Architectural Transformation Strategies from a Vertical Slum into a Nearly Zero-Energy Hybrid Building. A Study Case in Malaga (Spain)

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Abstract

The transformation of a vertical slum into a hybrid building in socially excluded neighbourhoods, represents a scarcely analysed approach for a building model traditionally developed outside of these areas. Furthermore, incorporating these buildings into comprehensive urban regeneration processes in large peripheral neighbourhoods can address deficiencies in infrastructure and amenities. This paper presents and analyses strategies for the physical, energy, and social transformation that aid in the regeneration of a socially excluded neighbourhood, applied to a real case study in the city of Málaga (Spain). The methodology proposes an integrated approach from the urban, architectural, and social dimensions, organised into three phases: analysis and needs, hybrid transformation, and transformation strategies. Twelve transformation strategies were found to be structured into three categories: spatial, energy improvement and new uses strategies. Spatial strategies include incorporating new semi-public spaces and reclaiming public and community spaces, distinguished either architecturally or functionally derived from new public uses. Energy transformation focuses on enhancing and incorporating passive systems, active energy input systems, and transforming the existing facade. Finally, use strategies suggest new public uses for the neighbourhood, the distribution of uses based on height, and the relationship between new uses and plazas at height.

Keywords: distressed urban areas; rehabilitation programs; zero emissions; hybrid building; urban regeneration.

Introduction

A vertical slum is defined as "a socially vulnerable community in a building, with serious problems of functionality, safety, and habitability. It is associated with a significant level of physical degradation and a precarious socioeconomic situation of its occupants" (Rosa-Jiménez et al., 2017). In this article, the term *vertical slum* does not refer to informal high-rise settlements, such as Brazilian favelas built upward without formal planning, but rather to high-rise buildings that have undergone processes of social disintegration. This phenomenon can be observed in the case discussed, as well as in certain social housing blocks in England and France — typically inhabited by migrant populations — which have experienced similar trajectories of decline and marginalization (see Wacquant, 2008). These are high-rise apartment blocks, an architectural typology that complicates the long-term coexistence of their residents, especially when their residents are low-income people and there are no quality communal spaces (Nguyen et al., 2024). They

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are often isolated from the main streets and suffer from social deficits in the design of semi-public spaces (Dovey, 2013). These buildings experience significant physical and social degradation, often being illegally occupied after the abandonment by their initial owners. Large ensembles or housing block projects on the periphery, created to accommodate immigrants and residents from informal settlements, are areas highly prone to the emergence of vertical slums.

Although rehabilitation policies in Europe have focused on comprehensive neighbourhood rehabilitation, the rehabilitation of vulnerable environments faces additional challenges and requires broader urban strategies, dynamic public-private partnerships, and extensive participation and support (King, 2016). Often, these comprehensive rehabilitation policies encounter vertical slums, which are almost impossible to incorporate into the comprehensive rehabilitation processes due to the lack of community management elements among their owners.

This is the case of Cabriel building, located in Málaga (Spain). A vertical slum whose extreme conditions of unsanitary living and illegal occupation forced the City Council to expropriate it. This circumstance was used to propose a prototype of urban regeneration based on the transformation of the vertical slum into a hybrid building for the social regeneration of the neighbourhood. Unlike the new proposed prototypes of hybrid buildings as social and energy hubs (Lanini & Barsanti, 2018), the novelty of this paper is to propose strategies for transforming a vertical slum into a prototype hybrid building located in a socially excluded neighbourhood, in line with the following Sustainable Development Goals of the 2030 Agenda: no poverty (SDG 1), good health and well-being (SDG 3), quality education (SDG 4), decent work and economic growth (SDG 8), reduced inequalities (SDG 10), sustainable cities and communities (SDG 11), peace, justice, and strong institutions (SDG 16). Therefore, it is an innovative solution to address housing problems and improve the quality of life for people living in these areas. These types of buildings combine residential, commercial, and community uses, allowing them to be a meeting point for the local community and providing affordable and quality housing while offering shared services and spaces for residents. They also allow access to jobs and services near their homes, reducing transportation costs and improving their quality of life (Cáceres & Ahumada, 2020).

Furthermore, in accordance with the Energy Performance of Buildings Directive (EPBD), the transformation into a hybrid building must comply with the requirements of a nearly zero-energy building (nZEB), which also entails the implementation of strategies to enhance the efficiency of the building envelope and HVAC (heating, ventilation and air conditioning) systems (Da Costa Duarte & Rosa-Jiménez, 2022). Vertical slums typically lack heating and air conditioning systems. Therefore, the transformation of the facade also contributes to changing the stigmatised image of the vertical slum, potentially having a positive impact on residents' self-esteem and confidence.

To address these objectives, the article is structured into four sections: the first outlines the conceptual framework (Section 2); the second describes the methodology and the case study (Section 3); the third presents and discusses the transformation strategies (Section 4); and finally, the fourth section provides the conclusions (Section 5).

Conceptual framework

Vertical slums in distressed urban areas

The concept of the vertical slum in this study refers to high-rise buildings located in distressed urban areas: zones characterised by regressive social, economic, and urban indicators that result in processes of social and residential exclusion (Temes, 2014, p. 126). Social exclusion involves limited opportunities for upward mobility within the social hierarchy (Alguacil, 2006), while residential exclusion denotes the inability to access adequate housing solutions (Antón et al., 2008). These distressed areas weaken the urban fabric by generating social injustice and potential economic stagnation (Conway & Konvitz, 2000). In this context, the vertical slum represents an intersection between two urban categories proposed by Roy (2011): the periphery and urban informality.

In Spain, peripheral neighbourhoods conceptually display a strong correlation between poverty and urban form, driven by four interrelated factors (Bruquetas Callejo et al., 2005): (a) inability to fully rehabilitate due to their large size, leading to widespread discouragement among neighbourhood stakeholders; (b) disjointed urban space that hinders participation processes and community network formation; (c) lack of maintenance of urban services and facilities; and (d) absence of economic activities and job insecurity, affecting a population sector impacted by globalisation and poor job quality. The vertical slum is also rooted in architectural typologies common to state-planned peripheral neighbourhoods, particularly the superblocks or Grands Ensembles that emerged from large-scale resettlement policies promoted – and later criticised – in the second half of the 20th century (Sarkar & Bardhan, 2020). Simultaneously, vertical slums can emerge through vertical informality, often linked to the illegal occupation of abandoned apartment blocks. According to the theory of complex adaptive systems, urban informality is shaped by self-organising processes that are dynamic, unpredictable, and resilient: forming what Dovey (2012, 2013) describes as a transgressive architecture.

Literature has identified two principal dimensions of informal urban processes. On the one hand, some authors argue that informal settlements impact the structural and functional organisation of the city (Barros & Sobreira, 2008). On the other hand, in developing countries, these phenomena are often understood as a response to rising population density, land scarcity, and socioeconomic shifts (Debnath et al., 2019). In many cases, the proliferation of vertical slums is linked to the implementation of social housing schemes characterised by poor construction quality and low living standards, which over time deteriorate into vertical slums (Taubenböck & Kraff, 2014). Additionally, vertical informality also arises from the construction of high-rise flat buildings without formal permits, as documented in the case of Kufr Aqab in East Jerusalem (Zugayar et al., 2021). For some scholars, squatting practices within these vertical spaces can be interpreted as a form of "social banditry": a subversive tactic aimed at challenging established power structures and promoting social change (Helepololei, 2022). Based on the literature, two distinct trends in vertical informality can be identified:

a Positive trend: This refers to the occupation of unfinished or abandoned buildings by self-organised communities that transform these structures into hybrid living spaces through spontaneous adaptation. Notable examples include the Torre de David in Caracas, Venezuela, where over 300 families occupied a nearly completed 45-story office building in 1994. This case became an emblematic model of grassroots social infrastructure and self-managed urban regeneration (Brillembourg & Klumpner, 2013; Navarro, 2015). Similarly, Prestes Maia in Sao Paulo, Brazil, was illegally occupied by a self-organised community that established informal services such as a library, hairdresser, and daycare, without links to criminal activity (Veas-Gutiérrez, 2019).

b Negative trend (vertical slum): This study focuses on this manifestation of vertical informality, which arises from the failure of innovative housing projects (Caudo, 2022). These spaces experience the displacement of their original residents and subsequent illicit occupations, often linked to criminal activities, degradation of the built environment, and the absence of stable social structures (Rosa-Jiménez et al., 2017).

Hybrid buildings as an urban regeneration infrastructure

Although literature has theoretically proposed the design of hybrid buildings based on informal vertical settlements, the transformation of a vertical slum – particularly one associated with criminal activity – into a hybrid building remains a novel concept that has been scarcely explored in scientific research. This transformation encompasses both the retrofit (renovation) or adaptive reuse of a building to accommodate new functions (Langston et al., 2008) and the rehabilitation associated with the modernisation of the building, which may include its expansion and significant structural alterations (Douglas, 2006). In the literature, major hybrid buildings are typically new constructions, especially on a large scale (Holl, 2014), with few examples of existing buildings being transformed into hybrids (Horwitz, 2009).

The hybrid concept has been used in urban regeneration projects as a resource to promote a compact city, as well as a strategy for active and diverse urban living (Marling et al., 2009). It can act as a social transformer of a degraded environment, offering community services and social housing. Multifunctional buildings are considered an element that promotes urban health (Marini, 2008) and, from a biological perspective (Mestre Martínez, 2012), are indirectly related to the resilience of natural living systems based on redundancy and differentiation (Weinstock, 2007).

The hybrid building combines technology and society, open to new concepts. High-rise typology is very common in hybrid buildings, as documented in monographs with systematic cataloguing (Fernández Per et al., 2011), or by authors who have specifically addressed hybridity in high-rise buildings (Ábalos & Herreros, 2000). Due to their revitalising functions, the overlapping and mixing of uses is a highly recommended solution in dense environments with occupancy limitations (Kaijima et al., 2003). Additionally, it allows for the creation of public spaces through internal porosities where public and private interactions occur. The hybrid building, containing this significant mix of uses, can be a crucial factor in urban acupuncture actions, understood as a cultural activator of urban spaces (Houghton et al., 2015), or as targeted intervention strategies in the city with great regenerative capacity and the ability to extend benefits to the rest of the city (Lerner, 2014).

Studies on recycled or retrofitted buildings have also demonstrated that hybridisation and functional diversification contribute to building longevity and neighbourhood resilience, particularly in contexts of social vulnerability (Conejos et al., 2013). On the other hand, the regeneration of informal settlements through innovative architectural solutions has been addressed by Hu et al. (2017), allowing for the evolution and transformation of existing structures into more formal and sustainable environments. A notable example of a hybrid building, relevant to this study, is the “Tour Porte de La Chapelle” (Abalos et al., 2015). This project features a program that transitions from public to private uses, including commercial spaces, a youth centre, a library, office spaces, a convention centre, student housing, sports facilities, and loft-style residences.

Moreover, hybrid buildings allow for resource optimisation (Gosalbo Guenot, 2012), as they comprise fragmentary forms with great unifying capacity. The hybrid scheme proposes environments where familiar uses are mixed: the intimacy of private life and the sociability of public life converge in a 24-hour continuous operation building (Fernández Per et al., 2011). A hybrid building can beneficially accommodate disparate uses. The building must be positioned in a balance between architectural determination and functional indeterminacy. For this reason, the hybrid building responds to the functional needs demanded by its surroundings without losing the specificity and identity required by each programme. The ecological advantages of hybrid architecture are evident. Different programs can complement each other energetically and structurally in a fruitful way (Haddadi, 2020).

On the other hand, reducing greenhouse gas emissions is an international challenge in addressing the climate emergency (Masson-Delmotte et al., 2018). The European Union’s commitment for 2030 entails a reduction in greenhouse gas emissions by 40%, an improvement in energy efficiency by 32.5%, and the incorporation of renewable energies by 32% (European Commission, 2014). A nearly zero-energy building (nZEB) is the new EU construction standard after 2021 according to the Energy Performance of Buildings Directive (EPDB).

From the perspective of symbiosis, Mestre (2012) identifies two trends in architecture: design symbiosis and metabolic symbiosis. On the one hand, Šijaković & Perić (2018) apply the biological concept of symbiosis to the field of architecture with the aim of redefining design principles in the reuse of existing buildings, categorizing them into three types: commensalism, where the new intervention benefits from the existing structure without causing it harm or detriment; mutualism, in which both the new addition and the original structure benefit from a balanced relationship; and parasitism, where the advantages of the new construction may compromise or damage the existing building. On the other hand, van Hinte et al. (2003) propose a vision of architectural efficiency focused on three key ideas: reuse, reduction in building weight, and minimization of resource consumption and waste generation. The latter is addressed through two potentially complementary strategies: metabolic symbiosis, which makes use of the waste produced by one facility as a resource for another, and autarkic living, based on energy and water self-sufficiency (Table 1).

Table 1

Relevant metabolic symbiotic actions combined with autarkic living lead to the transformation of an existing building into a nZEB

Area / Autarking living	Metabolic symbiotic action	Description/benefit	Source
Water / Independence from the public system	A01. Greywater reuse	Reuse water from sinks and showers for toilet flushing or irrigating interior green areas	Craig & Richman (2018)
	A02. Rainwater harvesting and reuse	Store rainwater for cleaning, evaporative cooling systems, toilet flushing or irrigating interior green areas	Bona et al. (2025)
Waste / Zero exit	A03. On-site composting of organic waste	Produce compost for use in indoor or rooftop gardens and green walls	Guo et al. (2018)
	A04. Domestic anaerobic digesters	Degrade organic waste, generating biogas and liquid fertilizer	Ajay et al. (2021)
	A05. Reuse of materials during renovation	Reclaim wood, glass, or metal from the original structure in the retrofit	Byers et al. (2024).
Energy / Zero input of the electrical system	A06. Passive cross-ventilation between spaces	Direct cooler air from certain areas to others needing natural cooling	Kinnane et al. (2016)
	A07. Passive heating/cooling systems	Thermal inertia, direct solar gain, cross ventilation, shading	Anand et al. (2023)
	A08. Internal redistribution of renewable energy	Prioritize direct use of on-site solar energy in areas with higher consumption	Hayter et al. (2011)
	A09. Solar PV systems on roof and facade	Use roof space to supply solar power	Kong et al. (2023)
	A10. Micro-wind power if it is viable	Solar supplements in windy areas	Fonseca & Schlueter (2013)
	A11. Shared internal battery storage systems	Use centralized batteries to supply power during peak demand or outages	Li et al. (2022)
	A12. High-efficiency passive thermal insulation	Minimizes losses and reduces energy demand	Yilmaz et al. (2024)

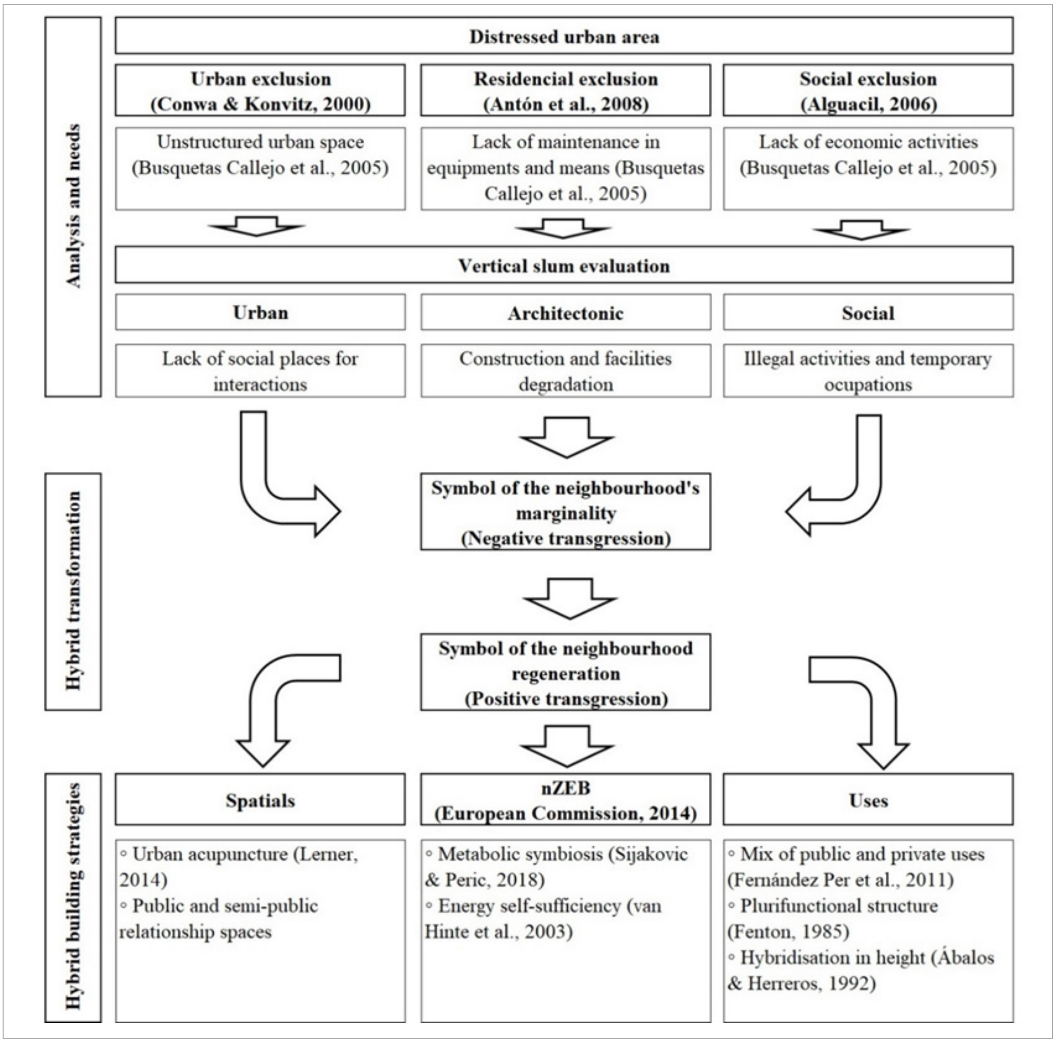
This achieves a net-zero energy state, carbon neutrality, or zero carbon, potentially saving an average of approximately 11 tons of CO2 per dwelling per year (Newton & Tucker, 2010). In the effectiveness of strategies for renovating an existing building to transform it into an nZEB, one must consider the factors determining the type of building, location, and climate (D'Agostino & Parker, 2018); the evolution of the regulatory framework for energy savings (López-Ochoa et al., 2021); and the methodologies for nZEB transformation (Las-Heras-casas et al., 2021).

Methodology

The methodology used in this research is based on a case study approach. In the realm of architecture, a case study involves a combination of different degrees of techniques, methods, strategies, or theories (Johansson, 2003). Moreover, in architectural hybrid design, the process constitutes a very relevant element in the development of the research's conceptual framework (Adeyeye et al., 2010). Building upon these premises, a methodological structure has been designed based on an integrated approach from the urban, architectural and social dimensions organised into three phases (Fig. 1): analysis and needs, hybrid transformation and transformation strategies.

Fig. 1

Methodological structure of the research



The first phase aims to understand the issues and needs at an urban scale within the distressed neighbourhood where the vertical slum is located, and at an architectural scale, the issues specific to the building. For this purpose, the following techniques and sources of information were used.

At the neighbourhood level, urban analysis sought to determine both urban and social needs of the environment, enabling the future hybrid building to offer services that enhance the neighbourhood's quality. Urban analysis data were gathered through a three-month fieldwork period (February-April 2015), using cartography, open statistical data, and interviews with technicians and residents. Residential and social analysis aimed to identify social needs and economic activities within the neighbourhood, drawing from the Integral Action Plan of La Palma Palmilla (2011), which included insights from a participatory Community Plan (2005-2007).

Regarding the building itself, urban analysis assessed the quality of adjacent urban spaces as areas for social interaction through morphological analysis. Architectural analysis included evaluating the current state of the building, structural safety, thermal and acoustic conditions, facades, roofs, and accessibility, alongside a solar exposure analysis to improve energy performance. Lastly, social analysis identified building users categorised by Egea et al. (2008) into the floating population, who access through more affordable rentals (informal and precarious housing), considering the neighbourhood as a transient place, and the criminal population engaged in illegal activities. This determination guided the public housing offering that the building should provide. Data were collected by technicians from the City Council of Málaga in 2014, involving the identification of users in each dwelling and photographic documentation of the physical condition of each unit and common areas of the building.

The second phase captured the main aspects defining the vertical slum as a negative transgressive element —contrasting, for instance, with the experience of the Torre de David (Brillembourg & Klumpner, 2013)— and its findings guided the project strategies to transform the failed residential building into a hybrid structure that would symbolise comprehensive regeneration of the neighbourhood. The third and final phase defined specific transformation strategies based on the previous phase, the theoretical framework, and the unique characteristics of the high-rise building itself.

Cabriel 27 as a case study

The building located at 27 Cabriel Street, in La Palma-Palmilla district, in the northwestern sector of Málaga (Andalusia, Spain), served as a pilot case for the city (**Fig. 2**). According to the classification of Davis (2006), it is a periphery-formal-public housing, segregated from the rest of the city by highways and large facilities. The residents of the neighbourhood experienced an enforced mobility caused by the demolition of their original neighbourhoods.

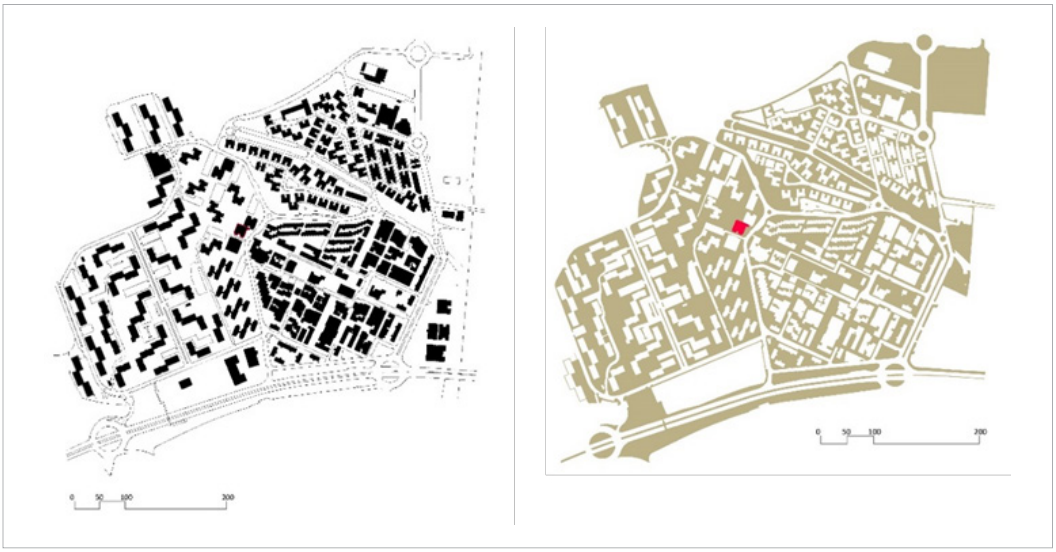
Fig. 2

Location of the neighbourhoods and the study building in the city of Málaga, Spain

Within the district, the neighbourhood of La Palma (1975) is the third and final phase of a peripheral housing construction operation initiated in the late 1960s. It consists of a polygon of mass housing based on standardisation similar to those in other studies of the periphery in Spain (Castro-Mellado, 2017) or France (García-Pérez, 2021). The neighbourhood comprises 3,067 multi-family homes distributed across 88 blocks ranging from 13 to 5 floors. The dimensions of the homes range between 90 and 120 square metres. The morphology of the neighbourhood consists of isolated or laterally connected blocks where the corridor street has been replaced by a series of open areas intended for gardens and attached to the buildings (Fig. 3). Despite the abundance of open spaces in the neighbourhood, there is a lack of significant public spaces and identity. Residual character predominates in most of the unbuilt space, which hinders participation and transformation processes due to the difficulty in creating community networks (Bruquetas Callejo et al., 2005).

Fig. 3

Building morphology and open space layout in the neighbourhoods surrounding Cabriel 27 (highlighted in red)



Cabriel 27 is centrally located within the polygon, near a major access route. It has 14 floors, a stairwell with an elevator, and four apartments per floor, totaling 52 identical 120 m2 apartments. Following the tenets of the Modern Movement (Marsh, 2017), its solar orientation allows the main facades to face east and west, facilitating natural ventilation (Jiang et al., 2023) (Fig. 4). Although the neighbourhood underwent a comprehensive rehabilitation program, this block could not be renovated as it was not occupied by its original owners and lacked a community of owners capable of managing aid funds. By 2016, the building suffered significant deficiencies in comfort and clear problems with functionality, safety, and habitability, with serious physical degradation and pathologies affecting all its units. There were continuous damages in common areas, misuse leading to illegal electrical connections posing serious risks, poorly maintained and unhealthy living conditions due to lack of cleanliness and hygiene, among other issues. Its demolition was not necessary because the structure was in good condition.

This situation of severe physical deterioration and basic infrastructure problems (Fig. 5) was caused, among other factors, by socio-economic issues affecting its owners and occupants. The original owners left due to cohabitation problems. Most of the apartments were transient rentals with illegal leases, characterised by constant turnover that hindered community cohesion and care for common areas. Families engaged in marginal activities benefited from and perpetuated the building's precarious state, preventing the formation of a community and thwarting any rehabilitation efforts.

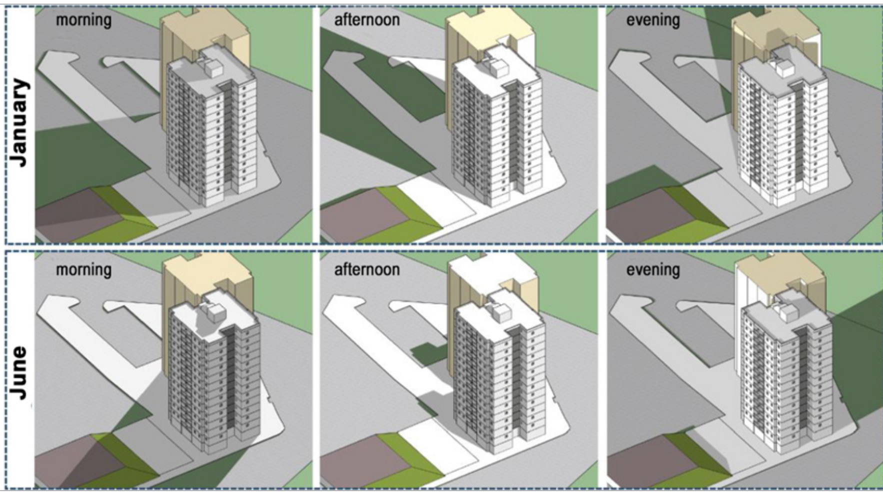


Fig. 4

Solar exposure to the Capriel 27 building. The benefit of exposure has a dual effect: it seeks the best locations for homes and identifies areas with the greatest solar energy gains

Fig. 5

Location of the main construction defects in the building

As a result, the building became a symbol of social marginalisation within the neighbourhood, perceived negatively by its surroundings. After multiple interventions by the local government to repair damages and subsequent inadequate maintenance by users, combined with fires caused by poor electrical installations and health hazards due to garbage accumulation in common areas, the decision was made to expropriate and transform it into a new nearly zero-energy hybrid building. Residents requested that the new building become a symbol of neighbourhood regeneration, emphasising the need for uniqueness and iconicity as a strategy to combat the stigma associated with marginalised areas (Kim, 2019).

Transformation strategies from a vertical slum into a nZEB hybrid building

The transformation process of turning a vertical slum into an nZEB hybrid building is approached comprehensively, addressing not only its physical aspects but also its functional and social transformation. To achieve this, three categories of transformation strategies have been designed: (a) spatial, (b) energy-related, and (c) usage-related.

Spatial transformation strategies

According to Šijaković & Perić (2018), the new building design follows a metabolic strategy of mutualism, that is, new elements are added, but the formal logic of the old building is respected. Given that the hybrid building must assume a central role, these strategies (Fig. 6) primarily focus on increasing the complexity and richness of gathering spaces. This includes incorporating new semi-public spaces (E01) and reclaiming public (E02, E04) and community spaces (E05), distinguished either architecturally (E03) or functionally derived from new public uses (E06).

The strategy of creating open spaces at height (E01) aims to reclaim rooftops and construct outdoor spaces across different levels by partially demolishing the existing facade. This enhances these spaces from an environmental perspective, as they provide shading to the facade (A07), in addition to the community and health benefits highlighted by Le Corbusier (community equipment space and sun terrace). Authors like Períes (2022) emphasise the importance of creating voids, asserting that the art of structure lies in how and where holes are placed.

The strategy of an open and permeable ground floor (E02) involves partially opening the ground floor to the public space. This not only aims to recover the original project, currently encroached upon by illegal occupations, but also enhances the relationship between the building and its surrounding exterior space. This more open character of the ground floor serves as a connection between the ground-level uses of the hybrid building and its environment.

Creating double-height spaces as distinctive elements (E03) through the selective demolition of certain floor slabs provides a more institutional scale suitable for a building with public amenities and uses. It adds architectural uniqueness to the building and accommodates the necessary space for utilities and installations required by new uses, which the residential building lacks. These large openings transform the building's appearance, organising and articulating the various public uses in the elevated outdoor spaces. The insertion of these openings focuses on facades with greater visibility to the neighbourhood and optimal solar orientation. Verifying the variable thickness of the facade and its relational value between interior and exterior space is a crucial design criterion for a more urban, habitable, and environmentally integrated architecture, qualities increasingly relevant in response to urban densification and verticalization processes (Fontana et al., 2014).

The strategy of using the surrounding public space as an opportunity (E04) addresses the issue of underused residual spaces with poor environmental quality. The hybrid building requires a public space for cultural and regenerative actions (Houghton et al., 2015). The design of a high-quality space around the hybrid building aims to create a comfortable place that facilitates neighbourly gatherings. Public space has the capacity to shape social practices through its spatial configuration, material attributes, and use. These conditions promote social interaction and consequently enhance community life (De La Torre, 2015, p. 498).

The strategy of the rooftop as a communal living space among residents (E05) aims to repurpose the roof for resident use (area of 480 m^2). In urban culture, habitable rooftops are being rediscovered as hidden urban spaces (Herranz, 2016), and within architecture, as design spaces (Jodidio & Kim, 2016), particularly for their potential in creating urban gardens. Elements such as benches and pergolas were incorporated to provide comfortable conditions (A07) on the rooftop as a new meeting place centred around a communal urban garden. Ultimately, all these elements aim to encourage the use of rooftop spaces and foster community interaction among residents. Strategy E06 involves the implementation of a new stairwell, designed to serve multiple functions: (a) it functions as an emergency exit, complying fully with fire safety regulations, and (b) it facilitates the separation of public and private circulation flows, ensuring compatibility between both and preventing their overlap.

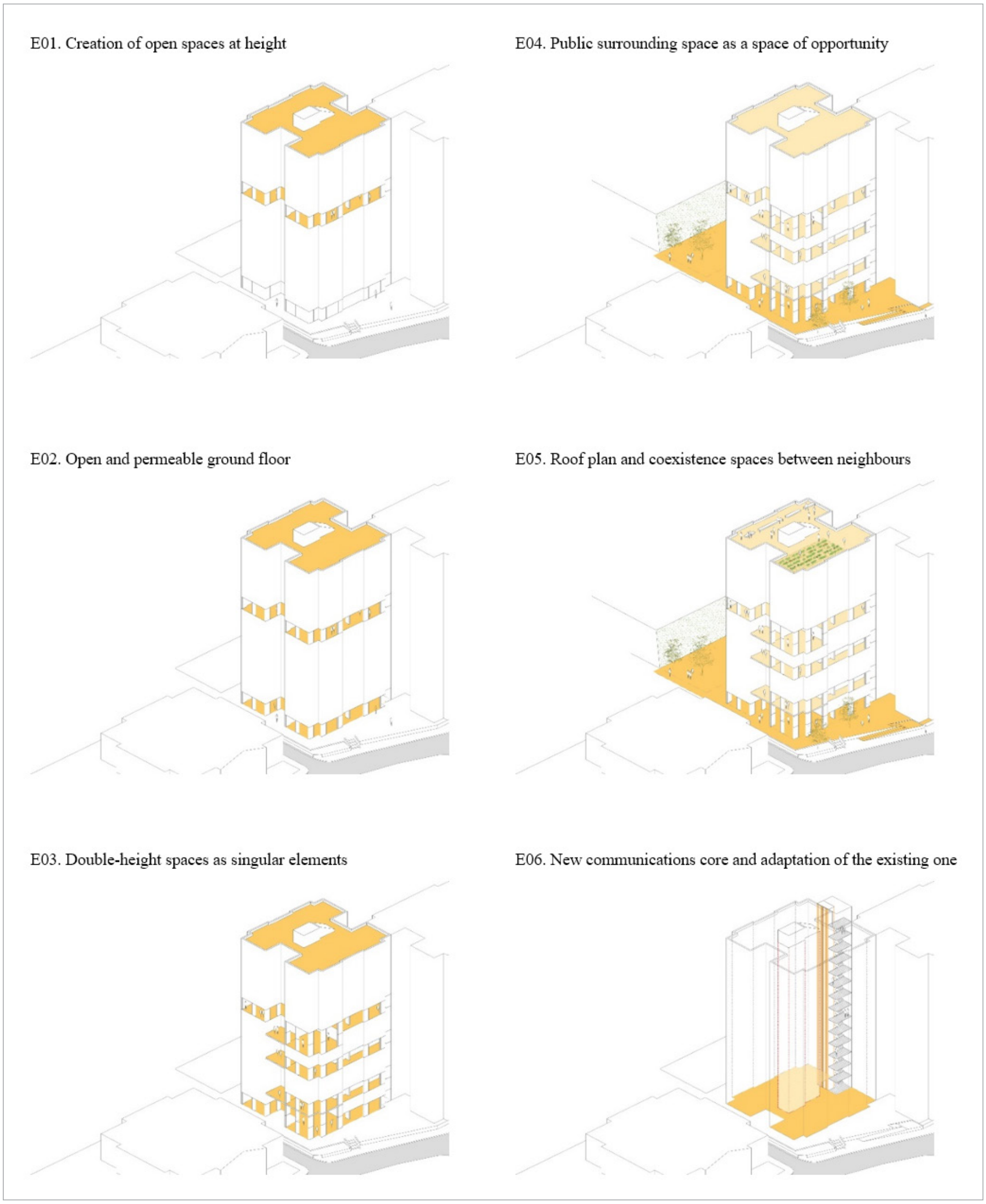


Fig. 6

Strategies for physical and spatial transformation

The creation of new social spaces enables the integration of rooftop urban gardens (E05) and multilevel gardens (E01, E03, E04), which can be irrigated autonomously through the reuse of greywater (A01) or the collection of rainwater (A02). The rooftop level functions as a composting area (A03) and accommodates domestic anaerobic digesters (A04), which generate compost and fertilisers for the maintenance of the new gardens. Additionally, waste produced by both the external physical transformation (E01, E02, E03, E05) and the internal spatial reconfiguration (E09) ca be repurposed (A05) for the construction of new circulation cores (E06) and for the improvement of the building envelope (E06).

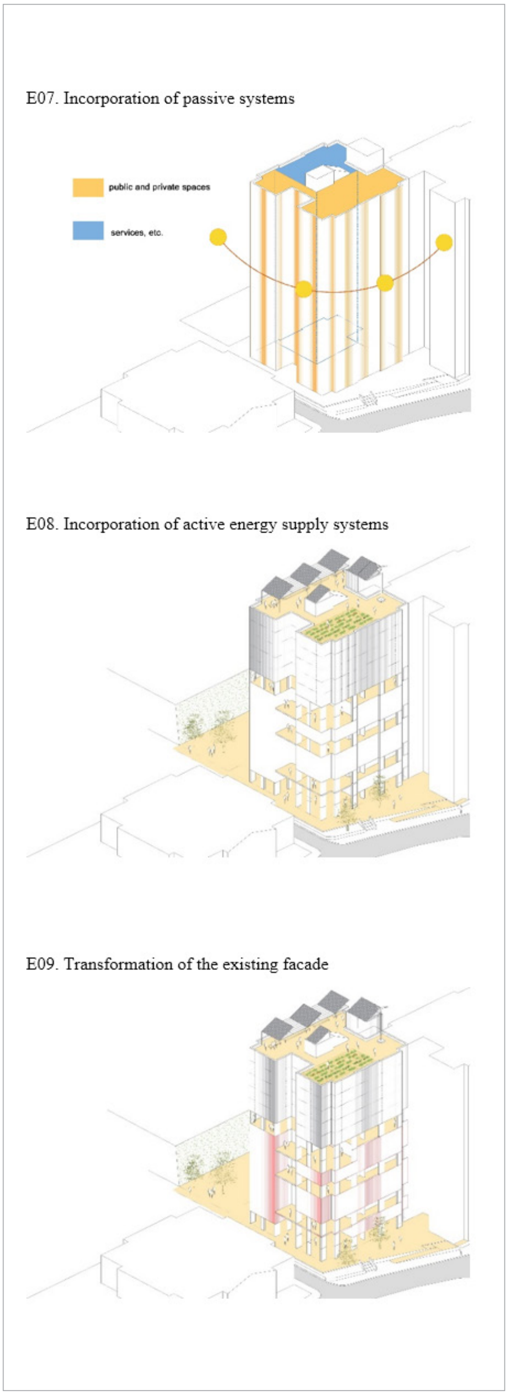


Fig. 7

Strategies for energy transformation (E07-09)

Energy transformation strategies

To achieve a nZEB, two main strategies are required: first, minimising energy demand through the implementation of eco-efficient bioclimatic measures; and second, maximising energy production from renewable sources. This is achieved through three specific strategies (Fig. 7): enhancing and incorporating passive systems (E07), active energy input systems (E08), and transforming the existing facade (E09).

In enhancing and incorporating passive systems (E07), the building's orientation determines the distribution of uses. Residential areas and height plazas are located on southeast, south, and southwest facades, while classrooms, workshops, corridors, communication cores, facilities, and services are oriented towards northwest, north, and northeast (A06). This design facilitates cross-ventilation for all residential units and ensures adequate natural lighting to reduce the demand for artificial light. Additionally, the new plazas at height mitigate excessive solar exposure (A07).

On the other hand, in the incorporation of active energy input systems (E08), the aim is to reduce energy consumption required for hot water production, lighting, heating, ventilation, and equipment. This involves improving the efficiency of the systems and installations, particularly heating, cooling, hot water supply, and lighting, and integrating locally produced renewable energies. This can be achieved through the installation of photovoltaic systems - on roofs or integrated into facades or sunshades (A09) - for electricity generation (Gallo et al., 2014), as well as solar thermal panels for hot water production.

Other alternatives include wind self-generation systems (A10), such as those designed for the Torre de David in Caracas (Fonseca & Schlueter, 2013). It is also advisable to implement an energy management and storage system (A11) for the building to monitor, and prioritize on-site solar energy consumption (A08), interacting with building users to encourage responsible and sustainable energy consumption habits.

Finally, through the transformation of the existing facade (E09), the original facade is completely renovated to modify existing openings and improve the building's energy performance. This includes reducing energy demand by enhancing the envelope with external thermal insulation systems (e.g., External Thermal Insulation Composite Systems -ETICS-) (A12) or incorporating elements that provide shading or use natural light effectively (A07). The redesigned facade also integrates solar panels on southeast and southwest facades as part of a comprehensive overhaul of the window system (A09).

These strategies collectively aim to transform the building into a nearly Zero Energy Building by minimising energy demand through passive measures, maximising energy production from renewable sources, and optimising energy efficiency through active systems and facade improvements.

Strategies for the transformation of uses

The strategy of transforming uses is closely linked to urban articulation of needs identified during citizen participation processes and their role in shaping urban space (Ovalle Garay & Páez Calvo, 2017). To achieve this, three strategies were established: new public uses for the neighbourhood (E10), distribution of uses based on height (E11), and the relationship between new uses and open spaces at height (E12).

In the strategy of new public and private uses for the neighbourhood (E10), the transformation of the failed residential building into a hybrid building allows for the incorporation of a new program including public facilities and residential accommodations for the neighbourhood's targeted groups of interest. Although the pre-existing residential use is reduced (32 apartments in the case study), the aim is to enhance community regeneration capacity by designing a multi-level public building that provides dignified housing for transient populations and offers facilities and amenities for the comprehensive regeneration plan (Rodríguez-García & Navarro Yáñez, 2023). Additionally, the project facilitates the creation of a social enterprise or cooperative network that fosters local entrepreneurship within the neighbourhood. This new area of social centrality (Table 2) consolidates the necessary services for the community development identified by the Palma-Palmilla Comprehensive Rehabilitation Plan (Proyecto Hogar, 2011), which includes education, employment and training, economic development (support for local business creation, participation in financial and credit plans), promotion of social diversity, and support for local organisations and resident groups. This mix of uses is a mutually reinforcing system capable of accommodating interconnected programs and providing services to vulnerable groups such as youth, single-parent families, and ethnic or racial minorities, hence nonprofit organisations play a significant role.

In the strategy of distributing uses based on height (E11), it is particularly visualised in the building section, leveraging the potential of vertical space as an opportunity (Fig. 8). The gradation of spaces in height corresponds to the achieved level of social cohesion and social learning: the higher the floor, the greater the level of individuality and maturity. As a general strategy, the most productive uses are located on the ground floor. In the intermediate levels, community and cultural facilities are placed (from 2nd to 8th floors), while residential use is situated on the upper floors (from 9th to 13th floors).

Finally, in the strategy of the relationship between new uses and height squares (E12), the new uses of community facilities and residential areas are integrated around outdoor spaces at various heights. In this way, the same outdoor space can be associated with different uses and activities.

Table 2

Strategy of public and private uses (E10) and potential uses that the hybrid building can offer

General use		Specific use
Residential	[RES]	Residence
	[SC]	Residential common services (TV rooms, work rooms, communal kitchen, laundry facilities...)
Education	[ED. EPM]	Education centre (I) Fathers and mothers' school. Education in values and civics. Sociocultural citizenship classroom (Popular University). Reinforcement of the educational level, literacy and culture of proximity.
	[ED. RE]	Education centre (II) After-school educational resource centre. School failure, school reinforcement and extracurricular activities. Alternative leisure and educational measures adapted for young people, a meeting and learning space.
	[ED. AE]	Education centre (III) Classroom for expelled people: Alternative educational measures for school expulsions.
Training and employment	[PRO]	Business incubator
	[EM. CFE]	Employment centre (I) Employment guidance and training centre. Services aimed at facilitating the search for employment, guidance and training adjusted to the socioeconomic profile of the neighbourhoods.
	[EM. CE]	Employment centre (II) Entrepreneurs Centre. Space for specific training for entrepreneurs.
Neighbourhood co-existence and other social services	[SG]	General services. Provision of social services that are not for residential use, nor health, educational or cultural assistance. Cooperatives for remote childcare. Management and development office of the Palma-Palmilla Community Home Project Plan. Spanish workshop for foreigners Legal advice office for immigrants.
	[JU]	Youth Centre Information point and youth communication network. Music recording centre. Dynamization of sports among women and mixed sports. Technology and Audiovisual Room.
	[CO. AS]	Civic Centre (I): Headquarters of the association of neighbourhood communities of La Palma and La Palmilla. Neighbourhood entity advisory centre.
	[CO. TD]	Civic Centre (II). Dance studio.
Health and Wellness	[SA]	Health support centre. Uses related to the provision of non-specific health care but in relation to health issues. Workshop for caregivers of dependent people. Psychoeducational learning and social skills programs. Maternal and child health promotion program. Prevention program aimed at children, adolescents and young people. Social incorporation and support for drug addicts. Training and psychological support actions for families of addicts.

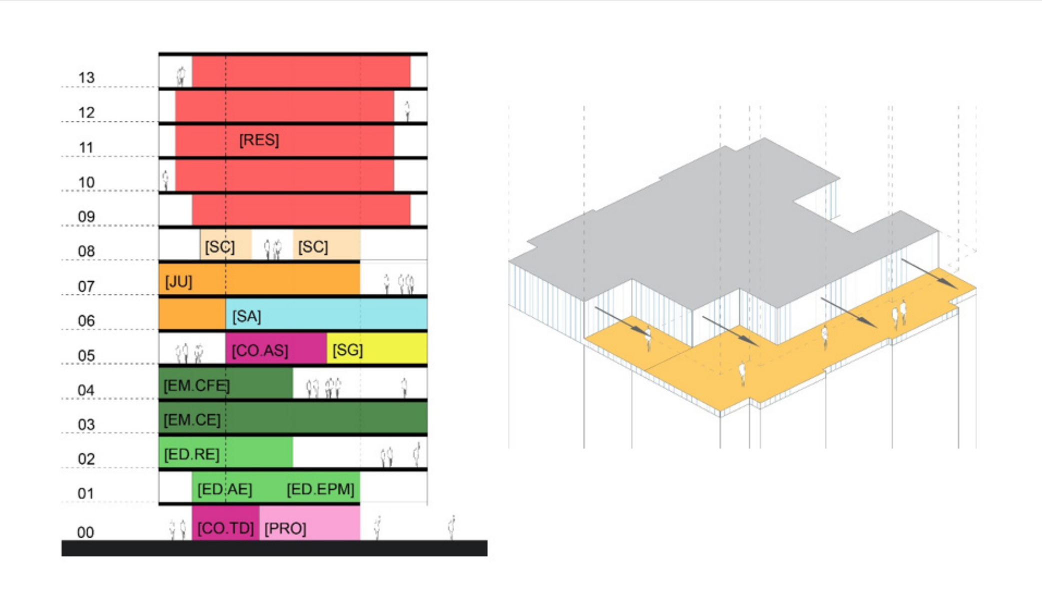


Fig. 8

Strategies for the distribution of uses at height (E11, left) and the relationship between new uses and squares at height (E12, right)

These new outdoor spaces facilitate interaction among different users of the building and help organise circulation routes to access various services. The goal is to avoid the formation of indoor corridors and instead provide these interaction and circulation spaces with a welcoming character as a new meeting place. Factors such as city views, double-height spaces, and their orientation will be project constraints aimed at ensuring the quality of these new viewing plazas.

In terms of metabolic strategies, all bathrooms serving both public and private functions (A10) are supplied with recycled greywater (A1) and harvested rainwater (A2). This diversification of functions also facilitates the optimisation of energy demand (A07): during working hours, peak energy consumption is concentrated in the public-use areas, whereas in non-working hours, energy demand shifts predominantly to the residential zones.

Conclusions

Construction of hybrid buildings in socially excluded neighbourhoods represents a novel approach for a building model traditionally developed outside these areas. Furthermore, incorporating these buildings into comprehensive urban regeneration processes in large peripheral neighbourhoods can address deficiencies in infrastructure and amenities. These buildings aim to provide a variety of uses that meet the needs of the local community, integrating a mix of residences, businesses, workspaces, and green areas. In this way, they can contribute to creating more vibrant and sustainable communities while helping to break the cycle of social exclusion and poverty often associated with marginalised neighbourhoods. Constructing these buildings can help improve access to services and opportunities, promote social and community interaction, and foster a sense of belonging and pride in the neighbourhood.

The research results demonstrate the project and environmental feasibility of transforming failed high-rise residential buildings into nZEB hybrid buildings (Table 3). While the study has focused on a specific case, the methodologies and strategies defined are generic and can be applied to buildings with similar characteristics in the peripheral environments of large cities. Hybrid buildings have the potential to address some of the key challenges faced by socially excluded neighbourhoods by offering a mix of uses and services that can meet the needs of the local community.

However, this model must confront several challenges that should be addressed in future research. First, funding is a significant consideration, as constructing hybrid buildings can be expensive and may require substantial capital investment. However, adapting existing buildings can access public assistance for rehabilitation and energy efficiency improvements. Second, transforming buildings into hybrids may reduce the number of housing units available, although the building itself can provide accommodations specifically designed for the transient population facing social exclusion. Another potential challenge is balancing the interests of different user groups such as residents, businesses, and commercial enterprises. Creating a functional and sustainable environment for all users may require careful design processes and effective management of shared space.

Table 3

Relationship between transformation strategies (design symbiosis) with nZEB metabolic symbiotic actions

			nZEB metabolic symbiotic actions											
			Water		Waste			Energy						
			A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12
Transformation strategies (design symbiosis)	Spatial	E01. Creation of open spaces at height	●	●	●	●	●		●					
		E02. Open and permeable ground floor					●							
		E03. Double-height spaces as singular elements	●	●		●	●							
		E04. Public surrounding space as a space of opportunity	●	●		●								
		E05. Roof plan and coexistence spaces between neighbours	●	●	●	●	●		●					
		E06. New communications core and adaption of the existing one					●							
	Energy	E07. Incorporation of passive systems						●	●					
		E08. Incorporation of active energy supply systems								●	●	●	●	
		E09. Transformation of the existing facade					●		●		●			●
	Uses	E10. New public uses for the neighbournood	●	●					●	●				
		E11. Distribution of uses based o height							●					
		E12. Relationship between new uses and open spaces at height												

Actions:

A01.Greywater reuse

A02. Rainwater harvesting and reuse

A03. On-site composting of organic waste

A04. Domestic anaerobic digesters

A05. Reuse of materials during renovation

A06. Passive cross-ventilation between spaces

A07. Passive heating/cooling systems

A08. Internal redistribution of renewable energy

A09. Solar PV systems on roof and facade

A10. Micro-wind power if it is viable

A11. Shared internal battery storage systems

A12. High-efficiency passive thermal insulation

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