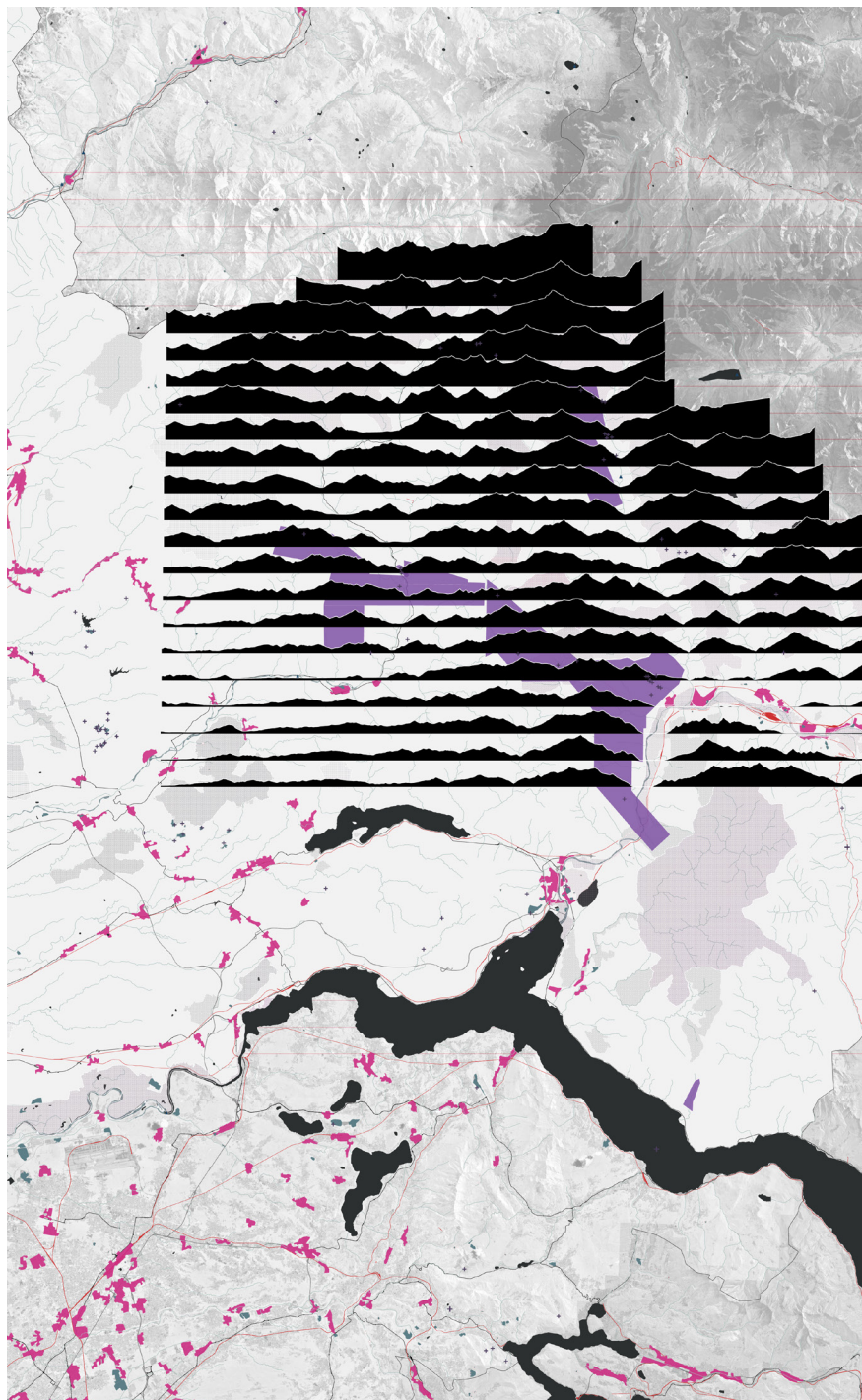
fig.10.9 Through the territorial section of the Val d'Ossola, the structural configuration of the valley emerges in relation to productive landscapes, settlements, and infrastructure.

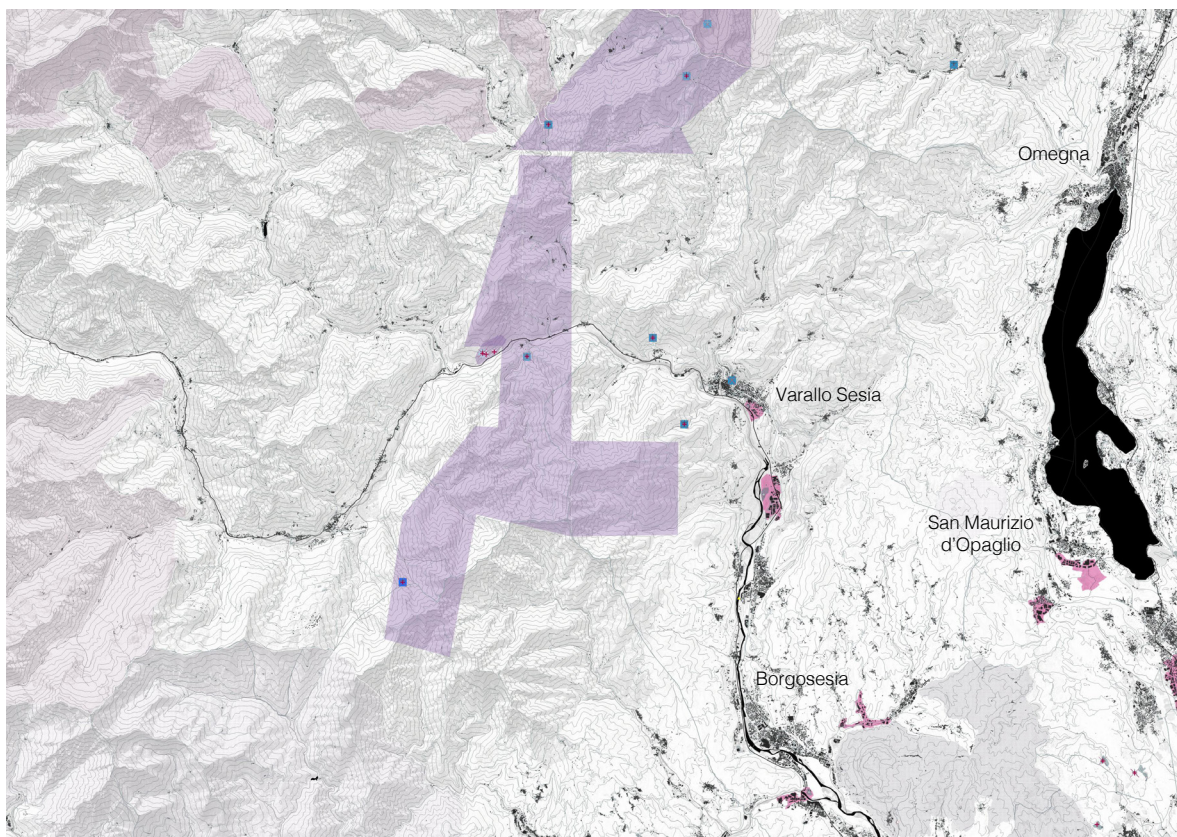
fig.10.10 In the Val d'Ossola, the cartographic representation underlines the interdependence between extractive concessions, hydroelectric infrastructures, and territorial morphology, completing the comparative reading across the three valleys.

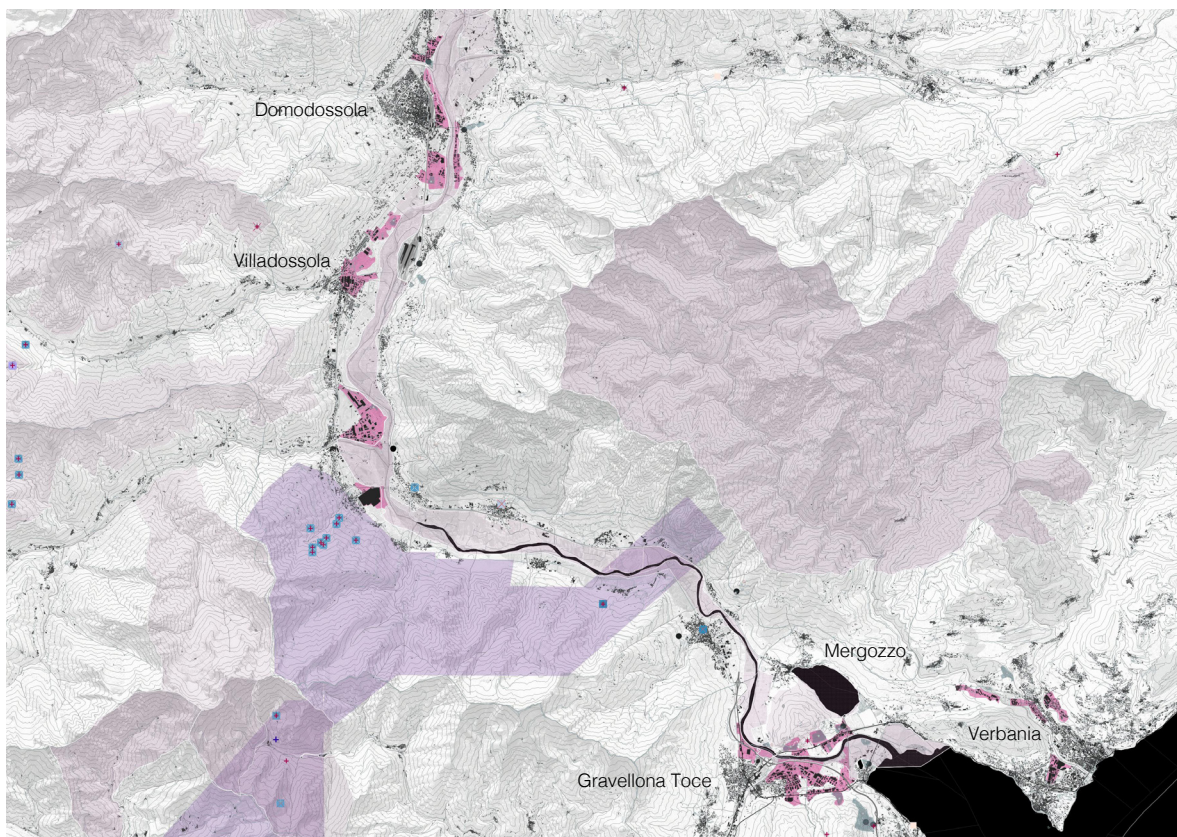
fig.10.11 Geological map of Piedmont highlighting the main lithological formations across the region. The map emphasizes the structural continuity between Alpine, pre-Alpine, and lowland areas, illustrating the spatial distribution of geological units as detailed in the accompanying legend.

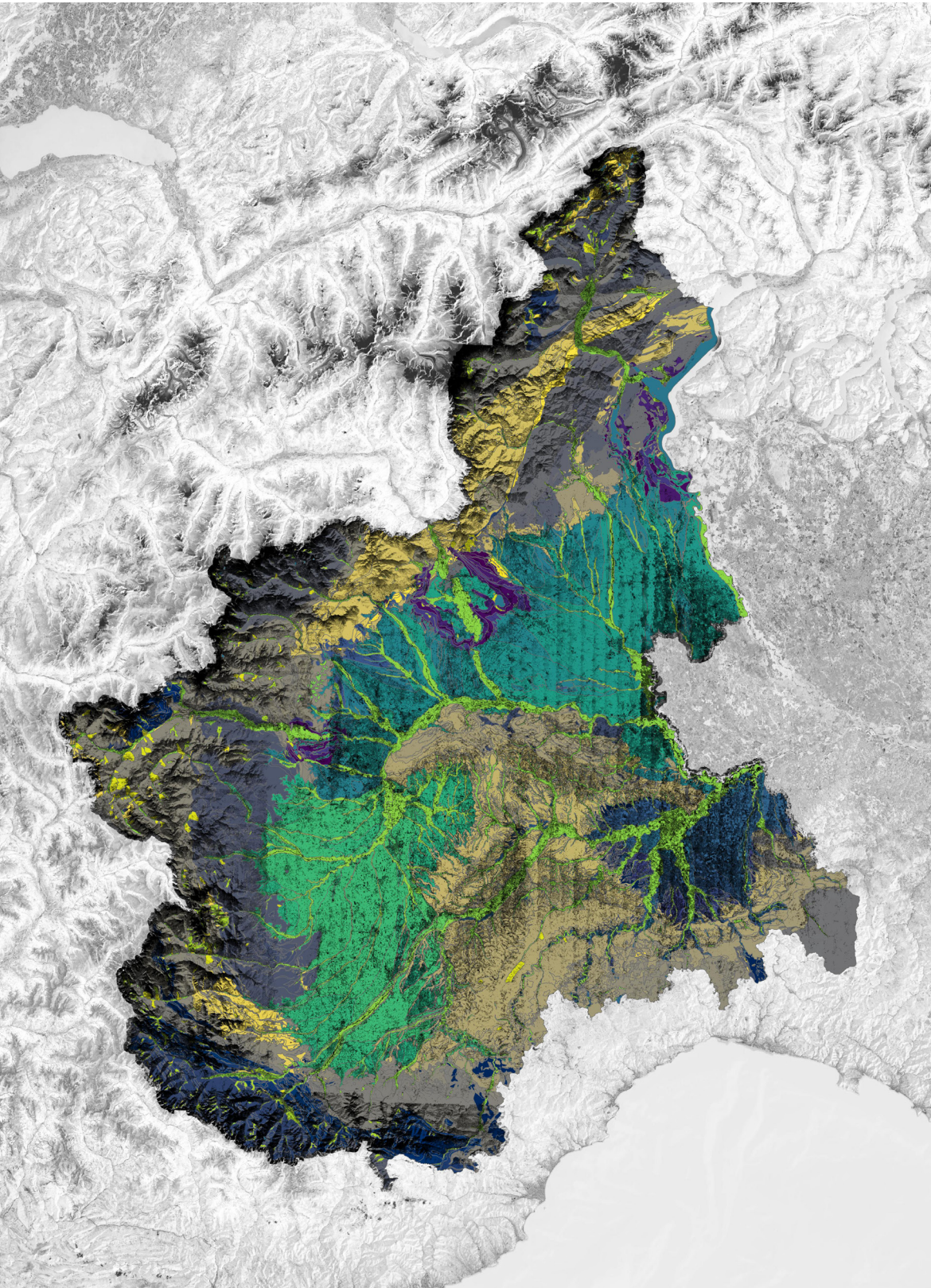












■	Amphibolite
■	Arenite
■	Basalt
■	Breccia
■	Carbonate Rich Mudstone
■	Claystone
■	Conglomerate
■	Diorite
■	Dolomite
■	Gabbro
■	Gneiss
■	Granite
■	Granofels
■	Hornfels
■	Limestone
■	Marble
■	Migmatite
■	Monzodiorite
■	Phyllonite
■	Orthogneiss
■	Paragneiss
■	Peridotite
■	Quartzite
■	Rhyolite-Conglomerate
■	Schist
■	Serpentinite
■	Shale
■	Shale-Dolomite
■	Silicate-bearing marble
■	Siltstone-Arenite-Claystone
■	Slate
■	Tonalite

10.1.infrastructures and territorial recycling between reactivation and new mining sites

The first set of themes explored how extraction landscapes are not merely sites of depletion but also spaces where materials, infrastructures, and territorial dynamics can be reconfigured. Through recycling infrastructures and territories, we have observed that reactivating mining sites cannot be treated as a singular intervention. Rather, it must be framed within the broader context of reusing and adapting existing infrastructures. Many of these Alpine landscapes hold untapped material and logistical resources, hydroelectric facilities, abandoned transport networks, and extractive sites that could be reintegrated into regional development strategies. At the same time, new synergies between ecological and industrial logics demonstrate that extraction cannot exist in isolation. It must be woven into regenerative cycles that align resource use with landscape and ecosystem transition processes. These dynamics suggest a fundamental shift: from viewing Alpine territories solely as resource providers to recognizing them as spaces for experimentation, where circular perspectives on extractive economies and waste-to-resource approaches challenge the linear logic of depletion. In this sense, cobalt mining is not merely a return to past extractive economies but an opportunity to rethink the relationship between materials, landscapes, and infrastructures in transition.

The Alps have historically been viewed as natural barriers or marginal spaces. Still, in recent years, understanding has shifted, recognizing them as central to the social, economic, and environmental dynamics of the regions they traverse. The Alps, in particular, stand out as a critical feature in European geography. This mountain range has become emblematic of how natural landscapes can serve as vital infrastructure. Far from being peripheral, the Alps are pivotal in connecting regions, providing essential ecosystem services, and supporting human activities ranging from tourism to sustainable energy. In this context, the Alps can be re-envisioned as a natural resource and a central component of European infrastructure, with their significance extending beyond their peaks and picturesque landscapes⁴³. They serve as ecological infrastructure, are critical for biodiversity preservation, and provide ecosystem services essential for the well-being of European societies (Price 2000). Concurrently, the Alps are shaping the environmental policies of the countries they span, and conservation efforts underscore the need to balance development pressures with the region's ecological and cultural

43 The range provides freshwater to millions of people through river systems such as the Rhine, Rhône, and Po, which originate in the Alps.



fig.10.12 Aerial perspective illustrating the proximity between the Valmaggia concession site and the settlement, itself connected to the infrastructural system unfolding along the Sesia valley.

(Aerial survey by Davide Simoni, elaboration by the author, 2023)



fig.10.13 In Isola di Vocca, the same sequence of spatial relations between settlement, concession area, and infrastructure becomes clearly legible within the valley landscape.

(Aerial survey by Davide Simoni, elaboration by the author, 2023)

significance. Thus, the Alps can be considered both a natural feature and a collective responsibility, an infrastructural entity that necessitates coordinated governance across national boundaries.

Beyond their environmental contributions, the Alps are deeply integrated into Europe's socio-economic fabric. The development of transportation networks through them has transformed this natural barrier into a crucial corridor for European connectivity⁴⁴. The tunnels reduce travel times and foster trade and mobility, strengthening economic ties between northern and southern Europe. The Alps are far from isolated. Instead, they serve as a core network for mobility and transport, connecting urban centers across Europe. Besides, the tourism industry in the Alps highlights its socio-economic role. Tourism has transformed mountains into consumption spaces (Debarbieux and Rudaz 2015), where leisure, sport, and culture converge. They also hold political and cultural significance that further justifies their conceptualization as infrastructure. Historically, mountains were perceived as obstacles to progress, a view that shifted during the Enlightenment. The shift from being seen as wild to spaces of political interest began notably when European states asserted control over their high-altitude borders. Today, they are physical and political boundaries, representing national identity and transnational cooperation. The region's unique cultural heritage, from language and traditions to architecture, adds a layer of human infrastructure to its physical and ecological elements⁴⁵.

Extraction, logistics, and territorial reconfiguration along the Rhine-Alpine corridor The Genoa-Rotterdam Corridor, also known as the *Rhine-Alpine Corridor*, is one of Europe's most significant transnational transportation routes, facilitating the movement of goods and people between the Mediterranean and the North Sea⁴⁶. This corridor spans approximately 1,300 kilometers, connecting two of Europe's largest ports, Genoa in Italy and Rotterdam in the Netherlands, while traversing critical regions in Switzerland, Germany, and the Alpine arc. As its central segment, the Alpine stretch is a gateway between northern and southern Europe. It is a natural passage and a vital node within Europe's economic, environmental, and infrastructural systems. The corri-

⁴⁴ Key infrastructure projects, including the Gotthard and Brenner Base Tunnels, epitomize this shift.

⁴⁵ In this framework the Alps are thus a living infrastructure, where tradition and innovation coexist, shaping the region's future within the broader European framework.

⁴⁶ https://transport.ec.europa.eu/other-pages/transport-basic-page/rhine-alpine-core-network-corridor_en

dor intersects major economic zones: the industrial districts of northern Italy, the manufacturing core of Germany, and the commercial hubs in northern Europe. This transformation has been enabled by large-scale transportation projects that carve through the Alpine terrain, allowing for faster and more efficient connections. *The Gotthard Base Tunnel* (GBT) in Switzerland is a monumental example of how Alpine geography has been harnessed to enhance connectivity⁴⁷.

In this case, the Alpine region's strategic importance lies primarily in facilitating European trade flows. The corridor is responsible for a significant portion of Europe's freight transport, particularly for goods moving between the Mediterranean and the northern part. Ports serve as gateways for global trade, and the Alpine region forms the crucial land bridge connecting these ports to Europe's industrial and commercial centers. As a result, the area has become an indispensable hub in European logistics. The infrastructure within the Alps, including the GBT

⁴⁷ Opened in 2016, the GBT dramatically reduced travel time for goods and passengers traversing the Alps, alleviating road congestion and providing a more efficient and sustainable means of transport. This tunnel is part of a broader network of infrastructural developments aimed at integrating the Alpine region into European logistics and supply chains.

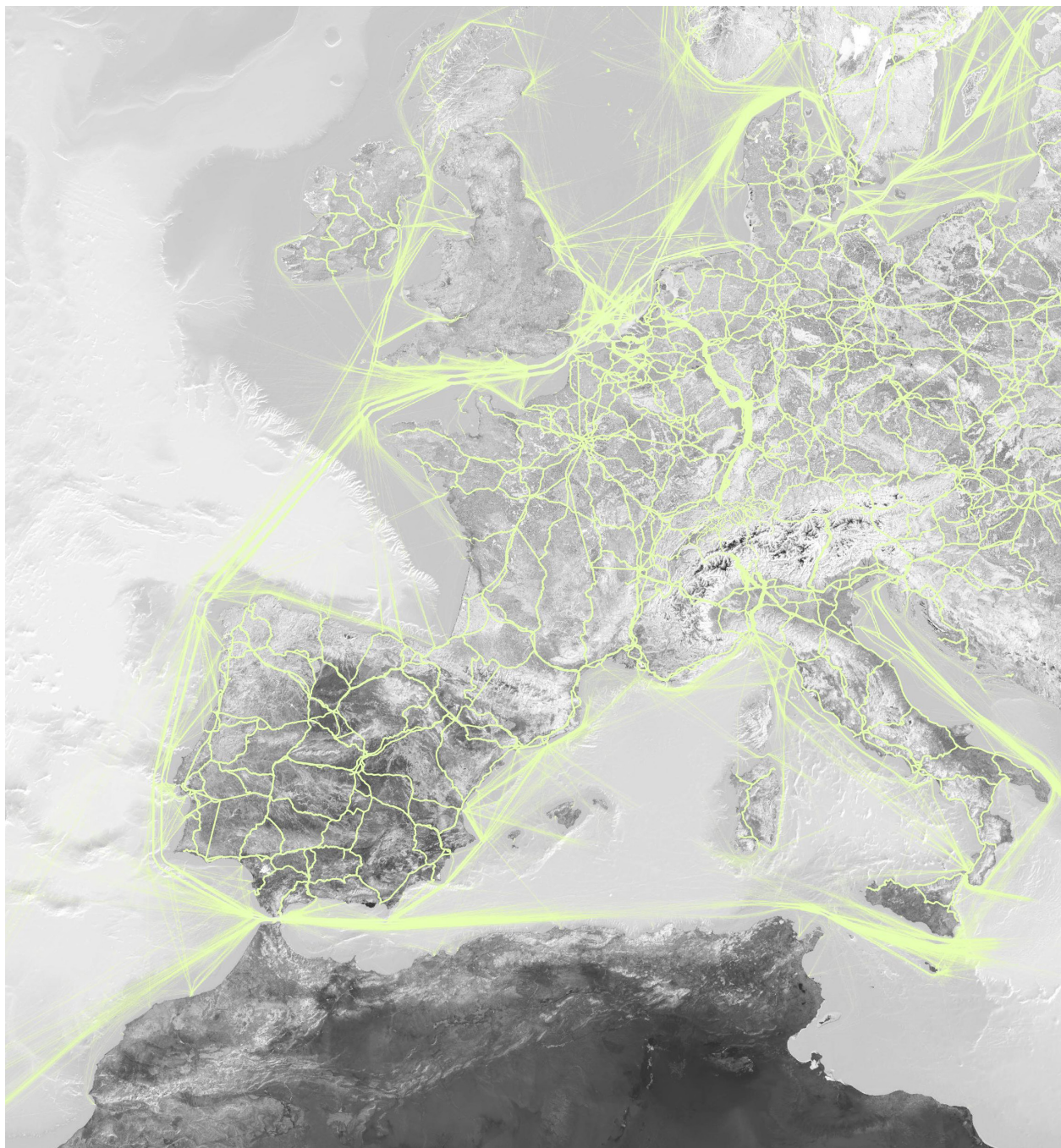
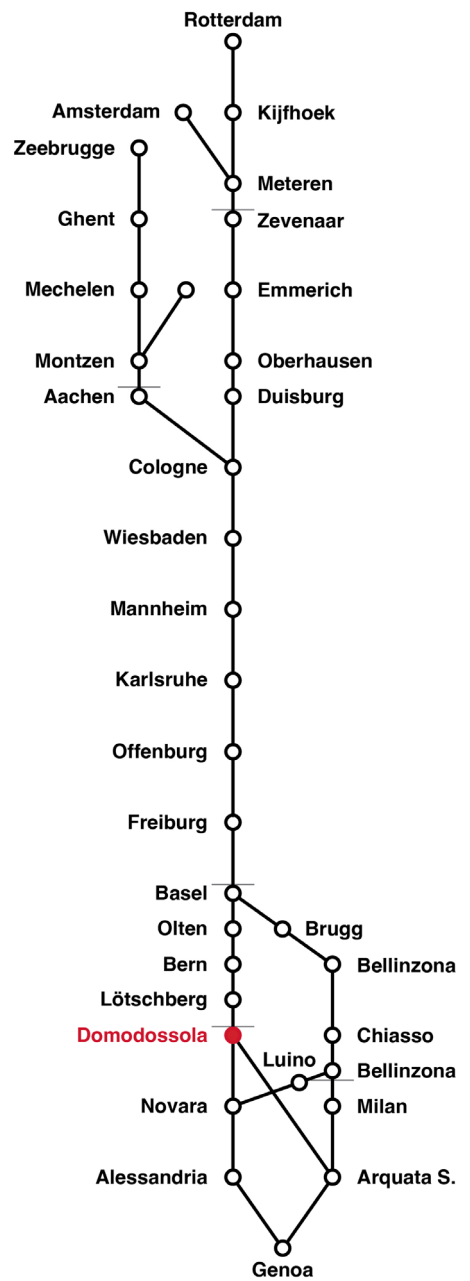
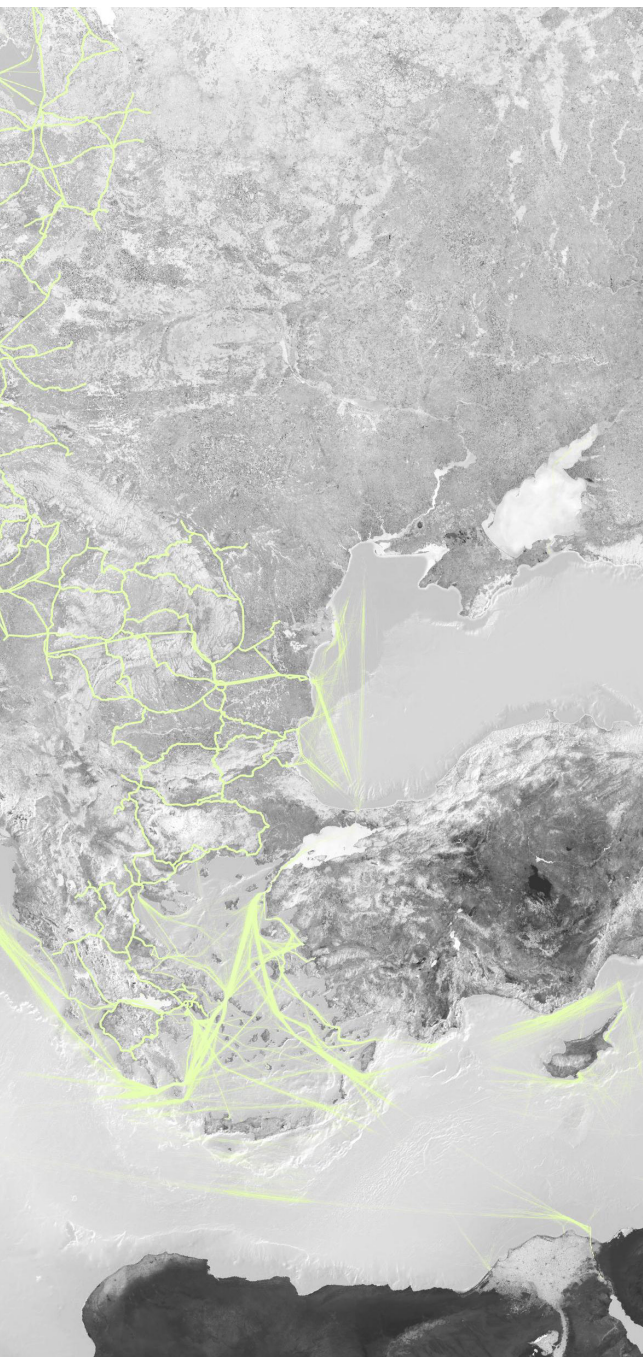


fig.10.14 European-scale map combining the TEN-T railway network with major maritime routes connecting key EU ports, based on data from the European Marine Observation and Data Network (EMODnet).

fig.10.15 Schematic representation of the Genoa–Rotterdam corridor, depicting the rationalized structure of the trans-European transport network as it crosses the Alpine region, with Domodossola highlighted as a fundamental transboundary hub.



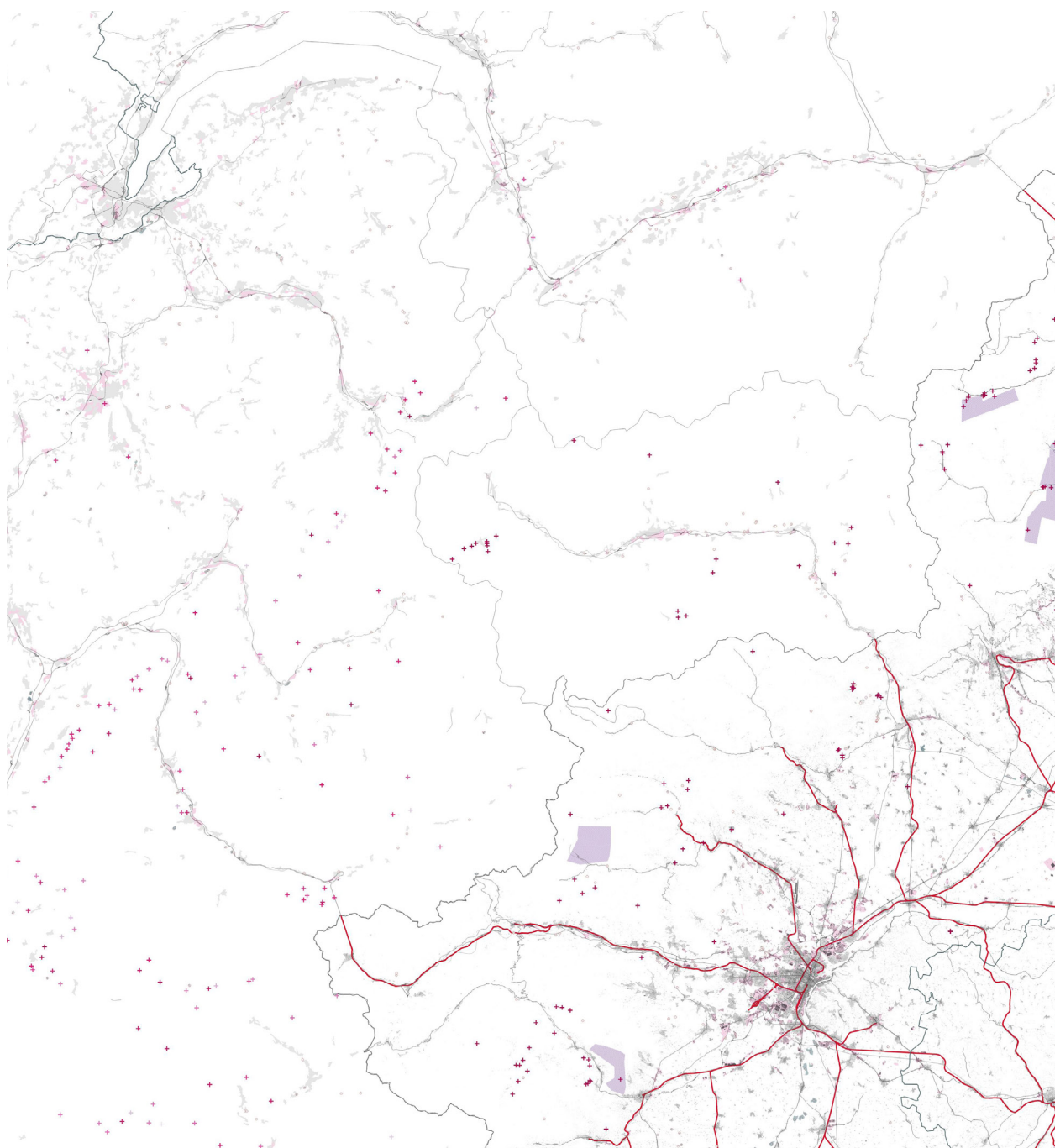


fig.10.16 Infrastructural axis, both active and latent, extending from the Novara plain to the lake district and along the productive valley floor of Domodossola toward the transboundary passage. The map traces its relation to existing and potential extractive sites and mining concessions, outlining how mobility infrastructures could be reactivated not only for trade and logistics but also reimagined as a shared territorial framework, an infrastructural commons reconnecting productive, ecological, and social dimensions.



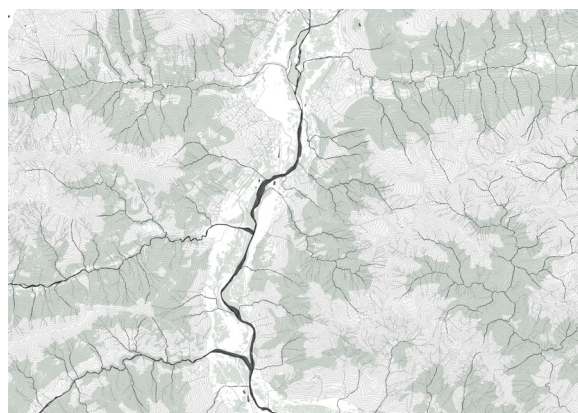
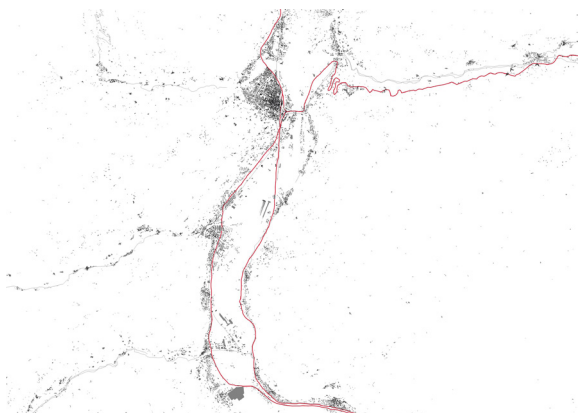
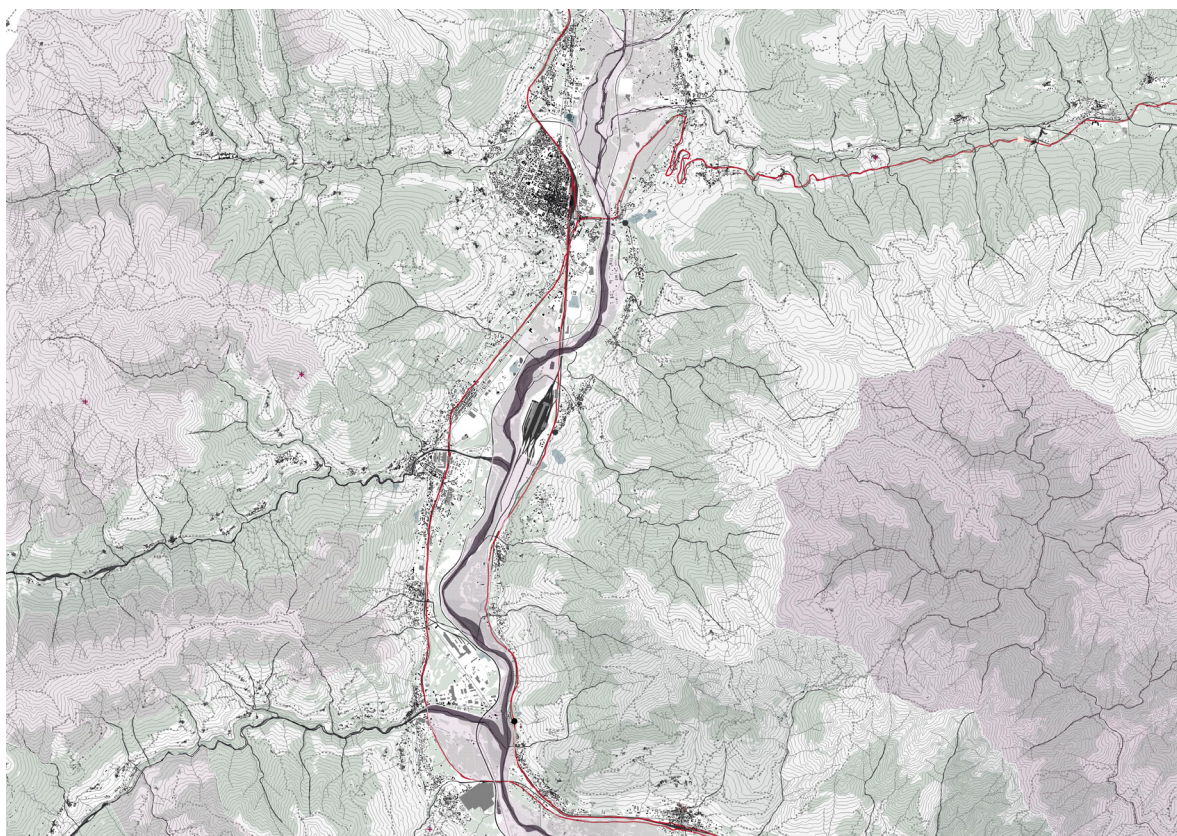


fig.10.17 Zoom on the Domodossola junction (Domo 2), illustrating the convergence of rail and road infrastructures and their proximity to productive areas and extractive sites within the valley system.

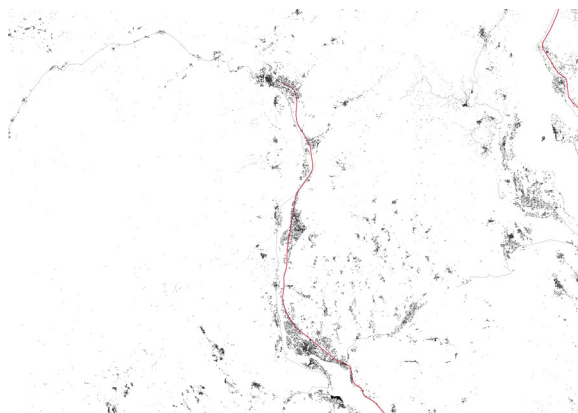
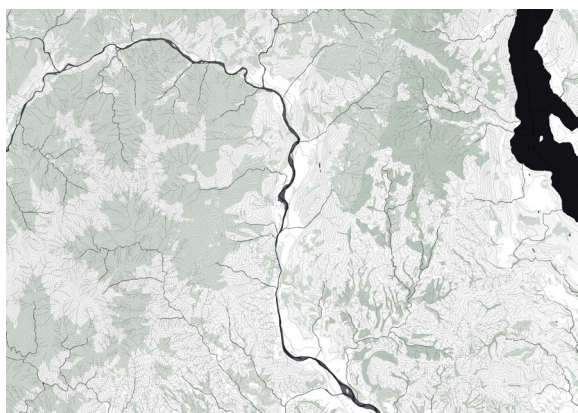
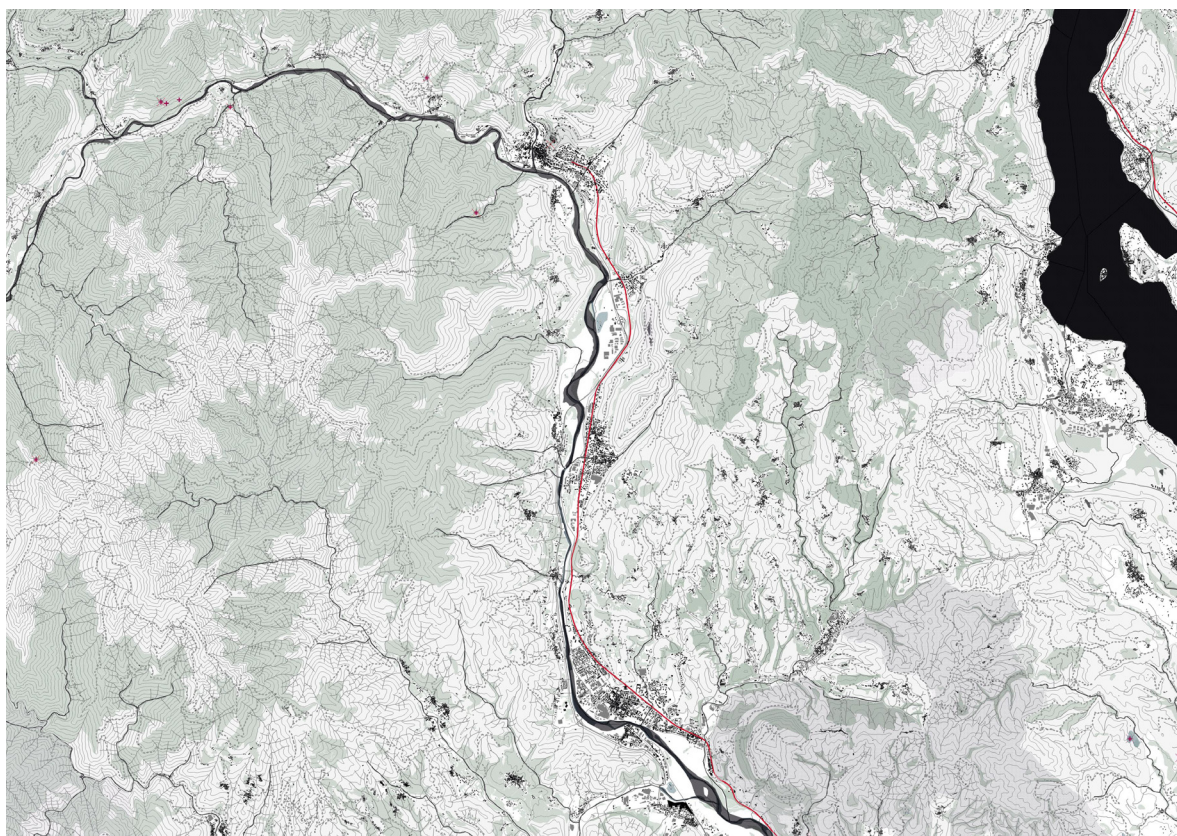


fig.10.18 Zoom on the terminus of the Novara–Varallo Sesia railway line, deactivated for passenger service in 2014, showing the interface between the infrastructural corridor, the urban fabric, and the surrounding landscape.

and other rail and road networks, plays a crucial role in ensuring the smooth transit of goods. The shift from road to rail freight transport, a critical policy objective, further underscores its strategic significance. In this context, the region is a physical passage and a vital part of a broader effort to create more sustainable and efficient transportation networks across Europe. Also, it brings significant environmental and economic implications⁴⁸. Heavy traffic through the Alpine passes has long posed ecological challenges⁴⁹. However, the infrastructure improvements, particularly the promotion of rail transport, aim to mitigate these environmental impacts while maintaining the economic benefits of cross-border trade⁵⁰.

From a political perspective, the Alpine region's inclusion in this strategy illustrates the importance of transnational cooperation in European infrastructure planning. The Rhine-Alpine Corridor is one of the nine core network corridors identified in the European Union's *Trans-Euro-*

⁴⁸ <https://www.egtc-rhine-alpine.eu/projects/code-24/> This was an important initiative aimed at coordinating spatial and infrastructural development along the corridor. Although the official project period has ended, its findings continue to shape strategies for enhancing transport efficiency, resolving capacity issues, and promoting ecological sustainability along the corridor

⁴⁹ Including air pollution, noise, and the degradation of fragile ecosystems.

⁵⁰ The GBT, for example, is part of Switzerland's strategy to shift freight transport from road to rail, thereby reducing the environmental footprint of transalpine transport. This aligns with broader European Union goals for sustainable transport and reducing carbon emissions. The Alpine region's ability to support environmentally friendly transportation solutions while maintaining its position as a critical logistics hub enhances its importance within the corridor.

pean Transport Network (TEN-T)⁵¹, a policy to develop integrated and efficient transport infrastructure across Europe. It requires close collaboration between multiple nations, including Switzerland, which, although not an EU member, plays a crucial role in the corridor's functioning. This cross-border cooperation is essential for maintaining and developing transport infrastructure, as well as addressing standard environmental protection and sustainable development challenges⁵². Thus, its strategic importance extends beyond logistics and trade; it is a space where European nations collaborate to balance economic, environmental, and social objectives.

The northern Piedmont area is set to play a crucial role in developing the corridor owing to its strategic position. Domodossola will benefit from improvements in rail infrastructure, facilitating smoother connections between northern Italy and Switzerland. The *Domodossola Intermodal Terminal* is expected to see increased activity as it connects to the broader European rail network, offering faster, more sustainable transit

51 The *Trans-European Transport Network* (TEN-T) is a crucial element of the European Union's infrastructure policy, aimed at fostering connectivity, efficiency, and sustainability across the continent. Launched in the 1990s, this initiative seeks to create a seamless and integrated transportation system by connecting road, rail, air, sea, and inland waterway networks across member states. This supports the movement of goods and people, driving economic growth, regional cohesion, and sustainable development throughout Europe. At its core, the network's primary aim is to enhance Europe's transport infrastructure by addressing gaps, linking isolated regions, and improving accessibility. This interconnected system is essential for reducing travel times and enhancing the EU's economic competitiveness. Moreover, the project is closely aligned with the EU's climate goals, particularly the European Green Deal, by promoting environmentally friendly modes of transport such as rail and inland waterways. The modernization of transport corridors not only reduces congestion and emissions but also contributes to the overall decarbonization of the transport sector. The network is divided into two layers: the *Comprehensive Network*, which covers the entire EU to ensure all regions are well-connected, and the *Core Network*, which focuses on the most critical and strategic transport links. The Network is expected to be completed by 2030 and is centered around nine major Core Network Corridors. These corridors are essential for facilitating long-distance travel and cross-border connectivity. They are designed to be multimodal, integrating various forms of transport to maximize efficiency and sustainability. The European Union supports the development and expansion of this transport system through several funding mechanisms, with the *Connecting Europe Facility* (CEF) being a key instrument. CEF provides grants for projects that help to remove bottlenecks, improve infrastructure, and foster digitalization in the transport sector. These investments are critical to ensuring that the network meets modern standards while aligning with broader EU policies—such as the *Sustainable and Smart Mobility Strategy*, which promotes digital and environmentally friendly advancements in transportation.

52 The Alpine region, with its complex topography and ecological sensitivity, requires coordinated efforts to ensure that its role as a transit region does not come at the expense of its natural and cultural heritage.

through the Simplon Tunnel⁵³. Novara, situated along the Genoa-Milan rail line, will see its role as a critical logistics and industrial hub within the corridor enhanced. The city already has a well-established network of intermodal terminals and distribution centers serving northern Italy and southern Switzerland. Improvements in connectivity via high-speed rail and road networks will likely increase freight-handling capacity at Novara's logistics centers⁵⁴.

The Rhine-Alpine Corridor focuses on promoting sustainable transport, primarily through the Gotthard Base Tunnel in Switzerland and other Alpine rail tunnels, thereby reducing reliance on road transport. For Domodossola and Novara, this shift means reducing heavy road traffic, with environmental benefits such as reduced emissions and less road congestion, especially in sensitive alpine environments. Economically, both Domodossola and Novara stand to benefit from their roles in handling increased freight volumes. Local industries, particularly logistics, manufacturing, and distribution, are expected to grow, supported by improved infrastructure and better connectivity to European markets. These developments will also create jobs in logistics, transportation, and related sectors. The area will integrate more into Europe's essential freight and transport networks through the Genoa-Rotterdam Corridor. Rail improvements and the expansion of intermodal logistics will enhance its role as a strategic gateway between Italy and northern Europe while contributing to environmental sustainability goals. This transformation will have long-term economic benefits, bolstering local economies and industries.

The potential to reactivate these infrastructures extends beyond their functional revival. It offers an opportunity to redefine how Alpine territories integrate with urban-industrial corridors, ensuring that their reconnection serves extractive imperatives and contributes to territorial cohesion. Alpine infrastructures have historically been shaped by productive cycles that, left unmediated by a territorial project, reinforce fragmentation rather than integration. The material legacy of extractive economies, disused roads, logistical hubs, and obsolete industrial sites,

⁵³ <https://www.corridor-rhine-alpine.eu/about-us.html>.

⁵⁴ Novara's proximity to Milan and its connection to significant transport routes also positions it to play a critical role in enhancing the efficiency of freight movement within northern Italy. The corridor's infrastructure upgrades, particularly the railway improvements, will reduce congestion and increase the reliability of services between the Port of Genoa and north Europe, directly benefiting Novara.

can either become a network of reactivation or a landscape of dereliction, depending on how these spaces are reinterpreted with ongoing infrastructural transformations. The planned reactivation of the Novara–Varallo railway line, originally designed to extend to Alagna, suggests the potential for a light-rail system running through the valley. Beyond its historical function, this infrastructure represents a possible prototype for how mobility in Alpine valleys could shift away from extractive dependence toward a regional connective logic. Such a system could reduce reliance on road transport, enhance local connectivity, and support more sustainable economic models that align with broader regional development goals. These considerations extend to the logistical integration of extractive industries within broader regional and European transport networks. The demand for critical metals is inseparable from the capacity to transport, process, and distribute these materials, requiring an infrastructural strategy that minimizes territorial and environmental impacts.

In this sense, the Alps can be understood as a continental equivalent of the Mediterranean: a complex geography of resources and trade corridors where historical extraction routes now intersect with emerging logistical economies. A key example is *Domo2*, the intermodal freight terminal in Domodossola, which functions as a crucial port within this Alpine system, connecting raw material flows to the expanding logistics hubs of Novara and Piacenza. Just as Mediterranean ports channel global maritime trade into European supply chains, *Domo2* plays a pivotal role in absorbing and redistributing transalpine freight traffic, particularly in growing rail-based logistics corridors linked to the Rhine-Alpine axis. The renewed relevance of such nodes suggests that any extractive resurgence must be planned not as an isolated operation but as part of an evolving infrastructure of material flows, linking extraction to processing and distribution within a broader European economic geography. In this framework, the case of Domodossola and the broader Ossola Valley exemplifies a form of infrastructural and territorial reconfiguration that moves beyond the classical narratives of either abandonment or resilience.

The project, located at the threshold between national and transalpine logistic systems, is not simply a technical node but a spatial device that embodies the region's attempt to reinsert itself into broader mobility, production, and innovation networks. It is being reimagined as a new intermodal hub capable of reconnecting the valley with key European

corridors while accommodating space for light manufacturing, services, and research as part of a larger strategy to reconvert obsolete railway and logistics infrastructure. In this sense, it represents a paradigmatic case of territorial recycling in which infrastructures are neither erased nor monumentalized but reworked into a contemporary regional metabolism (Sega 2018). This process is not neutral. It entails a profound redefinition of the valley's socio-spatial relations, particularly in mobilizing dormant spatial assets and previously marginal lands. The shift from a passive logistical hinterland to an active territorial interface suggests a broader recalibration of the Ossola Valley's economic geography. In this case, infrastructure recycling serves as a form of anticipatory design, responding to ecological urgencies, transport efficiencies, and the demand for new territorial centralities in regions that have experienced decades of industrial delocalization and demographic decline. Crucially, Domodossola's position at the intersection of multiple layers enables a rereading of Alpine peripheries not as terminal spaces but as reconfigurable thresholds. The case invites a broader reflection on how former servant territories, historically configured to channel resources outwards, might be re-territorialized through a new ecology of infrastructures, hybrid spaces where mobility, production, and territorial care coexist.

Reconfiguring Alpine infrastructures While mobility infrastructures have traditionally dominated the discourse on territorial recycling in Alpine contexts, it is increasingly evident that a more comprehensive approach must also address the latent infrastructural ecologies embedded in energy systems. Among these, hydropower represents a crucial yet often overlooked layer. Despite being materially pervasive and historically transformative, hydroelectric infrastructures frequently recede from the perceptible landscape, becoming part of the invisible landscape of energy transitions (Ferrario and Castiglioni 2015). These landscapes do not merely shape material geographies: they generate hidden territorial hierarchies, long-distance dependencies, and asymmetrical exchanges that have structured Alpine valleys across the twentieth century and beyond. In this light, infrastructures such as dams, reservoirs, pipelines, and underground channels, many of which are still operational or undergoing reactivation, should be regarded as key components of the contemporary recycling project of the Alpine territory. Their visibility may be partially or entirely suppressed, but their spatial and political agency remains significant. These invisible landscapes, shaped

by past energy regimes, alter local ecologies and economies and retain the capacity to frame new territorial imaginaries by reinterpreting them through the lens of infrastructural reuse rather than abandonment or obsolescence. A different geography of potential emerges, complicating the binary between technological heritage and environmental risk and opening new debates on governance and territorial justice.

Similar tensions between visibility and infrastructural persistence can be observed across the three valleys under investigation. In the Ossola region, the hydroelectric system presents a particularly dense and layered presence: multiple plants remain operational with minimal formal adaptation, silently sustaining long-established energy flows between mountain and plain. Their physical traces are often absorbed by the landscape or concealed beneath it, yet their spatial and ecological implications remain considerable. In Valsesia, a more fragmented hydroelectric geography emerges, shaped by a mix of legacy infrastructures and more recent, small-scale installations. While their impact may appear modest, their cumulative spatial and ecological footprint raises critical questions regarding territorial equity and long-term landscape transformation. In the Lanzo valleys, the presence of hydroelectric plants is comparatively more diffuse. However, it still exemplifies the subtle persistence of invisible infrastructures that mediate resource extraction, often with limited public visibility and local benefit.

If infrastructures such as hydroelectric plants and mobility corridors shape the latent geographies of Alpine valleys, institutional tools like territorial programs reveal how these spatial legacies are being strategically reframed. Among them, a recent territorial program⁵⁵ offers a significant lens on current efforts to reterritorialize energy and infra-

⁵⁵ In the context of regional planning in Piedmont, the term ‘*territorial program*’ refers to the *Programma Territoriale Integrato (PTI)*, a policy instrument promoted and coordinated by the Regione Piemonte to implement the objectives of the Regional Territorial Plan and the European Cohesion Policy. PTIs are elaborated through partnerships among municipalities, Mountain Unions (*Unioni Montane*, which replaced the former *Comunità Montane* under Regional Law no. 11 of 28 September 2012, *Disposizioni organiche in materia di enti locali*, *B.U.R. Piemonte n. 39 S2/2012*), provinces, and local stakeholders, and are formally approved by the Regional Council. Each program defines an integrated strategy for sustainable development within a defined territorial area, combining environmental, infrastructural, cultural, and socio-economic dimensions. They identify priority projects, allocate regional and European funds, and establish governance mechanisms for their coordinated implementation. Within the Alpine context, PTIs serve as operational frameworks to link local initiatives with broader regional policies on ecological transition, energy management, and territorial innovation.

structure systems in the Ossola region⁵⁶. The program articulates a vision of quality-driven regional development, where movement is not merely mobility but a metaphor for transformation. Anchored in the Verbano-Cusio-Ossola province, the initiative explicitly addresses the reuse and reconfiguration of existing hydroelectric infrastructure, reframing it as an asset within a broader strategy of ecological transition and territorial innovation. Rather than viewing hydroelectricity solely as a technical matter, it emphasizes its potential to drive regional identity, environmental stewardship, and economic diversification. Reusing legacy energy infrastructures intertwines with broader ambitions: enhancing territorial cohesion, fostering a culture of innovation among local enterprises, and improving the quality of life through more efficient governance of natural resources. The program portrays the hydroelectric system not as a residual structure from past industrial cycles, but as an infrastructural substrate around which new economies and ecologies can arise. In this sense, it becomes a medium for spatial negotiation, reconciling local resource control with regional, national, and even European energy agendas. By emphasizing landscape quality, the document serves as both a policy instrument and a narrative device. It repositions the Ossola region from a peripheral energy supplier to a laboratory of integrated territorial governance. Within this perspective, infrastructural recycling is not only about technical retrofitting but also about reactivating the spatial imaginaries embedded in the fabric of the Alpine territory.

If, in the Ossola Valley, the energy question intersects with historical infrastructures and their territorial legacy, in the Valli di Lanzo and Canavese, the narrative shifts toward a broader ecological and socio-economic rebalancing. Another territorial program represents a strategic initiative to rearticulate these marginalized mountain territories within a framework of long-term sustainability and territorial resilience⁵⁷. The program frames development not as expansion but as a realignment of local resources, productive capacities, and governance structures, in light of emerging environmental constraints and demographic chal-

⁵⁶ The reference is to the program “*PTI V.C.O. Qualità in Movimento*”, a regional initiative developed in the Verbano-Cusio-Ossola area, which addresses the reuse and reconfiguration of existing hydroelectric infrastructures as part of a broader strategy for ecological transition and territorial innovation.

⁵⁷ This refers to the “*PTI Sviluppo Sostenibile delle Valli di Lanzo e del Canavese*”, a program aimed at promoting the ecological and socio-economic rebalancing of mountain areas through the realignment of local resources, governance structures, and productive capacities.

lenges. Its focus is not limited to reusing existing infrastructure but extends to reevaluating forest systems, soft mobility networks, and diffuse energy systems. The goal is to recombine fragmented geographies into a more integrated and self-sustaining territorial system. The hydroelectric question is present in this context, albeit more in the background than in Ossola. While water and energy are not the program's central focus, they are understood as key elements in a broader landscape of territorial metabolism. The program supports a systemic valorization of local resources conceived not in isolation but in their material and symbolic interdependence. This is particularly evident in projects that aim to activate circular flows, such as those combining forest management with bioenergy production or small-scale hydropower interventions. The valleys cease to be passive recipients of external development logic and instead emerge as laboratories for alternative economies, governance practices, and forms of inhabiting the Alpine space.

Reactivating marginal Alpine territories cannot rely solely on infrastructure interventions; it also requires cultural, symbolic, and experiential reconfigurations. A cross-border project introduces a complementary yet essential dimension to the broader territorial recycling strategies outlined in the previous cases⁵⁸. Positioned within a transboundary framework, it enhances the visibility and accessibility of often-overlooked landscapes, embedding them into new circuits of meaning, use, and value. Rather than treating tourism as an external imposition or merely an economic vector, the project reframes it as a territorial practice, capable of revealing latent ecologies and re-inscribing peripheral spaces into broader geographic imaginaries. It encourages a shift from passive conservation to active interpretation, where walking paths, local narratives, and ecological infrastructures become part of an extended system of situated knowledge. In doing so, the program contributes to the formation of a landscape-based infrastructure that is both immaterial and operational. While its direct connection to energy infrastructures may seem tenuous, its logic of reinterpretation aligns closely with the invisible geographies explored in previous sections. As hydroelectric networks carve subterranean paths of extraction and transformation, so do interpretive and experiential projects rewire perceptual and symbolic geographies. Both operate through visibility and invisibility, what is shown,

⁵⁸ The “*EXPLORLAB – Exploration Laboratory Interreg France–Italy ALCOTRA project (2017–2020)*”, focuses on enhancing the visibility and accessibility of cross-border Alpine landscapes through cultural, ecological, and tourism-based initiatives that foster new forms of territorial cooperation and landscape interpretation.

what is hidden, and what can be made legible through narrative, design, or participation. Within this perspective, exploring becomes a method of territorial activation: walking, mapping, and storytelling serve as tools for tourism development and as devices for territorial governance. This offers a framework for envisioning infrastructural recycling in material terms and for reanimating spatial meaning and collective memory.

Between narratives and strategic resources These programs collectively suggest a renewed spatial focus on Alpine territories, framing them as sites for ecological experimentation, infrastructural adaptation, and cultural revaluation. However, this vision remains incomplete unless it is set within broader geopolitical and economic dynamics. The northwestern Alpine arc, especially the Piedmontese sector, currently stands at the intersection of multiple large-scale forces: trans-European mobility networks, national logistical hubs like Novara and Alessandria, and emerging forms of strategic resource extraction. Recent interest in cobalt mining, linked to the global demand for battery technologies and green transitions, positions these valleys within a new geography of resource frontiers—one that revives extractive imaginaries long viewed as obsolete. Nevertheless, the very institutional tools designed to guide territorial transformation⁵⁹, such as the *PTIs*, largely fail to address the resurgence of mining as a territorial issue. While they articulate coherent visions of sustainability, heritage, and innovation, they often exclude or marginalize the material question of resource extraction, treating it as either outdated or external. This omission creates friction between planned sustainability and the actual processes of territorial exploitation. Bridging this gap will be essential for any future strategy to engage with the Alps as a landscape and as a living, contested, and resource-rich territory.

⁵⁹ These interventions suggest a form of infrastructural metabolism wherein energy production, forest management, and circular economy intersect, producing both material flows and situated knowledge. In this logic, the energy transition is neither abstract nor post-territorial: it is routed through historically sedimented infrastructures and negotiated through local governance mechanisms.

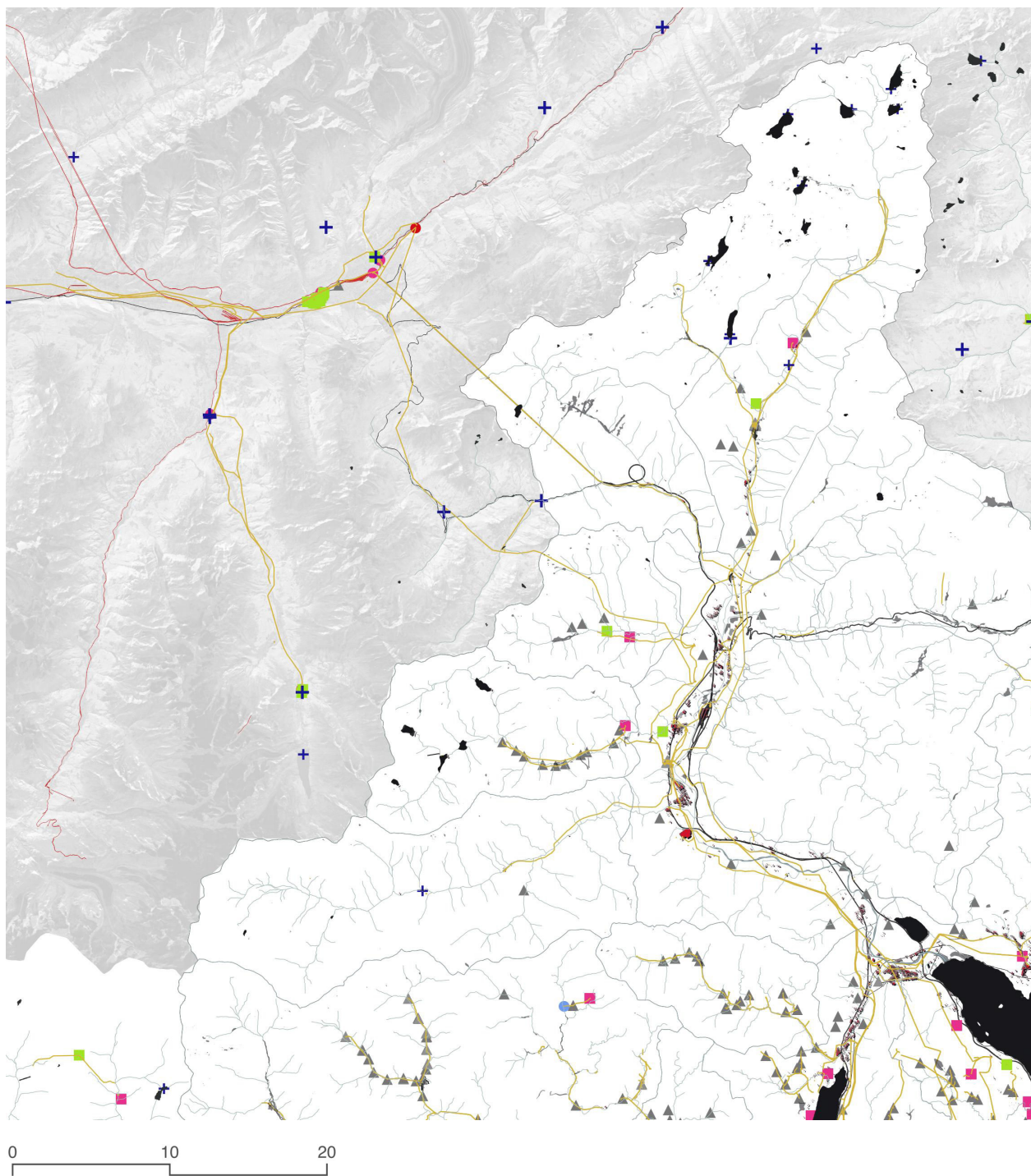
10.2.new synergies: towards a systemic reconfiguration of productive ecologies

As previously discussed, the renewed interest in Alpine territories for extracting strategic resources has brought these regions back into the spotlight of national and transnational agendas. These extractive processes raise familiar tensions: they promise short-term fiscal returns and employment and trigger long-term environmental and social concerns in ecologically fragile contexts.

In this setting, a key question emerges: can the new extractive economies contribute meaningfully to the reactivation of disused productive valleys, those often marked by industrial decline, demographic contraction, and infrastructural redundancy, or do they risk reproducing historical patterns of territorial exploitation under a new ecological guise? Are these operations capable of interfacing with existing landscapes, knowledge systems, and infrastructural residues, or will they remain isolated within the logic of resource extraction and disconnected from local regeneration? It is precisely here that the concept of *metro-montagna* (Dematteis 2021) offers a compelling analytical framework. Rather than rejecting extraction outright, this paradigm reframes Alpine regions as relational territories, zones of interaction between metropolitan demands and mountain-specific ecologies. It imagines the Alps not as marginal suppliers of raw materials but as experimental grounds for new socio-ecological integration. From this perspective, extractive activities could, at least in theory, be repositioned within broader territorial metabolisms, contributing to multi-scalar projects of sustainability and resilience, if governed with adequate spatial awareness and distributive justice. However, this potential remains speculative.

The extraction logic often reasserts itself through spatial segregation, environmental externalities, and economic dependency. The challenge is not only to assess the impacts of these industries but also to interrogate whether and how they might be enrolled in more ambitious territorial agendas that align with the long-term regeneration of Alpine valleys and the socio-ecological ambitions of the *metro-montagna* vision. However, the extractive practices driven by neoliberal globalization (Sassen 2014) create a fundamental contradiction within this vision. The extractive industries often reinforce the peripheral status of Alpine regions, depleting local resources for short-term economic gains while leaving behind environmental and social costs⁶⁰. This extractive model

⁶⁰ This refers to the *expulsive* extractive model of neoliberal globalization, which is inherently unsustainable and often causes long-term socio-environmental costs that far outweigh short-term economic gains (Sassen 2014).



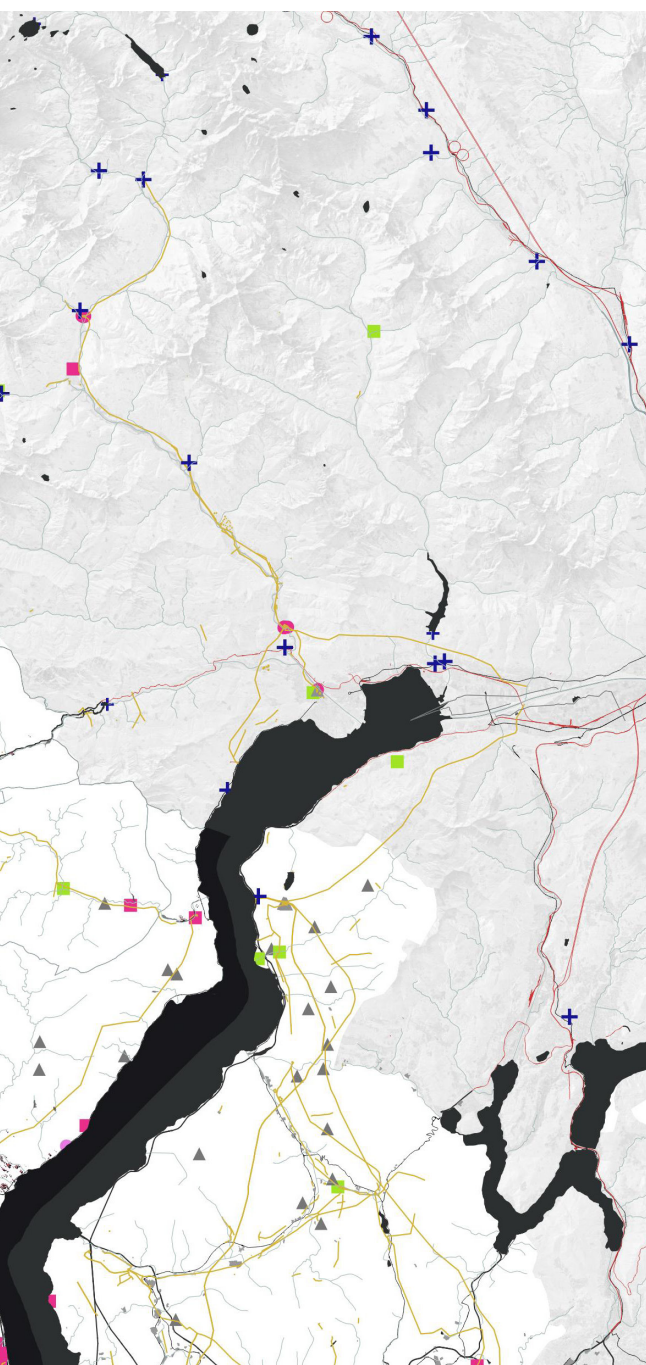
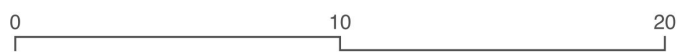


fig.10.19 Energy landscape of the Upper Ossola, showing the relationship between the power transmission network and the hydroelectric plants still in operation. The map highlights the dense concentration of productive areas along the valley floor and their connection to the regional energy infrastructure.

- + Lake Control Dam
- + Low Permeable Dam
- + Alpine Hydroelectric power plant
- Power
- Generator
- Insulator
- Portal
- Substation
- Supply
- ▲ Switch
- Terminal
- ▲ Transformer



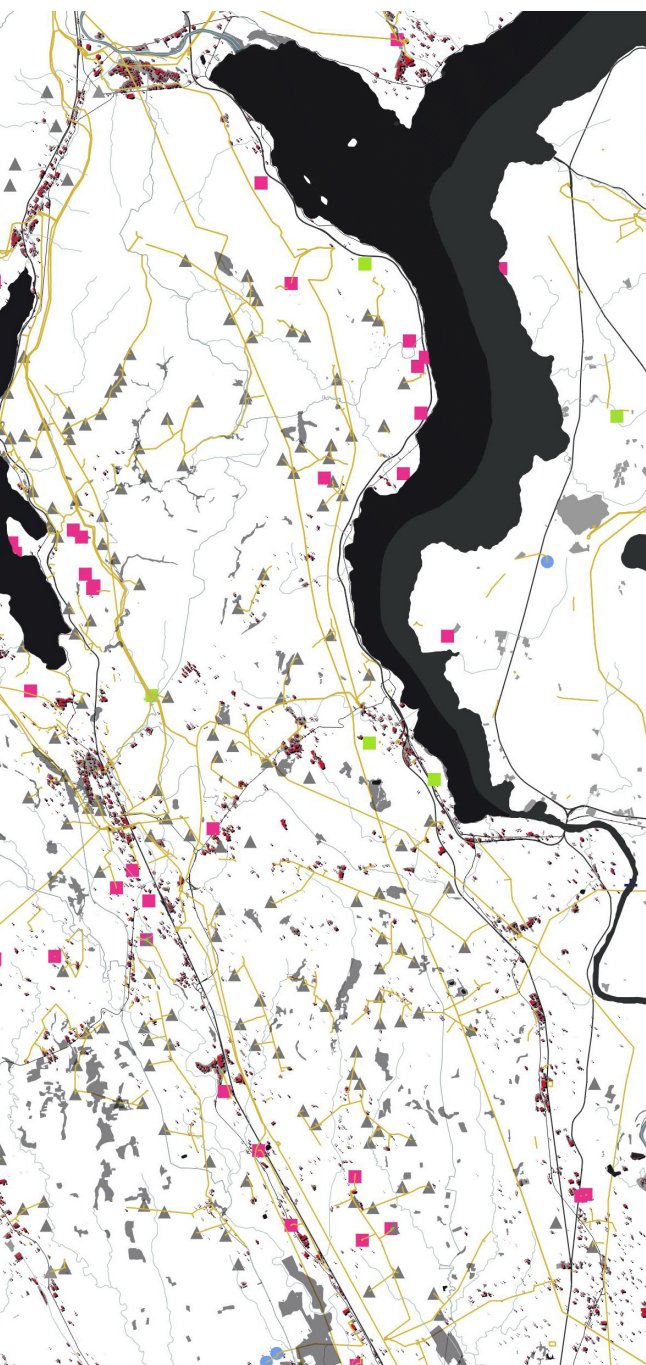
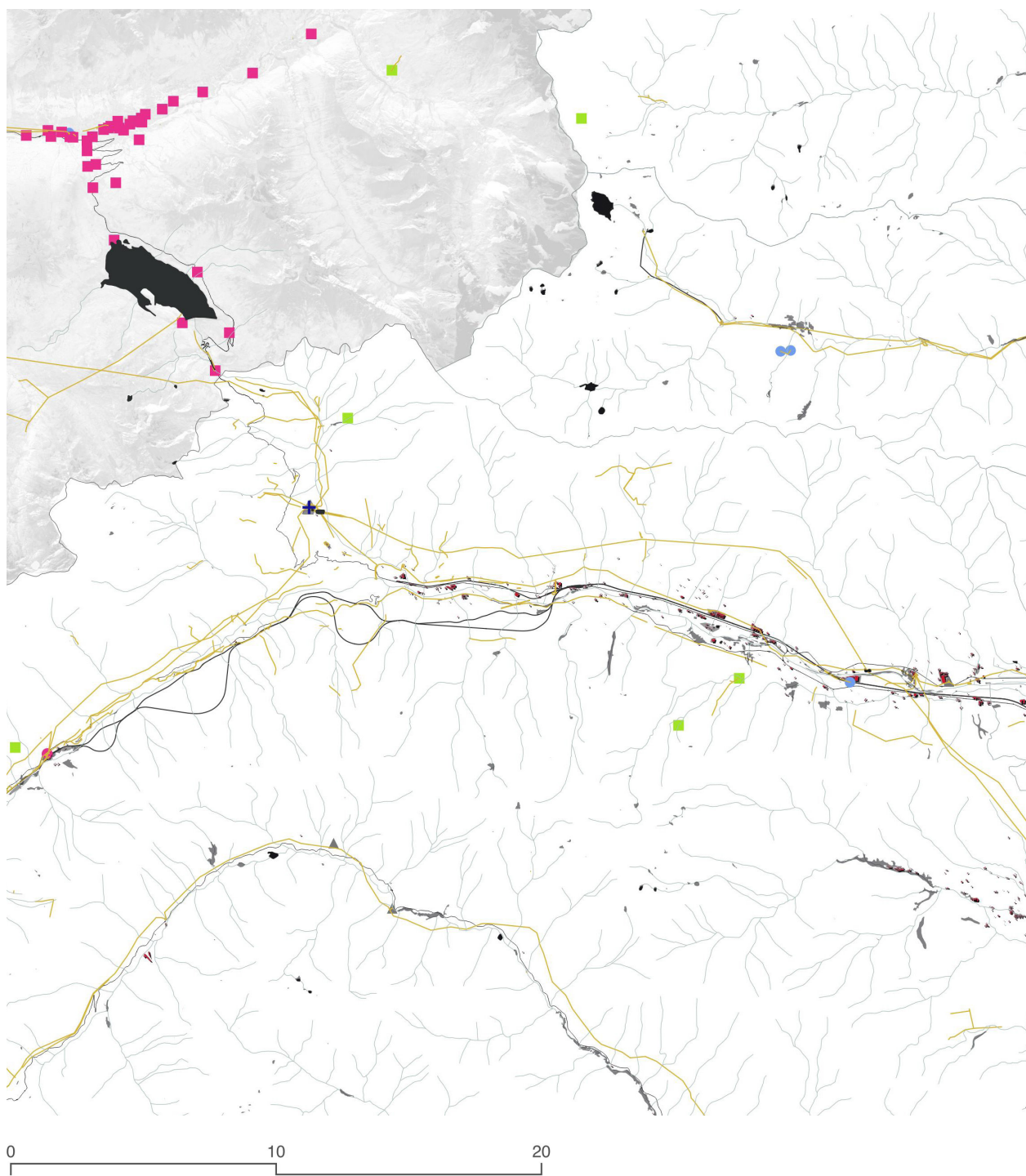


fig.10.20 In the Valsesia, the same energy network reveals its branching structure across the secondary valleys, tracing the articulation between hydroelectric facilities, industrial sites, and the topographic framework.

- + Lake Control Dam
- + Low Permeable Dam
- + Alpine Hydroelectric power plant
- Power
- Generator
- Insulator
- Portal
- Substation
- Supply
- ▲ Switch
- Terminal
- ▲ Transformer



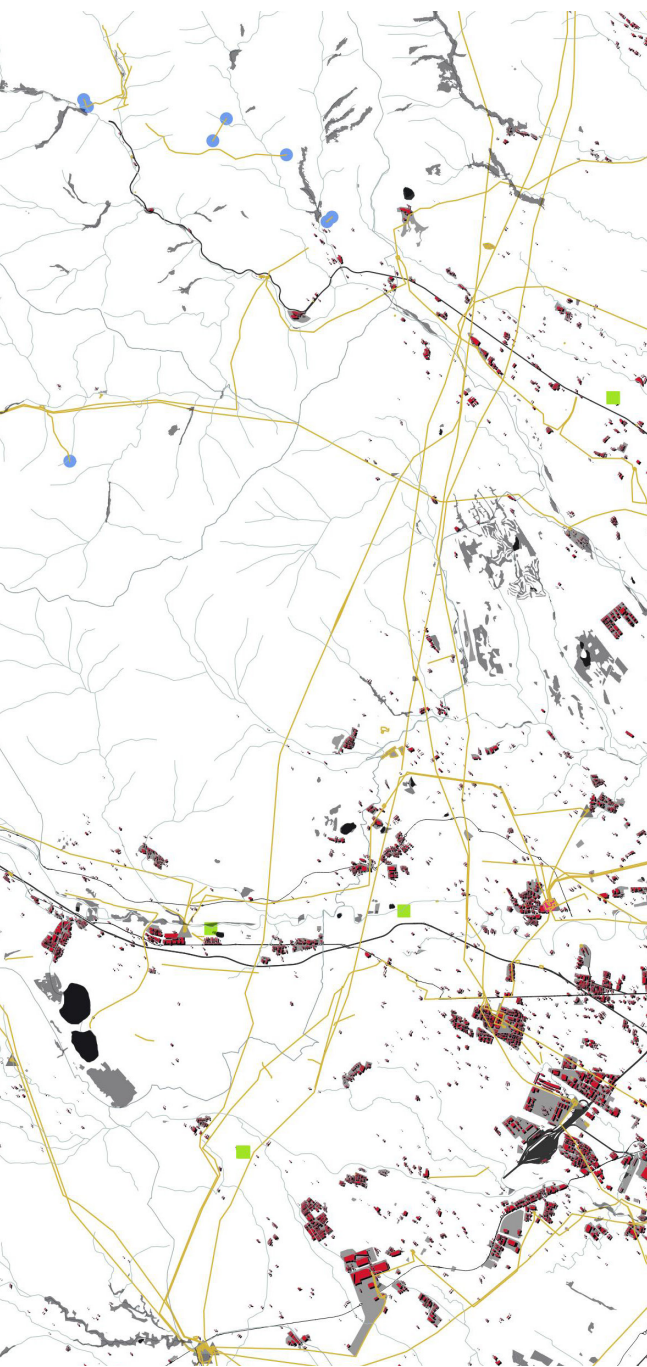


fig.10.21 In the Val di Viù, the map illustrates the transition between a sparsely infrastructured mountain system and the threshold of the Turin metropolitan network, emphasizing the changing density and configuration of the regional energy landscape.

- + Lake Control Dam
- + Low Permeable Dam
- + Alpine Hydroelectric power plant
- Power
- Generator
- Insulator
- Portal
- Substation
- Supply
- ▲ Switch
- Terminal
- ▲ Transformer



fig.10.22 The image depicts the relationship between the underused industrial stock of the Alpine and pre-Alpine valleys and the surrounding ecological network, where traces of production and natural processes coexist within a hybrid landscape.
Valduggia (*photograph by the author, 2025*).

threatens the long-term viability of Alpine ecosystems and the communities that depend on them, particularly as these areas are envisioned as laboratories for sustainable futures. The industry's risk stymies this potential by reinforcing economic dependency and environmental vulnerability (Perlik 2011). Paradoxically, both frameworks highlight the tension between immediate benefits and long-term sustainability. While resource extraction remains a significant revenue source, it is increasingly seen as incompatible with the sustainable development goals needed to preserve the ecological and social integrity of the Alps. The challenge for policymakers is to balance these fiscal benefits with environmental conservation, ensuring that extraction activities align with broader sustainability goals. Strengthening environmental oversight and reinvesting revenues into local communities for sustainable projects, as suggested by initiatives like *EUSALP*, could help resolve this contradiction, fostering a new development paradigm that prioritizes resilience, innovation, and ecological integrity in Alpine regions (Debarbieux and Price 2012). While extraction concessions view the Alps as a source of natural wealth, the *metro-montagna* concept advocates for a relational perspective, seeing the Alps as interaction spaces⁶¹. For Alpine regions to thrive amid global forces, resource extraction must be subordinated to broader sustainable development goals, promoting a long-term vision for ecological and social well-being.

Brownfield geographies and resource frontiers in valley floors Disused industrial areas across the Alpine Arc challenge the conventional image of mountain regions as purely pastoral, natural, or recreational. While often perceived as marginal remnants of a fading industrial era, these sites constitute a strategic layer of Alpine territoriality with significant implications for spatial design, ecological transition, and regional resilience. Contrary to common assumptions, industrial decline in the Alps did not occur uniformly or in parallel with broader European patterns of deindustrialization. Instead, it was delayed, uneven, and structurally different, often unfolding in the shadow of more significant urban transformations in the surrounding lowlands (Modica 2019). As discussed in *section 6.3*, the persistence of these industrial legacies highlights the interdependence between valley-floor infrastructures and low-

⁶¹ Achieving this vision will require concerted efforts at multiple scales, from local initiatives to global policy reforms, as well as a rethinking of how we conceptualize the value and role of mountain regions in the worldwide economy (Debarbieux 2008, Price 2012).

land production systems, revealing how Alpine territories were structurally embedded within wider metropolitan economies. A long history of extractive and manufacturing activities has left behind a fragmented yet extensive brownfield landscape, particularly along major transit corridors and valley floors⁶².

In this context, Ossola appears to be a paradigmatic old industrial region within the Alpine space. This infrastructural thickness positions Ossola within a broader conversation on industrial recycling, where disused spaces are not passive voids but latent resources for territorial reinvention. The layering of logistics, energy, and extractive histories in Ossola renders it particularly sensitive to the question of what kinds of economies and governance models can emerge in post-industrial Alpine valleys (Sega 2018). By contrast, Valsesia presents a more fragmented industrial morphology. It is characterized by a mix of small and medium-sized enterprises, primarily in the textile and mechanical sectors, which have experienced a gradual decline or relocation since the late twentieth century. While the valley lacks the dense concentration of heavy industry seen in Ossola, it nonetheless bears the imprint of past productive cycles in disused factory buildings, abandoned rail spurs, and residual water infrastructures. The dispersed nature of these sites, combined with the valley's challenging accessibility, makes coordinated regeneration strategies more complex and opens up possibilities for bottom-up or landscape-integrated reuse. In the Lanzo valleys, the industrial legacy is even more subtle, often embedded in a context of rural production, resource harvesting, and seasonal migration. Here, small clusters of past productive activity create a latent geography of industrial residue⁶³.

Across these three cases, a common thread emerges: disused industrial sites are not inert containers awaiting transformation, but complex socio-material assemblages embodying historical contradictions and future possibilities. Their spatial logic, typically situated along valley floors, close to energy sources and transport axes, aligns closely with the emerging geography of strategic resource extraction. This raises critical

⁶² According to Modica's survey, at least 289 large-scale industrial sites across the Alpine region, of which nearly half are either decommissioned or significantly downsized. Italy alone accounts for 130 of these, concentrated in regions such as the Ossola Valley, Biellese, and the valleys of Bergamo and Brescia.

⁶³ These areas are often overlooked in metropolitan planning narratives but still serve as active frontiers for experimenting with territorial recycling and re-signification forms (Sega 2018).

questions: Could the new extractive economies interface productively with these disused sites, contributing to a broader project of territorial reactivation? Or do they risk overlaying new extraction forms onto old ones, bypassing opportunities for more embedded, regenerative transformation? The answer depends on how these sites are approached: as a *tabula rasa* for speculative reinvestment or as situated infrastructures with histories, spatial grammars, and potential for systemic reintegration. In this sense, the intersection between brownfield regeneration and critical mineral extraction is a matter of land use planning and territorial strategy. Considering these sites as part of a regional system, with shared infrastructural legacies, ecological conditions, and socio-economic challenges, opens the door to more ambitious forms of industrial recycling (Modica 2019). This would involve shifting the narrative from isolated redevelopment projects to coordinated frameworks of reindustrialization, environmental requalification, and community co-production. Such a reorientation could help align extractive interests with territorial regeneration agendas, mainly if resource flows are reinvested locally, governance mechanisms ensure transparency and equity, and infrastructure is reused rather than duplicated. Without this, the risk is that new extractive operations will re-enact the spatial asymmetries and vulnerabilities they claim to address, reinforcing dependency rather than enabling resilience. Expanding the territorial lens beyond the Alpine valleys themselves, a recent industrial initiative provides a valuable vantage point for understanding the broader spatial dynamics of the ongoing energy transition. Conceived as an emblematic project for Italy's green reindustrialization, it sought to transform a major post-industrial site in northwestern Piedmont into a large-scale production hub for battery technologies⁶⁴. Despite its ambitious scope, the initiative encountered severe financial, legal, and infrastructural obstacles that ultimately led to its suspension, revealing the fragility and unevenness of large-scale transition strategies when detached from local material and institutional realities.

⁶⁴ The reference is to the *Italvolt* initiative, launched in 2021 with the aim of establishing a lithium-ion battery gigafactory within the former *Olivetti* industrial site in Scarmagno (Piedmont). Envisioned as a flagship project for Italy's green transition, the plan projected a production capacity of 45 GWh per year and up to 3,000 new jobs. The project soon faced unresolved financial liabilities, operational delays, and infrastructural shortcomings—such as limited energy connectivity and the presence of environmental constraints—that ultimately compromised its implementation. In 2024, the initiative was formally suspended, highlighting the structural fragility of large-scale industrial transition projects when insufficiently grounded in local governance frameworks and infrastructural realities.

Beyond extraction: toward a situated metabolism From a spatial perspective, this episode highlights that the challenge of reactivating post-industrial sites is not limited to isolated Alpine valleys but resonates across broader peri-Alpine and foothill regions, historically positioned between metropolitan influence and mountain economies. These are the spaces where a renewed integration of extractive, productive, and regenerative logics could take shape, provided institutional and spatial frameworks evolve accordingly⁶⁵. Such projects cannot be understood in isolation from the larger economic geographies in which they exist. The feasibility of reindustrialization in peripheral or post-productive territories depends on technological readiness and resource availability, as well as the degree of functional and relational integration with broader regional systems (Calafati 2015). In this respect, battery production, like cobalt extraction, should be examined not as isolated innovation nodes but as potential catalysts for reweaving territorial fabrics fractured by decades of uneven development and policy neglect. The Alpine brown-fields mentioned earlier, whether in Ossola, Valsesia, or Lanzo, may not compete with large-scale industrial zones in size or logistics. However, they offer an increasingly rare accumulation of infrastructural legacies, ecological potential, and embedded knowledge. These sites often possess latent adaptive capacity, provided that institutional actors can move beyond conventional land-use logic toward more localized forms of spatial intelligence. However, unlocking this potential demands a profound rethinking of what the transition entails, not only in technological terms but also in governance and justice. In this context, the convergence of critical mineral extraction, battery production, and territorial reactivation cannot be reduced to a simple narrative of circularity or innovation. It must also face questions of ownership, benefit distribution, and ecological accountability, especially in areas that have long been positioned at the margins of national decision-making processes. The alignment between new extractive economies and the reactivation of neglected industrial territories remains an open hypothesis. Its realization depends on articulating coherent, place-sensitive strategies that avoid the pitfalls of spatial abstraction and economic short-termism. Whether in the entrenched infrastructures of Ossola, the dispersed productive remnants of Valsesia, or the latent rural-industrial patterns of

⁶⁵ In this regard, the legacy of locations like Ivrea, once emblematic of an industrial modernity rooted in territorial specificity and social experimentation, serves as a reminder that industrial reuse is not merely a technical issue but a cultural and political project (Indovina 2005).

Lanzo, the potential exists to rethink resource economies as instruments of territorial care and innovation. But achieving this requires moving beyond the logic of substitution, replacing one form of extraction with another—and toward a more integrated metabolism of space, history, and ecological responsibility.

Reclaiming marginality through territorial metabolism The future of Alpine post-industrial regions will not be determined solely by the functions they accommodate, but rather by the epistemologies and frameworks through which they are interpreted, governed, and transformed. The territorial question cannot be resolved through technological fixes or isolated investments. Instead, it calls for a paradigmatic shift in how spatial legacies, peripheral geographies, and infrastructural residues are perceived and mobilized within contemporary territorial design and planning discourses. The infrastructural density of valley floors such as the Ossola creates a *linear periphery* (Sega 2018) that resists conventional narratives of obsolescence⁶⁶. These territories require a redefinition of transition that is not based on replacement, substituting past extractive economies with clean-tech clusters or logistic platforms, but on metabolization⁶⁷.

The *Strategia d'Area delle Valli dell'Ossola*⁶⁸ proposes a paradigmatic shift in how Alpine marginality is conceived and governed, invoking the notion of a *Green Valley* as an ecological ambition and a socio-territorial imaginary.

Within the framework of Italy's *National Strategy for Inner Areas*, a territorial initiative proposes a paradigmatic shift in how Alpine marginality is conceived and governed, invoking the notion of a *Green Valley* as both an ecological ambition and a socio-territorial imaginary. Rather than presenting itself as a passive recipient of post-industrial decline or external

⁶⁶ These are not voids, but palimpsests—territories layered with productive histories, social imaginaries, ecological thresholds, and latent capacities.

⁶⁷ This approach draws from the notion of a situated metabolism, where spatial transformation occurs through iterative engagement with existing conditions, infrastructures, and territorial narratives. They are no longer a passive support to urbanization, but an agent of spatial transformation in itself.

⁶⁸ *Strategia d'Area – Area Pilota Valli dell'Ossola*, Ministry for Territorial Cohesion and the South, Piedmont Region, and Unione Montana delle Valli dell'Ossola, May 2018 (updated December 2020). This policy document outlines the strategic framework for the territorial development of the Ossola valleys within the National Strategy for Inner Areas (SNAI), addressing issues such as infrastructure, public services, ecological transition, and the valorization of local resources. Available at: https://politichecoesione.governo.it/media/2771/strategia_valli-dellossola.pdf

development logic, the territory is reframed as a platform for integrated regeneration, articulated through the converging lenses of green economy and community, and infrastructural requalification. This framing mobilizes the conceptual lexicon of Alpine urbanism and productive ecologies by repositioning the valley floor as a site of extractive memory and as a material infrastructure for spatial and institutional experimentation. The aim is not to erase the industrial past but to metabolize it through the coordinated reuse of residual infrastructures, hydroelectric systems, brownfields, forest assets, and localized logistics platforms, toward a model of sustainable inhabitation. The strategic narrative that underpins this approach is deeply relational: it rejects inward-looking developmentalism in favor of a situated metabolism capable of engaging both metropolitan demands and mountain-specific territorialities. At the core of the strategy lies the idea of a green community, described not as a rhetorical device but as an operational framework for institutional and civic innovation. This concept seeks to reconcile identity-based attachment to place with forward-looking environmental stewardship. It envisions social capital as infrastructure, woven through networks of mutual aid, intergenerational transmission, and inclusive governance. Crucially, it reorients the demographic question from a narrative of loss to one of distributed participation: engaging both remaining residents and diasporic actors who retain affective and symbolic ties to the valleys. From a spatial perspective, the strategy seeks to stabilize and reconfigure territorial functions across multiple gradients: valley floors, peripheral hamlets, and nodal centers like Domodossola. This reconfiguration unfolds along four principal thematic axes: health and social infrastructure, educational innovation, territorial accessibility, and low-impact productive systems. Within this framework, infrastructural recycling becomes not only a technique of reuse but a principle of territorial justice, ensuring that investment, services, and symbolic capital are redistributed across the fragmented geography of the Ossola valleys. Among the most emblematic devices is the explicit reactivation of rural and energy infrastructures⁶⁹.

⁶⁹ Projects such as the biomass cogeneration plants (SL2), the small hydroelectric station on the *Rio Tambach* (SL1), and the revalorization of local wood supply chains (SL3c) reveal an effort to embed ecological transition within territorial specificities.

Situated transitions Rather than concentrating investment in central nodes, the strategy disperses opportunities across multiple sites: a distributed field of ecological and infrastructural interdependencies. However, the strategy also reveals specific temporal asymmetries. While its vision is notably sophisticated and forward-looking in ecological and infrastructural terms, it was articulated in 2018, before the full institutional emergence of CRM as a geopolitical and territorial issue within the EU framework. As a result, it does not directly engage with the reactivation of extractive economies related to minerals such as cobalt, which have since become central to the European green transition and battery supply chains. This temporal gap does not reflect a conceptual oversight, but rather the shifting material and political landscape in which such strategies now operate. At the same time, a broader awareness is gradually emerging around the systemic implications of resource governance, particularly as calls intensify to decolonize extractive logics and to reintegrate extraction within inclusive territorial frameworks and territorial specificity. These shifts challenge the technocratic framing of mining as a neutral infrastructure of transition and instead invite a re-politicization of resource economies as contested and situated processes⁷⁰. Still, this absence creates a partial disconnect between the strategy's ecological ambitions and the evolving economic drivers actively reshaping Alpine geographies. Without a critical engagement with the governance of mineral resources, the spatial and legal architectures of mining concessions, and the broader territorial rationalities underpinning the CRM agenda, there is a risk that future transformations may unfold in parallel to the imaginaries of resilience and regeneration articulated by the strategy. Yet, the potential for strategic alignment remains. The strategy does not operate as a prescriptive roadmap but as a generative framework through which peripheral mountain territories can be repositioned within broader post-carbon transitions. Rather than conceptualizing these territories as terminal zones of industrial decline, it outlines conditions under which they may be reinserted into processes of territorial reactivation, grounded in ecological compatibility, institutional experimentation, and spatially embedded forms of value pro-

⁷⁰ What emerges, then, is the need to recast these territories as operative landscapes: zones of convergence between ecological care, economic innovation, and spatial justice. This implies not only infrastructural requalification, but also the development of new institutional ecologies capable of negotiating between metropolitan logics and local specificities. While such strategies often offer ambitious visions of resilience and sustainability, they frequently remain silent on how to confront the material implications of a renewed extractive turn.

duction. In this context, infrastructural remnants, as discussed in the previous chapter, are not framed as inert residues but as components of a potential territorial metabolism. Similarly, local communities are engaged not as passive subjects of intervention, but as actors whose spatial knowledge, organizational capacity, and historical presence form essential elements of place-based governance⁷¹.

In this light, the Ossola valleys can be interpreted as a strategic threshold, not simply between past and future, but between competing development paradigms⁷². Their potential role as laboratories of territorial metabolism hinges on the ability to reconcile temporal discontinuities and thematic divergences: between legacy infrastructures and emerging functions, ecological constraints and economic aspirations, local knowledge systems and supra-regional planning frameworks. The extent to which these elements can be aligned within coherent and adaptive spatial strategies will ultimately determine the capacity of these territories to articulate alternative models of post-industrial transition.

Positive energy territories as levers for spatial and ecological regeneration. Positive energy strategies must be considered strategic configurations in which energy drives territorial transformation. In this sense, energy is not a discrete sector but a transversal infrastructure that intersects with land use, mobility, ecology, and social organization. Implementing these strategies in dispersed or marginal contexts such as inner valleys, peri-alpine basins, or deindustrialized corridors requires a shift in emphasis. The challenge lies less in energy densification and

⁷¹ The notion of sustainability advanced here is thus not fixed or universal, but understood as contingent, negotiated, and situated within evolving territorial conditions.

⁷² This disconnect risks reproducing a territorial dualism in which strategic resources are extracted under the guise of a green transition, while affected regions remain locked in cycles of dependency and marginalization. From a design perspective, the challenge lies in developing frameworks that do not merely mitigate these contradictions, but actively reframe them. This involves working with the grain of existing landscapes and infrastructural residues, cultivating slow forms of reactivation that foreground temporality, reversibility, and place-based knowledge. It also entails embracing hybrid models—where logistics coexists with cultural production, and industrial reuse overlaps with environmental stewardship. Ultimately, the question is not whether post-industrial Alpine regions will participate in the green transition, but on what terms and with whose agency. *Will they remain strategic surfaces for external agendas, or will they become actors in their own right, capable of redefining the meaning of sustainability at the intersection of extraction, memory, and future-making?* The answer depends on whether planning practices can evolve from a paradigm of control to one of negotiation, from abstract strategies to grounded, metabolized, and just territorial projects. Such a shift would reposition Alpine valleys not as relics of a depleted industrial modernity, but as laboratories for a new territorial contract.

more in distributed reorganization. These areas often exhibit lower consumption density but higher availability of space, natural resources, and infrastructure. In this setting, energy becomes an opportunity to rearticulate existing assets: disused rooftops, underused hydro infrastructures, residual forestry, and low-density settlements. The territory is not a neutral backdrop but an active participant in shaping energy flows. This perspective invites a shift from nodal optimization to a relational configuration in which energy systems are embedded in everyday spatial practices and ecological cycles. Importantly, such territories often host overlapping demands: agricultural activity, tourism, extractive operations, environmental conservation, and dispersed habitation. Energy transitions can thus be envisioned not as isolated enclaves of technological performance, but as infrastructural processes that facilitate the coexistence of these functions. The pursuit of local energy autonomy becomes less of a quantitative target and more of a spatial logic that enables synchronization between production and use, between environmental cycles and infrastructural rhythms. This shift implies a form of spatial intelligence that accounts for seasonality, intermittence, and landscape heterogeneity. Moreover, the governance dimension is particularly salient in these contexts. Energy initiatives often intersect with complex property regimes, fragmented institutional capacities, and low population densities. Their development must therefore navigate not only technical feasibility but also local legitimacy and institutional coordination. Participation, transparency, and equitable redistribution of benefits become fundamental components of project viability.

Local energy autonomy, in this reading, is not a neutral condition but a contested and negotiated process. It must be anchored in collective arrangements that reflect local priorities and socio-spatial configurations. This approach also calls for reconsidering spatial design tools. Rather than conceiving energy infrastructure as an overlay to be minimally integrated, these strategies demand a design culture that sees energy as a generative layer capable of shaping public space, land-use patterns, and territorial imaginaries. Solar fields, biomass plants, or micro-hydro systems are not peripheral utilities but central actors in articulating future landscapes. Their design, location, and governance determine energy outcomes and territorial identity. In sum, rethinking energy through the lens of territoriality enables a more situated and integrative approach to transition. Local energy configurations do not emerge solely from technological assemblages or fiscal incentives. They are the result of infra-

structural and spatial negotiation. In areas characterized by fragmentation, underinvestment, or residual economies, these strategies represent an opportunity to mobilize latent resources for energy autonomy and broader processes of spatial regeneration and ecological rebalancing.

Community-based energy systems in high valleys: the spatial agency of renewable alliances

In recent years, community energy systems have emerged as a key device for mobilizing local resources and redefining development trajectories in peripheral and mountain areas. Rather than relying on large-scale centralized infrastructures, these configurations engage residents, municipalities, cooperatives, and small producers in the co-management of renewable resources. Their potential extends beyond energy supply: they serve as institutional platforms that can catalyze territorial cooperation, economic diversification, and spatial justice. In fragmented geographies such as the Piedmontese Alps, where demographic contraction and infrastructural redundancy pose structural challenges, community energy represents a transformative infrastructure, not only technical, but also social and territorial. The model of renewable energy communities has taken concrete shape in several Alpine valleys, often emerging from grassroots initiatives or inter-municipal coordination frameworks. In the upper section of Val Maira, a cooperative experiment⁷³ illustrates how community-based energy alliances can foster distributed production models, combining local governance with technological innovation. Structured as an open network between municipalities, civic associations, and local technical actors, the initiative builds on a distributed energy strategy that valorizes the solar potential of disused rooftops, integrates micro-hydro capacity, and supports prosumer engagement through shared storage and governance tools. Unlike isolated technological pilots, the project operates across multiple institutional levels, such as municipal, valley-scale, and regional, thereby embedding renewable production within broader planning dynamics.

The case of Val Maira is particularly significant because it reveals how energy transitions can mediate local identity, territorial resourcefulness,

⁷³ The reference concerns the cooperative platform “*Nuove Energie Alpine*”, established in the upper Val Maira as part of a broader effort to promote renewable energy communities in mountain regions. Although not directly related to the cases examined in this chapter, it is included for its relevance to comparable spatial and social contexts, exemplifying how community-led energy projects can function as instruments of territorial resilience and ecological transition.

and regional frameworks. In this context, the energy community is not a closed technical circuit but a socio-territorial infrastructure that supports spatial cohesion and enables collective agency. The alliance explicitly positions itself not just as a producer of renewable energy, but as a catalyst for territorial regeneration: income generated from self-consumption and grid feed-in is reinvested into local services, mobility schemes, and cultural initiatives. This mechanism reinforces material and symbolic infrastructural presence, countering the peripheralization often experienced in such contexts and the initiative aligns with broader strategic visions⁷⁴. However, while the latter offers a valuable governance framework, it represents a step forward, a situated implementation of the strategy's ambitions. While the original document highlights the need for integrated energy planning and community engagement, it has not yet institutionalized specific platforms to realize them. The cooperative thus anticipates and concretizes these goals, offering a model for operationalizing valley-wide sustainability agendas. The spatial implications of this energy model are also crucial. Rather than occupying new land or installing large infrastructures, the system works through existing buildings and infrastructures, from municipal rooftops to school canopies and agricultural sheds. In this way, energy infrastructure becomes an act of reuse, a reconnection mode between functions, scales, and social actors. Territorial accessibility is treated not as mere physical mobility but as a precondition for symbolic and institutional integration⁷⁵. It links transportation reorganization to the production of inclusive geographies via mapping, narrative design, and the co-production of tourist infrastructure. This work foregrounds mobility as a territorial right, especially for populations historically marginalized by Alpine inaccessibility. Not as an external paradigm but as an endogenous potential of the territory, leveraging place-based assets to build value chains rooted in ecosystem services, quality food production, and hospitality⁷⁶. This resonates with the broader perspective of infrastructural metabolism explored elsewhere in this thesis: solar panels, inverters, and batteries are not neutral technical devices, but spatial actors embedded

⁷⁴ Such as the *Strategia Nazionale per le Aree Interne* and the *Strategia Unitaria delle Valli Grana e Maira*.

⁷⁵ The *Valli accessibili axis (M1–M3)* addresses both infrastructural fragmentation and representational invisibility.

⁷⁶ This logic is reflected in the valorization of agroecological systems, short production chains, and landscape-based tourism strategies (*SL3a–SL3e*), where environmental stewardship and economic viability are mutually reinforcing.

in complex ecologies of governance, habitability, and environmental care. Equally relevant is the initiative's pedagogical and symbolic role. Through workshops, public meetings, and visual mapping, the project reactivates the relationship between residents and their energy landscapes, transforming passive consumers into territorial subjects. This re-politicization of infrastructure helps reframe the energy transition as a common project, not imposed from above but shaped from below through negotiation and shared responsibility⁷⁷. By working across spatial scales and institutional layers, community energy systems demonstrate a capacity to recompose territory, bridge sectoral silos, and support alternative logics of inhabitation. In doing so, they offer a path toward decarbonization and a new vocabulary of territorial integration, where energy is not merely a utility but a medium of spatial imagination and equal design.

Productive valley floors and solar stock: reframing industrial legacies through distributed energy infrastructures Today, these corridors, densely layered with disused logistics, industrial sheds, degraded infrastructures, and residual services, present a unique opportunity for advancing distributed energy models grounded in reuse rather than expansion. The question is no longer whether these sites can host clean energy infrastructure, but how *green* technologies can operate as spatial tools for reframing their future. The concept of solar stock, the latent photovoltaic capacity of existing built surfaces, offers a concrete entry point into this reframing⁷⁸. This built stock, already served by grid access and often centrally located within territorial mobility systems, enables high-efficiency energy generation without additional land consumption. But its activation requires a leap in scale and coordination: from individual installations to shared territorial infrastructures, capable of aggregating production and redistributing benefits across multiple functions and communities. This shift demands a different form of design approach that sees not isolated surfaces but interconnected elements of a broader energy infrastructure.

In contrast to more dispersed or rural-based renewable strategies, interventions on the valley floor must navigate a tighter weave of technical, institutional, and symbolic constraints. Building codes, heritage design-

⁷⁷ The experience of *Nuove Energie Alpine* suggests that energy can serve as a vector of cohesion in territories marked by fragmentation and decline.

⁷⁸ Roofs of warehouses, logistics terminals, school complexes, and industrial brownfields constitute a continuous, underutilized solar resource.

nations, multi-ownership regimes, and degraded structural conditions complicate straightforward implementation. Yet these complexities open new design fields: where solar retrofitting becomes an occasion to rethink building function, activate residual spaces, and consolidate inter-municipal cooperation. In this light, distributed photovoltaic infrastructure is not merely a matter of technical optimization but a territorial project⁷⁹. This vision aligns with emerging frameworks for positive energy configurations at the territorial scale. Unlike district-scale models rooted in dense urban form, energy strategies in Alpine valley floors must operate across discontinuous, heterogeneous, and historically sedimented geographies. Energy transition is inseparable from infrastructural reuse, symbolic re-legitimation, and institutional co-design. Distributed solar infrastructures are most effective when conceived not as add-ons but as mediators: between legacy and innovation, between centrality and highland fragility, between municipal autonomy and regional coordination.

The Domodossola basin offers a paradigmatic case for understanding how solar stock can support the reconfiguration of valley-floor territories⁸⁰. From the freight terminal at Domo2 to the chemical complex in Pieve Vergonte and the industrial plants of Villadossola, the landscape is marked by a thick layer of horizontal surfaces now largely disconnected from their original functions. These residual surfaces are not neutral voids but latent infrastructures: equipped with grid connections, embedded in territorial service networks, and spatially contiguous with residential and productive uses. Mapping exercises have already revealed the potential of the area's rooftops to generate significant photovoltaic output without additional land consumption or major environmental impact. Importantly, this energy capacity is not isolated—it can be linked to mobility services, public buildings, and small manufacturing clusters still active in the valley. Therefore, the reuse of industrial stock for solar generation can be coupled with a broader territorial agenda, where energy infrastructure is deployed not as a parallel layer but as a connective tissue across existing functions. Crucially, this approach

⁷⁹ Aggregated rooftops become energy assets and nodal points in broader ecological and economic metabolisms. Public buildings can anchor local energy communities. Former warehouses can be hybridized to include solar logistics, shared storage, or public services. Even abandoned industrial enclosures can be reimagined as energy parks, spaces where production, education, and ecological remediation cohabit.

⁸⁰ Historically a node of extractive, metallurgical, and logistical activity, the area retains an exceptional density of built infrastructure, much of which is underused or partially decommissioned.

is not just spatial but institutional. The Domodossola case shows how photovoltaic retrofitting can drive new governance models that link fragmented municipalities around shared objectives. The area already benefits from a certain infrastructural centrality: it hosts administrative services, transport interchanges, and energy distribution nodes. Building on this centrality, a coordinated strategy could leverage rooftop solar activation to fund inter-municipal services, support community energy schemes, and finance the rehabilitation of degraded assets. Public ownership of many of the most promising rooftops—especially schools, logistics depots, and service buildings—facilitates this potential, enabling pilot projects without the complexities of private-sector negotiations. The implications of this approach extend beyond Domodossola. Other valley-floor contexts, such as the lower Valsesia, particularly around towns like Varallo and Borgosesia, present similar morphologies: a mix of underused industrial assets, grid access, and public rooftops. Here, too, solar activation could catalyze a new role for valley-floor landscapes. A common condition links these cases: infrastructural density without current use, spatial centrality without strategic vision. Treating the solar stock of these valley floors as a shared territorial asset, rather than an assemblage of isolated surfaces, makes it possible to articulate a new geography of energy transition. One that works through reuse, builds institutional cooperation, and reclaims the valley floor not as a periphery, but as a laboratory for spatially grounded transition. In this perspective, the reactivation must be understood not as an isolated technical upgrade, but as the first step in a broader territorial reconfiguration. By enabling the partial reuse of disused industrial assets for energy generation, these interventions create the conditions for the emergence of parallel economies—grounded in care, resilience, and spatial redistribution. Over time, this renewed infrastructural metabolism can foster more complex forms of territorial integration, including potential synergies with future extraction scenarios. Rather than subordinating energy infrastructures to extractive imperatives, this trajectory suggests the possibility of aligning them within a more polycentric and negotiated framework, where energy and material flows are co-governed through situated, landscape-based logics.

10.3.from waste to resource circular perspectives and regeneration in extractive economies

Alpine regions face a paradoxical opportunity. While new extraction activities are often associated with environmental degradation, they may also serve as leverage points for reclaiming and regenerating landscapes damaged by previous industrial cycles. A key shift in this discourse is the redefinition of material and spatial waste, not as an end-point but as a potential source of value. Slag, contaminated soils, and obsolete infrastructure are increasingly reframed as secondary deposits capable of yielding new raw materials through advanced recovery processes. This shift opens up a dual trajectory: the possibility of initiating new extractive cycles while simultaneously undertaking long-overdue environmental remediation and territorial reintegration. In this light, territorial recycling becomes not only a land-use strategy but a material one that questions the linearity of extractive economies and invites a more circular understanding of matter, landscape, and value. Rather than expanding extraction into untouched environments, emerging approaches propose concentrating interventions within already-altered geographies, where legacy waste and infrastructural residues can be mined, transformed, and reintegrated. The third life of the territory, after use and abandonment, thus becomes an opportunity for ecological repair and material innovation. The challenge lies in designing governance frameworks, technical processes, and spatial visions that align the recovery of resources with the recovery of landscapes.

Territorial recycling as a strategy for landscape regeneration

Territorial recycling becomes essential to preserve land resources and reshape landscapes impacted by mining. In Italy, the institutional framework supports a balanced approach to mining and territorial regeneration through various regulatory and policy mechanisms. The *Testo Unico Ambientale*⁸¹ includes provisions for the recovery and remediation of contaminated sites. At the same time, the *Piano Nazionale delle Bonifiche*⁸² provides guidelines for the environmental restoration of disused industrial areas, including mining sites. However, a straightforward integration between territorial recycling policies and the management of new mining sites is still lacking. Local and national authorities must work toward a more integrated approach that maximizes the potential of former mining sites while avoiding unnecessary new land consumption. Once properly rehabilitated, disused mining sites can be transformed into valuable

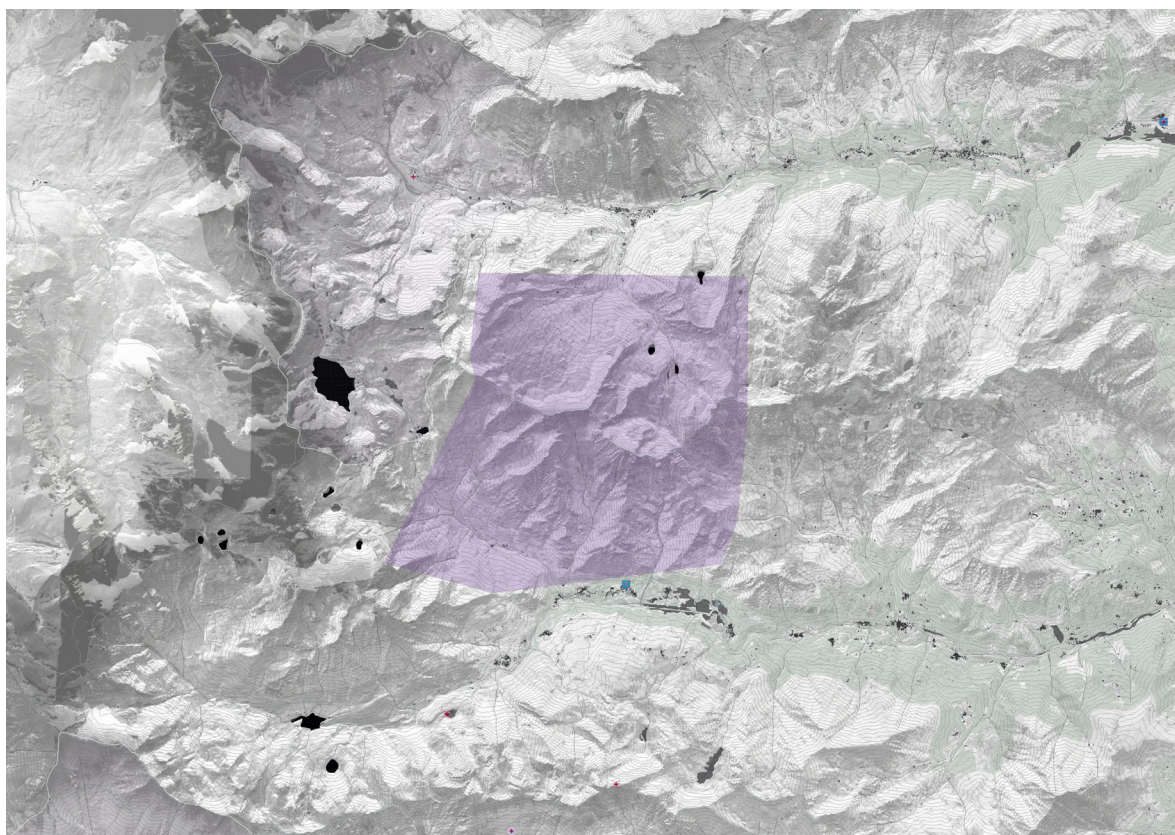
⁸¹ D.Lgs. 152/2006 *Environmental Consolidated Act*.

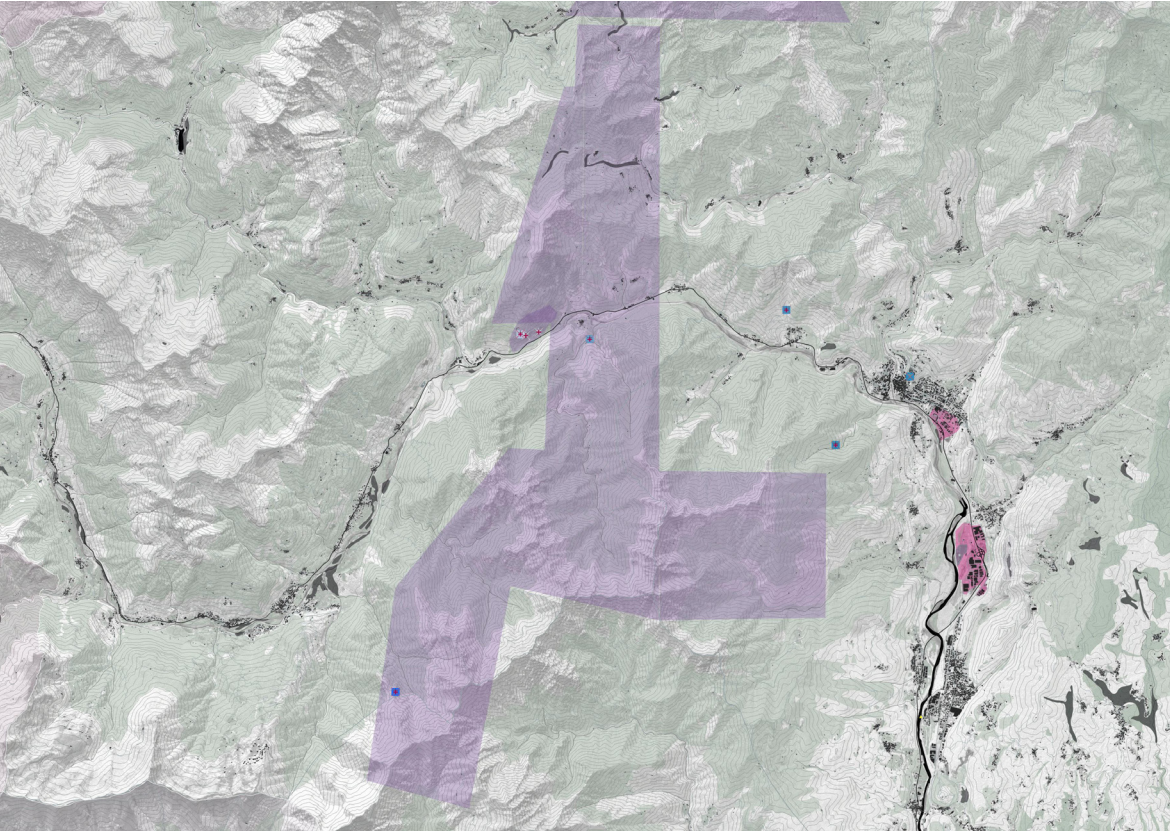
⁸² *National Remediation Plan*.



fig.10.23 The image records the residual footprint of an earlier extraction site near the *Supervulcano della Valsesia*, where a storage deposit adjacent to the former mine workings remains discernible within the Alpine landscape. Isola di Vocca (*photograph by the author, 2023*).

fig.10.24-26 The three maps present successive zooms on the concession areas, detailing their territorial context and the spatial relations





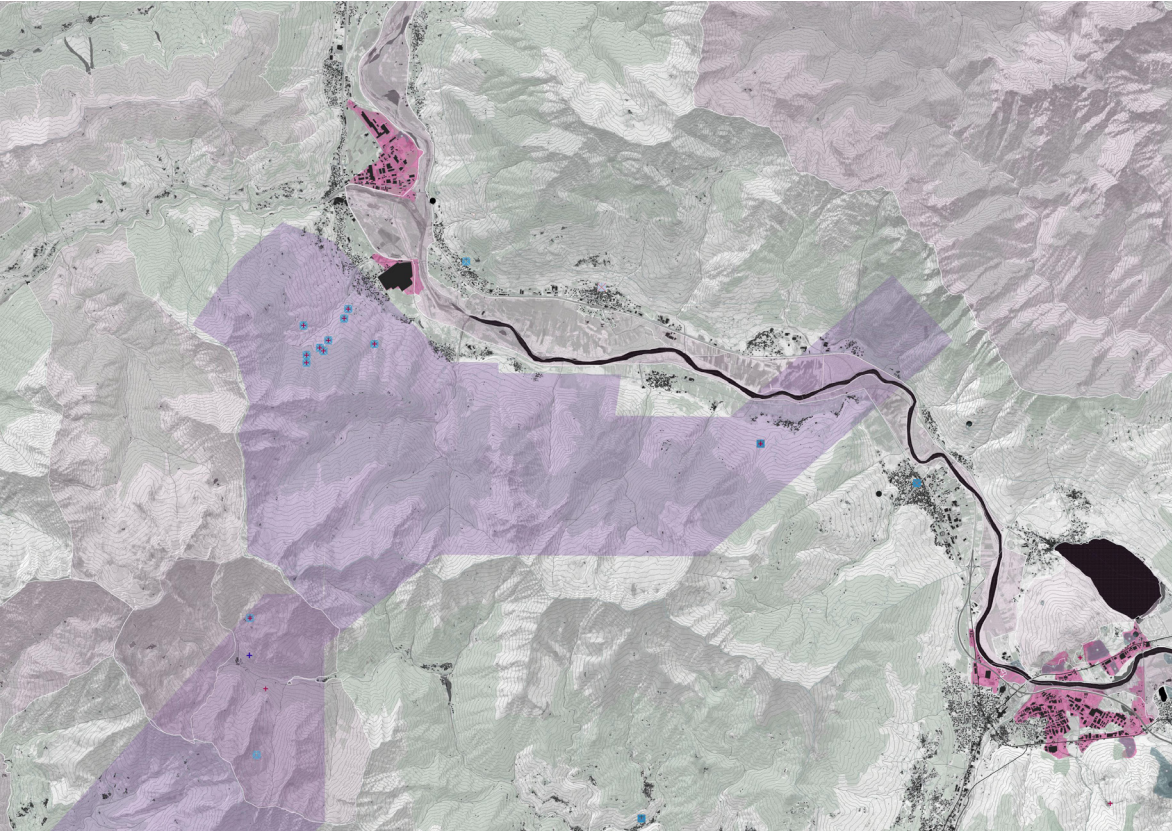




fig.10.27 View near the *Miniere della Balma al Monte Gavala*
(Aerial survey by Davide Simoni, elaboration by the author, 2023)



fig.10.28 Small infrastructures originally serving the mining sites have been converted for maintenance purposes and to provide access along the hiking routes. Isola di Vocca (*photograph by the author, 2023*).



fig.10.28 Former deposit from a previous extraction cycle, no longer connected even through the hiking path network; natural processes are progressively reclaiming the site, integrating it once again into the surrounding landscape.
(Aerial survey by Davide Simoni, *elaboration by the author*, 2023)

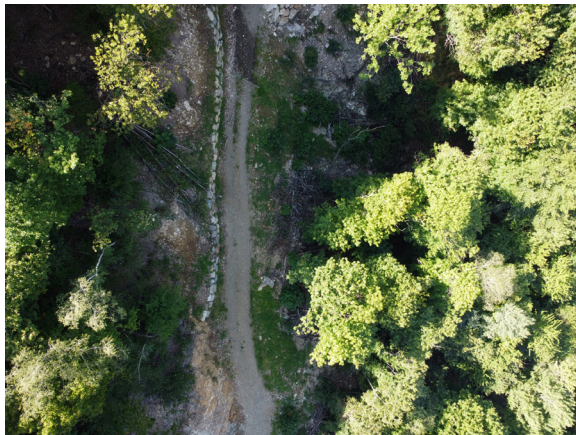


fig.10.29 Entrance to the Valmaggia mine (for further information: “Miniera di Valmaggia” catastogrotte-piemonte.net). Valmaggia 2023 (*photograph by the author*).



fig.10.30 Nickel deposit secured for safety reasons; the surface discoloration clearly reveals the effects of runoff and leaching. Campello Monti (*photograph by the author, 2023*).

fig.10.31-34 Service roads where traces of former deposits remain visible, in some cases reintegrated into recent consolidation works. (*Aerial survey by Davide Simoni, elaboration by the author, 2023*)



	Municipality	Province	extracted minerals	last concession holder	period of extraction
Maniglia	Perrero	Turin	Talc	Talc e Grafite Val Chisone	1933/1977
San Vittore	Balangero	Turin	Magnetite / Asbestos	Mineral & Intertrade	1936/1994
Chicu`	Viu`	Turin	Talc	Pietro Possio	1931/1994
Auriol	Sampeyre	Cuneo	Asbestos	Mineraria Italiana	1960/1984
Fornello Di Traversella	Traversella	Turin	Pyrite / Magnetite / Pyrrhotite / W / Silver-bearing galena / Au	Ilva Acciaierie e Altiforni d'Italia	1942/1992
Brunetta	Cantoira	Turin	Talc	Pietro Possio	1969/1984
Bourcet	Roure	Turin	Talc	Comune di Roure	1933/1978
Fontane	Prali	Turin	Talc	Luzenac Valchisone	1951/2002
Val Germanasca	Perrero	Turin	Talc	Luzenac Valchisone	1933/2002
Torrente Otro	Riva Valdobbia	Vercelli	Pyrite	Veneta Mineraria-Kreas	1965/1995
Bracchiello	Ceres	Turin	Talc / Asbestos	Piton Arturo	1981/1981
Giargiatta	Ceres	Turin	Talc	Piton Giuseppe	1933/1949
Malzas E Le Combe	Perrero	Turin	Talc	Talco e Grafite Val Chisone	1880/1951
La Roussa	Roure	Turin	Talc	Comune di Roure	1933/1967
Rio Pracchio	Chiusa Di San Michele	Turin	Talc	-	1933/1963
Uja E Lago Falin (Usseglio)	Usseglio	Turin	Asbestos	Comune di Usseglio	1930/1935
Alpe Rossa	Baceno	Verbano-Cusio-Ossola	Asbestos	Comune di Baceno	1932/1954
Fragne`	Chialamberto	Turin	Pyrite	Mineraria Fragné Chialamberto	1890/1973
Gias Rivet	Ceres	Turin	Talc	Piton Arturo	1933/1957
Baio E Bore	Brosso	Turin	Pyrite / Ematite / Magnetite	Montecatini	1929/1967
Pian Della Roussa	Ceres	Turin	Talc	Eugenio Maria Juvenal	1931/1951
Colletto	Roure	Turin	Talc	Talco e Grafite Val Chisone	1933/1965
Saret	Roure	Turin	Talc	Talco e Grafite Val Chisone	1931/1965
Isola Di Vocca	Vocca	Vercelli	Nickel-bearing pyrrhotite	A.M.M.I Azienda Minerali Metallici Italiani	1988/1990
Alpe Mondei	Montescheno	Verbano-Cusio-Ossola	Mica / Beryl / Feldspar	M.A.R.A.S.A	1943/1954
Punta Lunella	Condove	Turin	Asbestos	Bender e Martiny	1930/1937
Baio	Lessolo	Turin	Pyrite / Ematite	Sclopis e C.	1912/1929
Agogna - Motto Piombino	Gignese	Verbano-Cusio-Ossola	Sphalerite / Galena	Miniere del Gignese	1863/1939

tab.10.1-2 Tables based on data from the Piemonte section of the national inventory of closed or abandoned extractive waste facilities identified as having, or potentially having in the short or medium term, serious negative impacts on the environment or human health.

The inventory complies with *EU Directive 2006/21/EC* on the management of waste from extractive industries, implemented in Italy through *Legislative Decree 117/2008*, which mandates the registration of *Category A facilities under Article 20 and Annex II*.
(Source: *www.isprambiente.gov.it*)

type of extraction	environmental risk	potential waste	deposit	current status
underground	H	Asbestos	waste heaps	abandoned
open-pit	H	Asbestos / V	waste heaps	remediation works
mixed	H	Asbestos	waste heaps	abandoned
open-pit	H	Asbestos	waste heaps	abandoned
underground	H	As / Cd / Cyanide / Co / Mn / Ni / Pb / Cu / V	waste heaps	abandoned
underground	H	Asbestos	waste heaps	abandoned
underground	H	Asbestos	waste heaps	abandoned
underground	H	Asbestos	waste heaps	abandoned
underground	H	Asbestos	waste heaps	abandoned
underground	H	As / Cd / Mn / Ni / Cu	waste heaps	abandoned
underground	H	Asbestos	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
open-pit	MH	Asbestos	waste heaps	abandoned
open-pit	MH	Asbestos	waste heaps	abandoned
underground	MH	As / Cd / Mn / Ni / Cu	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
underground	MH	As / Cd / Mn / Ni / Cu / V	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
underground	MH	Co / Ni	waste heaps	Ex Ricerca
mista	MH	Be	waste heaps	abandoned
underground	MH	Asbestos	waste heaps	abandoned
underground	M	As / Cd / Mn / Ni / Cu	waste heaps	abandoned
underground	M	Cd / Cyanide / Pb / Zn	waste heaps	abandoned

	Municipality	Province	extracted minerals	last concession holder	period of extraction
Sapatle` - Pleinet - Comba La Fracia	Prali	Turin	Talc	Talco e Grafite Val Chisone	1888/1933
Baio E Montefiorito	Lessolo	Turin	Pyrite / Ematite	Sclopis e C.	1893/1912
Ogaggia	Montescheno	Verbano-Cusio-Ossola	Siderite	Industriale P.M. Ceretti	1796/1930
Alvani	Valstrona	Verbano-Cusio-Ossola	Nickel-bearing pyrrhotite	A.M.M.I Azienda Minerali Metallici Italiani	1874/1949
Bonda Del Chierico	Varallo	Vercelli	Pyrite / Co / Nickel-bearing pyrrhotite	Giovanni e Francesco Paganini	1874/1916
Freva	Premosello-Chiovenda	Verbano-Cusio-Ossola	Co / Ni / Cuprite / Nickel-bearing pyrrhotite	Miniere Cupro-Niifere Italiane	1859/1913
Balmafol	Bussoleno	Turin	Pyrite	Luigi Salton	1867/1907
Bagni (Rua`)	Vinadio	Cuneo	Silver-bearing galena	Regio Demanio	1866/1954
Monte Seyta	Vinadio	Cuneo	Fluorite / Baryte	CISAM Mineraria	1976/1991
Funghera	Traves	Turin	Talc	Pietro Possio	1930/1939
Bore (Ex Bore I E Bore li)	Brosso	Turin	Pyrite / Ematite/ Magnetite	Sclopis e C.	1912/1929
Vallauria	Limone Piemonte	Cuneo	Sphalerite / Pyrite / Silver-bearing galena	Elettro-Mineraria Savona	1807/1937
Bore li	Brosso	Turin	Pyrite / Ematite/ Magnetite	Alessandro e Giuseppe Sclopis	1858/1912
Gula	Cravagliana	Vercelli	Pyrrhotite / Au	Consorzio Minerario Valsesiano	1865/1955
Bore I	Brosso	Turin	Pyrite / Ematite	Alessandro e Giuseppe Sclopis	1858/1912
Envie`	Prali	Turin	Talc	Talco e Grafite Val Chisone	1881/1933
Valmaggia	Varallo	Vercelli	Pyrrhotite	A.M.M.I Azienda Minerali Metallici Italiani	1967/1969
Bella Costa	Ceres	Turin	Talc	-	1933/1943
Fabbriche	Riva Valdobbia	Vercelli	Copper-bearing pyrite	Brambilla	1853/1950
Pennino Grande	Valstrona	Verbano-Cusio-Ossola	Ni	A.M.M.I Azienda Minerali Metallici Italiani	1882/1949
Valbarbina (Sella Bassa)	Scopello	Vercelli	Sphalerite / Pyrrhotite / Nickel-bearing pyrrhotite	Miniere Cupro-Niifere Italiane	1859/1913
Frazze Rocconi	Montaldo Di Mondovi`	Cuneo	Mematite / Manganese minerals	Accornero Florinda	1838/1952
Campioli	Ceppo Morelli	Verbano-Cusio-Ossola	Gold-bearing ore	-	1990
Campello Monti	Valstrona	Verbano-Cusio-Ossola	Nickel-bearing ore	-	1944
Crocette A	Macugnaga	Verbano-Cusio-Ossola	Gold-bearing ore	-	-
Crocette B	Macugnaga	Verbano-Cusio-Ossola	Gold-bearing ore	-	1945
Pestanera A	Macugnaga	Verbano-Cusio-Ossola	Gold-bearing ore	-	1950
Pestanera B	Macugnaga	Verbano-Cusio-Ossola	Gold-bearing ore	-	-

type of extraction	environmental risk	potential waste	deposit	current status
underground	M	Asbestos	waste heaps	abandoned
underground	M	As / Cd / Mn / Ni / Cu	waste heaps	abandoned
underground	M	Fluorides / Mn	waste heaps	abandoned
underground	M	Co / Ni	waste heaps	abandoned
underground	M	Co / Ni / Cu	waste heaps	abandoned
underground	M	Co / Ni / Cu	waste heaps	abandoned
underground	M	As / Cd / Mn / Ni / Cu	waste heaps	abandoned
underground	M	Au / Cyanide / Pb	waste heaps	abandoned
underground	M	Fluorides	waste heaps	abandoned
underground	M	Asbestos	waste heaps	abandoned
underground	M	As / Cd / Mn / Ni / Cu / V	waste heaps	abandoned
underground	M	Au / As / Cd / Cyanide / Mn / Ni / Pb / Cu / Zn	waste heaps	abandoned
underground	M	As / Cd / Mn / Ni / Cu / V	waste heaps	abandoned
underground	M	Cyanide / Co / Ni	waste heaps	Ex Ricerca
underground	M	As / Cd / Mn / Ni / Cu	waste heaps	abandoned
underground	M	Asbestos	waste heaps	abandoned
underground	M	Co / Ni	waste heaps	former exploration
underground	M	Asbestos	waste heaps	abandoned
underground	M	As / Cd / Mn / Ni / Cu	waste heaps	abandoned
underground	M	Ni	waste heaps	abandoned
underground	M	Cd / Cyanide / Co / Ni / Zn	waste heaps	abandoned
underground	M	Mn	waste heaps	abandoned
-	MH	As / CN / Pb / TI	settling basin	abandoned
-	M	Ni / Cu	waste heaps	abandoned
-	MH	As / CN / Pb / TI	settling basin	abandoned
-	MH	As / CN / Hg / Pb / TI	waste heaps	abandoned
-	MH	As / CN / Hg / Pb / TI	waste heaps	closed
-	MH	As / CN / Hg / Pb / TI	settling basin	closed

assets for local communities, fostering new urban developments, areas⁸³. Territorial recycling can mitigate the negative impacts of mining on the landscape and reintegrate disturbed areas into broader urban and regional networks, contributing to more sustainable land-use patterns. However, for significant progress to be made, institutional policies and industrial practices must converge toward common sustainability goals, fostering a transition toward more responsible resource extraction and land management.

Incentivized by regulatory frameworks and public expectations, mining companies may integrate environmental remediation into the lifecycle of new operations. This approach can turn the reopening of mines into an opportunity to remediate legacy damage from past extraction activities. By aligning with contemporary ecological restoration practices, these projects could restore biodiversity and secure long-term environmental health in the region. One way to ensure that such mining developments contribute positively to the environment is through the principle of ecological compensation. This process can involve setting aside new protected areas adjacent to or near mining sites, allowing ecosystems to flourish under conservation measures. Establishing these conservation zones could create a network of protected areas that buffer the impacts of mining, provide additional habitat for species, and help offset biodiversity loss. The establishment of new protected areas can also be understood through the concept of the commons (Ostrom, 1990). The Alpine region, a space traditionally used for multiple purposes, could benefit from an approach that has all stakeholders collectively manage the ecological and socio-economic dimensions of mining activities. These new commons could be co-managed by local communities, conservation organizations, and the mining industry, establishing a framework for sustainable governance that mitigates environmental harm while promoting social equity.

Restoration and rehabilitation: ecological frameworks for post-mining landscapes. The Alpine region's fragile context, characterized by overlapping mining and post-mining operations, necessitates careful design to minimize environmental impact. Applying restoration and rehabilitation strategies to these landscapes offers two

⁸³ Territorial recycling offers significant opportunities for landscape regeneration and adaptive reuse. Moreover, the rehabilitation process can restore ecological balance by improving land and water management systems.

distinct, yet sometimes complementary, approaches to managing the ecological consequences of mining.

Restoration aims for the complete recovery of an ecosystem, seeking to return the land affected by mining to its original state. In the Alpine context, this means restoring native plant species, reestablishing natural hydrological cycles, and recreating habitats for indigenous wildlife. This is critical in mountain environments where watercourses are vital in ecosystem health and human activities downstream. Restoring the Alps aims to bring the mined area as close to its original pre-mining condition as possible, ensuring that ecological processes can function autonomously without ongoing human intervention.

On the other hand, rehabilitation does not aim to restore the original ecosystem fully. Instead, it focuses on improving specific ecosystem functions or mitigating environmental damage. In the Alps, it might prioritize specific practical outcomes, such as preventing soil erosion, controlling runoff, or creating new spaces that benefit local communities. In this context, it could involve revegetating areas with hardy plants that quickly stabilize soil, even if these species are not native. It could also improve water quality by constructing artificial wetlands or water filtration systems to treat any contaminated runoff before it enters rivers and streams. Additionally, *multi-use landscapes* could be created where the post-mining environment is adapted for new purposes without fully reverting to its natural state, but with minimal ecological disruption.

Both restoration and rehabilitation seek to mitigate the negative impacts of mining activities. They share standard practices, such as revegetation and erosion control, and prioritize the stabilization of soils and water systems to prevent further environmental degradation. These two approaches significantly diverge in their long-term environmental goals and the degree of intervention needed. Rehabilitation, in contrast, is more flexible and pragmatic, frequently aiming to recover essential ecological functions rather than replicate the original ecosystem. The use of non-native or hardy plants, the focus on human use, and the potential for creating new, altered landscapes all mark rehabilitation as a more adaptable method. Restoration would be ideal in high-value ecological areas, such as those near nature reserves or water sources, where maintaining biodiversity and environmental integrity is essential. In these zones, restoring the full ecosystem function is a priority to protect the delicate balance of the mountain environment. On the other hand, rehabilitation might be more appropriate in areas where the land has been

heavily altered or where there is a need for new post-mining land use. Here, the focus might shift to stabilizing the terrain and creating spaces that serve both ecological and economic purposes⁸⁴. Combining these approaches can allow for a nuanced response to the challenges posed by mining in such a sensitive and multi-functional landscape as the Alps.

Tecnonature and hybrid ecologies: rethinking mining landscapes

This complex interplay between remediation, regeneration, and resource recovery inevitably raises questions about the ontological status of the landscapes being reshaped. What kind of nature is being restored? Toward what ends are these ecological repairs directed? These questions suggest the need for a more nuanced understanding of mining landscapes that transcends binary oppositions between artificial and natural, degraded and pristine. *Tecnonature*⁸⁵ (Escobar 2018) becomes particularly relevant within this conceptual space. It offers a lens through which contemporary Alpine transformations can be read not as simple reversals of damage but as the production of hybrid ecologies mediated by technological intervention. From this perspective, new mining operations are not to be understood merely as technological intrusions into untouched environments but as actions embedded within already complex socio-natural systems. Far from being a pristine wilderness, the Alps are dynamic territories shaped by centuries of agricultural, industrial, and touristic activities⁸⁶ (Meili 2006). The notion of Tecnonature thus reframes mining not as inherently destructive but as potentially generative, if embedded within broader systems of ecologi-

⁸⁴ While restoration and rehabilitation share common goals of mitigating mining's impacts, their application in the Alpine context will depend on the specific characteristics and needs of each site. Restoration offers a pathway to full ecological recovery, emphasizing the integrity and autonomy of natural systems. In contrast, rehabilitation provides a more pragmatic approach that balances ecological improvements with human needs and land-use opportunities.

⁸⁵ Arturo Escobar has contributed significantly to understanding the relationship between technology and nature through his concept of "*Tecnonature*". This is pivotal in his broader critique of development and modernization. It emerges from critically examining how technological advancements and nature intertwine contemporary socio-ecological systems. It reflects that technology and nature are not distinct, isolated entities but deeply interrelated in shaping our world. A hybrid assemblage where natural and technological elements coalesce. This perspective challenges the conventional dichotomy that separates nature and technology and suggests that ecosystems must include technological influences and vice versa. This aligns with theories emphasizing the entanglement of humans, non-humans, and technological artifacts in producing social and environmental outcomes.

⁸⁶ Traditionally perceived as remote and wild, the Alpine region has undergone a complex transformation characterized by urban-like dynamics (Meili, 2006).

cal remediation, social equity, and long-term territorial vision. This view aligns with post-development thinking, which calls for locally grounded and ecologically situated models of sustainability that respect both technological needs and ecological limits (Escobar 2008).

From residual geographies to co-extraction: towards a circular alpine transition

The future of mining in the Alps could play a paradoxical yet constructive role in environmental conservation. By initiating new extraction projects under stringent environmental regulations, it is possible to create new commons managed for the collective benefit. In this sense, the mining industry could contribute to the sustainable future of the Alpine region by embracing the concept of *tecnonature*, in which technological interventions are *harmonized* with ecological processes, thereby promoting the health of both human and natural systems⁸⁷. These initiatives, supported by ecological compensation in the form of new protected areas, can ensure that mining not only extracts resources but also helps restore the fragile Alpine ecosystem. This integrated approach acknowledges the Alpine region's complex, overlapping uses, where urban, industrial, and natural elements collide. It seeks to foster a model of sustainable coexistence grounded in both technological and ecological realities. The reconfiguration of Alpine mining sites through territorial recycling reveals a broader shift in how we understand resource geographies in the age of transition. Rather than separating ecology and economy, past and future, waste and value, this perspective invites us to think about overlap, continuity, and mutual transformation. The Alpine region stands as a compelling site for testing this integrated approach. However, the success of such a vision depends on moving beyond sectoral silos, linking environmental restoration with industrial strategy, spatial design, and local governance.

Turning waste into a resource means more than extracting residual minerals: it requires reimagining the systems that produce, manage, and inhabit these landscapes. If this can be achieved, the Alps may cease to be a space of extraction in itself and become a territory of co-extraction. Past extractive economies' territorial and ecological legacies are neither

⁸⁷ The recognition of *tecnonature* necessitates moving beyond traditional Western paradigms that view nature as a backdrop to human action or as a resource to be exploited. Instead, it encourages an epistemological pluralism that respects local knowledge systems that often embody a more integrated view of humans and the environment. The concept is also crucial in understanding resistance movements and alternative development models that seek to reframe the relationship between technology and nature.

inert nor neutral. They continue to shape the material and symbolic infrastructures of the Alpine landscape, often in the form of residual geographies. These elements, catalogued and made visible through tools such as the *Inventario nazionale delle strutture di deposito dei rifiuti estrattivi*⁸⁸, are not simply the remains of a past that is closed. Instead, they constitute a distributed archive of potential futures, contingent upon how they are interpreted, governed, and reactivated. This inventory, part of the broader REMI project led by ISPRA, lists closed or abandoned waste deposit sites across Italy. Among these, a number are classified as “*Tipo A*”, indicating a high environmental or geotechnical risk level. Several are found in or near the valleys considered in this study, including historical mining zones in the Lanzo area, the high Valsesia, and multiple sites within the Ossola basin⁸⁹. As global demand for critical raw materials intensifies, these sites are reinscribed into strategic narratives of the circular economy and low-carbon innovation. The landscape thus becomes an evolving palimpsest of material cycles and territorial imaginaries.

Cartographies of residual frontiers: reclaiming extractive landscapes In the Ossola Valley, several historical sites in the ISPRA inventory coincide with areas now targeted for mineral exploration by private actors. The spatial proximity between legacy waste and current interest in strategic materials suggests a convergence between memory and innovation, loss and opportunity. In Valsesia, former nickel and copper zones, such as those in the Riva Valdobbia area, are under preliminary assessment, with their extractive potential revisited through new technologies and market logic. In the Lanzo region, the historical cobalt mines of Usseglio, long considered marginal, are being reassessed for their potential contribution to European battery supply chains. However, this convergence is not without contradictions. The transformation of legacy extractive sites into new resource frontiers raises fundamental questions of governance. Who defines what is extractable, and under what conditions? How are risks, benefits, and responsibilities distributed across actors and scales? Furthermore, most importantly,

⁸⁸ *National inventory of extractive waste storage facilities*, ISPRA 2022.

⁸⁹ These deposits are not only associated with traditional metals such as iron, copper, and arsenic but increasingly with CRM. This shift in material valuation is significant. What was once considered waste, subeconomic mineral deposits, processing residues, polluted sediment, is now being reframed as a secondary resource.

how can the recovery of materials be aligned with the recovery of landscapes, so that the renewed interest in subsurface wealth does not reproduce the logic of enclosure, degradation, and asymmetry historically associated with mining? The inventory is not merely a technical catalog but a cartography of tension between potential, vulnerability, and risk. It maps a subterranean archive of mineral residues, spatial opportunities, social memories, and ecological thresholds. In this sense, it becomes a critical tool for rethinking extractive policy. The landscape must be reinterpreted through a lens beyond linear remediation or techno-optimistic narratives of circularity. The concept of *living thickness* (Barcellona Corte et al. 2022) reframes the soil not as a passive surface or technical substrate, but as a dense, dynamic stratum, accumulated through geological, ecological, and socio-political processes, that actively participates in making space and meaning⁹⁰.

This territorial dynamic is not only conceptual. It becomes acutely legible when anchored in specific sites where the material legacies of past extractive cycles intersect with the speculative logics of contemporary mineral policy. In the Alpine valleys of Northern Piedmont, this condition is exemplified by a constellation of disused mining zones that, while dormant, remain geochemically and strategically significant. Among these, the former exploration sites at Valmaggia and Isola di Vocca offer two perspectives on the circular tension between waste and value⁹¹.

Valmaggia and the Alpe Laghetto concession: reconfiguration of territorial value The site at Valmaggia, in the municipality of Varallo, stands as a compact yet revealing fragment within the broader geography of Alpine mineral residues. The site was the object of subterranean cobalt and nickel exploration, and traces of these materials still exist in surface tailings. These residual accumulations, modest in scale yet rich in interpretive potential, are captured in a sequence

⁹⁰ The notion of *living thickness* is drawn from Barcellona Corte, Peleman, Ronner, and Viganò (2022), who reinterpret soil not merely as a physical support for human activities, but as a material and political palimpsest—shaped by overlapping geological formations, ecological cycles, and socio-economic histories. In their reading, soil is not a neutral or inert substrate but a contested commons whose stratified conditions demand situated design practices and long-term stewardship. See: Barcellona Corte M., Peleman D., Ronner E. and Viganò P. (2022) ‘Exploring the Soil: Not a Sentimental Journey’. In Barcellona Corte M., Peleman D., Ronner E., and Viganò P. (Eds.), *OASE #110: The Project of the Soil*. 4–17.

⁹¹ Though distinct in morphology and institutional framing, both were subject to cobalt and nickel prospecting by “A.M.M.P.”, and today persist as ambiguous fragments, neither fully absorbed into ecological processes nor reintegrated into territorial design.

of field images (*fig **), illustrating both the discarded material's physical disposition and its embeddedness within the surrounding topography. The site is entirely abandoned, with no visible containment or remediation infrastructure. The entrance is partially obscured by vegetation, while the surrounding terrain—uneven, eroded, and intermittently vegetated—suggests a slow, unmanaged reintegration into the landscape⁹². Perhaps most striking is the site's spatial entanglement: its proximity to a small hamlet, the course of the Sesia River, and a constellation of minor infrastructures positions it as an embedded fragment of the local geography rather than an isolated relic. This convergence of surface residues and underground voids reflects a broader Alpine condition: one in which the landscape is not only shaped by geomorphological processes but also stratified by industrial histories, legal traces, and geochemical risks. The presence of cobalt and nickel in these deposits not only signals possible re-exploitation—it raises the question of how we define extractive value today and how sites like Valmaggia might participate in the broader narrative of territorial recycling, remediation, and reinterpretation. Its current invisibility within planning discourse only underscores the need for situated investigations to reframe these spaces—not as inert pasts but as potential nodes in a new, integrated Alpine metabolism.

Crucially, the Valmaggia site lies within the perimeter of the *Alpe Laghetto* exploration permit⁹³, covering a mountainous area of approximately 4,188 hectares across the municipalities of Varallo, Cravagliana, Rimella, Cervatto, and Valstrona in Northern Piedmont. This territory includes portions of protected zones such as the Alta Valsesia and Alta Valle Strona Natural Park, making it a sensitive and contested space in ecological and regulatory terms. The renewed application seeks authorization to continue investigations for nickel, copper, platinum group elements, gold, and associated metals—resources increasingly central to European strategies for technological sovereignty and the energy transition. The documentation submitted as part of the renewal outlines a phased approach to mineral exploration. Initial activities include surface-level sampling, geological mapping, and geophysical surveys. Conditional on these findings, subsequent interventions would involve targeted drilling operations. While the company claims the technical and financial capacity to conduct these operations responsibly, the proposal

⁹² From the coordinates (45.829364, 8.222414), the mine entrance is also registered in the regional cave cadastre, hinting at a subsurface structure of potential complexity.

⁹³ Currently held by *Ivrea Minerals Pty Ltd*—a non-listed Australian company backed by *Macallum Group Ltd*.

raises questions about the compatibility between extractive ambitions and the multi-layered constraints of the Alpine context—ranging from hydrogeological vulnerability to landscape protection and from legal zoning to socio-cultural perceptions of value and risk.

Legally, the permit is anchored in a composite regulatory framework that includes national legislation⁹⁴ and regional laws governing extraction in environmentally constrained areas⁹⁵. These legal layers reinforce the complex governance dynamics, particularly in sites where exploration intersects with conservation designations and long-established ecological functions⁹⁶. However, the documentation remains ambiguous on mechanisms for public involvement, compensation schemes, or integration with broader territorial visions. It illustrates the emerging tension between strategic mineral policy and Alpine territorial fragility from a spatial and socio-political perspective. It reactivates long-dormant extractive geography, inserting local valleys into new global circuits of material demand, capital investment, and geopolitical positioning. This return of extraction is not simply a repetition of past cycles. It is qualitatively different in scale, instrumentation, and systemic framing. It also risks reigniting unresolved conflicts between short-term exploitation and long-term stewardship in landscapes already subject to demographic contraction, infrastructural obsolescence, and ecological stress. This case cannot be read as an isolated technical procedure. It must be situated within a broader reflection on the governance of critical raw materials in complex territories—where environmental sensitivities, legacy residues, and economic expectations collide. It brings to the fore the need for multi-scalar design tools capable of addressing extractive projects not only as legal-economic events but as territorial transformations with cumulative and distributed effects. This underscores the importance of developing anticipatory frameworks that connect exploration to questions of infrastructural reuse, and metabolic realignment across the Alpine region. In this perspective, the *Alpe Laghetto* concession becomes particularly relevant not only for its prospective mineral value but also for its capacity to reactivate and reframe the spatial and material legacies of previous extractive attempts. Including sites such as Valmaggia, where cobalt and nickel were explored in the late 1960s and where surface tailings remain untreated, suggests that new concessions

⁹⁴ *Regio Decreto 1443/1927* and *D.P.R. 382/1994*.

⁹⁵ *L.R. 45/1989* and *L.R. 40/1998*.

⁹⁶ The applicant argues that mineral prospecting can coexist with environmental protection, provided mitigation measures and post-exploration remediation plans are respected.

may, intentionally or otherwise, intersect with existing mining waste deposits. Rather than extending extraction into untouched ecologies, such permits could provide an opportunity to embed exploration within remediation or resource recovery strategies.

A shift is needed in how extractive operations are conceptualized and governed to realize this potential. Legacy sites should not be treated as inert leftovers while new exploration is projected as innovation. Instead, design frameworks must interweave these temporalities. The key challenge is to design protocols where extraction and environmental reclamation are not parallel but interdependent processes. The *Alpe Laghetto* case, in this sense, exemplifies both the vulnerabilities and opportunities of this paradigm: if conceived in linear terms, it may reproduce extractive asymmetries. However, if grounded in circular logic, it may serve as a laboratory for coupling resource access with ecological repair.

Isola di Vocca and the Sella Bassa permit: latent commons

The site at *Isola di Vocca*, located in Vocca (VC), consists of underground cobalt and nickel deposits. Today, it presents itself as a discreet yet materially significant landscape. The surface tailings, observable in aerial and ground-level field documentation, reveal the sedimented logic of past prospecting, even in the absence of built infrastructure or technical installations. In field images, the site appears as a diffuse terrain of low-lying mounds and disrupted topography, partially reabsorbed by vegetation but still legible in its geomorphological structure. Broader aerial views demonstrate how this residual area is integrated into a hybrid valley-floor system, bordered by the Sesia River, intersected by minor roads and infrastructure corridors, and adjacent to scattered residential clusters. This spatial entanglement undermines simplistic notions of extractive voids, suggesting instead a landscape where memory, infrastructural inertia, and environmental exposure coexist.

The site remains geochemically active despite its apparent invisibility in current design frameworks. Residues associated with cobalt and nickel extraction, including traces of arsenic and cadmium noted in previous assessments, are subject to weathering and hydrological dispersion, raising long-term questions about environmental responsibility and remediation potential. However, these residues could also be re-entered into circuits of secondary resource recovery. As the transition to green technologies redefines what counts as a resource, peripheral sites may shift from passive afterlives to strategic stockpiles capable of supporting

circular material flows, if governed accordingly. Vocca exemplifies the broader condition of landscapes in waiting found throughout the Alps: not ruins but open-ended infrastructures, where extraction has been initiated but never fulfilled. Whether these zones remain as unmanaged remnants or become re-functionalized within regenerative design paradigms depends not on their past productivity but on the frameworks we build to interpret and activate them. In this light, it is less a failed mine than a latent commons. Spatially, the site falls within the *Sella Bassa* exploration permit⁹⁷ area. This concession covers 3,661 hectares across several municipalities in the provinces of Vercelli and Biella, including Vocca, Fobello, Scopa, and Cravagliana. Notably, the site sits at the intersection of two overlapping geographies: the historical arc of late-industrial mineral exploration in the Sesia Valley and the contemporary push to resurvey the Ivrea-Verbano zone as a critical raw materials frontier. The *Programma dei lavori*⁹⁸ outlines a two-year research agenda, with a strong emphasis on non-invasive geological, structural, and geophysical investigations. While the company claims a non-disruptive approach, focusing on desktop studies, remote sensing, and limited field surveys, the permit's stated objective is to identify exploitable deposits of a wide range of metals⁹⁹. The inclusion of cobalt and nickel—precisely the metals formerly prospected at Isola di Vocca—suggests that the site may re-enter not only the geological but also the policy imagination, no longer as a failed experiment but as a latent node within a broader resource geography. The *Modulo di valutazione preliminare* reinforces this trajectory by explicitly referencing the Ivrea-Verbano geological complex as an underutilized yet highly promising zone for deep mineral exploration. Notably, the preliminary assessment insists on the absence of protected areas within the Sella Bassa concession, despite the ecological sensitivity of the broader Valsesian landscape. Although the documents deny foreseeable environmental impacts, this assertion sits uneasily with the proximity of multiple rivers, steep slopes, forested areas, and the cumulative legacy of past mining activities, all of which suggest a need for caution and critical oversight.

Within this framework, these sites are increasingly folded into a speculative circular resource-extraction economy. Their value lies not only in

⁹⁷ Currently held by *AGE EV Minerale S.r.l.*, an Italian subsidiary of the Australian company *AGE EV Minerals Pty Ltd.*

⁹⁸ Submitted by *AGE EV*.

⁹⁹ Including Ti, Cr, Co, Ni, Cu, Zn, Mo, Ag, Sb, Au, Pb, Bi, PGE (Platinum Group Elements), and REE (Rare Earth Elements).

the metals they might still contain but also in their eligibility for funding, attention, and infrastructural reintegration under the banner of innovation and sustainability. In this sense, the site represents both a material deposit and an archive of past state-led exploration, now repurposed by private capital for future supply chains. Yet the site's current condition, absent of monitoring, containment, or remediation, raises urgent questions about risk governance. Suppose the legacy of cobalt and nickel exploration is to be reintegrated into a new extraction cycle. What safeguards ensure that this process will not replicate the asymmetries and externalities of the past? How might exploration activities be aligned with the remediation of existing residues, and how can local communities be engaged in shaping the terms of this revival? To address these questions, a new design grammar is needed, one that moves beyond linear models of prospect-extract-abandon and toward circular frameworks where exploration, remediation, and regeneration are mutually reinforcing¹⁰⁰. In this context, it becomes more than a prospective site: it is a testing ground for reconciling extractive ambition with territorial responsibility. Its inclusion in the Sella Bassa permit thus demands not only technical scrutiny but conceptual innovation, linking legacy waste to future cycles not as an afterthought but as a structuring principle of a new Alpine resource governance¹⁰¹, an alternative geography of regeneration.

¹⁰⁰ Sites serve as more than case studies of extractive residue, they exemplify a broader territorial condition in which the remnants of past mining cycles linger as material traces and latent conflicts. These sites are not merely technical leftovers to be remediated or redeveloped, but spatial palimpsests that condense histories of ambition, interruption, and neglect. Their enduring presence challenges conventional planning categories, resisting simplistic classifications as either polluted voids or future assets. Instead, they occupy a complex middle ground: geochemically active yet politically underarticulated, environmentally fragile yet economically revalorized.

¹⁰¹ Reimagining governance not as a mechanism of control but as a shared negotiation process. In this sense, the question is not simply how to manage inherited contamination, but how to recompose socio-ecological relationships around it.

Punta Corna, the politics of legacy mining Among the numerous alpine sites where mineral exploration is being reconsidered under the European critical raw materials agenda, Punta Corna stands out as a paradigmatic case, not for the scale of its deposits, but for the complexity of its territorial entanglements. Located within the high-altitude valleys of Usseglio and Balme in the Graian Alps¹⁰², the area has long hosted a constellation of mineral traces, including historical extractions of cobalt, silver, and associated elements. Yet what makes Punta Corna particularly relevant today is less its geological profile than the overlapping ecological, infrastructural, and political configurations that frame its potential reactivation. Unlike other cases where mining residues are embedded in partially urbanized or post-industrial settings, the concession intersects with an almost entirely high-mountain, conservation-ori-

¹⁰² Usseglio and Balme are two small mountain municipalities located in the Lanzo valleys of northwestern Piedmont, respectively in the Viù and Ala valleys. Situated at elevations between 1,200 and 1,400 meters above sea level, both villages share a fragile yet actively maintained economy based on hiking tourism, alpine pastoralism, and landscape conservation. Usseglio, with around 190 officially registered residents—but a much lower de facto population—features a modest but structured tourism offer, including hospitality facilities, a local ski station, summer events, and mountain farming activities supported by the management of municipal grazing lands. The municipality is also advancing regeneration projects funded by the *National Recovery and Resilience Plan (PNRR)*, such as the adaptive reuse of the former Rocciamelone barracks as a sport and recreation center. Balme, with approximately 100 registered inhabitants and even fewer permanent residents, has pursued a consistent development strategy centered on environmental protection and sustainable tourism, focusing on hiking networks, alpine trails, and the valorization of the *Pian della Mussa Natura 2000* site. The two administrations have taken divergent positions on the proposed mineral exploration on the Punta Corna massif: while Usseglio has expressed cautious openness, conditional on infrastructure improvements and territorial compensation, Balme officially opposed the initiative in 2020, arguing that mining activity is incompatible with its local development model. This tension between neighboring municipalities exemplifies the complexity of decision-making in low-density Alpine areas, where the return of extraction intersects with delicate territorial equilibriums involving identity, landscape, and the coexistence of multiple functions.

ented geography¹⁰³.

The area lies near sensitive habitats such as Pian della Mussa and the Arnas basin, within the influence of *Natura 2000* designations and proximity to the protected zone of the *Parco Naturale Orsiera-Rocciavré*. Here, spatial design operates not on the logic of industrial conversion, but on that of landscape stewardship, seasonal pastoralism, and a precarious yet vital tourism economy. The material intensity of mineral prospecting, though limited to preliminary drilling, thus collides with a grammar structured around conservation, heritage, and low-intensity inhabitation. The current application for permit renewal and expansion¹⁰⁴ includes an *Environmental Impact Assessment* and an extensive *Monitoring Plan*.. Despite mitigation measures, such as closed-loop water systems, acoustic minimization protocols, and site-specific ecological evaluations, the document reveals the structural fragility of such operations in this context. Access to drilling areas requires helicopter transport or the temporary reopening of degraded paths. The proximity of workstations to alpine pastures, ecological corridors, and local water bodies, such as the Rio Servin and the artificial Lago del Servin, intensifies the pressure on already delicate ecosystems.

Even more complex is the socio-political dimension. Balme and Usseglio are small municipalities whose spatial narratives revolve around abandonment. The return of extraction, however framed as *green* or *strategic* risks unbalances long-standing efforts toward ecological tourism, local identity, and multi-functional land use. In this light, the Punta

¹⁰³ The Punta Corna exploration area sits within a distinct territorial morphology: that of high-altitude alpine environments characterized by fragile ecosystems, limited infrastructural accessibility, and a strong legacy of conservation. Unlike more hybrid or peri-urban extractive contexts—often shaped by the spatial logic of industrialization and infrastructural layering—this area exemplifies what might be termed a territory of ecological interdependence: a geography where the landscape is co-produced by centuries of pastoral practices, hydrological systems, and cultural sedimentations. In these “*terre alte*” (high lands), as described by various Alpine territorial studies, infrastructures are sparse, and the physical morphology imposes structural limitations on large-scale interventions, making any extractive activity a high-impact operation from the outset. These landscapes are not only ecologically sensitive, but also embedded in symbolic, recreational, and economic dynamics—ranging from transhumance systems and tourism economies to protected areas and *Natura 2000* designations—that reinforce their strategic relevance for biodiversity, climate resilience, and cultural heritage. The concession’s overlap with high-mountain commons thus raises critical questions about the compatibility of new mining operations with ongoing ecological functions and socio-spatial equilibriums. Rather than framing such territories as “empty” or underutilized, this perspective highlights the complex entanglement of human and non-human actors, where value is not defined solely by subsurface resources but by relational, interdependent systems of land use, memory, and ecological reproduction

¹⁰⁴ Submitted by *Strategic Minerals S.r.l.*

Corna project becomes a test case for the broader legitimacy of critical minerals policy in mountain contexts. It raises the question of how extractive ambitions can be negotiated within landscapes governed by vulnerability, retreat, and reinvention narratives. From a territorial design standpoint, the case demands reframing conventional categories. Rather than approaching it as a conflict between resource access and environmental protection, reading Punta Corna as a layered terrain where historical extraction, ecological thresholds, and contemporary territorial imaginaries intersect may be more productive. The goal is to regulate impact and design governance structures that can accommodate multiple temporalities. This requires tools beyond the scope of standard environmental monitoring. For instance, the archeological traces in the area, including the “*Taglio del Ferro*” trench and early cobalt exploitation galleries, signal a palimpsest of Alpine industrialization that predates modern mining legislation. These infrastructures, whether preserved, reused, or contested, shape the technical feasibility of extraction and its cultural legibility. Similarly, the site’s position within complex ecological corridors amplifies the urgency of framing mineral exploration within a more-than-human ethics of care and cohabitation. In this sense, the key challenge is not technical compatibility, but spatial responsibility.

What modes of coexistence can be designed between reactivated mineral economies and slow, seasonal practices of inhabitation? How can partial reindustrialization be orchestrated in ways that do not displace existing ecologies, imaginaries, or forms of local agency? The Punta Corna project remains under assessment. Yet its strategic significance lies less in its immediate extractive yield than in its capacity to serve as a prototype for alpine-scale design questions. It invites territorial practitioners to articulate frameworks where exploration is conditional upon collective agreements, legacy remediation, and systemic alignment with the fragile metabolisms of highland landscapes. In this regard, the site prompts a shift in focus, from technical evaluation alone to a broader inquiry into how extraction is framed, contested, and situated within territorial and political processes. *Exploring the soil* (Barcellona Corte et al. 2022) is a political and design act: it means interrogating the relations of power, production, and reproduction that shape space.

10.4.compensatory mechanisms and multi-layered approaches

Extraction concessions in Alpine areas, including the exploitation of natural resources such as minerals, water, and energy, are a significant source of tax revenue for national, regional, and municipal governments. These revenues are typically derived from several fiscal mechanisms, such as concession fees¹⁰⁵, royalties¹⁰⁶, environmental taxes¹⁰⁷, and corporate taxes¹⁰⁸. Regions and municipalities in Alpine areas, which often manage the concessionary process, benefit from these revenues in several ways. These funds support local infrastructure, environmental conservation, and development initiatives. However, exploiting natural resources in Alpine environments raises critical social, ecological, and economic concerns deeply intertwined with broader discussions of sustainable development and environmental integrity. The extraction of natural resources in Alpine areas provides a critical source of income for national and local governments, playing a central role in the economic landscape of many Alpine regions. These revenues are primarily generated through four fundamental mechanisms: concession fees, royalties, corporate income taxes, and environmental compensation. Each revenue stream has distinct characteristics. Below, we will delve deeper into these four sources, examining their implications and the broader context of resource extraction in environmentally sensitive areas like the Alps.

Revenue mechanisms of Alpine resource extraction include concession fees, royalties, taxes, and environmental compensation Concession fees are payments made by extraction companies to acquire the legal right to extract resources from public lands, including those in Alpine regions. These fees are typically calculated based on the estimated value or volume of the resources to be extracted and paid upfront or as part of the concession contract.

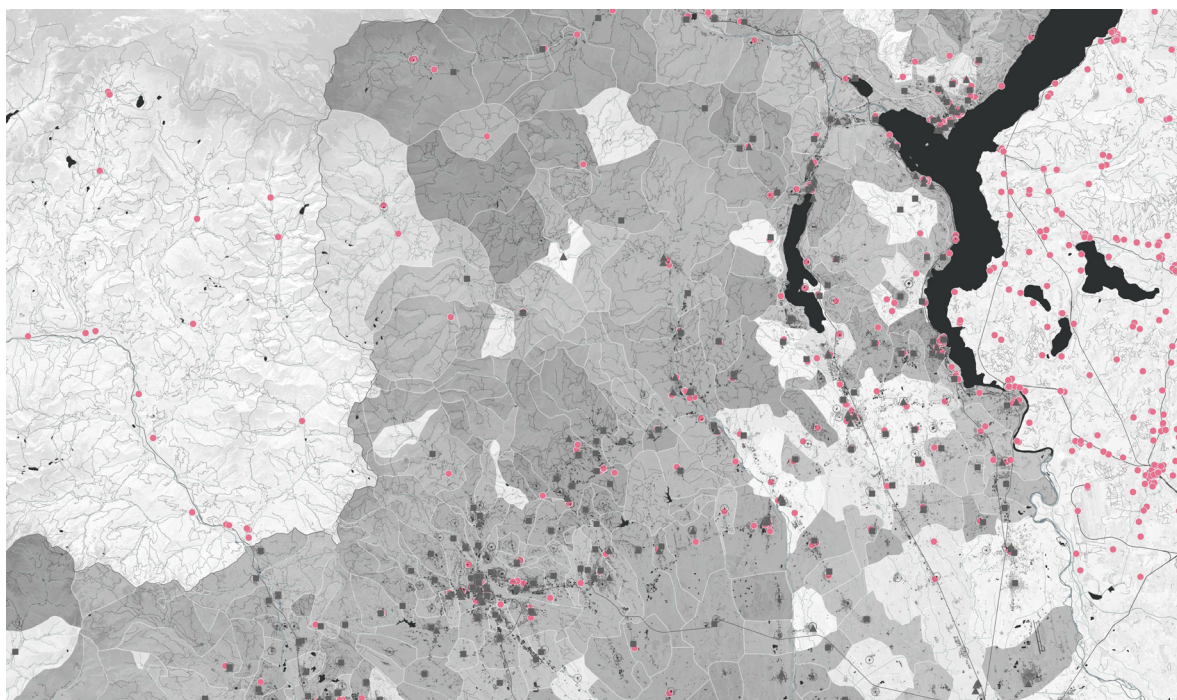
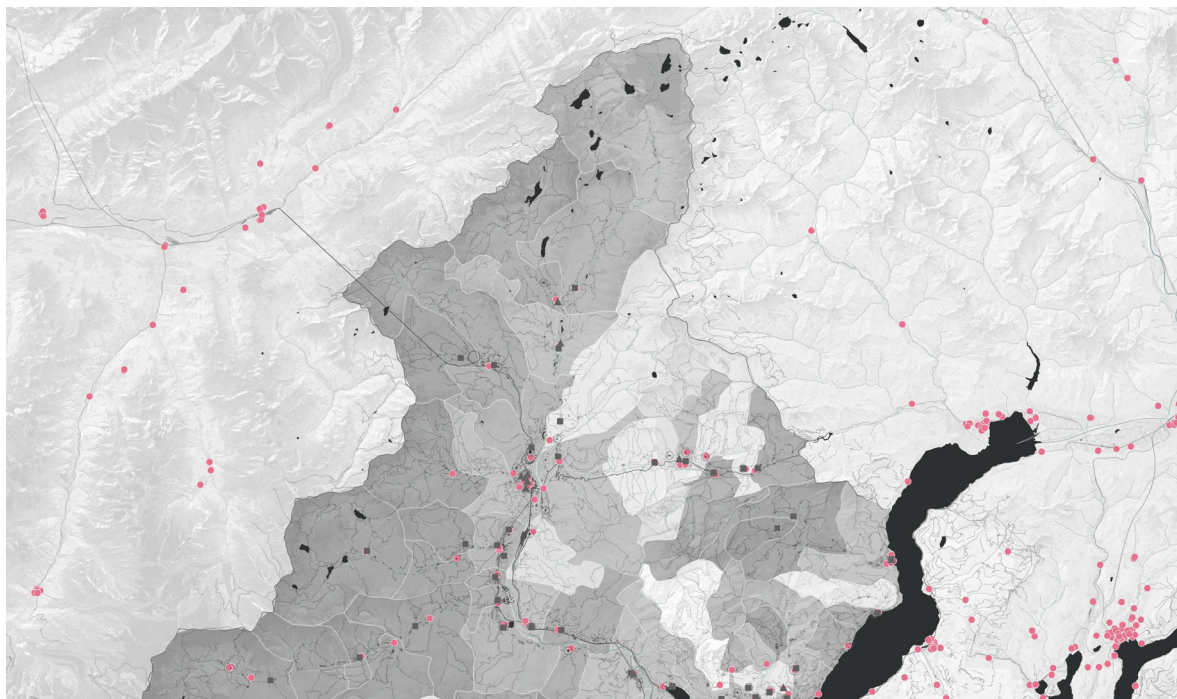
For governments, concession fees represent a direct and immediate source of income. They are essential in regions where resource extraction is a primary economic activity, as these fees can fund public services, infrastructure, and development projects. The terms of conces-

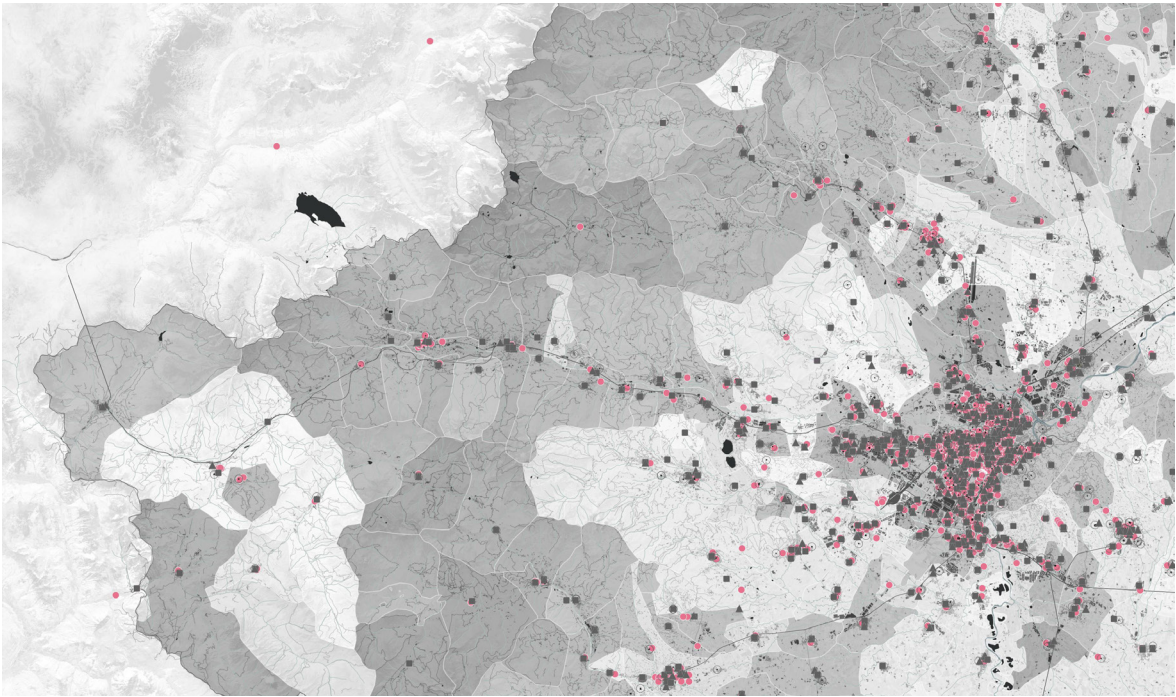
¹⁰⁵ Companies that obtain the right to extract natural resources must pay a fee to the relevant authorities for the use of public resources.

¹⁰⁶ A percentage of the revenues generated by the sale of extracted resources is paid to the state or local governments, representing a direct financial benefit from resource utilization.

¹⁰⁷ In certain jurisdictions, resource extraction is accompanied by environmental taxes or compensation mechanisms to offset ecological damage caused by these activities.

¹⁰⁸ Companies engaged in extraction activities are also subject to corporate income taxes on the profits generated by their operations.





- Preschool
- Primary school
- ▲ Secondary school
- ✚ University
- Healthcare

Population change (%)

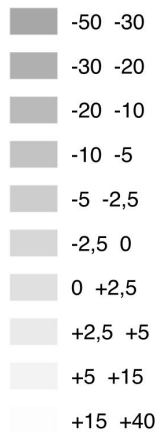


fig.10.35-37 The maps are based on *ISTAT* population data for 2005 and 2025. The varying color intensity represents the percentage change over the twenty-year period: darker shades indicate population decline, while lighter tones correspond to growth.

The same maps also visualize the distribution of healthcare, educational, and everyday infrastructure services.

(Source: *ISTAT*).



sion fees are usually outlined in long-term contracts that can last several years or even decades, depending on the nature of the extraction. This provides stability in government revenue streams over time. Concession fees are often the focus of government policy debates. While they generate essential revenue, there is a growing emphasis on ensuring that the fees reflect the actual economic and environmental costs of extraction, particularly in ecologically sensitive areas such as the Alps. Adjustments to concession fee structures can be used as tools for environmental policy, incentivizing more sustainable extraction practices. One of the critical challenges of concession fees is that they do not always account for the environmental damage caused by extraction. Governments are increasingly considering how to incorporate environmental externalities into the pricing of concession fees to ensure that natural resources are extracted in ways that minimize long-term ecological harm.

Royalties are payments made by extraction companies to the government, representing a percentage of the revenue from the sale of extracted resources¹⁰⁹. Unlike concession fees, which are typically fixed, royalties are variable and depend on market conditions and the volume of materials extracted. Governments often benefit from higher royalties during periods of strong market demand or high commodity prices. However, this means that their revenues can be unpredictable, fluctuating with changes in global market conditions. In many cases, they are shared between national and local governments, ensuring that Alpine communities directly benefit from extraction activities in their regions. This revenue sharing is critical to regional development and infrastructure projects, particularly in remote Alpine villages that may lack access to diverse income streams. Royalties are often structured to encourage companies to maximize extraction efficiency. However, this can also lead to overextraction, raising concerns about the sustainability of resource use and the long-term environmental impact. The main challenge of relying on them as a revenue source is their dependence on market prices. For example, a decline in global metal prices could significantly reduce the royalties governments collect, impacting local budgets and planned

¹⁰⁹ A detailed analysis can be found in studies of mining taxation systems, where royalties are typically categorized into three main types: unit-based, value-based, and profit-based. These systems are widely applied in extractive industries, and their impact on both governments and investors is discussed in literature like *Mining Royalties: A Global Study* by the World Bank (2006). This study outlines how different governments implement royalties to capture economic rents while balancing investor interests and market volatility. These royalties are critical for resource-rich regions and are often complemented by concession fees, which provide upfront income to governments.

projects. Royalties can sometimes encourage companies to extract resources more quickly to capitalize on favorable market conditions, leading to accelerated depletion of non-renewable resources and potentially causing long-term harm to the local environment.

Corporate income taxes are levied on the profits made by extraction companies operating in Alpine regions. This is a general tax that applies to all businesses¹¹⁰. Still, it is particularly significant in the extraction industry, where profits can be substantial, especially during boom periods for natural resource commodities. Governments derive income from the taxable earnings of extraction companies, which are calculated after accounting for operational costs, capital expenditures, and other allowable deductions. National governments set the tax rate, which varies by country. Corporate income taxes provide a stable and predictable revenue stream for governments, especially when extraction companies are profitable. Unlike royalties, which depend on the volume of extracted resources, taxes focus on a company's overall profitability, which may include diversified income sources beyond extraction activities. They can be structured to promote progressive taxation, ensuring that companies with higher profits pay a more significant share. This is particularly relevant in Alpine regions, where extraction companies may benefit from large-scale operations that generate substantial profits. One crucial challenge is the potential for tax avoidance. Extraction companies may employ sophisticated tax design strategies to reduce their taxable income, thereby decreasing the overall tax revenue available to governments. The extraction industry is highly cyclical, meaning corporate profits can vary dramatically based on global demand, commodity prices, and operational costs. This variability makes it difficult for governments to accurately predict revenue from corporate income taxes.

Environmental compensation is a financial mechanism that offsets the environmental impacts of extraction activities. This can include direct payments to fund environmental restoration projects, contributions to local conservation efforts, or penalties imposed on companies that fail to comply with environmental regulations. The payments are designed to

¹¹⁰ Corporate income taxes are another major revenue stream for governments from extraction activities. Extractive industries are subject to various tax regimes, often a combination of national and local taxes on profits. Countries like Australia and Brazil use systems where corporate taxes are paired with specific resource-based levies, such as the Petroleum Resource Rent Tax in Australia. These taxes help governments capture profits from extraction operations while offering deductions for operational and capital costs (International Monetary Fund 2012).

mitigate the negative externalities of resource extraction, such as habitat destruction, water pollution, and landscape alteration. In Alpine regions, these payments are crucial for maintaining biodiversity and protecting natural resources. It is often based on the polluter pays principle, meaning that companies responsible for environmental damage are required to finance mitigation or restoration efforts. This can involve restoring mined areas, reforestation projects, or efforts to prevent further environmental degradation. Implementing them reflects a growing recognition that long-term sustainability must be a priority in resource extraction. By requiring companies to compensate for the environmental harm they cause, governments can incentivize more sustainable practices and reduce the ecological footprint of extraction activities. One of the main challenges is determining whether the compensation level is sufficient to cover the actual environmental damage. In many cases, compensation payments may fall short of the funds needed to fully restore ecosystems, leading to long-term environmental degradation that is not adequately addressed. Ensuring that extraction companies comply with environmental compensation requirements can be difficult, particularly in remote Alpine areas where monitoring and enforcement may be limited. Each of these four revenue sources is vital in governing natural resource extraction in Alpine areas. While they provide essential income for national and local governments, they also raise significant questions about market volatility and environmental protection. As Alpine regions grapple with the competing pressures of economic development and environmental conservation, policymakers must carefully balance these revenue streams with efforts to promote long-term ecological and economic sustainability.

Circular economy and material criticality: implications for Alpine extraction and fiscal strategies The economic benefits of resource extraction in Alpine regions, however, raise significant concerns when examined through the lenses of sustainability and resource efficiency, particularly in the context of emerging frameworks such as the circular economy and criticality assessments (Graedel and Reck, 2016). The concept focuses on creating a regenerative system that minimizes waste and maximizes the reuse of resources (Stahel, 2016). In contrast to the traditional linear economy, which follows the take-make-dispose model, the circular economy aims to keep materials in use for as long as possible, thereby reducing the need to continuously extract virgin re-

sources. When applied to Alpine regions, this paradigm shift has several critical implications. Governments may need to consider balancing reliance on extraction revenue with efforts to promote circular strategies. As the circular economy gains traction, national and local governments may need to rethink their fiscal structures. The transition could result in a decline in extraction activities, reducing income from concession fees and royalties. However, new tax models could emerge that incentivize resource efficiency, product durability, and recycling initiatives, ensuring continued fiscal income while supporting sustainable practices. A systemic shift is necessary to balance economic growth with environmental preservation. The traditional extraction model as a primary revenue source may become increasingly incompatible with the growing need for sustainable development and long-term environmental preservation stewardship.

Criticality assessments evaluate materials based on their economic importance and supply risk (Graedel and Reck, 2016). Diversifying supply chains and improving recycling rates to reduce reliance on CRM. If materials extracted from Alpine areas are classified as critical, national governments may prioritize maintaining control over these resources, potentially extending the life of extraction activities. However, this approach should be balanced with long-term supply security strategies, such as promoting material substitution and increasing investments in recycling technologies. Governments may develop strategic reserves of critical materials, reducing the pressure for continuous extraction in the Alps. By building stockpiles, Alpine regions could shift towards a model emphasizing resource conservation rather than exploitation. This could involve redirecting some of the revenue from extraction concessions to develop recycling infrastructure in Alpine regions. This would not only support the principles of the circular economy but also align with national and regional efforts to secure long-term material supplies. The dual frameworks of the circular economy and criticality assessments pose significant challenges and opportunities for governments that rely on extraction revenues.

However, as circular economy practices become more widespread, reliance on these revenues may need to shift towards more sustainable income sources, such as environmental services or renewable energy initiatives. Governments must invest in resource-efficient technologies and

build resilience¹¹¹ to supply shocks, particularly for critical materials.

Compensation as a site-specific governance tool in ecologically and socially fragile Alpine territories

As the global economy shifts toward more sustainable practices, Alpine regions must adapt by fostering economic diversification. Governments must reconsider their fiscal strategies in light of these changes, ensuring that they continue to generate revenue while supporting the environmental integrity and social sustainability of the Alpine regions. This will require a coordinated effort to balance the fiscal benefits of extraction with the urgent need to transition towards more circular and sustainable economic models. This approach also reframes the function of criticality within compensation frameworks. In the Alpine cases under analysis, it is not the generic presence of raw materials that warrants attention, this has already been extensively established, but rather their specific territorial expression¹¹². The significance of cobalt and nickel in these sites is not only geological but institutional and distributive: it situates the valleys within emergent regimes of strategic extraction while reactivating unresolved legacies of past interventions. As such, the issue is no longer whether these materials are globally critical but what kinds of compensatory obligations arise when they intersect with ecological vulnerability, infrastructural obsolescence, and social marginality. In this light, compensation must be reframed not as a standard fiscal response to mineral value but as a negotiated process embedded in each site's situated fragilities and potentialities. Rather than abstracting value upward—to national or transnational scales—compensatory mechanisms must redistribute it toward the landscapes and communities most exposed to its externalities. This implies a shift in governance logic: from managing scarcity to enabling repair, from universal impact metrics to context-specific resilience thresholds, and from passive fiscal redistribution to active territorial co-design. The criticality of these sites thus becomes a relational condition, not a fixed attribute of their subsoil but a dynamic configuration of material demand, institutional visibility, and environmental risk. Any compensation model failing to account for this relational dimension

¹¹¹ By reusing and recycling critical materials, Alpine regions could become less dependent on risky extraction activities and more aligned with global efforts to secure sustainable material flows

¹¹² This does not mean that all mining zones must be reactivated; instead, it recognizes that even those left untouched by new concessions hold transformative potential, if approached as part of a distributed repair infrastructure.

risks reproducing the asymmetries it is meant to mitigate.

The question of compensation in extractive territories must be situated within the socio-spatial dynamics that shape the relationship between Alpine valley floors and highland areas. Far from being neutral containers of mineral value, these landscapes are traversed by persistent gradients of accessibility, service provision, and institutional attention. Mountain municipalities experience structural disadvantages, including demographic decline, aging populations, limited access to healthcare and education, and under-provision of mobility and digital infrastructure. These deficits are not incidental, they are the cumulative result of long-term spatial and policy asymmetries that have privileged valley infrastructures and urban centers while disinvesting in remote alpine communities. Within this context, resource extraction intensifies an already uneven geography. Mineral exploration and prospecting activities often occur in or near these highland zones, where legacies of past mining and new concessions converge with fragile ecological systems and shrinking social fabrics. However, where these operations exist, the fiscal returns rarely remain in the places most directly affected. Concession fees, royalties, or corporate taxes often flow toward central or regional institutions, reinforcing the structural marginality of extraction zones. Even when environmental compensation is enacted, it follows generic frameworks rather than addressing host communities' specific vulnerabilities and aspirations. Rebalancing this spatial inequity requires a paradigmatic shift from extractive logic to territorial reciprocity. This means recognizing that extraction's environmental, social, and infrastructural costs are not evenly distributed and that compensation cannot be confined to fiscal abstractions. Instead, it must be articulated as a situated strategy anchored in the everyday realities of Alpine municipalities. Compensation, in this sense, becomes a tool of territorial justice, not merely of accounting.

This shift implies rethinking the valley-highland relation itself. Rather than treating highland communities as isolated recipients of damage, compensation mechanisms should support forms of socio-ecological reconnection: reactivating services, restoring ecological corridors, and investing in multifunctional infrastructure that strengthens local resilience. Interventions range from rehabilitating disused mining access routes for ecological and recreational use to establishing decentralized energy or mobility networks and funding education and research platforms focused on circular economies in marginal contexts. The goal is

to enable new articulations among the center and the periphery, extractive memory, and regenerative futures¹¹³. In this vision, the Alps are not peripheral sacrifice zones but laboratories for alternative models of resource governance that bind compensation to reinvestment and place-based transformation. This approach demands financial instruments, design tools, and design visions capable of reading these landscapes as layered terrains

Territorial marginality and structural fragility in Viù, Valsesia, and Ossola: limits of current compensation models.

The contemporary return of extraction, whether framed as strategic autonomy or energy transition, requires a deeper interrogation of the territorial asymmetries that structure its material and political viability. In particular, the valleys of Viù, Valsesia, and Ossola articulate not only geologically promising areas for cobalt and other CRM-related materials but also socially fragile, infrastructurally under-equipped, and demographically shrinking spaces. These spatial configurations are not incidental: they reflect a historically sedimented disinvestment in mountain economies and services, which contemporary extractive interests risk exacerbating and instrumentalizing. Suppose concessions are increasingly concentrated in such contexts. In that case, it is not solely because of subsurface richness but because marginality becomes an enabling condition for extractive ambition. This structural marginality, well-documented in regional analyses and consolidated over decades of territorial imbalance, manifests in multiple interrelated dimensions. The municipalities under analysis exhibit clear demographic fragilities, including sustained population decline, demographic aging, diminishing service provision, and persistent marginality within regional infra-

¹¹³ They must articulate a new narrative in which the mountains are not simply exploited resources or *frozen* heritage but dynamic terrains of transition.

structure agendas¹¹⁴. Public transport is scarce and seasonal, digital connectivity remains partial, and educational and healthcare services have been progressively centralized on valley floors or regional hubs, exposing highland communities to an ongoing spiral of infrastructural thinning. These deficits are not simply logistical. They shape how territorial value is perceived, produced, and distributed, and frame specific geographies as available both geologically and socially: spaces where resistance is limited, governance is fragmented, and extractive narratives can be more easily naturalized. Within this framework, renewed interest in critical raw materials inserts itself into a pre-existing topography of vulnerability.

In the Val di Viù, municipalities struggle with public revenue shortfalls, ageing infrastructure, and limited institutional capacity to engage with transnational actors or to navigate technical procedures. The same is true in parts of Valsesia, where legacy sites like Valmaggia or Isola di Vocca re-emerge on the radar of foreign capital through concession renewals and exploratory campaigns. In Ossola, the situation is further complicated by a persistent dualism between the infrastructured valley floor (Domodossola, Villadossola) and the peripheral lateral valleys, where extractive residues persist in spatial isolation but institutional invisibility. In all three contexts, the relationship between the *fondovalle* and *terre alte* is topographic and political. Resource governance, whether in concession attribution, compensation flows, or strategic design, remains disproportionately managed at valley or regional levels, rarely incorporating the specific perspectives of the mountain municipalities most

¹¹⁴ Over the past century, the Alpine municipalities examined in this research have undergone significant demographic contraction, marked by population decline, aging, and institutional erosion. Balme (TO), for instance, declined from 431 inhabitants in 1861 to just 110 in 2021, reflecting a population loss of over 75% in 160 years. Similar trajectories are observed in peripheral areas of Valsesia and Ossola: Antrona Schieranco (VB), which had 604 residents in the early 1990s, dropped to approximately 404 by 2021, while Fobello (VC) counted only 194 inhabitants as of 2017. Montescheno (VB), another small mountain municipality, has seen a steady demographic contraction since the early 2000s. Across these territories, the aging index often exceeds 1,000—meaning there are more than ten residents over the age of 65 for every youth under 15. While all municipalities have followed a general pattern of demographic decline, the pace and inflection points vary. In Balme, the sharpest decrease occurred in the postwar decades, while in Fobello and Antrona Schieranco, the demographic contraction has intensified over the last thirty years, coinciding with the reduction of rural livelihoods and basic public services. These shifts have tangible consequences: not only statistical shrinkage, but also the disappearance of schools and clinics, the weakening of social networks, and the administrative vulnerability of local governments. As such, these demographic patterns translate into chronic underrepresentation in regional planning frameworks, with cascading effects on infrastructure investment and service provision.

exposed to the externalities of extraction. This is particularly evident in the mechanisms of fiscal redistribution. Royalties and concession fees often follow generic criteria and centralized routes, with little traceability or earmarking for site-specific reinvestment. Environmental compensation, when it exists, is framed in terms of generalized ecological offsets rather than tailored responses to the affected communes' histories, needs, or potentialities. However, these *terre alte* are not only recipients of extraction, they are also reservoirs of alternative imaginaries. Despite their structural fragility, many of these municipalities have developed local forms of stewardship, ecological restoration, or heritage-based economies that challenge the logic of resource linearity. In Usseglio, for instance, community initiatives have sought to reclaim mining memory as cultural infrastructure, transforming abandoned sites into trails, museums, or pedagogical tools. In Cervatto or Rimella, land management practices and forms of collective governance, though precarious, offer counter-narratives to the technocratic framing of resource value. These instances, while often under-supported and under-documented, demonstrate that territorial marginality does not coincide with political passivity. On the contrary, they highlight the latent capacity of these areas to propose different modes of relating to resource geographies—ones not driven by extraction but by reinvention, care, and relational value. A critical implication of this analysis is the need to move beyond compensation as an economic balancing mechanism and toward a more grounded logic of territorial reciprocity. In concrete terms, this means designing compensation frameworks anchored in the specific spatial configurations, governance challenges, and institutional capacities of mountain municipalities. It requires understanding that the impacts of extraction are not limited to soil and air but ripple through social systems, mobility patterns, ecological equilibriums, and long-term imaginaries of place. In this sense, Viù, Valsesia, and Ossola do not only host mineral deposits—they embody the tensions, contradictions, and possibilities of a more place-sensitive extractive policy. Their futures cannot be outsourced to technical procedures or market projections. They demand situated negotiation, reinvestment, and reimagination processes capable of reweaving broken connections between valley and summit, past and future, resource and territory.

Demographic and infrastructural asymmetries in Alpine valleys: risks of unbalanced extractive development

The contemporary resurgence of extractive activities across the Alpine arc—framed within discourses of strategic autonomy, energy transition, and raw material resilience—requires examining the territorial asymmetries underpinning its material and political feasibility. In particular, the valleys of Viù, Valsesia, and Ossola represent geologically promising zones for critical raw materials, but also reveal overlapping layers of socio-economic fragility, infrastructural deficiency, and demographic contraction. These spatial configurations are not incidental; rather, they reflect decades of disinvestment and structural marginality that risk further entrenchment by renewed extractive interests. In the case of Val di Viù, the demographic profile is emblematic of the wider condition. With an area of over 84 km², the municipality of Viù counted just 1,039 inhabitants in 2022¹¹⁵. This demographic stasis and spatial remoteness underscore a deeper fragility¹¹⁶. A similar demographic profile is observable in the Valsesia region, part of the Province of Vercelli. Though specific figures for all individual municipalities in the valley are not immediately available, broader provincial data indicate a steep age imbalance. The old-age index for Vercelli in 2023 was 256.5¹¹⁷. This statistic reflects long-term aging trends and suggests a contraction of the reproductive and working-age population¹¹⁸. The situation in Val d'Ossola is even more pronounced. Located within the Province of Verbano-Cusio-Ossola, this region reported an old-age index of 277.3 in 2023, among the highest in the Alpine arc. These numbers point to a demographic tipping point, in which the balance between active and dependent population groups becomes structurally unsustainable without targeted investment and strategic rebalancing¹¹⁹. These demographic dynamics are intimately connected to infrastructural and service-related asymmetries that disadvantage highland communities. Educational services, for instance, are unevenly distributed, with schools concentrated in accessible valley-floor towns, forcing youth from mountain municipalities

¹¹⁵ Resulting in a population density of only 12.4 inhabitants per km². The average age (49.7 years) is particularly high, confirming the area's advanced demographic aging. The foreign resident population is minimal (1.9%), and population variation between 2017 and 2022 has remained nearly flat, registering a mere +0.02% growth. See: *ISTAT – Censimenti della popolazione, 1921–2021*.

¹¹⁶ <https://ugeo.urbistat.com/AdminStat/it/it/demografia/dati-sintesi/viu/1313/4>

¹¹⁷ Indicating approximately 257 elderly individuals per 100 young people.

¹¹⁸ https://www.demos.piemonte.it/index.php?Itemid=13&id=76&option=com_content&view=article

¹¹⁹ *ibid.*

to travel significant distances or leave altogether. Healthcare follows a similar logic of centralization: medical facilities are clustered in urban areas or other accessible locations, creating critical access gaps for aging and isolated populations. These infrastructural deficits are compounded by limited digital connectivity. In some Alpine zones of Piedmont, broadband coverage as of 2015 reached only 55.2% of the population, drastically curtailing access to essential services and opportunities for digital work, education, and innovation¹²⁰. The implications of this socio-territorial marginality are profound when considered alongside the return of mineral exploration. On the one hand, economic precarity may render local administrations more willing to accept extractive operations in exchange for fiscal returns, even when these returns are neither sufficient nor equitably distributed. On the other hand, weakened institutions and shrinking populations reduce environmental oversight and governance capacity. As a result, valleys like Viù, Valsesia, and Ossola may become disproportionately exposed to the long-term costs of resource extraction, including ecological degradation, infrastructural strain, and social polarization. This convergence of ecological vulnerability, infrastructural underinvestment, and demographic decline transforms compensation into a key terrain of political negotiation. Rather than being abstractly indexed to mineral volume or market price, compensation in these contexts must respond to situated needs: reactivating essential services, repairing fragmented ecologies, and restoring territorial continuity. If treated merely as financial redistribution, compensatory frameworks risk reinforcing structural asymmetries. If approved, as instruments of spatial justice, however, they can support integrated strategies that link ecological stewardship to infrastructural reinvention and social inclusion. The valleys of Viù, Valsesia, and Ossola thus exemplify not only the material stakes of critical raw material extraction but also the necessity of embedding extractive governance within a deep understanding of Alpine socio-territorial dynamics. Their demographic indicators, infrastructural gaps, and institutional vulnerabilities are not marginal concerns. They are central to the long-term viability and legitimacy of any extractive strategy in these landscapes. Without a territorialized approach to compensation that engages directly with the structural conditions of marginality, resource governance in the Alps will remain uneven and potentially unsustainable.

¹²⁰ https://politichecoesione.governo.it/media/2709/strategia_valli-grana-e-maira.pdf and https://www.irespiemonte.it/irta/images/stories/Relazione/IRTA_RELAZIONE2.pdf

The governance capacity of Alpine municipalities The asymmetries are not accidental. They are the accumulated effect of decades of spatial disinvestment and policy inertia. In this context, the concept of compensation must evolve beyond technocratic accounting or environmental mitigation. It must become a tool for confronting structural marginality through site-specific reinvestment strategies. The *Indice di Marginalità Relativa (IMR)* offers a critical analytical lens to understanding these asymmetries across four interdependent dimensions: demographic fragility, accessibility constraints, service deficit, and institutional weakness. When applied to the territories currently under or adjacent to cobalt exploration permits, a shared profile of structural vulnerability emerges. These are not only peripheral zones in a geographical sense; they are peripheral in terms of service provision, population dynamics, and administrative reach. Demography presents the first and perhaps most visible fracture. Usseglio, Balme, Vocca, and Antrona all record steep population decline, with ageing indices among the highest in the region. In Usseglio, for example, the population fell by over 40% in the last three decades, with a median age above 55. Birth rates are minimal, outmigration continues, and youth retention is critically low. These trends reduce the resilience of the local social fabric and diminish the potential for endogenous development. Accessibility, both physical and digital, reinforces this isolation. Vocca and Cravagliana are accessible only via narrow, winding roads that are prone to frequent landslides or seasonal closures. Public transport options are scarce or nonexistent, particularly outside of school commuting hours. Broadband access remains limited in several localities, and digital literacy programs are underfunded or absent. These deficits render the promise of inclusive economic revitalization, whether via extraction or alternative economies, deeply uneven. Service provision is equally fragile. In many of these municipalities, local schools have closed or operate only as single-class units. Medical services are centralized in distant valley-floor towns; post offices and bank branches have been progressively withdrawn. Welfare infrastructure is minimal, and its erosion undermines not only the viability of residency but also the capacity for territorial stewardship¹²¹. Extraction risks exacerbating rather than mitigating these dynamics if imposed without an infrastructural counterweight. Governance ca-

¹²¹ In Balme, the closure of the last pharmacy and ATM transformed everyday logistics into structural challenges.

capacity, the fourth axis of the *IMR*, captures the difficulty small Alpine municipalities face in designing, managing, and negotiating complex territorial transformations. Usseglio, for instance, is managed by a micro-administration with limited human and financial resources, often relying on part-time or volunteer officials. Therefore, the capacity to engage meaningfully with concession holders, assess environmental risks, or negotiate redistributive agreements is severely constrained. In some cases, inter-municipal cooperation exists on paper but is weakly institutionalized and under-resourced. When mapped onto the extractive geography of the Alps, these indicators generate a profound disjuncture. Zones identified as targets for critical raw material exploration coincide with territories already under infrastructural, demographic, and administrative stress. This reveals a paradox: territories of high marginality also become high-strategic-interest territories, without an accompanying rebalancing of value flows or institutional empowerment.

Territorial compensation as infrastructural reinvestment and strategy of spatial justice In this light, compensatory mechanisms must shift from a logic of remediation to one of reconstruction—not only repairing environmental damage, but rearticulating the everyday conditions of inhabitation. Compensation should not be understood as a financial percentage indexed to extracted volume; it should be approached as a territorial project that engages with the layered vulnerabilities of place. This means investing in schools, mobility systems, digital infrastructure, and welfare services that reestablish the preconditions for living and working in these highland areas—not as amenities but as everyday infrastructures (Amin, 2014) essential to collective and territorial agency. These infrastructures, often taken for granted in urban or more accessible settings, are not simply technical systems but complex socio-material assemblages mediating daily life's rhythms, from accessing healthcare to participating in democratic processes. In Alpine marginal zones, their absence becomes a form of slow violence: a condition that renders participation in regional futures increasingly complex and shapes how communities experience extraction not only as environmental pressure but also as an intensification of abandonment. To address this, a situated compensation framework must be grounded in the specific profiles of fragility that characterize these extractive territories. It must recognize that the benefits of min-

eral exploitation cannot be abstracted upward or outward, but must instead circulate through the same spaces where its risks and burdens accumulate. This implies rethinking extraction not as a discrete act, but as a spatial and temporal process entangled with legacies of disinvestment, administrative asymmetry, and demographic erosion. In practical terms, this may involve establishing dedicated territorial funds whose use is co-governed by local institutions and communities; redirecting a portion of royalties or concession revenues to support inter-municipal cooperation; or integrating compensatory investments into long-term infrastructure plans that align with demographic regeneration goals. It also entails a normative repositioning of Alpine margins, not as peripheral spaces of extraction, but as experimental grounds for a new ecology of reciprocity between resource governance and territorial care. Such a reframing is particularly urgent given the dual pressures currently acting on these territories: on the one hand, the increasing geopolitical importance of critical raw materials like cobalt and nickel; on the other, the intensifying socio-economic vulnerabilities of mountain communities. The convergence of these dynamics demands a response that exceeds conventional compensation models, anchored instead in a new paradigm of territorial justice (Soja 2010), where extraction becomes legible through its mineral outputs and its capacity to regenerate the conditions for situated, resilient inhabitation. In this sense, marginality should not be seen as a static diagnostic category, but as a terrain of potential realignment: where extractive geographies can be re-scripted as infrastructures of care, and where compensation becomes the medium through which post-extractive futures are materially and institutionally staged. Only by grounding extractive governance within these logics of redistribution and infrastructural renewal can the Alpine region begin to articulate a mode of mineral transition that is socially inclusive, ecologically reparative, and territorially coherent.

10.5.coexistence with slow mountain economies: adaptive spatial strategies for diversification

The previous section argued for a situated compensation framework to address structural marginality and everyday infrastructural needs in highland communities. The present chapter shifts focus toward the spatial and economic diversification of Alpine territories. Rather than positioning extractive and non-extractive futures in opposition, it explores how alternative economies already operating in these contexts coexist with and shape emerging extractive geographies. The aim is not to preserve, but rather to place mining within a polycentric territorial logic that resists monocultural planning and embraces hybrid, adaptive development models¹²². It asks how the resurgence of mining activities might be embedded within broader regional strategies that foster economic plurality. This is particularly urgent in valleys like Viù, Valsesia, and Ossola, where emerging practices in permaculture, slow tourism, and heritage-based economies signal an ongoing reorientation of local development trajectories. Though often fragile, these initiatives represent not only forms of economic resistance but laboratories for reimagining value beyond extraction.

Coexistence, in this sense, is not a passive tolerance between sectors. It is an active project of spatial negotiation, where extractive infrastructures must be designed to interoperate with, rather than override, existing territorial grammars. The stakes are not merely environmental or *aesthetic*; they concern the very modes through which mountain regions articulate autonomy and futures worth inhabiting. This section explores the potential contradictions, opportunities, and paradoxes in reconciling the expansion of new extractive industries with the rise of sustainable economic models in the Alpine region.

Interactions between mineral extraction and local development models in Alpine regions. Once peripheral to industrial processes, mountain regions are now positioned—again—as essential suppliers of resources. The *second modernity* (Beck 2016) in the global era sees mountain areas re-evaluated for their strategic potential in addressing global challenges, including resource scarcity, climate adaptation, and ecological resilience. Simultaneously, mountains are experiencing a cultural and political re-evaluation. The *amenity migration* (Moss 1996, Perlik 1996), in which people relocate to mountainous regions for a better quality of life rather than solely for economic reasons, has increased

¹²² Mountain areas today are increasingly shaped by a condition of “*territorial arrhythmia*” (Dini 2018), marked by the simultaneous presence of contrasting spatial dynamics.

demand for non-extractive, sustainable livelihoods. This is seen in the rise of slow tourism, knowledge-based activities, and ecological agriculture (Membretti 2024). These new economies starkly contrast traditional extractive models, particularly given the fragile ecosystems of alpine environments and the risks associated with large-scale mining operations. In the Alps, introducing cobalt mining could also lead to conflicts with emerging sustainable economies. The juxtaposition of cobalt mining with alpine activities presents an evident paradox. To ensure a balanced and sustainable future for the Alpine region, policymakers and stakeholders must carefully navigate the tensions between resource extraction and sustainable economic development.

Integrating extraction and sustainable development through spatial and governance strategies Diversification of local economies is critical to reducing dependency on extractive industries and creating more resilient economic systems (Perlik, 2015). Supporting economic diversification in Alpine territories means protecting existing slow economies and enabling their evolution through infrastructural support, visibility, and institutional backing. While permaculture and ecological tourism represent potent alternative development paths, their long-term viability depends on creating supportive ecosystems—social, logistical, and regulatory—that allow such models to scale without losing their grounded, place-specific qualities. In this context, diversification must be understood not as sectoral addition but as territorial composition. This entails designing frameworks that allow extractive, agricultural, touristic, and cultural practices to cohabit the same landscapes through spatial zoning, governance mechanisms, and infrastructural compatibilities. For example, former mining roads could be reactivated as access routes for agritourism or ecological monitoring; buffer zones around extractive sites might be dedicated to biodiversity corridors or productive agroforestry; and revenue from mining concessions could be earmarked for incubating rural cooperatives, training programs, or community-supported agriculture projects. Importantly, diversification also requires confronting the symbolic dominance of extraction in territorial imaginaries. In many Alpine municipalities, the return of mining risks monopolizes public discourse, investment priorities, and future projections. Supporting alternative economies means narrating them as central—not residual—to the future of the area. This involves cultural recognition, education, and strategic communication that reframes re-

silience, slowness, and ecological intelligence not as signs of backwardness but as pillars of a post-extractive territorial vision. To this end, institutional innovation is essential. Intermunicipal alliances could be leveraged to design shared development plans that balance extractive revenues with investments in the slow economy. Regional authorities might experiment with hybrid governance bodies that include actors from mining, agriculture, tourism, and civil society. At the same time, academic and design institutions can play a key role in documenting, amplifying, and connecting these diverse practices across scales. Ultimately, supporting coexistence is about managing conflict and composing futures. This means recognizing that extraction may remain part of the economic palette in the Alps. However, it must be embedded within a diversified, context-sensitive, socially inclusive territorial development vision. Only then can the logic of the monoculture be displaced by a more reparative and generative approach to Alpine transformation.

Territorial infrastructures of coexistence: slow economies, reuse practices, and multifunctional landscapes In the wake of shifting territorial paradigms that seek to transcend the extractive/non-extractive binary, a growing body of situated practices in the Piedmontese Alps reveals the emergence of what might be termed productive coexistence. These are not romantic retreats into pastoral *nostalgia*, but context-specific strategies of inhabitation that articulate livelihood, landscape, and local knowledge as intertwined registers of territorial resilience. Permaculture¹²³, an agricultural system mimicking natural ecosystems, has gained significant traction in alpine regions¹²⁴. By promoting local food production and reducing dependence on imported goods, alpine permaculture fosters self-sufficiency and reduces vulnerability to global economic fluctuations. Moreover, as climate change disrupts traditional agricultural practices, the resilience of permaculture-based systems becomes increasingly valuable. However, scaling these models remains challenging. The remote and rugged terrain of many alpine regions complicates access to markets and resources, limit-

¹²³ Permaculture, which integrates agricultural, ecological, and social practices, is particularly suited to the unique challenges of alpine environments, where steep slopes, cold temperatures, and fragile ecosystems necessitate innovative and adaptive strategies. Examples such as the *Tiroler Kräutergarten* in Austria showcase how permaculture can support ecological sustainability, cultural preservation, and economic viability by cultivating medicinal herbs and other high-value crops.

¹²⁴ Such practices align with the ethics of environmental stewardship and long-term sustainability.

ing the economic scalability of these practices. The harsh and variable climate conditions continuously threaten crop survival and productivity, requiring constant innovation in land management and resource use¹²⁵ (Lanzani and Pasqui, 2011).

Within the three study areas, such practices constitute more than residual cultural expressions. They operate as slow yet persistent alternatives to the logics of extractive monoculture, enabling new forms of territorial valuation grounded in ecology, care, and collective autonomy. Local producers, often organized as family-run micro-enterprises, adhere to seasonal rhythms, rely on high-altitude grazing, and maintain open landscapes through animal presence, thereby preventing forest overgrowth, preserving biodiversity corridors, and maintaining visual permeability in the alpine terrain. This productive maintenance form resists enclosure: it does not extract but holds territory open through metabolic continuity. Such economies “*do not represent the past but the persistence of other logics of productivity*” (Ferrario and Marzo, 2022).

In Valsesia, the reactivation of high-altitude terraced landscapes around municipalities such as Rimella and Rassa further evidences how agro-ecological practices can serve as spatial devices of resistance and reinvention. Here, diversification is not merely an economic hedge but a form of territorial narration: it renders visible otherwise marginal knowledge and landscapes, transforming abandonment into potential. These initiatives tend to resist standard scaling logic, instead cultivating dense micro-networks of solidarity that operate at the valley scale. While their economic footprint may remain modest, their spatial and symbolic significance is disproportionate, offering pathways for reinhabiting post-extractive terrain.

The Ossola region, particularly the lateral valleys of Antrona and Bognanco, has seen the rise of hybrid models that intertwine low-impact tourism, forest management, and medicinal herb cultivation. These projects do not treat nature as scenery but as a living archive of practices. The slow economies emerging in these contexts function as infrastructures of presence. They make inhabitation legible and viable not

¹²⁵ This is in the face of the need for a new dynamism that does not repeat processes, such as colonization by big capitalism or aggressive urbanization, which have often impoverished these areas. On the contrary, the enhancement of historical and natural commons and the protection and promotion of local resources through overcoming internal competition are strategies to be adopted, with goals that go beyond just economic growth (Lanzani and Pasqui 2011).

through vast investment plans but through situated repertoires of making, caring, and learning coextensive with the terrain. These emergent economies, while often modest in scale, must be interpreted through the lens of the territorial local infrastructure network. It is understood not as technical hardware but as assemblages of social, ecological, and spatial relationships that sustain forms of life over time. In this sense, activities such as mountain cereal cultivation, forest commons management, or pasture-based dairying are not merely economic niches, but systems of continuity, care, and circulation that enable durable inhabitation beyond extractive paradigms.

In Val di Viù, several municipalities have engaged in the recovery of abandoned *alpeggi* and *mulattiere*, integrating them into multi-use infrastructures that blend pastoral mobility, slow tourism, and local logistics. Reusing legacy infrastructures not only as cultural assets but as vectors for sustainable movement—both human and ecological. These routes are now being employed for guided trekking circuits, cattle migration, and botanical monitoring, reinforcing the embeddedness of mobility within territorial metabolism. Here, landscape is not a passive backdrop but a co-producer of value. Against the backdrop of extractive discourses framed in geotechnical expertise, these spaces reinstate vernacular know-how as a legitimate and necessary epistemology for mountain futures. These groups experiment with low-impact forest thinning, biochar production, and artisanal timber transformation, often coupled with storytelling practices and ecological art installations. Their interventions are spatially distributed across formerly inaccessible zones, now connected by thematic trails and open-air laboratories. In these projects, diversification exceeds the economic register: it becomes a form of aesthetic and ecological composition. Forests are not simply managed. They are curated as dynamic ecologies in which production, pedagogy, and performativity overlap. Crucially, these initiatives do not follow a model of additive cohabitation, where sustainable practices are added alongside extraction, but rather seek a deeper form of spatial entanglement. They articulate coexistence not as spatial separation but as material negotiation. The productive field is not segregated by sector but interwoven through multifunctional ecologies. As such, the diversification invoked in policy rhetoric gains concrete form through these practices: not as a menu of discrete options but as a dynamic mode of territorial reconfiguration.

This opens up new imaginaries for the post-extractive Alpine landscape, where regenerative capacities are activated not by displacing the extractive legacy but by metabolizing it through slower, denser, and more situated economies. What emerges across these territories is a mosaic of micro-economies that, while often informal or precarious, operate as prototypes of post-extractive territoriality. Their spatial logic resists the scalar rationality of mining concessions, which tend to abstract land into gridded coordinates, and reclaims fragmented landscapes as sites of continuity, experimentation, and place-making. This non-monocultural orientation resonates particularly in Valsesia, where projects such as *Ecomuseo della Valsesia*¹²⁶ have served as cultural initiatives and spatial anchors for economic re-articulation. By preserving and activating historical architecture¹²⁷, these Ecomuseums enable productive heritage¹²⁸. These activities are not simply nostalgic, they represent strategic re-uses of vernacular forms to generate livelihood opportunities embedded within recognizable landscapes. The buildings function as productive monuments, to borrow a phrase from heritage studies, in which the past is not conserved but operationalized for new modes of collective sustainability. Val d'Ossola presents a more ambiguous terrain, with its deep mining past. Here, reuse and reinvention often contend with residual toxicity and contested memory. However, some of the most innovative spatial strategies have emerged precisely because of these tensions. For example, the *Sentiero dei Minatori*¹²⁹ in Viganella traces former extraction paths but overlays them with layers of interpretation and new use. In all three valleys, we witness the emergence of porous infrastructures: trails that are also economic arteries; ruins that are also pedagogical tools; forests that are also institutions. This porosity allows for adaptive layering rather than exclusive land uses. Crucially, it enables co-habitation with extractive operations without subsuming local economies into ancillary functions. Instead, it creates parallel economies with their rhythms, values, and spatial claims. Such a condition challenges standard models of compensation or impact mitigation, which tend to operate through sectoral silos. In multifunctional and site-bound econ-

¹²⁶ <https://www.unionemontanavalsesia.it/it-it/download/guida-ecomuseo-del-territorio-e-della-cultura-walser-103118-9-10030-583c9f32bcf4b3cfbe359ac050a9269b>

¹²⁷ Such as *forni comunitari*, *fenili*, and *mulini ad acqua*.

¹²⁸ For example, in Rassa and Riva Valdobbia, some restored structures now house artisanal bread-making workshops, small grain mills, or educational centers on local materials (wool, stone, wood).

¹²⁹ <https://percorsi.estmonterosa.it/c/IC07.pdf>

omies, compensation must likewise become spatially intelligent, capable of recognizing and strengthening the infrastructural tissues that sustain diversification. This entails financial transfers but support for organizational capacity, access to land, water governance rights, and inter-municipal coordination, dimensions often absent from extractive governance frameworks.

From local practices to inter-municipal coordination: relational infrastructures and landscape-based governance

Beyond their physical and symbolic functions, the initiatives described above point toward the emergence of territorial infrastructures understood not only as material assemblages or micro-economies, but as relational devices capable of holding together space, governance, and socio-ecological meaning. These infrastructures operate across temporal and institutional scales, enabling forms of coexistence that are not merely spatially juxtaposed but politically and organizationally entangled. However, for these configurations to stabilize and expand, they require support mechanisms to translate situated practices into shared territorial visions—instruments that connect fragmented administrations, redistribute decision-making power, and articulate collective stakes around land use, heritage, and environmental care. In this regard, the experience of the *Ecomuseo del Lago d'Orta e Mottarone* offers a particularly relevant precedent. Rather than limiting itself to cultural documentation or community engagement, the ecomuseum has positioned itself as a territorial interface between local practices and institutional planning. Its involvement in the *Contratto di Lago del Cusio* exemplifies a shift from preservation to coordinated transformation: an operational platform where municipalities, regional bodies, technical agencies (such as *ARPA*), and civil society actors negotiate a long-term agenda for environmental regeneration, sustainable economies, and landscape-based development. The contract enables planning at the catchment or watershed scale, overcoming the administrative fragmentation of lakeside and mountain municipalities by fostering inter-municipal collaboration and a systemic approach to resource governance.

This framework does not merely aggregate local interests; it reconfigures them within a shared governance ecology that aligns ecological, cultural, and economic priorities. By doing so, the *ecomuseum* occupies a critical intermediate position, neither purely institutional nor entirely grassroots, capable of anchoring distributed practices into actionable

territorial strategies. Its work demonstrates how heritage infrastructures can evolve into institutional prototypes that extend beyond commemoration, enabling durable coalitions and site-specific planning tools. In this sense, the Cusio experience offers a valuable model for Alpine areas seeking to navigate the complexities of post-extractive transition: not by erasing past uses or resisting development, but by rearticulating value through multi-scalar coordination, infrastructural reuse, and landscape-based cooperation.

Rethinking spatial design to recognize and support non-extractive development logics

However, articulating this coexistence requires more than celebrating small-scale initiatives—it demands reframing territorial governance and planning categories. Many productive practices surveyed in Val di Viù, Valsesia, and Val d'Ossola operate in what institutional documents still define as residual or *non-urban* zones, often excluded from strategic investment plans. Their invisibility in policy terms is not simply a reflection of marginality but a product of epistemic asymmetries: design instruments calibrated to urban or industrial logics fail to register economies whose value is embedded in social ties, seasonal cycles, and landscape stewardship. From this perspective, spatial diversification must be understood as economic variety and an ontological challenge to the categories through which development is imagined and measured. The productive practices observed across the Piedmontese Alpine arc are not alternatives to extraction. They are alternative ways of composing space, enacting time, and distributing value. Their rhythms—*slower*, seasonal, and embedded—may conflict with the tempo of mining concessions, which often require long lead times, rapid mobilization, and a timely return on investment.

Nevertheless, this tension also opens a space for negotiation. If recognized and institutionalized, these economies could form the backbone of a post-extractive territorial metabolism in which minerals are no longer the only measure of worth. Such a shift requires recalibrating spatial instruments. One avenue is the recognition of productive landscapes (*paesaggi produttivi*), a notion gaining traction in Italian regional planning, which frames certain territories not as wilderness or heritage but as living infrastructures of local livelihood. This concept would allow municipalities like Balme, Cervatto, or Montescheno to articulate their spatial claims through preservation, tourism, and ongoing, situated production. It also provides for experimental spatial configurations beyond

conventional zoning, enabling hybrid and temporally layered land uses attuned to ecological cycles and socio-economic rhythms. Practices such as seasonal pasturing, rotational forest management, agroecological cultivation, or small-scale energy production—often marginal in dominant planning frameworks—require spatial instruments that accommodate variable use intensities, non-linear productivity, and place-specific governance. Rather than segregating functions, these configurations invite coexistence through negotiated thresholds and shared stewardship.

A relevant institutional model in this direction is that of the *biodistretto* (biodistrict), as promoted by national and trans-local networks such as the Italian Association for Organic Agriculture (*AIAB*). They are not fixed administrative units or sectoral programs; they are territorial pacts in which farmers, residents, local authorities, businesses, and civil society actors collaborate to manage resources in accordance with shared ecological, cultural, and economic values, grounded in principles of organic agriculture, environmental protection, and participatory governance. While primarily designed to support sustainable food systems, biodistricts serve as platforms for territorial coordination, linking local livelihoods, ecosystem management, and community-based planning. Crucially, such frameworks are not necessarily opposed to all forms of resource extraction. Instead, they propose a relational approach to evaluating compatibility between extractive projects and local development trajectories. This means asking: under what conditions might extraction be integrated within a biodistrict? What are the ecological, social, and institutional thresholds beyond which coexistence becomes untenable? By embedding extractive activities within a landscape governed by collective norms and negotiated limits, it can offer tools for territorial filtering: not blanket acceptance or rejection, but contextual decision-making based on locally defined priorities and constraints. In this way, the scope of non-extractive governance can be extended without demanding the exclusion of mining per se.

They shift the axis of decision-making from national or sectoral imperatives to place-based criteria, enabling forms of territorial reflexivity where extraction must respond to existing social fabrics, ecological patterns, and landscape projects. As such, they represent one of the few institutional formats currently available to bridge the gap between situated practices and multi-level governance. They offer a glimpse of what integrated, adaptive, and plural spatial futures might look like in post-extractive Alpine territories.

From mitigation to composition: designing coexistence How can mining infrastructure be designed to support, rather than undermine, landscape continuity? Can extraction sites be co-programmed with ecological restoration, educational functions, or seasonal productive uses? What models of time-sharing or spatial phasing might allow multiple economies to inhabit the same territory without erasing one another? These are not technical questions alone, but fundamentally political ones, implicating questions of visibility, voice, and control over the future of the Alpine region. The practices documented ranging from permaculture and forest management to the reuse of the alpine commons, do not represent isolated initiatives. They point to broader spatial logics and design strategies that, if recognized and supported, can guide a post-extractive reconfiguration of Alpine territories. These strategies operate through adaptation and reuse, working with what already exists to generate new forms of inhabitation, production, and ecological continuity.

Three interrelated trajectories can be identified, grounded in the situated dynamics explored in the previous sections. The first is the seasonal diversification of mountain uses, which challenges the temporal and functional monocultures that often characterize extractive or touristic economies. In territories historically shaped by winter-centric tourism or mineral extraction, extending uses across seasons allows new socio-ecological relations to emerge. Practices such as year-round pastoralism, cultural programming, or eco-pedagogical trails, already visible in segments of Val di Viù and Valsesia, foster a more resilient territorial metabolism, where rhythms of use are aligned with ecological cycles and collective care. The second trajectory involves reprogramming existing infrastructures, particularly those tied to extraction or single-purpose tourism. Across the Alpine cases, cableways, forest roads, disused *alpeggi*, and mining buildings are reactivated as multifunctional platforms. Rather than being dismantled or memorialized, these structures are incrementally transformed into connectivity, productivity, and hospitality nodes—hosting services such as educational spaces or cooperative markets. This reuse does not erase the extractive legacy, but metabolizes it through socially and ecologically grounded functions. A third strategy concerns the reactivation of rural and forest landscapes as living infrastructures. Abandoned terraces, woodlands, and alpine commons are mainly reclaimed through small-scale activities. These practices recover ecological functions and produce new economies anchored in local

knowledge, material cycles, and vernacular techniques. Here, landscape becomes both a productive and narrative medium, a space where memory, experimentation, and situated value coalesce¹³⁰.

To support such transitions, spatial design must move beyond impact mitigation and become a composition tool: composing uses, actors, and temporalities around existing landscapes and their latent potential. In this sense, the future of Alpine territories may lie not in the return to extraction, but in the layering of practices that redistribute value, regenerate ecologies, and redefine the forms through which mountains are inhabited. The coexistence of extraction and slow mountain economies in the Piedmontese Alps cannot be reduced to balancing impacts or distributing profits. It must be framed as a broader negotiation over the alpine space's form and meaning. Though diverse and uneven, the practices observed offer concrete pathways toward a more plural and situated development model: one that resists territorial monocultures and reclaims the mountains not as resources to be extracted but as territories to be inhabited, cultivated, and transformed.

¹³⁰ These strategies resonate with broader reflections developed in other mountain contexts, such as the Monte Cimone area in the northern Apennines, where similar forms of adaptive reuse have been tested through design research. Since 2021, I have been involved as a teaching assistant in the course *Built Environment and Landscape Design Studio*, held by Professors Federico Zanfi, Sebastiano Brandolini d'Adda, and Laura Daglio within the MSc programme *Landscape Architecture. Land Landscape Heritage* at *Politecnico di Milano*. The design research, developed within this studio, has contributed to the formulation of adaptive strategies for marginal and post-touristic mountain territories. While the Alpine cases presented in this thesis differ in scale and governance structures, they share key spatial challenges with the northern Apennines, particularly regarding infrastructural obsolescence, mono-functional economies, and territorial fragmentation.

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11.the negotiation space: a new alpine productive landscape

The true challenge of the territorial project within this renewed extractive cycle lies in recognizing its inherent temporality. While the European Union's strategic objectives for the energy and digital transitions have heightened urgency around raw materials, the extractive resurgence in Alpine territories is unlikely to constitute a structural transformation. Instead, it is bound to specific technological frameworks, global commodity logic, and temporal asymmetries between demand, regulation, and ecological repair. As these frameworks shift, so will the intensity and legitimacy of resource extraction. The real question, therefore, is not simply how to manage extraction but how to anticipate its conclusion.

This requires rethinking Alpine territories not as peripheries subordinated to metropolitan centers or global markets but as spaces of strategic foresight, spaces where the rhythms of extraction are embedded within broader transition trajectories. It also entails recognizing the multiple layers of temporality that govern these landscapes: the slow geological time of resource formation, the accelerated technological obsolescence, and the suspended time of territorial reactivation. Design must evolve from reactive to proactive, where extractive infrastructures are conceived not as monofunctional devices but as adaptable, multi-scalar assets. These could support regional and local mobility, circular economies, and distributed energy systems, extending their relevance well beyond the cessation of mining activities. In this regard, the design and governance of extraction exhibit strong analogies with the dynamics of mega-event infrastructure. Promises of short-term employment, capital influx, and infrastructural upgrades often justify mining projects. However, as with mega-events, the post-extraction phase is frequently overlooked, leading to stranded assets, structural oversizing, and unresolved socio-environmental legacies. The difference, however, is that Alpine territories lack the absorptive capacity of large urban centers: once the extractive function ends, little remains to sustain the infrastructures, skills, or institutional frameworks developed to support it. This means embedding extraction within broader socio-ecological transition strategies that consider what is extracted and how the territory is altered, physically and institutionally. Rather than treating mining as an exceptional phase, its beginning and end must be governed as part of a continuous territorial metabolism. This calls for a form of governance that is neither exclusively extractive nor merely compensatory, but one that makes Alpine communities co-authors in scripting their transformation.

This territorial reframing also opens up a broader space for negotiation, in which the reconfiguration of the Alpine productive landscape can be envisioned not merely as a matter of industrial policy or resource management but as a spatial design project. In this negotiation space, it becomes possible to identify and integrate multiple elements, environmental, social, and institutional, that are instrumental to constructing a post-extractive, post-carbon territorial condition. Such a framework calls for a supra-regional vision capable of navigating across scales, from the hyperlocal dimension of specific mining sites to the geopolitical scale of European strategic autonomy. At the core of this process lies the need for reconnaissance: an updated, critical mapping of extractive geographies, both active and latent. This involves identifying critical raw material deposits and quantitatively and qualitatively assessing residual materials that could be remediated, transformed, or used to provide foundational layers. However, they must be coupled with spatial, ecological, and socio-political readings of the territories they describe. Alongside this reconnaissance, a parallel effort must address the preservation and repair of ecological capital. Due to their topographic complexity and ecological fragility, Alpine environments cannot simply be absorbed into extractive logics. Environmental compensation, land restoration, and biodiversity regeneration mechanisms must be conditioned by their transformation. At the same time, this opens up the possibility of new forms of dwelling and neo-productive processes—spaces where post-extraction is not synonymous with decline but with reactivation through agroecology, renewable energy, cultural infrastructure, and situated knowledge production. To make this possible, territorial interactions must be recognized and activated. This includes cross-sectoral integration among energy, mobility, landscape restoration, and waste management; institutional collaboration among local governance, national policy, and European frameworks; and temporal integration among extraction, transition, and legacy. These synergies provide the necessary scaffolding for a truly integrated territorial project capable of generating spatial, social, and ecological value beyond the extractive function. The outcome of this process is not a new mining strategy in the traditional sense but a new spatial grammar for resource territories. This grammar includes elaborating an updated Mining Map, defining areas permanently excluded from permitting due to ecological or social vulnerability, and operational identification of zones open to strategic exploration—always within a framework of territorial justice. It also re-

quires a rethinking of compensation itself: monetary redistribution and a return of agency, ecological viability, and long-term coherence to the landscapes that host extraction. Ultimately, the Alpine space emerges not as a backdrop for extractive modernity but as a laboratory of negotiation. In this space, new balances can be tested between technological demand and ecological resilience, between mineral value and territorial meaning. Recognizing and institutionalizing this negotiation space is perhaps the most crucial task of contemporary design if the goal is not to replicate past cycles of extraction and abandonment but to construct a productive landscape that is at once temporary, strategic, and regenerative.

A central obstacle to reconfiguring Alpine territories within a long-term post-extractive logic lies in the persistent misalignment between contemporary challenges and obsolete design instruments. Among the most emblematic is the *Carta Mineraria Nazionale* of 1927, still formally in effect and routinely referenced in administrative procedures. Conceived under a radically different industrial and geopolitical paradigm, the *Carta* frames resource-rich regions as passive repositories to be catalogued, segmented, and eventually exploited. Its regulatory logic reflects a linear conception of extraction, in which territorial value is determined exclusively by subsoil potential, with little to no consideration of ecological thresholds, socio-spatial conflicts, or the cultural dimensions of place. Most critically, the *Carta* neither anticipates nor provides tools to address the multitemporality and multiscalearity that now define extractive geographies¹. It fails to articulate mechanisms for reversible land use, omits any meaningful framework for socio-ecological compensation, and treats environmental remediation as a postscript rather than a coextensive obligation. This outdated architecture quietly enables the persistence of a territorial extractivism fundamentally out of step with contemporary ecological and political commitments, including those articulated at the European scale under the banners of strategic autonomy and just transition².

¹ One possible direction lies in constructing an updated Mining Map (*Mappa Mineraria del XXI secolo*), conceived not as a technical appendix but as a strategic spatial device. This new cartography would not merely delineate areas of geological interest but integrate: criticality thresholds, socio-spatial indicators and compensation geographies.

² This reconceptualization of mineral mapping draws on the emerging notion of productive landscape and territories in which multiple economies, temporalities, and knowledges overlap, and where extraction becomes legible not only in terms of value withdrawn but also in terms of value co-produced. Within this framework, post-extractive design is not an afterthought but a design condition from the outset.

Crucially, this reframing is not purely technical. It requires a redistribution of agency: local communities, mountain cooperatives, and territorial alliances must become active interlocutors in defining what is to be extracted, how, and under what conditions. Just as infrastructures generate intensive but short-lived transformations, so too do extractive projects produce profound spatial and social impacts whose aftermath is rarely governed. The challenge, then, is to pre-design the *after*, to imagine how extractive sites can become catalysts of ecological regeneration, knowledge production, and spatial experimentation rather than sources of long-term liability. A renewed framework is needed that abandons the static logic of the mining register and embraces dynamic and negotiated cartographies. The goal is to locate mineral deposits and contextualize them within territorial ecologies that include human infrastructures, biophysical systems, and socio-cultural practices. This shift implies both a methodological and institutional leap: from extractive zoning to adaptive territorial scenarios, capable of governing the presence of minerals and the futures of the places where they lie. In this regard, the temporal asymmetry of extractive processes, where cycles of activation and abandonment rarely coincide with design frameworks, leads to a decisive proposition: extraction must be embedded within projective trajectories that anticipate its afterlife. This demands a new generation of tools capable of licensing and regulating extraction and conditioning it through spatial commitments: future uses, post-mining economies, landscape continuity, and socio-ecological coherence. Territorial visions, in this light, function not as forecasts but as design hypotheses, proposals that hold together material, political, and symbolic dimensions over time. The Alpine region must be recognized not as a resource frontier, but as a territorial testbed for new modes of transition. To operationalize this vision, three domains must be aligned. The creation of inter-municipal planning consortia capable of co-managing extractive projects and reinvestment strategies. The development of spatial tools that represent not only resource presence but also the territorial metabolism in which resources circulate. The embedding of extraction within transcalar scenarios that articulate short-term technological needs with long-term ecological and social priorities. Only through this articulation can the return to mining in Alpine territories transcend its extractivist legacy and contribute to the construction of a regenerative transition.

