White paper on the integration of PED Action Plans within spatial strategy making for just energy&climate transitions

CITIZENS4PED

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1 Introduction

1.1 Background information

Citizens4PED has been funded under the JPI-Urban Europe Call 2021 for Positive Energy Districts and Neighbourhoods for Climate Neutrality. The Citizens4PED project seeks to develop PED transition pathways by integrating technological, socio-cultural, and institutional/regulatory dimensions. Central to the project is the promotion of just energy transitions through the engagement of local communities and stakeholders through living labs and participatory action plans.

This report summarizes some of the activities carried out under Work Package 5 (WP5), which focuses on identifying mechanisms that enable or hinder the development of PEDs. Specifically, this WP examines how regulatory and policy frameworks, as well as stakeholder dynamics, influence the planning and implementation of PEDs. The ultimate goal is to design tools and frameworks that can guide just energy transitions at the neighbourhood scale and how they can be linked with city wide strategies and planning. The four pilot areas include challenging features for PED development and just energy transitions. They are:

- **San Paolo (Bari)**: A public housing neighbourhood facing physical decay and socio-economic marginalization.
- **La Roue (Brussels)**: A garden city with heritage buildings under protection and a large number of social housing.
- **USquare (Brussels)**: Former barracks being transformed into a mixed-use campus.
- **Kahlenbergerdorf (Vienna)**: A diverse area with heritage buildings under protection and mixed ownership structure.

The work performed under WP5 includes two main components:

- Regulatory and Policy Analysis: This component encompasses the examination of the policy frameworks impacting PED development, such as regulations on renewable energy communities, energy performance of buildings and urban regeneration strategies. Key findings are synthesized into a PED Policy Canvas for each city, outlining the opportunities and constraints of the regulatory and policy environment.
- Stakeholder Analysis: This component includes the evaluation of the roles, relationships, and influences of various stakeholders involved in PED development. Working with participatory methodologies, it highlights power dynamics, motivations, and potential for collaboration. A PED Community Map is created for each target neighbourhood to support local network-building.

By integrating insights from policy and stakeholder analyses, an Enabling Framework is then developed to guide PED action plans. This framework focuses on four core processes: transforming energy demand, promoting community-led initiatives, fostering innovation in energy systems, and supporting place-based ecological transitions.

The findings will inform future project activities, including detailed action plans for just energy transition and PED development in the four pilot neighbourhoods, and contribute to creating guidelines for promoting innovative and inclusive practices for PED transition in other cities.

The project aims to contribute to the development of PEDs in four existing neighbourhoods in Belgium, Austria and Italy by integrating several dimensions: techno-energetic, socio-cultural, and institutional/regulatory. It adopts a holistic approach, including sufficiency as a core dimension to achieve zero-emission cities alongside efficiency, production and flexibility. It envisages the development of living labs to facilitate co-creation of PED action plans by a wide range of actors in each neighbourhood and foresees the involvement of users and stakeholders at all stages of the PED development (planning, implementation and operation) as a key success factor in a long-term perspective.

Citizens4PED specifically explores synergies with renewable energy communities as key enabling mechanisms for just transitions. Equity stands out as an implication of transitions, as not only is energy poverty unevenly distributed across the EU – both socially and spatially – but transition policies may unexpectedly create further inequalities, including shifting the financial burden to low-income and low adaptive capacity groups and areas. Thus, the four target areas of the project include challenging contexts for just transitions, such as social housing estates, while the overall research design aims to increase knowledge about what processes can promote just transitions in positive energy districts in very different urban contexts.

To ensure replicability of good practices, in the last phase of the project specific guidelines and process-based roadmaps for PED planning, design, implementation and monitoring will be developed through a proposal for a CEN Workshop Agreement (CWA).

1.2 Objectives and structure of the report

This report constitutes a core deliverable of Work Package 5 “Institutional/policy analysis and spatial strategy making for just energy & climate transitions”. It includes the outcomes of the research activities undertaken within Task 5.4 “Integration of PED Action Plans within spatial strategies towards just energy & climate transitions” whose main goal is to investigate the relationships between PED-development processes within the target neighbourhoods and the wider city/region governance dynamics that might have a bearing on local energy transitions.

After introducing the chosen methodological approach (**Section 2**), the report reviews and briefly describes relevant spatial strategy-making processes in one of the target neighbourhoods (the San Paolo district in Bari, Italy). **Section 4** is devoted to identifying PED-relevant policy linkages, according to the main PED-development processes that have been conceptualised in Deliverable 5.1. In **Section**

5, all relevant spatial strategy-making processes are combined to map alternative district transition pathways against which (in **Section 6**) existing community commitments, along with missing opportunities are assessed. The report ends with a discussion of the constraints to and enabling factors for, effective synergies between PED-action planning and the relevant spatial strategies (**Section 7**) which also covers the relationships between the positive energy district under investigation, the other districts and the city/region.

2 Methodology

The definition of **spatial strategies** for the purpose of the Citizens4PED project commands a clarification. Following Healey (2007), spatial strategies can be understood as interpretive, future-oriented frameworks that make sense of the complex relational dynamics shaping cities and regions, while offering a coherent direction for their spatial evolution. Healey hence conceptualises spatial strategies as tools that frame ways of understanding place qualities, relationships and potentials and that mobilise relational complexity into a structured, place-based narrative for collective action (Healey, 2007). Rather than plans in the regulatory sense, these constructs belong to *strategic discourses* that articulate how territories might evolve and how actors can engage in shaping that evolution. However, to become operational, spatial strategies must translate their interpretive narrative into selective priorities, visions, and action-oriented frameworks that integrate different policy domains (Albrechts, 2004). Along similar lines, Innes& Booher (2018) argue that implementing a spatial strategy requires collaborative processes that align institutions and stakeholders, generate shared commitments, and mobilise collective, adaptive action across levels and sectors. Spatial strategies therefore depart from technical-rational master planning and rather resonate with collaborative, adaptive approaches that recognize cities as complex, open systems shaped by multiple networks, knowledges, and power relations operating across interconnected spatial scales.

The investigation of the interlinkages between relevant spatial strategies and PED-action planning was based on the methodological approaches to the transformative enabling framework and to the local activation of stakeholder networks that had been developed, respectively, under WP 5 and WP 6.

The table of contents reflects such methodological integration, by adopting the two crucial steps in PED-action planning to define Sections 3 and 4, while the priority PED-development processes described in Deliverable 5.1 are resorted to when structuring the paragraphs nested into Section 3. This is particularly apt to support the mingling of hints from different spatial strategies in each transitioning district.

Given the complementarity of the methodology adopted for the present deliverable to that extensively illustrated in Deliverable 5.1, no further specifications are provided in this introduction as it will suffice to explain any minor concept or definition in the following sections. Consequently, the application to one study context (Bari S. Paolo, Italy) is chosen to illustrate the proposed approach.

3 Tracing relevant spatial strategy-making processes

The most relevant spatial strategies have already been identified in D.5.1, as it follows:

- Plans and programmes for integrated urban regeneration, based on the Programmatic Document for Urban Regeneration, adopted by the City of Bari, according to the provisions of regional law 21/2008.
- Metropolitan Urban Plan for Sustainable Mobility, consistently with the regional guidelines approved with Regional Deliberation n. 1645/2018.
- Regional Territorial Landscape Plan strategic scenario's provisions that apply to Bari, which have been directly scrutinized pending the adoption or approval of the new general urban plan (compliant to regional law 20/2001).

To improve the coverage of this review, which is premised upon more flexible inclusion rules than those applied to the enabling framework, we also considered the following plans and programmes because each may have a bearing on the spatial reconfiguration of the San Paolo district as it relates to the current or future local energy transition:

- The combined electrical network development plans by the national Transmission System Operator and by the Distribution System Operator which is responsible for the grid operations in all but one municipality falling into the Metropolitan City of Bari
- The latest Metropolitan Strategic Plan, approved in July 2024; this is a new planning tool, introduced in 2014 amid the reform of second-level administrative governance
- The most recent Single Programming Document (2026-2028) by the municipal government (as provided for under Legislative decree 267/2000, art. 170), which is chosen pursuant to its role in setting the short- to mid-term priorities of Bari's municipal government (especially with its Strategic Section), while harmonizing the provisions of the main development-funding instruments – including both the National Recovery and Resilience Plan and the Regional Programme for European Structural and Investment Funds (ESI).

In the following paragraphs, a brief description of each spatial strategy is provided.

3.1 Plans and programmes for integrated urban regeneration

Urban planning in the San Paolo district as well in the city of Bari as a whole, is still governed by the provisions of Quaroni's 1976 General Regulatory Plan (GRP, Piano Regolatore Generale, in Italian) and is thus based on planning policies that are now obsolete, dating back almost fifty years. The Programmatic Document for Urban Regeneration (PDUR) was approved in 2011; it identified target areas for urban regeneration within the municipal territory—encompassing the urban peripheries in general and the San Paolo district in particular—and the regeneration strategy for each of them,

paying large attention to the improvement of public spaces, service networks, and inter-neighbourhood accessibility.

Figure 1 The strategic orientations for the San Paolo district (bottom pane) and the description of the settlement pattern (top pane), as developed in the Programmatic Document for Urban Regeneration of the City of Bari in 2011.

Under the 2011 PDUR, the analysis of settlement patterns combined with the concept for a strategic orientation of the integrated urban regeneration programme to be implemented following the provisions of regional law 21/2008, as illustrated in Figure 1.

In the San Paolo neighbourhood, diverse regeneration initiatives were carried out in the last 10 years, as briefly outlined in the following paragraphs.

Funded under the 2015 **National Programme for the Redevelopment of Deprived Urban Areas**, a regeneration initiative focused on redeveloping public spaces in the San Paolo neighbourhood was implemented. Key goals included upgrading infrastructure and accessibility, enhancing public and slow mobility, and reclaiming interstitial spaces for collective use.

Creative regenerations was a participatory urban regeneration initiative promoting inclusive public space activation by local civil society organisations and residents. Through workshops and co-designed activities, it aimed at fostering sense of place and community. In San Paolo, a community garden was developed under the leadership of the In.Con.Tra association and the Tracceverdi cooperative, which led to planting of 400 trees, engaged schoolchildren and care centre users, and included raised gardens for wheelchair accessibility.

The renowned architect Renzo Piano's **G124 initiative** for the redevelopment of Corte Don Bosco in San Paolo aimed to reconnect residential buildings with surrounding green areas through a new public courtyard, enhancing neighbourhood identity and social cohesion. The adopted design includes 110 trees to create a canopy, a circular clearing for collective activities, and features that link public space to nearby parks and the urban art installations.

These belong to the **"Quartiere Museo"** (Museum Neighbourhood) San Paolo, a series of around 10 mural works by Apulian, national and international street artists aiming to drive urban regeneration and community engagement. With support from Fondazione Mecenate 90 and the Puglia Region, and in collaboration with the public housing agency Arca Puglia Centrale, the project brought artworks by to public housing blocks, strengthening neighbourhood identity[1].

Recent and ongoing urban renewal and regeneration projects have been mapped in Figure 2. A description of each project is provided in Deliverable 5.1.

[1] See https://www.secondowelfare.it/governi-locali/rigenerazione-urbana/bari-rione-san-paolo-un-quartiere-museo (in Italian).

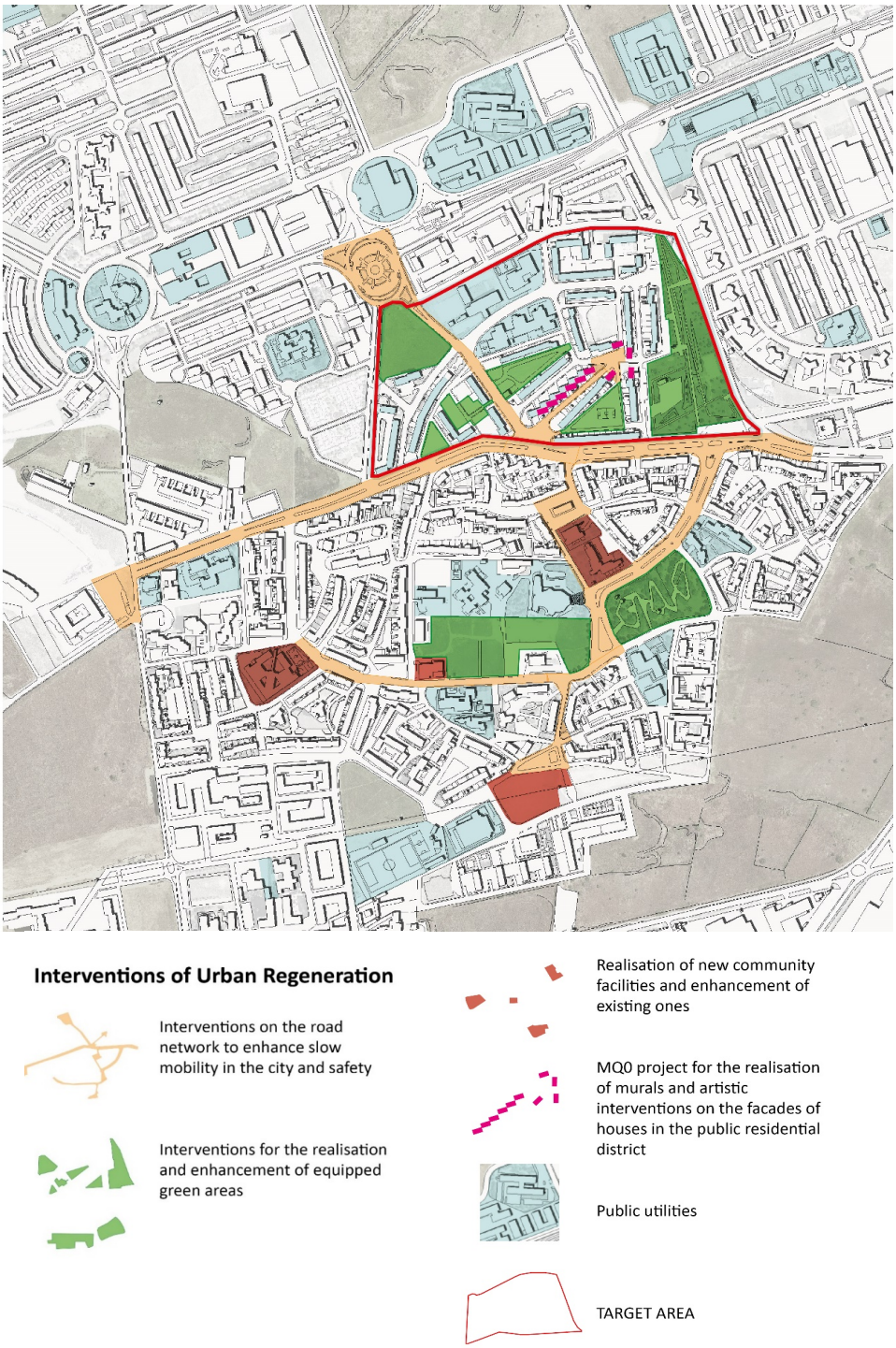

Figure 2: Recent and ongoing urban renewal and regeneration projects within and around the target area in San Paolo district (Bari, Italy).

The drafting of the new General Urban Plan (GUP, Piano Urbanistico Generale, in Italian) has been underway for several years. In addition to incorporating and aligning with the regulatory constraints

established by the Regional Territorial Landscape Plan (RTLP, Piano Paesaggistico Territoriale Regionale, in Italian), the new plan defines clear objectives focused on environmental sustainability, the reorganisation of mobility and urban connectivity, and the promotion of urban regeneration through integrated building renewal, environmental and energy retrofitting, functional mix, and social inclusion.

Throughout the rest of the document, reference is made to an overall Urban Regeneration Strategy (URS) which encompasses the different policies and projects that have been reviewed in the present Section.

3.2 Sustainable Mobility Urban Plan

The Sustainable Mobility Urban Plan of the Metropolitan City of Bari has been approved with decree of the Metropolitan Council no. 55 of 17/05/2024. The policy scenario is hinged on two parallel tracks: metropolitan actions and dedicated interventions for municipalities. These are organised using an origin-destination model, which sorts them into generators and attractors of mobility flows.

At the metropolitan level, five policy priorities have been identified:

1. Limitations to and rationalisation of logistics
2. Environment-friendly technological upgrade of local public transport services
3. Improving road network safety
4. Elimination of architectural barriers to ensure accessibility of transport systems for persons with disabilities
5. Service model for the metropolitan railway based on regular-interval timetabling and primarily cross-city lines serving the metropolitan capital.

As for the municipal level, Bari is classified as an attracting pole of first order, since the flows it attracts are 2.6 times higher than those it generates: The modal share in Bari is illustrated in Table 1, with the figures for both attracted flows and generated flows.

Table 1: The modal share attracted to and generated from, the metropolitan capital city of Bari.

Transport Mode	*Inbound Trips Share*	*Outbound Trips Share*
Car	***49%***	***89%***
Train	***27%***	***6%***
Bus	***24%***	***5%***

The categories of measures directly concerning the San Paolo district and its surroundings, as envisaged in the Sustainable Mobility Plan for the Metropolitan Area of Bari, are mapped in Figure 3.

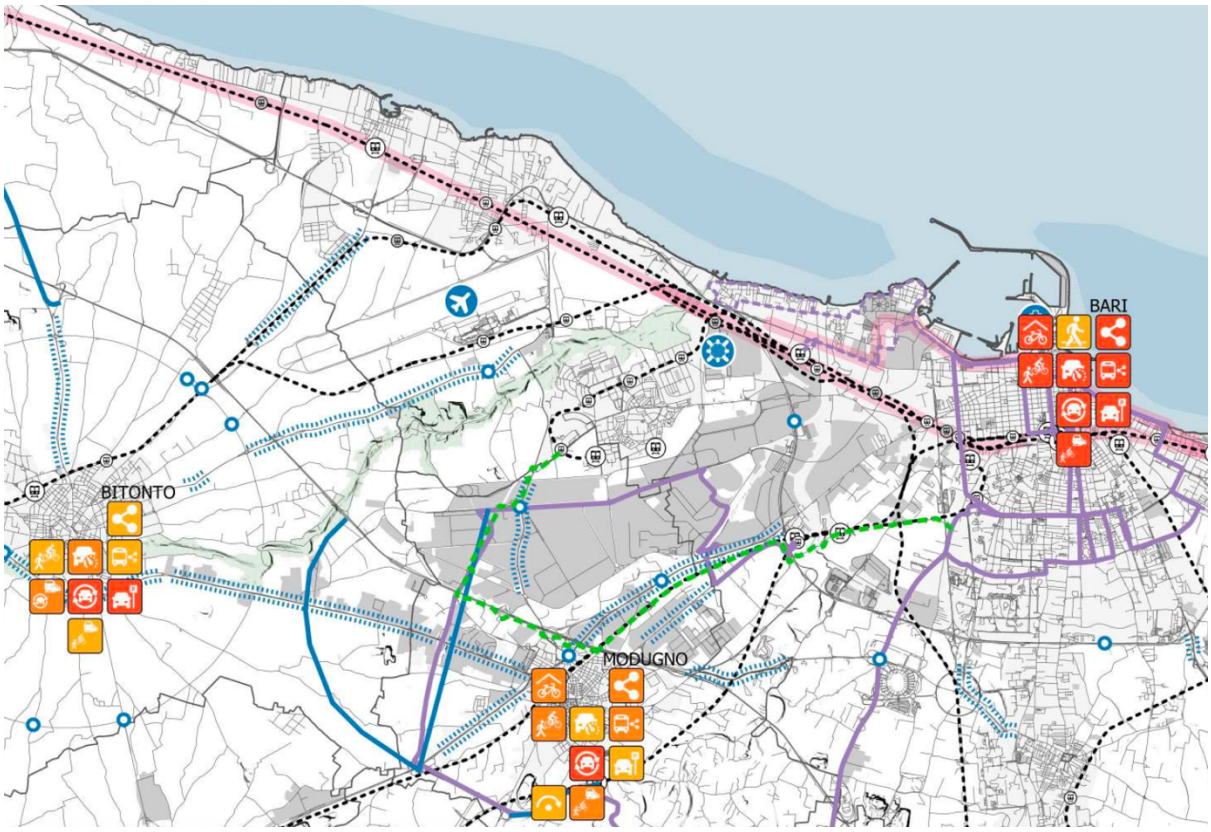

Figure 3: The new measures concerning the San Paolo district and its surroundings, as envisaged in the Sustainable Mobility Plan for the Metropolitan Area of Bari. Adapted after Metropolitan City of Bari (2024b).

Based on their relevance to PED development, the main measures include the following ones:

- Bus Rapid Transit system with full electrical vehicles running on four (mainly dedicated) lanes and using platform-level boarding – but coming nowhere near the San Paolo district, which is however already reached by the only metropolitan rail service that has already been activated in Bari.
- Additional Modal switch facility (Park&Ride)
- Strengthening of interurban public transport
- Innovations in last-mile logistics systems
- Expanding the bike lane network and bike sharing services – through integrated approaches that also target the connections between the airport and the main industrial&commercial across the municipal boundaries of Bari and Modugno, which develops through the San Paolo district ()
- Improving urban road network safety, including in the San Paolo district (provincial road 45 Bari San Paolo-Bitonto).

Figure 4: the planned bike lane network passing through the San Paolo district while connecting the industrial&commercial area (south of the neighbourhood) and the airport (north of the neighbourhood). Adapted after Metropolitan City of Bari (2024a, p. 301).

The San Paolo district is also concerned by an experimental application of an Intelligent Transport System, named SIMBA and relying on sensoring networks and data sharing protocols, centred on the nodes mapped in Figure 5.

Figure 5: The area of experimentation of the Intelligent Transport System "SIMBA". Adapted after Metropolitan City of Bari (2024a, p. 356).

3.3 Regional Territorial Landscape Plan's strategic scenario

The regional territorial landscape plan (RTLP, Piano Paesaggistico Territoriale Regionale, in Italian) integrates the functions of a landscape plan (under arts. 135 and 143 of legislative decree 42/2004 (the Italian landscape and heritage code) and of regional land use planning, under regional law 20/2009. The RTLP aims to protect and enhance the landscapes of Puglia, promote sustainable socio-economic development, and enable conscious land-use and land-use change by public and private actors.

The approach is integrative and multi-sectoral (it addresses open spaces, agriculture, coastlines, built environment, infrastructure, and the ecosystem structure within one unified framework) and is addressed to all actors — public authorities, developers and other entrepreneurs, civil society organisations, and the citizens with a view to letting landscape become a shared goal of governance, avoiding uncoordinated transformations that would erode long-term sustainability of landscape heritage.

The plan has three key components: (a) the Atlas of Environmental, Territorial and Landscape Heritage, (b) the Strategic Scenario, and (c) the regulatory constraints and guidelines. The Atlas describes and maps the identity of the various landscapes of Puglia, identifying structural, ecological, geomorphological, historical and cultural characters across scales. The regulatory constraints and guidelines lay down rules for conservation, rehabilitation and redevelopment, in line with landscape identity, defining obligations and permissions for public and private interventions. Within this framework, the Strategic Scenario sets out the vision, policies and transformative projects for future landscape change heritage-driven sustainable development. The Scenario comprises five territorial projects for the regional landscape (Regional Ecological Network; City–Countryside Pact; Slow Mobility Infrastructure System; Integrated Requalification of Coastal Landscapes and Territorial Systems for the Experience of Cultural and Landscape Heritage), along with the guidelines for their implementation within each of the 11 landscape areas that have been identified in Puglia.

The city of Bari is completely located within the Bari Basin landscape sub-area, which is in turn part of the Central Puglia landscape area – for which a tailored implementation of the strategic scenario is provided (Puglia Regional Government, 2015a). The Bari basin reaffirms and yet also departures from the settlement pattern that is characteristic of the Central Puglia landscape area: a double track of coastal and inner urban centres which traditionally specialised, respectively, in trading and in agriculture, surrounded by olive groves (away from the urban centres) and arable land and gardens (closer to the towns and villages). Around Bari, the hydrogeological and geomorphological specificities let such pattern evolve into a double-ring settlement structure arranged in a radial pattern around the capital, with development axes that run alongside the network of fluvial-karstic gullies (the "lame"), as shown in Figure 6. The fast-paced economic and political growth of Bari as of the beginning of the 19th century influenced the emergence of a clear hierarchy and, more recently, of conurbation processes, while a prevalence of mixed agricultural land covers (mainly olive groves and arable land) in this sub-area make leaves way towards its south-eastern boundaries to fruit orchards and vineyards.

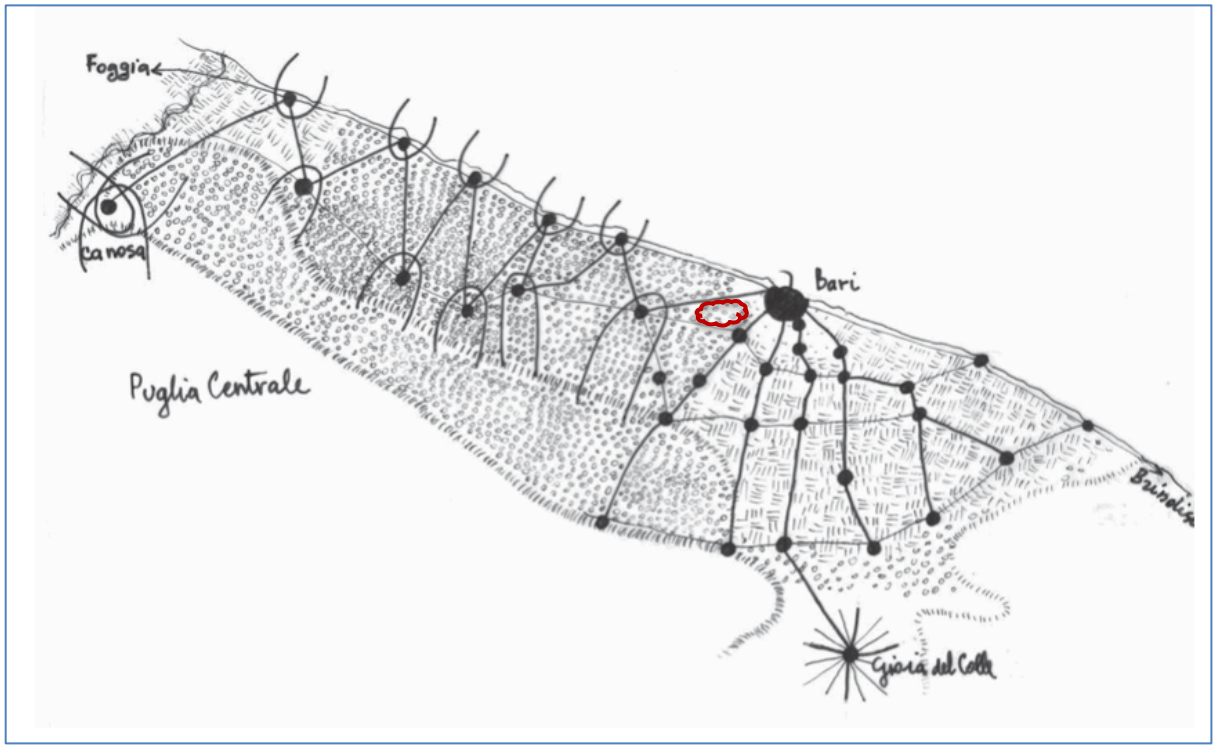

Figure 6: The settlement pattern in the Bari basin sub-area (eastern part) within the Central Puglia landscape area. Adapted from Puglia Regional Government (2015a, p. 51). The red cloud approximately maps the San Paolo district.

In this framework, San Paolo appears as a paradigmatic suburban district: a large public housing estate built from the late 1950s in the expanse of olive groves, eight kilometres away from the city centre, surrounded to the north by the main fluvial-karstic gully (Lama Balice) and immediately beyond it, by the airport, to the south by the large industrial&commercial area, to the west by the main logistics hub and by a wastewater treatment plant. Over time, it has concentrated physical degradation and social hardship, becoming a district of more than 30.000 inhabitants and one of the city's most fragile contexts.

Within this context, the five RTLP territorial projects, as detailed with the specific provisions laid down in the landscape area report for Central Puglia, provide a strategic framework that can be read as a multi-scalar strategic scenario for San Paolo's territorial regeneration, linking ecological, agricultural, mobility, coastal and heritage issues.

3.3.1 Regional Ecological Network

The RTLP identifies the *lame* (including Lama Balice and Lama Lamasinata) as structural ecological corridors connecting the Murge plateau to the coast through the urbanised basin of Bari. In the San Paolo area, where these corridors are partly degraded by urbanisation and infrastructure the REN strategy supports:

- the ecological and hydraulic requalification of the *lame* as continuous green-blue corridors;
- the creation of linear parks and naturalised spaces along these corridors, mitigating environmental risks and improving everyday landscapes;
- the reconnection of San Paolo to the wider ecological system, countering the image of an isolated "island" in the urban fringe.

3.3.2 City–Countryside Pact

The City–Countryside Pact moves from discussing the planned residential decentralisation that produced estates like San Paolo and Enziteto/San Pio within the expanse of olive groves, far from the densely built urban areas. The result was a weakening of the peri-urban agricultural mosaic, a blurred city–countryside interface and low-quality urban environments. Applied to San Paolo, the strategy that directly addresses such issues implies:

- protecting and consolidating agricultural wedges and peri-urban mosaics still present around the district, particularly along the *lame*;
- reusing the main historical farmsteads (*masserie*) and other rural buildings as neighbourhood facilities and cultural anchors;
- promoting peri-urban agriculture and multifunctional open spaces (community gardens, educational farms, etc.) as tools for social inclusion and landscape restoration;
- integrating housing policies with innovative agro-silvo-pastoral policies, so that San Paolo is not only a housing container but part of a living city–countryside system.

Among the different policy tool set forward by the RTLP, the San Paolo district falls in between two rural multifunctional parks (Figure 7):

1) the multifunctional rural park for the enhancement of hamlets and towers in northern Bari;
2) the multifunctional rural park for the requalification of the conurbation of Bari.

3.3.3 Slow Mobility Infrastructure System

The RTLP highlights how major infrastructures (the A14 motorway, the SS 16 and the SS 96 highways, the airport, the national railways) have fragmented the perception and continuity of landscapes and weakened historic access routes. In San Paolo, these infrastructures reinforce physical and symbolic peripherality, although a recently built metropolitan rail services connecting the district and its large hospital to the city centre has marked a clear departure from this trend.

The Slow Mobility strategy translates into:

- developing cycle-pedestrian routes along the green-blue corridors and historic roads, linking San Paolo to the coast, the Murge and neighbouring districts;
- enhancing visual and perceptive access to the surrounding landscapes from key streets and open spaces;

- integrating slow mobility networks with existing public transport, thereby reducing car dependence and improving accessibility for residents with fewer resources.

3.3.4 Integrated Requalification of Coastal Landscapes

The RTLP warns against the formation of a continuous linear metropolis along the Puglia centrale coast, driven by land take and soil sealing and the urbanisation of the coastal strip. Since the more functions and amenities concentrate on the coast, the more inland districts risk remaining mono-functional and marginal, coastal requalification and inland urban regeneration appear to be complementary.

these dynamics indirectly affect the San Paolo district, where the synergies between them may be strengthened by:

- enhancing the San Paolo area, as well as other inland districts, as alternative locations for cultural, recreational and social facilities to help relieve pressure on the coast;
- improving connections between San Paolo and coastal areas via slow mobility and public transport reinforce a balanced distribution of access to coastal landscapes;
- re-establishing the sense of place about, and the awareness of, the ecological, landscape and cultural connections between the two temporary watercourses (lame) and their highly artificialized mouths.

3.3.5 Territorial Systems for the Experience of Cultural and Landscape Heritage

The RTLP calls for recognising cultural and landscape assets in peri-urban and rural contexts and integrating them into coherent systems of experience. For San Paolo, this means:

- treating masserie, traces of the rural landscape, fluvial-karstic gullies and public spaces as part of a territorial heritage network rather than as residual spaces;
- requalifying key open spaces and routes (e.g., around Viale Europa and other central axes) as gateways to the wider metropolitan landscape;
- connecting local community projects, such as libraries, cultural initiatives and the 'Quartiere Museo' (illustrated in Section 3.1), to the broader RTLP objective of making heritage accessible, understandable and meaningful.

The San Paolo district is included in one of the historically layered topographical context identified by the RTLP and named after Lama Balice. In this area where multiple material, functional, and symbolic elements accumulate and interact, forming a complex and dynamic spatial entity (mapped in Figure 7), settlements with different purposes and uses are documented between the 9th century BCE and modern times. The unifying factor is represented by the fluvial-karstic gully, which guaranteed water supply and constituted a natural crossing point.

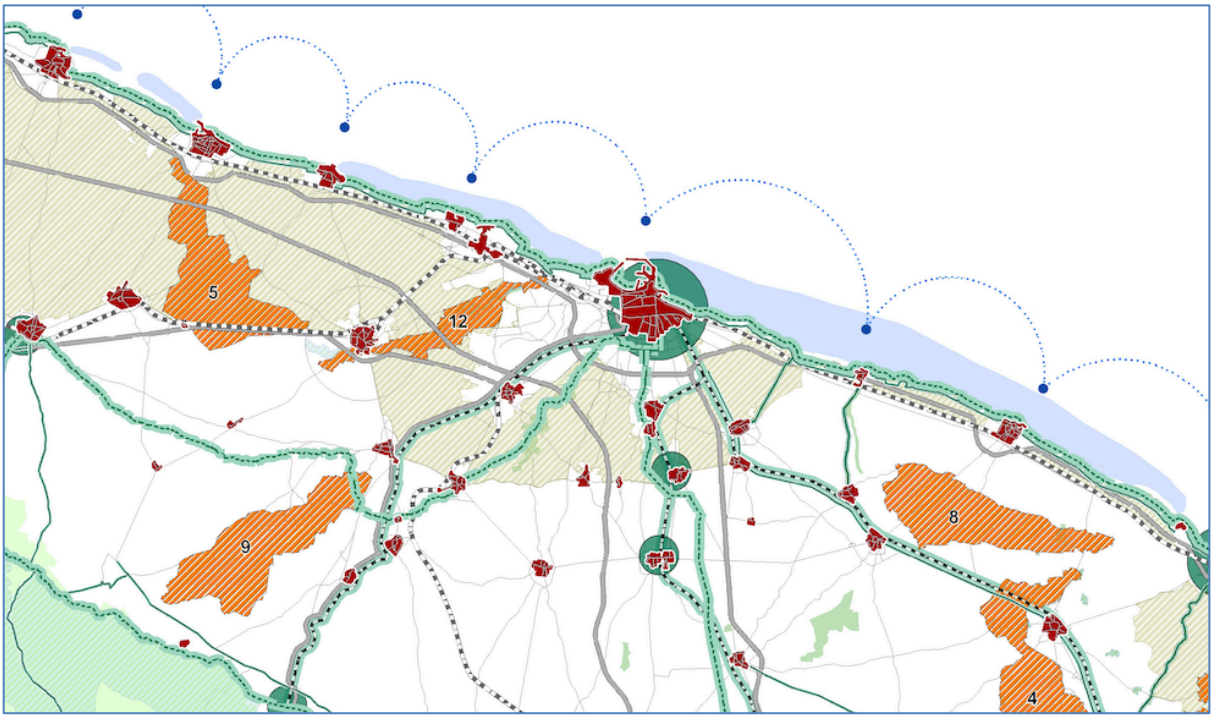

Figure 7: The historically layered topographical context named after Lama Balice (the orange striped polygon numbered as 12) and the multifunctional rural parks represented by the light green slanted mesh: the multifunctional rural pars for the enhancement of hamlets and towers in northern Bari (north-west) and the multifunctional rural park for the requalification of the conurbation of Bari. Adapted from Puglia Regional Government (2015b).

3.4 Electrical network development plans

Under the unbundling arrangement introduced by EU Directive 1996/92/EC concerning common rules for the internal market in electricity (subsequently amended and repealed by a series of updating legislation, up to EU Directive 2019/944), the electrical network is managed by private operators under public license. In Italy, the Transmission System is operated by Terna S.p.A., while the main electricity Distribution System Operator (DSO) is E-distribuzione S.p.A. (part of the former monopolist), which is also responsible for the operations in Bari and in all other but two municipalities in Apulia.

As for Transmission System, the main project affecting the target area concerns a series of interconnected extra-high- and high-voltage lines and transforming stations. The project focuses on optimizing transmission around the main station serving the region's major gas-fired power plant (800 MW, located on the outskirts of Bari near the target district) and enhancing transport capacity from

the large power plants in Brindisi (south of Bari). To date, €52 million has been invested in the project, with a further €35 million required for completion[2] (see map in Figure 8 below).

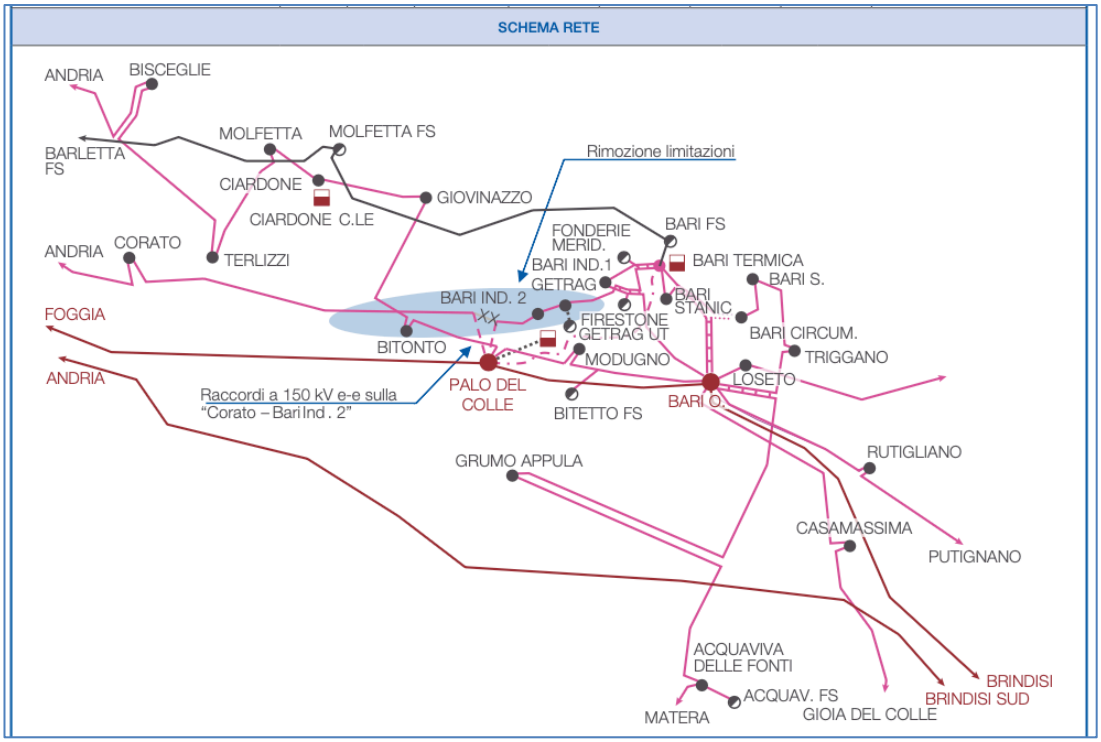

Figure 8: the electricity network around Bari, including primary substations and some of the main consumers (industrial compounds and railway stations). Source: Terna S.p.A. National Transmission Network Development Plan 2025, Monitoring of previous plans in central and southern Italy, p. 156.

The Distribution Network Operator is working on several projects concerning the high, medium and low voltage grids in and around Bari. At least one of these projects will reach a primary substation in the industrial and commercial area situated south of the San Paolo district. The spatial configuration of primary substations is of key importance to PED development, because of the current rules for premium feed-in tariffs on electricity sharing within renewable energy communities as introduced by EU directive 2018/2001. Almost the entire district is served by the same primary substation (identified by the code AC001E00347), along with most of the nearby industrial and commercial area, the airport and some of Bari's northern coastal districts (Figure 9).

[2] https://www.terna.it/it/sistema-elettrico/programmazione-territoriale-efficiente/piano-sviluppo-rete.

Figure 9: The AC001E00347 Conventional area includes almost the entire district of San Paolo, along with the other areas in Bari that are served by the same primary substation and therefore qualify for the energy-sharing feed-in premium tariff.

3.5 Metropolitan Strategic Plan

The Strategic Plan of the Metropolitan City of Bari (SPMC) was approved by the Metropolitan Council with Decree No. 76 on 25 July 2024. The SPMC is structured around 11 thematic axes and their associated key priorities. **Table 2** outlines the plan's overall structure, focusing particularly on elements strictly relevant to local energy transitions (highlighted in bold).

Table 2: Aims and actions of the Strategic Plan of the Metropolitan City of Bari.

Axis	Title	Key Thematic Priorities	Actions (when relevant)
Axis 1	Metropolitan Digital Agenda - from Smart City to Smart Land	Digital governance and participation	Implementing enabling digital platforms Promoting digital training and Living labs Enhancing data-driven economies
Axis 2	(Right to) Sustainable Mobility	Upgrading mobility networks and devices, innovating mobility behaviours	**Intermodality and modal shifts in mobility management** **Encourage pedestrianisation and cycling** **Introduce Rapid transit local public transport and foster the upgrading of buses and trains** **Electric Vehicle Charging Infrastructure Masterplan** **Smart logistics**
Axis 3	Tourism and Culture - Destination Bari	From destination management to community involvement	Restoration and reorganisation of facilities for cultural activities and entertainment Improving tourist services and activities
Axis 4	More skills, less gaps - Education, research and work ecosystem	From learning communities to local development	Vocational education and training Parenting-support services Increasing student housing and improving research facilities
Axis 5	Housing First, Active Inclusion and Social Innovation - No one left behind	Urban poverty, local welfare, social innovation	**Public and social housing, housing first** Building capacity among welfare recipients
Axis 6	Sea - A single metropolitan waterfront	Marine ecosystem protection and coastal landscape rehabilitation	Coastal eoclogical networks and landscapes rehabilitation Construction of a new marina in Bari
Axis 7	Open Peripheries - No one is on the outskirts	Polycentric urban regeneration	**Urban afforestation** Redevelopment of brownfield sites for residential use **Creating climate shelters**
Axis 8	Historical Centres and Urban Economies - Metropolitan identities	Protecting heritage and a sense of place in the face of depopulation, an ageing population and an explosion in short-term rentals	Harmonising heritage protection and livability/accessibility improvements in historical centres Harnessing cultural indfustry innovation for socio-economic regeneration
Axis 9	Agriculture, Rural Landscape and Food Transition - Land counts	Food system transition: short value chains, designations of origin, agrobiodiversity	**Metropolitan green belt network** **Green communities and Renewable energy communities** Bari Wholesale Food Market
Axis 10	Green Transition and Adaptation to Climate Change - Sustainable communities	Community-driven climate change mitigation&adaptation	**Updating of general and sectoral planning tools** **Deep renovation** **Smart grids in smart cities** **Positive Energy Districts** **Nature-based solutions** **Blue, green and grey infrastructures**
Axis 11	Competitiveness - Knowledge at the core	Smart Specialisation Strategy meets Strategic Industrial & Commercial Areas	Supporting the Research&Innovation ecosystem Master plan of the Industrial Development Area Enhance logistics infrastructure Establishing Special Economic Zones and Customs-free Areas

A flagship action concerning positive energy districts is included (Axis 10, Action 10.2.2.c): it builds on Citizens4PED itself to promote public&social housing PEDs in the San Paolo and San Girolamo districts (Bari), with an expected timeframe of 6 years and an estimated investment of €35 million.

3.6 Single Programming Document

The Single Programming Document (SPD) 2026-2028, adopted in November 2025 by the municipal government. It is included in the present review of PED-relevant spatial strategies because of its role in setting the short- to mid-term priorities of Bari's municipal government (especially with its Strategic Section), while harmonizing the provisions of the main development-funding instruments – including both the National Recovery and Resilience Plan and the Regional Programme for European Structural and Investment Funds (ESI). It is interesting to note how programming is defined in this context as "*the process of analysis and evaluation which, by comparing and coherently aligning the various policies and plans for territorial governance, enables the organisation—within a predefined temporal framework—of the activities and resources required to achieve social objectives and promote the economic and civic development of the concerned communities*"[3].

The SPD of the Municipality of Bari[4] is prepared in accordance with Article 170(1) of the Consolidated Law on Local Authorities (Legislative decree 267/2000) and the guidelines in Annex 4/1 of Legislative Decree 118/2011. It is structured in two sections. The Strategic Section, covering 2024–2029 (the mayor's term), outlines the strategic guidelines of the municipality in line with national, regional, and EU frameworks, and contributes to public finance objectives. The Operational Section, covering 2026–2028, translates these strategic goals into a general and programmatic framework that guides the drafting of annual and multi-year financial planning documents.

The file SPD 2026-2028 serves as the strategic and operational guide for the Municipality of Bari: it aligns with the sources cited elsewhere in this report when describing the San Paolo district as a public housing neighbourhood facing physical decay and socio-economic marginalisation and consequently identifying it as a priority area for strategic interventions.

The general strategic framework for energy transition and sustainability set out in the SPD resonates with European and national goals for ecological transition. The following overarching strategies apply to San Paolo:

- The administration intends to strengthen a "**Pact on Climate, for a greener city**" to reduce fossil emissions by 55% by 2030 (per the metropolitan Sustainable Energy and Climate Action Plan, adopted and implemented by all 41 metropolitan municipalities) and strive to become carbon neutral by 2040.

[3] Annex 4/1 to Legislative Decree 118/2011.
[4] https://www.comune.bari.it/web/trasparenza/esercizio-finanziario-2026.

- The municipality promotes **renewable energy communities** (RECs) to address energy poverty—San Paolo is explicitly listed as one of the key neighbourhoods, alongside San Pio, Santa Rita, Loseto, and Torre a Mare—, supported by a dedicated help desk. The wider strategy envisages synergies with **positive energy districts** and nature-based solutions (such as green roofs and sustainable drainage and water recovery systems), within a policy context where both national and regional laws stand out to call for RECs to involve low-income groups and public housing management bodies (such as ARCA Puglia Centrale).
- As for **energy efficiency**, key goals include the improvement of energy performance of the publicly owned real estate and supporting the energy retrofitting of municipal buildings.
- Actions planned to adapt to urban climate change and reduce the urban heat island effect include promoting massive greening initiatives (urban forests), the progressive desealing of artificial surfaces and the creation of **climate shelters**.
- The SPD emphasizes shifting the development model from urban growth to **urban regeneration**, focusing on reducing land take and soil sealing and enhancing proximity planning (the "15-minute city" concept).
- The document embarks on a reform of **energy infrastructure governance** and details the planned corporate reorganization of the municipal gas companies, to comply with the unbundling regulations by fully separating distribution from sales.
- As for **waste management and circular economy**, the city is striving to complete the activation of the door-to-door separate waste collection system across all districts by 2028.

Specific initiatives and priorities that are being implemented in or apply to the San Paolo district, and can be considered relevant to PED development, include:

- Several specific deep renovation projects of public housing buildings in the San Paolo district, with a dedicated budget of approximately 6.5 million euros.
- The commitment to complete ongoing regeneration programs, including the National Programme for the Redevelopment of Deprived Urban Areas, which specifically involves the San Paolo district.
- The upgrading of the stormwater drainage system, funded by a regional contribution of 3.5 million euros.
- The installation of a new or more efficient street lighting system (via Puglia, via Barisano da Trani, via Violante, Piazza Romita and others) funded by both the Civic Budget and a Regional contribution.

In summary, the DUP 2026-2028 formalizes a commitment to ecological transition as a core priority, targeting San Paolo (Municipio 3) specifically for social and energy equity measures through the promotion of RECs and public housing renovation works focused on energy efficiency, funded primarily by the national complementary programme to the recovery and resilience funding instruments. This local focus is integrated into the wider municipal strategy aimed at achieving carbon neutrality by 2040 and transforming the city through greening and urban regeneration.

4 Identifying spatial strategies' policy linkages to PED development

The overview of spatial strategies that are likely to have a bearing on PED development in the Italian target area of Bari San Paolo–selected in the framework of the Citizens4PED project–has highlighted several objectives or actions that might influence energy transition pathways orientation and timing. In the following paragraphs, these elements are grouped according to the four priority processes in PED development that have been conceptualised as a key component of the PED enabling framework, in **Deliverable 5.1**. The purpose of the concise comments included in each of the following paragraphs is to highlight the implications of the referred measures for PED development.

4.1 Energy demand transformation

Deep renovation & municipal building energy performance improvements (Single Programming Document): dedicated public-housing retrofits in San Paolo (about €6.5m) and broader municipal upgrades—direct demand cuts and heat-pump readiness.

Street-lighting upgrades (Single Programming Document): new/efficient lighting on key streets/squares—steady, metered demand reduction and potential smart controls.

Transition Planning playbook (Urban Regeneration Strategy, Metropolitan Strategic Plan): integrated building renewal/energy retrofits embedded in planning tools—creates district-scale envelopes (a block, cluster of blocks, or a whole neighbourhood) suited to PED balancing (the match between local demand and local supply), that planning tools are to treat as one unit for design, permits, and investment.

Active/low-carbon mobility (Sustainable Urban Mobility Plan, SUMP): cycle lanes, park-and-ride, safer roads; modal shift reduces transport energy demand within the district boundary and across districts.

4.2 Community-led adaptation to climate change

Urban greening & climate shelters (Single Programming Document): urban forests, de-sealing, climate-shelter creation—heat-island mitigation for vulnerable groups.

Renewable Energy Communities for energy poverty (Single Programming Document): REC help-desk and priority rollout in San Paolo; explicit poverty-reduction framing within PED governance.

Civic co-production (Urban Regeneration Strategy, Regional Territorial Landscape Plan): participation platforms that build trust and stewardship—useful foundations for community-level PED engagement and energy demand management actions.

City–Countryside Pact (Regional Territorial Landscape Plan): peri-urban agriculture, reuse of farmsteads (masserie) as socio-cultural anchors—nature-based cooling, co-benefits, and inclusive spaces for REC/PED activities.

4.3 Local energy system innovation

Distribution System perimeter advantage: most of San Paolo is under the same primary substation, securing an optimal geometry for energy-sharing incentives, district-scale Energy Management Systems (EMS, a supervisory control platform that sits "above" individual buildings and coordinates them as one virtual district) and **flexibility pilots**:

- shifting loads (pre-heating/cooling, delaying dishwashers/EV charging)
- shaving peaks with batteries/thermal storage
- soaking up surplus PV (charge batteries/EVs, raise DH supply temps within limits)
- providing grid services (local congestion relief, voltage support, *etc*.).

TSO/DSO grid developments: transmission upgrades plus medium voltage/low voltage works near San Paolo and the industrial and commercial area increase hosting capacity and speed interconnections—critical for PED photovoltaics and storage scale-up.

Intelligent Transport System "SIMBA" (SUMP): sensor networks and data-sharing nodes—feeds real-time data for PED EMS (load forecasting, smart charging, demand response).

Public transport electrification (SUMP): BRT/e-fleets (even if routes avoid San Paolo) plus stronger inter-urban public transport—opens depot-charging hubs (just like the one that is actually located in the industrial&commercial area adjacent to San Paolo and served by the same primary sub-station) and unidirectional smart charging (V1G) or vehicle-to-grid *two-way* power charging (V2G) are tied to district flexibility because those smart/bi-directional charging actions are scheduled by the district's EMS to help the district hit its targets (peak shaving, self-consumption, congestion relief).

Flagship PED action (Metropolitan Strategic Plan, Axis 10—Action 10.2.2.c): €35m concept for **public & social-housing PEDs** in San Paolo and San Girolamo—platform for standardised contracts, EMS, storage facilities, and REC revenues allocation.

4.4 Place-based ecological transition

Regional Ecological Network (Regional Territorial Landscape Plan): restore the **fluvial-karstic gullies** (Lama Balice/Lama Lamasinata) as green-blue corridors—flood mitigation, cooler microclimates, walkable paths shaping low-carbon behaviours.

Slow-Mobility Infrastructure System (RTLP + SUMP): bike corridors connecting airport, industrial area, and San Paolo—reduces car dependence and ties district life to metropolitan landscapes.

Coastal–inland rebalancing (RTLP): counter coastal linear sprawl by strengthening inland amenities—supports compact, mixed-use regeneration compatible with PED efficiency.

Urban-rural interface (RTLP): under planning approaches that integrate agroecology, culture, and public space, the RTLP aims to connect peri-urban proximity gardens both (inward) with densely populated recent urban developments and (outward) with the relics of the olive groves and arable land that extend into the multifunctional rural park for the requalification of the conurbation of Bari. Within this scenario, PEDs can resort to small-scale, multi-use assets that fit place identity, such as community hubs (small pavilions that host REC meetings, bill-advice desks, tool libraries, repair cafés, or co-working spaces), PV canopies (solar shade structures over markets, walkways, or parking lots), and learning labs ("living lab" corners with sensors, dashboards, and signage for students and other citizens, turning the PED into a public learning asset).

5 Reviewing community commitments

PED development in the San Paolo district appeared to be in its very early stages at the time the Citizens4PED project was launched. There were, indeed, initiatives to foster the local energy transition but they tended to be uncoordinated and more focused on certain domains (energy efficiency, urban renewal) rather than others (renewable energy development, energy community building, *etc*.).

Therefore, the community-building process in the San Paolo neighbourhood aimed to lay the social groundwork for a potential PED. Given the area's complex social dynamics and historical mistrust towards external interventions, engagement required gradual, trust-based approaches. Hence, the 4-phase roadmap briefly illustrated in the following paragraphs.

Phase 1 – Establishing the Living Lab

The local living lab was initiated to open a direct, ongoing communication channel with neighbourhood associations. Initial public meetings, held at various community hubs with a headway of approximately one month (on 15 February, 25 March and 9 May – in 2024), were well attended but did not lead to sustained engagement or strong associative bonds (

Figure 10).

Figure 10: An overview of participants to the kick-off meeting of the San Paolo Living lab, held on 15 February, 2024.

Phase 2 – Engagement through Schools

A more effective entry point was found through schools. Workshops were conducted in three comprehensive institutes, involving both primary and secondary students. Activities included energy-themed games, creative drawing sessions, and collective visual outputs (Figure 11), fostering dialogue with families via school communication channels. This phase served to indirectly build trust and lay the foundation for broader community involvement.

Figure 11: Snapshots from one of the creative drawing sessione held in primary schools (top pane) and an example of collective visual output of energy-themed games.

Phase 3 – Resident Outreach and Questionnaire

Building on the school-based connection, a self-administered questionnaire was completed (partly online, partly in-person) to explore household energy use, heating/cooling systems, interest in renewable energy, and willingness to participate in an energy community. Targeted outreach to residents of ARCA Puglia's public housing involved collaboration with building managers and local religious representatives. A face-to-face meeting at Don Bosco parish significantly boosted participation and allowed for transparent communication about the project's goals ().

Figure 12: Images from a preliminary meeting with the parish priest (top-right pane) and a public session, held in the Don Bosco parish, inside the target area for the San Paolo Living lab.

Phase 4 – Engagement with Local Authorities and other public bodies

On 13 May 2025, a formal meeting was held with representatives of the Bari city administration to present the outcomes of the engagement activities and stimulate institutional interest in supporting subsequent phases of the PED's development. During the meeting, the councillors responsible for urban regeneration and ecological transition explained that the municipal government was focusing on drafting regulations for its participation in and in-kind contribution to renewable energy communities. The energy manager then provided an overview of the main orientations of these regulations. They expressed a desire for a REC to be established in San Paolo as well, representing the first building block of a future PED.

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Around the same time (on 20 May 2025), a follow-up meeting was held with ARCA Puglia Centrale — the public housing provider — to explore their potential role in future project implementation. The CEO reaffirmed their interest in participating in either a REC or any other organisational arrangement that could foster PED development in San Paolo. However, at that time, ARCA Puglia Centrale was also very focused on a specific initiative: the call for expressions of interest from Energy Service Companies (ESCos), with a view to submitting a joint application for funding under measure M7.I.17 'REPowerEU' of the National Recovery and Resilience Plan, which is dedicated to improving the energy efficiency of publicly owned residential buildings[5].

These two meetings reinforced the idea that the institutional context in San Paolo is very favourable for PED development, while suggesting that it may take time for the individual agendas to align.

[5] https://www.italiadomani.gov.it/content/sogei-ng/it/it/Interventi/investimenti/strumento-finanziario-per-l-efficientamento-energetico-dell-edilizia.html.

6 Mapping PED transition pathways

A mapping exercise of energy transition pathways followed, which built on the orientations that had been shared by the partners of the international consortium during WP3 and WP6 research activities. The Living lab arrangements didn't allow a thorough consideration of the four Pareto optimizations scenarios that had been developed over WP3 and based on the methodology put forward by the VUB. Nor a fully fledged integration between those techno-economic scenarios and the insights from the spatial strategies summarised in Section 3 could be devised. However, the general orientations and specific elements of both the scenarios and the spatial strategies were repeatedly discussed, individually and collectively, in the framework of the engagement activities recounted in Section 5.

For research purposes, we applied a qualitative multicriteria evaluation method based on an ordinal scale (del Pozo *et al*., 2020) to the four scenarios developed using Mixed Integer Linear Programming (MILP) for multi-objective optimisation of PED energy solutions (see **Deliverable 3.5**).

The four PED energy scenarios were defined as follows:

- ***Per Dwelling Scenario***: An individualized energy scenario where each dwelling is responsible for its own energy. In this scenario the only option for heating is an air-source heat pump for both heating and cooling and electricity is only available from the grid.
- ***Per Building Scenario***: A per-building energy scenario, where each building can have energy systems installed which share energy across the different dwellings within that building. No energy is shared between buildings. A building can be fitted with air-source heat pumps, ground-source heat pumps, and solar panels.
- ***Energy Hub Scenario***: A centralized energy hub scenario, with energy sharing for heating, cooling and electricity. To distribute the energy a low-temperature heating district is included. The system options here are air-source heat pumps, ground-source heat pumps, solar panels, thermal energy storage, wind energy and batteries.
- ***Renewable Energy Community Scenario***: A scenario where the electricity can be shared within the community, but heating is individualized. The possible technological solutions in this case are solar panels, wind energy, air-source heat pumps, batteries and gas boilers.

We set up a preliminary test by adopting a set of eight criteria, whose scoring assumptions are briefly explained in Table 3. Under such assumptions, transition pathways have been defined as the scoring patterns for each PED energy scenario (as defined in Deliverable 3.5), split over two phases: a start-up phase (2025-2032) and a consolidation phase (2033-2040). Scoring is relative to the simulated performance of the four scenarios over 57 iterations performed by an interactive tool set up in Anthropic's Claude generative AI chatbot, which were needed to finetune the definitions of criteria and to remove logical inconsistencies in scoring. Scaling is done to have 5 as the best performance and 1 as the worst one. Further key assumptions include:

- Grid electricity decarbonizes over time (per-dwelling improves passively to score 4);

- centralized hub achieves carbon neutrality (score 5) through active renewable generation, storage optimization, and grid export by 2032-2040;
- REC achieves near-neutrality (score 4) but decentralized heating prevents full carbon neutrality;
- CAPEX decreases in phase 2 as amortization materializes;
- job creation front-loads in phase 1 (construction-intensive) and declines in phase 2 (operations-focused).

Below, we first illustrate each PED transition pathway and then discuss them comparatively.

Table 3: Criteria definitions and scoring assumptions to devise the PED transition pathways.

1. Investment Cost (CAPEX) Period-specific incremental CAPEX in each phase. Score: 5 = minimal/near-zero investment needed (systems already installed), 1 = high capital investment required. Phase 1 (2025-2032): Major system deployment. Phase 2 (2032-2040): Minimal new investment; only maintenance and minor replacements (scores improve to 5). Per-dwelling scores 4-5 (cheapest individual units, minimal phase 2 investment). Centralized hub scores 1 in phase 1 (network infrastructure), then 5 in phase 2 (minimal new CAPEX). Per-building and REC show dramatic improvement in phase 2 as installation phase completes.
2. Operational Cost (OPEX) Period-specific annual running costs (electricity, maintenance, distribution losses) during each phase. Score: 5 = lowest OPEX, 1 = highest OPEX. Phase 1 (2025-2032): High operational costs during transition. Phase 2 (2032-2040): OPEX may decrease as systems mature and efficiency improves. Centralized hub maintains score 2 (optimized efficiency via storage and load matching throughout). Per-dwelling scores 3 (high grid costs, no optimization; minimal improvement in phase 2). Per-building and REC improve in phase 2 as renewable self-consumption increases and distributed systems reach operational maturity.
3. CO_2 Emissions Period-specific annual carbon footprint during each phase. Score: 5 = best emissions performance (lowest CO_2 through active renewable generation), 1 = worst emissions performance (highest CO_2). Phase 1 (2025-2032): Systems deploying; high emissions during transition. Phase 2 (2032-2040): Emissions improve as systems reach full operational efficiency. Centralized hub achieves score 5 (best performance: ~50% renewable locally, optimized efficiency, minimal grid import). REC achieves score 4 (strong performance through community renewables + individual heating). Per-dwelling achieves score 2 (passive grid decarbonization only; zero active renewable contribution—worse than REC despite some grid improvement). Per-building achieves score 2 (modest local solar reduces but cannot offset grid dependency). Virtual PED concept needed for all pathways to reach 2040 climate neutrality targets.
4. Renewable Energy % Share of total demand met by local renewables (solar, geothermal). Score: 5 = 80-100% renewable, 1 = <20%. Per-dwelling: minimal solar feasibility. Centralized: leverages 31,096 m² rooftop area, optimizes with thermal storage, can reach 50%+ on-site + virtual PED for further integration.

5. Energy Independence Period-specific degree of decoupling from external grid and district networks in each phase. Score: 5 = high autonomy, 1 = full grid dependency. Phase 1: Lower independence during deployment (systems not yet optimized). Phase 2: Improves as systems reach full capacity and storage capability matures. Per-dwelling: Remains at 1 throughout (100% grid-dependent). Per-building and REC show modest improvement in phase 2 as local renewable buffering increases. Centralized hub maintains 4-5 in phase 2 through optimized renewable-storage interaction and reduced grid import dependency.
6. Landscape Protection Period-specific minimization of visual, acoustic, and ecological impact during each phase. Score: 5 = minimal footprint, 1 = significant impact. Phase 1: Major impact during construction/deployment (high disturbance). Phase 2: Stabilizes after construction (physical footprint established and unchanging). Per-dwelling: Distributed ASHP units (noise, space)—ongoing impact in both phases. Per-building: Unknown geothermal drilling feasibility; similar pattern to per-dwelling. Centralized hub: Concentrated infrastructure in energy centre; high phase 1 impact (construction) then stable in phase 2. REC: Distributed rooftop solar (favourable, minimal ground impact) with improvement from phase 1 to phase 2 as construction ends.
7. Social Justice Period-specific equity in cost burden, access to benefits, and participatory governance during each phase. Score: 5 = inclusive & collective benefit, 1 = regressive. Phase 1: Higher social burden during expensive deployment phase. Phase 2: Improves as costs amortize and benefits distribute. Per-dwelling: Regressive throughout (high burden on low-income residents in both phases). Centralized hub: Score 5 in phase 1 (collective front-loading), remains high in phase 2 as long-term savings accrue collectively. REC: Strong community governance model; stable high score across phases. Per-building: Moderate equity (score 3 both phases) due to building-level rather than community-level pooling.
8. Job Creation Period-specific local employment in design, construction, operation, and maintenance during each phase. Score: 5 = high job intensity, 1 = minimal employment. Phase 1 (2025-2032): Construction-intensive; high employment across all pathways. Phase 2 (2032-2040): Reflects operational labour-intensity of each pathway—decreases less for complex systems requiring skilled technicians, decreases more for simple systems with minimal maintenance. Per-dwelling: Low skills, minimal jobs (2→1; only occasional ASHP servicing). Per-building: Moderate phase 1 (construction), drops to 2 in phase 2 (building-level maintenance). REC: High phase 1 (3→3; sustained by technician team for battery/renewable management and community coordination). Centralized hub: Highest phase 1 (5) then 4 in phase 2 (skilled staff for energy centre 24/7 operations, network monitoring, storage management—most labour-intensive operat.).

The scoring assumptions are further detailed, especially as concerns their application over the two subsequent phases, in Table 4.

Table 4: Scoring assumptions that apply differently to the two transition phases.

Criterion	Phase 1 (2025-2032)	Phase 2 (2032-2040)	Logic
CAPEX	Phase-specific investment needed	5 for most (minimal new capital)	Per-dwelling: 4→5; Per-building: 2→5; Hub: 1→5; REC: 2→5
OPEX	Annual costs during deployment	Annual costs during operations	Relatively stable; modest improvement as systems optimize
CO_2 Emissions	High (systems transitioning)	Improving (systems at full capacity)	Hub: 2→5 (carbon neutral); REC: 3→4 (near-neutral); Per-dwelling: 3→4 (grid decarbonization)
Renewables %	Lower (installations in progress)	Higher (full capacity reached)	Hub: 4→5; REC: 3→4; Per-building: 2→3; Per-dwelling: 1→1
Energy Independence	Lower (systems ramping up)	Higher (optimized performance)	Hub: 4→5; REC: 2→3; Per-building: 2→3; Per-dwelling: 1→1
Landscape Protection	High impact (construction phase)	Stable (post-construction)	All improve slightly in phase 2 as disturbance ends
Social Justice	Variable (deployment burden)	Generally improves (cost amortization)	Hub: 5→4 (costs absorbed), REC: 4→4 (community benefit stable)
Job Creation	High (construction-intensive)	Reflects operational labour-intensity	Hub: 5→4 (most labour-intensive oper.); REC: 4→3 (technician team); Per-building: 3→2 (minimal maintenance); Per-dwelling: 2→1 (minimal oper.)

6.1 Per Dwelling PED transition pathway

This *PED transition pathway* is characterised by relatively high costs in the consolidation phase but low greenhouse gas reductions; it performs very well on (local) landscape protection and very poorly on most other indicators (Figure 13).

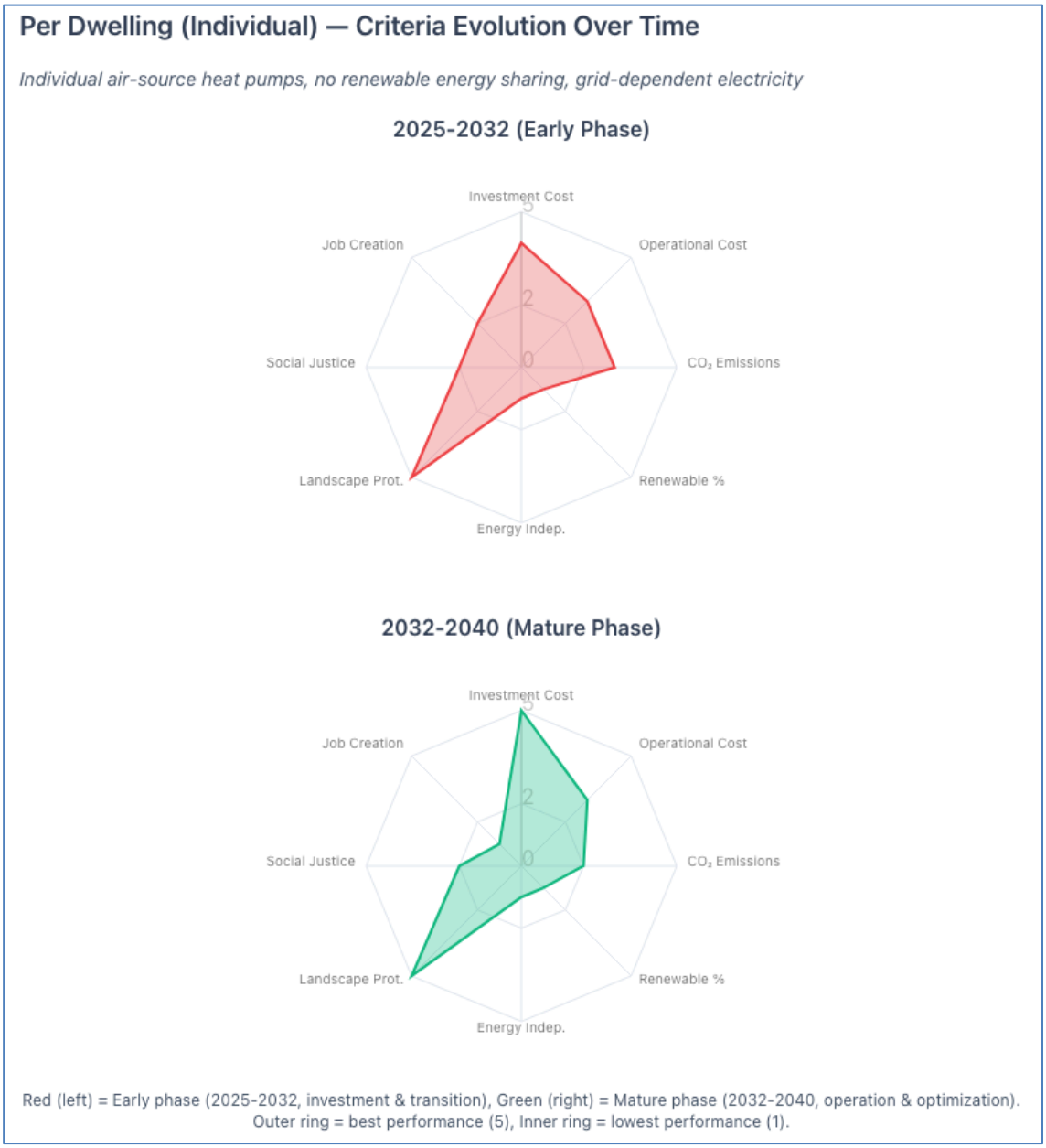

Figure 13: A radar diagram of the "Per dwelling" PED transition pathway with regard to the 8 assessment criteria, in the start-up phase (top pane) and in the consolidation phase (bottom pane).

6.2 Per Building PED transition pathway

When compared to the previous one, the *Per building PED transition pathway* shows better performance according to the socio-economic criteria and of the energy indicators, while CO_2 emissions and investment costs in phase 1 are worse (Figure 14).

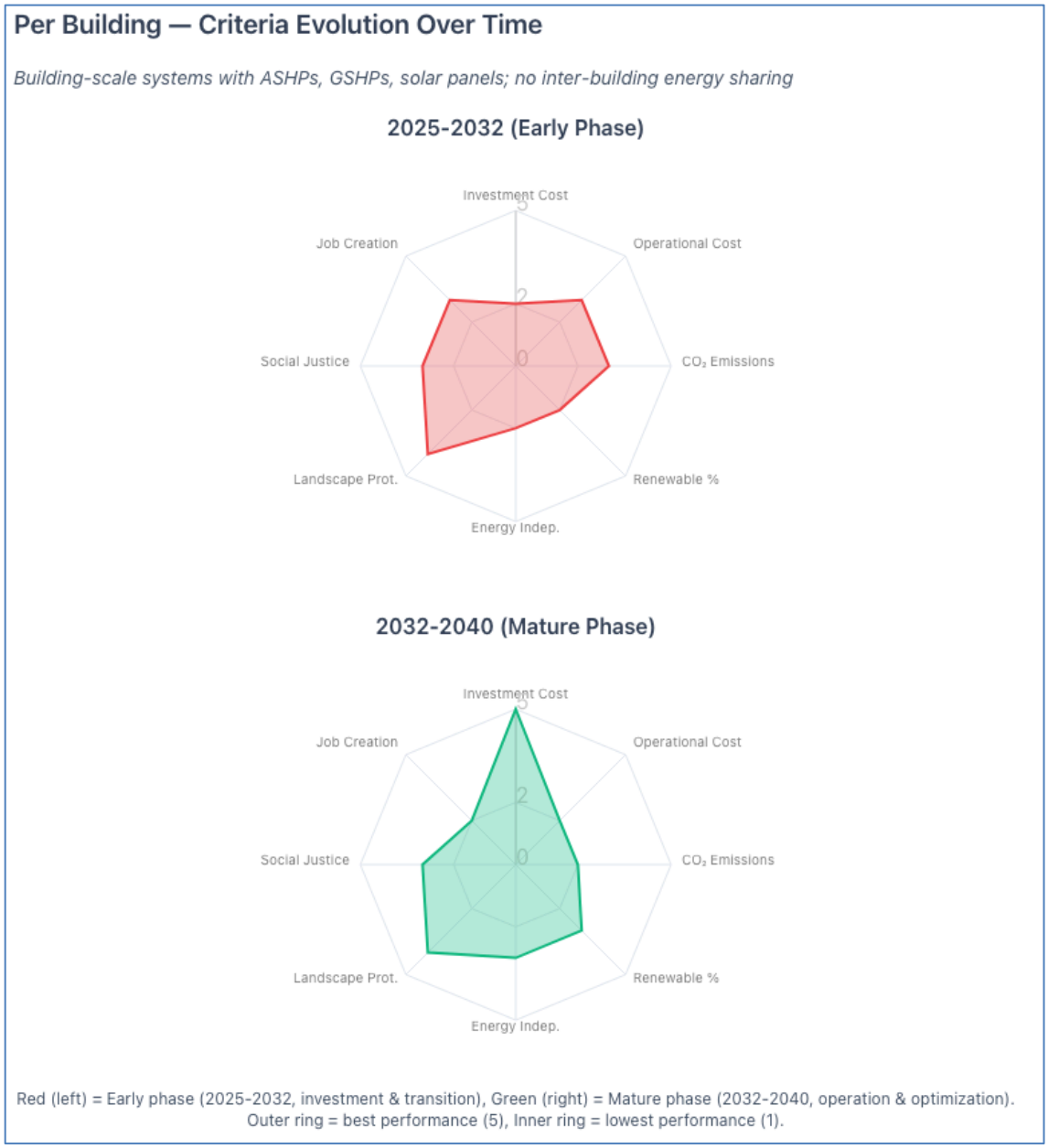

Figure 14: A radar diagram of the "Per building" PED transition pathway with regard to the 8 assessment criteria, in the start-up phase (top pane) and in the consolidation phase (bottom pane). ASHP=Air Source Heat Pump; GSHP=Ground Source Heat Pump.

6.3 Energy Hub PED transition pathway

Under the centralised Energy Hub PED transition pathway there is a clear difference between the two phases, with both CO2 emissions and investment costs dropping over time. This is the only pathway potentially achieving climate neutrality by 2040 (Figure 15).

Figure 15: A radar diagram of the "Energy Hub" PED transition pathway with regard to the 8 assessment criteria, in the start-up phase (top pane) and in the consolidation phase (bottom pane).

6.4 Renewable Energy Community PED transition pathway

The profile of performances according to the eight criteria under the REC transition pathway is similar to the centralised Energy Hub, yet smoothed (Figure 16).

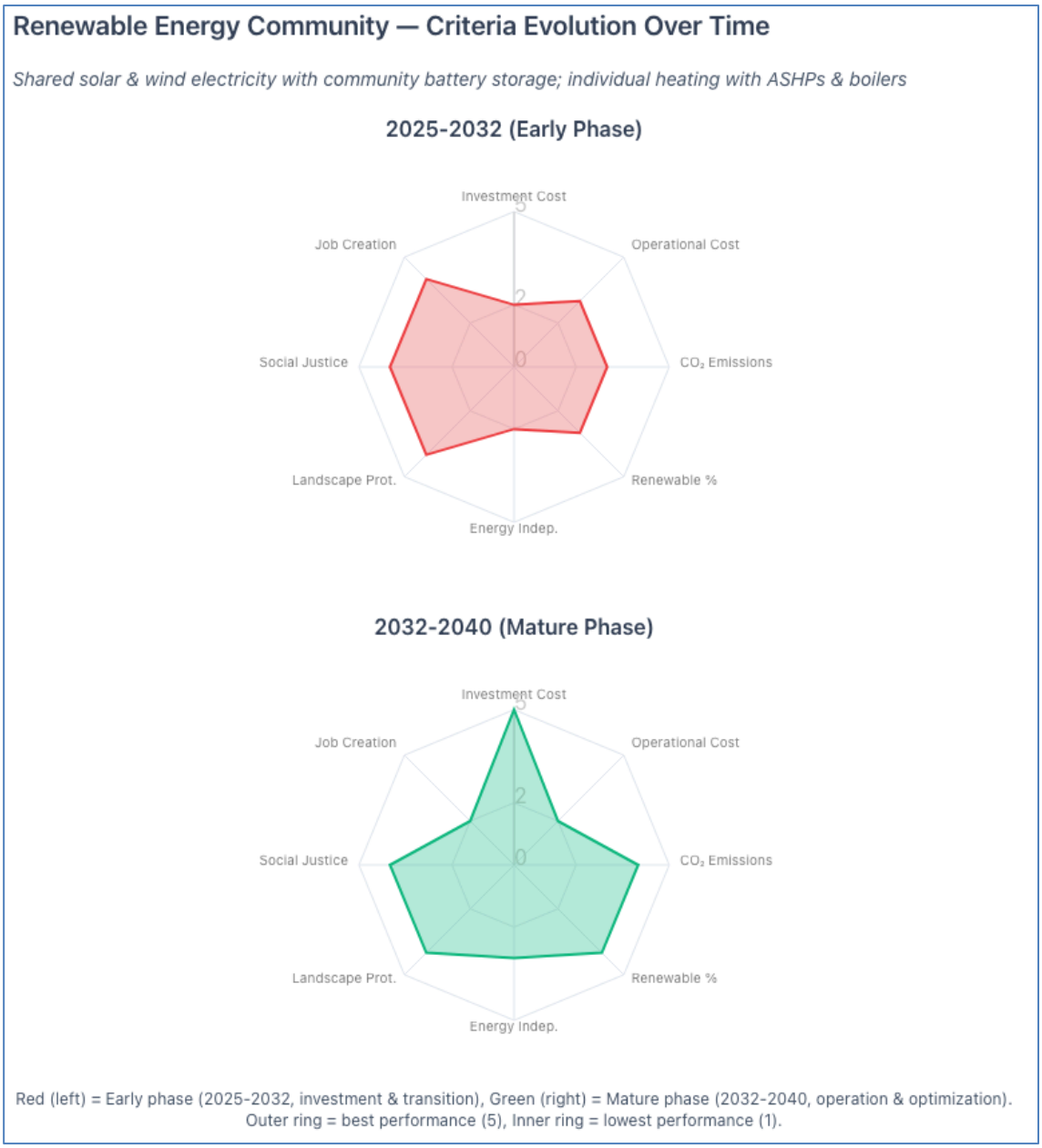

Figure 16: A radar diagram of the "Renewable Energy Community" PED transition pathway with regard to the 8 assessment criteria, in the start-up phase (top pane) and in the consolidation phase (bottom pane). ASHP=Air Source Heat Pump.

6.5 Comparing PED transition pathways

Only Centralized Energy Hub independently achieves strict carbon neutrality. REC approaches it (score 4). Per-dwelling and per-building would require virtual PED renewable imports or deep building renovation to meet 2040 climate targets set by the City of Bari in its Single Programming Document.

Given all pathways require virtual PED renewable imports to achieve strict carbon neutrality, centralized Hub and REC are most efficient architectures (requiring least external support due to active renewable generation). Per-dwelling and per-building require disproportionately large virtual PED contributions.

The key Findings from the analysis of San Paolo PED transition pathways can in fact be summarised as follows:

- **Energy Hub**: Only pathway approaching carbon neutrality by 2040, though still relying on renewable energy imports. Lowest total annual costs (cut in half when compared to the Per-dwelling PED transition pathway) due to economies of scale, thermal/battery storage optimization.
- **Renewable Energy Community**: Advances toward decarbonization through community-scale renewable generation and battery storage. Decentralized heating limits full neutrality but offers better social equity and job creation than per-dwelling arrangements.
- **Per Dwelling**: Highest costs; improves emissions passively via grid decarbonization but cannot actively contribute to renewable generation. Fails to get anywhere close to 2040 climate neutrality municipal targets.
- **Per Building**: Moderate costs with modest emissions reduction from local solar deployment. Insufficient for carbon neutrality without external support.

Against the backdrop of alternative PED models (Vandevyvere *et al*., 2020) no transition pathway is full in line with an autonomous arrangement; the Energy Hub and, to a lesser extent, the REC transition pathway, may approach a dynamic PED model; both decentralised transition pathways (Per dwelling and Per building) require virtual PED renewable imports or deep building renovation to meet climate targets.

Spatial strategies also have a bearing on the feasibility and performance of PED transition pathways. Although causal effects cannot be easily attributed, in the following paragraphs we discuss these relationships for each spatial strategy with reference to the eight evaluation criteria used in the assessment.

Urban regeneration strategy (URS)

By embedding energy renovation, envelope upgrades, and building-services modernisation in the regeneration toolkit (common design standards, coordinated works, predictable sequencing), this strategy may reduce transaction costs and permit uncertainty at building and block scale. It therefore increases the feasibility of the Per-Building pathway (bundled roof, plant-room, and wiring works) and

supports Renewable Energy Communities (consistent, PV-ready rooftops). Expected gains concentrate in capital expenditure (procurement efficiencies and shared works), operating expenditure (lower losses and maintenance), landscape compatibility (heritage-sensitive detailing), and—where renovation depth is meaningful—CO_2 reduction and share of renewables.

Sustainable Urban Mobility Plan (SUMP)

New slow-mobility links, public-transport upgrades, depot electrification, and the intelligent transport system provide schedulable electric-vehicle loads at depots and along major streets. When coordinated by a district-level energy management system (EMS), charging can be shifted to align with local photovoltaic production and tariff signals. Because chargers and cables are installed along existing transport or utility corridors—rather than in parks or open land—visual and ecological effects are limited and more easily managed. The main improvements accrue to operating expenditure (higher self-consumption), CO_2 reduction, and energy independence, with low landscape impact when siting follows the service-corridor principle.

Regional Landscape and Territorial Plan (RTLP)

The plan articulates ecological and cultural structures (green-blue corridors, heritage landscapes) that must be preserved. These areas are not suitable locations for network infrastructure. However, by clarifying the spatial structure and the buffers such assets require, the plan indirectly supports infrastructure planning in separate service corridors—existing streets, brownfield spines, rail margins—running parallel to or connecting with protected elements without overlapping them. This reduces siting conflict and helps maintain landscape quality while enabling ducting and equipment placement at nearby nodes (depots, civic yards, car parks). The result is greater feasibility for both Energy Hub interconnections (pipes, cables, data links) and Renewable Energy Community canopies and micro-hubs, with steady gains in CO_2 reduction, renewables share, and social justice where access to amenities improves.

Electrical network development (transmission and distribution)

Transmission reinforcements and Medium Voltage/Low Voltage upgrades expand hosting capacity and shorten interconnection lead times. Critically, most of the district falls under a single primary substation, which aligns well with the regulatory perimeter for energy sharing. This sharpened geometry materially improves the feasibility and economics of Renewable Energy Communities and simplifies interfacing for the Energy Hub. The principal effects are higher energy independence (more local matching), better operating expenditure (reduced curtailment and delays), and stronger CO_2 reduction.

Metropolitan Strategic Plan (MSP)

The Metropolitan Strategic Plan introduces a flagship public-investment action for Positive Energy Districts focused on public and social-housing stocks. By securing early coordination capacity and initial capital costs, it raises near-term feasibility for the Energy Hub pathway (shared assets, storage, controls) and stabilises employment in operations and maintenance. Consolidation of generation,

storage, and demand management within the district boundary supports strong CO_2 reduction and renewables share without relying on electricity or heat exports.

Single Programming Document

The Single Programming Document commits to municipal retrofits, climate-adaptation measures (greening, de-sealing, climate shelters), and targeted rollout of RECs to address energy poverty. Demand-side reductions improve the feasibility of all pathways. The REC help-desk lowers soft costs and may improve social justice (through targeted inclusion). Urban greening reduces cooling loads, further improving operating expenditure and CO_2 outcomes across Per-Building, REC, and Energy Hub PED configurations.

Taken together, the spatial strategies:

- Lift Per-Building above Per-Dwelling on capital and operating expenditure and landscape through coordinated renovations.
- Enable Renewable Energy Communities to approach Energy Hub levels on CO_2 reduction, renewables share, and operating expenditure where substation geometry and rooftop potential are fully exploited.
- Position the Energy Hub as the only architecture capable of approaching neutrality by 2040 through local generation, storage, and low-temperature thermal networks, within the district boundary and without export logic, provided infrastructure follows service corridors that are spatially coordinated with—yet distinct from—ecological and heritage structures.

7 Conclusions

Task 5.4 “Integration of PED Action Plans within spatial strategies towards just energy & climate transitions” examined the relationships between PED action planning in the target neighbourhoods and spatial strategies that could significantly impact the development trajectories of area-based energy transitions (Moroni *et al*., 2019). Based on a preliminary test addressing the Italian target area (the San Paolo district in Bari), the outcomes of the research activities carried out under Task 5.4 have helped clarify some of the connections and interdependencies between the relevant spatial strategies (Section 3), a condensed representation of the processes through which the energy transition progresses (Section 4) and the multistakeholder dynamics through which the opportunities and constraints of the regulatory and policy framework can be tapped into and overcome, respectively.

Building on previous deliverables (such as D.3.5), the report investigates how the techno-energetic dimension of PED building interacts with the institutional and policy dimensions. According to the simplified assumptions made in Section 6, it was found that transition pathways can be conceptualised as multidimensional and flexibly evolving over time. This analysis is based on the development of the four PED energy scenarios in D.3.5, which are examined through two subsequent stages: start-up and consolidation. When these results are applied to the specifics of local community dynamics, they align with reflections on the influence of path dependency and timing on energy transitions (Sovacool, 2016).

However, many research prospects have only been hinted at, including the implications of each spatial strategy, and of the regulatory and policy framework in general, on the alternative scenarios and pathways. The multicriteria evaluation approach, which broadens the two-objective optimisation put forward in D.3.5, is worth further investigation. This would only truly make sense if a co-creation approach were adopted, in line with the problematisation of stakeholder engagement discussed in Deliverable 5.1 (Lennon et al., 2019; Marcon Nora *et al*., 2023; Ruggiero *et al*., 2014).

References

Albrechts, L. (2004). Strategic (Spatial) Planning Reexamined. *Environment and Planning B: Planning and Design*, 31(5), 743–758. https://doi.org/10.1068/B3065.

del Pozo, R. G., Dias, L. C., & García-Lapresta, J. L. (2020). Using Different Qualitative Scales in a Multi-Criteria Decision-Making Procedure. *Mathematics* 2020, 8(3), 458. https://doi.org/10.3390/MATH8030458.

Healey P. (2007). *Urban Complexity and Spatial Strategies: Towards a Relational Planning for Our Times*. Routledge, London.

Innes J.E., Booher D.E. (2018). *Planning with Complexity – An Introduction to Collaborative Rationality for Public Policy (Second edition)*. Routledge, London.

Lennon, B., Dunphy, N. P., & Sanvicente, E. (2019). Community acceptability and the energy transition: A citizens' perspective. *Energy, Sustainability and Society*, 9(1), 1–18. https://doi.org/10.1186/s13705-019-0218-z

Marcon Nora, G. A., Alberton, A., & Ayala, D. H. F. (2023). Stakeholder theory and actor-network theory: The stakeholder engagement in energy transitions. *Business Strategy and the Environment*, 32(1), 673–685. https://doi.org/10.1002/bse.3168

Metropolitan City of Bari. (2024a). Metropolitan Urban Plan for Sustainable Mobility, General report (Relazione generale, in Italian), https://www.cittametropolitana.ba.it/EG0/EGSCHTST113.HBL?en=eg527&MESSA=PUBBLICA&SRL=108.

Metropolitan City of Bari. (2024b). Metropolitan Urban Plan for Sustainable Mobility, Policy scenario (Scenario di Progetto, in Italian), https://www.cittametropolitana.ba.it/EG0/EGSCHTST113.HBL?en=eg527&MESSA=PUBBLICA&SRL=108.

Moroni, S., Alberti, V., Antoniucci, V., & Bisello, A. (2019). Energy communities in the transition to a low-carbon future: A taxonomical approach and some policy dilemmas. *Journal of Environmental Management*, 236, 45–53, https://doi.org/10.1016/J.JENVMAN.2019.01.095.

Puglia Regional Government. (2015a). *Regional Territorial Landscape Plan. Elaborato n. 5 del Piano Paesaggistico Territoriale Regionale - Schede degli ambiti paesaggistici: Ambito 05 Puglia* centrale (in Italian). Bari: Puglia Regional Government, https://pugliacon.regione.puglia.it/web/sit-puglia-paesaggio/tutti-gli-elaborati-del-pptr [15/11/2025].

Puglia Regional Government. (2015b). *Regional Territorial Landscape Plan. Elaborato n. 4.2.5 I sistemi territoriali per la fruizione dei beni patrimoniali (in Italian)*. Bari: Puglia Regional Government, https://pugliacon.regione.puglia.it/web/sit-puglia-paesaggio/tutti-gli-elaborati-del-pptr [15/11/2025].

Ruggiero, S., Onkila, T., & Kuittinen, V. (2014). Realizing the social acceptance of community renewable energy: A process-outcome analysis of stakeholder influence. Energy Research and Social Science, 4, 53–63. https://doi.org/10.1016/j.erss.2014.09.001

Sovacool, B. K. (2016). How long will it take? Conceptualizing the temporal dynamics of energy transitions. *Energy Research & Social Science*, 13, 202–215. https://doi.org/10.1016/J.ERSS.2015.12.020

Terna S.p.A. (2025). Terna S.p.A. National Transmission Network Development Plan 2023.

Vandevyvere, H., Ahlers, D., & Wyckmans, A. (2022). The Sense and Non-Sense of PEDs—Feeding Back Practical Experiences of Positive Energy District Demonstrators into the European PED Framework Definition Development Process. *Energies,* 15(12), 4491. https://doi.org/10.3390/EN15124491.

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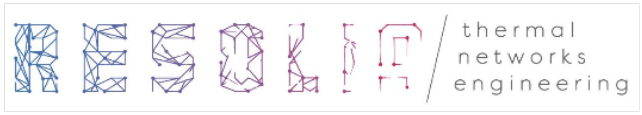	Resolia Engineering bureau Sustainable & efficient thermal networks (Resolia)
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