Assessing Greek policies for energy efficiency in urban scale: the case of Chalepa neighbourhood

Despina Dimelli[1][1]

[1]Technical University of Crete, Akrotiri campus, 73100, Chania, Greece

Abstract. This study examines the environmental challenges and sustainability potential of Chalepa, a historic neighbourhood in Chania, Crete, through the lens of the LEED for Neighbourhood Development (LEED-ND) framework. While Greece's national energy and climate strategies align with EU directives and promote energy efficiency and urban resilience, localized implementation remains uneven. Chalepa faces pressing issues such as coastal erosion, urban heat island effects, inefficient building stock, and inadequate mobility and waste infrastructure. Applying LEED-ND highlights critical deficits in transit accessibility, green infrastructure, and community engagement. Despite these shortcomings, Chalepa's cultural identity, mixed-use potential, and scenic character offer a foundation for sustainable transformation. The paper proposes context-specific strategies including coastal protection, energy retrofitting, green space revitalization, and sustainable transport enhancements, supported by participatory planning and nature-based solutions. The findings emphasize the need for integrated policy execution and capacity-building at the municipal level to align neighbourhood development with national climate and energy goals.

Introduction

Greece's energy efficiency policies today are largely shaped by its commitments under the European Green Deal and the EU Energy Efficiency Directive [1]. The country's primary guiding document is the National Energy and Climate Plan (NECP) 2020–2030, which outlines targets for reducing energy consumption and greenhouse gas emissions. It aims for a 38% reduction in primary energy consumption compared to business-as-usual projections by 2030, while also promoting energy savings across all sectors—residential, public, transport, and industrial [2]. A central legislative instrument is Law 4342/2015, which transposes the EU Energy Efficiency Directive into national law. It establishes frameworks for energy audits, energy service companies (ESCOs), and obligations for energy savings in the public sector, including regular renovations of public buildings and the use of energy-efficient public procurement. Greece has also aligned with the Energy Performance of Buildings Directive (EPBD) through the KENAK regulation, which mandates minimum energy performance standards for new and renovated buildings. This framework promotes thermal insulation, efficient heating and cooling systems, and building energy certification. National support schemes, such as "Exoikonomo-Autonomo", provide financial incentives to homeowners and building managers to enhance energy efficiency through retrofits, smart technologies, and the integration of renewable energy. At the urban level, Greek

1 Despina Dimelli ddimelli@tuc.gr

municipalities have been encouraged to adopt Sustainable Energy and Climate Action Plans (SECAPs) under the Covenant of Mayors for Climate and Energy, with over 100 municipalities participating [3]. These plans address urban energy use through building retrofits, efficient public lighting, and sustainable mobility strategies, although implementation varies widely based on local capacity [4]. Recent national initiatives further support urban energy efficiency. The "Electra" programme targets the renovation of public buildings while the “Iliaktida” scheme supports small-scale residential photovoltaic systems and battery storage. Additionally, the Recovery and Resilience Facility (RRF) and the Just Transition Fund channel EU resources into sustainable urban and energy projects [5].-Despite progress, key challenges remain the limited administrative capacity in small municipalities, fragmented governance between national and local levels, and slow building renovation rates. Nonetheless, the policy environment is increasingly supportive, with Greece recognizing the urban scale as a critical level for meeting its energy efficiency and climate targets.

1 Environmental assessment tools for urban neighborhoods

Environmental assessment tools are essential for promoting sustainable development at the neighborhood scale. They provide structured frameworks for evaluating environmental, social, and economic sustainability in urban planning. Key frameworks include LEED for Neighborhood Development (LEED-ND), BREEAM Communities, CASBEE for Urban Development, and the Living Community Challenge. These tools guide decision-makers, planners, and developers in embedding sustainability into planning, design, and implementation.

LEED-ND, developed by the U.S. Green Building Council with the Congress for the New Urbanism and the Natural Resources Defense Council, is globally influential. It integrates smart growth, urbanism, and green building principles. Assessment categories include smart location and linkage, neighborhood pattern and design, and green infrastructure. It promotes compact, walkable, transit-accessible, and low-impact development, advancing health, livability, and resilience. BREEAM Communities, developed in the UK by BRE, targets early-stage planning of large projects, examining stakeholder engagement, land use, ecology, resources, and transport. CASBEE-UD, developed in Japan, emphasizes quantitative performance indicators such as heat island mitigation, stormwater management, and energy efficiency.-Unlike building-level tools, these frameworks consider urban systems—mobility, public space, and community life—aligning projects with sustainability goals like climate resilience, resource efficiency, and inclusivity [6]. LEED-ND offers distinct advantages. It provides internationally recognized certification, boosting marketability and stakeholder trust. It aligns with smart growth, fostering dense, mixed-use development, reduced automobile dependence, and lower greenhouse gas emissions while supporting active mobility. It promotes ecosystem preservation, green infrastructure, and biodiversity while improving stormwater management. LEED-ND also values community participation and equitable development, encouraging inclusive, healthy neighborhoods [7]. Despite critiques of cost and complexity, it remains a robust, adaptable framework successfully applied worldwide.

This study applies a qualitative urban sustainability assessment using LEED-ND. Methods include desktop research, spatial analysis, field observation, and policy review to evaluate Chalepa, Chania. Fieldwork in 2025 involved walking audits, photography, and qualitative notes on land use, buildings, and street activity. Secondary data included spatial plans (GUP of Chania, NSCCA, OPCC), statistical sources (ELSTAT, municipal mobility and tourism reports), remote sensing and GIS data (land use, slope, building footprint), and literature on Chalepa's history and environmental challenges.

2 Environmental Problems of Chalepa's Neighbourhood.

The coastal city of Chania, located on the northwest coast of Crete, is characterized by a blend of historic urban fabric, scenic waterfronts, and vibrant neighborhoods that are shaped by centuries of multicultural influence. However, like many other coastal cities in Greece, Chania is facing mounting environmental challenges that threaten its sustainability, quality of life, and resilience to climate change. Chalepa is a historic neighborhood located on the eastern outskirts of τthe city (Fig.1). It is known for its distinctive architectural identity, shaped during the late 19th and early 20th centuries when the area served as a diplomatic and political hub during the Cretan State era. Chalepa is particularly notable for its neoclassical mansions, many of which belong to foreign consuls and Cretan political figures. The urban fabric of Chalepa is characterized by low- to medium-density development, with detached and semi-detached houses, often accompanied by private gardens and internal courtyards.

Fig. 1. Chalepa neighborhood

The neighborhood occupies a gently sloping terrain, offering sea views from many locations. Land use in Chalepa is predominantly residential, though there are elements of mixed-use, including schools, churches, small commercial establishments, and cultural institutions. The neighborhood retains a suburban feel, with green plots and open spaces, although public green areas are limited and fragmented. While accessible by public transport, the area is more reliant on private vehicles due to the infrequent bus service and minimal cycling infrastructure. Pedestrian infrastructure exists but is inconsistent in quality. In recent years, Chalepa has experienced increasing development pressures, with historic buildings being restored for private residences or tourist accommodations. Despite these changes, it retains a quiet, residential character, marked by cultural heritage, architectural value, and scenic views, making it one of Chania's most sought-after and emblematic neighborhoods. A primary environmental concern in Chalepa's neighborhoods is coastal erosion, driven by both natural processes and human activities. Rising sea levels, intensified by climate change, have increased the frequency and intensity of storm surges, leading to visible degradation of beaches and public coastal infrastructure. The absence of adequate soft and hard coastal defenses worsens the vulnerability of built environments near the sea.

Another critical issue is the urban heat island (UHI) effect, resulting from high-density construction, limited vegetation, and the predominance of impervious surfaces such as asphalt and concrete. Coastal neighborhoods, although benefiting from sea breezes, still experience elevated temperatures during the summer months due to the lack of shading, green infrastructure, and thermal insulation in older buildings. Public green space is scarce, fragmented, and often poorly maintained, reducing both ecological value and community well-being. Chania's growing popularity as a tourist destination puts significant pressure on the city's waste management system. During peak tourist season, coastal neighborhoods generate high volumes of solid waste that exceed collection and disposal capacities, leading to littering, overflowing bins, and marine pollution. Moreover, the wastewater system in older districts is often outdated, with limited separation between rainwater and sewage, increasing the risk of effluent discharge into the sea during heavy rains [8]. The increasing number of private vehicles, particularly from tourists and seasonal residents, contributes to traffic congestion, noise, and localized air pollution. Coastal roads are often gridlocked, and sidewalks are narrow or obstructed, compromising accessibility and pedestrian safety. Public transport options are limited, and there is a lack of cycling infrastructure, which discourages sustainable transportation. The building stock in the area is diverse, ranging from listed heritage buildings to modern apartments. Many older buildings lack proper thermal insulation, energy-efficient systems, or integration with renewable energy. Consequently, energy inefficiency is widespread, leading to high emissions and operating costs, particularly in the residential and hospitality sectors. While some efforts have been made under programs such as "Exoikonomo-Autonomo," retrofitting remains uneven and underfunded.

3 The application of LEED-ND Assessment in Chalepa's Neighborhood.

Applying LEED-ND to Chalepa's Neighborhood offers a multidimensional perspective on its urban sustainability performance. Situated in an urban area historically marked by industrial uses, Chalepa has evolved into a mixed-use district characterized by residential, commercial, civic, and recreational facilities. This transformation makes it a suitable candidate for LEED-ND evaluation, particularly across the three main categories: Location and Linkage, Neighborhood Pattern and Design, and Green Infrastructure and Buildings (Table 1).

Table 1. LEED-ND Assessment Table: Chalepa's Neighborhood, Chania

Category	LEED Credit/Element	Assessment Summary	Qualitative Rating
Location & Linkage (LL)	Brownfield Redevelopment	No explicit brownfield development mentioned; historic and residential land use predominates.	Not Applicable
	Preferred Location (Urban Infill)	Urban neighborhood within city limits, characterized by historical continuity and existing infrastructure.	Satisfactory
	Proximity to Transit	Some bus access, but service is infrequent and public transport infrastructure is limited.	Needs Improvement

Category	LEED Credit/Element	Assessment Summary	Qualitative Rating
	Bicycle Network and Storage	Lacks adequate cycling infrastructure; bicycle use is minimal.	Needs Improvement
	Housing and Jobs Proximity	Some mixed-use functions are present (schools, shops, institutions), but primarily residential with limited job density.	Needs Improvement
	Wetland and Water Body Conservation	Coastal erosion is a major issue; lack of adequate protective infrastructure.	Poor
	Steep Slope Protection	Gently sloping terrain: no major concerns noted.	Satisfactory
	Floodplain Avoidance	Some vulnerability to storm surges and sea-level rise; existing structures at risk due to inadequate coastal defenses.	Needs Improvement
Neighborhood Pattern & Design (NPD)	Walkable Streets	Some pedestrian infrastructure, but inconsistent quality and narrow/obstructed sidewalks.	Needs Improvement
	Compact Development	Low to medium density, suburban character; not compact but also not sprawled.	Moderate
	Mixed-Use Neighborhoods	Limited mixed-use development; predominantly residential with few amenities.	Needs Improvement
	Housing Diversity	Mix of building ages and types; however, housing affordability and typological diversity are not detailed.	Incomplete
	Reduced Parking Footprint	No data on parking strategy; dependence on private vehicles suggests a high parking footprint.	Not Assessed
	Connected and Open Community	Strong cultural identity and scenic character; open in terms of views and layout but limited public green space connectivity.	Needs Improvement
	Transit Facilities	Lacking integrated transit stops, shelters, or facilities.	Needs Improvement
	Access to Civic and Public Space	Some cultural and educational institutions, but public green space is fragmented and poorly maintained.	Needs Improvement
	Community Outreach and Involvement	No information is provided on participatory planning or community engagement.	Not Assessed
Green Infrastructure & Buildings (GIB)	Energy Efficiency in Buildings	Older building stock largely lacks insulation or efficient systems; uneven retrofitting under national programs.	Needs Improvement
	Renewable Energy Production	Minimal integration of renewable energy (e.g., photovoltaics); below potential.	Poor
	Water Efficiency and Reuse	Outdated wastewater infrastructure; limited separation between sewage and rainwater, increasing pollution risks.	Poor
	Stormwater Management	Lacks green stormwater infrastructure; risk of overflows and pollution during storms.	Poor
	Heat Island Reduction	UHI effect present due to high impervious surface coverage and limited vegetation; older buildings lack thermal performance.	Needs Improvement
	Green Infrastructure and Open Space	Some green plots and gardens exist, but public green infrastructure is fragmented, under-maintained, and inadequate for ecological and social function.	Poor
	Construction Waste Management	No mention of recycling or waste minimization during construction.	Needs Improvement
	Solid Waste Management	High seasonal waste loads due to tourism; inadequate collection and disposal systems lead to marine pollution and public hygiene issues.	Critical Issue

Category	LEED Credit/Element	Assessment Summary	Qualitative Rating
	Air Quality and Pollution	Increased vehicle use causes localized air pollution and noise; no air quality mitigation measures noted.	Needs Improvement

4 Strategies for Environmental Improvement in Chalepa, Chania

Chalepa, a historically significant neighborhood in Chania, faces environmental challenges that jeopardize its long-term sustainability and resilience. These include coastal erosion, the urban heat island (UHI) effect, energy inefficiency in buildings, unsustainable mobility patterns, and inadequate waste and stormwater management. Drawing on the principles of the LEED for Neighborhood Development (LEED-ND) rating system, this paper proposes integrated strategies for environmental development tailored to the specific context of Chalepa.

Given the neighborhood's proximity to the coastline and its exposure to rising sea levels and intensified storm surges, implementing a climate-adaptive coastal protection strategy is critical. This should include a combination of soft and hard engineering solutions. Soft measures, such as beach nourishment and vegetated dunes, can be employed to absorb wave energy and enhance ecological resilience [9]. These can be complemented by hard infrastructure like breakwaters and seawalls in high-risk zones. Establishing setback lines and restricting new constructions in vulnerable areas is essential to mitigate future risk [10].

The urban heat island effect in Chalepa results from limited vegetation, a predominance of impervious surfaces, and aging building stock. Increasing vegetative cover through green corridors, pocket parks, and tree-lined streets can significantly reduce ambient temperatures and improve air quality [11]. Native Mediterranean plant species should be prioritized for their drought resistance and low maintenance needs. Green roofs and vertical gardens on public and residential buildings would also contribute to thermal regulation and enhance biodiversity [12].

Many buildings in Chalepa lack thermal insulation and rely on outdated mechanical systems, leading to high energy consumption and greenhouse gas emissions. Energy retrofitting should be expanded under national programs such as “Exoikonomo-Autonomo,” focusing on improving envelope insulation, upgrading HVAC systems, and integrating renewable energy technologies like photovoltaic panels. However, retrofitting should be sensitive to the architectural heritage of the area, guided by conservation principles that preserve façades and character-defining features.

Mobility in Chalepa is currently dominated by private vehicle use due to inadequate public transport and lack of cycling infrastructure. Enhancing the frequency and coverage of the public bus network would reduce dependence on cars and alleviate congestion and pollution [13]. Developing a safe and continuous cycling network, as well as improving the quality of pedestrian infrastructure, will foster active transport modes. These interventions would not only reduce emissions but also promote healthier lifestyles and social interaction.

Tourism-induced seasonal waste peaks in Chalepa often exceed the neighborhood’s collection and disposal capacity, leading to littering and marine pollution. A comprehensive waste management strategy should include waste separation at source, local recycling points, composting initiatives, and public awareness campaigns [14]. Simultaneously, the neighborhood’s aging combined sewer system requires upgrading to separate rainwater from sewage, thereby minimizing overflow risks and coastal contamination during heavy rainfall events. Nature-based solutions like bioswales and rain gardens can further support sustainable stormwater management. Chalepa’s limited and fragmented green spaces reduce opportunities for social cohesion, recreation, and ecosystem services. Strategic revitalization of existing public spaces and the creation of new ones, especially in underutilized plots, are essential. Community gardens, shaded seating areas, and children's play zones should be integrated to promote inclusive use and intergenerational interaction[15]. These efforts can be supported by participatory planning processes that ensure alignment with resident needs and historical context. Behavioral change and stewardship are essential for sustaining environmental gains. Local environmental education programs, community clean-up days, school initiatives, and participatory design workshops can build environmental awareness and empower citizens. Building local capacity for sustainable practices also ensures continuity and ownership, fostering a culture of resilience.

5 Conclusions

The application of the LEED for Neighborhood Development (LEED-ND) framework to Chalepa, a historic neighborhood in Chania, Crete, uncovers significant gaps and only partial alignment with Greek environmental policies. Although Greece has adopted EU-aligned legislation for environmental protection, challenges persist in implementing these policies locally, especially in heritage-rich areas like Chalepa. In the Location and Linkages category, intended to promote smart growth and ecological conservation, enforcement is weak, particularly in coastal zones where development pressures often overshadow environmental concerns. Coastal management measures such as setback enforcement and erosion control are poorly applied. Within the Neighborhood Pattern and Design category, sustainable urban development goals like walkability and mixed-use are inadequately supported. Chalepa's dependence on private vehicles persists due to limited public transit, poor pedestrian infrastructure, and a lack of cycling networks, reflecting a gap in localized planning and funding. Regarding Green Infrastructure and Buildings, despite national retrofit incentives, challenges arise from the complexity of upgrading historic buildings and outdated waste and stormwater systems. The study highlights limitations of LEED-ND's North American origins and methodological constraints, emphasizing the need for local adaptation, participatory governance, and enhanced data integration. A holistic, context-aware approach is essential to transform Chalepa into a resilient, sustainable urban district.

References

1. European Commission, The European Green Deal (2019), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640.
2. Ministry of Environment and Energy, National Energy and Climate Plan (NECP) 2021–2030. (2019). Retrieved from https://energy.ec.europa.eu/system/files/2020-03/el_final_necp_main_en_0.pdf
3. Covenant of Mayors, Signatories in Greece, (2023) Retrieved from https://www.covenantofmayors.eu.
4. A. Sdoukopoulos,, I. Argyriou, & D. Semicopulas, Municipal Sustainable Energy and Climate Action Plans in Greece: A critical review. Sustainability, 12(21), 8823. (2020), https://doi.org/10.3390/su12218823.
5. European Commission, Recovery and Resilience Facility: Greece, (2021), https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages/greeces-recovery-and-resilience-plan_en
6. A. Sharifi, & A. Murayama, A critical review of seven selected neighborhood sustainability assessment tools. Environmental Impact Assessment Review, 38, 73–87. (2013), https://doi.org/10.1016/j.eiar.2012.06.006

7. D. Farr, Sustainable urbanism: Urban design with nature. John Wiley & Sons. (2011).
8. N. Skoulikidis, N. (2016). The State and Origin of River Water Composition in Greece. In: N. Skoulikidis,, E. Dimitriou,, I. Karaouzas, (eds) The Rivers of Greece. The Handbook of Environmental Chemistry, vol 59. Springer, Berlin, Heidelberg. https://doi.org/10.1007/698_2016_468
9. L. Pinto, I.Mendes, & F. Taveira-Pinto, Coastal protection alternatives for climate change adaptation: A Portuguese case study. *Ocean & Coastal Management*, *186*, 105111, (2020).
10. R. Nicholls, P. Wong, V. Burkett, J. Codignotto, J. Hay, R.McLean,... & C. Woodroffe, Coastal systems and low-lying areas. In M. L. Parry et al. (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge University Press, (2007).
11. S. Gill, J. Handley, A. Ennos, & S. Pauleit, Adapting cities for climate change: The role of the green infrastructure. *Built Environment*, *33*(1), 115–133(2007).
12. E. Oberndorfer, et al., Green roofs as urban ecosystems: Ecological structures, functions, and services. *BioScience*, *57*(10), 823–833 (2007).
13. D. Banister, The Sustainable Mobility Paradigm. *Transport Policy*, *15*(2), 73–80(2008).
14. D. Wilson, C. Velis, & C. Cheeseman, Role of informal sector recycling in waste management in developing countries. *Habitat International*, *30*(4), 797–808 (2012).
15. V. Jennings, A. Baptiste, N. Osborne Jelks, & R. Skeete, Urban green space and the pursuit of health equity in parts of the United States. *International Journal of Environmental Research and Public Health*, *14*(2), 143, (2016).