# AGRIVOLTAICS AS A CATALYST FOR NATURE-POSITIVE TRANSITIONS: TERRITORIAL POTENTIAL AND POWER PLANT REGENERATION IN THE PO VALLEY

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ABSTRACT: The convergence of energy and ecological transitions presents a unique opportunity to reimagine the relationship between energy production, environment, and territory. This paper explores how agrivoltaic systems can serve as catalysts for territorial regeneration through a nature-positive approach that delivers measurable ecosystem benefits. Moving beyond traditional compensatory models, we propose a framework where energy infrastructure becomes the foundation for ecosystem restoration and biodiversity enhancement. Drawing upon the theoretical foundations of the Super Valley research project and the practical application at the Castelguglielmo agrivoltaic plant in the Veneto region, this study demonstrates how strategically designed agrivoltaic installations can contribute to the EU's dual 2030 goals of 65% renewable energy production and 20% restoration of degraded ecosystems. The case study reveals how compliance with both energy and ecological mandates can become an opportunity for territorial innovation rather than regulatory constraint.
Keywords: agrivoltaics, landscape integration, nature-positive, territorial transition, energy landscapes, ecosystem restoration.

## 1 INTRODUCTION

The current decade marks a pivotal historical moment characterised by the convergence of energy and ecological transitions. The climate change challenge demands a radical rethinking of the relationship between energy production, environment, and territory—where energy infrastructure can serve as a catalyst for regeneration and shared value creation rather than an environmental burden requiring mitigation.

The European Union has established ambitious 2030 targets: 65% of energy production from renewable sources and restoration of 20% of degraded ecosystems [1]. In Italy specifically, the national energy strategy aims for 70 GW of installed capacity from new renewable plants, with an average of 10 GW annual installations required to meet these objectives [2]. This dual transition presents a unique opportunity to develop a new energy landscape paradigm that transcends traditional compensatory approaches in favour of a nature-positive model capable of generating net positive ecosystem benefits.

The Nature Restoration Law, adopted by the Council of Europe, mandates the restoration of terrestrial and marine habitats, guaranteeing 25,000 km of natural connectivity of waterways, reversing the decline of pollinator populations, and ensuring differentiated management of agricultural ecosystems [3]. These policy frameworks create both an imperative and an opportunity for landscape architects and urbanists to reconceptualise the agrarian space as a site of ecological transition.

This paper positions agrivoltaic systems as territorial infrastructure capable of addressing this dual mandate. Drawing upon the theoretical foundations of the Super Valley research project and its practical application at the Castelguglielmo site, we demonstrate how energy landscapes can be cultivated as rehabilitators of nature and activators of place, moving beyond the extractive and compensatory paradigms that have characterised renewable energy development to date.

## 2 THEORETICAL FRAMEWORK: LANDSCAPE AS A PLATFORM FOR TRANSITION

### 2.1 The agrarian space in transition

Contemporary landscape urbanism demands a radical reconceptualisation of energy landscapes as productive territorial systems. The pressure of humanity on bio-geo-chemical earth systems is today unprecedented; from water to land, passing through the atmosphere, the effects of contemporary life are affecting directly and indirectly many geographies around the world [4]. Processes of urbanisation, specifically under the form of land use change, contribute to widespread processes of ecosystem degradation and environmental depletion.

Within polycentric city agglomerations—the urban phenomenon of our age—defined by declining and redistributing densities and processes of peri-urbanisation, there has been a growing focus on the structural and functional importance of open spaces in urban planning, design, and practice. This is evident in the latest disciplinary developments of urbanism toward landscape and ecological urbanism, and in the rise of new epistemologies related to operational landscapes as geographies of primary production which generate and support processes of urbanisation [5].

The European Landscape Convention, adopted by the Council of Europe in Florence on 20 October 2000, represents the first international legally binding instrument dedicated entirely to landscape [6]. Twenty-five years later, its mandate for integrated landscape planning and management becomes ever more critical as territories face the compounded challenges of climate change, biodiversity loss, and energy transition.

### 2.2 From net zero to nature positive

A paradigm shift is underway in how we conceptualise energy infrastructure's relationship with the environment. The Paris Climate Agreement of 2015 established the net zero framework, focusing primarily on climate mitigation through carbon neutrality. However, the Kunming-Montreal Global Biodiversity Framework of 2022 introduces the nature-positive paradigm, which integrates climate action with biodiversity conservation and ecosystem restoration [7].

The nature-positive approach represents a fundamental departure from compensatory and mitigatory frameworks. Where conventional practice operates through hierarchies of avoidance, reduction, and offsetting—ultimately accepting a net loss or, at best, neutrality—the nature-positive paradigm demands that every intervention leaves more nature than it found. The objective shifts from minimising harm to actively restoring and regenerating ecosystems, improving baseline conditions through each project rather than merely compensating for their impacts [8], [9]. Within this framework, energy infrastructure is conceived not as an environmental burden requiring mitigation, but as a catalyst for ecological restoration—a trigger capable of initiating regenerative processes that enhance biodiversity, rebuild ecosystem functions, and generate net positive territorial value.

Applied to energy landscapes, this paradigm shift moves beyond the extractive approach—where energy production comes at the expense of nature and people—past the compensatory approach that characterises current practice, toward a transformative approach where energy, nature, and people all benefit synergistically (Figure 1). Agrivoltaic systems, which integrate solar energy production with agricultural activity, represent a prototype of this transformative model.

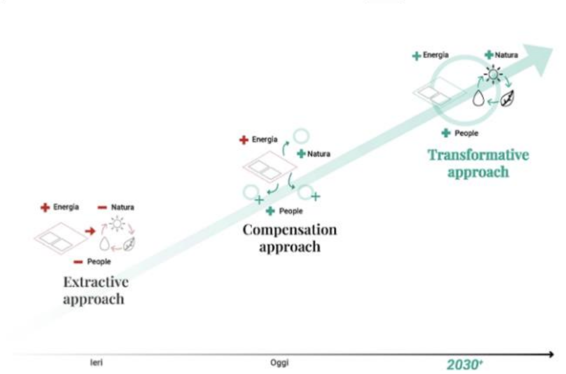


**Figure 1:** Energy landscapes within the nature-positive paradigm: from compensation to transformation. The diagram illustrates the evolution from extractive approaches (energy gains at the expense of nature and people) through compensatory models (current practice) toward the transformative approach where energy, nature, and people all benefit synergistically. The trajectory toward 2030+ positions energy landscapes as "rehabilitators of nature and activators of places." Image by LAND.

## 3 TERRITORIAL POTENTIAL: THE SUPER VALLEY FRAMEWORK

### 3.1 Geography of investigation

The Po Valley represents a paradigmatic case study for investigating the transformative potential of agrarian space. As the defining urban phenomenon of our age, post-metropolitan polycentric agglomerations made of concentrated and extended urbanisation create continuous city-territories that become ideal laboratories for testing alternative urbanisation pathways and possible futures [10]. The Alpine-Padano-Adriatic megaregion, encompassing approximately 4.95 million hectares, presents a critical geography where 83% of the territory is dominated by arable land, primarily non-irrigated agricultural production (Figure 2).

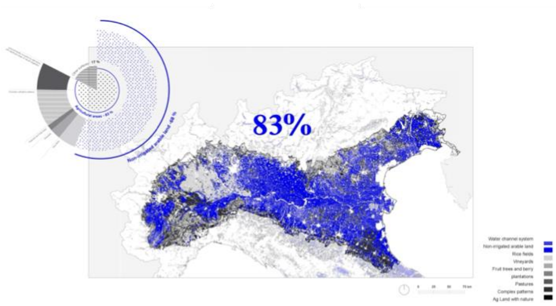


**Figure 2:** The Alpine-Padano-Adriatic megaregion: territorial structure and land cover composition. The diagram illustrates the spatial dominance of agricultural land (83%) within the 4.95 million-hectare territory, highlighting the transformative potential of agrarian space as a platform for ecological transition. Image by F. LaFleur.

The Super Valley research project, developed through a joint PhD programme between Politecnico di Milano and TU Delft, establishes an agro-ecological planning and design framework for this territory. The project employs research-by-design methodology combined with backcasting to envision transformative futures for agrarian space, positioning soil regeneration as foundational infrastructure for life-sustaining systems [11].

### 3.2 Spatial grammar for agro-ecological transition

The Super Valley framework develops a spatial grammar comprising compositional elements that respond to the desirable future under an agro-ecological planning and design model. These elements include environmental field margins, agroforestry systems, silvopasture, renatured rice fields, wetlands, and critically for this study, agrivoltaic installations (Figure 3). Each element is parameterised with quantifiable performance metrics enabling scalable territorial application.

The methodology employs a 25-hectare landscape unit as the fundamental building block for analysis and design intervention (Figure 4). This pixel-based approach allows systematic territorial transformation while respecting local conditions and landscape character. Within a 180,000-hectare study transect, the research demonstrates how minimal land conversion—approximately 6% of total agrarian space dedicated to agrivoltaic systems—can achieve transformative energy capacity whilst maintaining agricultural productivity and enhancing ecological function [12].

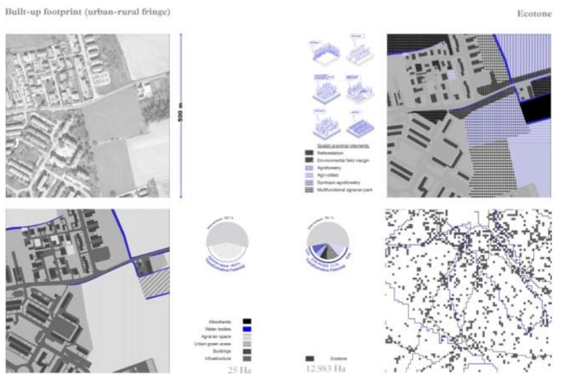


**Figure 3:** The 25-hectare landscape unit in a peri - urban-built up spatial prototype: from baseline condition to agro-ecological transformation. Left: satellite imagery revealing homogeneous monoculture patterns. Right: project scenario demonstrating the integration of spatial grammar elements including environmental field margins, agroforestry, and agrivoltaic systems. Image by F. LaFleur.

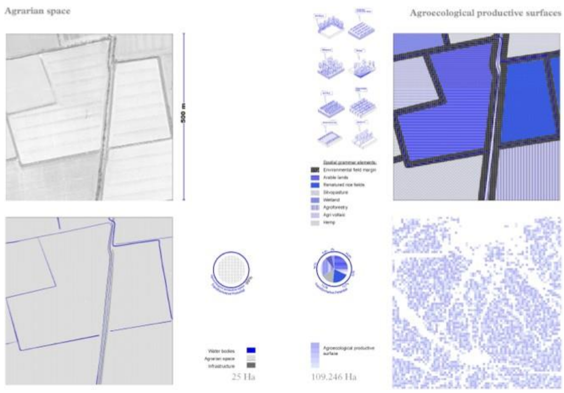


**Figure 4:** The 25-hectare landscape unit in a typical agricultural spatial prototype: from baseline condition to agro-ecological transformation. Left: satellite imagery revealing homogeneous monoculture patterns. Right: project scenario demonstrating the integration of spatial grammar elements including environmental field margins, agroforestry, and agrivoltaic systems. Image by F. LaFleur.

3.3 Quantifiable outcomes and scalable parameterisation

The Super Valley framework enables scalable parameterisation with benefits per hectare quantified across multiple domains: 3 tonnes of $CO_2$ sequestered, 44 watts of electricity produced, 13,700 litres of increased water holding capacity, and 795 trees introduced. These parameters provide a flexible framework for assessing interventions across the broader mega-regional scale.

Applied to the 180,000-hectare transect, agrivoltaic installations covering 9,685 hectares could generate 7.7 GW of renewable energy annually. Upscaled to the full4.95 million hectares of the Alpine-Padano-Adriatic megaregion, the transformative potential reaches 267.8 GW—exceeding Italy's 2030 renewable target of 131 GW and equivalent to 134 large nuclear power plants (Figure 5). This demonstrates how the regeneration of soil and territory as agro-ecological-energy landscapes can address both energy and ecological transition mandates simultaneously.

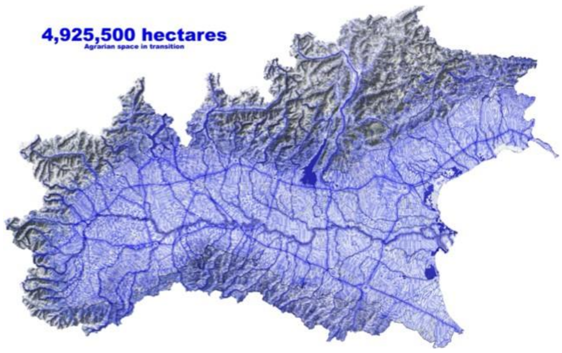


**Figure 5:** Upscaling the Super Valley: megaregional transformation potential. 4.95 million hectares in transition in the Alpine-Padano-Adriatic plain. Image by F. LaFleur.

4 CASE STUDY: CASTELGUGLIELMO AGRIVOLTAIC PLANT

The theoretical framework and territorial potential outlined above establish a comprehensive vision for agro-ecological transition across the Po Valley megaregion—a vision grounded in the Super Valley spatial grammar and animated by the nature-positive paradigm. Yet systemic territorial ambitions remain abstractions until tested through concrete spatial practice. The translation from regional strategy to site-scale intervention requires pragmatic demonstration projects that operationalise the framework's principles within real-world constraints. The Castelguglielmo agrivoltaic plant provides precisely such an opportunity: a working laboratory situated within the broader megaregional context, where the compositional elements of the spatial grammar—agroforestry, wetlands, field margins, and integrated agrivoltaics—can be assembled, monitored, and validated (Figure 6). As one node within the potential network of 267.8 GW across the Alpine-Padano-Adriatic territory, the site exemplifies how individual interventions gain strategic significance when conceived as components of a larger territorial transformation.

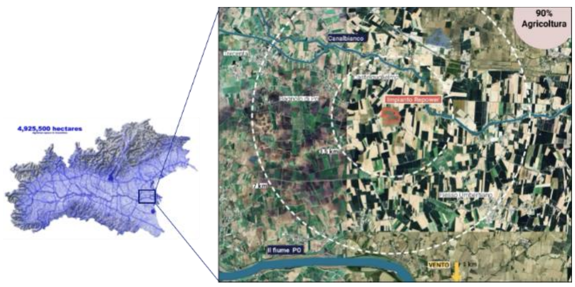


**Figure 6:** Castelguglielmo territorial context: the Repower agrivoltaic facility within the Po Valley landscape. Located 3.5 km from the Po River in Rovigo Province, the 34-hectare site exemplifies the monocultural conditions characteristic of the broader megaregion—a prototype for nature-positive interventions replicable across thousands of similar contexts. Image by LAND.

### 4.1 Territorial context and project genesis

Located in the Province of Rovigo within the Veneto region, the Castelguglielmo site embodies the conditions that characterise much of the broader megaregion: 3.5 km from the Po River, within a territory dominated by 90% agricultural land use, the site exemplifies the Po Valley's agricultural desert—monocultural landscapes shaped by intensive arable production with minimal ecological infrastructure. As such, the site serves not merely as an isolated intervention but as a prototype replicable across thousands of similar contexts throughout the Alpine-Padano-Adriatic territory.

The Repower facility comprises 34 hectares with 7.5 MW installed capacity, featuring bifacial photovoltaic panels integrated with agricultural production of wheat, soybean, and protein pea. Operational since 2013, the plant represents an early example of agrivoltaic integration in Italy. LAND Italia was engaged to develop a landscape enhancement strategy that would transform the installation from a productive energy facility into a catalyst for territorial regeneration.

### 4.2 Nature-positive design strategy

The design strategy positions the Repower plant as an agro-ecological-energy oasis within the Po Valley agricultural desert. The intervention operates across three integrated dimensions: ecosystem restoration, socio-economic-cultural activation, and recognisability-identity enhancement.

The ecosystem restoration component addresses biodiversity through morphological requalification of canals, introduction of tree rows, creation of flowering strips for pollinators, establishment of forest areas for infiltration, provision of wildlife refuges, and implementation of sustainable agricultural management models. These interventions directly respond to the Nature Restoration Law's mandates for pollinator support, habitat connectivity, and differentiated ecosystem management.

The design creates four principal intervention areas (Figure 7). The Threshold establishes a highly recognisable gateway through paired tree plantings and wayfinding signage. The Central Spine introduces new ecological infrastructure along the main circulation route, featuring transversal tree rows, flowering meadows, and expanded wetland areas along existing drainage channels. The Square creates an attractive stopping point with e-bike and electric vehicle charging stations, panoramic viewing terrace, and integrated social amenities. The Farmstead Entrance Avenue becomes a colourful landmark for pollinators, featuring flowering shrub strips, wildlife refuges, and apiaries (Figure 8).


**Figure 7:** Nature-positive masterplan: the four principal intervention areas. The design strategy transforms the energy facility into an agro-ecological-energy oasis through the Threshold (gateway plantings), Central Spine (ecological infrastructure corridor), Square (social amenities and charging stations), and Farmstead Entrance Avenue (pollinator habitat and apiaries). Image by LAND.

**Figure 8:** The Farmstead Entrance Avenue: a colourful landmark for pollinators. The visualisation illustrates the transformation of the historic farmstead access into an ecological gateway integrating wildlife refuges, flowering shrub strips supporting pollinator populations, informational-educational totems, and apiculture facilities adjacent to the bike path. Image by LAND.

### 4.3 Positive energy landscape measuring framework

The project develops a measuring framework with specific key performance indicators across the three intervention dimensions (Figure 9). For ecosystem restoration: 183 trees planted, 78 plant species introduced, 0.12 hectares of new wetland areas, 0.4 hectares of new forested areas, and 10 hectares under sustainable agricultural management models—representing 30% of the total agricultural surface.

For socio-economic activation: 1 rest area, 1 integrated supply chains (dye production and apiculture), while for recognisability and identity: 4 informational-educational panels, 1 e-bike charging station, 1 automobile charging station, and 1 integrated artistic element through valorisation of the former grain dryer through an artist call. These metrics demonstrate how the project transforms regulatory compliance into an opportunity for generating multiple forms of territorial value.

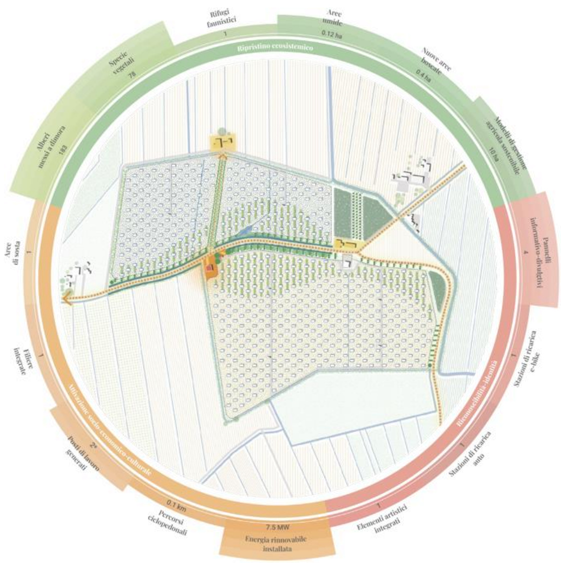


**Figure 9:** Positive energy landscape measuring framework: key performance indicators across three intervention dimensions. The diagram quantifies ecosystem restoration outcomes (183 trees, 78 species, 0.12 ha wetland/forest areas, 10 ha sustainable agriculture), socio-economic activation (rest area, supply chains, employment), and recognisability enhancement (educational panels, charging infrastructure, artistic intervention). Image by LAND.

## 5 DISCUSSION

The Castelguglielmo case study demonstrates how the theoretical framework of nature-positive energy landscapes can be translated into concrete spatial interventions with measurable outcomes. Situated within the Super Valley's territorial vision—where 9,685 hectares of agrivoltaic installations could aggregate into 7.7 GW of regional capacity—the single-site intervention acquires strategic significance beyond its immediate boundaries. The project moves beyond viewing renewable energy as a disruptive element requiring compensation; instead, energy infrastructure becomes an opportunity to revitalise and regenerate territories, each installation contributing to a cumulative territorial transformation.

This approach not only streamlines authorisation and permitting processes but also builds positive social consensus around projects, transforming them into exemplary models of integration between energy development and landscape enhancement. Regulatory compliance thus evolves from a constraint into an opportunity for innovation and territorial value generation.

The integration of the Super Valley's spatial grammar elements—environmental field margins, wetlands, agroforestry, and agrivoltaic systems—creates a hybrid landscape that synergistically supports environmental and economic needs. This multifunctional and diversified mosaic, where each element amplifies the benefits of others, addresses climate, food, water, and energy challenges concurrently.

The project validates the hypothesis that strategically designed agrivoltaic systems can contribute simultaneously to energy and ecological transition goals. By positioning energy installations as green-social infrastructure that generates multiple forms of territorial value, the approach demonstrates practical pathways for achieving the EU's dual 2030 mandates whilst creating local benefits for communities and ecosystems.

## 6 CONCLUSIONS

This paper has demonstrated how agrivoltaic systems can serve as catalysts for nature-positive territorial transition, positioning landscape as the fundamental platform upon which the convergent energy and ecological transitions must unfold. The landscape—understood not as scenic backdrop but as dynamic infrastructure mediating flows of energy, water, carbon, and biodiversity—emerges as the essential substrate for decarbonisation. The theoretical framework developed through the Super Valley research project establishes both a spatial grammar and quantifiable metrics that enable systematic territorial transformation—moving from isolated interventions toward coordinated regional strategies. From the 25-hectare landscape unit to the 4.95-million-hectare megaregion, the framework demonstrates how landscape architecture provides the operative language through which transition can be spatially articulated. The Castelguglielmo case study provides concrete evidence that this approach can be implemented within operational contexts, generating measurable ecosystem benefits whilst maintaining energy production objectives.

Key findings include: (1) Arable land conversion—approximately 6% of total agrarian space—can exceed national renewable energy targets set at 2030 whilst enhancing ecological function; (2) the nature-positive paradigm reorients energy landscape design from minimising harm toward actively generating ecosystem benefits, in this sense it suggest a clear shift form do not significant harm toward do significant improvement; (3) integrated measuring frameworks can quantify biodiversity impact, ecosystem services, and social benefits; and (4) individual site interventions gain strategic significance when situated within broader territorial frameworks that aggregate site-scale benefits into regional transformation.

The findings underscore the essential role of interdisciplinary collaboration in achieving nature-positive outcomes. The complexity of territorial transition—where energy systems, hydrological networks, agricultural practices, and ecological corridors must be orchestrated simultaneously—cannot be addressed through disciplinary silos. Energy transition, in this framing, is not primarily an engineering challenge but a spatial-ecological project requiring new coalitions of professionals toward common decarbonisation goals. Landscape architects, urbanists, ecologists, agronomists, hydrologists, and energy specialists can work in concert, their respective competencies integrated through the medium of the territory itself. The landscape discipline, with its inherent capacity to synthesise ecological, social, and technical dimensions across scales, emerges as a critical integrating platform for coordinating these diverse expertise domains. Landscape urbanism, in particular, offers methodological frameworks capable of bridging analytical rigour with design imagination—transforming the abstract imperatives of decarbonisation into spatially legible, implementable strategies. The formation of such interdisciplinary teams and the recognition of landscape as their common operational ground, represents a precondition for achieving the scale and speed of transformation that the climate emergency demands.

The next phase for the Castelguglielmo project moves from vision and feasibility to execution in 2026, providing an opportunity to monitor and validate the projected outcomes through empirical measurement. More broadly, this research contributes to the emerging discourse on energy landscapes as territorial infrastructure, demonstrating how landscape urbanism methodologies can guide the transformation of energy systems toward nature-positive outcomes. In this framing, agrarian space is reconceptualised not as passive territory awaiting development, but as an active agent in the ecological transition—a platform through which energy, water, carbon, food, and biodiversity systems can be integrated and regenerated simultaneously. The convergence of the energy and ecological transitions thus presents an unprecedented opportunity for landscape architecture and allied disciplines: to move from consultants on individual projects toward key strategists in complex multi-actor, multi-scope transitions. The landscape, as both material substrate and conceptual framework, becomes the medium through which landscape architects as decarbonisation and regeneration professionals can translate policy mandates into spatial realities. The dual mandate of the EU's 2030 targets thus becomes not a constraint but an invitation to reimagine the productive landscape as the foundation for a regenerative territorial future.

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## 9 LOGO SPACE