Circular Regeneration Pathways for Rural Heritage: The Role of Adaptive Reuse Across 18 European Villages

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Abstract. The transition to a circular economy in the built environment represents a significant challenge for European territorial policies, particularly in fragile rural areas affected by depopulation, economic decline, and environmental vulnerability. Rural villages, which cover a large portion of Europe's territory, require regeneration models capable of integrating heritage conservation, ecological transition, and socioeconomic revitalization. This article analyzes the role of adaptive reuse as a key "circular invariant" within the broader regeneration process for rural heritage. To do so, a comparative framework was applied to 18 European case studies (10 Italian and 8 international villages). The methodology combines document analysis, qualitative assessment based on source interpretation, fuzzy normalization, cluster analysis, and correlation tests. Two analytical matrices were developed: a diagnostic framework that identifies structural drivers, constraints, catalysts, and triggers; and a strategic framework that examines regeneration actions related to heritage, environment, innovation, energy, and governance. The findings identify three recurring regeneration profiles: (i) transition-oriented models, driven by innovation and environmental performance; (ii) reactive models focused on heritage recovery and territorial resilience; and (iii) strategic governance models supported by institutional capacity or long-term investments. In all clusters, adaptive reuse emerges as a recurring enabling factor, albeit with different functions depending on local conditions.

The study suggests that rural circular regeneration does not follow a single model, but rather combinations of strategies based on the local context, shaped by the territorial context, social capital, and available resources. Adaptive reuse can therefore act as a multidimensional lever to transform abandoned cultural assets into resources for sustainable rural development.

Keywords: Adaptive Reuse · Circular Regeneration · Rural Heritage · Fuzzy Logic · Soil Safeguard · Territorial Resilience

1 Introduction

The transition toward a circular economy in the built environment represents a fundamental challenge for current European cohesion policies, particularly within the framework of the Green Deal. Recent European strategies, from the Green Deal to the New

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European Bauhaus, have identified sustainability and circularity as two priority axes for transforming the built environment [1]. At the same time, policies dedicated to rural territories—from the Cork Declaration to the Smart Villages programmes—promote place-based approaches aimed at strengthening local resilience, quality of life, and the valorization of endogenous resources [2, 3]. In this context, the ecological transition does not concern only large urban areas, but also small rural settlements, which cover around 83% of the territory of the European Union and constitute an essential component of Europe's territorial heritage.

However, many European rural villages are currently affected by processes of systemic fragility caused by depopulation, demographic ageing, declining services, and the progressive loss of historical land-management practices. Population decline not only leads to the deterioration of the built heritage through lack of use, but also causes the interruption of ordinary activities—water regulation, terrace maintenance, forest management, and widespread land stewardship—that for centuries ensured the dynamic balance of rural landscapes [4, 5]. The resulting "anthropic void" transforms the cultural landscape into a vulnerable system, exposed to erosion, hydrogeological instability, and increasing fragility in the face of extreme climatic events [6].

In this scenario, village regeneration cannot be interpreted merely as a building restoration process. It requires an integrated approach capable of connecting heritage conservation, environmental innovation, social inclusion, and new local economies [7–11]. In rural contexts, indeed, the village is not an isolated entity, but rather the settlement node of a broader cultural landscape, understood as the outcome of the historical relationship between nature and human communities [12–15]. Architecture, agricultural patterns, ecological infrastructures, and social practices all contribute to the definition of layered territorial identities, whose resilience depends on the ability to maintain an active relationship between settlement and territory [16, 17]. From this perspective, landscape care and the reactivation of the genius loci may represent not only cultural values, but also tools for risk prevention and attractors of new social capital [18].

The Italian situation is particularly significant. The widespread presence of small historic centers undergoing progressive decline has turned the country into a privileged laboratory for experimenting with new territorial regeneration policies [19, 20]. At the same time, the debate on inner areas has highlighted the complexity of the issue: while processes of marginalisation are driven by long-term structural factors, the COVID-19 pandemic, recent energy crises, and the growing demand for more sustainable lifestyles have renewed interest in forms of rural renaissance and new residential geographies [21, 22]. The National Strategic Plan for Inner Areas 2021–2027 also highlights the need to complement anti-depopulation measures with innovative tools for shared service management, intermunicipal cooperation, and support for the most fragile territories [23, 24].

In this context, circular development assumes a central role [25]. In rural villages, circularity does not merely coincide with the optimisation of material flows or energy efficiency, but tends to acquire a territorialised meaning, encompassing the reuse of built heritage, the reactivation of local knowledge, landscape stewardship, community resilience, and the creation of new economic and social functions [7, 26]. Adaptive reuse

of the existing architectural heritage represents, in this perspective, a privileged strategy to contain land consumption, preserve biodiversity and agricultural land, enhance soil permeability, and strengthen hydrogeological resilience [27]. Recent literature also highlights how the success of regeneration processes depends on the ability to balance energy performance, soil protection, and landscape integration [28–32].

Despite growing attention to the circular economy and adaptive reuse, comparative studies dedicated to rural villages remain limited, especially regarding the ways in which these strategies combine with different territorial conditions, levels of fragility, and governance models. In particular, there is still a lack of a systematic interpretation capable of relating regeneration triggering factors to the intensity and nature of the strategies subsequently implemented.

In light of this gap, the present research analyses 18 case studies (10 Italian and 8 European) through the application of a multidimensional evaluation framework [33, 34]. The aim is to identify recurring regeneration configurations in rural villages and to further investigate the role played by adaptive reuse within broader processes of circular transformation [35, 36]. The underlying hypothesis is that effective strategies for territorial revitalization must start from a careful reading of the local status quo, since the material, environmental, and social conditions of each village often already contain the potential trajectory of an authentically place-based regeneration process.

2 Methodology

2.1 Purposeful Case Selection and Data Sources

The cases were deliberately selected to ensure geographical diversity and to represent different regeneration trajectories. Given the exploratory nature of the research and the limited sample size, the results should be interpreted as the identification of patterns rather than predictive classifications. The 18 selected cases are listed in Table 1.

Table 1. Cases study

id	Country	Village	id	Country	Village	id	Country	Village
V1	France	Cahors	V7	Romania	Piscu	V13	Italy	Fiamignano
V2	France	Ungersheim	V8	Austria	Feldkirch	V14	Italy	Calcata
V3	France	Mouans-Sartoux	V9	Italy	S. Stef. di Sessanio	V15	Italy	Torri Superiore
V4	Portugal	Monsanto	V10	Italy	Bagnoregio	V16	Italy	Solomeo
V5	Spain	Fanzara	V11	Italy	Brisighella	V17	Italy	Piaggine
V6	Hungary	Gyermely	V12	Italy	Casale Monferrato	V18	Italy	Santa Fiora

The 18 case studies were selected as representative of a range of possible regeneration strategies for fragile territories. Given the specificity of the topic, and the heterogeneity of rural contexts and achievable objectives, it was necessary to diversify the sample as much as possible, including cases attributable to different regeneration approaches and intentions. Data were collected through document analysis, including academic literature, planning documents, institutional reports, websites, and technical sources (n = 311 sources). This document-based approach made it possible to reconstruct the regeneration process of each village. The document analysis of the case studies revealed several recurring themes (Fig. 1).



Fig. 1. Network map of recurring themes emerging from the comparative analysis of 18 European rural regeneration case studies. Node size indicates thematic frequency, while links represent thematic co-occurrence.

2.2 Concept-Driven Coding Framework and Scoring Protocol: Diagnostic and Strategic Framework

In order to make the case studies comparable, it was considered appropriate to develop a concept-driven coding framework. The multidimensional analysis of the 18 case studies (10 Italian and 8 European) was therefore preceded by the construction of two complementary interpretative frameworks: a diagnostic framework, aimed at identifying the causes and factors that triggered regeneration processes [34], and a strategic framework, intended to classify the main multi-objective strategies adopted in different contexts, thereby enabling the systematic comparison of the case studies. Through an inductive process [37], moving from the particular to the general, the specific causes and the actions concretely implemented in the villages were progressively traced back to

broader categories and recurring fields of intervention considered significant for the sustainable regeneration of rural villages. This synthesis phase proved crucial for the construction of the analytical matrices subsequently employed in the comparative analyses and cluster analysis [36, 38]. The adopted approach makes it possible to organize territorial complexity by breaking down phenomena of crisis and revival into logical categories ordered according to a temporal and functional sequence. The interpretative grid integrates the territorialisation model [39] for the analysis of structural drivers, the push-pull factor dialectic typical of studies on inner areas [40], and the perspective of evolutionary resilience [41], with the aim of identifying the dynamics that caused territorial decline or fostered territorial revitalization through regeneration processes. The "diagnostic" framework classifies the determining conditions and processes into four main macro-categories (Table 2).

Table 2. Diagnostic framework

Macro-Category	Category		
STRUCTURAL DRIVERS	SOCIO-DEMOGRAPHIC DECLINE	**T1**	**-**
(Socioeconomic)	INDUSTRY DECLINE	**T2**	**-**
(-)	LOCAL ECONOMIC DEPRESSION	**T3**	**-**
STRUCTURAL DRIVERS	BUILDING STOCK DECAY	**T4**	**-**
(Landscape-Env.)	HYDROGEOLOGICAL INSTABILITY	**T5**	**+**
(-)	EROSION OF RURAL CHARACTER	**T6**	**-**
STRUCTURAL DRIVERS	EROSION OF COLLECTIVE MEMORY	**T7**	**--**
(Immaterial) (-)/(+)	RECOGNITION OF IDENTITY VALUE	**T8**	**+**
PRECIPITATING FACTORS	HEALTH / ENV. / SEISMIC EMERGENCY	**T9**	**-**
(Triggers)	SPECIFIC HISTORICAL DECOMMISSIONING	**T10**	**-**
(-)	SOCIAL CONFLICT	**T11**	**-**
	ENERGY VULNERABILITY	**T12**	**-**
CONSTRAINTS	LANDSCAPE-ENVIRONMENTAL RESTRICTIONS	**T13**	**+**
(-)/(+)	LAND SCARCITY/ SOIL QUALITY	**T14**	**-**
CATALYSTS	FINANCIAL PUBLIC RESOURCES	**T15**	**+**
(+)	FINANCIAL PRIVATE RESOURCES	**T16**	**+**
	SOCIAL AWARENESS	**T17**	**+**
	EXISTING COOPERATIVE MODEL	**T18**	**+**

Structural Drivers, divided into socio-economic components such as socio-demographic decline, industrial decline, and local economic depression [42–44], landscape-environmental components such as building stock decay, hydrogeological instability, and erosion of rural character [45–47], and intangible components such as erosion of collective memory and recognition of identity value [48], represent the long-term "background" conditions affecting rural areas, such as demographic decline or the erosion of collective memory. Precipitating Factors are interpreted as "trigger" events that accelerate processes of abandonment or require urgent intervention [41, 49, 50]. These include health, environmental, or seismic emergencies, specific historical decommissioning events, social conflict, and energy vulnerability. Constraints are factors that limit action, such as regulatory restrictions [51] or land scarcity and poor soil quality [30]. Catalysts are considered enabling factors, such as public and private financial resources [52], social awareness, and existing cooperation models [53, 54], which positively activate the regeneration process.

The "strategic" framework (Table 3) is useful for constructing a structured multidimensional matrix aimed at describing the transformation strategies through which rural villages can evolve from marginal areas into laboratories of sustainability.

Table 3. Strategic framework

PILLAR	STRATEGIES ADOPTED	
Heritage	ADAPTIVE REUSE	S1
	HERITAGE CONSERVATION	S2
	ENERGY EFFICIENCY	S3
Knowledge and Innovation	MATERIAL EXPERIMENTATION	S4
	KNOWLEDGE TRANSMISSION	S5
	DIGITALIZATION	S6
New Buildings, New Perfomance and Public Spaces	INTEGRATION OF NEW BUILDINGS	S7
	NEAR ZERO ENERGY BUILDING	S8
	PUBLIC SPACES	S9
Environment	SOIL SAFEGUARD	S10
	LANDSCAPE INTEGRATION	S11
	WATER MANAGEMENT	S12
Social/ Economic	PARTICIPATORY GOVERNANCE	S13
	BOTTOM-UP CO-DESIGN	S14
	NETWORK DEVELOPMENT	S15

Each domain defines a pillar of regeneration. The identified pillars are as follows:

Heritage, namely the historic fabric of rural villages—including buildings, roads, squares, and agricultural structures—understood as active capital. Strategies related to the regeneration of this heritage include: Heritage Conservation; Adaptive Reuse, aimed at reintegrating abandoned buildings into the economic cycle and reducing the need for new construction; and Energy Efficiency. These strategies balance the conservation of historical identity with the contemporary need to reduce the carbon footprint of the built environment.

Knowledge and Innovation, insofar as the village can become a centre for the production of intangible value linked to: Material Experimentation, involving the recovery of local construction techniques (e.g., earthen architecture) integrated with new performance standards; Knowledge Transmission, related to traditional know-how; and Digitalization. Digitalisation (Smart Villages) helps bridge geographical gaps, while the transmission of traditional knowledge ensures cultural continuity and creates new specialised employment opportunities.

New Buildings, New Performance and Public Spaces, which considers the integration of the "new" in a synergistic and functional way. This domain includes the return of new public spaces to villages. Strategies include Integration of New Buildings, such as architectural insertions or functional extensions; Near Zero Energy Buildings; and Public Spaces, where the regeneration of vacant urban areas and squares acts as a social "connector," transforming residual spaces into places of aggregation and community resilience.

Environment, related to the climate challenge and the protection of resources. Strategies include Soil Safeguard, meaning zero land consumption and the prioritisation of permeability; Landscape Integration, namely the harmonious relationship between the built environment and the agricultural/natural landscape; and Water Management, involving the implementation of water recovery and circular management systems, which are essential to counter drought in fragile rural contexts.

Social/Economic, since long-term sustainability depends on human involvement and financial solidity. Strategies include Participatory Governance; Co-design, whereby community involvement ensures that reuse responds to the real needs of inhabitants, increasing acceptance and stewardship of the project; and Network Development, meaning the creation of networks among villages and regional stakeholders (public and private), enabling circular economies to scale and attracting investments that a single municipality could not manage alone.

Each variable was assessed using a five-point scale, based on the relevance of the cause/catalyst or on the intensity of implementation of the strategies emerging from the literature review. Scores were assigned by the author through expert coding based on the documented information available for each case study. The scores were then converted into normalised fuzzy values ranging from 0 to 1 in order to improve comparability among cases (Table 4).

The matrices relating to the diagnostic framework (Table 5) and those relating to the strategic framework (Table 6) were then constructed accordingly.

Table 4. Scoring protocol

Diagnostic framework	Strategic Framework	Score
Very relevant	Fundamental pillar of the strategy (project excellence)	1
Somewhat relevant	Strategy successfully and relevantly implemented	0,75
Neither relevant nor irrelevant	Strategy present but not defining or standard	0,5
Slightly relevant	Strategy partially or with difficulty implemented	0,25
Not at all relevant	Strategy absent or with significant critical issues	0

Table 5. Diagnostic Matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18
T1	0,75	0,75	1	0,75	0,75	0	1	0,5	0,75	0,5	0,25	1	0,75	0,5	0,5	0,75	0,75	0,75
T2	0,75	0,75	0,75	0,75	0,75	0	0,75	0,75	1	0,75	0,75	0,75	1	0,75	0,75	0,75	1	0,75
T3	1	1	0,5	1	1	0,25	0,75	1	1	0,75	0,75	0,75	1	1	1	1	0,75	0,75
T4	0,5	0,5	0,75	0,5	0,5	0,5	0,5	1	0,75	1	1	0,75	0,75	1	0,75	0,5	0,5	0,5
T5	0,75	0,75	1	0,75	0,75	0,75	0,75	0,75	0,75	0,25	0,75	0,75	0,75	0,75	0,5	0,75	0,75	0,75
T6	0,75	0,75	0,75	0,75	0,5	0	0,75	0,25	0,75	0,75	0,5	0,5	0,75	0,5	0,25	0,75	0,5	0,5
T7	1	1	0,75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
T8	1	1	1	0,5	0,75	0,5	0	0,75	1	1	0,75	1	1	1	0,5	0,5	0,5	0,75
T9	0,75	1	0,75	0,75	0,75	0,75	0,75	1	0,75	0,75	0,75	1	0,75	1	1	0,75	0,75	0,75
T10	0,5	0,5	0,75	0,5	1	0,5	0,5	0,75	0,5	0,5	0,5	0,75	0,5	0,75	0,5	0,5	0	0,5
T11	1	1	0,75	0,75	0,5	0,75	1	0,75	0,75	0,75	0,75	0,5	0,75	0,75	0,75	0,5	0,75	0,75
T12	1	0,75	1	0,75	0,5	0,75	0,75	0,75	1	1	1	1	0,75	1	1	1	1	1
T13	0,75	0,75	1	0,75	0,5	0,75	0,5	1	0,5	1	0,75	0,5	0,5	1	1	0,75	0,5	0,5
T14	1	1	1	1	0,75	0,75	0,5	1	0,75	0,75	1	1	1	0,75	0,25	0,25	0,75	1
T15	0,75	0,75	1	0,75	0,75	1	1	0,75	1	0,75	0,75	0,75	0,75	1	1	1	0,25	0,75
T16	0,75	1	1	0,75	1	1	1	1	0,75	1	1	1	0,75	1	1	0,75	1	0,75
T17	1	1	1	1	1	1	0,75	1	1	0,75	1	0,75	1	0,75	1	0,75	1	0,75
T18	1	1	1	1	1	1	0,75	1	1	0,75	1	0,75	1	0,75	1	0,75	1	0,75

Table 6. Strategic Matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18
S1	1	1	0,75	0,75	1	0,75	0,75	0,75	1	1	1	0,75	1	1	1	0,75	1	1
S2	1	0,75	0,75	1	0	0,5	1	1	1	1	1	1	0,75	1	1	1	0,75	1
S3	1	1	0,75	0,5	0,5	1	0,75	1	0,75	0,25	0,75	0,5	0,75	0,25	0,75	0,75	0,75	0,75
S4	0,75	0,75	0,5	0,75	0,75	0,75	1	1	1	0,5	0,5	0,75	0,5	0,5	0,75	0,5	0,5	0,5
S5	1	1	1	1	1	1	1	1	1	0,75	1	1	0,75	1	1	1	1	0,75
S6	0,75	0,5	0,5	0,75	0,75	0,75	0,75	0,75	0,5	0,75	0,5	0,5	1	0	0,5	0,5	0,75	1
S7	0,75	0,75	0,5	0	0	0,75	1	1	0	0	0	0,25	0,25	0	0,5	0,75	0,25	0
S8	0,5	1	0,5	0,5	0	0,75	0,75	1	0,25	0	0	0,25	0,75	0	0,75	0,5	0,5	0,5

(*continued*)

Table 6. (*continued*)

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18
S9	1	1	0,75	0,75	1	1	0,75	1	0,75	0,75	1	1	1	0,75	1	0,75	1	0,75
S10	0,75	1	1	1	0,75	1	0,75	1	1	1	0,75	1	0,75	1	1	1	0,75	0,75
S11	1	1	1	1	1	1	1	0,75	1	1	1	1	1	1	1	1	1	0,75
S12	0,75	0,75	0,75	0,75	0	0,75	0,5	0,75	0,5	0,5	0,5	0,75	0,5	0,5	0,75	0,75	0,5	1
S13	1	1	1	0,75	1	1	0,75	1	0,75	0,75	0,75	1	1	0,75	1	0,25	1	0,75
S14	0,75	1	1	0,75	1	0,75	1	0,75	0,75	0,5	0,75	0,75	0,75	1	1	0	1	0,25
S15	1	1	1	1	1	1	1	0,75	1	1	1	1	1	0,75	1	0,75	0,75	1

2.3 Data-Set Analysis

By combining the two matrices, a normalised dataset was obtained, consisting of 18 cases and 33 variables, of which 18 represent the initial territorial conditions (T) and 15 represent the implemented response strategies (S). To achieve a multidimensional understanding of the dataset, the following complementary procedures were adopted: descriptive statistics; contingency tables with Pearson's Chi-square test; and K-means cluster analysis (K = 3) (Table 7), using the PSPP software [55, 56]. This combination made it possible both to analyse individual variables and to identify overall patterns among the cases. First, descriptive statistics were calculated, including mean, standard deviation, skewness, kurtosis, minimum, maximum, and range. Subsequently, contingency tables were produced between T and S variables using Pearson's Chi-square test, with the aim of identifying possible relationships between the two groups of indicators. Associations between territorial drivers (T) and adopted strategies (S) are considered statistically significant if the p-value is lower than 0.05, and as borderline trends if the p-value is between 0.05 and 0.10.

Table 7. Village Clusters

CLUSTER 1	CLUSTER 2	CLUSTER 3
Ungersheim	*Mouans-Sartoux*	*Cahors*
Gyermely	*Monsanto*	*Piscu*
Feldkirch	*Fanzara*	*Corciano-Solomeo*
Torri Superiore	*S. Stefano di Sessanio*	*Santa Fiora*
	Bagnoregio	
	Brisighella	
	Monferrato Casalese	
	Fiamignano	
	Calcata	
	Piaggine	

Finally, the theme of adaptive reuse of heritage was further explored through the construction of binary 0/1 matrices, identifying reuse functions, together with energy efficiency measures, the use of renewable energy sources, and the use of traditional materials/bio-materials.

2.4 Limitations

Among the main methodological limitations of the study are the small sample size, which limits the generalisability of the results and the robustness of the statistical analyses; the dependence on secondary sources for the construction of the dataset; and the presence of interpretative scoring procedures, which are inevitably exposed to margins of subjectivity in the coding of indicators. Moreover, the exploratory nature of the adopted techniques suggests caution in interpreting the results. Therefore, the associations identified should be considered preliminary and exploratory evidence rather than causal relationships or generalisable models.

3 Results

The analysis of the diagnostic framework shows that, in most cases, the loss of collective memory is perceived as a central critical issue, social awareness is high, and pre-existing cooperative models constitute a concrete lever for action. The analysis of the strategic framework indicates that the examined cases prioritise landscape-integrated strategies, based on knowledge transmission, oriented toward territorial cooperation, and founded on the reuse of existing heritage.

The correlation analysis reveals a system of relationships between certain determining factors and regeneration strategies, highlighting recurring configurations rather than isolated relations. In contexts characterised by socio-demographic decline (depopulation, ageing, reduction of the resident population), the conservation of built heritage tends to emerge as a priority strategic response. A relationship close to statistical significance also emerged between demographic decline and the adaptive reuse of underused, abandoned, or no longer functional buildings. Even where not statistically strong, some relationships appear conceptually plausible: When collective memory weakens, practices of transmitting local, artisanal, and cultural knowledge become central; the presence of pre-existing cooperative models may facilitate participatory governance in regeneration processes; greater social awareness tends to favour shared planning processes and bottom-up co-design; and contexts vulnerable from an energy perspective are naturally more oriented toward efficiency and energy self-sufficiency strategies.

The cluster analysis produced the following results. Cases belonging to Cluster 1 show convergence toward maximum scores in the dimensions of Knowledge and Innovation and Environment. Cases such as Gyermely (HU) and Ungersheim (FR) stand out for the integration between local production chains and resource management (Water Management and Soil Safeguard). Cluster 2, the largest in the sample, reflects a condition of structural fragility. It shows systematic polarisation toward Adaptive Reuse and Heritage Conservation strategies (constant scores), contrasted with lower values in technological performance (Energy Efficiency). Cluster 3 groups cases representing regeneration

models driven by a strategic vision supported by significant public or private capital. The matrix shows high and balanced scores across all 15 strategies, with peaks in the Social/Economic dimensions (Network Development and Participatory Governance).

The integration of this matrix with the analysis of functions identified in the 18 case studies makes it possible to complete the analysis of adaptive reuse through the lens of functional mixité. Three main functional clusters emerge. The first configures the village as a productive and knowledge hub, where adaptive reuse supports local supply chains, energy production, food processing, and training centres, transforming the built heritage into infrastructure for a circular metabolism. The second cluster, definable as a model between dispersed hospitality and culture, includes villages that rely on hospitality, cultural functions, and craftsmanship as economic drivers, enhancing historic and landscape heritage to counter decline. The third cluster concerns the integration of advanced services, with coworking, offices, and local services, showing how strategic investments can attract urban functions and new temporary residents. In all clusters, the creation of public space and cultural centres emerges as a recurring element.

From a technological perspective, a low-tech approach prevails, consistent with the constraints of historic rural contexts. The most widespread solutions are internal insulation, high-performance windows, the use of natural thermal inertia, and natural ventilation, all of which recover bioclimatic principles of vernacular architecture. More advanced systems, such as mechanical controlled ventilation or solar greenhouses, appear only in a few pilot cases.

For energy production, strong attention is paid to landscape integration. Photovoltaic roof tiles are more widespread than traditional panels in historic villages, while geothermal energy and biomass represent relevant solutions for local heating. In some cases, innovative management models also appear, such as Renewable Energy Communities (RECs) and digital systems for monitoring consumption.

From a material perspective, regeneration is based on a combination of traditional local materials and bio-materials. Central is the use of hemp (lime-hemp, hemp-clay), alongside local timber, plant fibres, cork, sheep wool, blown cellulose, raw earth, and natural lime. This confirms that the circular regeneration of villages is based on new construction techniques that integrate vernacular knowledge, environmental compatibility, and bio-ecological innovation

4 Discussion

The comparative analysis carried out shows that the circular regeneration of rural territories cannot be reduced to a single operational model. Rather, the eighteen case studies reveal a plurality of trajectories determined by different combinations of territorial resources, institutional capacity, socio-economic structure, environmental fragilities, and cultural capital. This finding is particularly relevant when compared with part of the circular economy literature, which is still predominantly oriented toward urban and building-centred models focused on material flows, energy retrofit, and technological efficiency [57, 58]. In fragile rural contexts, circularity tends instead to acquire a territorialised meaning, encompassing the reuse of built heritage, the reactivation of local knowledge, landscape stewardship, community resilience, and the generation of new economic and social functions [59–61].

The comparative analysis between triggering drivers and the intensity of implemented strategies makes it possible to identify three recurring regeneration configurations in European villages. The circularity paradigm is not applied uniformly, but adapts to the nature of initial conditions, generating differentiated development trajectories:

Evolutionary Transition and Bio-Economic Metabolism. In this configuration, regeneration does not arise as a response to an explicit crisis, but as a proactive choice of territorial transformation. Circularity is expressed through the integration of local production chains, resource management, and new forms of self-sufficiency. Cases such as Mouans-Sartoux and Ungersheim show how food sovereignty, innovative public policies, and ecological planning can configure the village as a territorial laboratory of sustainability [61, 62]. In such contexts, adaptive reuse goes beyond the mere conservation of buildings and assumes the role of "bio-economic infrastructure", while soil protection coincides with safeguarding local natural capital.

Reactive Emergency and Identity Resilience. In this second configuration, structural fragility, depopulation, and physical vulnerability constitute the initial drivers of regeneration. Circularity takes on an adaptive function: the reuse of existing heritage becomes a necessary response to resource scarcity and to the impracticability of traditional expansionary models. The reactivation of consolidated urban voids thus becomes a form of territorial stewardship against abandonment. Santo Stefano di Sessanio, Fiamignano, Brisighella, and Civita di Bagnoregio show how landscape or geomorphological constraints can be reinterpreted as factors of cultural and identity-based attractiveness [63, 64]. In these cases, resilience derives from the ability to convert conditions of marginality into new territorial opportunities.

Strategic Vision and Institutional Governance. The third model includes processes guided by a holistic top-down vision, supported by significant public or private capital. Strategic profiles are high and relatively balanced across the entire analytical framework. In such contexts, institutional capacity or corporate patronage makes it possible to integrate conservation, innovation, territorial networks, and the quality of public space. Solomeo, Gyermely, and Feldkirch show how adaptive reuse can be elevated to an advanced standard of aesthetic and functional quality, while digitalisation and the refunctionalisation of collective spaces act as catalysts for new settlement and professional flows [65]. Soil protection and urban permeability also become components of a territorial strategy based on sustainability and quality of life.

Beyond the differences among the three identified clusters, the comparative analysis highlights several recurring cross-cutting themes present in numerous regeneration processes. These recurrences should not be interpreted as universally valid recipes, but as recurring factors whose impact depends on the institutional, social, economic, and territorial conditions in which they are activated. Their effects may therefore vary and are not without controversial aspects.

A first cross-cutting theme concerns the role of *local governance*. The most coherent and durable transformation processes are found where public administrations, cooperatives, or strong territorial actors have been able to coordinate integrated policies rather than isolated interventions. The case of Mouans-Sartoux shows how local food sovereignty, sustainable public procurement, and the *Maison d'Éducation*

à l'Alimentation Durable transformed food policy into a territorial strategy [62, 66]. Similarly, Feldkirch demonstrates that even small centres can integrate heritage, climate neutrality, and administrative innovation when supported by solid institutional capacity. However, the centrality of governance also raises controversial issues: not all territories possess the same administrative skills, planning capacity, or civic leadership, with the risk that regeneration may concentrate in already relatively strong contexts, thereby widening pre-existing territorial inequalities.

A second theme concerns the relationship between *culture, identity, and regeneration.* Several cases suggest that symbolic and social reactivation may precede economic reactivation. Fanzara transformed local conflict into a process of civic mediation through urban art, generating new territorial attractiveness [67, 68]. Piscu shows how the recovery of ceramic craftsmanship and the creation of a museum-workshop can become tools of heritage pedagogy. Calcata confirms the potential of creative communities and spontaneous reuse in countering village abandonment. These experiences show that rural regeneration depends not only on infrastructural investment, but also on the capacity to generate new shared meanings. At the same time, identity-led processes may create tensions between authenticity and local memory on the one hand, and external cultural consumption on the other, especially when symbolic valorisation prevails over the everyday needs of residents.

The recurring creation of *public spaces* following adaptive reuse interventions also suggests that circular village regeneration often begins with the reconstruction of social capital. The reuse of architectural and urban heritage does not merely produce new functional containers, but recreates the place of relationships: the square, understood in both physical and symbolic terms, as the beating heart of community life. From this perspective, reuse also appears as a process of resemanticisation, capable of enriching the village's system of intangible values in addition to its material assets. However, the mere creation of refurbished spaces does not automatically guarantee social inclusion or lasting participation: in the absence of active communities, some spaces risk remaining underused or dependent on occasional events. At the same time, the comparison invites caution against overly celebratory readings of tourism-led strategies. Some of the best-known cases reveal significant structural tensions. Civita di Bagnoregio represents an emblematic paradox, where heritage valorisation coexists with geomorphological risk, increasing tourist pressure, and the progressive reduction of residential functions [64, 69]. When the visitor economy becomes dominant, villages risk turning into consumable images rather than living communities. Tourism success therefore does not automatically coincide with sustainable territorial regeneration.

This observation is particularly relevant for the *Albergo Diffuso* model, often presented as a paradigmatic response to depopulation in minor historic centres. The case of Santo Stefano di Sessanio confirms the model's capacity to reactivate unused properties, attract economic resources, and improve the architectural quality of heritage assets. However, the comparison suggests that dispersed hospitality cannot automatically be equated with comprehensive regeneration. In the absence of permanent services, stable residency, economic diversification, and inclusive governance, such models may remain exposed to seasonality, dependence on external demand, and social fragility. The risk is that villages may be physically restored without fully reconstructing their civic fabric.

From a constructive and environmental perspective, the *low-tech approach* to energy efficiency, rooted in the principles of traditional and bioclimatic architecture, emerges as particularly coherent with rural contexts. The use of bio-materials and local materials for thermo-hygrometric insulation and envelope retrofitting contributes to soil and environmental protection through three main levers: reduction of embodied energy, improved healthiness and building permeability, and valorisation of local productive landscapes. Cahors experimented with energy retrofits using bio-based materials in historic heritage [58], while Piaggine and Vorarlberg show the connection between building reuse and new forest-based and territorial economies. In this sense, the circular regeneration of villages should be read as reintegration into material cycles. However, it must also be noted that such solutions require technical skills, active local supply chains, and compatible regulatory frameworks, which are not always present in more marginal territories.

Likewise, the *decarbonisation* of villages does not follow a single technological path. Rather, there is a tendency toward forms of discreet electrification—such as geothermal systems or integrated photovoltaic tiles—in contexts of high historical value, while collective systems such as biomass plants or Renewable Energy Communities emerge where social cohesion and public support are stronger. In all cases, energy production tends to remain confined within the perimeter of the built environment or nearby resources, avoiding new occupation of virgin land and confirming the role of the regenerated village as an energetically dense and relatively self-sufficient territorial unit. Nevertheless, open questions remain concerning economic replicability, long-term maintenance, and the managerial capacity required by such systems.

Overall, the results suggest that effective regeneration of fragile territories rarely depends on a single intervention. Rather, it emerges from the integration of adaptive reuse, governance capacity, identity activation, ecological stewardship, and economic diversification. However, despite the plurality of observed models, one recurring mechanism cuts across all identified clusters: the transformation of unused built heritage into new social, productive, cultural, or environmental functions. For this reason, although it is not possible to derive a universal model of rural regeneration, the collected evidence suggests interpreting adaptive reuse as a circular invariant, that is, a possible structural constant capable of connecting different trajectories of territorial transformation.

5 Conclusions

The research highlights that Adaptive Reuse, in synergy with Soil Safeguard, represents a recurring element in the regeneration processes of fragile rural villages, which are primarily based on the enhancement of existing resources rather than on expansionary models. The analysis nevertheless shows that its role varies according to context: in evolutionary clusters, it assumes a performative and innovative value; in critical scenarios, it performs an adaptive and conservative function; while in strategic models, it becomes a systemic lever for governance, local networks, and long-term investment.

The results also suggest that effective regeneration depends on the integration of adaptive reuse, governance, environmental innovation, public space quality, and economic diversification, while remaining exposed to limitations such as intensive tourism, administrative fragility, or dependence on external capital. Although the study does not

allow the definition of a universal model, it proposes adaptive reuse as a circular invariant, that is, a recurring constant capable of connecting different trajectories of territorial regeneration.

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