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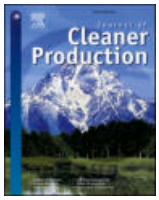

Sustainable transformation in the Latin American and Caribbean districts through the implementation of a qualitative methodology. Challenges and key aspects to be addressed

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ABSTRACT

To mitigate the advance of rapid urbanization and the growing percentage of energy consumption in the countries of the Latin American and Caribbean region, it is necessary to transform these inhabited environments into efficient and sustainable areas. Energy consumption in this region has been mainly understood as an indicator of activity and development, often relegating the parameters of efficiency, environment and sustainability to the background. Therefore, it is necessary to adapt these criteria in the transformation processes of cities, considering energy efficiency, environment, energy accessibility, social inclusion and the green economy as key aspects. This requires governance models based on local factors that consider all the agents involved, enacting more sustainable and inclusive regulations and standards. This article presents a transformation methodology based on the analytical study of several districts in the Latin American and Caribbean region. This methodology enhances the ease implementation, provides great adaptability and replicability in different areas and contextual situations, and reduces reliance on information availability, focused instead on practically relevant and impactful solutions. It has been executed through the application of three matrices: SWOT, stakeholders and contextual factors, which allow for the identification of key barriers, driving factors and baseline situation. Applied to four real cases, this approach has resulted in the formulation of tailored improvement proposals for each case. The global analysis has identified environmental and sustainability issues, infrastructure and social aspects as the main challenges to be addressed, while the main gaps have been economic, infrastructure, mobility and governance issues. The design and execution of efficient solutions require central coordination, generally led by the local administration, which enhances the participation of the main actors and manages energy flows.

1. Introduction

Countries in the Latin America and Caribbean (LAC) region are particularly sensitive to the effects of climate change (Conde-Álvarez et al., 2007), with projections suggesting temperature increases of up to 4.5 °C by the end of the century compared to the pre-industrial era (Reyer et al., 2017). This is mainly due to the accelerated urbanization process; the migration from rural areas to cities; the external energy dependence; the use of fossil fuels; the inequalities or the situations of vulnerability (Rodriguez, 2008). The effects of climate change will provide raises of 80% in total energy use by 2040, with an average annual growth rate of 2.2% (Balza et al., 2015). In 2005, the average

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increase in final primary energy consumption in the LAC region was 5% (CEPAL, 2009), with inequalities between countries. Furthermore, final consumption is mainly due to fossil fuels and their derivatives, representing more than 50% in 2019 (OLADE, 2021). Despite disparities in pollutant emissions per country in this region (World Bank, 2019), these non-renewable energy sources accounted for 7.9% of greenhouse gas emissions in 2000 compared to the global amount, rising to 12% worldwide considering land use change (IDB, 2011).

This region is therefore highly susceptible to the effects of climate change, with a great variability of ecosystems associated with different climatic conditions. This variability generates high potentials for utilizing local natural resources, facilitating the development of sustainable areas. Although the significance of renewable energy investment in mitigating emissions and minimizing environmental impacts (Bekum, 2022), the exploitation of natural resources in LAC is unsustainable. This results in depleted biocapacity and prevents resources from regenerating (Nathaniel et al., 2021). Moreover, other factors such as real GDP per capita, economic complexities, and tourism activities also influence regional CO_2 emissions (Adedoyin et al., 2021).

To overcome the challenge of making cities sustainable, it is necessary to change the conceptualisation, planning, design and operation of existing urban areas through models with safe and affordable housing, sustainable public transport, local renewable generation, green public spaces, increased local jobs or comprehensive urban management (UNEP, 2015). This urban concept requires high level of innovation, presenting multiple challenges (Krangsås et al., 2021). Thus, a sustainable district aims to minimize its environmental impact, promote social equity, and ensure economic prosperity within a specific geographical area with similar urban context, population density, infrastructure, or resource availability. In developing countries, the proper management of these new models needs the application of multi-dimensional and multi-sectoral participatory measures, coordinated at local, national and general levels (Madlener et al., 2011).

Several international proposals have been promoted under the sustainable or positive energy district perspective but most of them come from European and North American countries (IEA-EBC Annex 83 Website). Contrary, with very few initiatives have been proposed in the LAC region and there is a lack of specific concepts developed for this purpose. Instead, existing European and North American definitions have been adopted (UN, 2017; IDB, 2011). These countries are characterized by peculiarities and contexts different from those in Europe (UN, 2012), being necessary to analyse their current situation and identify the specific challenges that must be faced. For instance, in the urban context, LAC cities exhibit varying rates, densities, and degrees of fragmentation compared to the EU, leading also to diverse socioeconomic aspects. Transforming an existing district into an efficient and sustainable one in a developing country requires a different roadmap than in developed countries (Marchetti et al., 2019). This process involves identifying fundamental contextual factors for successful transformations, considering aspects such as economically viable solutions, uncontrolled urbanization or reduction of social vulnerability.

Despite the relevance of LAC countries in global environmental assessments, there is an evident lack of flagship actions reported in this context. Therefore, this article aims to deepen the identification of the most important contextual factors in transforming this region based on the sustainable district approach. Key aspects include the developed methodology, which identifies factors driving the transformation process of existing districts in these countries. It evaluates different frameworks such as SWOT, stakeholders, and contextual matrices, proposing new improvement measures. As a novelty, these outputs were contributed by professionals from the LAC region during a training course organized by CIEMAT and the Spanish Agency for International Development Cooperation (AECID). To illustrate the application of this methodology to real-world scenarios, we evaluated four districts with different climate, urban and socioeconomic characteristics: Mendoza (Argentina), Ciudad de Azul (Argentina), Tegucigalpa (Honduras), and the National District (Dominican Republic). This assessment aims to promote the development of future sustainable districts.

2. Methodology

The transformation of existing inhabited environments into sustainable districts in the LAC region is a complex process that needs to consider technical, environmental, social, economic, regulatory, legal and educational aspects (Krangsås et al., 2021). This process requires methodologies that contextualizes the real situation of the LAC districts. Nevertheless, the existing literature presents few examples of sustainable neighbourhoods or cities in these countries (Valente de Macedo et al., 2021;Altamirano-Avila et al., 2021), whose priority interests are different from those of developed countries (Grazieschi et al., 2020). To alleviate this situation and delve deeper into the district transformation in this region, a phased methodology has been developed to identify the main challenges, barriers and driving factors. This transformation process was created under the framework of the training course 'Positive Energy Districts and their adaptation to climate change conditions' (Soutullo Castro et al., 2022), which is part of the training itinerary developed by CIEMAT under the INTERCOONECTA program of the AECID in the LAC region (AECID, 2019).

This training activity on Positive Energy Districts (PED) was attended by 20 participants from public, semi-public and private administration institutions, as well as non-governmental organisations and companies from the Dominican Republic, Argentina, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Panama, Paraguay, Peru and Uruguay. To identify which pillars most promote or block the implementation of a PED, seven pillars plus a generic one were proposed: technological, environmental and sustainability, economic and financial, infrastructure, mobility, social, governance and other. Seven groups of stakeholders were proposed (citizenship, industry, administrations, academia, financial institutions, energy services and infrastructure operators and real estate sector) to act across five phases of the process (planning, design, implementation, operation and assessment). In both cases a generic option was proposed to identify specific aspects. Participants were asked a series of questions to contextualize the real situation: What are the existing gaps, challenges and needs? How can these requirements be covered? What prevents or delay their implementation? Who are they relevant to? Who are the relevant actors in the implementation of these districts? To complete the participants' opinion on the pillar prioritisation, the relevant drivers and blocking factors and the importance of the actors involved in each stage of the process, additional questions were also formulated. Fig. 1a shows the average scores for the pillars (left) and Fig. 1b for the stakeholders and project phases (right), obtained from the participant responses. According to these results, the most important pillars in the urban transformation are environmental and sustainability, technological and governance factors. The main challenges are also centred on environmental and sustainability issues, infrastructure and social aspects. The main gaps are focused on economic and financial aspects, infrastructure, mobility and governance factors. In the planning and design phase, the most relevant actors are administrations and academia. In the implementation phase, the main players are industry, energy services and infrastructure operators and the real estate sector. In the operation phase, the main actors are industry, energy services and infrastructure operators. Finally, in the evaluation phase, the most important actors are administrations, citizens and academia.

No other pillar was proposed but the importance of considering capabilities, cultural aspects, poverty, research and educational issues was emphasized. No new group of stakeholders was proposed, although a new phase was identified: management and control of the district.

To identify which aspects can block or promote this transformation and who is affected and at what stage, a phased methodology was developed. This methodology contextualizes the existing situation and needs and requirements for implementing efficient and sustainable

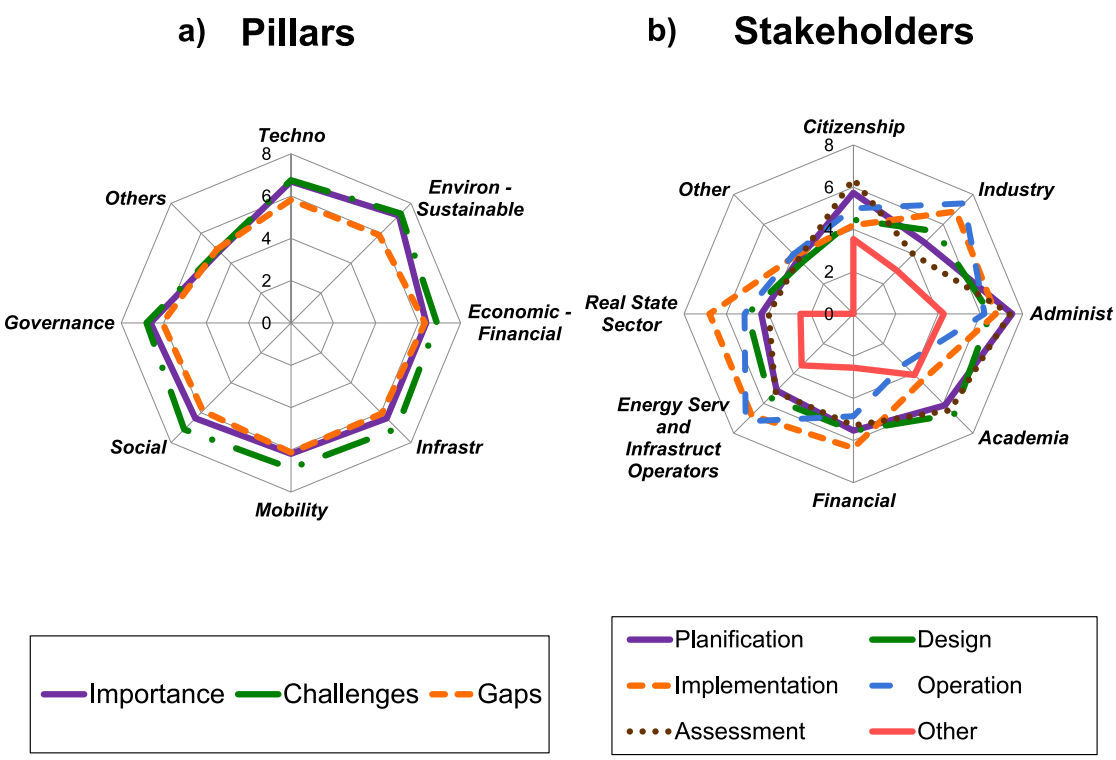

Fig. 1. Distribution of the participant's votes on: a) pillar prioritisation: influence of importance, challenges and gaps proposed; b) influence of stakeholder in each project phase.

districts. Initially, the baseline situation and contextual factors are defined, allowing for the identification of the main challenges that must be addressed. Next, three analysis matrices were developed to identify priorities and fundamental pillars. Finally, an improvement proposal is defined that prioritizes the challenges with the highest impact on the initial situation. This methodology is schemed in Fig. 2. Its applicability has been demonstrated through its application in four of the case studies proposed in the PED course.

2.1. Phases of the developed methodology

The methodology developed is structured in several phases drawn from the qualitative analysis of case studies. This approach aims to identify the key aspects and challenges of each case, facilitating the understanding of the planning processes and their contextual characteristics. The implementation of these phases aims to gather the necessary information to formulate a sustainable proposal for a district transformation:

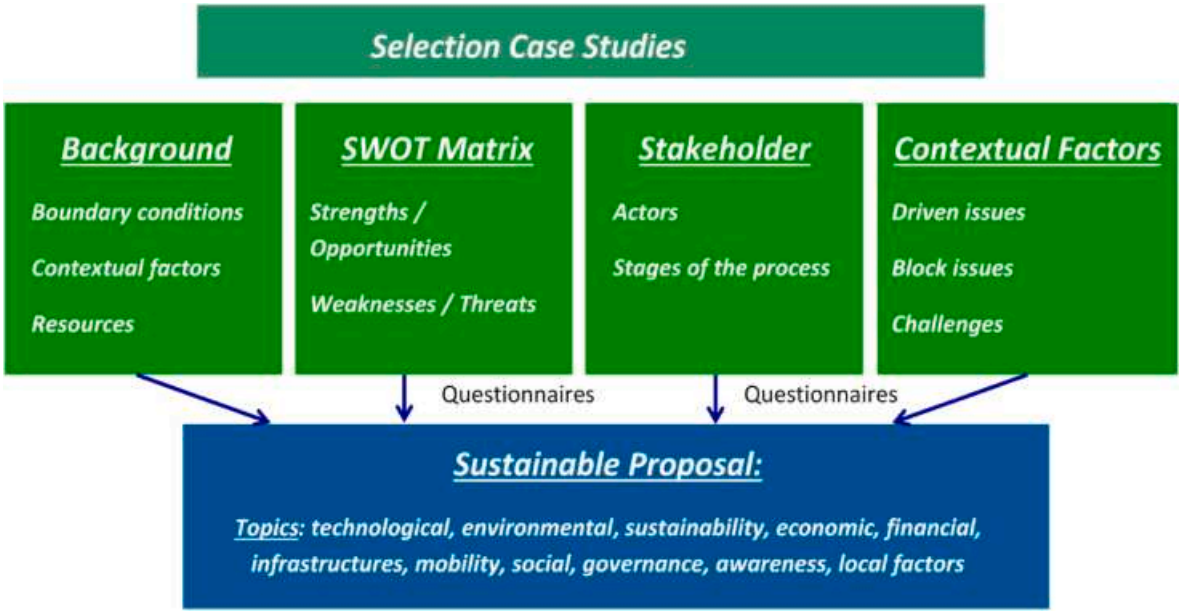

Fig. 2. Descriptive outline of the qualitative urban transforming methodology developed.

- *Background*. This phase contextualizes the baseline situation, identifying the inlet information, available resources and boundary conditions. Priority objectives should be defined to identify which indicators will be measured, allowing the subsequent analysis of their impact and evolution after the implementation of an improvement measure.
- *SWOT matrix*. This phase highlights the internal factors (strengths and weaknesses) and external factors (opportunities and threats) that need to be considered in the transformation process depending on the local context of each study area.
- *Stakeholder's matrix*. This phase identifies the main actors involved at different stages of the process, providing information on who needs to be involved and at which stage of the implementation process.
- *Contextual factor matrix*. The combination of the baseline situation with the results of the SWOT and Stakeholders matrices allow the identification of different aspects that should be addressed before proposing any type of improvement measure based on the local requirements. These challenges are categorized based on the seven pillars proposed in the transformation process.
- *New proposal.* This proposal should include several improvement measures to enable the energy transition of the neighbourhood, quantified by the time evolution of the indicators and the impact produced compared to the background phase.

2.2. Studied cases in the LAC region

The initial selection of case studies was based on the collection of examples presented in the training activity on 'Positive Energy Districts and their adaptation to climate change conditions' organized by CIEMAT and AECID within the Inter-American Development Bank website, programme (Soutullo Castro et al., 2022). These examples represented different energy urban transformations in different LAC regions. Afterwards, a group of cases was identified based on several requirements: diversity of climatic zones; different urban developments (new expansions and rehabilitation areas), socio-economic diversity, accessibility to public infrastructures and accessibility to information from the case studies. The final choice was made based on the participants' willingness to contribute to this study. These selected cases are located in four different climatic zones but located in three different LAC countries: Argentina (2 cases), Honduras (1 case) and Dominican Republic (1 case).

3. Results

This methodology has been applied to the four case studies identified through the selection process, given that they meet the established requirements. These cases are differentiated by location, climatic characteristics, urban development and socioeconomic situation.

3.1. Case 1: Decima Seccion Los Cerros District (Mendoza, Argentina)

This case represents a new urban centre in the province of Mendoza (Argentina): "Distrito Decima Seccion Los Cerros". The city of Mendoza is located in the centre-west of Argentina (City of Mendoza website), at the base of the Andes Mountains (latitude 32.8° S, longitude 68.8° W and altitude 746 m). This area is characterized by warm and mostly clear summers, cold winters and high heliophany in both winter and summer, defined as BwK class according to the Köppen- Geiger classification (Köppen-Geiger website).

3.1.1. Background

The growth process of the Mendoza Metropolitan Area has led to an urban sprawl characterized by low-building density development. This area has climatic and geomorphological conditions that are well suited for the optimal urban integration of bioclimatic strategies and renewable technologies (solar and wind). However, an urban heat island effect has been detected in the foothills of the city, causing temperature differences of between 8° and 10 °C compared to rural or peripheral zones of the metropolitan area (Correa et al., 2006). In addition, it is necessary to minimize the expansion of municipal landfills and improve existing infrastructures. To change this trend, a sustainable urban strategy is being promoted for this area, controlling expansion processes and supporting orderly and compact growth. In 2021 a National Competition was launched by Dalvian S.A. and the College of Architects of Mendoza, to promote a Master Plan and blueprint for the development of an urban ensemble (CAU-PSF website). The studied land is located in Section 10 of the city: Residencial Los Cerros (Fig. 3). It is a private land, without current use, intended to be incorporated into the urban structure.

3.1.2. SWOT analysis

The analysis of the Sector's characteristics identifies a number of strengths and weaknesses that should be considered in its sustainable transformation (Fig. 4). On the one hand, integrating bioclimatic measures in buildings with solar and wind generation would reduce conventional energy needs, decrease pollutant gas emissions and improve comfort and quality of urban life. Infrastructures should be improved and located closer to consumption points. In addition, efficiency and sustainability criteria should be included in urban planning.

There are also significant barriers, mainly related to governance and economic aspects that need to be overcome to achieve stable economic, social and institutional development. It is necessary to check whether the suggested intensity of land occupation, based on the compact city criterion, is adequate to the capacity of the implantation site (a high vulnerability, environmental and social risk area). A palliative or compensatory strategy for the impact of a high land use intensity could be the implementation of a PED.

3.1.3. Stakeholder's matrix

The transformation process requires the collaboration of all stakeholders involved at both local and national levels, considering their interests throughout all stages of the process as shown in Fig. 5.

3.1.4. Contextual factors

The study of the above matrices allows the identification of aspects that either enhance or block the development of Section 10, highlighting which contextual factors need to be addressed in a proposal for improvement. These factors have been structured into seven pillars, as illustrated in Fig. 6.

The proposal should adjust the use and availability of natural resources and energy flows to incorporate new efficiency improvement measures. Urban strategies should be improved and adapted to the local context. Economic and regulatory aspects are also factors to be considered.

3.1.5. New proposal

The proposal covers an area of approximately unused 30 ha, located on the departmental limits of the capital city of Mendoza, in the contact zone between the foothills and the extensive eastern plains, on the alluvial cone of the Mendoza River. The main objective is the design of a new sustainable urban environment, integrating local equipment with the existing urban sector, emphasising connectivity, mobility and accessibility. The neighbourhood will incorporate mixed uses and several activities to promote sustainability, ensuring interaction between open and built spaces.

The main proposed measures are summarized as:

- Urban structure adapted to seismicity using the INPRES-CIRSOC code, and climate with drought-resistant green and permeable areas to cope with heat stress, flooding and Zonda wind.
- Rational use of available natural resources, high-efficiency HVAC systems, use of renewable wind and solar technologies, and recycling

Fig. 3. a) Location of Decima Seccion Los Cerros district marked with a yellow area [Source: Google Earth]; b) Current situation of the district [Source: Boletín Memo website]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

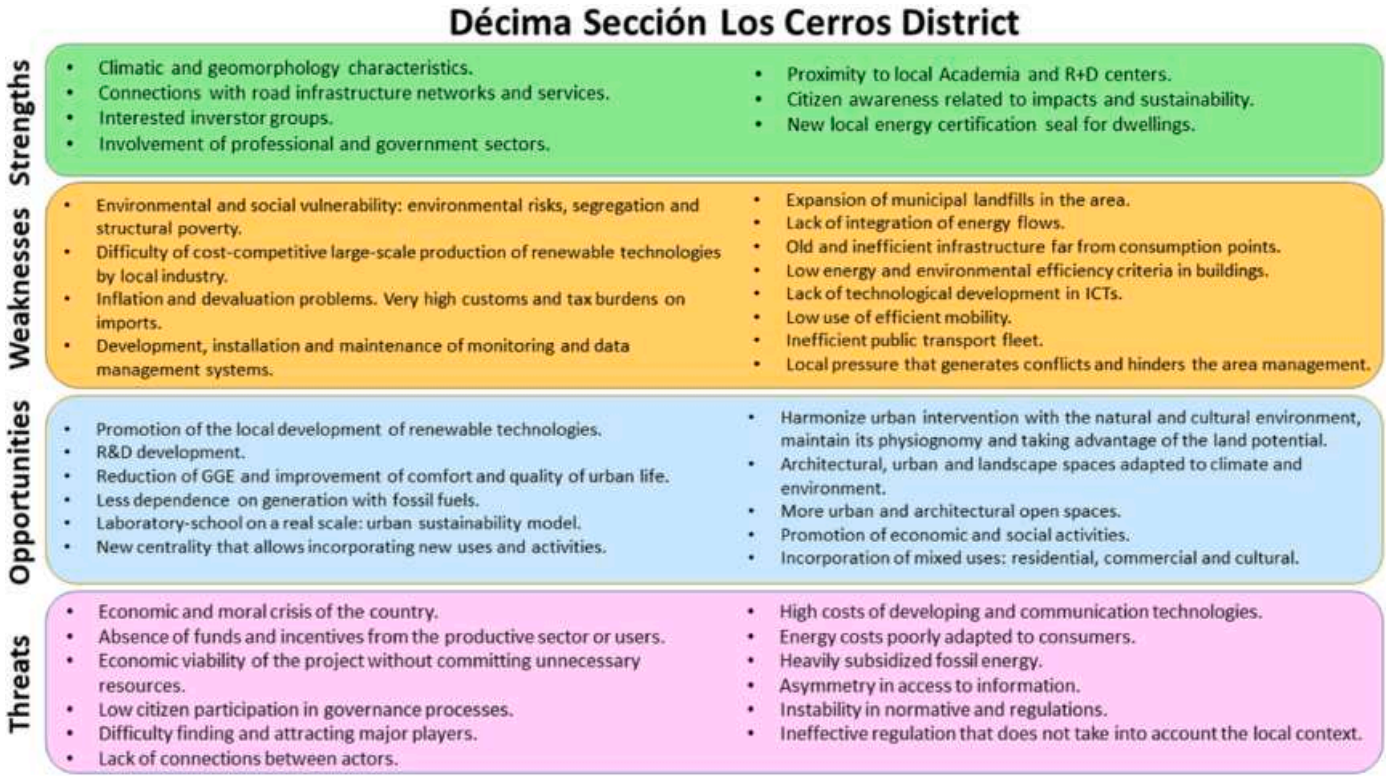

Fig. 4. SWOT matrix developed for Decima Seccion Los Cerros district.

and composting management models to minimize solid and liquid waste.

– Optimal rates of land occupation, fostering flat buildings and shared spaces leading to a compact city model that guarantees sustainability.
– Implementation of sustainable, efficient and economically viable construction strategies: exterior and interior solar control systems; materials on exterior horizontal surfaces to mitigate the absorption of solar radiation in low pedestrian transit areas (albedo: 0.8–1); green areas composed by species with low water requirements for natural cooling and ventilation (patios, walls, etc.).
– Reduction of the vehicular structure of streets, prioritizing pedestrian areas. Promotion of public and sustainable transport with good city connectivity and accessibility.
– Use of the Energy Performance Index (IPE) defined in the Argentinean regulations (IEDS, 2016), as an indicator of the degree of building energy efficiency (Qalcular Software, 2016).

3.2. *Case 2: Ciudad de Azul District (Ciudad de Azul, Argentina)*

This case evaluates the implementation of a sustainable district in the city of Azul (Azul Municipality Website), in the province of Buenos Aires (Argentina). This city is located in the northeast region of Argentina

DÉCIMA SECCIÓN LOS CERROS DISTRICT (ARGENTINA)						
Stakeholders/ Phases	**Planning**	**Design**	**Implementation**	**Operation**	**Assessment**	**Management and control**
Citizenship	Architect college in Mendoza - CAMZA	Architect college in Mendoza - CAMZA	Citizenship	Citizenship	Citizenship	Citizenship
Industry			ENERG, industry, etc.	Industry		
Administrations	Capital Mendoza Municipality		Capital Mendoza Municipality	Capital Mendoza Municipality	Capital Mendoza Municipality	Capital Mendoza Municipality
Academia		Universities, UNCuyo, UTN, Mendoza, Maza, Congreso, ETC			Universities, UNCuyo, UTN, Mendoza, Maza, Congreso, ETC	
Financial	Dalvián S.A /BID		Dalvián S.A /BID		Dalvián S.A /BID	
Energy Services and Infrastructure Operators			EDEMSA, DISTROCUYO, OSM, Waste Management, Transport	EDEMSA, DISTROCUYO, OSM, Waste Management, Transport		
Real State Sector	Dalvián S.A	Dalvián S.A, professionals Architects or Architecture Studios in competition	Dalvián S.A			

Fig. 5. Stakeholder's matrix developed for Decima Sección Los Cerros district.

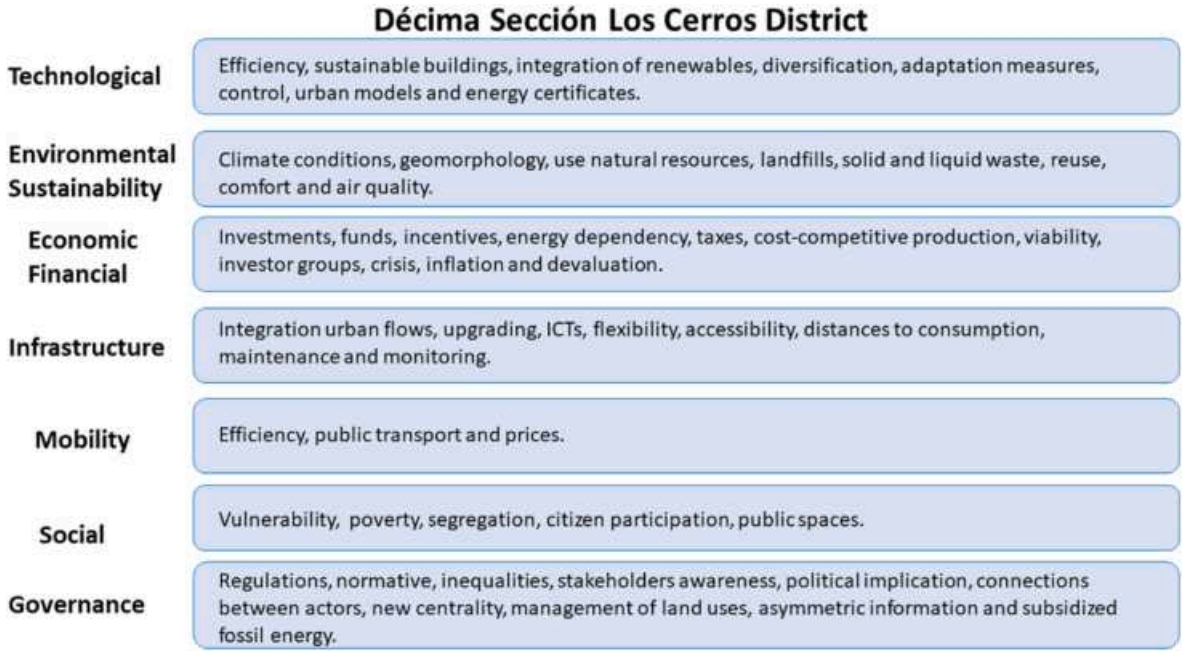

Fig. 6. Contextual matrix developed for Decima Sección Los Cerros district.

(latitude 36.8° S, longitude 59.8° W and altitude 137 m). This built area is characterized by a temperate Pampas climate, with hot summers and cool winters and more humid periods from May to July, defined as Cfa according to the Köppen-Geiger climate classification (Köppen-Geiger website).

3.2.1. Background

The city of Azul has 29 neighbourhoods, many of which require improvements to their facilities and building stock (see Fig. 7). The land use is mainly for animal husbandry and agricultural purposes, but also has agricultural, metalworking, food, chemical and construction industries. The manufacturing industry is currently developing. Furthermore, urban infrastructures are old and poorly digitized. Different initiatives are being carried out to reduce the low levels of habitability in six popular neighbourhoods of the city, which barely cover the minimum services (Diario el Tiempo website). But it is still necessary to

Fig. 7. a) Location of Ciudad Azul district marked with a red area [Source Google maps]; b) Current situation of the district [Source: *Telam, 2016]*. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

promote greater financial and fiscal incentives to improve building efficiency and urban structures, and increase the integration of renewable technologies.

This region is affected by the effects of climate change, projecting CO_2 emissions between 614 and 820 ppm and temperature increases between 1° and 2 °C for the years 2030 and 2060, according to the climate model generated by the Center for Weather Forecast and Climate Studies of Brazil (CPTEC website). These effects reduce the citizens' quality of life and increase health problems.

3.2.2. SWOT analysis

The SWOT matrix, represented in Fig. 8, highlights the opportunity to promote a more efficient and digitized building stock by integrating local renewable technologies and storage systems; developing more flexible infrastructures that incorporate management systems and facilitate energy access; creating local energy-related jobs and improving transport and common areas in the city.

However, numerous barriers have been identified that need to be overcome. It is necessary to improve financial conditions and increase economic incentives; create new business models; minimize variations of the energy market; develop a favourable legislative and regulatory

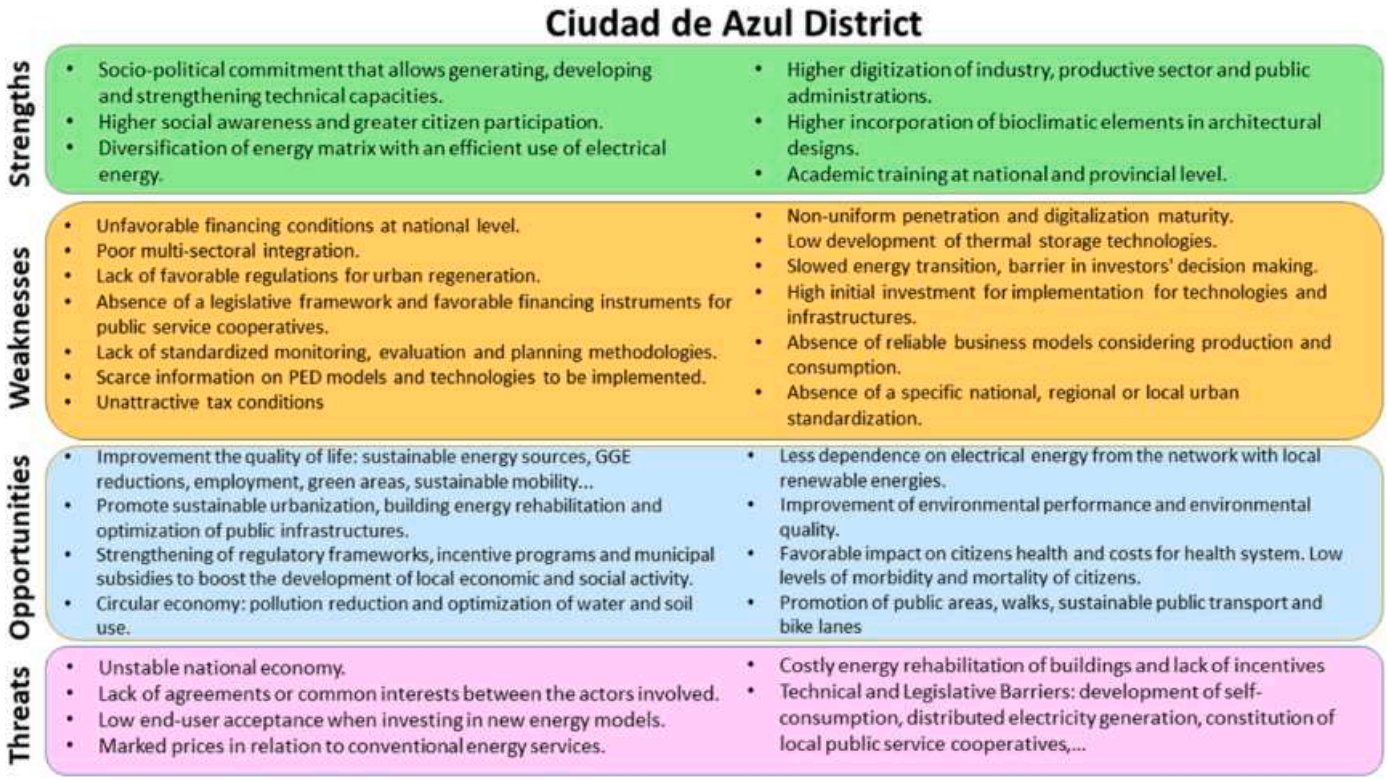

Fig. 8. SWOT matrix developed for Ciudad Azul district.

framework; and optimize existing infrastructures. This requires a governance model adapted to the local context that considers the interests of all stakeholders.

3.2.3. Stakeholder's matrix

The Stakeholder matrix developed (Fig. 9) aims to identify the actors and the phases in which they are involved, enhancing the coordination of all interests and reducing the risk of failure of sustainable proposals.

3.2.4. Contextual factors

The contextual factors identified in Fig. 10 highlight the need for efficient building retrofitting through the integration of bioclimatic measures and renewable technologies, as well as the improvement and digitalisation of energy supply infrastructures. This requires the development of new governance models adapted to the area, reducing administrative and economic barriers.

3.2.5. New proposal

The main objective is to improve the quality of life for citizens in an 8000 m^2 pilot area with a 2010 population density of 9.9 Hbs/km^2 (Censo Website). The proposal foresees the execution of one or more pilot cases incorporating sustainability and energy efficiency criteria. The measures propose the implementation of commercially viable solutions considering contextual factors of the area:

- Building rehabilitation periodization and/or new construction under nearly-zero energy consumption, sustainability and comfort parameters: passive solar design, natural ventilation, high-performance insulation, energy-efficient lighting, HVAC systems, and windows.
- Flexible energy systems and integration of ICTs: smart meters, demand response programs, and building automation systems (IoT).
- Renewable generation and energy recovery based on local resources: solar, wind and biogas.
- Thermal and electrical storage systems to deal with energy market unsteadiness (peaks or outages), minimizing the impact on the energy networks.
- Improvement of water management systems and treatment of urban waste: low-flow fixtures, greywater recycling systems, and recycling and composting programs.
- Increasing the accessibility and connectivity through more efficient transport, sustainable fuels or the inclusion of bike lanes and renting.
- Monitoring campaigns to manage building and district performance, promoting the replicability of successful solutions in other adequate areas.
- Development of more inclusive and coordinated governance models: citizen advisory board, simplified administrative processes, and sustainability awareness workshops.

3.3. Case 3: La Gloria a Dios Residential (Tegucigalpa, Honduras)

This case proposes the transformation of an existing small residential community into a fully sustainable one. The case study is La Gloria a Dios neighbourhood, located in the city of Tegucigalpa in the department of Francisco Morazán in the municipality of the Central District (Honduras) (Tegucigalpa website). This area is located in the south-central mountainous region of Honduras (latitude 14.1° N, longitude 87.2° W and altitude 990 m). The city of Tegucigalpa has a tropical savannah climate, characterized by a cold dry season (November–March) and a warm and cloudy rainy season (April–October), and defined as Aw according to the Köppen-Geiger classification (Köppen-Geiger website).

3.3.1. Background

To promote sustainable proposals in Tegucigalpa, the Emerging and Sustainable Cities Initiative prepared a report to contextualize the current situation of the city. This study, financed by the IADB (IDB website), assessed several environmental, urban, fiscal, and governance indicators; evaluated greenhouse gas emissions, natural disaster risks and

CIUDAD DE AZUL DISTRICT (ARGENTINA)					
Stakeholders / Phases	**Planning**	**Design**	**Implementation**	**Operation**	**Assessment**
Citizenship	Citizenship	Citizenship		Citizenship	Citizenship
Industry		Technological and services industries	Technological and services industries		
Administrations	Municipality areas of energy and urban planning	Municipality area of urban planning	Municipality areas of urban planning, mobility and environment	Infrastructure operators	Municipality
Academia	Universities, Research and Technological centers				Universities, Research and Technological centers
Financial		Municipality incentives, banks and local financial entities.	Financial solutions providers		Financial areas from municipalities and economic evaluators
Energy Services and Infrastructure Operators	Energy data providers.		Local energy companies and Infrastructure operators	Infrastructure operators.	
Real State Sector	Real estate data providers.	Architects , Architecture Studios and Construction Companies	Construction and Renovation Companies		Property Managers

Fig. 9. Stakeholder's matrix developed for Ciudad Azul district.

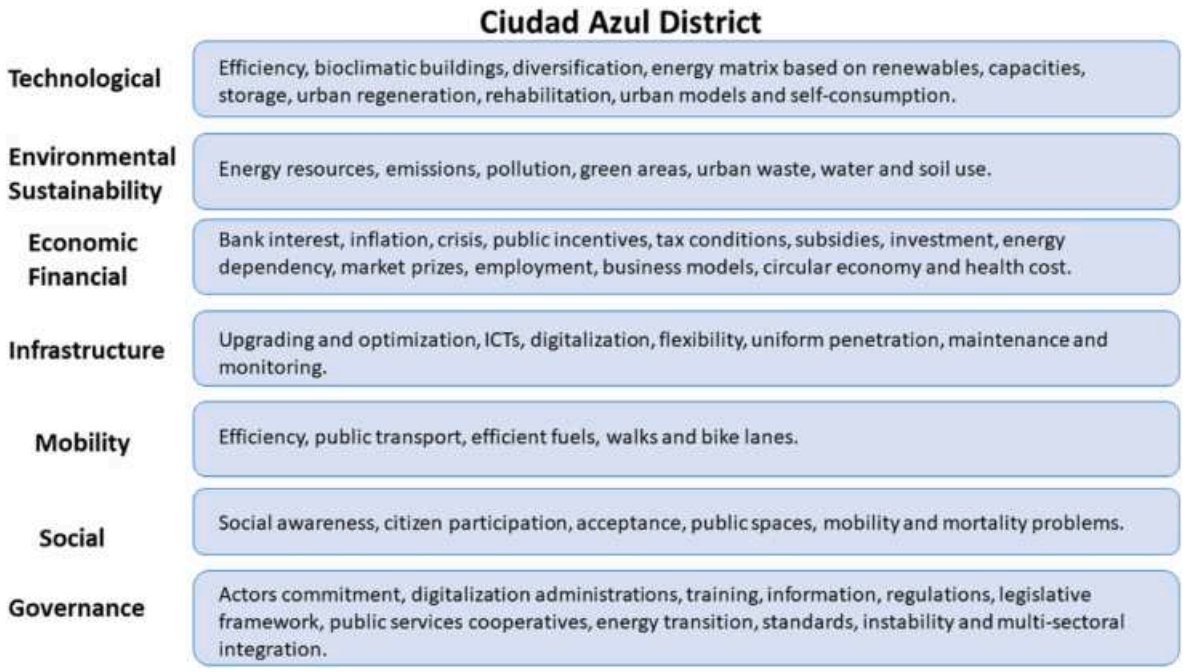

Fig. 10. Contextual matrix developed for Ciudad Azul district.

urban footprint; analysed vulnerability levels and urban development patterns. The report proposed a roadmap to promote measures and actions for a sustainable growth in the city (Plan de Acción Tegucigalpa). One of the areas of application is the Residential La Gloria a Dios (Fig. 11). This complex is closed to other residential areas, an institute, several green areas and the CA-6 Oriente highway. These blocks of buildings are mainly electrically conditioned; with some equipped with air conditioning systems, inefficient equipment and without integration of renewable technologies. However, there are few incentives to improve these aspects, both for residents, and for financial institutions and municipalities. The starting situation has been analysed through local surveys with residents (Soutullo Castro et al., 2022).

3.3.2. *SWOT analysis*

The SWOT matrix in Fig. 12 identifies environmental, economic, mobility and social aspects as the most influential factors in transforming the complex. This process seeks to improve the habitability conditions and the quality life of citizens, increasing its energy, economic, environmental and social benefits. Most of the residents are owners and are open to the implementation of new measures, which facilitates their involvement in the transformation process. However, economic and administrative aspects complicate this process.

Aspects of public safety and road accessibility are also relevant for residents.

3.3.3. *Stakeholder's matrix*

The transformation process of La Gloria a Dios Residential into a more sustainable and efficient complex requires the participation and involvement of several local and national actors throughout the implementation process, as can be seen in the following matrix (Fig. 13).

3.3.4. *Contextual factors*

The contextual factors identified for this residential complex (Fig. 14) highlight the need to improve both the efficiency of existing buildings and systems and the integration of renewable technologies. Control devices are required to optimize the energy performance of the whole complex. Additionally, central coordination, higher user awareness and more favourable economic measures are necessary for the

Fig. 11. a) Location of Residential Gloria a Dios marked with a yellow area [Source: Google Earth]; b) Current situation of the complex [Source: Soutullo Castro et al., 2022]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

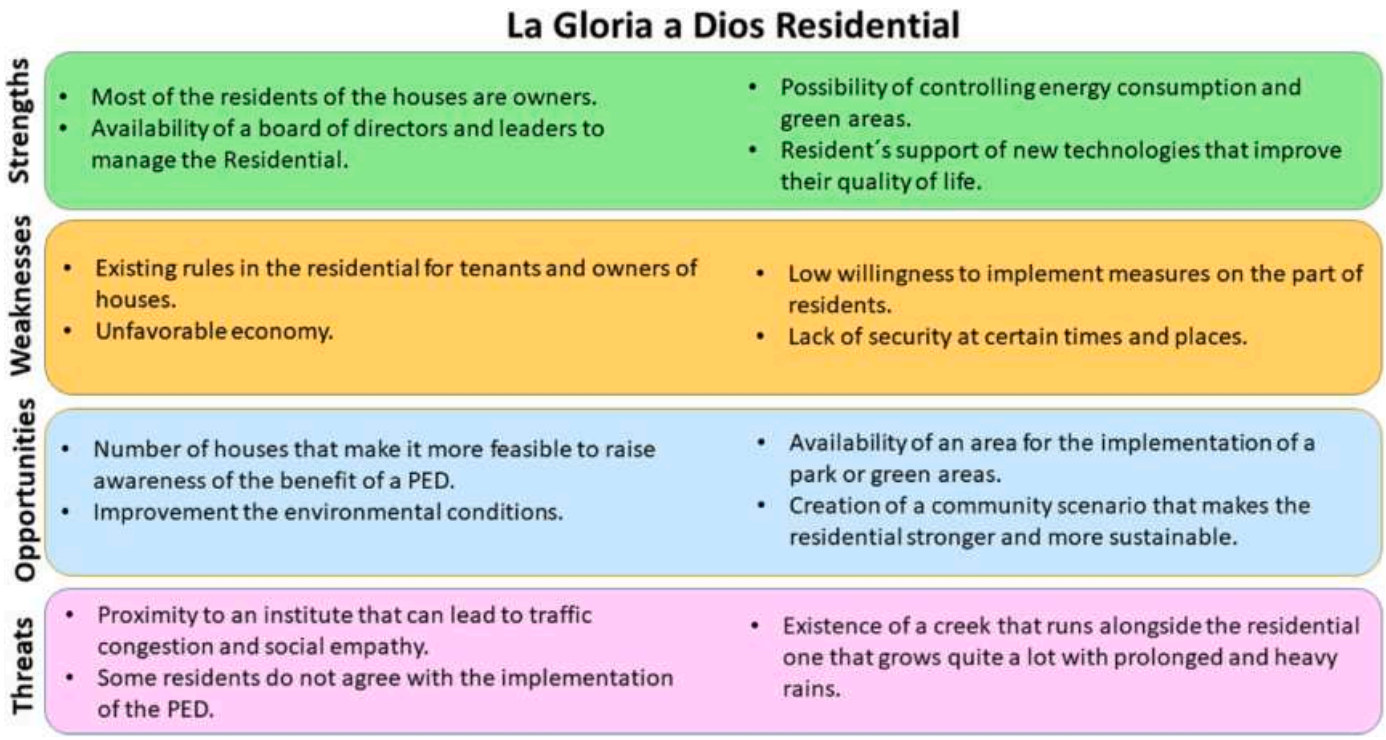

Fig. 12. SWOT matrix developed for La Gloria a Dios Residential.

LA GLORIA A DIOS RESIDENTIAL (HONDURAS)					
Stakeholders / Phases	Planning	Design	Implementation	Operation	Assessment
Citizenship		Residents of la Res. Gloria a Dios.	Residents of la Res. Gloria a Dios.	Residents of la Res. Gloria a Dios.	Residents of la Res. Gloria a Dios.
Industry	Construction companies of new apartments or refurbishment of houses.		Construction companies of new apartments or refurbishment of houses.	Construction companies of new apartments or refurbishment of houses.	
Administrations	Management board and leaders of the residential.		Management board and leaders of the residential.		Management board and leaders of the residential.
Academia				Non-profit youth for the sustainability of the PED	
Financial	Fee paid per house		Fee paid per house	Fee paid per house	
Energy Services and Infrastructure Operators			Electrical energy service of the entire residential area, ENEE company and Energy Honduras	Electrical energy service of the entire residential area, ENEE company and Energy Honduras	
Real State Sector			Residents and construction companies.	Residents and construction companies.	

Fig. 13. Stakeholder's matrix developed for La Gloria a Dios Residential.

proper operation of the complex.

3.3.5. New proposal

The main objective is to increase the efficiency of this residential complex through sustainable measures adapted to its current situation. This neighbourhood has 27 houses distributed in 3 blocks (approximately 300 m^2), housing 108 residents. Passive measures are proposed to reduce energy demands while improvements to existing energy systems and integration of renewable technologies is defined to reduce energy consumption. The new proposal details are summarized as

Fig. 14. Contextual matrix developed for La Gloria a Dios Residential.

follows:

- Thermosyphon-type solar collectors on roof to obtain domestic hot water. These systems eliminate the use of high-resistance thermo showers.
- Replacement of electric gas stoves with significant saving of up to 45% of the electrical consumption thanks to the reduction of highly resistive devices.
- Switching all light bulbs to LED technology.
- Upgrading the A/C units to Inverter technology.
- Replacement of refrigerators with those using Inverter technology.
- Implementation of a programmable logic controller to operate cisterns of pumps at night, when electricity prices are lower.
- Substitution of appliances with those rated to levels "A" for high energy efficiency.
- Photovoltaic modules with a storage system for the whole complex. Energy surpluses will be injected into the grid through a high-capacity inverter and with harmonic elimination. Emphasis is placed on its use directly for lighting.
- Specialized communal areas for drying clothes using solar resources, catering to homes without roof space. It will be possible to eliminate clothes dryers, highly resistive devices.
- Waste water treatment system using Biodiscs for the irrigation of organic gardens.
- Bioclimatic architecture measures: Trombe walls, overhangs in windows …
- Creation of a coordination committee to optimize the operation of the implemented measures in the residential complex.

3.4. Case 4: Distrito Nacional (National District, Dominican Republic)

This case presents the transformation of the National District, which is the geographical demarcation of the Dominican government (National District website). This area is an entirely urban territorial demarcation that exercises the functions of both the municipality and province. The National District is located in the Ozama region of the Dominican Republic (latitude 18.5° N, longitude 69.9° W and altitude 52 m). This area is characterized by a tropical monsoon climate, with regular annual rainfall and a dry season in winter (February and March), identified as Am according to the Köppen-Geiger classification (Köppen-Geiger website).

3.4.1. Background

The urban structure of Santo Domingo is quite heterogeneous and combines formal and informal settlements with great inequalities between them (Núñez Collado, 2019). Therefore, ambitious challenges are being set regarding greenhouse gas emissions, dependence on fossil fuel imports or environmental impacts (National Energy Commission, 2018). Meeting these challenges will require a shift in the country's energy matrix, with renewable energies playing a crucial role.

The studied case has a total area of 92 km^2 divided into 70 sectors and subdivided in turn into 257 sub-neighbourhoods without any rural area. Jurisdiction is managed from a municipal office (Fig. 15). These sectors mostly have an outdated grid network that supplies electricity to a large population in a relatively small area. Currently, energy consumption of the National District is distributed as follows: 26.6% public, 25.5% industrial, 21.7% commercial and 20.3% residential (National Energy Commission, 2019). The main economic activity of the National District is commercial, although industrial, communications and port activity (especially tourism) are also important. This area is characterized by strict controls by the electricity distribution companies to censure accurate information for consumed energy.

To contextualize the situation of the National District, the city council designed a Municipal Development Plan for 2030 (D'Alessandro, 2020). This document presents an urban diagnosis based on the identification of the deficiencies produced in human developments and infrastructures, as well as the impact that these deficits produces on people and the environment. This report also includes a SWOT matrix for the area, identifying blocking and enabling factors. As a result, this document provides an Action Plan that outlines the strategies, actions and projects necessary to address the identified challenges.

3.4.2. SWOT analysis

Driving and hindering factors have been identified in the SWOT matrix in Fig. 16. In the energy sector, the main challenges are institutional, economic and technical aspects. Technical challenges include ensuring the sufficiency and flexibility of generation, the adequate

Fig. 15. a) Location of the National District marked with a red area [Source: Google maps]; b) Current situation of the district [Source: *2015*]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 16. SWOT matrix developed for the National District.

development of the energy network, the variability management, the promotion of renewable generation and the optimal management of its penetration levels. Locally, it is essential to promote appropriate financial incentives and business models to attract investment. Success in this transformation process requires modifying contextual factors to align the district closer to the definition of a PED, being necessary an effort from all sectors of society.

3.4.3. Stakeholder's matrix

The proposal to transform the energy system of the National District is a challenge that requires the participation and collaboration of all involved actors (Fig. 17). The identification of the main stakeholders is crucial for the optimal implementation and operation of a sustainable district, being necessary to ensure a lasting commitment to collaboration and coordination between all the interested parties.

It must be taken into account that the commitment of each actor varies throughout the implementation process. In addition, some actors tend to change their position or rethink their participation when moving from one phase to another.

3.4.4. Contextual factors

The transformation of the energy system in the National District requires the consideration of several contextual factors, as shown in Fig. 18. A new proposal requires improving the efficiency of buildings as well as energy infrastructures that support them; increasing the efficiency of transport through the application of integrated traffic models;

DISTRITO NACIONAL (REPÚBLICA DOMINICANA)					
Stakeholders / Phases	Planning	Design	Implementation	Operation	Assessment
Citizenship	Ombudsman, neighborhood council, cultural groups.				
Industry	Ege Haina, Elecnor, Soventix Caribbean, SRL, TSK, Inkia Energy				Currently there is none.
Administrations	Ministry of Energy and Mines. National Housing Institute. Electric Transmission Company (ETED).		Distrito Nacional Council		
Academia		INTEC, ITLA PUCMM, UNIBE UASD		Currently there is none.	
Financial	Central Bank Dominican Republic. Development Agency of France. iBAN Online SRL.		Popular Bank, Banreservas, BHD León Bank, Scotiabank Bank, Progreso Bank		
Energy Services and Infrastructure Operators		Ege Haina, Edeeste, Edesur Edenorte, AES			
Real State Sector			Construction company Bisonó, construction company Rizek & Asoc., Estrella Group, Remax RD		

Fig. 17. Stakeholder's matrix developed for the National District.

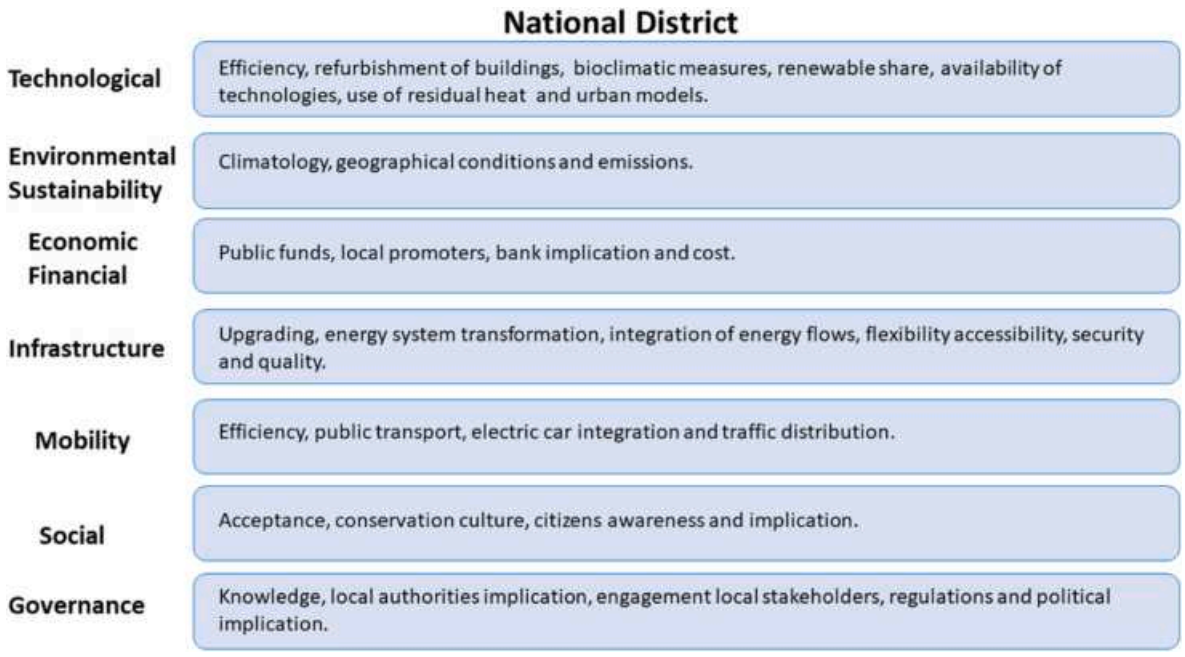

Fig. 18. Contextual matrix developed for the National District.

or the development of urban models that consider available energy flows. These new proposals require improving the current regulations, available economic measures, citizen participation and political involvement.

3.4.5. New proposal

The studied case covers 92 km^2 with a 2014 population density of 10,544.58 Hbs/km^2 (ONE Website). The main objective is to transform the National District's energy system, guarantying the security and quality of the energy supply and allowing sustainable urban services fed by natural resources. This process poses a significant challenge in managing and restoring local natural resources. Based on the outcomes provided, several sustainable measures are proposed:

– Building refurbishment under passive-bioclimatic criteria such as natural ventilation and Nature Base Solutions.

- Increased use of renewable technologies in buildings providing financial incentives for owners.
- Expansion of solar photovoltaic installations by distribution companies: facilitate grid connection and the possibility of selling the excess energy, enhancing grid stability.
- Improvement of the electrical network infrastructure to ensure the accessibility and reliability of electricity, including enhancements to the blackout reduction program.
- Increased use of other energy flows such as residual heat produced from other industrial processes.
- Improved public transport efficiency; optimization of traffic distribution, integration of electric cars and expansion of bike and pedestrian infrastructure within urban areas.
- Increased of citizen and political engagement through public and stakeholders awareness campaigns on sustainable and energy efficiency.

4. Discussion and summary

The path towards a sustainable transformation of the analysed districts requires identifying their driving and blocking factors. These factors are summarized in Fig. 19.

Three of the cases studied involve the rehabilitation of existing areas while one of them focuses mainly on a new urban expansion. In the latter case (Decima Seccion, Argentina), a new urban model adapted to the local climate and morphology is proposed, taking advantage of natural resources and maximising the connections with existing infrastructures. The new improvement proposals require measures aimed at increasing efficiency and sustainability in both buildings and infrastructures; with priorities determined by contextual factors and energy needs. The implementation of these proposals has generated positive impacts by addressing some of the main challenges in these regions. Fig. 20 shows the main impacts and challenges addressed and the remaining challenges to be tackled.

The adaptation of energy networks to the existing building stock is a key point; nevertheless this process is associated with several challenges. Technical challenges include the renovation of available urban infrastructures and buildings, the incorporation of bioclimatic concepts, the use of sustainable materials and processes, the sufficiency and flexibility of energy generation, the adequate development and management of energy networks, the optimal incorporation of control systems, the adequate incorporation of renewable technologies and the management of the renewable penetration levels. Economic challenges require attractive fiscal conditions with greater incentives and lower initial investments. It is necessary to define a reliable business model that considers net zero energy buildings and local renewable generation, applicable both in the design phase and in the operational phase of a district. Digitization is also a key factor, enabling solutions, technologies and procedures, essential for improving and unifying the levels of penetration and maturity. To ensure that the proposed urban measures are truly sustainable, governments must encourage public and private investment in efficient solutions adapted to the contextual situation, prioritizing urban actions according to local needs, generating policies and regulations in a dynamic and flexible way with real problems, facilitating administrative processes and promoting the communication through digital tools. These governance models must be more flexible to promote inclusion, accessibility and stakeholder participation, reducing the risks of vulnerability and social and economic exclusion. Finally, homogenous information and training activities are crucial, requiring a greater understanding of sustainability and PED concepts based on the boundary conditions (Ashton et al., 2017).

To successfully deploy and replicate these districts, standardized management, control, and monitoring systems must evaluate their performance. Therefore, key performance indicators should be defined, focusing on relevant, measurable, reliable, and accessible metrics. Qualitative indicators will be based on key questions while quantitative indicators could include energy efficiency or renewable energy production; reduction of emissions or air quality; ICTs or energy accessibility; vulnerability or social exclusion; financial costs or risks; legal frameworks or administrative procedures. However, while qualitative indicators from open surveys can delve deeper into case studies, future analysis plans to convert them into quantitative indices to enhance the methodology by simplifying monitoring and evaluation. Other further advancements include replicating the studies and creating a database of urban sustainable solutions to develop tailored LAC guidelines.

Comparative analysis of case studies identifies common challenges in the transformation process, aligning with sustainable urban guidelines (UNEP, 2015), but needing specific adjustments for the LAC region. Some differences compared to developed areas include, climate conditions, lack of sustainable codes, monitoring or databases, low carbon-fuel prices or high socioeconomically inequalities. In that sense, Fig. 21 highlights key factors associated with these challenges across

National District (Dominican Republic)

Climate	Main objectives	Blocking factors	Enabling factors	Proposal
Tropical monsoon	Transformation of the existing energy system	Owners willingness, regulation bureaucratic procedures, public funds	Climatic and geomorphological conditions, technologies available and electricity distribution companies	Building refurbishment, renewable technologies, energy flow´s use, electrical quality and accessibility, mobility, participation

La Gloria a Dios Residential (Honduras)

Climate	Main objectives	Blocking factors	Enabling factors	Proposal
Tropical savannah	Sustainable residential rehabilitation	Economic and administrative aspects, lack of security	Residents support, energy consumption management	Solar technologies, technological improvements, control, water treatment, bioclimatic measures, coordinated committee

Los Cerros District (Argentina)

Climate	Main objectives	Blocking factors	Enabling factors	Proposal
Dry arid	Sustainable urban expansion	Governance, economic and social aspects, infrastructures	Climatic and geomorphological conditions. Integration with local connections	Urban and bioclimatic measures, renewable technologies, mobility

Azul District (Argentina)

Climate	Main objectives	Blocking factors	Enabling factors	Proposal
Temperate Pampas	Rehabilitation of an existing area: new pilot cases	Governance, financial conditions, business models, legislative and regulatory framework	Bioclimatic criteria, social-political awareness, digitalization industry	Building refurbishment, renewable technologies, control, water treatment, monitoring, governance

Fig. 19. Identification of objectives, blocking and enabling factors and measures implemented in the studied cases.

Cases	Main Impacts	Main Challenges addressed	Main Challenges to be addressed
Décima Sección Los Cerros (Argentina)	Polycentric grow adapted to an arid climate, prioritising mixed uses Higher efficiency, connectivity, accessibility and green areas. Reducing urban sprawl. Reducing infrastructure and service cost. Reducing environmental vulnerability.	Technological, sustainability and environmental, mobility and governance	Financial, social and infrastructures
Azul district (Argentina)	Use of distributed local natural resources. Infrastructures that have smart devices with bi-directional flow. Increased connectivity, accessibility and flexibility. Adapted business models that improve operational, economic, employment or social conditions. Assistance to citizens with low economic resources. Increased urban resilience and environmental quality. Increased cross-sectoral collaboration.	Technological, sustainability and environmental, infrastructures, mobility and governance	Financial and social
La Gloria a Dios Residential (Honduras)	Higher energy efficiency, renewable generation and environmental quality. Efficient and lower cost lighting. Higher use of communal areas and ecological gardens. Community level management with high resident participation.	Technological, sustainability and environmental, infrastructures and social	Financial, mobility and governance
National District (Dominican Republic)	Improved urban infrastructures that guarantee the security and quality of energy supply. Optimal integration of renewable sources and waste heat in urban infrastructures. Open and local energy trade. Increased participation of citizens. Increased environmental and sustainable commitment of local authorities.	Technological, sustainability and environmental, infrastructures, mobility and governance	Financial and social

Fig. 20. Identification of impacts, challenges and challenges to be addressed in each case study.

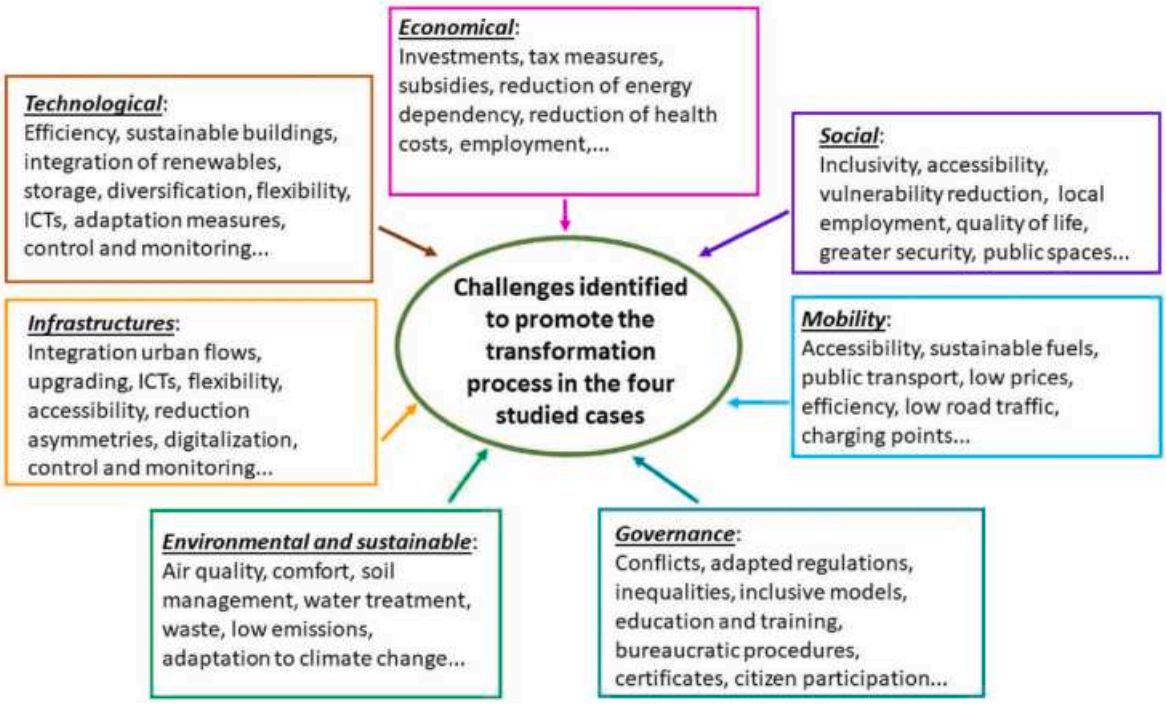

Fig. 21. Main challenges and key factors associated with the four case studies.

seven categories.

On the one hand, it is necessary to propose efficient multi-sectorial solutions that are well structured and coordinated by a committee, led by the local administration, in which the main actors participate. Available local renewable technologies should be implemented and financed by public and private instruments adapted to the political and social situations. Improvements in the existing infrastructures and mobility are required, increasing the accessibility and flexibility of energy services. Proper management of these solutions requires governance models that generate clear regulations and directives. Finally,

there is a need for training and capacity building of all stakeholders, involving them in the operation of these solutions.

5. Conclusions and political recommendations

New urban models need to be characterized by safe and affordable housing, sustainable transport, local renewable generation, green public spaces, increased local jobs or urban global management. Currently, the countries in the LAC region have been poorly studied despite being densely populated areas, very sensitive to the effects of climate change and with high potential for renewable and efficient local energy sources. To reverse this situation and facilitate a sustainable transformation process, a new methodology has been developed within a training activity involving professionals from different sectors of the LAC countries. This methodology, based on the qualitative analysis of case studies, offers new assistance for decision makers in urban planning, allowing key aspects to be considered. Seven categories have been identified as main pillars: technological, environmental and sustainability, economic and social, infrastructure, mobility and governance. Three matrices have been developed: SWOT, stakeholders/phases and contextual factors. The information generated highlighted the main factors that block or drive the transformation process, providing the necessary information to formulate a successful proposal adapted to the local context. Although different climate areas, urban developments and contextual situations have been considered, it is necessary to continue collecting case studies to expand the applicability and replicability of the developed methodology.

The main opportunities are especially linked to the availability of natural resources and awareness about the necessity of a change in the urban patterns. Greater application of efficient and sustainable measures for urban regeneration is necessary, taking into account the real estate stock, available assets and energy and environmental requirements. While numerous technologies are available, significant barriers can hinder and delay the implementation and replication of positive energy districts. Environmental, economic, mobility and social aspects are highly influential in the transformation process. But the most important weaknesses or threats are related to administrative and political issues. New inclusive governance models are needed, capable of setting priorities according to the local context, addressing problems collaboratively, managing development initiatives and innovations and digitising infrastructures and control systems. However, there is no standard or optimal model of governance, and it is necessary to define, in each situation, the role of each stakeholder. The capacity of different states to formulate and execute policies that respond to the common interest seems to be a crucial factor for the development of sustainable districts in the LAC region. Governments need to promote local regulations and policies, streamlining financing instruments and encouraging and enabling the participation and collaboration of all actors in the planning and decision-making processes.

CRediT authorship contribution statement

Silvia Soutullo: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jose Antonio Ferrer:** Supervision, Methodology, Conceptualization, Writing – original draft. **Oscar Seco:** Writing – review & editing, Writing – original draft, Validation, Methodology. **Helena López:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Investigation, Validation. **Maria Nuria Sánchez:** Data curation, Validation, Writing – review & editing. **Mario Jorge Vitale:** Writing – original draft, Formal analysis, Data curation. **Alba Liony Reyes:** Writing – original draft, Formal analysis, Data curation. **Erica Norma Correa:** Writing – original draft, Formal analysis, Data curation. **Lara De Diego:** Supervision, Project administration, Conceptualization, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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