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PREPARING FOR JUST GREEN TRANSITION – A SCENARIO-BASED ASSESSMENT IN A PREFABRICATED HOUSING DISTRICT IN TIRANA, ALBANIA

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Abstract. The global imperative to transition to sustainable, carbon-free systems has a significant impact on urban areas, especially the residential sector. Through a case study of Tirana (Albania), this paper aims to investigate how a just green transition can be achieved at the neighbourhood level and what impacts can be expected in a prefabricated, multi-household residential area. Employing an ex-ante scenario-based approach, the research highlights and compares four alternative pathways for the future development of the housing stock by 2040, ranging from minimal upgrades (enhanced energy performance) to integrated greening (enhanced environmental performance with renewables and nature-based solutions) and full redevelopment. Utilising both qualitative and quantitative methods, including surveys, in-site measurements, co-design processes with local stakeholders, and GIS-based environmental mapping, the study evaluates the costs, benefits, and co-benefits of implementing a just green transition in a challenging urban context, with a focus on neighbourhood communities. Findings from this research provide valuable evidence to inform the drafting of long-term renovation strategies at the local level in Western Balkan countries, in line with recommendations from the Green Agenda in the Western Balkans.

Keywords: just green transition, green infrastructure, cost-benefit analysis, ENVI-met microclimate modelling, urban retrofit, Western Balkans.

Introduction

Climate change and the pursuit of climate-neutral development have made a just green transition a top policy priority across Europe and beyond. The European Green Deal, launched in 2020, commits the European Union to lowering net greenhouse gas emissions by approximately 55% by 2030 (relative to 1990 levels) and achieving net-zero emissions by 2050, in accordance with the objective of 'leaving no person or place behind' (EC, 2023). This principle stresses the importance of a just transition, ensuring that the benefits and burdens of the envisioned green shift are shared fairly across society (Newell & Mulvaney, 2013; Heffron & McCauley, 2018; Resnik, 2022; EEA, 2024; Kortetmäki et al., 2025).

In the Western Balkans (WB), countries endorsed these goals through the Green Agenda for the Western Balkans (GAWB), as confirmed by the Sofia Declaration of 2020. The latter reflects EU priorities across five pillars: climate action (decarbonisation, energy, and mobility), circular economy, depollution, sustainable agriculture, and biodiversity. However, implementing these commitments occurs in a context characterised by structural socio-economic constraints, ageing infrastructure, and limited fiscal capacities, raising questions not only about environmental effectiveness but also about affordability, feasibility, and social equity (RCC, 2020).

A particularly pressing challenge in this context is the decarbonisation and renewal of post-socialist urban neighbourhoods dominated by large-panel, prefabricated apartment buildings. Albania, like many Western Balkan countries, faces an ageing housing stock built during the mid-20th century that is energy-inefficient and vulnerable to climate stresses. To a large extent, Albania's urban population reside in multifamily apartment buildings, many of which were built using prefabricated concrete panels starting from the 1960s. In general, these buildings present low thermal performance standards and, to date, face problems with insulation, drafty exteriors, and obsolete mechanical systems (Guri et al., 2023). The Institute of Statistics (INSTAT, 2023) highlights that residents of buildings in this category experience excessive energy consumption and uncomfortable living conditions. Until recently, the lack of a comprehensive strategy for building renovations (particularly prefabricated ones), along with insufficient financial support for energy efficiency, has created a gap in retrofitting Albania's existing housing stock (Murataj et al., 2018). Many households are unable to afford extensive energy renovations, raising concerns about energy poverty and inequality as energy costs rise. In this context, a just green transition must address not only technical sustainability measures but also social factors such as affordability, meaningful stakeholder participation, and the avoidance of 'green gentrification' (Anguelovski et al., 2019).

Tirana, Albania's capital, exemplifies these challenges and, at the same time, opportunities. Rapid urbanisation, increasing exposure to heat stress, and ageing residential infrastructure have prompted policymakers and researchers to explore alternative neighbourhood-level transition pathways that balance climate mitigation, urban environmental quality, and social equity. Implementing a just green transition at the neighbourhood level entails balancing multiple objectives under a holistic approach: reducing emissions and energy demand, improving microclimatic and environmental conditions, and protecting residents from displacement, unaffordable costs, or exclusion from decision-making processes. The holistic approach resonates with the concept of nature-based solutions and ecosystem-based urban planning, which aim to synergise environmental and social benefits (Demuzere et al., 2014; Kabisch et al., 2016). For the purposes of our study, we operationalise 'just' aspects of the green transition through two main dimensions: distributional justice (fair distribution of costs and benefits among stakeholders, avoiding undue burdens on vulnerable groups) and procedural justice (inclusive, participatory decision-making processes).

In this context, the research problem examined in this paper is how various neighbourhood-level green transition pathways perform when assessed simultaneously in terms of socio-economic efficiency, environmental outcomes, and justice-related implications within a post-social urban setting. To explore this issue, the paper develops and compares four scenarios for a selected prefabricated housing neighbourhood in Tirana, extending up to 2040 and ranging from delayed transition to full redevelopment (see Table 1). These scenarios represent different levels of systemic intervention and transformation, leading to varying economic, environmental, and social trade-offs.

Table 1. Preparing for just green transition scenarios

Scenario	Description
Scenario 0 Delayed Transition (baseline)	A counterfactual scenario with no proactive climate action and only minimal maintenance.
Scenario 1 Enhanced energy performance	A deep retrofit of existing buildings to enhance energy efficiency, including thermal insulation, efficient windows, and heating systems, to meet modern standards, aiming for energy class A performance.
Scenario 2 Renewables and Nature-Based Solutions	An integrated green retrofit scenario which, alongside provisions in Scenario 1, includes on-site renewable energy (photovoltaic panels, solar thermal heaters) and nature-based solutions such as rooftop rainwater harvesting and urban greening.
Scenario 3 Redevelopment (build-anew)	A transformational scenario in which the old buildings are torn down and the neighbourhood is rebuilt from scratch. New energy-efficient, multi-storey buildings replace the old stock through public-private partnerships and land value capture to finance the redevelopment.

Source: authors processing.

The main contribution of the paper is its comparative evaluation of these scenarios using a mixed-methods framework, in which Environmental and Social Cost-Benefit Analysis (ES-CBA) is employed as a decision-support tool to assess socio-economic efficiency, while environmental and justice-related aspects are examined through a combination of quantitative indicators and qualitative analysis (including urban heat island mitigation, air quality improvements, and stormwater management) for each scenario. ES-CBA is utilised to estimate net socio-economic impacts and support comparisons across scenarios, but it is not regarded as a comprehensive measure of justice. Instead, justice considerations – covering distributional effects, affordability, and procedural aspects such as stakeholder participation – are used to critically interpret and contextualise the economic results, recognising that efficiency gains may coexist with unequal or contested social outcomes. This approach is demonstrated through various theoretical and practical examples of multi-criteria evaluation of green infrastructure and retrofit interventions, recognising that the use of solely financial indicators might overlook other important unintended outcomes (Hansen & Pauleit, 2014; Meerow, 2020). In developing the scenarios and assessing their feasibility, residents and city stakeholders were engaged through surveys and design workshops. Co-design processes in similar contexts have been shown to enhance the relevance and acceptance of green infrastructure solutions, while also posing challenges in blending scientific and local knowledge (Schaefer, 2022).

Accordingly, the paper addresses the following research question: How do different neighbourhood-scale green transition scenarios vary in their socio-economic efficiency, environmental performance, and justice-related impacts within a Western Balkan, post-socialist urban context? By answering this question, the paper does not aim to rank scenarios solely based on economic factors, nor to reduce justice to a single metric. Instead, it seeks to reveal trade-offs and synergies among efficiency, environmental quality, and justice considerations, thereby supporting more balanced and transparent decisions in urban transitions.

The aim of the paper is therefore to offer evidence-based guidance for local authorities and planners in Tirana and similar Western Balkan cities, supporting the development of long-term renovation and redevelopment strategies that are economically sustainable, environmentally effective, and socially fair, in accordance with the Green Agenda for the Western Balkans and the EU's just transition goals.

Background and Conceptual Framework

Just Transitions in Urban Renovation: Justice as an Analytical Lens

Research on "Just Transition" originates from debates in climate and energy policy, where it emerged as a response to concerns that decarbonisation might impose disproportionate socio-economic burdens on certain groups or territories (Heffron & McCauley, 2018). While early work primarily focused on labour markets and regions dependent on fossil fuels, more recent research has expanded the concept to urban settings, where climate mitigation and adaptation intersect directly with housing, affordability, and daily living conditions (EC, 2023). In cities, a just transition is increasingly seen as one that achieves environmental improvements without exacerbating existing inequalities or causing displacement or 'green gentrification,' especially in disadvantaged neighbourhoods. For instance, retrofitting older buildings can lower emissions and improve living standards, but without safeguards, it may cause higher rents or 'green gentrification,' pushing vulnerable residents out of redeveloped neighbourhoods (Anguelovski et al., 2019).

A key issue in urban sustainability research is balancing environmental goals with social equity. Environmental justice studies show that low-income and marginalised communities often reside in areas with poorer environmental quality, such as increased pollution and fewer green spaces, and may lack resources to adapt or benefit from green investments (Fairburn et al., 2009). Achieving a just green transition requires targeted support for these communities, inclusive decision-making, and the sharing of benefits such as energy savings and improved health outcomes (ILO, 2015). In Eastern European and Western Balkan cities, this issue is particularly relevant given the prevalence of large housing blocks and economic constraints. Ensuring fairness might involve community participation in planning (co-design), providing subsidies or financial tools for low-income residents to fund building renovations, and implementing policies to prevent involuntary displacement during neighbourhood redevelopment (Bouzarovski & Tirado Herrero, 2017). This study emphasises co-design and scenario analysis at the neighbourhood level, driven by justice concerns, recognising residents as key stakeholders and assessing scenarios based not only on economic efficiency but also on their impact on local communities (Schaefer, 2022).

Economic Evaluation of Green Urban Interventions: Evidence and Limits

A second, closely related strand of literature concerns the economic evaluation of green urban projects, particularly through the Cost-Benefit Analysis (CBA) and its extended forms, often called Social Cost-Benefit Analysis (S-CBA) or Environmental and Social CBA (ES-CBA) (OECD, 2018; O'Mahony, 2021). Empirical studies apply these frameworks to energy-efficiency retrofits, renewable energy deployment, and urban infrastructure investments, especially where public funding is limited and economic justification is required (EIB, 2020; Ekins & Zenghelis, 2021). At the same time, scholars have long acknowledged the limitations of CBA in capturing non-market values and distributional concerns (Hanley & Spash, 1993). Ecosystem services, social cohesion, and perceived well-being are often only partially monetised or excluded altogether, which can bias decision-making towards interventions with easily quantifiable returns. In response, several authors advocate combining CBA with complementary qualitative or multi-criteria assessments to ensure that economic efficiency does not overshadow broader sustainability or justice considerations (Geneletti, 2011). Regional evidence, such as the Bosnia Energy Efficiency Project (BEEP), which successfully applied CBA to building retrofit programmes, confirms both the usefulness of CBA as a screening tool and the need for contextual interpretation of results (World Bank, 2020). Our approach builds on this evidence, tailoring the ES-CBA to reflect the various outcomes for each scenario in Tirana.

Environmental Performance and Ecosystem-Based Approaches at Neighbourhood Scale

There is a body of literature focusing on the environmental performance of urban interventions, particularly through ecosystem-based planning and nature-based solutions. Research indicates that incorporating green infrastructure into dense urban neighbourhoods offers multiple co-benefits, such as regulating microclimates, enhancing air quality, managing stormwater, and improving liveability (Hansen & Pauleit, 2014; Kabisch et al., 2016). Studies in Mediterranean and warm-climate cities emphasise the potential of vegetation, permeable surfaces, and shading techniques to reduce urban heat stress, though there are context-specific trade-offs related to ventilation and pollutant dispersion (Demuzere et al., 2014; Meerow, 2020). Benefits from these green interventions include cooling through evapotranspiration and shade, which can dramatically lower air and surface temperatures. Large canopy trees, such as the plane tree (*Platanus sp.*), can significantly reduce heat buildup by lowering surface temperatures under their shade by up to 20–25°C (Akbari et al., 2001). Adding trees and green areas to a neighbourhood can lower ambient temperatures during heat waves by a few degrees Celsius, potentially saving lives in extreme situations (Renuka et al., 2022). Trees and urban greenery also improve air quality by filtering pollutants: they absorb gases such as NO_2 and O_3 and intercept particulate matter on their leaves, reducing nearby pollutant levels (Nowak et al., 2006; Abhijith et al., 2017). A fully grown deciduous tree can produce oxygen, store carbon, and absorb tens of kilograms of pollutants each year (Nowak et al., 2006). Nature-based solutions provide vital stormwater management by using green infrastructure – such as permeable surfaces, vegetated swales, and rainwater harvesting – to reduce runoff and prevent flooding, especially as climate change intensifies storms. The ecosystem approach boosts biodiversity by restoring habitats and providing recreational and aesthetic benefits, thereby enhancing mental health and urban livability (Mansor et al., 2012; Byrne, 2022). The multifunctionality of green infrastructure is widely acknowledged. Demuzere et al. (2014) describe urban green spaces as providing a range of ecosystem services, from local cooling and pollution mitigation to enhancing city-wide climate resilience. However, planning often reveals trade-offs and challenges, such as conflicts between green space development and urban growth, as well as the ongoing need for governance and funding for nature-based solutions (Meerow, 2020).

Importantly, the literature increasingly recognises that environmental performance cannot be assessed in isolation from social outcomes. High-quality green amenities may inadvertently contribute to green gentrification if governance mechanisms fail to protect affordability and access (Anguelovski et al., 2019). As a result, recent studies argue for integrated assessment approaches that evaluate environmental benefits alongside social and economic implications, particularly at the neighbourhood scale where residents most directly feel impacts.

Co-Design and Participation as Enablers of Just Urban Transitions

Implementing neighbourhood-scale transitions successfully requires more than just technical solutions; social innovation within the planning process is essential. Participatory approaches are shown to enhance procedural justice, incorporate local knowledge, and improve the legitimacy of planning decisions (Holman et al., 2018; Cook et al., 2021; Langhans et al., 2023; Ricci et al., 2025).

Empirical evidence from co-designed green infrastructure and retrofit projects suggests that while participation does not eliminate trade-offs, it can make them more transparent and negotiable, thereby improving implementation prospects (Schaefer, 2022). Schaefer (2022) describes a project in Dortmund (Germany), in which scientists and urban planners collaborated with local stakeholders in a workshop to develop Green Infrastructure (GI) measures for a disadvantaged neighbourhood. These measures were then simulated using ENVI-met to predict their impacts on heat and air quality. The study found that while the GI scenario could reduce the thermal comfort index (Physiological Equivalent Temperature – PET) by up to 2.5°C, it also led to a slight increase in particulate matter in some areas due to reduced wind. The result highlights a trade-off that underscores the importance of simulation. Interestingly, the study also showed that the learning effects of the co-design process were more significant for researchers than practitioners, suggesting a need for better integration of knowledge. Therefore, co-design must be carefully managed to encourage mutual learning; academics might need to adapt their communication for practicality, and residents or planners may require accessible tools to visualise and understand proposed changes (Tewdwr-Jones & Wilson, 2022; Utami et al., 2022).

In post-socialist and Western Balkan countries, documented experiences with formal co-design remain limited. However, emerging initiatives indicate increasing recognition of community engagement as a prerequisite for successful neighbourhood regeneration. Stakeholder engagement is vital for a fair transition; it underpins social acceptance and the sustainability of interventions. A retrofit programme that requires households to pay must build residents' trust and demonstrate benefits, or it risks failure. Likewise, a redevelopment plan (like our Scenario 3) needs consensus on compensation, relocation, and return options, which calls for extensive dialogue and transparency. Co-design can help identify acceptable solutions, such as work sequencing, the inclusion of community facilities, or maintaining some housing affordability for original residents. Overall, literature suggests that co-design and active stakeholder involvement generally lead to better outcomes in sustainability efforts (Fraser et al., 2006). Our approach leverages these findings by combining technical analysis with participatory methods to create scenarios that are both innovative and grounded in the local context.

Therefore, these strands of literature converge on a shared insight: neighbourhood-scale green transitions are inherently multidimensional, requiring simultaneous consideration of economic efficiency, environmental performance, and justice-related outcomes. Prior research demonstrates that focusing on any single dimension in isolation risks producing partial or misleading conclusions. This review, therefore, motivates an integrated analytical framework in which economic evaluation tools serve as decision-support instruments, environmental assessments capture ecosystem-based co-benefits and trade-offs, and justice considerations critically contextualise both. The present study positions itself at the intersection of these research streams by comparatively assessing alternative neighbourhood-level transition scenarios through a combined socio-economic, environmental, and justice-oriented lens. The following section details how this integrated perspective is operationalised in the study's methodology.

Methodology

Case Study Area and Data Collection

The study employs a mixed-methods approach, including both qualitative and quantitative methods. Qualitative methods include case studies, observational, stakeholder interviews and workshops for assessing the potential costs and benefits of the net-zero transition. The case study area is confined to the '21 Dhjetori' neighbourhood of Tirana (Fig. 1), a typical community characterised by prefabricated apartment blocks.

Figure 1. Case study area (map and birdview image)
Source: authors' processing.

This area mainly consists of mid-rise residential buildings (3–5 storeys) built in the 60s-70s, housing both owner-occupied and rented units. The selection of the targeted area is based on criteria such as accessibility, costs, and the area's socio-economic and environmental conditions. The latter were assessed through an observational approach, including interactions among the incumbents and with the neighbourhood (Fig. 2). The quantitative approach included the use of several tools, including a questionnaire-based survey and on-site measurements conducted according to standardised methods. All information collection occurred throughout 2023–2024 and laid the groundwork for environmental modelling, ecosystem assessment, and ES-CBA at the scenario level.

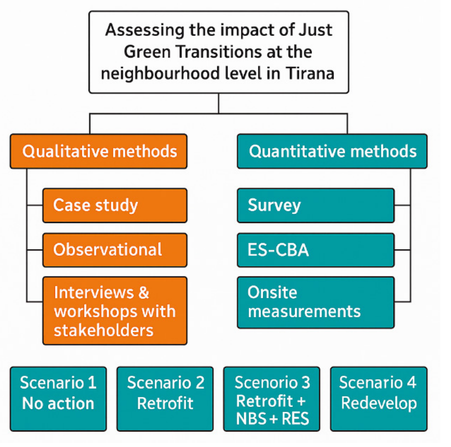

Figure 2. The research approach and instruments
Source: authors' processing.

Household survey, targeting the entire population in the case study area (11 buildings) through a structured questionnaire to gather information on demographics, household income, energy use patterns, recent renovation activities, willingness to pay for improvements, and perceptions of neighbourhood issues. The survey aimed to explore current energy consumption patterns (heating, cooling, appliances), comfort levels, and residents' priorities and concerns. Additionally, the survey explored social cohesion factors relevant to co-financing potential, such as whether buildings have functioning homeowner associations or administrators. Detailed findings from the survey can be found in (Toska et al., 2025).

Stakeholder semi-structured interviews and workshops, including local municipal officials, the Tirana Energy Efficiency Agency, the community of households and businesses in the area, and building managers (from the private sector). The interviews informed the feasibility assumptions for scenarios set up, taking into account upcoming city programmes, regulatory constraints, and developer interest in redevelopment opportunities. Additionally, a co-design workshop was held where residents, urban planners, and researchers collaboratively discussed challenges and potential ideas for the neighbourhood's future. Participants used maps and simple sketches to suggest desired improvements, such as playgrounds, parking reorganisation, greenery, and solar panels, which contributed to developing the scenario. The co-design process helped ensure that the scenarios reflected community needs and that any radical interventions, like redevelopment, were considered in terms of social acceptance.

On-site measurements included environmental monitoring, energy audit, GIS mapping and urban form analysis. For environmental monitoring, an Aeroqual portable air quality monitoring station was positioned at seven locations throughout the neighbourhood (and two additional comparison areas) from late October 2023 to March 2024. This device measured levels of key pollutants (CO_2, NO_2, $PM_{2.5}$ and PM_{10}[1]) as well as basic meteorological conditions (temperature, humidity) at 1.5 m above ground. Measurements were taken continuously over several weeks in each season, capturing variability and identifying pollution hotspots (near main roads). In addition, thermal imaging and spot temperature readings were taken on selected winter and summer days to assess building envelope performance (to pinpoint heat-loss areas) and outdoor heat distribution.

[1] CO_2 – Carbon Dioxide; NO_2 – Nitrogen Dioxide; $PM_{2.5}$ – Fine Particulate Matter (2.5 micrometers or smaller); PM_{10} – Coarse Particulate Matter (10 micrometers or smaller)

Energy audits were conducted on five apartment units across three buildings in the neighbourhood, representing typical layouts of one-, two-, and three-bedroom units. Following the national methodology outlined in Albanian Regulation No. 5 (Regulation, 2021), the process involved inspecting the building envelope (including materials, insulation, and window types), cooling and heating systems, and analysing energy bills. Simulation tools like RETScreen or local software helped estimate each unit's current energy performance class (likely low, Class E or F). The energy audits offered a clear understanding of energy consumption and efficiency, establishing an essential baseline for future savings in both Scenario 1 and Scenario 2. The findings revealed several main issues, including poor wall insulation (with U-values far exceeding current standards), significant air leaks, and inefficient electric heating systems, all of which lead to higher heating costs and lower comfort levels.

A detailed GIS model of the area was developed, including building footprints and heights, vegetation (trees and green spaces identified through satellite images and site surveys), land use, and impermeable surface coverage. This spatial database supported both ENVI-met simulations and the calculation of key indicators, such as current green space per capita, which was significantly lower than Tirana's average. It also assisted in identifying available roof space for solar panel installation and suitable sites for planting new trees, either along streets or in vacant patches between buildings.

Scenario Development

Using the baseline data and stakeholder inputs, four transition scenarios were identified, as outlined in the previous section. Each scenario is a coherent set of interventions and assumptions for the period 2024–2040 (as presented in Table 2). Each scenario's design was informed by both local context and best-practice examples. For instance, Scenario 1 reflects measures implemented in successful energy retrofit programmes in Central and Eastern Europe, such as reducing buildings' energy use to 60–70 kWh/m²-year (Staniaszek, 2019). Scenario 2 draws on net-zero energy community pilots and urban greening projects, combining multiple interventions to generate synergy. Scenario 3 aligns with the concept of urban regeneration through densification, a strategy observed in some Tirana projects and internationally, such as the regeneration of old estates in Europe through public-private redevelopment.

The underlying assumptions are applied uniformly to all scenarios, enabling a meaningful comparison in the cost-benefit analysis over a reference period 2024–2040. For Scenarios 1–3, it is assumed that interventions commence early (2024–2030 for the initial phase, with full implementation by 2040). Scenario 0 assumes the continuation of current trends, with periodic minor repairs every 5 years. Macroeconomic assumptions include an average annual energy price increase of about 3% above inflation, reflecting regional trends and carbon pricing, and a social discount rate of 6.28% for Albania, based on local long-term government bonds and guidance for developing countries, since Albania lacks an official rate. All monetary values are in euros at 2024 prices, with inflation excluded by working in constant euros and applying present-value discounting.

Table 2. Overview of transition scenarios and key assumptions (2024–2040)

	Description	Key Interventions and Assumptions
S0: Delayed Transition (Baseline)	Business-as-usual: No significant steps taken towards decarbonisation; only routine building maintenance.	No retrofit beyond minor repairs. Energy performance remains at the current low level (Class E/F). Energy prices rise moderately, leading to a modest increase in energy expenses and an increased risk of energy poverty. No new policies or subsidies implemented before 2030 (reflecting a delay in the green agenda's uptake).
S1: Enhanced Energy Performance (Retrofit)	Deep energy renovation: Improve existing buildings to high efficiency.	Building envelope insulation: exterior walls, roofs, and ground floors insulated to meet Class A or B standard; replacement of old single-glazed windows with double-glazed low-E units. Heating/cooling upgrades: Install efficient heat pump systems or modern boilers; add solar water heaters where feasible. Target: reduce building energy use by ~50%+, achieving energy class A (for some) by 2040. Implementation is phased: half of the buildings retrofitted by 2030 (Class C) and all by 2040 (Class A). Costs: Households co-finance retrofits with expected support from municipal or donor programs (assumed grant covering 30% of costs).
S2: Renewables & Nature-Based Solutions (Green Retrofit)	Net-zero neighbourhood: Integrate energy retrofit with renewable energy systems and nature-based solutions.	Includes all measures of Scenario 1. Solar photovoltaics (PV) installed on available flat rooftops (up to approximately 70–80% roof coverage, 340 kWh system size as per design simulation) with grid connection for surplus exchange. Solar thermal panels for domestic hot water. Rainwater harvesting, using roof catchment and storage systems for non-potable water use (irrigation, toilet flushing). Urban greening and trees (50+ new trees, species such as plane and linden for shade), creating small green parks or community gardens on vacant plots, and replacing some asphalt surfaces with permeable materials. Avoided soil sealing: All new paving is permeable; existing green spaces are protected and improved. Aim: achieve net-zero operational energy (with remaining energy needs supplied by PV) and improve the microclimate (reduce UHI effects, enhance stormwater management). Assumption: supportive policy (net metering regulations in place, community renewables permitted) and community co-management of green spaces.
S3: Full Redevelopment (Build anew) Comprehensive redevelopment: Demolish existing buildings and construct new, efficient	Comprehensive redevelopment: Demolish existing buildings and construct new, efficient buildings, with integrated planning.	Demolition: gradual dismantling of the old blocks (except perhaps very tall buildings, if any) and relocation of residents during construction, assuming temporary housing is provided or phased construction allows people to move within the site. New construction: modern mid-rise apartment buildings (with increased floor-area ratio if permitted by the city plan) that are high-performance, designed to NZEB or passive house standards. Include green roofs, high-efficiency HVAC, and more. Land-use reconfiguration: the masterplan introduces additional green spaces (such as a central park), enhanced parking solutions, and community facilities (playgrounds, etc.). Financing via value capture: the extra floorspace in new buildings (by adding additional floors or new commercial units) is sold, with profits used to cover costs and provide some compensation to the original owners. Assumption: (i) a developer or public-private partnership undertakes the project around 2030; (ii) policy assumption, with the city providing incentives such as land assembly and expedited permits, and guarantees fair compensation by offering each owner an equivalent or larger new apartment. This scenario anticipates disruption (social risk if not handled). However, it ultimately creates a new, resilient neighbourhood by 2040, completely aligned with climate neutrality through all new buildings, renewable systems, and extensive green infrastructure.

Source**:** authors processing.

Environmental Modelling and Ecosystem Assessment

Microclimate and environmental impacts were assessed using ENVI-met 4.4, a three-dimensional model that simulates surface–plant–air interactions to capture the effects of urban form, materials, and vegetation on near-ground temperature, humidity, wind flow, and pollutant dispersion (Bruse & Fleer, 1998). Neighbourhood GIS data were translated into ENVI-met inputs, including building heights, surface materials, and vegetation, and simulations were conducted for representative extreme conditions (a typical hot summer day in July and a winter day). For the baseline scenario (Scenario 0), ENVI-met generated spatial outputs of potential air temperature, relative humidity, and concentrations of CO_2, NO_2, and PM at pedestrian level, incorporating traffic emissions from adjacent roads. Model calibration was performed by comparing simulated outputs with in situ measurements, achieving reasonable agreement (approximately 1–2°C for air temperature and 10–20% for pollutants) after adjusting soil moisture and albedo parameters, consistent with validation studies in Mediterranean cities (Tsoka et al., 2018; Koletsis et al., 2021).

For intervention scenarios, a combination of targeted ENVI-met tests and empirical evidence was applied rather than full simulation of each pathway. A greening variant approximating Scenario 2 was modelled to assess microclimatic effects of added trees and permeable surfaces. Results indicate that introducing approximately 50 mature trees (8–10 m height) can reduce peak mid-afternoon air temperatures by 0.5–1.0°C locally and lower sun-exposed surface temperatures by over 10°C through shading and evapotranspiration, in line with findings by Akbari et al. (2001) and Shashua-Bar et al. (2011). Simulations also showed slight increases in relative humidity in shaded areas, reflecting common trade-offs between cooling and perceived humidity during hot periods.

Pollutant dispersion modelling highlighted additional trade-offs. Trees planted along major roads can reduce pollutant penetration into inner courtyards but may increase roadside NO_2 and PM concentrations by approximately 10–20% under low wind conditions due to reduced ventilation, consistent with Berndtsson (2010), Gromke and Ruck (2012), and Abhijith et al. (2017). These findings underscore the need for careful species selection and spacing, as emphasised by Demuzere et al. (2014). In Scenario 2, this was addressed through design assumptions that prioritised airflow while maximising shading benefits.

Rainwater harvesting potential under Scenario 2 was estimated using historical rainfall data for Tirana (approx. 1,200 mm/year). With a combined rooftop area of approximately 1.65 ha, annual collection was estimated at 10,000–15,000 m^3, sufficient to support irrigation and partial non-potable use, while reducing stormwater runoff and flood risk. Although ENVI-met does not simulate sewer flows, these benefits were incorporated qualitatively and monetised in the ES-CBA through avoided stormwater management and flood damage costs. Biodiversity-related ecosystem benefits, including improved habitat conditions for urban birds and pollinators in Scenarios 2 and 3, were assessed qualitatively, consistent with the ecosystem service literature (Canzonieri, 2007).

Overall, environmental modelling served two functions: (i) to inform the ES-CBA by supporting estimates of microclimate-related energy savings and air quality health benefits, and (ii) to provide a standalone assessment of each scenario's contribution to climate adaptation and environmental quality, including indirect effects on building cooling demand and outdoor thermal comfort (Berardi, 2016).

Environmental and Social CBA

The viability of the proposed scenarios is evaluated through ES-CBA, a modified version of the standard CBA that considers the social and environmental impacts of an intervention (DG Regio, 2014). The modified ES-CBA is a structured analytical framework grounded in welfare and environmental economics that connects economic efficiency, environmental limits, and social justice (Stern, 2007; OECD, 2018).

From a technical perspective, preparing the ES-CBA involves a structured yet iterative process. It starts by identifying the relevant costs and benefits associated with a proposed intervention, including both market and non-market effects. These impacts are then quantified and, where possible, monetised, using available data, established benchmarks, or well-supported assumptions when direct information is lacking. The core of the analysis focuses on estimating net impacts by comparing a 'with-project' scenario to an appropriate counterfactual, typically a business-as-usual or do-minimum scenario, to isolate changes attributable solely to the intervention. During the chosen reference period, the expected behaviour of each cost and benefit category is evaluated using growth rates, trend extrapolations, or expert judgement, depending on data quality and context. These future flows of costs and benefits are then discounted to present values using a social discount rate that mirrors society's time preferences. Finally, the overall economic performance of the intervention is summarised using standard indicators, namely the Economic Net Present Value (ENPV), the Economic Internal Rate of Return (EIRR), and the Benefit-to-Cost Ratio (BCR), which collectively support informed decision-making:

- The economic net present value indicator (ENPV) measures the overall contribution of a project to social welfare by calculating the difference between discounted benefits and discounted costs over the chosen reference period. In simple terms, it shows whether the total value created by the intervention outweighs the resources it absorbs. A positive ENPV indicates that the project is economically viable and generates net benefits for society. In contrast, a negative ENPV signals that costs exceed benefits and the intervention does not add value. In this framework, in the ENPV formula, the benefits (Bi) and costs (Ci) are assessed over the time horizon n and discounted using the social discount rate (SDR) to reflect society's time preference.

$$NPV = \left(\left[\Sigma \frac{B_i}{(1+sdr)^i}\right]\right) - \left(\left[\Sigma \frac{C_i}{(1+sdr)^i}\right]\right)$$

- The economic internal rate of return (EIRR) identifies the discount rate at which the ENPV equals zero. For an intervention to be considered worthwhile, the EIRR should exceed the social discount rate applied in the analysis, indicating that the project generates value over and above the opportunity cost of public resources; if it falls below the social discount rate, the intervention fails to create economic value.

$$\left(\left[\Sigma \frac{B_i}{(1+irr)^i}\right]\right) - \left(\left[\Sigma \frac{C_i}{(1+irr)^i}\right]\right) = 0$$

- The benefits-to-cost ratio (BCR) shows the relationship between discounted benefits and discounted costs, emphasising the value created for each Euro invested. A BCR greater than one means that benefits exceed costs over the reference period and that the intervention adds value, while a BCR below one indicates that costs outweigh benefits. A BCR of exactly 1 indicates a break-even point, where the project's economic viability is marginal and depends on underlying assumptions. A BCR of zero means the intervention does not create value, and its viability is uncertain.

While ES-CBA provides a transparent and structured framework for comparing the economic benefits of different interventions, it has limitations in fully capturing justice aspects. ES-CBA focuses on outcomes that can be measured and monetised, often leaving out important distributive, procedural, and recognitional justice issues. Challenges such as unequal power structures, varying vulnerabilities across social groups, intergenerational fairness, cultural values, and perceptions of justice are difficult to quantify reliably and may not be captured by a single overall indicator. As a result, positive economic outcomes may conceal uneven distributional effects or social trade-offs that are not apparent in aggregate data. Therefore, ES-CBA should be regarded as a decision-support tool rather than a comprehensive measure of justice. To optimise its effectiveness, its results should be complemented by qualitative methods, distributional analyses, stakeholder engagement, and justice-centred criteria, ensuring policies are both efficient and socially fair and legitimate.

Results and Analysis

Quantitative outcomes (ES-CBA)

The ES-CBA showed clear differences in performance across the four scenarios. Table 3 summarises key indicators and investments for each scenario. All values are in euros and cover the entire 2024–2040 period (discounted to 2024).

Table 3. Cost-Benefit Summary of Scenarios (ENPV, EIRR, BCR)

Scenario	Estimated total Investment (in euro)	ENPV (in euro)	EIRR (in %)	BCR Ratio
S0: Delayed Transition	1,640,000	4,280,000	20%	1.8
S1: Energy Retrofit	7,190,000	2,580,000	10%	1.5
S2: Renewables + Nature-Based Solutions	10,570,000	10,224,000	14%	1.9
S3: Redevelopment	51,700,000	33,140,000	13%	2.1

Note: All monetary figures are rounded to the nearest thousand. Values >0 ENPV, >6.28% EIRR, >1 BCR indicate socio-economic viability.
Source: author's processing.

Several observations emerge from these results.

Scenario 0 (Baseline) involves a minimal Investment (EUR 1.64 million), yielding a positive ENPV (about EUR 4.28 million) and the highest EIRR (20%). As per its setup, the baseline scenario avoids immediate additional costs for the stakeholders rather than creating new benefits (some minor benefits, such as no relocation disruptions, are assumed). The BCR ratio of 1.8 shows that doing nothing 'creates value' by saving expenses. Nevertheless, economic performance indicators must be handled cautiously, since the baseline scenario does not contribute to decarbonisation or improvements in living conditions. In policy terms, while Scenario 0 appears economically viable by metrics, it is not aligned with Albania's commitments to reduce emissions or address energy poverty. Therefore, we regard Scenario 0's results as a reference point rather than an endorsement. It emphasises that the cost of inaction is low in the short term, which can be misleading when climate and social externalities are not fully accounted for.

Scenario 1 (Energy Retrofit) requires an upfront investment of about EUR 7.19 million for deep renovations. In this case, the ENPV is positive (about EUR 2.58 million) and an EIRR of about 10% (which is about 3.72 percentage points higher compared to the discount rate of 6.28% used in the analysis). The BCR results show that implementing the energy retrofit measures generates about euro 1.50 in benefits per euro invested, mainly driven by energy savings and property value increases. However, Scenario 1's ENPV is lower than Scenario 0's, and its EIRR is the lowest among all scenarios. Scenario 1 appears to be the least financially attractive among active interventions, due to a high investment level and its focus solely on buildings, with benefits such as comfort and health not fully monetised. The payback on retrofits is positive but not significant over 16 years, partly because energy prices in Albania are subsidised or low, and the savings per building are moderate. Therefore, while Scenario 1 takes steps towards climate and energy goals (reduced consumption and emissions), from a purely economic perspective, it offers the smallest net benefit, making it potentially less attractive unless supported by grants or non-market values (such as carbon pricing or improved health).

Scenario 2 (Renewables and Nature-Based Solutions) shows a strong economic performance. Despite a higher capital cost (about EUR 10.57 million), the investments foreseen provide for a high and positive ENPV (about EUR 10.22 million, approximately four times that of Scenario 1) and an EIRR significantly higher than the discount rate (about 7.72 pp higher). The BCR for investments in Scenario 2 is about 1.9 (higher than those in Scenario 0 and Scenario 1). Based on the performance indicators presented, the integrated approach of combining energy retrofits with renewables and nature-based solutions yields substantial net benefits. In this scenario, key drivers for value generation include energy savings and extra energy generation (PV reduces bills and generates income), untapped benefits like lowering water bills and higher property value from a greener neighbourhood. Therefore, the interventions foreseen in Scenario 2 offer broad improvements at a relatively low additional cost compared to Scenario 1, resulting in better economic returns. Notably, Scenario 2's positive results highlight that environmental and social benefits can have tangible economic value, simultaneously contributing to climate objectives such as near-net-zero energy, local renewable sources, and green adaptation while remaining financially viable.

Scenario 3 (Redevelopment) envisions an investment of about EUR 51. 7 million, far surpassing investment levels required in the other scenarios. It delivers the highest ENPV (about EUR 33.14 million) and an EIRR of about 13% (higher than the discount rate), showcasing its economic viability. The BCR ratio level suggests that for every euro invested, the investment generates about euro 2.1 in benefits. The benefits of this scenario are extensive: energy-efficient buildings considerably reduce energy costs; additional floor space (through extra storeys or new constructions) creates revenue (assuming developers sell or rent units, with some income regarded as a societal economic benefit rather than merely private profit); urban benefits include decreased pollution and better land use efficiency. The high ENPV is broadly driven by land value uplift, transforming an ageing neighbourhood into a modern one substantially increases property values, which is a benefit in CBA terms (although how that value is shared remains a separate issue). However, these at first sight positive figures come with important caveats: the success of Scenario 3 depends on securing investors and developers willing to provide the necessary capital and oversee the project, as well as on its proper execution. In reality, such projects face risks: delays, community opposition and social resistance, legal challenges to property acquisition, and the challenge of ensuring all current residents are fairly compensated or rehoused. Residual land value, what land is worth after redevelopment, could benefit the public by funding green spaces or affordable housing. If not, the social ENPV decreases, while private profits remain high. Although Scenario 3 appears financially promising, it carries a higher risk of disbalanced net benefits and costs, in particular social disruptions, stress and displacement. A just green transition in Scenario 3 requires careful management and protection of residents to harness the benefits outlined and foster transformative city change.

The outlined ES-CBA results show that all three active transition scenarios (1–3) are more financially beneficial than doing nothing (Scenario 0). The green integrated approach envisioned in Scenario 2 yields higher returns than the energy-only retrofit Scenario 1, emphasising the benefits of combining energy and ecosystem measures. Redevelopment (Scenario 3) offers the highest value but is more complex and scale-intensive, making it an outlier. These findings confirm the financial viability of the neighbourhood-level just green transition, with Scenario 2's broader strategy surpassing simpler retrofit benefits.

Qualitative benefits and trade-offs

While ES-CBA indicators quantify viability monetarily, qualitative outcomes and trade-offs emerge and need to be addressed.

Energy and emissions

Scenario 1–3 enhance energy efficiency and reduce emissions more than Scenario 0. Scenario 1's upgrades could cut heating energy use by about 60%, saving thousands of MWh over 16 years and preventing several hundred tonnes of CO_2 emissions, assuming fossil-fuel reliance remains. Scenario 2 may make the neighbourhood a net energy producer by transferring excess PV energy to the network. Scenario 3's low-emission buildings leverage modern technology and renewable energy. All scenarios support climate mitigation, with Scenario 2 and Scenario 3 approaching near-net-zero emissions by 2040, aligning with the EU 2050 goals, unlike Scenario 0, which would worsen emissions due to building deterioration and climate extremes.

Microclimate and comfort

Assessments indicate that only Scenario 2 and Scenario 3 improve outdoor thermal comfort. Scenario 1 (insulation) enhances indoor comfort and reduces energy use without impacting the outdoor environment. In Scenario 2, greening and shading decrease the urban heat island effect, making courtyards and streets cooler and more pleasant. Assessment shows that it might help lower the courtyard's peak temperature from 50°C to 35°C and the air temperature from 34°C to 33°C, thus creating comfortable shaded areas. Buildings in this scenario would also be cooler, boosting indoor comfort. Scenario 3, which involves site redesign with optimal orientation and green space, could deliver the best microclimate conditions but may temporarily impair comfort during construction and tree removal. Increased humidity in green zones can lead to muggy conditions, but overall reductions in temperature improve comfort indices such as PET[2] and Universal Thermal Climate Index (UTCI)[3].

Air quality

In Scenario 0 and Scenario 1, there is no significant change in local air pollutants expected, except for a slight decrease if heating fuel use drops. The latter is unlikely, as Toska et al. (2025) found that households and businesses in the study area already use electricity or efficient heating

[2] PET – the air temperature at which the human body would experience the same thermal stress in a typical indoor setting.

[3] UTCI – the equivalent temperature that would cause the same physiological response under reference conditions.

systems. Scenario 2 is expected to improve air quality through tree filtration and reduced dust, as greening bare soil decreases particulate resuspension. We estimate a slight percentage reduction in $PM_{2.5}$ levels across neighbourhoods due to new vegetation. If the PV and efficiency improvements reduce the need for grid electricity, there is an indirect regional emission benefit. In the case of Scenario 3, construction dust during the rebuilding process is a short-term negative impact and requires mitigation measures such as watering and careful demolition practices.

Water management

Scenario 2–3 effectively address water management. Scenario 2 incorporates rainwater harvesting and permeable landscaping, which help reduce stormwater runoff and provide irrigation water, especially important during Tirana's occasional summer water shortages. Toska et al. (2024) note that in the city of Tirana, water services are discontinued (water tanks are used), and irrigation needs are met with tap water (no other alternatives are available). Promoting a culture of resource efficiency in the community, Scenario 3 introduces modern drainage systems and could include larger infrastructure such as underground retention tanks, potentially solving existing drainage problems, as some old neighbourhoods flood easily. Overall, both options enhance resilience against heavy rainfalls.

Social and household budget impact

Despite requiring the lowest upfront investment level, Scenario 0, residents still face high energy costs and worsening living conditions, effectively increasing energy poverty as energy prices rise. From a social perspective, Scenario 0 provides no benefits for local employment or skills development. Conversely, Scenario 1–2 could generate local jobs and business opportunities in retrofits, equipment installation, and planting, thereby supporting the green economy. Energy efficiency initiatives are known to have significant job multipliers (like installers, manufacturers), and renewable projects exert similar impacts (ILO, 2015). Scenario 3 also involves substantial construction efforts, likely creating numerous jobs over 10 years, though potentially favouring larger, well-established firms. For residents, Scenario 1–2 allow them to stay in their homes during or after renovations, as retrofits can be completed with minimal relocation. While Scenario 3 involves temporary relocation, causing social disruption and risking the loss of community ties or residents' return, it is a common gentrification outcome. With effective management, residents would return to improved conditions, such as new apartments and better community and neighbourhood services. It also increases housing supply, supporting city growth, but may attract wealthier residents, changing the social fabric. Conversely, Scenario 2 focuses on in-situ upgrades and community empowerment, such as co-owning PV systems, which can strengthen community organisation through energy co-ops or green space groups.

Fund mobilisation for green transition

Scenario 1–2 entail mobilising additional funding at the household or municipal levels. Their moderate Internal Rate of Return (IRRs) indicate that incentives may be necessary for implementation. For Scenario 1, retrofitting buildings might not be financially appealing to owners unless they receive subsidies or access to long-term, low-interest loans, as a 10% weighted IRR is barely sufficient for private investment. Scenario 2 offers a better EIRR, particularly if the community can monetise PV electricity, which could attract entities such as an Energy Saving Company[4] (ESCO)

[4] ESCO is a company that provides energy efficiency improvements and gets paid from the energy savings those improvements generate.

or a community energy fund. Feed-in tariffs or net metering are critical to realising PV benefits. Albania is developing enabling frameworks for renewables and energy efficiency, but as of 2025, these are still emerging (Energy Community, 2022). S3 exceeds the capacity of individual owners and requires developers with substantial capital availability (or access to capital). The CBA shows it is profitable overall, so a public-private partnership might recover costs, though coordination challenges might occur. The high ENPV indicates that, with fair compensation, land leases, or increased tax revenues, it benefits society. The government may need to de-risk the project through guarantees or by sharing initial infrastructure costs.

Basically, each scenario involves trade-offs. Scenario 0 sacrifices long-term sustainability for short-term savings; Scenario 1 offers smaller benefits in exchange for reduced complexity, resulting in only incremental improvements; Scenario 2 requires a higher initial investment but provides a well-rounded set of benefits. It is a compromise that depends on community initiative rather than a complete overhaul; Scenario 3 demands significant capital and could cause social disturbance, but offers maximum renewal and economic growth. The analysis so far suggests Scenario 2 may be the 'sweet spot' for maximising net benefits while keeping feasibility and community stability. Conversely, Scenario 3 is appealing due to its high returns but comes with many implementation difficulties.

Although our study area does not include historical buildings, some might argue that the socialist-era blocks hold cultural significance or at least reflect a way of life. Redevelopment could erase that physical heritage. Some communities value familiar environments and social networks (Toska et al., 2025). Mitigating this involves documenting heritage and involving sociologists in the design of new developments that promote social interaction (such as preserving communal courtyards in updated designs to maintain lifestyle patterns). The co-design approach helps identify what residents value in the old neighbourhood, like specific apartment layouts that encourage neighbourly relations. It ensures those qualities are retained in the new design.

The results are site-specific, but they might have broader relevance. Prefabricated apartment neighbourhoods are common across Eastern Europe and other regions. The integrated approach and the redevelopment pathway could serve as models. However, caution is necessary: every neighbourhood has unique social dynamics and physical conditions. While our economic results can be inspiring, each new case requires its own participatory planning and analysis. Replicability depends on local support.

Limitations of the study

The analysis relies on many assumptions that may not match real conditions. Our estimates of environmental benefits are approximate; actual health gains or willingness-to-pay could differ. Some benefits, like community wellbeing, are hard to quantify but important, so we described them qualitatively. Unforeseen costs, like asbestos removal or legal expenses, could reduce net benefits. The EIRR and BCR are affected by the discount rate and energy price trends. In the case of falling energy prices, expanding hydro capacity could reduce energy savings, while rising carbon prices could increase benefits. While not conducted entirely here, a sensitivity analysis is recommended for a thorough economic assessment.

We treated each scenario independently, but in reality, options might be combined, such as pursuing Scenario 1 now and considering Scenario 3 We did not analyse phased or combined approaches, such as retrofitting now and rebuilding later. Such strategies could be useful – retrofitting for immediate benefits and planning redevelopment over time when funding or consensus is available. Our study's static scenario choices are a simplification.

We gathered input, but a truly co-produced plan needs more engagement and iterative revisions. We hope the insights reflect community needs through surveys and the workshop, but not all concerns can be captured. Future work could involve a stakeholder committee to refine scenarios and oversee implementation, embodying a co-created transition.

Summary

This research evaluated the efficacy of various neighbourhood-scale green transition pathways concerning socio-economic efficiency, environmental results, and specific justice-related factors within a post-socialist urban framework. Instead of providing a thorough evaluation of 'just transition' in a normative context, the analysis implemented justice through two complementary perspectives that could be empirically examined within a singular case study: distributional effects (who incurs costs and who reaps benefits) and procedural dimensions (the influence of participation and local acceptance in determining viable pathways).

The results show that there are clear trade-offs between economic efficiency, environmental performance, and societal risk in all four scenarios. The baseline scenario (Scenario 0) seems good for the economy in the short run, but it doesn't do anything about long-term environmental damage or increased energy vulnerability. This shows how misleading 'cost savings' may be when externalities and future risks are left out. The energy-only retrofit scenario (Scenario 1) provides moderate economic benefits and lower emissions, but it is still limited in scope and does not offer much of a return on investment because of Albania's present energy price structure. This shows that substantial retrofits that only focus on building envelopes may not be able to get private investment without help from the government.

The integrated scenario that combines energy retrofits, renewable energy, and nature-based solutions (Scenario 2) is the best balanced way to go. It does well in terms of social and economic factors, and it also has measurable environmental benefits, such as better water management and better microclimatic conditions. Importantly, Scenario 2 reduces the possibility of displacement by focusing on in-situ upgrading and shared assets like shared photovoltaics and common green spaces. This is in line with concerns about distributional justice that have been expressed in studies of green gentrification. But its success depends on ongoing community involvement and support from institutions, especially when it comes to managing shared infrastructure, which is something that is often not taken into account in strictly techno-economic studies.

The redevelopment scenario (Scenario 3) yields the most substantial economic rewards, mostly due to increased land value and contemporary construction norms. However, these advantages are accompanied with significant social concerns, such as temporary displacement and possible exclusion in the event of inadequate governance structures. In theory, redevelopment can lead to a fair outcome, but this needs strong procedural protections, clear ways to pay people back, and rights of return that can be enforced. In the absence of these criteria, economic efficiency may coexist with socially regressive effects, hence substantiating the reviewer's apprehension regarding the conflation of green transition with equitable transition.

In general, the results show that initiatives that are good for the economy or the environment don't always lead to justice-related outcomes. Instead, they depend on how transition pathways are planned, paid for, and run in each neighborhood. Tirana's example shows that integrated retrofit techniques can be a practical middle ground between little upgrades and major rebuilding, but their effectiveness depends on the situation and the institutions involved.

Recommendations

The case study results provide several context-specific and conditional recommendations for urban policymakers and planners in Tirana and other post-socialist cities.

First, neighborhood-level green transition plans should focus on integrated retrofit methods that include energy efficiency, on-site renewables, and solutions based on nature. Scenario 2 shows that these kinds of combinations can have better socio-economic and environmental effects than initiatives that only serve one aim, and they also lower the chance of residents being forced to move.

Second, public funding is still quite important, especially for energy retrofits in buildings with more than one unit. Because energy prices are not very high right now, grants, concessional loans, or ESCO-based solutions are needed to get households involved and keep costs fair. Linking incentives for retrofitting to other environmental actions, like greening or reusing water, could make the overall value even higher.

Third, justice should be built into the process instead than just being presumed to be a standard. This involves getting residents involved early on, being open about costs and advantages, and making sure everyone knows how to handle shared property. People should not only see community engagement as a democratic goal, but also as a necessary step for making it happen and keeping it going over time.

Fourth, redevelopment plans should be handled with care, even though they may be good for the economy. If they are followed through on, they must be subject to clear social protections, such as guaranteed rights of return, appropriate compensation, and protection against being forced to leave. Without these steps, redevelopment could hurt the social goals that go along with a fair green transition.

Lastly, the findings of this study should not be considered immediately applicable to other circumstances without modification. Although the analytical framework and scenario-based methodology can guide decision-making in other contexts, results are contingent upon local housing markets, institutional capability, and social factors. Subsequent study may examine analogous frameworks across various neighborhoods to enhance comprehension of the circumstances in which integrated green transitions yield socially equitable results.

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Annex 1. CBA results table for each scenario 0, 1, 2, 3

Table 1. Scenario 0 (key assumption: social discount rate – 6%; appraisal period (years) – 16; currency – euro)

Year	Cumulative values	2024	2025	2027	2029	2031	2033	2035	2036–2040
Discount factor		1.000	0.941	0.833	0.738	0.653	0.578	0.512	0.428
CAPEX									
Annual investment		–	328 911	328 911	246 683	411 138	328 911	328 911	328 911
Total CAPEX		**–**	**328 911**	**328 911**	**246 683**	**411 138**	**328 911**	**328 911**	**328 911**
Present value of CAPEX		–	309 490	274 021	181 963	268 516	190 194	168 398	142 137
Cumulative PV of CAPEX		3 289 777							
Benefit sources									
S0B1 Less investment at the current stage		–	716 889	716 889	955 852	–	–	–	–
S0B2 Gentrification of neighbourhood		1 188 367	1 188 367	1 188 367	1 224 018	1 071 015	1 071 015	945 554	924 436
Total Benefits		1 188 367	**1 905 256**	**1 905 256**	**2 179 870**	**1 071 015**	**1 071 015**	**945 554**	**924 436**
Present Value of Benefits		1 188 367	1 792 760	1 587 303	1 607 959	699 484	619 321	484 110	396 975
Cumulative PV Benefits		15 809 907							
Cost sources									
S0C1 Electricity costs		249 125	249 125	249 125	256 599	256 599	256 599	264 297	267 468
S0C2 Annual maintenance cost		154 910	154 910	154 910	159 557	159 557	159 557	164 344	166 316
S0C3 Parking costs		75 476	75 476		77 740	77 740	77 740	80 072	81 033
S0C4 Air quality		–	–	–	–	–	–	–	–
S0C5 Noise pollution		–	–	–	–	–	–	–	–
Total Costs		**479 511**	**479 511**	**479 511**	**493 896**	**493 896**	**493 896**	**508 713**	**514 818**
Present Value of Costs		479 511	451 198	399 489	364 318	322 566	285 598	260 454	220 171
Cumulative PV of Costs		5 387 574							
Undiscounted cash flows									
CAPEX		–	(328 911)	(328 911)	(246 683)	(411 138)	(328 911)	(328 911)	(328 911)
Total costs		(479 511)	(479 511)	(479 511)	(493 896)	(493 896)	(493 896)	(508 713)	(514 818)
Total benefits		1 188 367	1 905 256	1 905 256	2 179 870	1 071 015	1 071 015	945 554	924 436
Net Cash Flow	(5 262 571)	708 855	1 425 744		1 685 973	577 119	577 119	436 840	409 618
Discounted cash flows (SDR1)									
CAPEX		–	(309 490)	(274 021)	(181 963)	(268 516)	(190 194)	(168 398)	(142 137)
Benefits		1 188 367	1 792 760	1 587 303	1 607 959	699 484	619 321	484 110	396 975
Costs	(3 289 777)	(479 511)	(451 198)	(399 489)	(364 318)	(322 566)	(285 598)	(260 454)	(220 171)
Net Cash Flow	–	708 855	1 032 071	913 792	1 061 678	108 403	143 528	55 258	34 667
Cummulative cash flow		708 855	1 740 927	3 553 048	5 474 563	6 418 687	6 714 749	6 959 222	7 067 881

Table 2. Scenario 1 (key assumption: social discount rate – 6%; appraisal period (years) – 16; currency – euro)

Year	Cumulative values	2024	2025	2027	2029	2031	2033	2035	2036–2040
Discount factor		**1.000**	**0.941**	**0.833**	**0.738**	**0.653**	**0.578**	**0.512**	**0.428**
CAPEX									
S0I1 Investment in renovations (once in 5 years)		–	328 911	328 911	246 683	411 138	328 911	328 911	328 911
S1I1 Investment in improving energy performance (1)		257 173	342 898	342 898	–	–	–	–	–
S1I2 Investment in improving energy performance (2)		–	–	–	385 394	513 858	642 323	–	–
Total CAPEX		257 173	**671 808**	**671 808**	**632 077**	**924 997**	**971 233**	**328 911**	**328 911**
Present value of CAPEX		257 173	632 141	559 696	466 245	604 119	561 621	168 398	142 137
Cumulative PV of CAPEX		6 458 645							
Benefit sources									
S0B1 Less investment at the current stage									
S0B2 Gentrification of neighbourhood		1 485 458	1 485 458	1 485 458	1 360 020	1 360 020	1 360 020	1 225 718	1 240 426
S1B1 Energy saving from energetic performance (1)		11 211	14 948	14 948	11 547	15 396	19 245	15 858	16 024
S1B2 Energy saving from energetic performance (2)			–	–	11 211	14 948	18 684	15 396	15 558
S1B3 Increase in property values			–	–	2 710 497	–	–	–	–
Total Benefits		**1 496 669**	**1 500 406**	**1 500 406**	**4 093 274**	**1 390 363**	**1 397 949**	**1 256 971**	**1 272 008**
Present Value of Benefits		1 496 669	1 411 814	1 250 015	3 019 362	908 051	808 372	643 551	544 038
Cumulative PV Benefits		18 705 470							
Cost sources									
S0C1 Electricity costs		249 125	249 125	249 125	256 599	256 599	256 599	264 297	267 468
S0C2 Annual maintenance cost		154 910	154 910	154 910	159 557	159 557	159 557	164 344	166 316
S0C3 Parking costs		75 476	75 476	75 476	77 740	77 740	77 740	80 072	81 033
S0C4 Air quality			–	–	–	–	–	–	–
S0C5 Noise pollution			–	–	–	–	–	–	–
S1C1 Maintenance costs I1		11 211	14 948	14 948	11 547	15 396	19 245	15 858	16 024
S1C2 Maintenance costs I2			–	–	11 211	14 948	18 684	15 396	15 558
Total Costs		**490 722**	**494 459**	**494 459**	**516 654**	**524 240**	**531 826**	**539 967**	**546 400**
Present Value of Costs		490 722	465 263	411 943	381 105	342 383	307 531	276 455	233 718
Cumulative PV of Costs		5 647 921							
Undiscounted cash flows									
CAPEX		(257 173)	(671 808)	(671 808)	(632 077)	(924 997)	(971 233)	(328 911)	(328 911)
Total costs		(490 722)	(494 459)	(494 459)	(516 654)	(524 240)	(531 826)	(539 967)	(546 400)
Total benefits		1 496 669	1 500 406	1 500 406	4 093 274	1 390 363	1 397 949	1 256 971	1 272 008
Net Cash Flow	(9 546 350)	1 005 947	1 005 947	1 005 947	3 576 620	866 123	866 123	717 004	725 608
Discounted cash flows (SDR1)									
CAPEX		(257 173)	(632 141)	(559 696)	(466 245)	(604 119)	(561 621)	(168 398)	(142 137)
Benefits		1 496 669	1 411 814	1 250 015	3 019 362	908 051	808 372	643 551	544 038
Costs	(6 458 645)	(490 722)	(465 263)	(411 943)	(381 105)	(342 383)	(307 531)	(276 455)	(233 718)
Net Cash Flow		748 774	314 410	278 377	2 172 013	(38 450)	(60 781)	198 698	168 182
Cummulative cash flow		748 774	1 063 184	1 564 602	3 801 965	3 779 725	3 733 296	5 757 993	6 255 310

Table 3. Scenario 2 (key assumption: social discount rate – 6%; appraisal period (years) – 16; currency – euro)

Year	Cumulative values	2024	2025	2027	2029	2031	2033	2035	2036–2040
Discount factor		**1.000**	**0.941**	**0.833**	**0.738**	**0.653**	**0.578**	**0.512**	**0.428**
CAPEX									
S0I1 Investment in renovations (once in 5 years)		–	328 911	328 911	246 683	411 138	328 911	328 911	328 911
S1I1 Investment in energy performance (1)		257 173	342 898	342 898	–	–	–	–	–
S1I2 Investment in energy performance (2)		–	–	–	385 394	513 858	642 323	–	–
S2I1 Photovoltaic panels:		–	86 091	114 788	143 485	–	–	–	–
S2I2 Solar Thermal Panel:		42 750	57 000	57 000	–	–	–	–	–
S2I3 Rainwater collections system:		–	–	–	105 975	–	–	–	–
S2I4 Greening (increase with 30% the green area)		–	30 050	–	–	–	–	–	–
S2I5 Preventing soil sealing		–	–	–	–	–	–	–	–
Total CAPEX		**299 923**	**844 949**	**843 596**	**881 536**	**924 997**	**971 233**	**328 911**	**328 911**
Present value of CAPEX		299 923	795 059	702 815	650 256	604 119	561 621	168 398	142 137
Cumulative PV of CAPEX		7 313 423							
Benefit sources									
S0B1 Less investment at the current stage		825 255							
S0B2 Gentrification of neighbourhood		11 211	825 255	825 255	850 012	850 012	850 012	525 308	531 611
S1B1 Energy saving from energetic performance (1)		–	14 948	14 948	11 547	15 396	19 245	15 858	16 024
S1B2 Energy saving from energetic performance (2)		–	–	–	11 211	14 948	18 684	15 396	15 558
S1B3 Increase in property values		–	–	–	2 710 497	–	–	–	–
S2B1 Energy production of photovoltaic panels		–	–	–	–	2 394 890	2 394 890	2 394 890	2 466 736
S2B2 Saving on energy bill from solar thermal panel		–	11 211	41 106	74 738	79 289	84 118	89 241	97 601
S2B3 Saving of water for irrigation purposes		–	–	–	19 331	19 331	21 265	23 391	24 327
S2B4 Improved air quality due to higher greening		–	16 121	19 442	22 764	54 321	65 264	114 309	148 309
S2B5 Disaster risk resilience and climate change		–	–	159 749	159 749	159 749	159 749	159 749	159 749
S2B6 Increase in property values		–	–	–	2 710 497	–	2 710 497	–	–
Total Benefits		**836 463**	**867 533**	**1 060 500**	**6 570 345**	**3 587 936**	**6 323 723**	**3 338 141**	**3 459 915**
Present Value of Benefits		836 465	816 310	883 522	4 846 549	2 343 295	3 656 729	1 709 080	1 479 947
Cumulative PV Benefits		32 268 848							
Cost sources									
S0C1 Electricity costs		249 125	249 125	249 125	256 599	256 599	256 599	264 297	267 468
S0C2 Annual maintenance cost		154 910	154 910	154 910	159 557	159 557	159 557	164 344	166 316
S0C3 Parking costs		75 476	75 476	75 476	77 740	77 740	77 740	80 072	81 033
S0C4 Air quality		–	–	–	–	–	–	–	–
S0C5 Noise pollution		–	–	–	–	–	–	–	–
S1C1 Maintenance costs I1		11 211	14 948	14 948	11 547	15 396	19 245	15 858	16 024
S1C2 Maintenance costs I2		–	–	–	11 211	14 948	18 684	15 396	15 558
S2C1 Maintenance costs		–	–	2 905	5 219	40 274	41 518	42 316	43 267
S0B2 Gentrification of neighbourhood		356 510	356 510	356 510	367 205	321 305	321 305	283 666	277 331

Year	Cumulative values	2024	2025	2027	2029	2031	2033	2035	2036–2040
Total Costs		**847 232**	**850 969**	**853 874**	**889 079**	**885 819**	**894 649**	**865 949**	**866 998**
Present Value of Costs		847 232	800 723	711 378	655 820	578 532	517 336	443 354	371 321
Cumulative PV of Costs		9 489 409							
Undiscounted cash flows									
CAPEX		(299 923)	(844 949)	(843 596)	(881 536)	(924 997)	(971 233)	(328 911)	(328 911)
Total costs		(847 232)	(850 969)	(853 874)	(889 079)	(885 819)	(894 649)	(865 949)	(866 998)
Total benefits		836 465	867 533	1 060 500	6 570 345	3 587 936	6 323 723	3 338 141	3 459 915
Net Cash Flow	(10 568 464)	(10 767)	16 565	206 626	5 681 267	2 702 118	5 429 074	2 472 192	2 592 917
Discounted cash flows (SDR1)									
CAPEX		(299 923)	(795 059)	(702 815)	(650 256)	(604 119)	(561 621)	(168 398)	(142 137)
Benefits		836 465	816 310	883 522	4 846 549	2 343 295	3 656 729	1 709 080	1 479 947
Costs	(7 313 423)	(847 232)	(800 723)	(711 378)	(655 820)	(578 532)	(517 336)	(443 354)	(371 321)
Net Cash Flow		(310 690)	(779 473)	(530 672)	3 540 473	1 160 644	2 577 772	1 097 329	966 489
Cummulative cash flow		(310 690)	(1 090 162)	(2 436 553)	539 160	2 985 129	6 711 399	10 633 572	13 604 637

Table 4. Scenario 3 (key assumption: social discount rate – 6%; appraisal period (years) – 16; currency – euro)

Year	Cumulative values	2024	2025	2027	2029	2031	2033	2035	2036–2040
Discount factor		**1.000**	**0.941**	**0.833**	**0.738**	**0.653**	**0.578**	**0.512**	**0.428**
CAPEX									
S0I1 Investment in renovations (once in 5 years)									
S1I1 Investment in energy performance (1)									
S1I2 Investment in energy performance (2)									
S2I1 Photovoltaic panels:		–	86 091	114 788	143 485	–	–	–	–
S2I2 Solar Thermal Panel:		42 750	57 000	57 000	–	–	–	–	–
S2I3 Rainwater collections system:		–	–	–	105 975	–	–	–	–
S2I4 Greening (increase with 30% the green area)		–	30 050	–	–	–	–	–	–
S2I5 Preventing soil sealing		–	–	–	–	–	–	–	–
S3I1 Development cost		–	7 602 387	10 136 516	12 670 645	–	–	–	–
Total CAPEX			**7 775 528**	**10 308 304**	**12 920 104**	**–**	**–**	**–**	**–**
Present value of CAPEX		42 750	7 316 422	8 588 036	9 530 385	–	–	–	–
Cumulative PV of CAPEX		42 750							
Benefit sources		**42 720 695**							
S0B1 Less at the current stage									
S0B2 Gentrification of neighbourhood									
S1B1 Energy saving from energetic performance (1)									
S1B2 Energy saving from energetic performance (2)									
S1B3 Increase in property values									
S2B1 Income from energy production of photovoltaic panels		–	–	–	–	2 394 890	2 394 890	2 394 890	2 466 736
S2B2 Saving on energy bill from solar thermal panel:		–							
S2B3 Saving of water for irrigation purposes		–	–	–	19 331	19 331	21 265	23 391	24 327
S2B4 Improved air quality due to increased greening		–							
S2B5 Disaster risk resilience and climate change adaptation		–	–	159 749	159 749	159 749	159 749	159 749	159 749
S2B6 Increase in property values		–							
S3B1 Revenues from selling of residential buildings		–	–	1 256 870	3 456 391	17 910 391	10 369 174	–	–
S3B2 Revenues from commercial spaces		–	–	742 959	2 043 137	10 587 165	6 129 411	–	–
S3B3 Revenues from selling of parking spaces		–	–	169 635	466 496	2 417 295	1 399 487	–	–
S3B4 Improved air quality		53 726	53 726	64 797	75 868	181 041	217 509	380 967	494 280
S3B5 Improved living conditions of vulnerable categories			–	–	–	1 452 440	1 850 385	1 850 385	1 850 385
Total Benefits		**53 726**	**53 726**	**2 394 010**	**6 220 972**	**35 122 302**	**22 541 869**	**4 809 382**	**4 995 477**
Present Value of Benefits		50 554	50 554	1 994 493	4 588 838	22 938 509	13 034 966	2 462 334	2 135 560
Cumulative PV Benefits	95 993 224								

Year	Cumulative values	2024	2025	2027	2029	2031	2033	2035	2036–2040
Cost sources									
S0C1 Electricity costs									
S0C2 Annual maintenance cost									
S0C3 Parking costs									
S0C4 Air quality									
S0C5 Noise pollution									
S1C1 Maintenance costs I1									
S1C2 Maintenance costs I2									
S2C1 Maintenance costs		–	–	1 503	2 992	40 020	40 536	41 296	42 937
S0B2 Gentrification of neighbourhood		356 510	356 510	356 510	367 205	321 305	321 305	283 666	277 331
S3C1 Energy costs		(199 300)	(199 300)	(199 300)	492 255	492 255	522 233	554 037	605 940
Total Costs		**157 210**	**356 510**	**358 012**	**370 198**	**361 325**	**361 841**	**324 962**	**320 268**
Present Value of Costs		157 210	335 460	298 267	273 072	235 983	209 237	166 376	137 462
Cumulative PV of Costs		3 611 823							
Undiscounted cash flows									
CAPEX		(42 750)	(7 775 528)	(10 308 304)	(12 920 104)	–	–	–	–
Total costs		157 210	(356 510)	(358 012)	(370 198)	(361 325)	(361 841)	(324 962)	(320 268)
Total benefits		–	53 726	2 394 010	6 220 972	35 122 302	22 541 869	4 809 382	4 995 477
Net Cash Flow	(51 704 694)	157 210	(302 784)	2 035 997	5 850 775	34 760 978	22 180 029	4 484 419	4 675 210
Discounted cash flows (SDR1)									
CAPEX		(42 750)	(7 316 422)	(8 588 036)	(9 530 385)	–	–	–	–
Benefits		–	50 554	1 994 493	4 588 838	22 938 509	13 034 966	2 462 334	2 135 560
Costs	(42 720 695)	(157 210)	(335 460)	(298 267)	(273 072)	(235 983)	(209 237)	(166 376)	(137 462)
Net Cash Flow		(199 960)	(7 601 328)	(6 891 810)	(5 214 620)	22 702 526	12 825 730	2 295 958	1 998 099
Cummulative cash flow		(199 960)	(7 801 288)	(23 627 046)	(34 058 955)	(2 907 432)	31 203 839	39 670 212	45 851 421