

Article

Ecological Design for Urban Regeneration in Industrial Metropolitan Areas: The Santa Cruz Refinery Case

Juan Diego López-Arquillo ¹, Cano Ciborro Víctor ¹, Oliveira Cristiana ^{2,*}, Esteban Penelas José Luis ³,
Domouso de Alba Francisco ³ and Arteaga Orozco Mariana Bernice ⁴

¹ School of Architecture, Universidad Europea de Canarias, 38300 Tenerife, Spain; juandiego.lopez@universidadeuropea.es (J.D.L.-A.); victor.cano@universidadeuropea.es (C.C.V.)

² Faculty of Social Sciences, Universidad Europea de Canarias, 38300 Tenerife, Spain

³ School of Architecture, Engineering and Design, Universidad Europea de Madrid, 28670 Villaviciosa de Odón, Spain; jluis.esteban@universidadeuropea.es (E.P.J.L.); francisco.domouso@universidadeuropea.es (D.d.A.F.)

⁴ School of Agronomics, Food and Biosystems, Universidad Politécnica de Madrid, 28040 Madrid, Spain; mb.arteaga@alumnos.upm.es

* Correspondence: cristiana.oliveira@universidadeuropea.es

Abstract: Ecological design is crucial in shaping contemporary, resilient, and livable cities. The Santa Cruz de Tenerife Refinery, a prominent landmark in the Mid-Atlantic, serves as an exemplary case study for understanding advanced metropolitan processes and integrating trans-scalar, trans-disciplinary, and nature-based solutions (NBS) practices into urban contexts. This article explores the challenges of transforming obsolete industrial areas, including the refinery's decommissioning process, its port, and industrial heritage value, and their relationship with the sea, into vibrant urban cores. It examines innovative strategies for land use, decontamination, and urban resilience, which are vital for fostering adaptability and recovery from natural and anthropogenic disasters. By emphasizing the refinery's connection to Santa Cruz de Tenerife and its metropolitan area, as well as its coastal interface, this study proposes a comprehensive methodology to assess the territorial impacts of urban processes and guide project decisions toward enhancing the quality of life for the region's residents.

Keywords: ecology; green and blue infrastructure; regeneration; world value survey; urban data; metropolitan; refinery



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1. Introduction: 'Ecological Design', 'Trans-Scalarity', 'Transdisciplinarity', and 'Nature-Based Solutions' in Neglected Urban and Industrial Areas

The conversion of central urban spaces formerly used for industrial purposes is a crucial aspect of contemporary urban development [1]. This global trend highlights city consolidation and growth dynamics [2], prompting a critical reevaluation of land use, infrastructure, and the social functions of underutilized areas [3,4]. The aim is to better integrate these spaces into the urban fabric, optimizing their use while advancing sustainability, equity, and quality of life.

This article focuses on three interrelated operational concepts, illustrated through practical examples and case studies: ecological design, trans-scalar approaches, transdisciplinarity, and nature-based solutions (NBS).

Ecological design, defined in 1996 by Sim Van der Ryn and Stuart Cowan as “any form of design that minimizes environmentally destructive impacts by integrating itself with living processes” [5], shifts our understanding of urban design. It emphasizes the relationships between human and non-human bodies with their surroundings [6], moving beyond the composition of architectural objects to consider trans-scalar dynamics, flows, and organisms. Design thus becomes sensitive to multiple entities and scales.

This process necessitates a transdisciplinary approach, recognizing the complex interplay between physical space, social dynamics, and the environment [7]. It involves collaboration among residents, planners, architects, developers, and policymakers, with participatory planning strategies essential to reflect community needs and aspirations, promoting social and economic inclusion. Regenerating central urban spaces challenges traditional notions of urban growth and development, requiring a planning approach that balances innovation with conservation, promotes functional diversity, and anticipates future needs. Comprehensive urban regeneration can thus initiate and direct sustainable transformation in the medium and long term [8].

The impact of sustainable urban interventions emerges from the intersection of physical space, social dynamics, and environmental factors. This interdependence informs advanced interventions through the mapping of metropolitan processes, leading to the fourth operational concept: nature-based solutions (NBS). According to the International Union for Conservation, NBS are “actions to protect, sustainably manage, and restore natural or modified ecosystems, addressing societal challenges effectively and adaptively, while providing human well-being and biodiversity benefits” [9]. Implementing NBS, such as green infrastructures and low-impact technologies, demonstrates a commitment to mitigating climate change effects, promoting urban resilience, and building a shared identity [10], facilitating the transition towards urban models centered on spatial justice, ecological efficiency, and social inclusion [11].

Today’s urban development recognizes previously overlooked urban spaces in architectural historiography, once termed ‘non-places’ [12] or ‘third landscape’ [13], as areas of significant relevance and potential for new forms of city and habitation development. The late 1980s marked a reconsideration of these interstitial and residual urban areas as valuable architectural spaces.

Early projects reflecting these concerns include the Barcelona ‘92 operation, led by Oriol Bohigas during the 1992 Olympics. Bohigas’ work focused on these residual spaces across neighborhood, city, and territorial scales [14], notably the recovery and conversion of Barcelona’s coastline and port from a degraded, disconnected area. A similar transformation occurred with the smelter in Monterrey, Mexico (Figure 1).



Figure 1. Aerial view of the smelter. 1959. Monterrey, Nuevo León, Mex. Credits: (a) Monterrey Historical Archive. (b) Fundidora Regeneration Project. Monterrey, NL, Mex. By MBO.

This example led to other localized and updated recoveries worldwide, such as the recovery of Boston’s harbor.

In Boston, new neighborhoods, infrastructures, and museums were introduced, showcasing the interaction between preserved historical elements and new developments at both urban and neighborhood scales. Particularly noteworthy is Boston’s 2018 urban remodeling plan in response to climate change, which transformed the coastline into a highly resilient

edge. This project stemmed from the “Imagine Boston 2030” initiative (Figure 2) and was based on the analysis of “Climate Ready Boston 2070” flood maps. The plan aims to build infrastructures along Boston’s most vulnerable flood zones, focusing on the city’s four most critical areas.



Figure 2. Boston’s long-term climate resilient strategy, with coastal resilient solutions useful now and in any flooding event for east Boston, by Stoss Klienfelder, One Architecture, Woods hole group, image produced by SCAPE.

The coexistence of Boston’s edges and new architectures, such as the ICA by Diller Scofidio + Renfro, could serve as a model for other cities with declining industrialized maritime edges. The conversion of the old port of Genoa, initiated in the 1990s for the Columbus Expo, acted as a catalyst for a highly sensitive rehabilitation based on Renzo Piano’s architectural proposal and his delicate, technological, tensile, and textile architectures. This provides another example of urban suturing on a city’s maritime edge.

This text, therefore, focuses on the consideration of industrial residual voids located on maritime edges as fields of study or as architectural entities. This perspective emphasizes mutability and constant change, reflecting the novel conception of edge public space or regenerated industrial space as understood today.

Finally, we highlight a project that demonstrates the trans-scalar nature and NBS of new urban practices in industrial zones adjacent to water bodies. The project “Oyster-tecture” by landscape architect Kate Orff envisions an active oyster reef enhancing marine life and recreational potential in New York Harbor. It proposes a living reef made of a woven web of ‘fuzzy rope’ that supports marine growth, generates a 3D landscape mosaic, attenuates waves, and filters harbor water through the biotic filtration of oysters, mussels, and eelgrass. This nature-based approach improves habitat and water quality, restores biodiversity to tidal marshes, and fosters new relationships between New Yorkers and their harbor (Figure 3).

As architect Lydia Kallipoliti points out, “ecological design” fell into oblivion, overshadowed by “sustainable design”, which, rather than genuinely addressing the conditions and processes of the place and its inhabitants, is marketed as “a moral framework and a heroic model that serves government agencies” and is a consequence of “the advocacy of unfettered growth, free-market capitalism” [15]. In the following pages, we will contextualize, develop a methodology, and offer results for ecological design in the Santa Cruz de Tenerife refinery.

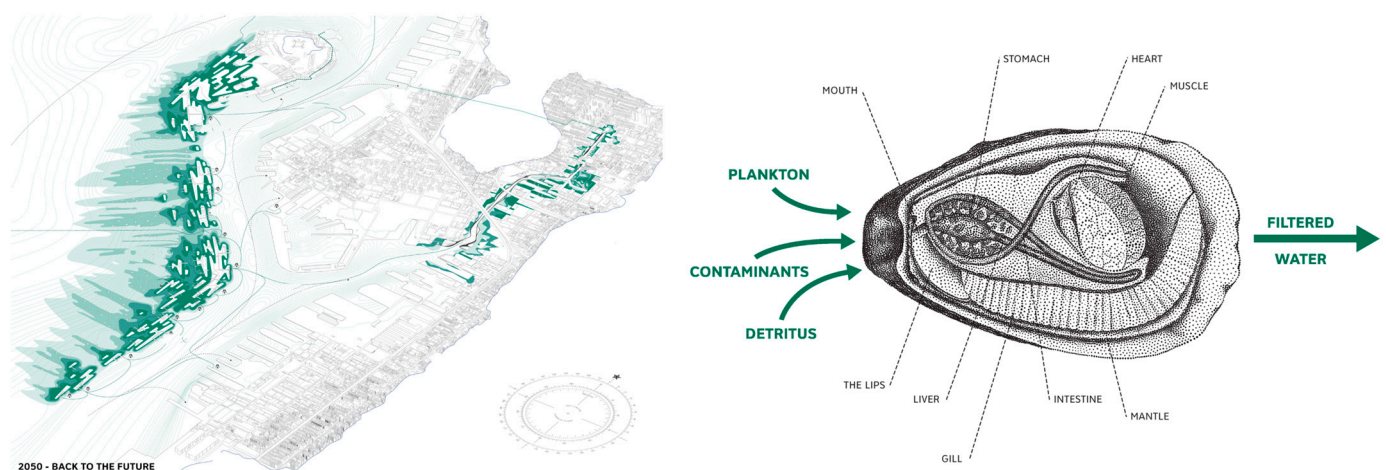


Figure 3. Oyster-tecture implemented in the Brooklyn area of waterfront park at Red Hook Point, Gowanus Channel, and its mouth to the Hudson River. Kate Orff, SCAPE, 2009.

From these considerations of the need to develop a methodology that responds to the characteristic urban complexity of the system, the methodology develops three main hypotheses:

1. The implementation of ecological designs in obsolete industrial areas significantly improves urban sustainability.
2. Nature-based solutions increase urban resilience to disasters and enhance the competitiveness of an urban model.
3. Analytical development from metropolitan positions, outside the boundaries of the area of action, expands the impact of the area's reversion to a much larger scale than that of direct influence.

2. Just Another Consideration on Previous Co-Existence: Conservation as an Opportunity for Eco-Systemic Optimization

Reusing built heritage is part of history and allows the conservation of buildings from different eras capable of adapting to new uses or needs. This process was interrupted at the beginning of the 20th century with the onset of exponential urban growth, facilitated by a new construction industry capable of demolishing, replacing, and building new structures in increasingly shorter times, consuming resources and land without limit. Therefore, our current obligation should be to mitigate its environmental impact at the end of its life cycle, or more responsibly, to provide it with a new, less polluting urban projection, incorporating all the necessary features of new buildings.

Currently, around 56% of the world's population, approximately 4.4 billion people, live in cities [16]. By 2050, the urban population will have doubled, with 7 out of 10 inhabitants living in cities. The global urbanization rate (the percentage of the population living in cities relative to the total population) has evolved from 13% in 1900 to 29.1% in 1950, and it is projected to reach 60.8% by 2030 [13]. The built footprint currently occupies 3% of the Earth's surface, about 4.5 million km², and the growth appears like unstoppable. In less than 20 years, an additional 1.5 million km² of built-up area will be added to the planet, mostly in the form of uncontrolled urban developments. Ninety-five percent of this will occur in the developing world.

From an environmental perspective, the data is alarming: cities account for between 60% and 80% of energy consumption and generate approximately 75% of carbon emissions. The construction life cycle (design, construction, use, demolition, and possible/desirable material recycling) is responsible for 40–50% of greenhouse gas emissions [17].

Demolishing obsolete or disused buildings to construct new projects is very attractive from an architectural creation standpoint and simplifies and enhances the real estate business, but it is incompatible with controlling the carbon footprint. Demolition is often

the only option (due to poor construction quality, structural exhaustion, etc.), but the environmental impact generated by material recycling is increasingly unsustainable. That is not the reality in Santa Cruz de Tenerife, in which one of the largest groups of rationalist architecture from the 1920s and 1930s, even during Spanish Civil War (1936–1939) until the 1950s, was built in Spain, with a well-known average quality in architectural composition in systems and materials (Figure 4).



Figure 4. Representative examples of the architectural quality of Rationalism (1925–1965) in Santa Cruz de Tenerife: Hardisson Building (c.1939) by Enrique Rumeu de Armas (1907–1978) and the Pilots’ house of Port of Santa Cruz (c.1947) by Tomás Machado and Méndez Fernández de Lugo (1908–2003). Photos JDLA.

Separated more than 2000 km from Spain’s mainland—from which most of construction materials are imported by ship—building in Tenerife must always respond to the standard of a dynamic city generating high economic value in its area of influence. Its coastal condition is an incentive but also a limitation for the responsible management of demolition waste recycling.

The recovery of industrial architectures is a challenge that requires architects and engineers to approach the problem not from exclusively historicist perspectives but from design approaches that generate new architectures with the same cultural and urban validity for citizens as new constructions. Conceptually, recovering obsolete architectures and spaces should not be limited solely to energy savings and carbon footprint reduction (which are necessarily required), but should involve interventions incorporating social, cultural, urban, or technological factors essential to understanding the digital society of the third decade of the 21st century (Figure 5). Necessary intervention on obsolete buildings and spaces is an opportunity for architects. Far from being a design or creative limitation, it is an opportunity to reinterpret the relationship between existence and transformation, with full design freedom.

In this sense, the intellectual position of rehabilitation versus demolition–construction is not new. Architects like Lacaton and Vassal, Pritzker Prize winners in 2021, have been working for years on intervention strategies in residential buildings, conserving, reinforcing, and/or manipulating the structure while radically transforming the interior uses and the envelope, defining a model of intervention applicable to many properties. These transformation projects generate radical changes in buildings and environments that citizens initially judged and perceived negatively [18]; after the intervention, these become significant architectural, urban, and real estate investments. These are not rehabilitation projects; they are urban transformation projects.

In the seminal works of Van der Ryn and Cowan (1996) on ecological design, the lines of simulated nature reproduction were already marked, which later inspired the nature-based solutions (NBS) adopted by the International Union for Conservation of Nature (IUCN). These natural simulation solutions have been adopted in urban regeneration projects such as the recovery of Boston’s harbor and the “Oyster-tecture” project in New York.



Figure 5. Transformed smelter after 'Fundidora Regeneration Project' (a) aerial view, (b) garden area. Credits: (a) Fundidora Regeneration Project. Monterrey, NL, Mex. (b) MBAO.

3. The Refinery of Santa Cruz de Tenerife

Port cities inherently represent a potential as laboratories for ideas on the reconversion of coastal industrial systems [19] and the conditioning they have imposed on urban and territorial development, given that these cities are often created around their ports.

The urban evolution of Santa Cruz de Tenerife has been irregular in its growth and form since its founding in 1494. Originally established as a military camp, all its growth until the end of the 19th century occurred around its port [20]. The urban history of Santa Cruz de Tenerife reveals a non-sequential growth model that has undergone various accelerated expansion processes but has always maintained a non-historical stability. However, this stability experienced an almost exponential acceleration during the developmental period from the 1950s to the 1980s [21]. During this period, social and economic stability, industrial progress, and qualified housing policies allowed for the expansion of large housing areas and the overcoming of the city's bounding ravines, which limited its growth, a very elliptical process in certain areas, well into the 1930s [22].

The Santa Cruz de Tenerife refinery exemplifies this transformation. The refinery, established as a key industrial hub, presents a unique case for studying the interplay between urban development and industrialization. Its strategic location and historical significance make it an ideal subject for examining how industrial sites can be integrated into modern urban landscapes.

The future transformation of the refinery area involves addressing the coexistence of iconic industrial elements and their potential repurposing, considering both their historical value and their role in the city's urban fabric. This process includes exploring sustainable urban practices, ensuring environmental resilience, and promoting social cohesion through thoughtful urban planning and design interventions.

The city of Santa Cruz de Santiago de Tenerife had remained stable within its confinement by the natural boundaries of the Santos Ravine to the southeast, the Rambla to the north, and the port to the southeast (Figure 6), with scarcely any settlements outside these limits until well into the 20th century. The necessary expansion associated with its role as the island and subregional capital facilitated the development of its main urban axes, including a large garden area, the García Sanabria Park [23], which continued the layout of the existing city. Additionally, the arrival of a new architectural style, Rationalism [24], renewed the architectural image of the city through the work of architects trained outside the islands, most notably José Blasco Robles [25], Miguel Ángel Martín Fernández de la Torre [26], Domingo Pisaca y Burgada, Rudolph Schneider, and Enrique Rumeu de Armas [27].



Figure 6. Guide map of the city and its port, Santa Cruz de Tenerife in 1917, with the city inscribed within the natural determining features of the main triangulation. Author: Juan M. de Foronda y Cubilla. Code 31-E-1 from the Geographical Documentation Service of the National Geographic Institute.

Architectural rationalism also implied the application of the scientific method at the city scale, facilitating a renewed urban planning model with sectional blocks that formed a constellation of small neighborhoods connected to main roads by secondary streets. This approach led to neighborhood growth with specific differential qualities stemming from their layout (Figure 7), creating the discontinuous and characteristic image of the city for decades [28]. This was consolidated by the 1956 General Urban Plan by Enrique Rumeu de Armas and Luis Cabrera Sánchez, which established the Plan of Volumes that determined the growth of these areas [29]. Additionally, it laid the foundations for the massive transformation of alignments in the city's traditional streets, although it resulted in two significant losses: firstly, the emphasis on the Insular Council building as a model to follow, an artificial architectural neo-regionalism that delayed the full entry of more functional and internationalist Rationalism; and secondly, the demolition of a substantial part of the historic center around the Church of the Conception and the streets between it and the Plaza de Candelaria [30]. From a nucleus that in 1930 had approximately 62,000 inhabitants, the city has evolved over nearly a century to currently have approximately 240,000 inhabitants (2023), with a metropolitan area approaching half a million [31].

In a position removed from that central urban core, the Santa Cruz de Tenerife refinery was established. Inaugurated in 1930, it was the first in Spain, built under the protective possibilities offered by the 1927 Petroleum Monopoly Law. Initially covering nearly 1,000,000 m², it was partially dismantled during the “Cabo Llanos” operation in the 1970s and 1980s [32], creating a purportedly contemporary area on the southwestern edge of the city, between the historic center—bounded by the Santos Ravine—and the active refinery surface. Still in consolidation four decades later [33], this urban operation defined the main urban growth of Santa Cruz, generating representative facilities that shifted the city's activity to positions close to the refinery itself, which ceased refining operations in 2018 and began its dismantling process in 2022. There are several interesting architectonic heritage buildings, such as the machinery warehouse (Figure 8).



Figure 7. Map of Santa Cruz de Tenerife, 1927. Note the growth towards the north surpassing the rambla on the eastern slope of the Santos Ravine, and the lack of settlements on its western slope. by Rafael Villa Calzadilla and Antonio Núñez Maturana. Source: Archive of the Municipal Urban Planning Office of Santa Cruz de Tenerife.



Figure 8. The machinery warehouse of the refinery, by architect José Blasco Robles (c.1957), catalogued in DOCOMOMO, is notable for its constructive and plastic values. The structure is formed by a combination of longitudinally directed warehouses, topped by others with a transverse direction. However, it was shortened by one-third of its total length due to the construction of the avenue next to it. It was previously protected as a cultural heritage site. Assembly by JDLA.

The Santa Cruz de Tenerife refinery represents a unique urban opportunity. The built volume cannot be marginalized, nor can the impact of the final phase of these constructions' life cycle—understood as demolition and material recycling—be ignored, as it is environmentally unfeasible (Table 1). The focus should be on transforming the existing structures rather than replacing them, due to the surface relevance for both city and metropolitan area.

Table 1. Relation between surfaces of Santa Cruz, refinery, port area, and metropolitan area.

Urban Zone	Total Surface (km ²)	% of Total City Surface	% of Total Metropolitan Surface
Santa Cruz de Tenerife	12.95	100	35.72
Refinery	0.75	5.79	2.06
Ports area	0.92	7.10	2.53
Metropolitan area	36.25	279	100

The approach to the Santa Cruz refinery area can be based on an extrapolation of the previously developed concepts: the maintenance and coexistence of iconic industrial elements, and the transformation or reconstruction of one of them as an amplifying trigger for the recovery and transition of the city with the coastline, creating an edge and transition space of resilience. This also considers the simultaneous power and delicacy of this area, which has already become inexorably urban.

4. Potential Metropolitan Transformation Processes from Internal Conditions on Refinery

The methodology employed in order to identify development potential areas through the interpretation of zones requiring regeneration follows an RILUS (Research-by-Integrative Lecture of Urban Space) methodology. In this approach, the potential for regeneration is determined by the sum of the integrated analysis and specific proposals for each urban boundary.

The research design is based on a mixed approach that combines qualitative and quantitative methodologies to evaluate the urban regeneration of the Santa Cruz de Tenerife refinery. The RILUS (Research-by-Integrative Lecture of Urban Space) methodology (Table 2) is employed to integrate spatial, social, and environmental analyses.

Table 2. Components of the methodology, subdividing them into specific analysis elements, research methods, and development proposals. Each row of the matrix describes a component or subcomponent, indicating its hierarchical relationship within the RILUS methodology.

Main Component	Title 2	Title 3
Integrated Urban Space Analysis	Analysis Elements	Topography Land Use Infrastructure Cultural Heritage
	Methods	Direct Observation Cartography Spatial Data Analysis
Identification of Urban Boundaries	Neighborhoods	Border connectivity
Sum of Integrated Analysis and Specific Proposals	WVS Indicators	Well-being Quality of Life Perception of Safety Satisfaction with Urban Services
Metropolitan vs. Nodal Cities	Metropolitan areas Node cities and rural areas	Impact of Scale on Quality of Life Perception

Through this RILUS methodology, the current situation is assessed in terms of spatial configuration, environmental impact, social impact, and potential relationship with gentrification [34], as well as urban conditions and the suitability of existing open data. From this evaluation, a matrix is developed to assess the potential impact of renaturalization and urban regeneration strategies and their relationship with the indicators. Subsequently, simulation models will be used to visualize the proposed strategies and their impact on metropolitan scalability from the urban project.

The local government has aimed as a main urban need to replan the area that will be vacated by the refinery and enhance its relationship with the sea, called the “Santa Cruz Verde 2030” plan. This ambitious plan aims to transform the land occupied by the refinery into a public and commercial space, connecting it with the rest of the city and advancing towards a greener and more sustainable city model. For this reason, it has been decided to suspend the land-use planning instruments for the refinery to facilitate the development of this project, highlighting the need for coordination between all involved administrations and Cepsa, the refinery owner. This transition from a local industrial use to a metropolitan approach based on environmental sustainability implies redefining the city’s relationship with its metropolitan reality, including the connection with the sea.

4.1. Geometry, Representation, and Genius Loci

The design of large-scale territories requires a certain degree of geometrization to conceptualize spaces and dynamics. In this context, we will highlight two examples of very distinctive geometries: the coastal park of Barcelona (1988–1992, MBM architects) and the Parc de la Villette in Paris (1987, architect Bernard Tschumi). These two projects exemplify the morphological complexity and difficulty that such projects must face from geometries and urban situations of very diverse characteristics, which will very likely occur in the refinery area. The choice of these two projects is due to their location in degraded urban residual spaces and the geometries used, which can be considered antagonistic and applicable to various areas of the refinery. On the one hand, the coastal park is based on a fluctuating and sinuous geometry, more organic, based, one might say, on the movement of the waves. The Parc de la Villette—also inserted on an industrial grid to be recovered and regenerated—takes its foundation in a reticular structure marked by the “follies”, chromatic architectural elements with various functions.

When examining beyond the seemingly sustainable appearance of these projects, unsustainable practices are revealed, such as legally sanctioned but communicatively opaque planning mechanisms. Particular interests dominate the concepts of megaprojects, ignoring a participatory approach. These projects often disconnect from the urban process and situate themselves outside collaborative planning structures, despite attracting public attention and improving the city’s global visibility; they tend to emphasize broad benefits, which are especially attractive during election campaigns.

In this perceptive scale, inner geometry is understood as a merely physical element that is discovered through the opening of visual vertices that draw a mixture of contrasts, colorimetry, textures, scales, and graphic rhythms; it is also a tangible element fragmented into different non-material variants. These roots emerge from within a thought, materializing into a planned idea and subsequently into spatial plasticity. The ontological and phenomenological roots that compose the essence of an individual evoke lines of thought that, in the metamorphosis of their intrinsic universe, derive into the cultural significance of each entity [35], thereby granting a unique, singular identity without comparison.

The territory representation [36] refers to the understanding of urban space as the container of all entities and the various ways of residential being. The inherent ability of societies to connect with their environment is established through the core of their spirit, evoking ideologies translated into typologies that define the lived physical space. As witnesses and heirs of ancient civilizations, it can be synthesized that respect and empathy for the natural environment is the path to survival, so the regeneration process is an actual phase of city survival. The remembrance and consideration of what was previously

established, its antecedents, and the elements that compose the landscape, whether artificial or natural, as well as the pre-established alternate ecosystems, achieve the construction of the *pneuma* of space [37], the breath that can infuse life and animate environments within the material medium. In other words, recalling that the *Genius Loci* allows not only for survival but also enriches spaces with culture, art, and tradition. If the idyllic landscapes of the past are the introduction to future possibilities, sustainability achieved through a full understanding of space and its components would be the guidelines to follow in the contemporary era to build the near future.

4.2. Beyond the Local Scale and Non-Protected Heritage

That is the reason for this article to focus on the multiscalar potential of the morphological and planimetric reconfiguration of the current refinery's urban space from a territorial analysis perspective. The renaturalization of urban space is addressed through the conversion of this industrial area (Figure 9) into a large natural space connected to the city's green space network, also applying integrative principles of green infrastructure to efficiently manage rainwater, mitigate heat islands, and improve microclimatic conditions, as well as respect heritage elements.



Figure 9. Southeast edge of the refinery, view from the sea (2023). Note the construction of the industrial image characteristic of the last 9 decades from the accumulation of industrial figures that, however, do not have legal protection for permanence or reconversion. Photo JDLA.

Likewise, the memory of the occupied space, respect for heritage—presented not only in monuments, but in industrial elements and ancient buildings waiting for a qualified classification [38]—and empathy and appreciation for the environment create architectural, urban, and landscape possibilities that can serve as agents of social change. In the case of the refinery in Santa Cruz de Tenerife, there is even the possibility of reconnecting the inhabitant with their own spirit and that of the place, thus linking the individual with their antecedents and opening up new spatial possibilities by reusing the old facilities. This approach also outlines a new framework within its dimensions that additionally includes a psycho-sensory focus, making the individual the delineator of a realizable utopia. It suggests, beyond the implementation of new planning and execution systems, tangible actions that can resume and establish previous development strategies, analogous to those that once allowed humans to blend with the landscape, providing them with history and roots. This cultural baggage can directly impact one's identity, as well as foster a suitable, habitable, and enjoyable environment—one that is alive and aimed at finding quality of life leading towards the concept of happiness.

4.3. Happiness and Well-Being in Cities: Factors

In this context, the World Values Survey (WVS) indicators [39] serve as a crucial measurement of quality-of-life perception, offering a comparative analysis between metropolitan areas and nodal cities that are significant centers but not surrounded by extensive

metropolitan regions. This juxtaposition highlights how the psycho-sensory elements of urban planning can influence the perceived quality of life differently in dense, urbanized metropolitan settings versus more autonomous nodal cities, thus providing deeper insights into the cultural and environmental factors that contribute to an individual's overall sense of well-being and happiness.

The World Values Survey (WVS) indicators serve as comprehensive measures of various dimensions of human values and beliefs across different societies. These indicators encompass a wide array of topics, including perceptions of quality of life, societal well-being, economic conditions, political engagement, and cultural values. By systematically collecting and analyzing data from diverse populations worldwide, the WVS provides valuable insights into how individuals and communities perceive their lives and environments. Of all the indicators, we selected those related to the impact of urban network and their scale:

1. **Urban scale:** population size is studied to understand how the size of the population in different cities affects the perception of quality of life, community cohesion, and satisfaction with public services. Population density is related to perceptions of safety, accessibility to services and green spaces, and urban stress.
2. **Geographical location:** region and subregion are analyzed to see how geographical differences influence the values and perceptions of respondents. For example, cities in coastal areas may have different concerns and priorities than inland cities. Proximity to metropolitan areas examines how closeness to large urban centers affects economic opportunities, access to services, and social mobility.
3. **City size:** large cities and metropolitan areas versus medium and small cities compare the quality of life and satisfaction of residents in major metropolises versus smaller cities. Aspects such as infrastructure, health and education services, and cultural life are considered. Urban growth studies the impact of rapid urban growth on infrastructure, public services, and social cohesion.
4. **Climate:** climatic conditions analyze how different climate conditions (temperate, tropical, cold, etc.) affect perceptions of quality of life and well-being. Climate change examines awareness and attitudes towards climate change and how local experiences influence environmental concerns.

The issue of urban heat islands [40] and urban climate underscores the importance of incorporating green and blue infrastructure solutions to mitigate the effects of climate change in cities. Urban housing and urbanization, in turn, must balance density and habitability [41], integrating sustainability from design to space management. Pollution and waste management, along with the promotion of sustainable cities and the circular economy, reflect the urgency of transitioning towards economic models that minimize waste and maximize resource reuse. This is why all these conditions are being included in proposals for renaturalization and urban regeneration, along with contact with the sea in a new waterfront.

Energy solutions and transitions to renewable sources, as well as considerations of respect for heritage [42]—especially industrial heritage—in defining the Urban Agenda in a post-industrial evolving space, are essential for creating local identities and promoting inclusion and well-being in urban environments. Therefore, the former Santa Cruz de Tenerife refinery is not only presented as a space for physical intervention but as a living laboratory for experimenting and applying urban sustainability principles, paving the way for the transformation of contemporary metropolises into intermediary islands.

4.4. Integration through Superposition of Geographic Information Systems (GIS) and Spatial Decision Support Systems (SDSS)

The integration of geometry and its representation, together with the understanding of local actions in industrial heritage areas and the consideration of cross-scale problems, can be combined with happiness and well-being indices to act precisely in complex envi-

ronments. This is possible by simultaneously using Geographic Information Systems (GIS) and Spatial Decision Support Systems (SDSS).

GIS (in particular the GRAFCAN integration portal, which has been dedicated to the production and management of geographic information in the Canary Islands since 1989) allows for the collection, analysis, and visualization of large amounts of geospatial data, providing a detailed view of the operating environment, including terrain morphology, topography, vegetation, land use, noise, and sunlight indices, as well as existing infrastructure. Analyzing the reality of the refinery involves facing complex challenges related to regeneration, sustainability, the construction of new equipment, and all of this must be considered from a metropolitan scale. Such analysis is impossible without the large-scale visualization facilitated by the GRAFCAN portal (Figure 10).

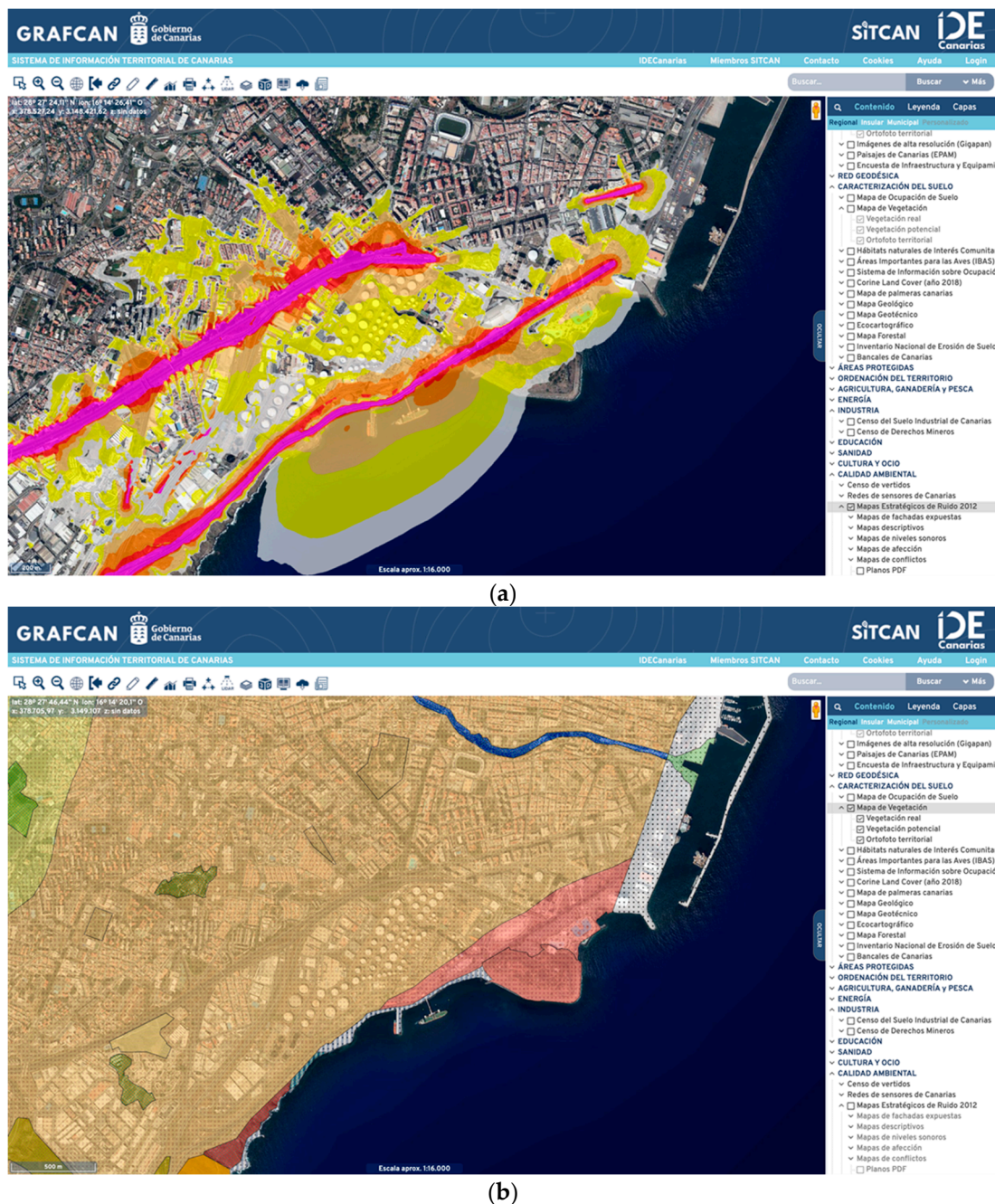


Figure 10. Interface of the GRAFCAN GIS portal, from the refinery area, (a) noise, and massive vegetation (b).

This representation of reality according to its physical modeling parameters and its legal regulatory framework can be superimposed (Table 3), in favor of precision in the effectiveness of the intervention, with SDSS, which provide advanced tools to model and simulate different development scenarios based on urban impact simulation assumptions, such as pollutant dispersion models, hydrological models, and heavy metal soil penetration models, among others.

Table 3. Integration of Geographic Information Systems (GIS) and Spatial Decision Support Systems (SDSS) within the RILUS methodology. The columns detail the type of system, the specific data and measurement parameters used, and the impact and relevance of these data for the project. Each row describes how different types of systems utilize precise and up-to-date data to provide critical information, facilitating informed decision making and the planning of effective urban interventions in the medium and long term.

Type of System	Data and Measurement Parameters	Impact and Relevance for the Project
GIS	Topography: Detailed mapping using high-resolution elevation data and digital terrain models (DTM). Source: GRAFCAN Viewer	Identification of flood risk areas and suitable areas for green and blue infrastructure.
GIS	Land Use: Analysis of current land use and zoning, evaluating soil quality and monitoring changes in vegetation cover. Source: GRAFCAN Viewer	Planning the conversion of industrial areas into public, commercial, and residential spaces.
GIS	Green Infrastructure: Identification of areas for urban parks and green corridors using remote sensing data. Source: GRAFCAN Viewer	Reduction of urban heat islands and increase in biodiversity.
GIS	Blue Infrastructure: Planning of stormwater management systems and creation of artificial wetlands. Source: GRAFCAN Viewer	Flood risk mitigation and improvement of water quality.
SDSS	Air Quality: Pollutant dispersion models using historical emission data and meteorological patterns. Source: AERMOD and CALPUFF Models	Evaluation of the impact of removing industrial structures and introducing green spaces on air quality.
SDSS	Water Management: Stormwater flow simulations using hydrological models. Source: SWMM Models	Design of sustainable drainage systems to mitigate flooding and improve aquifer recharge.
SDSS	Smart Zoning: Development of zoning scenarios for efficient use of space. Source: Climate Ready	Maximization of efficient space use and minimization of land use conflicts.
SDSS	Socioeconomic Impact: Evaluation of the socioeconomic impact of different development scenarios. Source: Climate Ready	Ensuring the environmental, social, and economic sustainability of urban interventions.
GIS	Participation Platforms: Georeferenced surveys and collaborative mapping to gather residents' opinions. Source: OpenStreetMap	Ensuring that interventions reflect the community's aspirations and are inclusive.
GIS	Collaborative Mapping: Community workshops using interactive maps for inclusive planning. Source: OpenStreetMap	Fostering community participation and a sense of ownership in regeneration projects.
SDSS	Satisfaction Evaluation: Georeferenced surveys on satisfaction with urban services and quality of life. Source: World Values Survey	Measuring the impact of interventions on residents' quality of life and adjusting regeneration strategies.

This combination of GIS and SDSS provides a solid foundation for informed decision making, based on accurate and up-to-date data, which is crucial to ensure that urban interventions are effective in the medium and long term.

5. Results: Border-Lines, Border-Scapes, and Border-Bodies: The Challenge of Four Borders to Transcend Local Scale

This methodology explores the possibilities for metropolitan development and regeneration by examining the transformative potential of specific areas, such as the Santa Cruz de Tenerife refinery. The refinery area, with its diverse urban conditions and degraded spaces, offers a unique opportunity to reconnect the urban fabric by focusing on its edges and borders with the surrounding natural environment and the consolidated city [43]. By emphasizing the analysis of these borders, a comprehensive approach emerges that goes beyond physical and human-centered space transformation. It also respects and acknowledges the cultural, historical, affective, and non-human connections that shape a strong and contemporary urban identity.

Specifically, four borders, selected based on their potential, have been identified and will be studied through multiple and contemporary spatial dynamics (Figure 11).



Figure 11. Map of Santa Cruz Refinery and its four borders. Triggering of the project. Author: VCC.

- East Border: “Economic-Cultural Border”. Av. Manuel Hermoso Rojas/Los Llanos.

Taking Av. Tres de Mayo, we find one of the areas with the greatest cultural and economic potential in Santa Cruz. The Meridiano shopping center is joined by the Trade Fair Center, the proximity of “El Tanque”, and the César Manrique Maritime Park.

- South Border: “Maritime Border”. TF-4.

TF-4 highway acts as a barrier between the refinery and the sea. A significant change in elevation is observed until reaching the highway itself, leading to the laconic Buenos Aires beach, the Virgen de la Regla Fishing Club, and the Honduras Port.

- North Border: “Social Border”. Calle Panamá and TF-5.

A border widening creates an isolating zone fluctuating between industry and four residential blocks that encounter the TF-5 highway. This creates an oasis disconnected from the Somosierra or Los Gladiolos neighborhoods.

- Meta-Border: “Landscape and Recreation Border”. Refinery Ravine.

There is an abrupt ravine running through the refinery from northwest to southeast. In the southern area, this particular crack in the territory ends in a roundabout, impeding its passage towards the Palmetum. In the northern area, the highway and its branches create another frontier.

5.1. *Border-Lines, Border-Scapes and Border-Bodies: Mappings and Potential Designs*

By understanding the lines ('border-lines'), the landscapes they create ('border-scapes'), and the human and non-human bodies ('border-bodies'), that inhabit the four borders of the refinery, we can promote ecological design strategies that are sensitive to context-specific issues. This research-by-design methodology is founded on three stages that hybridize analysis and design across various scales and degrees of detail.

5.1.1. Border Cartographies: Making Visible the Invisible

Following philosopher Félix Guattari and his notions of the "Three Ecologies" [44], the intention is to visualize the physical, social, and affective infrastructures related to the refinery. This means mapping not only the visible lines of city layouts and constructions but also the invisible lines that form the city's affective and relational networks.

At this stage, ethnography will be of great importance: visiting the site, observing, and noting what is happening. These border cartographies should incorporate the reality of the place while emphasizing a particular theme that stands out and takes center stage. What dimension, element, or community are we highlighting? Why is making such an entity visible interesting? We are not seeking generic and abstract knowledge; we aim for "situated knowledge" [45].

5.1.2. Border Proposal: Responds to Necessities

Once the cartography is complete, a spatial understanding of both tangible dimensions (morphological and infrastructural) and intangible dimensions (affective, sociological, and ecological) is achieved. It is then time to cross the borderline and engage in urban design that addresses the population's needs. At this stage, urban forms, morphologies, and geometries emerge in the area. Different necessities are linked to ecological designs related to specific areas, devices, soft infrastructures, buildings, dynamics, processes, and programs. Architecture and urban design extend beyond objects and static forms.

5.1.3. Border Detail: Body Scale

The final phase involves a detailed exploration at an architectural/bodily scale of one of the responses offered by the project at its most urban scale. The goal of this last stage is to avoid creating decontextualized constructions and to continue providing specific solutions to the analyzed issues.

5.2. *Ecological Design Strategies for Pollution Mitigation*

To illustrate this methodology, the project 'From Pollution' is presented. This project offers a detailed analysis and design that is as specific as it is pertinent to these industrial metropolitan areas.

In the first stage, a cartography is created to analyze the presence, location (through a study of dominant winds and temperature), and type of pollutant particles (PM2.5) that have existed at the refinery until the beginning of its dismantling, particularly around the petroleum burner tower. The aim is to map the invisible, i.e., the pollution emitted by the refinery, and how human bodies (respirators) and non-human bodies (vegetation) can breathe or reduce this pollution, such as CO₂ (Figure 12).

In the second stage, a solution to this problem is proposed. Instead of seeking a purely formal solution, the focus is on "skins" and how pollution accumulates on them. This involves mapping pollution at a microscopic scale on human skin, cacti, and textile fabric. Based on this, a skin-like fabric is proposed that reduces atmospheric pollutants [46]. This skin can cover industrial heritage buildings as if they were sculptures by artists Christo and Jean-Claude.

In the third stage, details are provided on how these skins would wrap certain surfaces and create "breathing zones" that are completely clean in an area that was once a refinery. This area also faces other harmful atmospheric conditions, such as dust storms from the Sahara Desert.

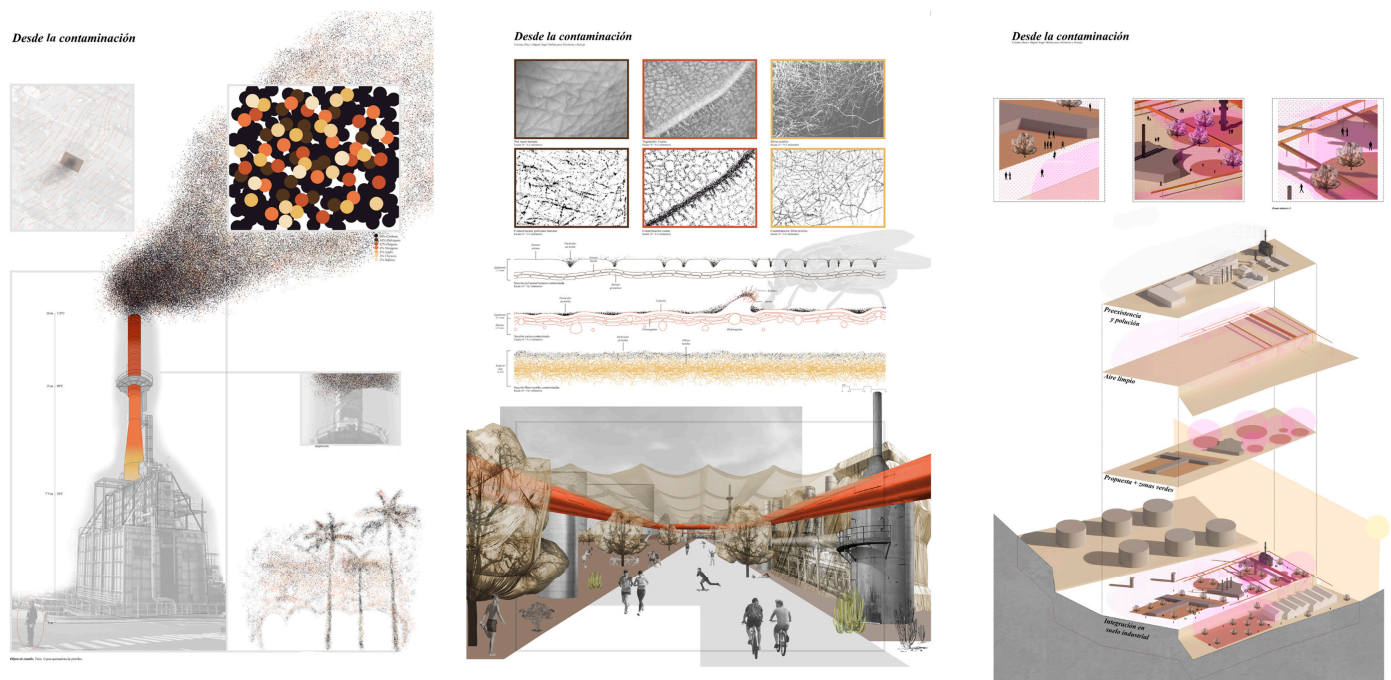


Figure 12. Project “From Pollution” [Desde la contaminación]. Left: Analysis of pollutant particles and how people and vegetation absorb them. Center: Study of possible skins at a microscopic scale and view of the refinery with decontaminating skins applied. Right: Detail of the urban project creating a pollution-free air zone in the refinery. Authors: Cristina Díaz Morales and Miguel Ángel Melián Vera under the supervision of Víctor Cano-Ciborro.

5.3. WVS Indicators and the Inhabitants Predilection for Metropolitan Areas

After studying the common categories between the operations of expanding the local scale towards the metropolitan project with the WVS that affect perception according to the urban environment and its main conditions, we then perform a comparison between the ratings of WVS survey according to these parameters. Data from Spain and Europe from the World Values Survey report have been extracted and analyzed, highlighting the differences between non-metropolitan areas and large cities in terms of security, satisfaction with services, and community cohesion (Tables 4 and 5).

These mean values highlight the differences in perceptions between urban and rural areas, with urban areas generally having higher satisfaction with services and community cohesion, while rural areas have slightly lower scores in these categories (Table 6).

Considering WVS factors such as security, satisfaction with services, and community cohesion in city governance and urban planning is key issue in regeneration of the Santa Cruz de Tenerife refinery and its four surrounding areas.

Table 4. Differences between non-metropolitan areas and large cities in terms of security, satisfaction with services, and community cohesion in Spain.

Country	City Type	Location	Security	Satisfaction with Services	Community Cohesion
Spain	Metropolitan	Madrid	3.7	4.3	4.1
Spain	Metropolitan	Barcelona	3.3	4.0	4.0
Spain	Rural	Andalucia	3.6	3.9	3.6
Spain	Rural	Ourense	3.4	4.0	3.7
Spain	Metropolitan	Valencia	3.8	4.4	4.2
Spain	Rural	Castilla y León	3.4	3.9	3.5

Table 5. Differences between non-metropolitan areas and large cities in terms of security, satisfaction with services, and community cohesion in Europe.

Country	City Type	Location	Security	Satisfaction with Services	Community Cohesion
Germany	Metropolitan	Berlin	3.9	4.5	4.3
Germany	Rural	Bavaria	3.4	4.1	3.9
France	Metropolitan	Paris	3.2	4.1	4.1
France	Rural	Normandy	3.8	4.4	3.9
Italy	Metropolitan	Rome	3.6	4.3	4.0
Italy	Rural	Tuscany	3.3	4.1	3.7

Table 6. Comparison of the mean values for security, satisfaction with services, and community cohesion between urban and rural areas in Spain and Europe.

Country	City Type	Security	Satisfaction with Services	Community Cohesion
Spain	Urban	3.7	4.3	4.1
Spain	Rural	3.2	3.9	3.6
Europe	Urban	3.77	4.4	4.13
Europe	Rural	3.3	4.07	3.87

These potential areas for conversion can transform a local process into a metropolitan regeneration initiative. By focusing on security, service satisfaction, and community cohesion, these regenerated zones can become vibrant, multi-use spaces that significantly enhance the urban network. The southeast edge of the refinery, for example, with its proximity to the coast, can be developed into a public waterfront, improving recreational opportunities and community engagement. The northeast and northwest borders can be integrated into the city's green corridors, providing ecological benefits and promoting sustainable transport options. The southwest border, with its potential for mixed-use development, can offer new housing and commercial opportunities, reducing urban stress and enhancing overall livability. By incorporating these previously industrial areas into the broader metropolitan framework, Santa Cruz de Tenerife can leverage their redevelopment to support sustainable development and enhance the overall quality of life for its residents, creating a resilient and inclusive urban environment. Moreover, incorporating practices of regenerative agriculture soil health can be restored and enhanced, increasing biodiversity, and improving the water cycle, so these areas can transform into productive green spaces that support local food sources and urban biodiversity.

6. Discussion: Internal Processes vs. Metropolitan Processes: Complementarity in the Global Development of the City

The transformation of the Santa Cruz de Tenerife refinery area has the opportunity to become a complex interaction of internal processes, becoming a metropolitan key, a global solution for this part of the island, and turning into a resilient and sustainable urban environment. The internal dynamics of transforming the refinery, following the inertia of such projects, might end up being just a set of localized urban regeneration efforts that emphasize housing construction, renaturalization, and sustainability. This includes integrating green and blue infrastructure to improve urban resilience, reduce environmental impacts, and promote biodiversity. This approach aligns well with contemporary urban sustainability principles, transforming the refinery area into a vibrant green space. However, by including the preservation and reuse of iconic industrial structures within the refinery area, historical continuity and cultural identity are also maintained. Economic revitalization is another key aspect, creating new commercial and residential opportunities within the regenerated area to stimulate local economies. Mixed-use developments integrate housing, commerce, and recreational spaces, reducing the need for long commutes and enhancing urban density.

The great opportunity lies in opening the refinery to metropolitan processes that include it in the broader insular framework, with improved connectivity through the development of trans-scalar transportation infrastructure systems. This involves modernizing public transportation networks and creating new mobility corridors that connect the refinery area with other parts of the city and the island, thereby enhancing overall mobility in this area.

Addressing metropolitan-scale challenges positions the refinery transformation within the regional economic landscape to attract investments and foster innovation. Leveraging the site's strategic location and historical significance helps create new economic hubs that contribute to the metropolitan area's competitiveness and sustainability.

The complementarity of internal and metropolitan processes is crucial for the holistic development of Santa Cruz de Tenerife. Aligning urban regeneration efforts with much broader metropolitan strategies ensures an urban environment with a clear multi-scalar approach that considers the impacts of local developments on the metropolitan scale. This integrates local green spaces into ecological networks across the island to improve environmental quality and overall connectivity. Therefore, promoting urban growth that balances the necessary housing density with livability, incorporating sustainable practices at the insular level, and involving extensive green areas will improve the overall quality of life for residents and support long-term urban resilience. Future research could explore comparative studies, analyzing similar urban regeneration projects in other metropolitan areas to identify best practices, such as in the conversion of industrial lands in the Ruhr basin.

7. Conclusions: Challenges and Opportunities in Urban-Territorial Planning of Expanded Landscapes through Expanded Inner Metropolitan Processes

Regarding the integration of mixed uses, a new mindset of urban planning is proposed to allow learning from morphology and geometry, for the coexistence of residential, commercial, and recreational functions in proximity, aimed at reducing the need for long commutes and optimizing urban density. This approach promotes a polycentric urban structure, where each core offers a balanced mix of activities, strengthening the efficiency and experience of urban space from connectivity with the metropolitan road system, in which the refinery's surroundings shift from a city scale to an island scale.

In exploring the urban and territorial consequences of incorporating the refinery into the city and metropolitan area, this methodology has been designed, based on this case study, across quantitative evaluation conducted through the collection and analysis of data on environmental, urban, and social variables concerning the refinery and its surroundings, as well as its contextual reading from the metropolitan territorial relationship with macroeconomic and global environmental status indicators, as the quality of life is better in metropolitan areas depending on WVS factors.

Furthermore, transforming the refinery through metropolitan processes rather than local processes can significantly enhance the quality of life for all residents. This metropolitan approach allows for a more integrated and comprehensive planning strategy that leverages broader regional resources and infrastructure. By expanding the process beyond the boundaries of Santa Cruz, the transformation can benefit from a larger scale of investment, expertise, and strategic alignment with regional development goals. This holistic perspective ensures that the redevelopment not only meets local needs but also contributes to the overarching sustainability and resilience of the metropolitan area. This methodology underscores the importance of adopting a wider scope, integrating metropolitan strategies to achieve a higher quality of life and more sustainable urban development.

For the effectiveness of integrated actions, the proposed analytical methodology has included data from Geographic Information Systems (GIS) and Spatial Decision Support Systems (SDSS) for the design of solutions. This is to study each physical and simulation parameter and effectively plan to convert these industrial areas into public, commercial, and residential spaces from metropolitan positions. The data from the GRAFCAN portal have enabled the mapping and potential metropolitan significance of the internal actions

of the refinery, while the SDSS have allowed the development of simulation models that anticipate the effects of various urban interventions, evaluating how regeneration strategies impact beyond the physical scale of the projected space.

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