Athens Journal of Architecture 2026, 12: 1-21
https://doi.org/10.30958/aja.X-Y-Z

Designing Hydropower: Interpretations and Design Approaches for Hydropower Infrastructure in the Italian Mountain Landscape

By Giulia Azzini[*]

This paper investigates the design potential of hydropower infrastructure in enhancing the Italian mountain landscape. After the intense exploitation of the early twentieth century and the more recent aftermaths of the climate change, many plants have been abandoned or replaced by alternative renewable sources. However, recent studies clearly show their enduring relevance within the European energy transition, calling for their reconsideration. Within this framework, the research aims to expand the still-limited design-oriented discourse on the topic, reframing hydropower as a powerful actor in the development of the mountain regions. To do so, the paper proposes a design-driven methodology, reinterpreting hydropower through three analytical lenses: space, time, and energy. These points are being articulated into key questions and explored via literature review, case studies, and redrawing. Such readings conclude in three design approaches — adaptability, recycling, and hybridization — to valorize the mountain landscape through its infrastructures.

Introduction

The term "hydropower infrastructure" refers to a complex system. As Michael Jakob strongly argues, this contributed to shaping the mountain into a "coherent whole," both physically and culturally.[1] Notably, it articulates the mountain territory across its multiple scales — from vast landscapes to minor technical components — forming a powerful, artificial network. This connective role is particularly evident in power plants, which act as "hinges of a variegated system of flows",[2] linking valleys and peaks by converting water's kinetic potential into energy.

In Italy, between the late nineteenth and the first half of the twentieth century, the widespread construction of hydropower structures profoundly transformed the Alps and the Apennines. From the outset, this operation elicited contrasting reactions: on the one hand, inhabitants were concerned about the disfigurement of natural landscapes and ecosystems;[3] on the other, they hoped for social and economic development. Beyond the opposing views, plants, penstocks, and dams

---

[*]PhD Candidate, Polytechnic University of Milan, Italy.

1. M. Jakob, "L'impronta della tecnica sul paesaggio alpino," *Archi. Rivista svizzera di architettura, ingegneria e urbanistica* 1 (2021): 15-18.

2. F. Irace, "Luci moderne: Muzio, Ponti e Baldessari e il progetto delle centrali," in R. Pavia (Ed.), *Paesaggi elettrici. Territori architetture culture*, 136-165 (Venice: Marsilio, 1998).

3. L. Parpagliolo, *La difesa delle bellezze naturali* (Foligno: Società Editrice d'Arte Illustrata, 1923).

marked an epochal transformation, deeply impacting local life, traditions, and economies.[4]

Today, hydropower infrastructures are largely met with their indifference.[5] This shift stems from many critical issues of the late twentieth century: climate change has introduced increasing instability in precipitation patterns across southern Europe, with prolonged droughts and intense rainfall, compromising the sector's reliability. Moreover, the extensive exploitation of available sites has led to the near exhaustion of viable locations for new plants, paving the way for more flexible renewables, such as solar and wind energy.[6] As a result, many facilities have been abandoned or, when still active, have been isolated from the communities they once served.

Nevertheless, several studies suggest that hydropower will play a crucial role in the European energy transition, prompting a renewed inquiry into its significance in mountainous contexts.[7] In particular, the contemporary literature, currently dominated by technical and quantitative approaches, reveals a significant gap in design-oriented perspectives. Addressing this gap calls for architectural insight that reimagines and reactivates the rich legacy of existing hydropower systems, informing their future development.

Against this backdrop, the paper[8] proposes an original, design-oriented re-interpretation of the topic through three interpretative lenses: space, time, and energy. The latter are organised around key questions: what is the spatial configuration of hydropower? How has it evolved and shaped the mountain landscape? Is it relevant in light of climate change and emerging renewables? The three issues are explored via literature review, case studies, and redrawing, culminating in a reflection on contemporary design. Indeed, the author identifies three main approaches to address the current challenges: adaptability, recycling, and hybridization.

This work has two main goals: to develop the still-limited design-focused discussion on hydropower and to view these infrastructures as active forces shaping mountain landscapes.

---

4. E. Genazzi, "Lo sfruttamento idroelettrico della Maggia: una svolta dai molti volti e sfumature," in E. Genazzi (Ed.), *Lo sfruttamento idroelettrico della Maggia. Metamorfosi di una valle*, 8-11 (Cevio: Museo di Valmaggia, 2024).

5. R. Pavia, "Architettura e paesaggi idroelettrici in Italia," in C. Masetti (Ed.), *Chiare, fresche e dolci acque. Le sorgenti nell'esperienza odeporica e nella storia del territorio. Atti del Convegno di Studi San Gemini, 18-20 ottobre 2000, Abbazia di San Nicolò*, 769-776 (Rome: Cisge, 2001).

6. C. Perpiña Castillo, C. Hormigos Feliu, C. Dorati, G. Kakoulaki, L. Peeters, E. Quaranta, N. G. Taylor, A. Uihlein, D. Auteri, and L. Dijkstra, *Renewable Energy production and potential in EU Rural Areas* (Luxembourg: Publications Office of the European Union, 2024).

7. E. Quaranta, K. Bódis, E. Kasiulis, A. McNabola, and A. Pistocchi, "Is There a Residual and Hidden Potential for Small and Micro Hydropower in Europe? A Screening-Level Regional Assessment," *Water Resources Management* 36, no. 6 (2022): 1745-1762.

8. The contribution is the result of an ongoing PhD thesis funded by the Istituto Nazionale della Previdenza Sociale (INPS), with Giulia Azzini as author, Emilia Corradi as Supervisor, Alisia Tognon as Co-supervisor, and Federico Cecchini as company tutor. It is framed within the "Convenzione Quadro" between the DAStU Department (Politecnico di Milano) and the municipalities of "Contratto di Fiume e di Paesaggio del Liri", with Professor Emilia Corradi as scientific director.

Critical and Theoretical Framework

A preliminary step in this dissertation is the clarification of two core concepts: "landscape" and "infrastructure".

A compelling contribution to the landscape debate comes from Vittorio Gregotti, who defines the term as an operable whole.[9] This definition is relevant for two reasons: first, Gregotti adopts a spatial register that encompasses any environment, anticipating the inclusive approach later formalized by the European Landscape Convention;[10] second, he highlights the active role of architects and urban planners, responsible for shaping and transforming various landscapes. The first aspect legitimizes an interpretation of infrastructure-generated sites, such as hydropower complexes, as landscapes in their own right; the second affirms their transformability through human intervention, and above all, through design. This perspective resonates with the views of other scholars: William John Thomas Mitchell, for instance, frames landscape as a cultural practice, a medium of exchange between the human and the natural.[11] Similarly, Claudio Ferrata asserts that such a concept "exists only in transformation, both as a changing gaze on reality and as a material and objective transformation of space. A landscape — as well as the meanings it expresses — is never given once and for all, but is the result of a continuous fabrication".[12] These reflections are fundamental to design-oriented research, emphasizing transformation — both material and perceptual — as a central topic in landscape discourse, particularly when considered through an architectural lens.

The paper specifically focuses on the Italian mountain landscape. Here, the need for design intervention is particularly urgent today. In fact, mountains are facing a range of socio-economic challenges, including limited opportunities, low productivity and income levels, demographic aging, and progressive depopulation.[13] At the same time, the disproportionate growth of urban centres and the accelerating effects of climate change increasingly compel us to look to such marginal contexts as potential laboratories for sustainable development,[14] thereby reaffirming the value of design-driven research in these regions.

The second key concept, "infrastructure", first emerged in the 19th century within the railway sector, but has since broadened to encompass all essential services

9. V. Gregotti, "La forma del territorio," *Edilizia moderna* 87/88 (1965): 1-11.

10. In 2000, the European Landscape Convention was born, which established that landscape includes both perceptive and symbolic aspects and that, above all, it also refers to "the parts of the territory that most need to solicit landscape intervention [...] the most devastated, those without a name, without a face in our suburbs or those degraded by extractive activities". R. Gambino, "La convenzione europea del paesaggio," in C. Cassatella, F. Baggiani (Eds.), *Creare paesaggi: realizzazioni, teorie e progetti in Europa. Atti del Convegno (Torino, 9-24 maggio 2002)* (Florence: Alinea, 2003).

11. W. J. T. Mitchell, and J. Thomas, *Landscape and power* (Chicago: University of Chicago Press, 1994).

12. C. Ferrata, "Quando le infrastrutture fanno il paesaggio," *Archi. Rivista svizzera di architettura, ingegneria e urbanistica* 1 (2021): 14. Translation from Italian to English is by the author.

13. G. Carrosio, and A. Facchini, "Le mappe della cittadinanza nelle aree interne," in A. De Rossi (Ed.), *Riabilitare l'Italia. Le aree interne tra abbandoni e riconquiste*, 51-78. (Rome: Donzelli, 2018).

14. R. Koolhaas, *Countryside. A Report* (New York: Guggenheim-Taschen, 2020).

supporting urban and territorial development, including energy production.[15] Since then, infrastructure has been traditionally conceived as an autonomous system, governed by technical logics and functions, and largely detached from the surrounding landscape. However, this conventional understanding is increasingly open to reinterpretation in light of contemporary shifts in architectural thinking, which emphasize the dialogue between form and function, architecture and technical works.[16] From this perspective, infrastructure can be seen as an architectural practice. It offers an opportunity not only to address the technical needs but also to regenerate natural and built environments, shaping the mountain image in meaningful and lasting ways. Viewed through this lens, infrastructure becomes a central test bed for contemporary design.

Methodology

The previous section established a critical and theoretical framework-based on two key terms: "mountain landscape", understood as lands characterised by multiple fragilities and thus fertile ground for contemporary design; and "infrastructure", a test bed for the architectural discipline, where technical and formal issues intersect. Building on this foundation, the paper seeks to understand the origins of hydropower infrastructure, its evolution, its present configurations, and the conditions that have shaped them. Such reflections inform contemporary architectural design, considered as a critical stance to mediate between past legacies and future transcriptions.[17]

As mentioned in the introduction, this paper offers a design-oriented reinterpretation of the topic through three analytical lenses: space, time, and energy. First of all, the space lens, explores the configurations and typological dimensions of hydropower infrastructure: drawing on the definition of "hydropower landscape" by Claudio Ferrata, the formal complexity of the whole system is deciphered. Secondly, the time lens, traces its evolution within the Italian context, identifying the key developmental phases and arguing that, regardless of formal outcomes, hydropower infrastructure has always served as a filter through which to interpret the mountain territory. Finally, the energy lens provides a comparison with other renewable sources to assess whether hydroelectricity remains a viable and competitive option in Italy and Southern Europe, highlighting the importance the relevance of design-driven research in this area.

---

15. L. Stalder, and C. Darò, "Eight Points of Infrastructure and Architecture." in I. Ruby, and A. Ruby (Eds.), *Infrastructure Space*, 26-29. Berlin: Ruby Press, 2017.

16. J. Conzett, and M. Linsi, *Landschaft und Kunstbauten. Ein persönliches Inventar von Jürg Conzett, fotografiert von Martin Linsi* (Zürich: Scheidegger & Spiess, 2010).

17. C. Andriani, "Ricordo al futuro," in C. Andriani (Ed.), *Il patrimonio e l'abitare,* XIII-XXIV (Rome: Donzelli, 2010).

Space

As asserted by Michael Jakob, mountains are no longer untouched wilderness but "cultural landscapes".[18] They have been interpreted, domesticated, and occupied by vast infrastructural systems, including hydropower, which rewrite their tectonic and hydrogeomorphological fabric. As a result, nowadays mountains are the product of a long process of environmental and technological transformation.[19]

In Italy, hydropower infrastructures emerged in the late 19th century to generate mechanical and electrical energy from water, particularly where the altitude gradient enhanced their potential.[20] They disrupted ancient ecological relationships while forging new spatial and cultural links with valley floors, integrating remote places into both national and global energy networks.[21] Thus, their articulation must be read at both territorial and architectural scales.

At the territorial scale, Claudio Ferrata defines the "hydropower landscape" as a stratified system, encompassing water, topography, power flows, and a set of interconnected elements that generate and transmit energy.[22] Surface, points and lines express this imaginary (see Figure 1): the former are rivers and watercourses, areas which reveal the natural morphology of the territory and guide following artificial interventions; points are the nodal elements, such as hydropower plants, collection basins, and water intakes; in turn, they are connected by lines, like penstocks, channels, and power grids (see Figure 2).

---

18. M. Jakob, "L'impronta della tecnica sul paesaggio alpino," *Archi. Rivista svizzera di architettura, ingegneria e urbanistica* 1 (2021): 15.

19. R. Pavia, "Architettura e paesaggi idroelettrici in Italia," In C. Masetti (Ed.), *Chiare, fresche e dolci acque. Le sorgenti nell'esperienza odeporica e nella storia del territorio. Atti del Convegno di Studi San Gemini, 18-20 ottobre 2000, Abbazia di San Nicolò*, 769-776. (Rome: Cisge, 2001).

20. D. Sijmons, et al., *Landscape and Energy. Designing Transition* (Rotterdam: nai010, 2014).

21. C. Geroldi, and G.Pessina, "Power stations and petroleum heritage in Italy. The Case of Porto Tolle," in C. Hein (Ed.), *Oil Spaces. Exploring the global petroleumscape*, 243-283 (New York: Routledge, 2022).

22. C. Ferrata, "Tra il visibile e l'invisibile, paesaggi idroelettrici nelle Alpi," *Archi. Rivista svizzera di architettura, ingegneria e urbanistica* 6 (2008): 12.

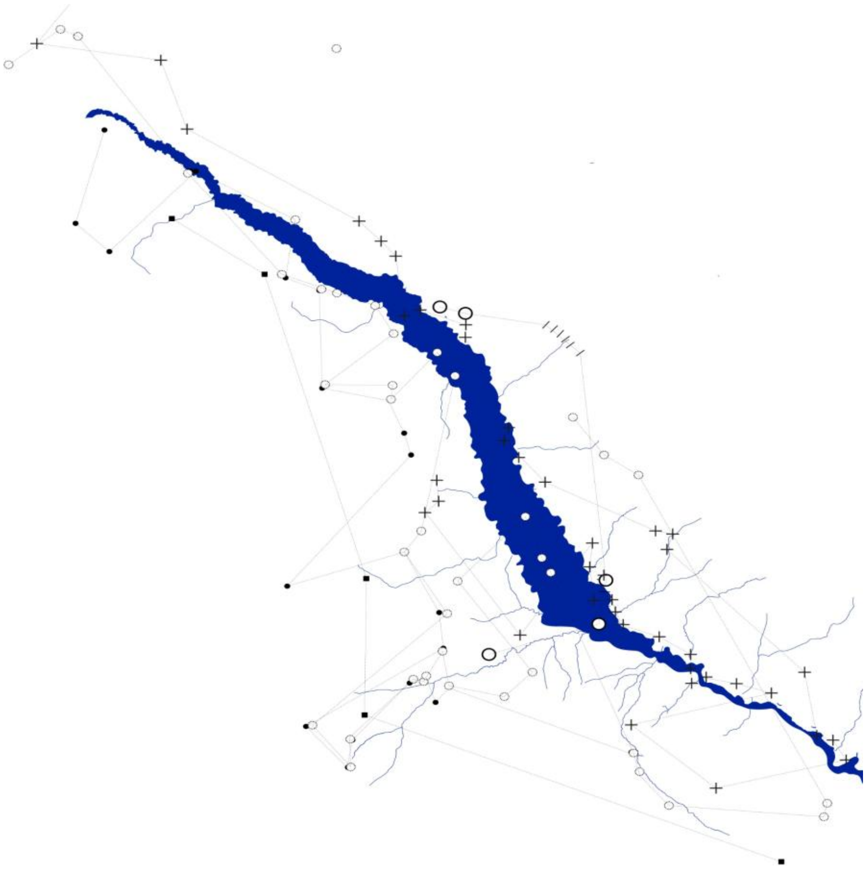

Figure 1. *The Hydropower Landscape, Interpreted by the Author as a System of Surfaces, Points, and Lines*
Source: Giulia Azzini 2023.

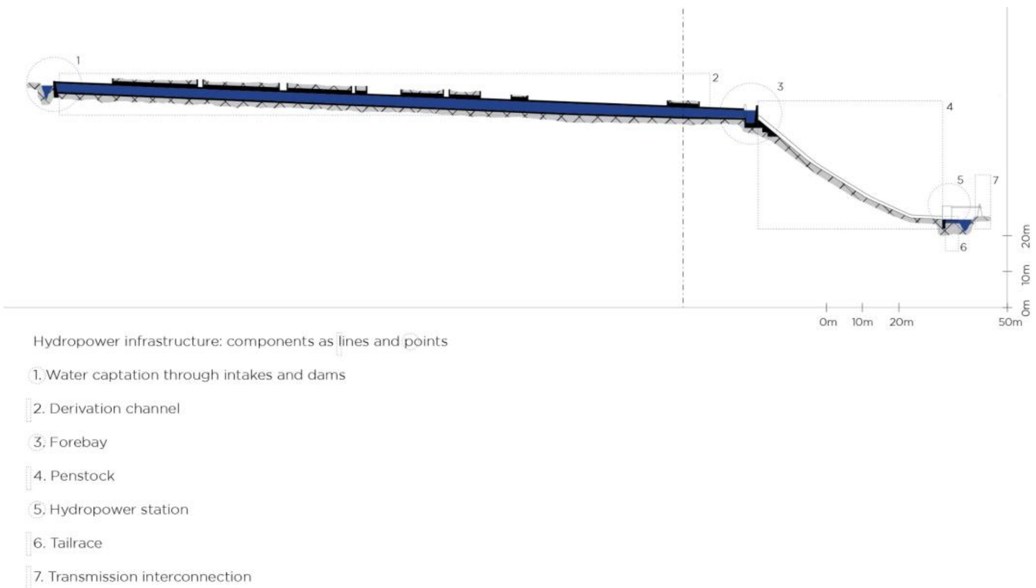

Figure 2. *Hydropower Infrastructure: Schematization of the Main Lines and Points*
Source: Giulia Azzini 2025.

Figure 3. *The "Torlonia" Plant in Canistro (Italy) and its Link with the Penstock (According to Fulvio Irace, the power plant is the central node of the hydropower system).*
Source: Giulia Azzini 2024.

At the architectural scale, the power plant (see Figure 3) serves as the primary infrastructural element. Fulvio Irace highlights its triple relevance:[23] from a spatial perspective, it connects the valley floor to the higher elevations of the mountain; functionally, it transforms the water movement into electricity; from a design point of view, it has long been a site of experimentation, shaping both the identity of remote regions and the image of energy companies.[24]

Before 1898, the plants were small, often integrated into existing buildings such as mills and factories, and operated locally. With the advent of more efficient technologies, the typology crystallized into two main elements: the turbine hall and the transformer station. The turbine hall was a large, luminous space, shaped by the

23. Irace, "Luci moderne: Muzio, Ponti e Baldessari e il progetto delle centrali," 1998.

24. The power plant is intended as a representative building and a formidable communication tool for the corporate image. In Italy, large electricity companies from Edison to SADE, SIP, Terni, SME, tie themselves to the best professionals of the moment, often establishing long-lasting relationships.

layout of turbines and generators: penstocks descended from the mountainside into its foundations, discharging water through channels at its base; windows were tall, crowned by overhead crane tracks, and topped by metal trusses supporting the roof (see Figure 4). The transformer station, instead, was higher, multi-level, and housed heavy equipment on the ground floor, with switches and ducts above; its façades were marked by layered window arrangements, ending with small apertures for cable outflow (see Figure 5). Other spaces included the control room, maintenance workshops scaled to transformer size, and service buildings for staff.[25]

After the Second World War, power plants underwent a strong evolution: the power increased, and the distribution system became more complicated. The new facilities were seen to be frequently constructed within mountain caves, often several hundred meters deep. Gradually, the transformer station was transferred outside the powerhouse for both economic and functional reasons (see Figure 6).

The typological variation of the hydropower plant reflects, on an architectural scale, the progressive obsolescence that has affected the entire system since the second half of the twentieth century, which can be further explored through the interpretive lens of time.

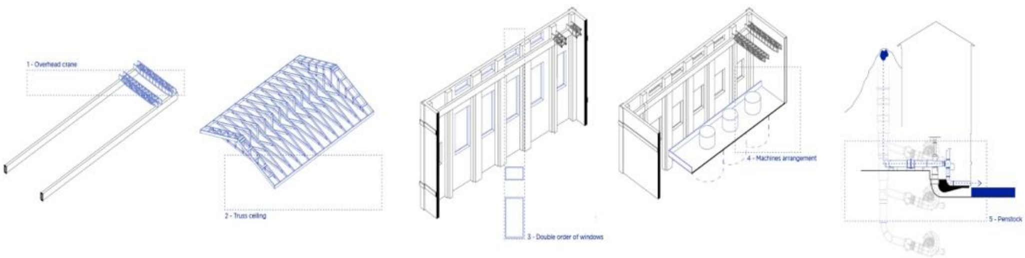

Figure 4. *Main Features of the Turbine All: Overhead Crane, Truss Ceiling, Double Order of Windows, Machines' Arrangement, and Penstock's Connection*
Source: Giulia Azzini 2025.

25. G. Menini, *I luoghi dell'acqua. Architetture e paesaggi delle centrali elettriche in Valtellina* (Sondrio: Fondazione Gruppo Credito Valtellinese, 2013).

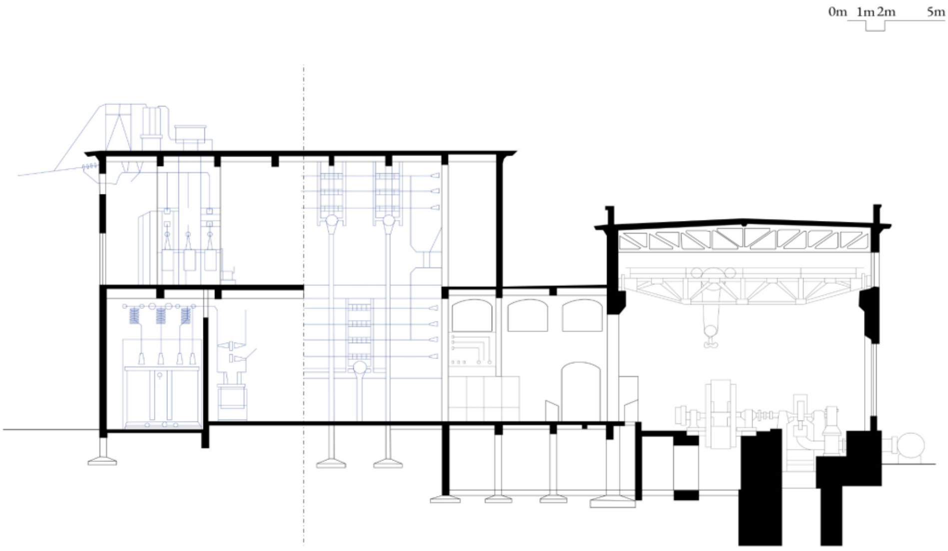

Figure 5. *Example of An Indoor Transformer Station in the Matese Hydropower Plant, Italy (Note the connection to the turbine hall and the detail of the upper windows, from which the electrical cables come out)*
Source: Giulia Azzini 2025.

Figure 6. *Example of an Outdoor Transformer Station at the Canistro Hydropower Plant, Italy*
Source: Giulia Azzini 2024.

Time

Electricity production and distribution, initiated at the end of the nineteenth century but the result of a much longer process, have redefined the modern and contemporary mountain landscape: not only for the technological innovation or the psychological impact, but also for its incisive action.[26]

The origins of hydropower may be traced to ancient mills exploiting kinetic energy for local production. Watermills proliferated in the Mediterranean from the third century BC,[27] peaking in the Middle Ages.[28] This phase was characterized by tight bonds between water and labor. Such bonds loosened with the first Industrial Revolution, as steam replaced water, giving rise to a landscape of terraces, dams, and canals.[29]

After the First and Second Industrial Revolutions, when steam and coal were the main energy sources, an incredible discovery emerged: the *houille blanche*[30], a term coined by Aristide Bergès in 1889. This moment marks the beginning of the hydropower "expansion" phase, as stated by Rosario Pavia[31]: slopes, basins, and altitudes were surveyed and reconstructed through an engineering logic,[32] modifying the mountain contexts in the wake of the previous century.

The expansion phase captivated artists, architects, and film directors: Giacomo Balla and Umberto Boccioni, for example, celebrated electricity as a symbol of progress; Tony Garnier centered a hydropower plant in his *Cité industrielle*; and Antonio Sant'Elia dramatized dams and conduits in his expressionist sketches (see Figure 7). However, the first institutions for landscape conservation and enhancement also emerged, revealing the limits of such optimism.

26. V. Fontana, "L'Italia elettrica," in R. Pavia (Ed.), *Paesaggi elettrici. Territori architetture culture*, 23-40 (Venice: Marsilio, 1998).

27. Historians attribute the earliest descriptions of water mills to the Greek engineer Philo of Byzantium and the Roman geographer Strabo. Even Vitruvius, within the *Ten Books of Architecture*, devotes the entire eighth book to the subject of water, describing within it a mill and its operation.

28. F. Braudel, *Civiltà materiale, economia e capitalismo. Le strutture del quotidiano (secoli XV-XVIII)* (Turin: Einaudi, 2006).

29. R. Dubbini, *Geografie dello sguardo. Visione e paesaggio in età moderna* (Turin: Einaudi, 1994).

30. In English, "white coal".

31. Pavia, "Architettura e paesaggi idroelettrici in Italia," 2001.

32. A. De Rossi, *La costruzione delle Alpi. Il Novecento e il modernismo alpino (1917-2017)* (Rome: Donzelli, 2016).

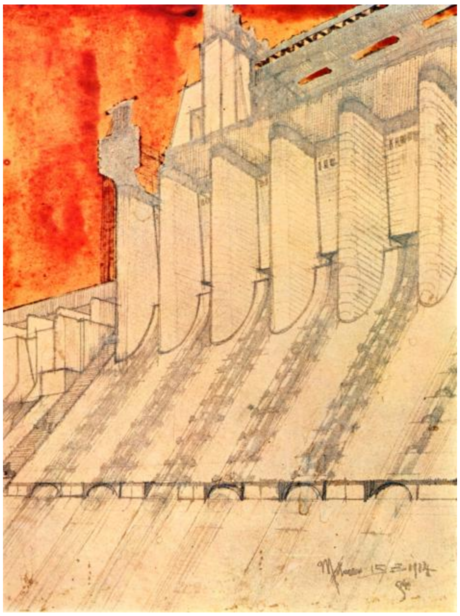

Figure 7. *Perspective of a Dam by Antonio Sant'Elia (1914)*
Source: Accetti collection, Milan. Drawing taken from Fontana, "L'Italia elettrica," 1998.

Among the various artistic expressions, hydropower plants themselves became a medium of representation. Their design was a very fertile ground for experimentation, as architects were charged with the promotion and affirmation of the image of energetic companies.

Finally, the period between the Second World War and the beginning of the twentieth century was characterized by a contraction of hydropower:[33] in Italy, production dropped from 90% in the 1930s to 50% by the 1950s–60s.[34] After its nationalization, the commitment in this sector was progressively reduced, especially due to the lack of suitable sites and a strong environmentalist opposition, until reaching the contemporary era, when the effects of climate change and technological innovations have led to the appearance of new forms of renewable energy and the obsolescence of many hydropower infrastructures.

This process of slow contraction easily reflects in the power houses: if in the first half of the twentieth century, the aim was to spread an image of perpetuity and safety, after the Second World War, these buildings acquired a different visibility, reducing their shell and adopting a more functionalist architecture.[35] Indeed, the machines had been reduced thanks to technological innovations, in turn contracting their envelopes. Furthermore, while in the first half of the twentieth century the plants offered a high demand for local labor and workers, gradually, a very strong automation and the development of remote control systems led to their progressive abandonment.[36] At the same time, the tragedies of Malpasset, Vajont, and Mattmark

33. Pavia, "Architettura e paesaggi idroelettrici in Italia," 2001.

34. Ibid.

35. W. Audéoud, and M. Jakob, *Guide des barrages suisses. 50 itinéraires alpins* (Gollion: Infolio, 2006).

36. V. Bonardo, K. Eroe, G. Zampetti, and E. Zanchini, *L'idroelettrico. Impatti e nuove sfide al tempo dei cambiamenti climatici* (Rome: Legambiente, 2018).

exhibited the hidden relationships between the rhetoric of progress and the logic of profit.[37]

Nowadays, hydropower infrastructure is pervasive yet largely unnoticed. As part of a dispersed fabric, it faces renewed scrutiny for its environmental and spatial impacts. And yet, as Rosario Pavia reminds us, while environmental concerns are widely acknowledged, their spatial potential remains underexplored.[38] However, both issues are relevant according to a design-driven perspective and are deeply interconnected with the energy lens.

Energy

According to Sijmons et al., there is a notable interaction between the production of energy and spatial design.[39] Sven Stremke has more recently described such a relationship as formed by the co-evolution of human energy systems and natural processes.[40] This perspective is especially relevant today, as climate change increasingly influences energy production and the configuration of its spaces.

In the hydropower sector, climate change primarily manifests through alternating periods of drought and intense rainfall, both of which compromise water availability.[41] Nonetheless, according to Perpiña Castillo et al., Italy remains one of Europe's leading hydropower producers, after Sweden and France, highlighting the strategic significance of this energy source at a national level.[42]

Even across Europe, hydropower is one of the most efficient low-carbon energy sources, with conversion efficiencies exceeding 80% and long operational lifespans.[43] It plays a vital role in decarbonization by stabilizing the grid and complementing intermittent renewables. In particular, storage hydropower plants constitute the primary large-scale energy storage technology, essential for long-term energy security. Efforts to modernize and digitize these systems are enhancing not only their flexibility and resilience but also their environmental performance.[44]

Beyond technical benefits, hydropower offers advantages in terms of visual perception. While the most visible impact concerns the formation of artificial reservoirs, engineered elements, such as dams, conduits, and powerhouses, occupy

---

37. A. De Rossi, *La costruzione delle Alpi. Il Novecento e il modernismo alpino (1917-2017)* (Rome: Donzelli, 2016).

38. Pavia, "Architettura e paesaggi idroelettrici in Italia," 2001.

39. Sijmons, et al., *Landscape and Energy. Designing Transition*, 2014.

40. V. Stremke, D. Oudes, and P. Picchi, *Power of Landscape. Novel Narratives to Engage with the Energy Transition* (Rotterdam: nai010, 2022).

41. Bonardo, Eroe, Zampetti, and Zanchini, *L'idroelettrico. Impatti e nuove sfide al tempo dei cambiamenti climatici* (Rome: Legambiente, 2018).

42. Perpiña Castillo, Hormigos Feliu, Dorati, Kakoulaki, Peeters, Quaranta, Taylor, Uihlein, Auteri, and Dijkstra, *Renewable Energy production and potential in EU Rural Areas*, 2024.

43. E. Quaranta, A. Georgakaki, S. Letout, A. Kuokkanen, M. Grabowska, J. Gea-Bermúdez, and J. Tattini, *Clean Energy Technology Observatory: Hydropower and Pumped Hydropower Storage in the European Union - 2023 Status Report on Technology Development, Trends, Value Chains and Markets* (Luxembourg: Publications Office of the European Union, 2023).

44. International Renewable Energy Agency, *Renewable Power Generation Costs in 2022* (Abu Dhabi: IRENA, 2024).

relatively limited space.[45] Moreover, these components are often situated in valley bottoms and partially concealed by topography, making them generally less invasive than solar or wind facilities.[46] From this perspective, hydropower systems can be approached not merely as functional infrastructure but as instruments that shape both territory and culture, opening up new avenues for design. Rather than focusing solely on mitigation, integrated strategies may merge energy production with architecture and landscape design, promoting both performance and aesthetics.

Within this framework, rural and mountainous regions emerge as key focal areas for the energy transition, owing to their water resources and spatial potential. As argued by Perpiña Castillo et al., these regions can actively contribute to climate action, not only through renewable energy generation but also as sites for broader social and economic revitalization. Strategic directions include the modernization of existing plants, the development of small-scale hydro, and hybrid solutions such as floating solar photovoltaics.[47]

In conclusion, despite ongoing challenges, hydropower is expected to remain a cornerstone of the European energy mix, increasingly focused on storage and grid support rather than expansion. This evolving role invites a critical rethinking of existing infrastructures, especially in fragile mountain contexts, where architectural and urban planning tools can reconfigure their territorial presence, fostering renewed relationships between energy, landscape, and community.

Results and Discussion

The interpretative lenses of space, time, and energy have guided a reflection on hydropower infrastructure design nowadays: space, in particular, has served to understand its typological configuration and identify its recurring elements; in addition, the time lens has proved an evolution of thought in the conception of these structures, rather than a break; finally, energy has demonstrated their effective importance in the contemporaneity, looking at the energy transition. These analyses bridge the current gap that sees architectural and spatial perspectives unrepresented, if compared to the technical literature. Such a gap, in fact, limits the possibility of reimagining these facilities as potential tools for landscape enhancement.

As mentioned previously, Rosario Pavia observed that the most common attitude towards hydropower at the start of the twenty-first century was indifference. However, many projects from the past two decades have revealed a shift in this way of thinking: growing environmental awareness and renewed interest in the mountain contexts have opened space for design experimentation. These recent cases have been collected by the author according to different criteria: the year of construction, limited to the period between 2000 and 2025; the scale, considering the landscape

45. A. M. Trainor, R. I. McDonald, and J. Fargione, "Energy Sprawl is the Largest Driver of Land Use Change in United States," *PLOS ONE* 11, no. 9 (2016): 1-16.

46. R. Ioannidis, and D. Koutsoyiannis, "A review of land use, visibility and public perception of renewable energy in the context of landscape impact," *Applied Energy* (2020): 276.

47. Perpiña Castillo, Hormigos Feliu, Dorati, Kakoulaki, Peeters, Quaranta, Taylor, Uihlein, Auteri, and Dijkstra, *Renewable Energy production and potential in EU Rural Areas*, 2024.

and object ones; the typology, including not only hydropower, but also broader systems for exploiting natural resources for productive purposes; the critical attitude, or an attention to the reuse, the visual and environmental impact, and the connection between public and productive spaces; and, lastly, the regenerative potential, keeping economic growth, built heritage preservation and environmental compatibility as parameters. The case studies display recurring features that can be merged into three design approaches: adaptability, recycling, and hybridization (see Figure 8). The latter are intended as open, evolving frames. Within, what matters are not the case studies themselves — of which, by choice, only a tiny selection has been made in the paper — but rather the logics leading to a certain spatial configuration.

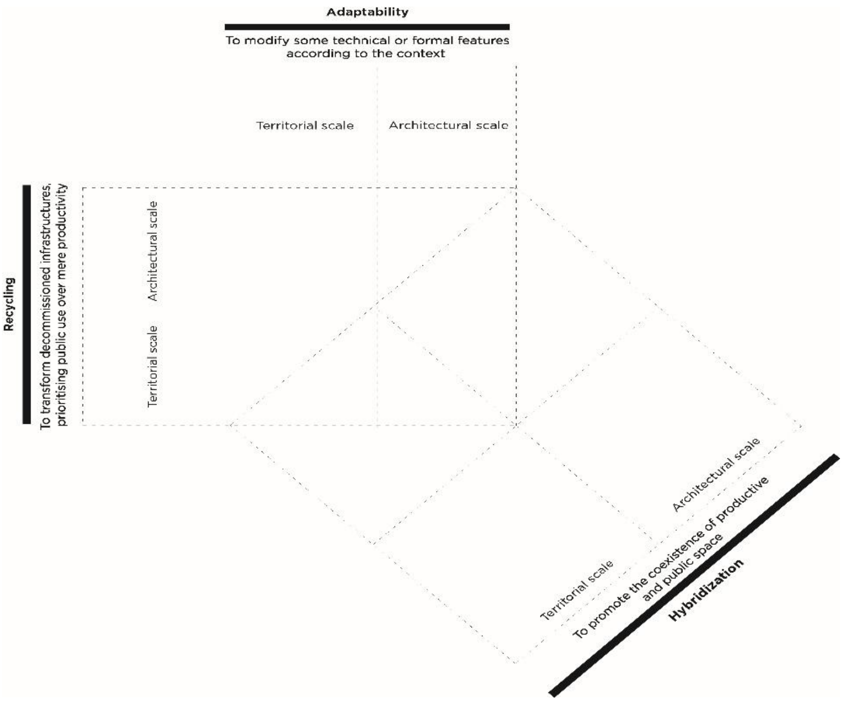

Figure 8. *Design Approaches: Adaptability, Recycling, and Hybridization*
Source: Giulia Azzini 2025.

Adaptability

Adaptability, a term largely employed in several disciplines and, here, shifted to the architectural one, concerns the project's ability to modify some technical or formal features according to its context. In mountain regions, historically marked by small-scale, carefully calibrated settlements, this entails rethinking the monumental presence of hydropower infrastructure in the nineteenth and early twentieth centuries. To this end, contemporary designers often prefer subtle and minimal, carefully considered interventions that harmonize with their surroundings, balancing between extroversion and introversion. The former involves exposing technical processes and integrating public space; the latter focuses on visual containment and material camouflage.

As for extroversion, we can mention the hydropower plant realized by Atelier Pierre Thibault in 2014 in Val-Jalbert, Canada, or the small Øvre Forsland station by Stein Hamre Arkitektkontor, in Norway, inaugurated in 2015: the first is grafted, at a territorial level, into a path of particular historical and landscape interest, opening onto the Ouiatchouan River waterfall through a system of accessible belvederes (see Figure 9); the others, instead, constitute small objects showcasing visible machinery through large glazed surfaces (see Figure 10).

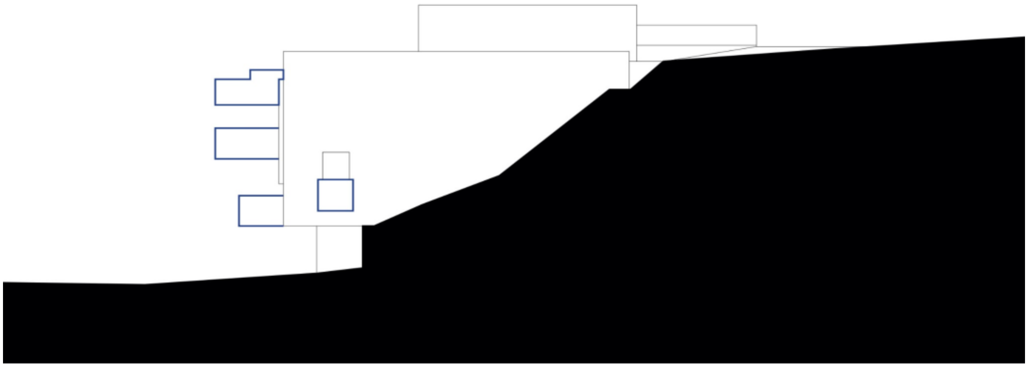

Figure 9. *Hydropower Plant in Val-Jalbert, Canada, by Atelier Pierre Thibault (2014) (The balconies are open to the public and offer a different perspective of the lake)*
Source: Giulia Azzini 2024.

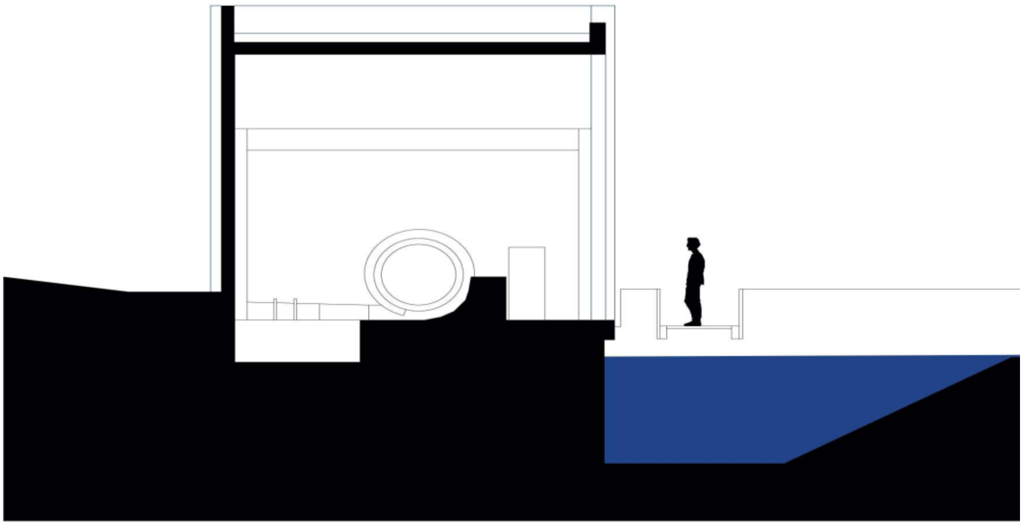

Figure 10. *Øvre Forsland Hydropower Plant, Norway, by Stein Hamre Arkitektkontor (2015) (The glazed facade allows visitors to see the machinery inside)*
Source: Giulia Azzini 2024.

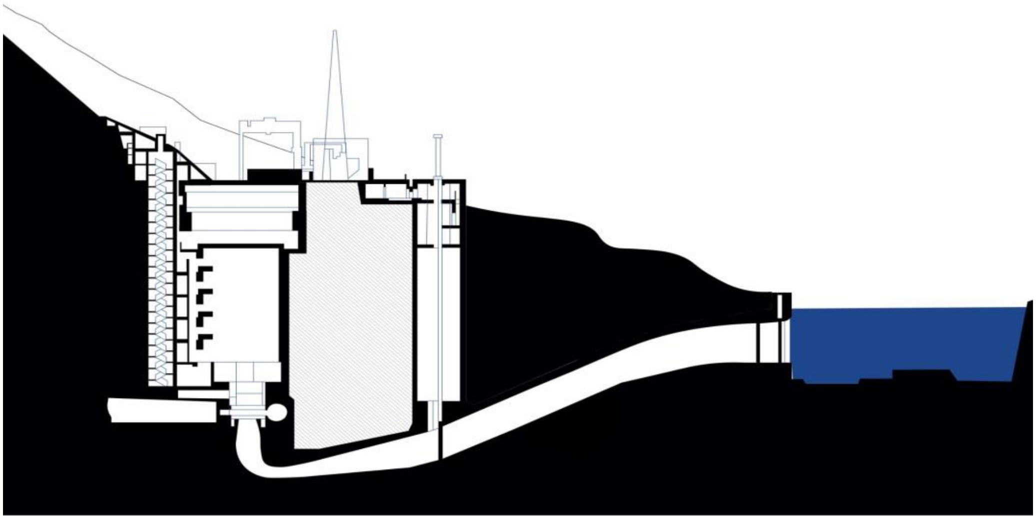

Figure 11. *Underground Hydropower Plant by Souto de Moura in Alijó, Portugal (2017) (The machinery is hidden inside the mountain, leaving only a few elements visible as sculptures in the landscape)*
Source: Giulia Azzini 2024.

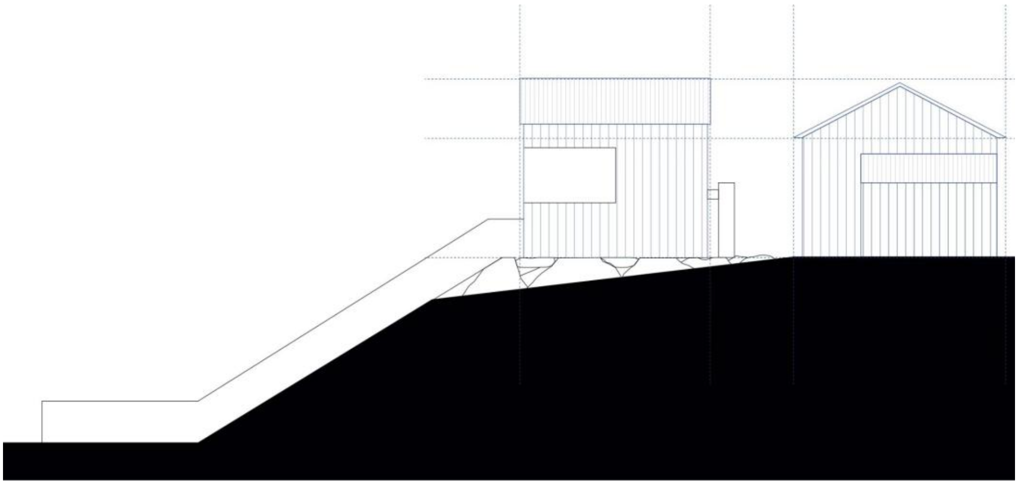

Figure 12. *Hydropower Plant by Thomas Wiedmer in San Martino in Passiria, Italy (2007) (The shape and materials of the envelopment echo those of the historic sawmill beside)*
Source: Giulia Azzini 2024.

On the other end, the Foz Tua Dam by Souto de Moura, inaugurated in 2017 in Alijó, Portugal, minimises visual impact on a territorial scale (see Figure 11). The various infrastructural elements — plant, shaft, vents, control room — are treated as sculptures that blend into the landscape. At the object scale, instead, examples include the hydropower station by Thomas Wiedmer, designed in 2007 in San Martino in Passiria, Italy, which echoes mountain dwellings (see Figure 12).

The cited examples show how adaptability fosters a renewed alliance between infrastructure and landscape. It channels engineering potential into spatial design strategies, reaffirming architecture's creative and critical role in shaping the contemporary mountain environment.

Recycling

Recycling is a key approach for transforming decommissioned infrastructures, prioritising public use over mere productivity. This is especially relevant in energy landscapes, where rapid technological evolution often renders existing systems obsolete,[48] affecting both fossil-based and renewable infrastructures.

In the hydropower sector, several cases show how to reactivate disused plants through new meanings and public functions. Recycling for cultural purposes is particularly common: at the architectural scale, examples include the Norwegian Museum of Hydropower and Industry (2005) in Tyssedal or the MUSIL museum in Cedegolo (2008) by Claudio Gasparotti. At the territorial scale, instead, the Allmannajuvet Zinc Mine Museum (2016) by Peter Zumthor in Sauda, Norway, transforms a former industrial site into a dispersed museum (see Figure 13). These projects, overall, are at the same time respectful of the pre-existence, maintaining as much as possible its typological and natural characteristics, and innovative, creating a new imagery through design. The construction of small pavilions in the Allmannajuvet Zinc Mine Museum, or the redefinition of paths and the restoration of interiors and public spaces, in the power plants of Tyssedal and Cedegolo, constitute simple but meaningful interventions in fragile mountain contexts. They show how recycling, as a design approach, can transform obsolete infrastructures into opportunities for economic and social regeneration.

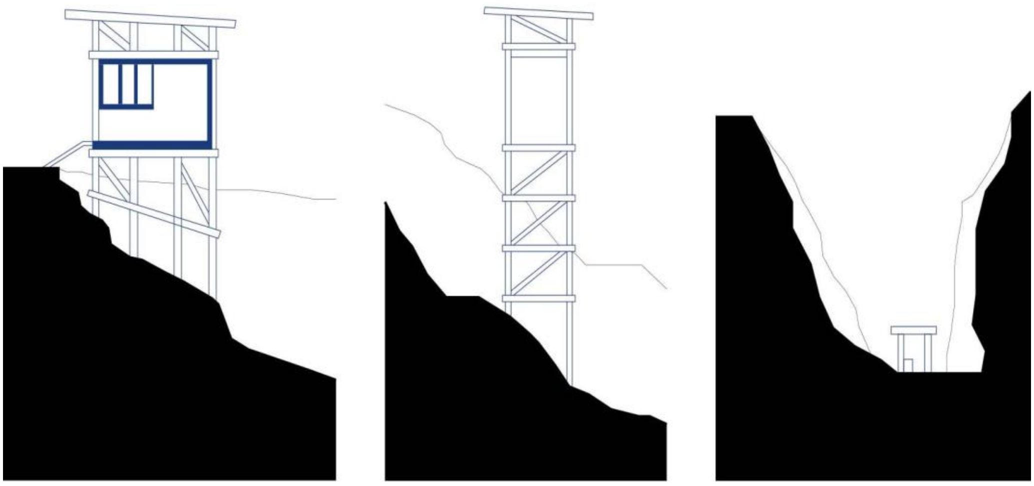

Figure 13. *Allmannajuvet Zinc Mine Museum in Sauda, Norway, by Peter Zumthor (2016) (Particulars of the pavilions within the former industrial site)*
Source: Giulia Azzini 2024.

48. Stremke, Oudes, and Picchi, *Power of Landscape. Novel Narratives to Engage with the Energy Transition*, 2022.

Hybridization

As Hillary Brown suggests, global urbanisation, climate change, and ecological degradation are reshaping the role of infrastructure, which can no longer be confined to technical efficiency. Architects and landscape designers, sensitive to spatial patterns, ecological dynamics, and human uses, now play a key role in imagining multifunctional systems. In this light, hybridization becomes a central design approach, promoting the coexistence of productive and public space.[49]

A clear example at the architectural scale is the regeneration of the Saumont hydropower plant in Aosta by Matteo and Antonio Lavarello, completed in 2015 (see Figure 14). This project combines energy production with cultural and public use by adding new volumes, restoring the existing ones, and redefining the open space. At the territorial scale, instead, there are several productive infrastructures in rural areas which can be seen as examples for the hydropower ones: for instance, the Water Treatment Plant in Hillerød, Denmark, by Henning Larsen Architects, shows how a water treatment plant can be perfectly integrated into a public space. Here, great attention is paid to the landscape design, where paths, viewpoints, natural and recreational areas intersect, reducing the strong visual impact usually attributed to this type of infrastructure.

The previous case studies interpret hydropower or water-related infrastructures as places sensitive to the environment in which they operate and to the users with whom, indirectly, they interact. Through the contamination between productive and public space, hybridization thus asserts itself as a necessary paradigm for contemporary design.

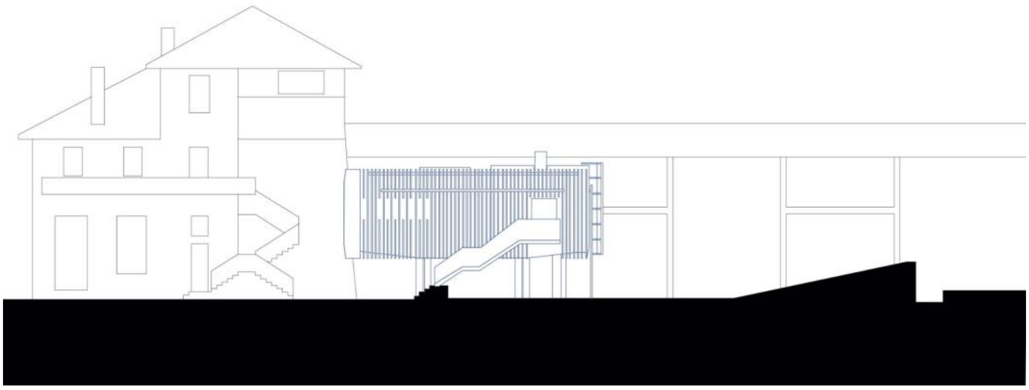

Figure 14. *Regeneration of the Saumont Hydropower Plant in Aosta, Italy, by Matteo and Antonio Lavarello (2015) (In blue, the new public volume added to the old power house)*
Source: Giulia Azzini 2024.

Conclusions

49. H. Brown, "NextGen Infrastructure: places of (resource) aggregation and (public) congregation," *Area* 158 (2018): 4-9.

The paper's interpretation of hydropower infrastructure emphasizes its implicit capacity for regeneration within the fragile mountain contexts.

By adopting the analytical lenses of space, time, and energy, this system is conceived as an interesting device from a typological, historical, and environmental point of view in the contemporary age. Simultaneously, the three design approaches of adaptability, recycling, and hybridization, demonstrate how many strategies architecture and landscape practices can employ to address productive infrastructures, thus informing their future design.

The perspective adopted is considered useful for several purposes: first, to bridge the current gap among design and technical perspective; second, to show existing practices that support a renewed alliance between hydropower and landscape; and finally, to reflect on a crucial issue in the southern Europe, where many facilities have become obsolete following past cycles of expansion and contraction, while currently an urgent need to promote renewable sources is arising.

Future research may further explore the operationalization of the three design approaches in specific contexts, taking up suggestions from the case studies and developing prototypes applicable not only in Italy, but also in similar areas from a morpho-typological, historical, and energetic point of view.

Bibliography

Andriani, C. "Ricordo al futuro." (Memory to the future.) In C. Andriani (Ed.), *Il patrimonio e l'abitare*, XIII-XXIV. Rome: Donzelli, 2010.

Audéoud, W., and M. Jakob. *Guide des barrages suisses. 50 itinéraires alpins.* (Guide to Swiss dams. 50 alpine routes.) Gollion: Infolio, 2006.

Bonardo, V., K. Eroe, G. Zampetti, and E. Zanchini. *L'idroelettrico. Impatti e nuove sfide al tempo dei cambiamenti climatici.* (Hydroelectricity. Impacts and new challenges in the age of climate change.) Rome: Legambiente, 2018.

Braudel, F. *Civiltà materiale, economia e capitalismo. Le strutture del quotidiano (secoli XV-XVIII).* (Material civilization, economy and capitalism. The structures of everyday life (15th-18th centuries).) Turin: Einaudi, 2006.

Brown, H. "NextGen Infrastructure: places of (resource) aggregation and (public) congregation." *Area* 158 (2018): 4-9.

Carrosio, G., and A. Facchini. "Le mappe della cittadinanza nelle aree interne." (Citizenship maps in the inner areas.) In A. De Rossi (Ed.), *Riabilitare l'Italia. Le aree interne tra abbandoni e riconquiste*, 51-78. Rome: Donzelli, 2018.

Conzett , J., and M. Linsi. *Landschaft und Kunstbauten. Ein persönliches Inventar von Jürg Conzett, fotografiert von Martin Linsi.* (Landscape and engineering structures. A personal inventory by Jürg Conzett, photographed by Martin Linsi.) Zürich: Scheidegger & Spiess, 2010.

De Rossi, A. *La costruzione delle Alpi. Il Novecento e il modernismo alpino (1917-2017).* (The construction of the Alps. The Twentieth century and alpine modernism (1917-2017).) Rome: Donzelli, 2016.

Dubbini, R. *Geografie dello sguardo. Visione e paesaggio in età moderna.* (Geographies of the gaze. Vision and landscape in the modern age.) Turin: Einaudi, 1994.

Ferrata, C. "Tra il visibile e l'invisibile, paesaggi idroelettrici nelle Alpi." (Between the visible and the invisible, hydropower landscapes in the Alps.) *Archi. Rivista svizzera di architettura, ingegneria e urbanistica* 6 (2008): 10-17.

Ferrata, C. "Quando le infrastrutture fanno il paesaggio." (When the infrastructures make the landscape.) *Archi. Rivista svizzera di architettura, ingegneria e urbanistica* 1 (2021): 11-14.

Fontana, V. "L'Italia elettrica." (Electric Italy.) In R. Pavia (Ed.), *Paesaggi elettrici. Territori architetture culture,* 23-40. Venice: Marsilio, 1998.

Gambino, R. "La convenzione europea del paesaggio." (The European Landscape Convention.) In C. Cassatella, F. Baggiani (Eds.), *Creare paesaggi: realizzazioni, teorie e progetti in Europa. Atti del Convegno (Torino, 9-24 maggio 2002)*. Florence: Alinea, 2003.

Genazzi, E. "Lo sfruttamento idroelettrico della Maggia: una svolta dai molti volti e sfumature." (Hydroelectric exploitation of the Maggia: a turning point with many faces and nuances.) In E. Genazzi (Ed.), *Lo sfruttamento idroelettrico della Maggia. Metamorfosi di una valle*, 8-11. Cevio: Museo di Valmaggia, 2024.

Geroldi, C., and G.Pessina. "Power stations and petroleum heritage in Italy. The Case of Porto Tolle." In C. Hein (Ed.), *Oil Spaces. Exploring the global petroleumscape,* 243-283. New York: Routledge, 2022.

Gregotti, V. "La forma del territorio." (The form of the territory.) *Edilizia moderna* 87/88 (1965): 1-11.

International Renewable Energy Agency. *Renewable Power Generation Costs in 2022*. Abu Dhabi: IRENA, 2024.

Ioannidis, R., and D. Koutsoyiannis. "A review of land use, visibility and public perception of renewable energy in the context of landscape impact." *Applied Energy* (2020): 276.

Irace, F. "Luci moderne: Muzio, Ponti e Baldessari e il progetto delle centrali." (Modern lights: Muzio, Ponti and Baldessari and the design of powerhouses.) In R. Pavia (Ed.), *Paesaggi elettrici. Territori architetture culture*, 136-165. Venice: Marsilio, 1998.

Jakob, M. "L'impronta della tecnica sul paesaggio alpino." (The footprint of the technique on the Alpine landscape.) *Archi. Rivista svizzera di architettura, ingegneria e urbanistica* 1 (2021): 15-18.

Koolhaas, R. *Countryside. A Report.* New York: Guggenheim-Taschen, 2020.

Menini, G. *I luoghi dell'acqua. Architetture e paesaggi delle centrali elettriche in Valtellina*. (Water places. Architecture and landscapes of powerhouses in Valtellina.) Sondrio: Fondazione Gruppo Credito Valtellinese, 2013.

Mitchell, W. J. T., and J. Thomas. *Landscape and power.* Chicago: University of Chicago Press, 1994.

Parpagliolo, L. *La difesa delle bellezze naturali*. (The defense of natural beauty.) Foligno: Società Editrice d'Arte Illustrat, 1923.

Pavia, R. "Architettura e paesaggi idroelettrici in Italia." (Architecture and hydropower landscapes in Italy.) In C. Masetti (Ed.), *Chiare, fresche e dolci acque. Le sorgenti nell'esperienza odeporica e nella storia del territorio. Atti del Convegno di Studi San Gemini, 18-20 ottobre 2000, Abbazia di San Nicolò*, 769-776. Rome: Cisge, 2001.

Perpiña Castillo, C., C. Hormigos Feliu, C. Dorati, G. Kakoulaki, L. Peeters, E. Quaranta, N. G. Taylor, A. Uihlein, D. Auteri, and L. Dijkstra. *Renewable Energy production and potential in EU Rural Areas.* Luxembourg: Publications Office of the European Union, 2024.

Quaranta, E., K. Bódis, E. Kasiulis, A. McNabola, and A. Pistocchi. "Is There a Residual and Hidden Potential for Small and Micro Hydropower in Europe? A Screening-Level Regional Assessment." *Water Resources Management* 36, no. 6 (2022): 1745-1762.

Quaranta, E., A. Georgakaki, S. Letout, A. Kuokkanen, M. Grabowska, J. Gea-Bermúdez, and J. Tattini. *Clean Energy Technology Observatory: Hydropower and Pumped Hydropower Storage in the European Union - 2023 Status Report on Technology*

Development, Trends, Value Chains and Markets. Luxembourg: Publications Office of the European Union, 2023.

Sijmons D., et al. *Landscape and Energy. Designing Transition.* Rotterdam: nai010, 2014.

Stalder, L., and C. Darò. "Eight Points of Infrastructure and Architecture." In I. Ruby, and A. Ruby (Eds.), *Infrastructure Space*, 26-29. Berlin: Ruby Press, 2017.

Stremke, V., D. Oudes, and P. Picchi. *Power of Landscape. Novel Narratives to Engage with the Energy Transition.* Rotterdam: nai010, 2022.

Trainor, A. M., R. I. McDonald, and J. Fargione. "Energy Sprawl Is the Largest Driver of Land Use Change in United States." *PLOS ONE* 11, no. 9 (2016): 1-16.