University of Stuttgart
Institute of Human Factors and
Technology Management IAT

Fraunhofer

Universidad de Piura

Municipalidad Provincial de Piura
República del Perú

SUMMARY REPORT

CITY LAB PIURA, PERU

Photo: MGI Piura team

mgi MORGENSTADT GLOBAL SMART CITIES INITIATIVE
GLOBAL APPROACH – LOCAL SOLUTIONS

MorgenStadt
City of the Future

Supported by:

Federal Ministry
for the Environment, Nature Conservation
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FOREWORD

MESSAGE FROM THE MAYOR OF THE PROVINCIAL MUNICIPALITY OF PIURA

Climate change is perhaps the greatest challenge we, as humanity, are facing in this century. Its consequences are undeniable and require us not only to redesign the systems that we have been developing as a society but also to take swift action to prevent, address, and mitigate its ravages.

Piura, the first city founded by the Spanish in the South Pacific, was born as a stately and enviable city. However, in recent years, the city of Piura has undergone a constant process of transformation: The lack of urban planning and weak institutions have favored the disorderly growth of the city, generating the informal occupation of land on the periphery or even in high-risk areas lacking basic services such as electricity or sanitation. The city center, a historic and commercial area, is affected by traffic congestion and it has become necessary to promote alternative solutions such as sustainable urban transport. Finally, in terms of leisure and recreation, the attention given to public spaces and the city's deficient green infrastructure needs to be improved.

In addition, the increase in climate variability and events such as the El Niño phenomenon of 2017 have shown that the city is not adequately prepared to respond to these extreme weather events.

As inhabitants, we have been forced to adopt immediate measures in order to lessen the impact of these events; however, it is necessary and extremely important to link the different local actors from academia, private institutions, and various levels of government to cooperate efficiently and generate solutions for the benefit of the city.

The City Lab Piura project, as part of the Morgenstadt Global Smart Cities Initiative (MGI), has managed to bring together the experience, knowledge, and ideas of experts in urban planning, energy, water management, the environment, and climate change in the city into a single baseline analysis document that will allow Piura to move towards a transition that increases its resilience and sustainability.

This international and local cooperation has been very enriching and the collaboration has generated a portfolio of project ideas that propose real solutions to the various problems identified in the short, medium, and long term. This portfolio not only include projects implemented by the local government, but will also generate participatory, innovative, sustainable, and intelligent processes.

As the mayor of Piura, I am more than pleased to receive a study of this magnitude and high professional quality in the framework of the Bicentenary of the Independence of Peru. This definitely helps to complement our efforts to restore the city to its rightful place.

For a beautiful Piura that we all deserve and long for.

Juan José Díaz Dios
Provincial Municipality of Piura

FOREWORD

MESSAGE FROM THE RECTOR OF THE UNIVERSITY OF PIURA

Globally, cities are undergoing significant transformations and face substantial challenges due to climate change and rapid urbanization. It is in cities where the population is concentrated and where the processes that generate the highest emissions take place. Therefore it is necessary to consider planning strategies for smart and sustainable urban development that address important challenges such as mitigating and adapting to climate change and improving resource efficiency.

In addition, a clear commitment is required to meet global targets according to the Paris Agreement and the Nationally Determined Contributions to reduce greenhouse gas emissions, and to increase resilience and reduce vulnerability to extreme weather events. Consequently, it seems to us that it is paramount to promote integrated and sustainable local/metropolitan governance based on the principles set out in the New Urban Agenda, and that projects should aim to be grounded on the principles of equity and inclusiveness, favoring efficient and sustainable land use, compactness, connectivity, appropriate densities, and multiple uses of space.

Similarly, mixed social and economic uses should be promoted in built-up areas, and mobility problems and needs and the per capita costs of service provision need to be reduced by taking advantage of densities, economies of scale, and agglomeration.

A few years ago, in 2017, the El Niño coastal phenomenon showed us Piura's high vulnerability to climate change. For this, the Morgenstadt Global Smart Cities Initiative: Global Approach – Local Solutions is an excellent step towards smart and sustainable urban development for Piura, as it proposes solutions for climate change adaptation and the efficient use of resources through a collaborative design.

The City Profile aims to be a diagnosis elaborated through indicators and interviews with more than 30 local experts in the water, urban planning, and energy sectors; it has also conceptualized priority areas and project ideas for concrete interventions to achieve sustainability in Piura.

The project portfolio presented has been validated by experts from the University of Stuttgart, the Fraunhofer Institute, and the University of Piura. We hope that it can become a guide that will help to facilitate climate change adaptation and mitigation efforts and contribute to the sustainable development of the city of Piura.

Dr. Antonio Abruño Puyol
University of Piura

1. INTRODUCTION

CITY LAB PIURA AND THE MORGENSTADT SMART CITIES GLOBAL INITIATIVE

The City Lab Piura aims to pave the way for Piura (Peru) to become a sustainable and resilient city. During the last decade, three milestones were reached in which guidelines and goals were defined at a global level to combat climate change: the 2030 Urban Agenda and Sustainable Development Goals in 2015 (CEPAL, 2018); the New Urban Agenda presented at the UN-Habitat III conference in 2016 (UN-HABITAT, 2016); and the Paris Agreement, initiated by the United Nations Framework Convention on Climate Change (UNFCCC) also in 2016 (UN, 1992). These new guidelines emphasize the fundamental role of cities in meeting these goals as they are home to a large part of the world's population and represent a unique opportunity for emissions reduction and climate change mitigation. The City Lab Piura is part of the Morgenstadt Global Smart Cities Initiative (MGI) funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) through the International Climate Initiative (IKI). In this context, the MGI project aims to stimulate transformational change in urban systems through a comprehensive and cross-sectorial analysis of the status quo. For this purpose, potentials for improving sustainability performance in selected sectors are identified and integrated. Furthermore, sustainable and customized solutions are developed to improve processes or services in urban infrastructures. While this approach has been applied in numerous cities[1] worldwide, the MGI initiative is concerned with three cities: Saltillo (Mexico), Kochi (India), and Piura (Peru).

At the core of the MGI project is the Fraunhofer Morgenstadt Initiative, which has been instrumental in establishing a network of experts who run the City Labs in the three selected cities. The Fraunhofer Morgenstadt Initiative is a network that includes institutes, municipalities, and companies. This initiative was launched in 2011 by the Fraunhofer Institute for Industrial Engineering (IAO) in order to conceptualize, develop, and test innovations for the cities of the future.

Recognizing that climate change represents a global challenge that can only be addressed through international cooperation, the main objective of the MGI is to mitigate the impact of climate change by reducing greenhouse gas (GHG) emissions within the boundaries of the pilot cities and thus increase their resilience to latent climate impacts and risks. In this scenario, Peru ratified the Paris Agreement on climate change in 2016, and was the first country in Latin America to do so.

The three MGI cities – Saltillo, Kochi, and Piura – were chosen for specific reasons. It is precisely these medium-sized urban settlements that are experiencing the fastest growth and that will face serious challenges in the future, in terms of both climate change adaptation and mitigation and sustainable urban development. In this sense, the MGI aims to support these cities in developing a coherent approach that underpins climate resilience and sustainable urban development with innovative policies and efforts to develop cross-sectorial proposals and interventions.

METHODOLOGY

In collaboration with the University of Stuttgart and partners from industry, the Fraunhofer Society developed the methodology for the Morgenstadt City Lab: A holistic analytical framework for designing individual sustainability strategies for cities based on

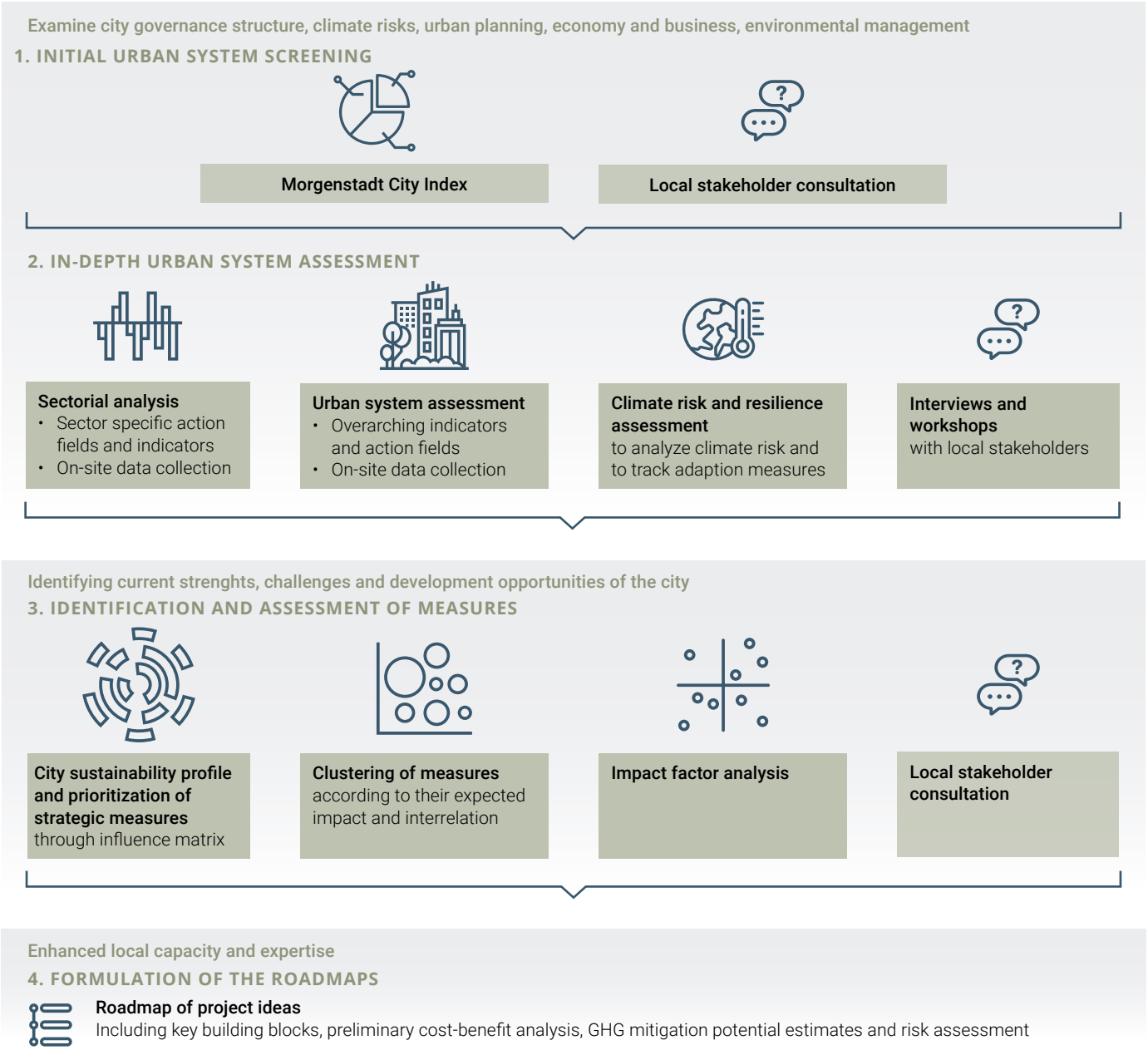
1 For more information, see: https://www.morgenstadt.de/en/projekte/city_labs.html

innovation aspects, promoting the use of clean technologies, and establishing a broad interdisciplinary dialogue with local stakeholders. This methodology consists of an in-depth analysis of the city based on performance indicators that assess quantifiable sustainability performance, key action fields essential for sustainable development, and the unique impact factors that affect each city. In addition to these quantitative elements, expert interviews and workshops are conducted with key stakeholders from the public, private, and academic sectors, as well as from the civil society, ensuring a high degree of local participation and complementing the quantitative analysis. Additionally, their participation in the co-creation of solutions ensures tailored and non-generic design responses, while guaranteeing a high degree of local ownership of the proposed measures.

The Morgenstadt City Lab is a unique instrument that has been developed based on the lessons learned from pioneering cities around the world, including Copenhagen (Denmark), Singapore (Singapore), New York City (USA), and Tokyo (Japan). Likewise, this methodology has been successfully applied to Berlin and Chemnitz (Germany), Prague (Czech Republic), Lisbon (Portugal), Tbilisi (Georgia), Joinville (Brazil), and Coimbatore (India), where each time it has been adapted to the needs and topics defined according to the demands of each city.

The results of each City Lab include an individual sustainability profile, a detailed analysis of specific urban sectors (mobility, urban development, energy, water, etc.), and an action-oriented roadmap, including concrete innovative, scalable measures and projects that aim to boost the sustainable development of the city in the medium and long term. Figure 1 illustrates the action framework used in this City Lab.

MORGENSTADT FRAMEWORK FOR MGI (FIGURE 1)



ABOUT PIURA

The city of Piura is located in northwestern Peru and is the capital of Piura Province and Piura Region. Its metropolitan area includes the districts of Veintiséis de Octubre, Castilla, Piura, and Catacaos.

Piura is located on a flat, slightly undulating terrain, which is crossed by the course of the Piura River that divides the districts of Piura and Castilla to the west and east, respectively. Parts of these districts lie on the former alluvial fan formed by the Piura River before it flowed into the Ramon Lagoon (INDECI, 2021). Due to its geographic location, both the city and the region are highly vulnerable to climate change. The most notable natural disasters in the north, specifically in the department of Piura, are caused by the El Niño phenomenon (FEN). During its last event, the areas surrounding the river, which crosses the city, and Bajo Piura (Catacaos) as a whole were exposed to the effects of flooding that affected 83,967 houses.

According to the latest report of the Regional Government of Piura (2016), the productive activity of the Piura region is very diverse and heterogeneous. With a higher economic share, manufacturing contributed 15.7% to the total economy of the region in 2013, followed by commerce at 14.1%, oil, gas, and mineral extraction at 12.9%, agriculture, livestock, hunting, and forestry at 8.2%, and finally construction

at 7.4%. Other services, such as transportation, gastronomy and telecommunications, contribute lower percentages. However, agriculture is the activity in which most of the economically active population (EAP) is employed and is considered the driving force behind regional employment. The Piura region has experienced significant economic growth in recent years, with an average annual growth rate higher than the national growth rate. In 2014, while the country's economic growth increased at a rate of 2.4%, the Piura region grew at a rate of 4.2%, mainly due to the fact that it contributes a wide range of export products from the agricultural sector. The latter sector, however, is also vulnerable to climate change through major flooding events as well as long periods of drought.

The city is among those with the highest population growth in Peru, with an intercensal growth rate of 2.3% (Zucchetti & Freundt, 2018). Piura has experienced accelerated urban growth in the last 60 years, as has happened at the national level, with an increase in informal housing and unplanned territorial expansion. It is estimated that informal or spontaneous constructions occupy about 70% of Piura's urbanized land (Rivera Saavedra, 2016).

A common denominator in these informal areas is the lack of one or more essential services (water, sewage, electricity, paving, etc.), making it a great challenge for governments (Municipalidad Distrital de Castilla, 2021) to implement public policies and management actions, programs, and projects aimed at addressing this (Jones, 2017). As a consequence of the lack of planning in the city, and in addition to flooding events, there has been an increase in air temperature in the city of Piura due to the growing processes of urbanization and deruralization associated with anthropogenic heat flows and, above all, the scarcity of vegetation. From an environmental perspective, rapid urbanization is perceived as promoting a reduction in biodiversity and causing congestion in vehicular traffic, leading to an increase in atmospheric pollution (CEPAL, 2003) and energy consumption.

OVERVIEW OF PIURA

POPULATION

Piura is the fifth most populated city in Peru, with 894,847 inhabitants (INEI projection estimate, 2020), and has the eighth highest urban growth in Peru (Zucchetti & Freundt, 2018).

GEOGRAPHY

The city has a surface area of approximately 589 km² and is located in the Sechura desert ecoregion in northwestern Peru, close to Ecuador.

SOCIOECONOMIC PROFILE

Urban poverty in Piura, at 24.2% in 2019, has followed a trajectory almost parallel with the region, and is higher than the national average (20.2% in 2019) (IPE, 2020). The trend has been decreasing over the last five years, where Piura stands out among the six departments, having made the most significant achievements in reducing poverty, both total and extreme (BCRP, 2008). In the districts that constitute the metropolitan area of Piura, more than one-third of the population has at least one unmet basic need (NBI, to use the Spanish acronym), such as access to housing, sanitation, etc. (MPP, 2015).

CLIMATE

Piura's climate is hot, desert-like, and oceanic, with a climatic variability of extraordinary rainfall and droughts due to El Niño-Southern Oscillation (ENOS) events.

Map by Free Vector Maps, http://freevectormaps.com

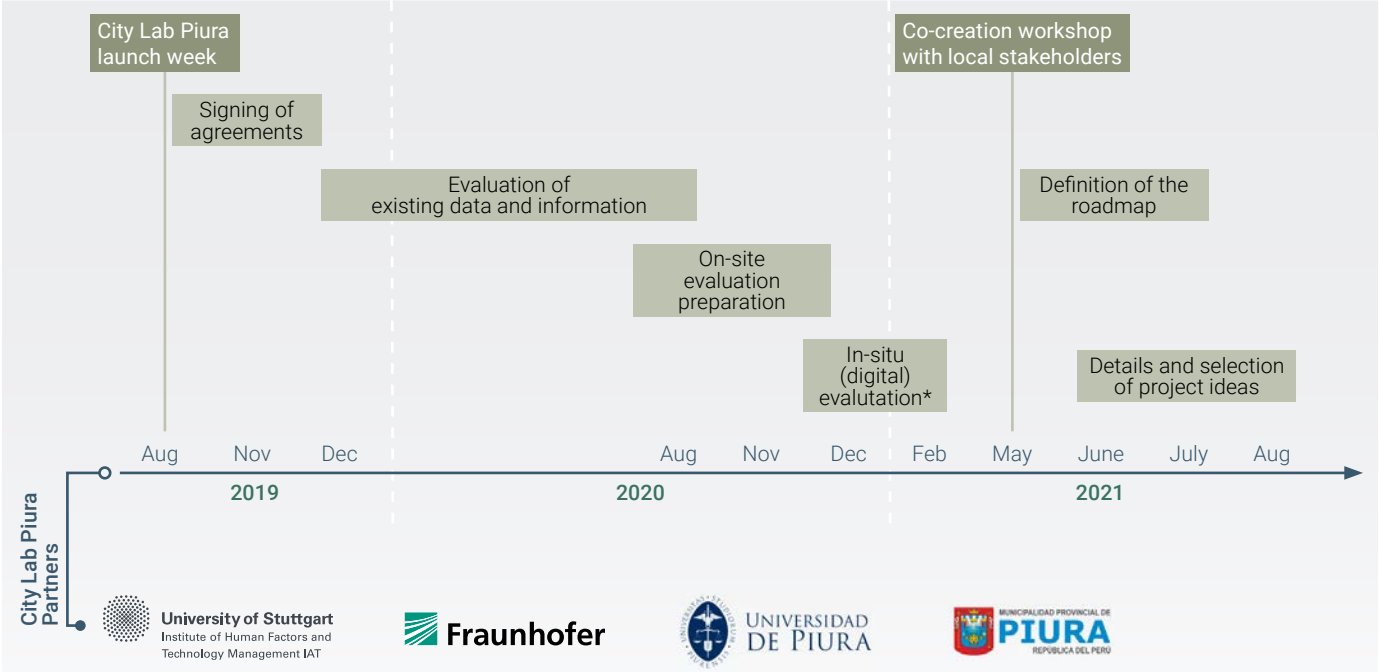
2. CITY LAB PIURA

The City Lab Piura builds on Piura's sustainable urban development priorities and supports the city's efforts towards sustainable and inclusive initiatives. The goal of this City Lab is to promote Piura to become a model of innovative, locally adapted, and climate-smart solutions aimed at increasing its resilience to the impacts of climate change, while, at the same time, preserving and efficiently using its natural resources and stimulating the local economy.

After reviewing the different challenges of sustainable urban development in Piura together with local partners – the Provincial Municipality of Piura (MPP) and the University of Piura (UDEP) – the City Lab focuses on the sectors of urban planning, water and sanitation, and energy, which are analyzed and discussed in Chapter 2.4.

In terms of the City Lab approach, the project phases were carried out by the City Lab team between August 2019 and August 2021, the chronology of which is illustrated in Figure 2 below.

TIMELINE OF THE CHRONOLOGY OF CITY LAB PIURA (FIGURE 2)

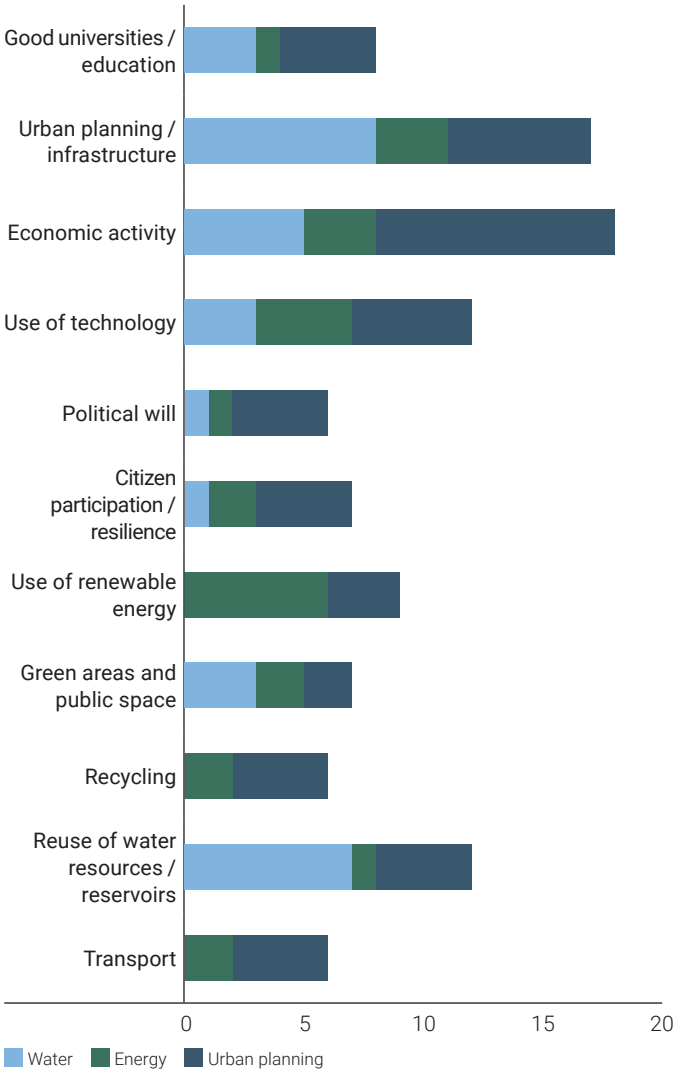


* The Morgenstadt methodology provides for an in-situ assessment, usually lasting two to three weeks. This part of the methodology had to be adapted so that it could be carried out using digital tools as a result of the Covid-19 pandemic, which, due to the confinement measures and travel restrictions in Peru and Germany, required an adaptation of the methodology.

2.1 PIURA SUSTAINABILITY PROFILE

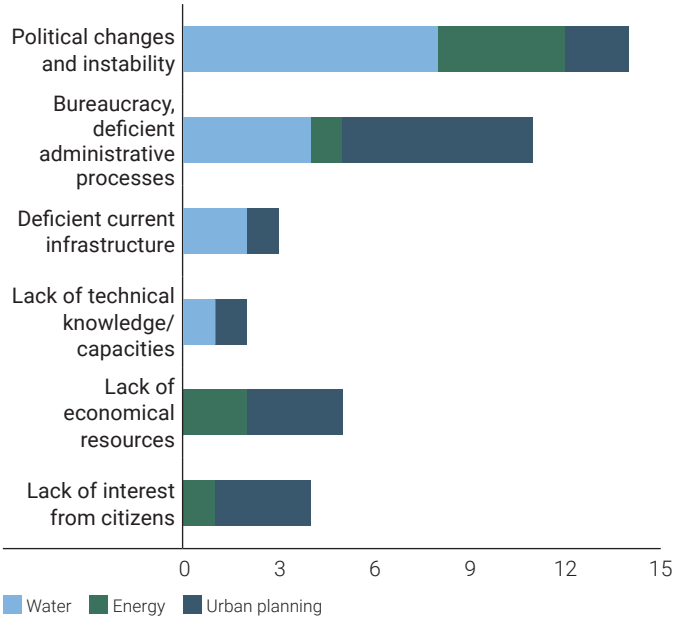
The city presents a wide range of opportunity in terms of sustainability, which was confirmed in the interviews conducted with local experts. As one of the cities with the highest population and economic growth in Peru, and with excellent potential and the political will to strengthen plans and strategies, Piura could improve its urban planning and infrastructure to ensure access to essential services for its entire population and better adapt to climate change by incorporating sustainability as a basis for urban development. Being located in an area vulnerable to floods and natural disasters, Piura has the potential to take advantage of these spaces by identifying at-risk areas and redesigning these as green or recreational areas (currently scarce in the city), integrating an efficient storm drainage system, and including nature-based solutions (NBS). Due to its dry tropical climate, the city has excellent potential to improve its water supply, minimizing water shortages by working on the maintenance, use, and construction of water reservoirs in the region's highlands, which could also serve as a measure to prevent flood damage. In addition, Piura has extraordinary potential to implement renewable energy systems (hydroelectric and photovoltaic) to cover its energy demand. Since much of its infrastructure has been damaged or is in a poor condition, there is an opportunity to develop technological upgrades to modernize public services such as water treatment (potable and wastewater), the design of public transport routes and waste collection. These opportunities for sustainable development were a recurring topic of discussion in the interviews conducted with local experts (from the civil society, academic, public, and private sectors) in the sectors of water, energy, urban planning, and climate change. Figure 3 shows the elements and sectors identified as opportunities and the number of mentions by respondents in each sector.

MAIN OPPORTUNITIES FOR SUSTAINABLE DEVELOPMENT IN PIURA (FIGURE 3)

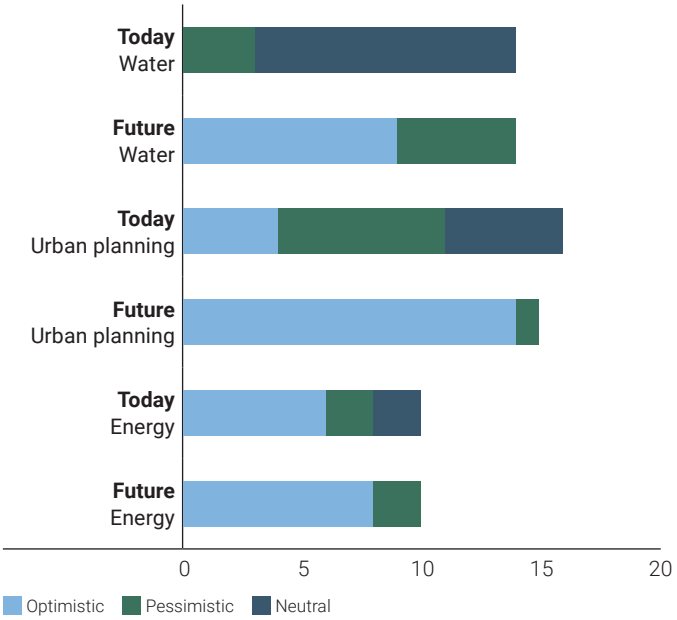


Interviewees also mentioned significant challenges that impede sustainable development. The most important factors inhibiting long-term transformational change are a lack of local and national political continuity to implement incentives in the given time frames; lengthy bureaucratic processes and a lack of

MAIN CHALLENGES FOR THE SUSTAINABLE DEVELOPMENT OF PIURA (FIGURE 4)



ASSESSMENT OF THE CURRENT SITUATION AND FUTURE VISION BY SECTOR (FIGURE 5)

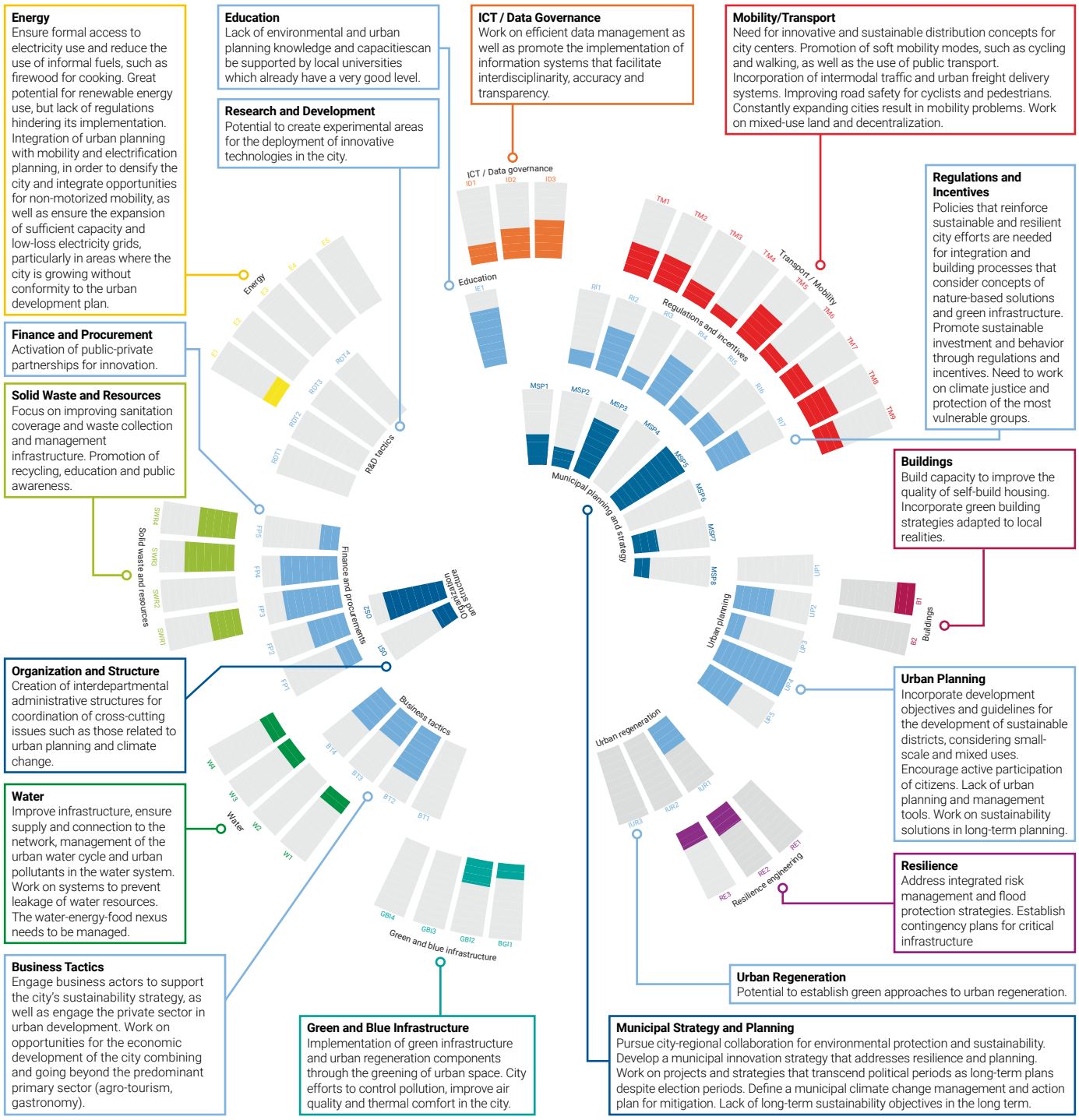


coordination between different levels of government; the creation of laws, together with agencies and processes that regulate and strengthen the implementation of aspects that support sustainable development; a poor basic infrastructure; and a lack of awareness, education, and citizen participation in environmental initiatives. Figure 4 illustrates the agreements and number of mentions by interviewees for the six main challenges identified for Piura's sustainable development.

During the interviews, each of the experts had the opportunity to detail their vision in terms of the current situation and the city's future, highlighting the opportunities and challenges mentioned. There was a strong tendency among the experts regarding their perception of the city: Although about 50% of the interviewees are pessimistic about current urban developments, the vast majority of respondents are positive and optimistic about the city's future. Figure 5 illustrates the interviewees' assessment of the current and future scenarios by sector.

The following figures, explained above, are based on the 34 expert interviews with the key stakeholders for the three sectors during the in-situ digital assessment.

PIURA CITY PROFILE (FIGURE 6)



The following chart summarizes the recommendations for the city's systems analyzed using the Morgenstadt methodology.

2.2. CLIMATE CHANGE IMPACTS AND VULNERABILITIES


Photo: MGI Piura team

Peru is considered a country highly vulnerable to climate change, having seven of the nine aspects defined by the UNFCCC as specific concerns that increase the vulnerability of countries to climate change (UN, 1992; MINAM, 2016). The country's high vulnerability is due to globally important ecosystems and geographical features, such as the Andes and the Amazon, and structural factors that are exacerbated by poverty and inequity (MINAM, 2015). However, climate change is recognized not only by the scientific community but also by the population in their daily lives. An example of this is the three extraordinary FEN events[2] (1982–1983, 1997–1998 and 2016–2017) that occurred in a short period, causing droughts, floods, and heat or cold waves in several regions of the country, Piura being one of those that was most devastated (MINAM, 2021).

In the Piura region, the impacts of climate change are manifested in an atypical increase or decrease in the temperature of the equatorial waters of the central and eastern Pacific Ocean, which results in periods of intense rainfall and drought. These events are known as El Niño-Southern Oscillation (ENOS), which refers to the FEN in the case of an increase in sea temperature, and the La Niña phenomenon, in the case of a decrease in sea temperature. Rainfall caused by the FEN and drought due to the La Niña phenomenon seriously affect the economic activities of the population, in particular agriculture and fishing. Likewise, the rains caused by the FEN and the coastal El Niño affect urban areas, causing floods that damage the infrastructure of cities, their transportation systems, and their energy, water, and sanitation systems.

The damages caused by these events are evidence of the city's vulnerability since it does not have an efficient drainage system and because risk areas, such as underground basins, old ravines, etc., are inhabited by the population. In this sense, it can be said that the area of Piura is considered one of the most vulnerable regions in the country to climate change due to its geographical location, poor drainage, and excessive urban growth. Based on the history and chronology of these events, periods of heavy rains and prolonged droughts are recurring events that will continue to occur and to which both the city and the entire region must know how to adapt.

Within the framework of the project, a two-part climate change risk and resilience assessment was conducted for Piura. The first part of the assessment was organized based on five climate-related risk clusters and included information from scientific analyses and

2 These events are called extraordinary El Niño, super El Niño, or mega El Niño events because they are a more intense version of these phenomena with even more devastating consequences and/or a duration of more than 12 months.

the results of an expert assessment. The latter was done through the Piura Resilience Questionnaire for MGI, which was completed by fifteen experts to incorporate better local knowledge and on-site results for risk clusters and vulnerabilities. The second part focused on adaptation measures. The City Lab Piura interviews were used to complement the findings on local structures and activities.

The five risk and climate vulnerability groups that impact the city of Piura were identified as follows:
- Overflowing of rivers, heavy rains, and stormwater flooding.
- El Niño phenomenon (FEN).
- La Niña, water scarcity, and droughts.
- Temperature increases and urban heat islands.
- Changes in the biological system.

The following are the results for the city of Piura concerning the climate change assessment according to the methodology used in this City Lab.

Overflowing rivers, heavy rains and stormwater flooding

The main reasons for the overflowing of the Piura River and the heavy rains are FEN events (see next section). Flooding from rainfall and river overflow damages infrastructure, including the different bridges connecting the city to the rural areas, the transportation system, and the energy, water, and sanitation systems. These vulnerabilities are accentuated by the lack of an efficient urban drainage system and the inhabitation of risk zones (low-lying areas, underground basins).

Most of the experts interviewed mentioned the average magnitude, probability, and irreversibility of the risks of heavy rainfall and stormwater, as such events are uncommon in the absence of the FEN. However, when a heavy rainfall event occurs, people and infrastructure are the most vulnerable.

According to the Climate Change Risk Index (IRCC) report in Piura (CAF, 2020), vulnerability is lower in the north and center of the city because there is a higher concentration of hospitals, educational centers, and a greater proximity to highways compared to the area in the south (INDECI & OEA, 2009).

On the other hand, the district of Catacaos is considered the most vulnerable due to its low adaptive capacity, as it has the highest levels of illiteracy[3] (Mileti, 1990) and vulnerability in the population and less access to basic services such as electricity, water, and sewage systems (CAF 2020).

El Niño phenomenon (FEN)

The main impact of FEN in Piura and in most coastal cities where this phenomenon occurs is heavy rains and large floods that affect the people, the economy, the environment, and infrastructure. Likewise, most local experts have considered the high magnitude of FEN events with a medium probability of occurrence and a medium to high probability of irreversibility. While these are not annual events, some of their impacts may be irreversible. For example, the event in 2017, known as El Niño costero, caused significant damage to the region's infrastructure, both in the urban and rural areas of Piura.

Regarding individual vulnerability, the urban poor has been identified by experts as the sector facing the most significant challenges in terms of adaptation to climate change. This vulnerability is reflected in the fact that a large part of this sector is located in squatter and human settlements in areas that are not regularized and at risk due to their geography, in addition to the

3 Literacy and numeracy skills, as well as general skills (e.g,. abstract thinking) obtained through formal education imply a better understanding and ability to process information about risk, weather forecasts, or warning messages.

fact that they do not have the necessary training and resources to prepare their homes to face the impacts of natural events and disasters.

Concerning economic vulnerability, the city's economy is strongly linked to and largely dependent on the rural agricultural areas of Piura. Agriculture is the leading employer of the people of Piura and is precisely one of the sectors most affected during ENOS events. However, due to damage to buildings and the impact on sea temperature, other economic activities, such as fishing and local businesses, are also severely affected.

Likewise, most local experts have indicated that the infrastructure of the city has high exposure and susceptibility to the FEN. Self-built infrastructure, the use of canals initially designed for agricultural irrigation purposes and now used as drainage systems for the city, and a lack of adequate urban planning are cited as key factors in the city's high vulnerability. Infrastructure is built and adapted to the city's new uses but lacks tools or guidelines that consider the future impacts of the FEN.

La Niña, water scarcity, and droughts

Throughout history, it has been shown that, after the torrential rains and floods of the FEN, ENOS also brings periods of drought and water scarcity, known as La Niña. This phenomenon is characterized by a reduction in sea temperatures to below the annual average (CAF, 2020), causing the opposite effect of the FEN, i.e., reducing rainfall and thus leading to water shortages and droughts. Like a FEN event, La Niña severely affects economic activities such as fishing and agriculture.

Local experts responding to the questionnaire mentioned that droughts are less frequent than floods in Piura. In general, droughts in the city and region have been much less studied, and therefore the idea of a less severe issue prevails. However, according to the meteorological records of the CORPAC[4] station in the city, between 1932–1992 there were 24 years where rainfall was less than 25 mm/year and 11 years where rainfall was equal to or less than 50 mm/year. This means that the city has faced severe drought for 40% of this time (Palacios-Santa Cruz, 2010). There are no measures or initiatives to mitigate the impact of droughts when they occur since they are not perceived in time and mainly affect agriculture. Moreover, when this situation occurs, the metropolitan area is also severely affected due to demographic expansion and a lack of urban planning to guarantee water supply to all inhabitants.

Temperature increases and urban heat islands

According to the IRCC, Piura is expected to experience a temperature increase by 2040 where the monthly average and maximum daily temperature would increase by 1.0 to 1.5°C during the rainy and dry seasons. Likewise, extreme temperature means are expected to increase by 1.0 to 1.5°C (CAF, 2020).

The assessment made by local experts shows a medium to high risk relating to the magnitude and probability of urban heat islands (UHIs) in Piura. Most of these assessments mentioned the lack of initiatives to reduce the effect of UHIs in the city and that, on the contrary, there is a lack of interest or intention to maintain the remaining long-lived trees in the city. On the other hand, and following the hypotheses presented by the research of Caldas et al. (2019), experts also mentioned that the reason for this effect could be due to deforestation and the felling of trees to increase the size of urban areas, the scarcity of green areas, grey infrastructure, and a lack of permeable surfaces and pavements.

4 Peruvian Corporation of Airports and Commercial Aviation (CORPAC).

Concerning people's vulnerability, the lack of vegetation cover to provide environmental comfort makes walking through the city uncomfortable, particularly during the summer. This situation also affects human health by producing thermal shocks, with children being the most vulnerable (Palacios 2020), and causing an increase in energy consumption through the use of fans and air conditioners, which will increase as the city grows economically. Again, the poorest communities are most affected as the thermal insulation of their homes is generally inadequate and they do not have the resources to purchase or maintain these devices (Daley, 2018).

Changes in the biological system

The Peruvian carob tree (Prosopis Pallida) is the flagship species in northern Peru. According to the National Forestry and Wildlife Service (SERFOR) and the Ministry of Environment of Peru (MINAM), 40% of the population of these trees is affected by persistent pests due to rising temperatures, together with new viruses and fungi that affect the species (El Regional Piura, 2020).

Another significant risk is the presence of epidemics and zoonotic diseases. Dengue, malaria, and Zika are becoming more frequent and lethal (UDEP, 2016). After the occurrence of the 2017 coastal FEN, the dengue and yellow fever mosquito vector, Aedes aegypti, underwent explosive growth and dengue cases increased. The city of Piura became one of the most affected cities, with 64% of the total national cases of dengue in Peru (Díaz-Vélez et al., 2020).

The experts also mentioned the moderate vulnerability of the population, mainly due to the health impacts caused by the increase in vectors and infectious diseases. Economically, sectors such as forestry, agriculture, and fisheries could be affected due to changes in pest populations, variations in temperature, and precipitation patterns affecting biodiversity and yields.

Recommendations for risk and vulnerability

Considering the information obtained for the five risk groups, the following is recommended:

- Urgent action to reduce the impacts of FEN events in Piura, as research predicts a higher frequency and intensity of FEN by 2040. The main impacts are a consequence of intense and extreme rainfall events that cause the Piura River to overflow and therefore flood the surrounding areas.
- Strengthening urban planning and managing the relocation of houses located in highly vulnerable sites is recomended, as well as work in the underground basins that are activated after heavy rains. In addition, the construction of infrastructure with appropriate materials and the reduction of self-construction should be encouraged, and, where this is not possible, safe self-construction skills should be provided in order to reduce exposure and increase resilience.
- Due to excess stormwater during the rainy season or during an ENOS event, implementing NBS is recommended to improve water retention. This could include detention ponds, infiltration gardens (bioswales), water harvesting, rain gardens, or other water management techniques.
- It is also important to focus on the Piura riverbank, as mitigation measures need to be implemented to prevent overflowing. These could include revegetation, reforestation, and the installation of gabions and live fascines lined with cuttings. In addition, flooding also affects human health, as tap water becomes mixed with sewage due to the lack of efficient urban drainage systems. This is considered one of the most urgent actions to be addressed in the city.
- Deforestation of the dry mountain forests in the upper areas of the Piura River basin in the northeast

of the region affects the ecosystem that impacts Piura due to its flat location and gradual slope. This activity threatens regulation, provisioning, support, and cultural ecosystem services. Based on this, an ecosystem or watershed approach is recommended for Piura.
- The lack of permeable surfaces and an increase in grey infrastructure, as well as a reduction of green areas and vegetation in urban development, produces UHIs in the city of Piura, which affects human health and economic activities due to a lack of thermal comfort that results in decreased economic activity. This situation demonstrates the need for an increase in green areas and permeabilization of urban land.
- More research is needed on changes in the biological system and outbreaks of new infectious diseases and pests affecting people, biodiversity, plants, animals, and related economic activities, e.g., agriculture. Further research is also needed on UHIs, on both the impacts and solutions for Piura as well as the identification of UHI hotspots in the city. This is essential for initiating specific actions related to this issue.

Climate change adaptation measures

According to the climate change assessment of the City Lab Piura, the following adaptation recommendations are made:
- It is necessary to increase climate awareness among stakeholders, mainly among civil society and public officials. It is recommended that good environmental practices and the involvement and participation of citizens in local policy processes and actions be promoted and encouraged. The climate capacities of local actors and stakeholders need to be strengthened to make better and more informed decisions relating to climate change in the future.
- A greater connection and synchronization are recommended for work between the different levels of government (regional and local) to coordinate their progress on climate and environmental issues.
- The city needs to participate in vulnerability and risk estimation studies on climate change, such as the CAF study launched in November 2021. This knowledge should be applied and reflected in regional and local development plans. Working towards the implementation and dissemination of this plan is recommended.
- It is considered a priority to coordinate and reorient regional and local management instruments towards sustainable development. At the same time, it is recommended that climate change adaptation and mitigation concepts be included as a key priority in city planning.
- Universities and professional associations should be encouraged to develop research topics related to environmental quality and risk management and thus build capacity and knowledge on these issues within the community.
- International cooperation should be sought for the development of research and the implementation of projects related to climate change.

Budget and finance for climate action

Climate finance throughout Peru, including in the city of Piura, has been gaining momentum in recent years. Among the key actors in this regard is MINAM, which has been instrumental in structuring the recent Green Finance Roadmap, a tool that establishes the lines of action and means of implementation needed to mobilize a significant amount of economic resources to fight climate change. From 2014 to 2020, a total of 5,743,496,391 Peruvian soles (around 1,4 billion USD) from public sources, with 38% coming from the national government, 41% from local governments, and 21.26% from regional governments, was invested in mitigation and adaptation measures.

However, Piura does not have a budget and funding clearly earmarked for climate risk and resilience

actions. The Multiannual Institutional Operational Plan (POIM) 2020–2023 includes a budget for vulnerability reduction and emergency response but not for pilot projects or integrating climate change into local policies or actions (MPP, 2020). Since there is no local climate change plan or strategy, climate change actions in Piura are supervised by the regional government of Piura and must be aligned with the Regional Climate Change Strategy. This results in a dependency on decisions and resources available at the regional level, weakening the possibilities for action at the local level. Therefore, the Regional Management of Natural Resources and Environment, together with the Management of Planning and Budget, has designed financing mechanisms to promote the incorporation and financial viability of implementing the Regional Climate Change Strategy (ERCC) in the plans and budgets of public entities.

The municipality of Piura has enormous potential to implement projects directed at a sustainable climate transition. There are already examples of projects that aim to implement sustainable investments in the city, mainly with a pay-as-you-go financing structure. However, it is considered important for the municipal budget to earmark part of its revenues and capital for the construction or maintenance of adequate infrastructure to increase resilience in the city. This appears to be a mechanism for private participation that will help local and regional governments mobilize more capital and promote sustainable technologies.

City Lab Piura – contributions to climate risk adaption

As part of the City Lab Piura, a roadmap has been developed that includes concrete project ideas to support the city in its future climate-friendly development (see Chapter 4). While most of these projects focus on specific challenges in the priority sectors of urban planning, water, and energy, the projects also have great potential to help improve climate resilience.

To enhance the synergies between climate change mitigation and adaptation and the potential for combating climate risks, resilience aspects are taken into account from the outset in the individual planning of each project idea.

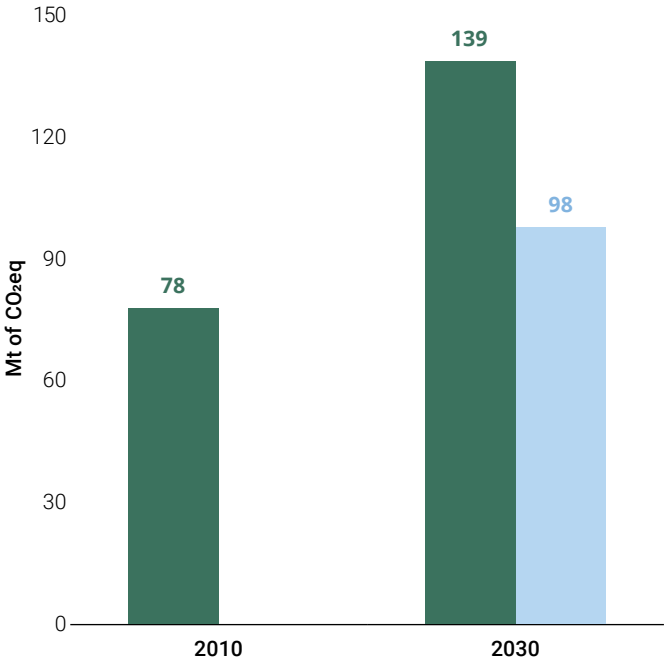
One way to ensure that the effects achieved can be measured, monitored, and improved is to select key performance indicators (KPIs) and their integration into a holistic project monitoring plan.

To see the full report of the risk and vulnerability assessment of climate change impacts in Piura, visit: https://mgi-iki.com/en/library/

2.3. CO_2 EMISSIONS

The Intergovernmental Panel on Climate Change (IPCC) has estimated that, within their boundaries, cities directly account for 44% of global GHG emissions and, if the final consumption of electricity generated outside the city is considered, this percentage could be as high as 75% (IPCC, 2015). Due to the high concentration of population and economic activity in cities, local authorities have unique opportunities for sustainable development, improving quality of life, and reducing GHG emissions. The high degree of vulnerability due to climate change adds importance to the local dimension of governance, where security, effective participation, and energy democracy represent a strategic interface (Ordonez & Zurita, 2019).

HISTORICAL EMISSIONS AND BASELINE ACCORDING TO PERU'S NDC (FIGURE 7).



Source: Own elaboration based on Peru's NDC (UNFCCC, 2015)

Because of the urgency in initiating an energy transition towards low-carbon economic growth, the Paris Agreement was signed by 195 nations, including Peru, agreed to keep the temperature increase below 2°C above pre-industrial levels and continue efforts towards a 1.5°C increase (UNFCCC, n.d.). Through Nationally Determined Contributions (NDCs), the agreement requires that each nation prepare, communicate, and maintain national GHG mitigation measures. In the case of Peru, a commitment to a 30% reduction in emissions compared to the baseline emission was determined (Figure 7), of which 20% of the reduction is unconditional and 10% conditional on international financial assistance (UNFCCC, 2015).

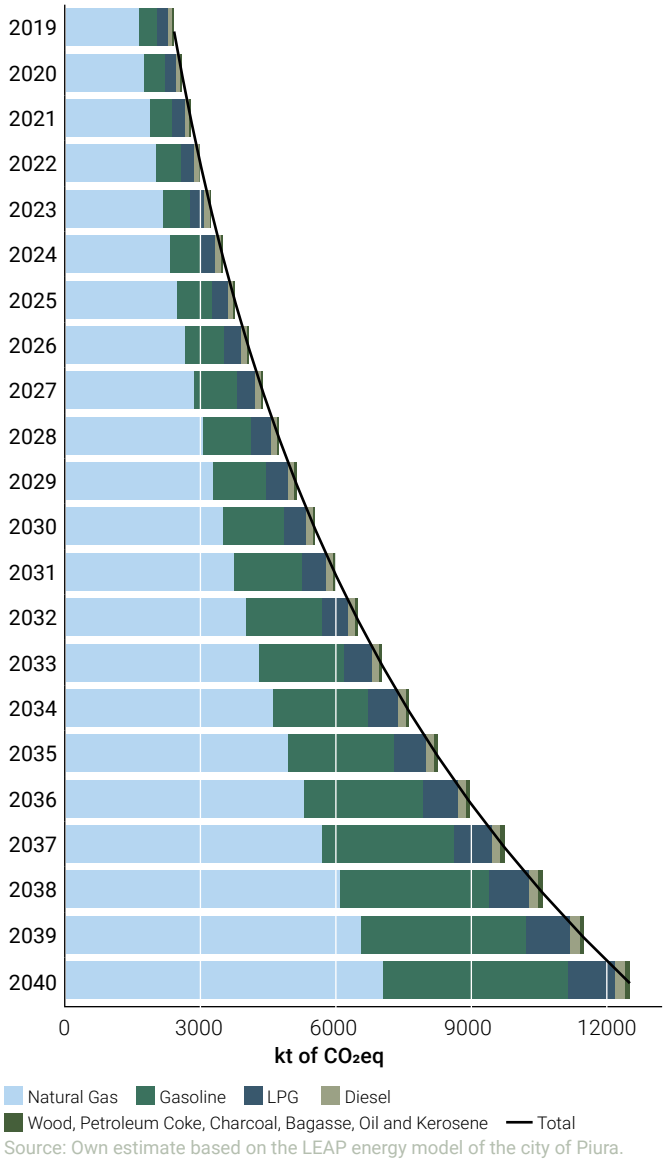
However, because Peru's NDC does not specify sectorial or sub-national targets, it is not possible to derive a direct relationship for either the region or the city of Piura. In the context of this project, an energy model[5] was developed to obtain estimates of CO_2 emissions for the city of Piura. In the absence of measures to promote renewable energies and energy efficiency, these are projected in a baseline scenario to grow from approximately 2,000 $ktCO_2eq$ to more than 12,000 $ktCO_2eq$ in 2040, increasing more than six times over two decades. This implies a growth from approximately 2.8 tonnes of CO_2 per capita in 2018 to 15 tonnes of CO_2 per capita in 2040. Natural gas used

5 The model was developed using the LEAP software (originally an acronym for Long-range Energy Alternatives Planning System), an integrated modelling software tool developed by the Stockholm Environment Institute (SEI) that helps to analyze energy policy and can be used to track energy consumption, production, and resource extraction in all sectors of an economy. The tool can be used to account for sources of GHG emissions, both in the energy sector and in other sectors. In addition to tracking GHGs, LEAP can also be used to analyze local and regional air pollutant emissions, making it well suited for studies on the climate co-benefits of local air pollution abatement. More information on the software is available at: https://leap.sei.org/

for electricity generation, as well as in the industrial sector, and the use of gasoline for private vehicles constitute the largest fraction of fossil fuels contributing to GHG emissions (Figure 8).

There is great potential in the energy sector in terms of climate change mitigation at both the local and national levels. In this respect, the International Energy Agency highlights two key strategies for climate change mitigation in the energy sector: the use of renewable energies as well as a substantial improvement in energy efficiency. These could both potentially be implemented in Piura by both the public sector and key private sector actors. The sectorial results of this report and the project catalogue presented in the roadmap highlight opportunities for exploiting the potential in Piura in the realization of these strategies.

ESTIMATED GREENHOUSE GAS EMISSIONS FROM ENERGY SOURCES IN PIURA IN 2020 AND PROJECTION IN THE ABSENCE OF MEASURES TO 2040 (FIGURE 8).



Source: Own estimate based on the LEAP energy model of the city of Piura.

2.4. SECTORIAL ANALYSIS

2.4.1. Urban planning

Aerial view of flood-vulnerable areas in the city of Piura (Figure 9).

Piura is a city that is growing both economically and in terms of population, resulting in the expansion of the territory and giving rise to informal housing in response to this situation. Although for some years urban residential growth in Piura has been directed along the main streets, informal growth in peri-urban areas has increased and been consolidated, mainly in those areas physically vulnerable to flooding caused by heavy rains during the FEN. Informal growth has also meant that more than a third of the population of Piura has at least one unmet basic need, which is a problem that needs to be solved at the city level. At the same time, this tendency gives rise to a great challenge that must be dealt with, mainly by the local government, but with the need for collaboration with different local actors that are likely to be able to play a significant role in finding solutions to these problems (Municipalidad Distrital de Castilla, 2021).

In addition, because Piura was one of the regions most affected by the FEN in 2017, it is included in the Comprehensive Plan for Reconstruction with Change (PIRCC). This plan aims to rehabilitate and reconstruct the physical infrastructure damaged and destroyed by the coastal El Niño at the national level, thus contributing to restoring the welfare lost by the most vulnerable social groups, especially those who lost their homes and livelihoods and who had to move from their usual place of residence as a result of the damage generated by the rains, floods and mass movements (earth or water movements).

One of the most urgent challenges for Piura is implementing an effective land-use plan that delimits habitable areas and determines land use in order to avoid residential areas in zones at high risk of flooding and extreme weather events. After the last FEN in 2017, more than 10,000 families were documented as living in areas exposed to floods and extreme rains, representing a vulnerable sector of the population with limited resources who are forced to live in these areas, as shown in Figure 9. In metropolitan Piura, 5.1% of the population is currently settled in areas at high risk from fluvial flooding and 13.4% from pluvial flooding (MVCS, 2020).

In addition, land use near the Piura River, both in the city and regionally, is destined for the private and public sectors, which shows a lack of planning concerning the main water resource that is a threat in times of unusual rainfall. This poor city-water relationship creates severe economic and environmental disturbances in the face of climate adaptation processes (Caldas et al., 2019) and means that the city center is considered highly vulnerable to the effects of climate change.

Key developments and status quo in the sector

Piura and the rest of the country have identified some limitations and challenges in the application of urban development management instruments. Urban land registries are decentralized, and few municipalities have a complete and up-to-date land use record. As

of 2018, only 30% of the district municipalities had an urban development plan (Gestion, 2018). As a result, local authorities do not offer urban planning tools that support city growth oriented to their institutions' visions, goals, and objectives. The existing tools and data are not digitized or maintained in a data infrastructure at the municipal level, which makes it difficult to access and implement plans.

Various urban analyses since 1993 have shown the need to implement actions and policies for the areas of Catacaos, Castilla, Veintiseis de Octubre and Piura. In 2013, Piura Province approved the Urban Development Plan (PDU) for the districts of Piura, Veintiséis de Octubre, Castilla and Catacaos until 2032. At the end of 2018, the Ministry of Housing, Construction, and Sanitation (MVCS) launched a unique public procurement process for reconstruction with changes, which includes the contracting of consultancy services for the elaboration of Metropolitan Development Plans (PDM) for different cities in Peru under the scope of reconstruction with changes. In the case of Piura, this plan aims to continue and complete the work of the PDU study.

In the same vein, the PDU (in the process of being approved at the date of publication of this document) will establish guidelines and strategies for the city's metropolitan area[6] (Lama More, 2015) to achieve sustainable and integrated development. This technical-normative and management instrument focuses on orienting and promoting urban and agro-urban growth and the development of activities, and serves as a fundamental support tool for the economic growth of the city and the improvement of the quality of life of the population. In the case of Piura, the PDM seeks to improve the rational use of urban land, coordinate the road network, and determine building regulations in the four districts to support the vision of an orderly and compact city. This document also seeks to incorporate risk management into land-use planning to improve resilience and reduce the impacts of ENOS and climate change hazards and introduce sustainability criteria for future city projects, plans, and investments.

VISION, CHALLENGES AND SOLUTIONS IN THE URBAN PLANNING SECTOR

FUTURE VISION

A MODEL CITY OF ECOLOGICAL, ECONOMIC, AND SOCIAL SUSTAINABILITY WITH ACCESSIBLE PUBLIC SPACES, NATIVE VEGETATION, AND ADEQUATELY DESIGNED URBAN INFRASTRUCTURE FOR ITS INHABITANTS.

CHALLENGES

- Continuous urban sprawl and a population without access to essential services.
- Informal construction on and occupation of urban land.
- Poor access and high maintenance costs for green areas and recreation.
- Areas in the city are uninhabitable due to being in risk zones (underground basins, flooding).
- Lack of awareness and disinterested citizenry regarding the impact of climate change and sustainability.

SOLUTIONS

- Updated plans and supporting tools (using GIS) to enable land-use planning, respecting risk zones and taking into account urban sprawl.
- Transformation of vacant land into green or recreational areas using flood-prone areas.
- Green areas, including the use of native vegetation.
- Tactical urbanism (including pocket parks, urban gardens) that support the development of citizen initiatives, interaction and appropiation of public spaces.
- Awareness-raising programs and campaigns on issues that support the concepts of sustainability and urban circularity (e.g., recycling strategies, new economic activities to diversify the economy (gastronomy), etc.).

6 Piura is considered a regional metropolis in the North macroregion, made up of four districts: Piura, Veintiséis de Octubre, Castilla and Catacaos.

Key actors, government structures, and policies

In terms of city planning, responsibity for the nation's public works is the role of both local governments and the national government through the MVCS. On the one hand, municipal governments refer to the district government and are responsible for drawing up development plans and municipal ordinances. In the case of Piura, the Municipality is responsible for the provincial and district governments. However, the metropolitan area contemplates four districts. On the other hand, the central government, through the Vice-Ministry of Housing and Urbanism (VMVU), is responsible for elaborating the policies and regulatory frameworks to be implemented throughout the country. This, therefore, also has a great impact on the expansion and functioning of the city of Piura. The National Directorates of Housing and Urban Planning, respectively, are considered relevant to the urban planning sector, and are attached to these bodies (VMVU and MVCS) by the central government.

The distribution of responsibilities between the different levels of government (national, regional, local) has meant difficulties in the implementation of public policies and programs, especially in the transport and housing sectors (García, 2009), where the national level is ahead of the municipalities, which do not have the necessary information or tools to carry them out (Fernandez Maldonado, 2016).

Regarding the legal framework, the most significant laws for the territorial development of the city are the National Building Regulations (RNE) for public administration programs and development, the Regulations for Land Development and Sustainable Urban Development, Law No. 27972 on Organic Law of Municipalities, and Law No. 30556 on Reconstruction with Changes. On 25 July 2021 the Law No. 31313 on Sustainable Urban Development (LDUS), was published in the official gazette El

DIAGNOSTIC INDICATORS OF THE URBAN PLANNING SECTOR (TABLE 1).

INDICATOR	VALUE FOR PIURA	CHALLENGES AND SOLUTIONS
Population in households with two or more NBI (MPP, 2015)	**23.2%** AT THE DISTRICT LEVEL **~ 10%** WITHIN THE URBAN AREA	In the case of Piura, in the districts that make up the metropolitan area, the most significant percentage of the population resides in inadequate physical housing and has at least one NBI, highlighting the vulnerability of its resident population.
Average annual population growth rate (INEI, 2019)	**1.8%**	This value reflects urban growth over the last ten years, which is increasing exponentially and predicted to continue with this trend. This growth is in line with the annual growth of the Piura economy (6.4%) and higher than the national average (4%) in 2018.
Green areas per capita (INEI, 2014)	**1.75 m²**	Compared to the WHO recommendation, which has established a minimum green area of between 10 m² to 15 m² per inhabitant distributed proportionally in terms of population density, the city has insufficient green areas. In Peru, only Lima, Arequipa and Tacna exceed 3 m² per inhabitant.

Peruano (2021), which consolidates the regulations on land development, urban planning, urban land use, and management.

Among the significant instruments for the urban development of the city of Piura, in addition to the PDM as mentioned above and the PIRCC, the Plan de Desarrollo Provincial Concertado 2016–2021 (Integrated Provincial Development Plan), and the Plan de Movilidad Sostenible (Sustainable Mobility Plan) are worth mentioning.

The potential for contributing to climate change mitigation and adaptation

According to the information obtained during the interview phase of the City Lab, it was observed that most of the actors agree and consider work on the urban planning of the city fundamental in order to manage its territory and resources efficiently and sustainably. This planning is also fundamental for integrating policies between the different sectors (transport, water, energy, waste) in direct alignment with each other and with the economy, the environment, and the city's inhabitants. In this sense, the interviewees agree that one of the most significant challenges faced in Piura is the lack of continuity in public policies resulting from changes in administration in the municipality or regional and national governments. It was also noted that public works are not always congruent with the development plans drawn up by the authorities and that there is a lack of resources for enforcement at all levels of government relating to the city. In this sense, it is worth mentioning that a high degree of centralization of public decisions hinders their successful implementation and leads to a lack of citizen participation. Some actors have also identified a disconnect between academia, government, and citizens, and limited knowledge of participation methods.

In addition, the construction and mobility sectors, which are directly related to urban growth, have been a constant challenge for city governments, both in terms of planning and regulation, as well as oversight. In this sense, working with service providers, as well as training the population in self-construction, is fundamental to improving the quality of housing and its connectivity. Another example is that urban expansion has also caused the industrial zone to be located within various residential areas, resulting in environmental nuisances due to the emission of gases and noise. Conflict situations in the future are foreseen if these (the industrial and residential zones) become increasingly consolidated when urban growth becomes more intense.

Based on these results, a vision for the city was defined to steer long-term development that reflects the most critical challenges for the city's future. The results of the City Lab will contribute to transforming Piura into a city that focuses on its opportunities to prepare and adapt in the face of its urban challenges, including those that go hand in hand with climate change. It will be a model city of ecological, economic, and social sustainability, with accessible public spaces, native or climate-adapted vegetation, and adequate urban infrastructure designed for its inhabitants.

Working on rescuing and improving public spaces, as well as increasing green infrastructure through urban design, are seen as key areas of action. These strategies could be reinforced by regularisations of urban trees and creating green areas in the city. This is intended to accommodate new native vegetation with low water requirements, improve soil quality, reduce heat islands, and promote shaded public spaces. To this end, interventions are suggested that include the mapping of available spaces in order to use vacant land and the identification of patrimonial and historical buildings (Piura's center). The aim is to link

the use of these spaces according to the vocation of the area in order to maximize their impact and use by citizens and to take into account the necessary infrastructure for the recommended activities (energy, lighting, water, maintenance, security, etc.) and thus increase social cohesion in the neighborhoods.

Another issue highlighted during the interviews was the importance of the recovery of public spaces. Regarding this point, the Ombudsman's Office was, in 2017, already alerted to 22 trash hotspots in the city where solid waste is dumped daily. These places have become infection-causing areas that constitute a health risk for the population (Defensoría del Pueblo, 2017). It is worth mentioning that of the 200 tons of rubbish produced by the city each day, about 25% is not collected. One of the issues affecting optimal waste collection is the poor state or inoperability of the municipalities' machinery (SPDA, 2017). In order to avoid this waste problem, it is essential to raise awareness among the citizens so that they do not litter and actively participate in recycling and environmental care initiatives. In this regard, Piura was one of the six provincial municipalities outside Lima that, in 2010, began waste segregation and selective collection programs (MINAM, 2011). At the same time, the city has implemented programmes, such as the Piura Recicla or the Programa Municipal de Educación Cultura y Ciudadanía Ambiental EDUCCA, to raise awareness on recycling, waste revaluation and environmental education. Along with these activities, it is recommended that the city define recycling points and waste collection optimization plans.

The issue of unused and neglected heritage was also repeatedly raised during the City Lab Piura interviews, in which most of the interviewees highlighted the potential of the gastronomic and cultural sector in this area. A general recommendation is based on creating spaces for gastronomic tourism, supported by the excellent quality of the agricultural products produced in the region. The decentralization of the market complex was also mentioned as well as the creation of a gastronomic experience from seed to table to highlight the positive regional characteristics of the city. Efforts are advised to concretize and strengthen these projects due to the city's remarkable economic and social potential.

Regarding digital urban planning instruments, it is expected that the scarcity of data in Piura will be improved, as the MVCS is expected to upload the spatial information generated from the new metropolitan, urban and provincial development plans to the GeoVivienda portal. However, this will not guarantee that the city will have a Geographic Information System (GIS) at the local level. Also, the municipality does not have sufficient technical knowledge or financial resources for the use, maintenance, updating, or analysis of spatial information. The implementation of an up-to-date spatial information system to facilitate urban planning and land use planning is recommended.

2.4.2 Water and Sanitation

Floods caused by the ENOS phenomenon in 2017 (Figure 10).

Water is one of the essential resources for generating and perpetuating the existence of any living organism. In addition, water resources are essential for the main

economic activity of the region, i.e., agriculture, where water consumption is the highest of all productive sectors worldwide (Proyecto Especial Chira Piura, 2019). In the case of the Piura region, the city has become established along the Piura River, which originates in the watershed of the Huancabamba river basin, crosses the metropolitan area, and continues flowing downstream until it reaches the Pacific Ocean through the Virrilá Estuary, for a total length of 280 km approximately. However, due to low rainfall, its flow is minimal most of the year. In addition, due to its unfavorable quality resulting from various factors, it has historically not been possible to use this resource efficiently. Thus, the people of Piura have sought alternative solutions to this problem, such as constructing an hydraulic connection between the Chira and Piura Basins to capture water for its purification and subsequent distribution to the different areas of the region (Proyecto Especial Chira Piura, 2019).

In addition to this situation, the region is geographically located within a desert biome, which leads to unfavorable conditions in terms of water resource security.[7] In contrast, its location makes it vulnerable to meteorological phenomena such as the ENOS, detailed in Chapter 2.2, which in 2017 affected 464,974 inhabitants and their homes in the Department of Piura (INDECI, 2017), as shown in Figure 10. It is worth mentioning that it is estimated that this natural phenomenon has been occurring for forty thousand years (MINAM, 2014).

Key developments and status quo in the sector

As previously mentioned, one of the water resource management objectives is potabilization and distribution to both urban and rural areas. In this context, according to the pre-investment feasibility study of the project, Expansion and Improvement of the System of Production, Storage and Primary Distribution of Drinking Water in the districts of Piura and Castilla, Province and Department of Piura, published by the MVCS in 2015, only 80% of the samples complied with the national drinking water quality standards that are established and monitored by the General Directorate of Environmental Health (DIGESA) (MVCS, 2015), which emphasizes the need to improve water resource management and has implications for the water treatment process, as this depends on the quality of the water to be treated.

VISION, CHALLENGES AND SOLUTIONS IN THE WATER SECTOR

FUTURE VISION

A RESILIENT CITY WITH AN INTEGRATED APPROACH TO WATER MANAGEMENT UNDER EFFICIENT ARTICULATION BETWEEN THE DIFFERENT GOVERNMENTAL, PRIVATE, ACADEMIC, AND SOCIAL LEVELS.

CHALLENGES

- Inefficient water resource management.
- Low quality of water for human consumption.
- Resilience to atmospheric phenomena and climate change.
- Flood control and lack of efficient urban storm drainage systems.
- Poor articulation between the different sector levels of government, private, academic, and social.

SOLUTIONS

- Master plan for water resource management with a multi-sectorial approach.
- Improvement of drinking water treatment systems.
- Restoration of green spaces and natural wetlands.
- Optimization of early warning and rapid response systems for natural disasters.
- Construction of storm drainage systems and flood defenses.
- Promote concerted working groups with decision-making capacity.

7 While it was not possible to find a concrete figure for water availability, the experts interviewed emphasized the scarcity of the city's water.

In terms of water management, the Empresa Prestadora de Servicios de Saneamiento (EPS) Grau reported a figure of -43% in 2018 as their operating margin, which is understood as the difference between the cost of purification and supply of water and the revenues from user payment. Although, on the one hand, this is worrying, it can also be considered an opportunity, having great potential for improvement in terms of the high percentage of water supplied but not billed: 50.3% of the non-revenue water, i.e., a specific volume of water is lost through spills, leaks, theft, or illegal use before it reaches the end user.

The age of the drainage system was also analyzed, as this affects the development of cracks in the pipes, which leads to a greater risk of physical water loss through leaks or even infiltration of foreign water that could be contaminated. According to this system, it has been established in the PDM that the pipes are approximately 40 to 50 years old. This age is classified as acceptable but not optimal. The distribution network has a length of 920 km, of which 257 km are made of steel, and the difference is made of PVC[8]. Similarly, this document also indicates that there are some houses without sewerage services, representing a deficit of 37% of all households in the metropolitan area of Piura (MVCS, 2020).

Access to sanitation is a significant indicator for defining part of the profile of a city. This definition includes the public sewerage network inside the dwelling, the public sewerage network outside the dwelling but inside the building, the septic tank, the septic tank or biodigester, the latrine, and the cesspit or cesspool (UNICEF & WHO, 2015). According to the sociodemographic profile of the National Institute of Statistics and Informatics of Peru, sanitation coverage in Piura is 94.1% (INEI, 2017). This figure corresponds to the "optimal" classification, as defined above. It is worth mentioning that, of this percentage of inhabitants with access to a toilet, only around 66.4% are connected to the public sewerage network inside the dwelling.

Key actors, government structures, and policies

Regarding water management at the national level, the related government agencies are MINAM, MVCS, and MINAG (Gobierno del Peru, 2014). Attached to these agencies of relevance to the water sector are 1) the National Water Authority (ANA), which represents the highest technical, regulatory body of the National Water Resources Management System, 2) the SENAMHI, which is responsible for generating and providing meteorological, hydrological and climatic information and knowledge, and 3) the Technical Agency for the Administration of Sanitation Services (OTASS), which serves as manager of the provision of sanitation services (Gobierno del Peru, 2020).

The legal framework for water resource management is mainly based on the Regulation of the Water Resources Law No. 29338, issued by ANA (2010). This document stipulates that the resource belongs to the nation and that there is no private ownership of it. In the case of the Piura region, the relevant committee is the Water Resources Council of the Chira-Piura Basin. Concerning drinking water supply and sanitation in the Republic of Peru, drinking water treatment, sewerage, and wastewater treatment services are provided according to the provisions of the General Law on Sanitation Services (Gobierno del Perú, 2020) through the EPSs that the OTASS manages. In Piura, the corresponding entity is the EPS Grau, a municipal company under private law, which has not yet adapted to the guidelines established by the OTASS.

8 PVC refers to polyvinyl chloride (PVC or vinyl), an inexpensive and versatile material used in a variety of applications, such as building and construction, healthcare instruments, electronics, and the automotive and other sectors. Products typically include pipes and coatings, among other things.

DIAGNOSTIC INDICATORS OF THE WATER SECTOR (TABLE 2).

INDICATOR	VALUE FOR PIURA	CHALLENGES AND SOLUTIONS
Water consumption (EPS Grau, 2018)	**130 L/D/CAPITA** WATER CONSUMPTION OF PEOPLE WHOSE HOUSEHOLDS ARE CONNECTED TO THE CITY'S WATER NETWORK	One of the best-categorized indicators is "Water consumption," which is within the range recommended by the Inter-American Development Bank (120-200 L/d/capita).
Storm drainage coverage (Consorcio de Inundaciones, 2019)	**40%** OF THE CITY THAT HAS A STORMWATER DRAINAGE SYSTEM	The current stormwater drainage system only covers 40% of the rainwater runoff from the districts of metropolitan Piura, which generates underground basins in large parts of the city, making the population vulnerable. An articulated storm drainage master plan for the city is required, taking green and grey infrastructure into account.
Water samples meet national drinking water quality standards. (MVCS, 2015)	**80%** OF THE TOTAL NUMBER OF WATER SAMPLES COMPLYING WITH THE ADMISSIBLE VALUES	Although the IDB considers critical values, the MVCS plans to comply with 100% by 2036. This implies significant investments by the government in the long term.
Operating margin of drinking water supply (EPS Grau, 2018)	**– 43%** DIFFERENCE BETWEEN THE COST OF WATER SUPPLY AND THE TARIFFS COLLECTED	The negative value implies that the operating costs are higher than the required investment in operation and maintenance on the drinking water supply system. This necessitates the implementation of system optimization projects.
Non-revenue water (EPS Grau, 2018)	**50.31%** THE RATIO OF NON-REVENUE WATER TO TOTAL WATER SUPPLY	Non-revenue water refers to supplied water that is "lost" in the network before reaching the customer due to the age of the system, theft, or illegal use, which results in poor service from the water utility due to a lack of revenue.

The potential for contributing to climate change mitigation and adaptation

Piura is inherently vulnerable to climate change, primarily due to its geolocation (see Chapter 2.2). Experts predict that the FEN will not cause more intense rainfall to generate greater flows in the Piura River than those seen on previous occasions. However, an increase in the frequency of such rains causing flows close to 4,000 m³/s in the river is predicted. This last value refers to an extreme flow rate with a high risk of overflowing, considering that the maximum flow of the FEN 1983 (a mega El Niño event) was 3,200 m³/s (Callañaupa Tocto, 2021).

After a sectorial analysis, including interviews with relevant stakeholders in the water sector, some are

convinced that in order to reduce the risk of flooding, or at least significantly reduce the damage caused during the FEN, it is imperative to update and improve the management of the Piura River, including artificial reservoirs to the north of the city, in order to control the flow of the river. However, such projects are outside the temporal and jurisdictional scope of the City Lab Piura project.

On the other hand, Piura has great potential to benefit from nature-based solutions (NBS), not only in the water sector, as these blue and green infrastructure techniques contribute to climate change adaptation and mitigation while promoting sustainable urban development. For example, in the context of Piura, the implementation of a floodable park along the Piura riverbank or a bamboo park near the oxidation ponds were identified as interesting projects for the city. This greater coverage of green areas in the urban environment could increase the social benefits, e.g., by improving air quality and mitigating urban heat islands.

Moving on to more technical solutions, a project with great potential for Piura is based on the implementation of decentralized wastewater treatment systems that have the great advantage of facilitating the planned reuse of treated water on site for the irrigation of green areas. Furthermore, the digitalization of the water supply system to identify and repair leaks could be considered in order to reduce water losses, thus also contributing to water availability.

The reduction of GHG emissions can also be achieved in the water sector, for example, by incorporating a system for capturing methane produced in oxidation ponds. In the same context, another proposal with an even more holistic approach is to develop the water-energy-food nexus, in which Piura would have the opportunity to follow an innovative and sustainable economic model represented by industrial ecology. This model would seek to reduce the "waste" produced in wastewater treatment plants (WWTP) by using it in agriculture and/or green areas, thus achieving a more efficient and environmentally responsible system. In addition, in the agricultural sector, the optimization of irrigation systems to reduce water consumption could also be considered.

2.4.3 Energy

Key developments and status quo in the sector

Modern society consumes large amounts of energy, making the energy industry a fundamental pillar of development. Energy is essential for economic and social development, providing direct access to electricity, mobility, air conditioning, refrigeration, engines, industrial processes, etc. Furthermore, globally and nationally, the energy sector is responsible for more than two-thirds of GHG emissions, mainly CO_2, representing a significant challenge for climate change mitigation.

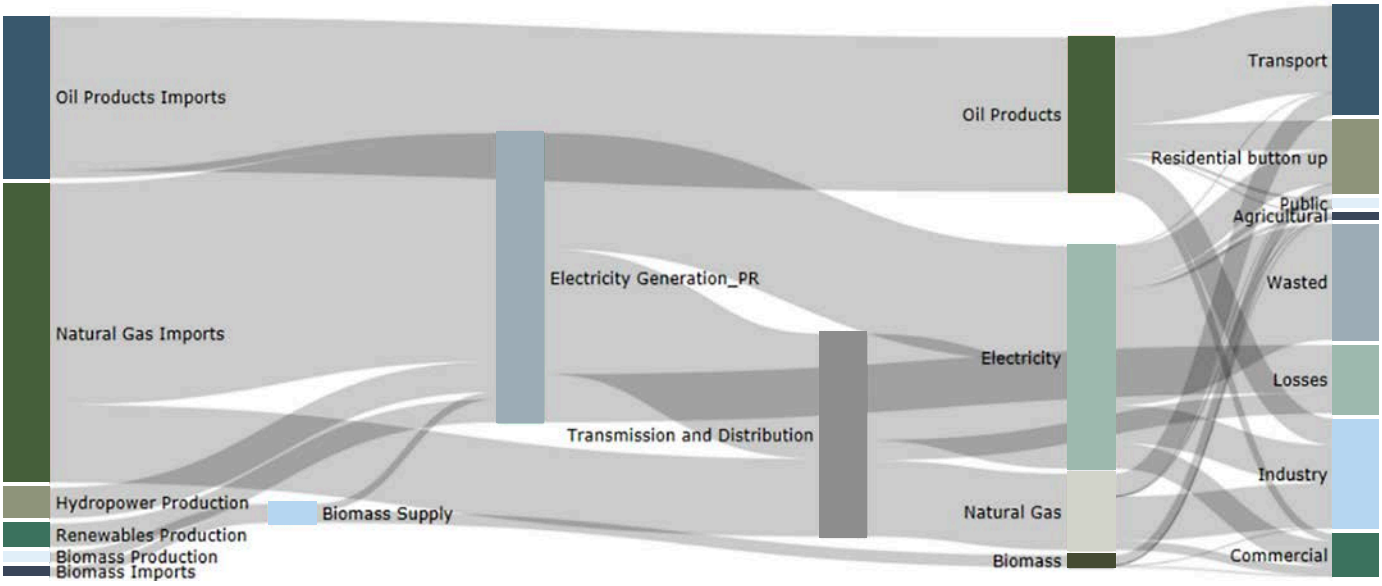
National energy production in Peru had an average annual growth rate of 6% in 2009–2018. In terms of final energy consumption at the national level, consumption is mainly concentrated in the transport sector (46%), followed by industrial and mining consumption (27%), and then residential, commercial, and public consumption (25%).

At the urban level, there is a clear challenge in collecting energy data, as statistical information systems focus almost exclusively on the national level, mainly the energy balance systems and the economic system of national accounts. In order to have a better overview of the energy consumption in the city of Piura in the context of this project, an energy simulation model has been developed that aims to estimate the energy consumption and GHG emissions of the city and to provide a basis for planning long-term energy and environmental alternatives.

Based on this model, the total energy consumption in Piura was estimated to be around 700 GWh in 2000, growing to approximately 1,900 GWh in 2018. For the same year, 31% was distributed in the transport sector, 31% in the industry sector, 21% in the residential sector, 12% in the commercial sector, 2% in the public sector, and 2% in the agriculture sector (Figure 12). The transport and trade sectors are also estimated to have increased substantially over the last decade. Using the growth rates of historical, socio-economic variables (number of households, inhabitants, urbanization, etc.), as well as the growth of value added by the economic sub-sectors (commerce, industry, agriculture, etc.), it is estimated that the transport and commerce sectors will have a more pronounced growth than the other sectors and will come to play a central role in Piura's energy consumption in the following decades.

In the energy sector, Piura has a 5% share of national energy consumption. The region is characterized by a low socio-economic level and a lack of access to quality energy services. Around 5% of the population have no access to electricity services in urban areas, with a higher percentage having no access in rural areas, where there is a greater use of informal energy sources, such as firewood (Table 3). There is a lack of access to electricity in rural areas, as rural electrification is not cost-effective. This is largely because high urban densities are required for grid investments to be economically beneficial. While electricity grids have been built in rural areas, the power levels used have been low, challenging reliable supply outside urban areas. In addition, the rapid and informal growth of the city creates a challenge for the planning and development of basic service infrastructure, including electricity supply. Proof of this is that firewood is still widely used for cooking and heating water in Piura, with approximately 45,000 of the 150,000 households (30%) in Piura using firewood for cooking, and 10,000 households (6%) using firewood for heating water. This represents a severe health risk for the poor population. The World Health Organization estimates that, globally,

SANKEY DIAGRAM OF PIURA (FIGURE 11).



Own elaboration based on the energy model.

DIAGNOSTIC INDICATORS OF THE ENERGY SECTOR IN PIURA (TABLE 3).

INDICATOR	VALUE FOR PIURA	CHALLENGES AND SOLUTIONS
Total energy demand per capita (Own calculation)	**3,400** KWH/A/CAP IN 2018	Although these values are low compared to other countries internationally, and reflect the moderate socio-economic level in Piura, economic growth will cause these values to increase substantially in the future. In particular, based on the developed energy model, we estimate an increase of total energy demand per capita to close to 20,000 kWh by 2040, while CO_2 emissions are projected to be close to 15 tCO_2 per capita. The implementation of energy efficiency measures as well as the supply of energy utilizing renewable technologies are two key strategies to reduce energy consumption and CO_2 emissions. This could bring many benefits beyond energy savings and CO_2 emissions. Together, they could reduce electricity costs for households, industries, commerce, and the public sector; they could generate local jobs; they could reduce local pollution and improve air quality; and they could create activities that drive economic growth in the region, among many other things.
CO_2 emissions per capita (MINAM, n.d.)	**2.8** T CO2EQ/A/CAP IN 2018	
Electricity demand in the residential sector per capita (Own calculation)	**340** IN 2018	
Households using firewood (MINAM, n.d.)	**30%** FOR COOKING **6%** FOR HEATING WATER	The high use of firewood represents a severe risk for the low socio-economic population. Household air pollution is a cause of diseases such as strokes, ischemic heart disease, chronic obstructive pulmonary disease (COPD), and lung cancer. Also, about half of all pneumonia deaths among children under five years of age are due to particles inhaled from household air pollution (WHO, 2021).

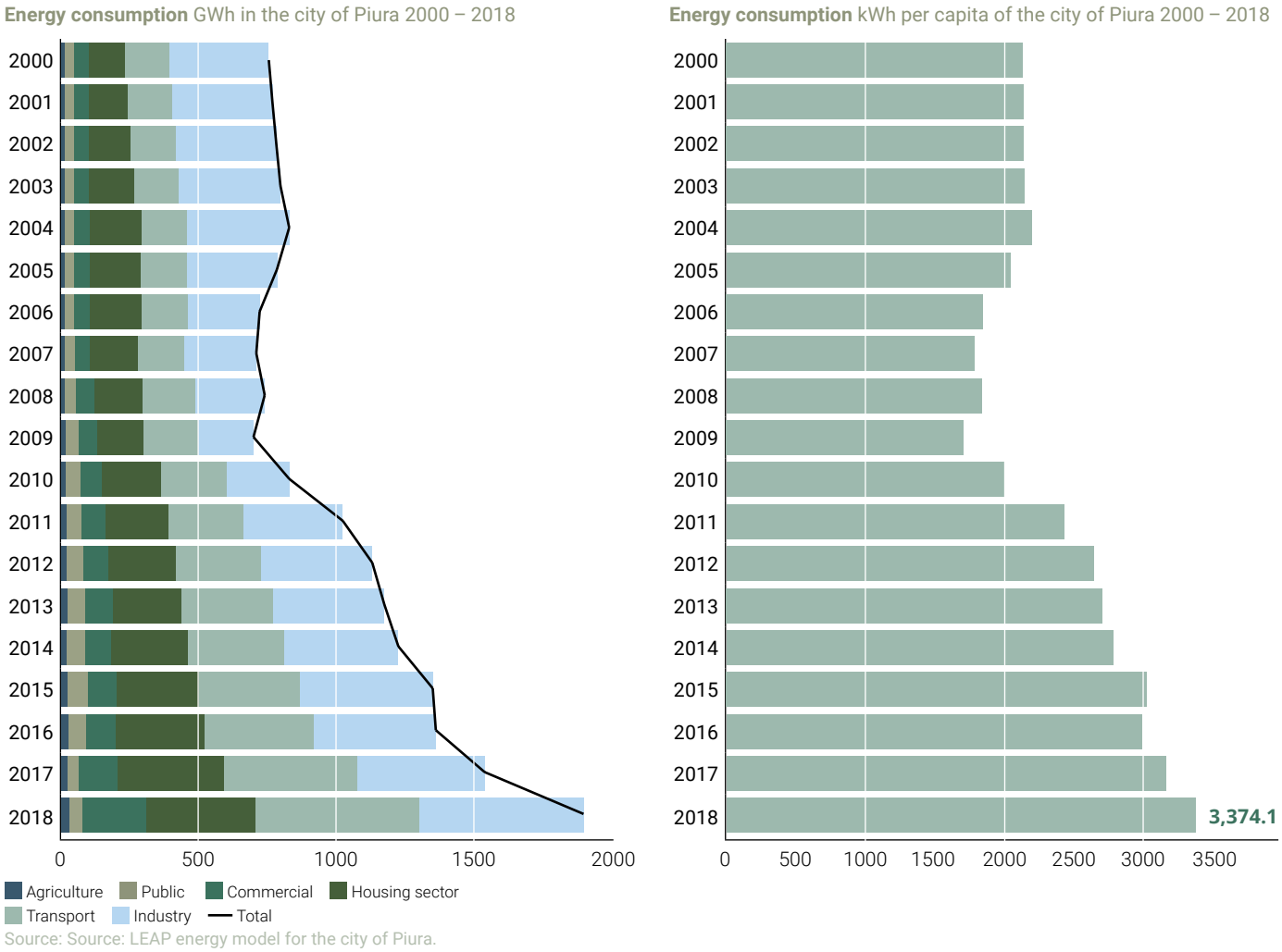
about 4 million people die prematurely each year from diseases attributable to household air pollution, in particular cardiovascular and pulmonary diseases, due to traditional cooking practices using firewood and kerosene (WHO, 2021).

As a result, programs have been implemented in the city to increase energy efficiency by modernizing the public lighting system by replacing its metallic ceramic lights with LED or energy-saving technologies. Likewise, as part of the photovoltaic program promoted by the Ministry of Energy and Mines (MINEM), solar panels have been installed to bring electricity to rural populations in the region, as well as through the installation of a wind farm in Talara. Despite these efforts, these actions only represent an insignificant fraction (<1%) of the region's energy supply.

Key actors, government structures, and policies

The jurisdiction of the energy sector is primarily governed at the national level. In terms of key actors, MINEM and the Supervisory Body for Investment in Energy and Mining (OSINERGMIN, the Spanish acronym) are the two most critical entities responsible for implementing the regulatory framework and enforcing regulations in Peru's energy and mining sector. However, they are not the only institutions. The electricity sector also comprises several public bodies having different roles, including the Private Investment Promotion Agency, which is responsible for promoting investment, and the Committee for Economic Operation of the Interconnected Systems – COES SINA, which acts as the coordinator of the electricity system.

ENERGY AND ELECTRICITY IN THE CITY OF PIURA (FIGURE 12).



Source: Source: LEAP energy model for the city of Piura.

The electricity service in Piura (districts of Piura, Veintiséis de Octubre and Castilla) is provided by the electricity commercialization and distribution concessionaire Electronoroeste S.A. (ENOSA), subject to the private activity regime and managed under the scope of the Fondo Nacional de Financiamiento de la Actividad Empresarial del Estado (FONAFE) (ENOSA, n.d.). In view of the lack of regulations relating to energy efficiency, ENOSA could play a fundamental role at the local level, developing pilot projects and thus contributing to the definition of the legal framework for renewable energy and distribution. In addition, there are some projects relating to the use of renewable energies in the academic sector (UDEP), so this sector is considered a key actor for promoting the generation of new energy sources.

The potential for contributing to climate change mitigation and adaptation

In terms of potential for climate change mitigation in

the energy sector, there are great opportunities to be explored, both locally and nationally.

There is the possibility of harnessing solar, wind, and hydropower in the electricity sector, with more than 60 GW of capacity still available. This is relevant considering Piura's rapid economic growth, which goes hand in hand with a growing demand for electricity and fuels. For example, the demand for refrigeration in the agricultural industry is playing an increasing role due to the rapid growth in this sector. The growth of economic activity also leads to the high use of individual mobility, as well as household appliances, air conditioners, etc., which substantially increase the energy demand per inhabitant. In recent years, the costs of renewable energy equipment, particularly photovoltaic equipment, have fallen substantially. Solar panel installations are already cost-effective if it is feasible to finance the equipment at a low cost[9].

Energy efficiency can also significantly reduce CO_2 emissions in all consumer sectors, as well as in energy supply. Reducing electricity transmission and distribution losses by 12% through improved networks and clandestine electricity use could significantly reduce CO_2 emissions in the public sector.

VISION, CHALLENGES AND SOLUTIONS IN THE ENEGRY SECTOR

FUTURE VISION

THE VISION FOR PIURA IS A CITY WITH A RELIABLE, SUSTAINABLE, AND EQUITABLE ENERGY SUPPLY. TO ACHIEVE THIS, THE CHALLENGES LISTED BELOW NEED TO BE ADDRESSED.

CHALLENGES

- Improving electricity supply and modern energy access, particularly in rural areas, is necessary for meeting basic needs and reducing poverty and inequality in the region.
- A lack of regulations for the implementation and use of renewable energy impedes the use of these technologies.
- A lack of awareness and sensitization regarding energy consumption and savings.

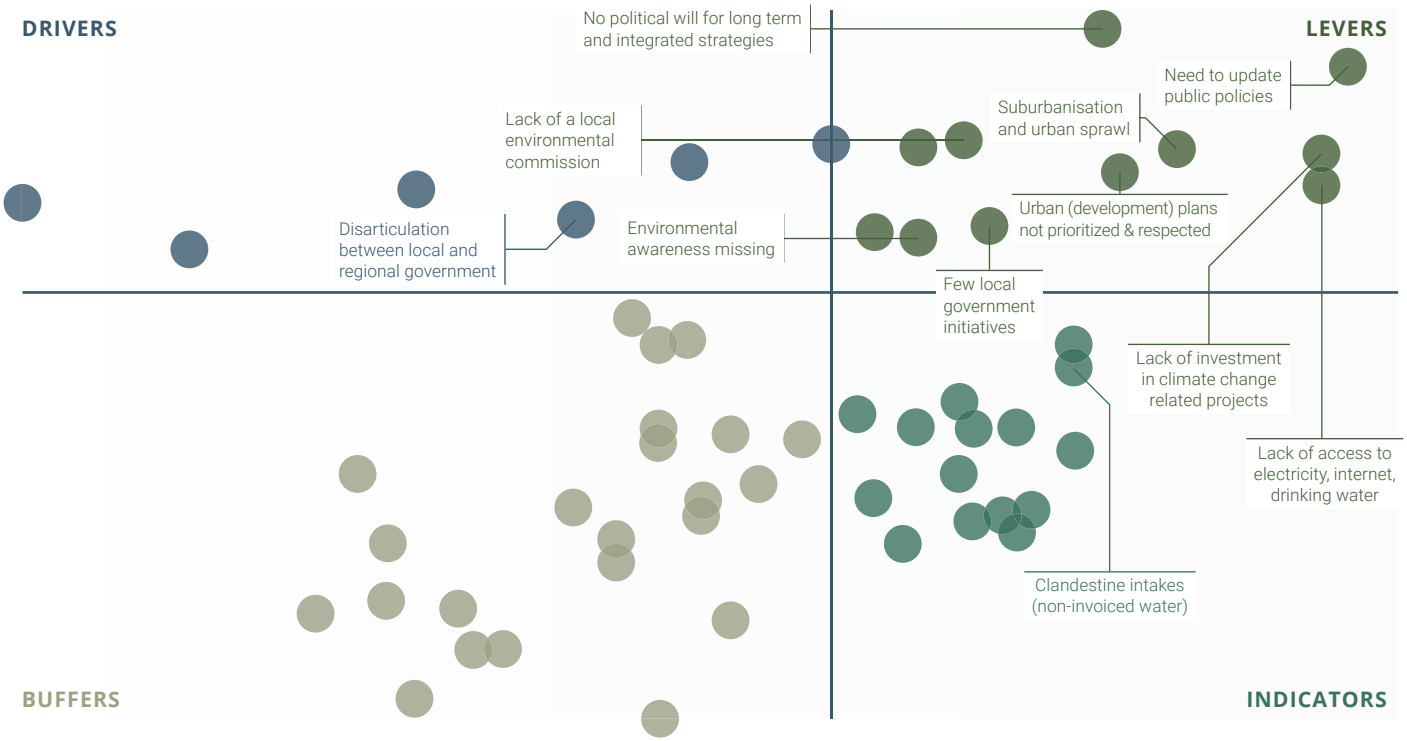
SOLUTIONS

- Take advantage of the solar potential of the region and promote the use of energy-saving technologies.
- Design and effect regulations for the implementation and use of renewable energy.
- Integrate urban planning with mobility planning to densify the city and incorporate non-motorized mobility opportunities into the urban environment.
- Incorporate green vegetation into the urban environment to avoid heat island effects that could lead to higher electricity consumption for air conditioning in the future.
- Increase awareness of sustainable development, as the implementation and use of environmental protection measures will require the support of civil society.

9 Due to the high capital intensity of renewable equipment, the profitability of projects is very sensitive to interest rates relating to financing the equipment, highlighting the role of access to financing schemes for the realization of such projects.

3. SENSITIVITY ANALYSIS

IMPACT FACTORS OF THE CITY OF PIURA (FIGURE 13).



Based on more than 30 interviews with local stakeholders, the on-site assessment of Piura revealed a total of 87 impact factors that have a substantial influence on urban development and systematically seek to define the unique and characteristic elements of the city.

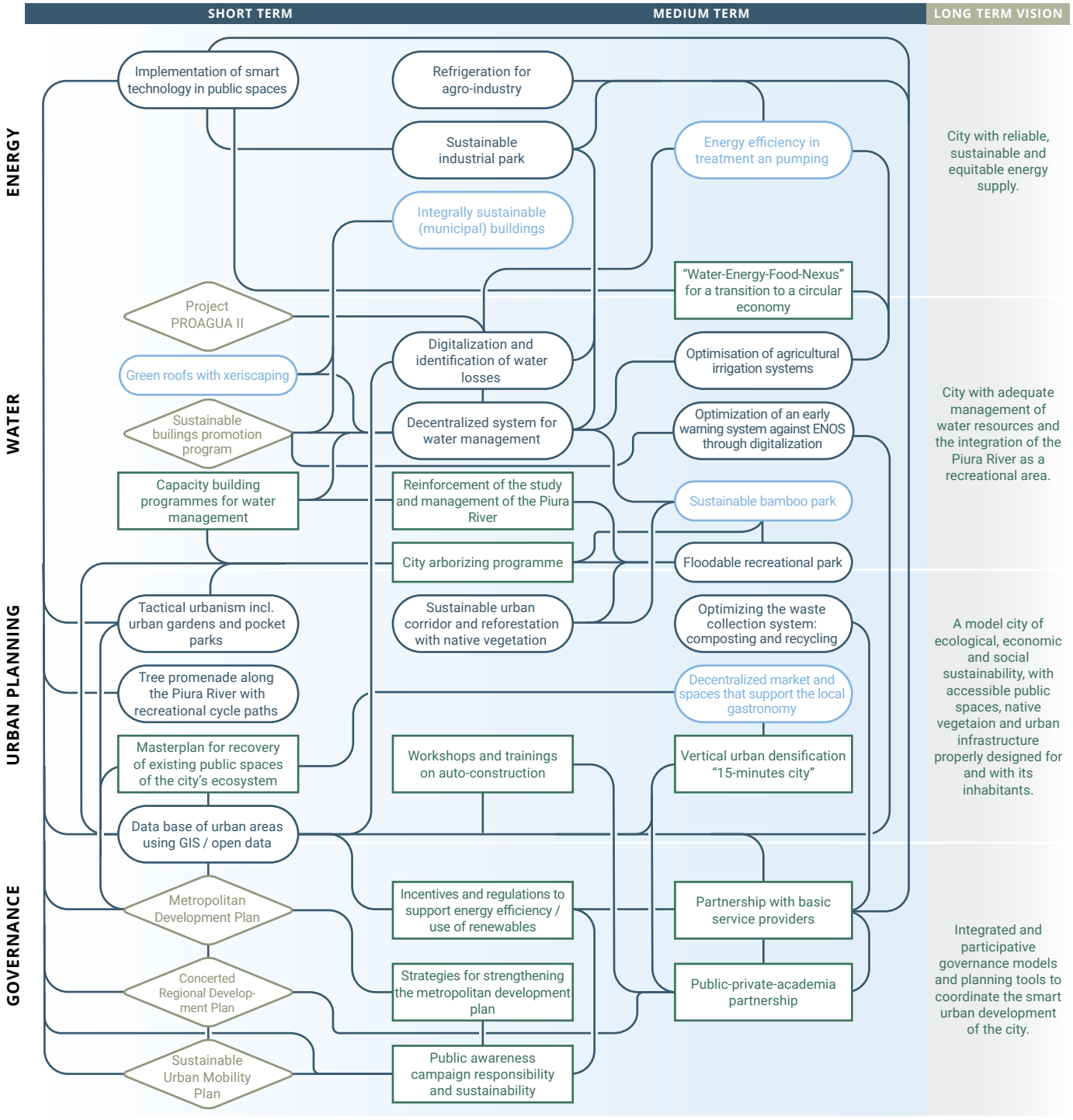
Among them are crucial factors that need to be addressed to transform the system in the desired direction. Using Frederic Vester's sensitivity model, a cross-analysis of these factors distinguished four different categories: drivers, levers, indicators, and buffers. Drivers have the potential to drive change and remain stable for longer, however, they tend to be resistant to change. Levers have a high impact on many factors and are also influenced by many others. Indicators have little influence on some components but are strongly influenced by others. Finally, buffers are relatively inactive in both directions.

A thorough analysis of the most crucial impact factors resulted in the identification of the following interrelated fields of intervention for the Piura city system:

- Need to update public policies/old and non-specific urban planning instruments.
- Lack of access to essential services/clandestine sewers.
- Lack of investment in projects related to climate change/lack of an environmental commission/lack of a public policy update.
- Lack of an environmental commission/few initiatives at the local level/lack of investment in climate change-related projects.
- Lack of environmental awareness.

4. ROADMAP: STRATEGY AND MEASURES

4.1. STRATEGY ROADMAP FOR SUSTAINABLE DEVELOPMENT OF PUIRA



The roadmap was developed from the analysis and evaluation of the project's first three phases, as shown in Chapter 1. It is a portfolio of projects that aim to address the identified challenges, building on the available opportunities towards achieving a long-term vision in the different sectors to boost sustainable development in Piura. The roadmap is a graphical representation of the project ideas and shows the complexity of the relationships between them and other relevant aspects, such as the current plans that the city is developing.

The project ideas have been arranged in an implementation time frame, i.e., the short and medium terms. At the same time, the projects are organized into three categories. The first category includes projects involving physical-tangible interventions. These are represented in the oval-shaped boxes. The second category corresponds to planning projects, such as measures, studies, training, master plans, or events, which, in some cases, are relevant for the implementation of projects in the first category. This category is represented by the rectangular boxes. Third, the projects or plans that the city is currently developing are represented by the diamond-shaped boxes. Of the projects in the first category, 12 projects have been selected to be developed within the framework of City Lab Piura. A brief description of these can be found in Chapter 4.2, Suggested Measures.

The projects on the left side of the roadmap are those that, can be implemented over a short period of time. For example, implementing a database of urban areas using GIS, a project that would be based on the mapping carried out during the development of the last PDM, could use a large part of the information already collected for this purpose. Efforts would be required for the creation of the database and data standardization. This project would serve as a basis for the development of other projects, so it is recommended that it be prioritized. In addition, the project could contribute to capacity building for the use of information technologies that are useful in other areas, such as mapping areas without access to essential services to manage the corresponding action, analyzing for example water efficiency, etc. This project would require the support of district municipalities, such as the MVCS in charge of the PDM. Another example of this type of project is the urban tree program, which aims to improve the microclimate of the city, avoid the heat island effect, enhance air quality, among others and could start as a small intervention within the municipality, presenting the possibility of joining efforts with environmental awareness campaigns. In addition, this intervention could include a program of citizen participation and empowerment, with the possibility of rapid replication in other city areas. In turn, the program could be combined with tactical urbanism interventions to achieve a high impact at a lower cost and over a shorter time.

Projects that require more time, resources, and infrastructure to be implemented are on the right side of the roadmap. This is the case for the reforestation of urban green corridors with native vegetation, which considers interventions on transport routes along the river and involves the transport sector in terms of sustainable mobility systems; the water sector for improving the management and control of river flow; and the urban planning sector in terms of the relocation of the population living in the intervention area.

In summary, the roadmap serves as a guide for the city to execute projects in a timely and articulated manner, thus achieving long-term visions and a better adaptation to climate change through interventions that cover the different needs and areas of the city. While most of the projects can be led by the municipality, project ideas could also be implemented by other local stakeholders.

4.2. SUGGESTED MEASURES

This chapter presents the 12 projects that were selected through a formal process that took into account the feedback received during the stakeholder workshop in Piura in May 2021 and internal workshops with local project partners. Some of the initial project ideas addressed similar issues; they have been combined into a single project proposal.

Decentralized system for sustainable water management

Due to its location, Piura is considered a desert region; natural water sources are scarce, both underground and atmospheric (rain). This leads to the need for adequate management of the resources. However, the management of the water cycle in the city is deficient, and is the result of a lack of planning in terms of sustainable development and the irresponsible use of this resource (e.g., using drinking water for irrigating green areas). Thus, the project aims to implement decentralized wastewater treatment systems to reduce irresponsible drinking water consumption (i.e., in areas where drinking quality water is not necessary). The decentralized system for sustainable water management aims to motivate the private sector and society to implement such methodologies as a means of orientation towards a circular economy, i.e., to increase an interest in its replication in other areas. In addition, implementing this type of system seeks to promote the responsible use of water and will contribute to raising public awareness of these issues.

Reforestation of urban green corridors – arborizing the city

This project contributes to mitigating heat islands and generating microclimates to reduce energy consumption in the city and improve thermal comfort. At the same time, it contributes to counteracting CO_2 emissions and represents an opportunity to promote sustainable mobility. Therefore, the main streets of the city of Piura have the potential to become areas where the urban vegetation cover will be increased. This will improve the citizens' quality of life, introduce native species that are representative of the region, and improve the appearance of the city.

Data base of urban areas using GIS / open data

This project involves developing a database through a GIS platform to collect information about the city and thus more efficiently manage and register the cadastral map of public areas. In this way, a digitalized cadastral map can become an instrument for improving urban planning in order to reduce encroachment on state land usually located in vulnerable and high-risk areas. On the other hand, it will allow future municipal authorities to better manage their projects based on reliable data. Furthermore, this project aims to ensure the transparency and efficiency of public processes concerning land management. Using such a GIS-based land registry will streamline processes, provide reliable information on which the population can draw in the future, and allow the city to move towards digital adaptation processes.

Optimizing the waste collection system: composting and recycling

This project promotes the collection of household waste and the implementation of a waste sorting and separation policy to optimize local recycling processes. This, in turn, provides an opportunity for using organic waste in a sectorized composting process, close to parks and schools, with the citizens of each sector of the city as the main actors involved.
The aim is to contribute to an environmentally conscious urban environment based on reusing part of the household waste through local composting. This project aims to provide organic substrate to the green areas of Piura, Castilla, and Veintiséis de Octubre districts.
In this sense, the main challenge for implementing this project is to engage civil society and the authorities to promote the selection of waste in order to help recycle and compost, resulting in a project that is sustainable over time.

Digitalization and identification of water losses

One of the main problems in the EPS of Piura is the high percentage of non-revenue water. This may be due to supply leaks that cause physical losses related to a lack of infrastructure. Another factor relevant in Piura is the clandestine tapping, connections, or the so-called "bypassing" of water meters that are typical practices by some citizens. For this reason, this project seeks to rely on the digitalization and modernization of the current water supply system to improve the management of this resource by efficiently identifying water losses. Furthermore, state-of-the-art digital control aims to optimize the maintenance of the water network and reduce the percentage of non-revenue water. Simultaneously, this could represent an opportunity for reinvesting the costs saved to improve the performance of the service to citizens. Indirectly, there is also a possibility of increasing energy efficiency related to the treatment and transport of the resource.

Optimization of an early warning system against ENOS through digitalization

Piura is inherently vulnerable: Its longitudinal and latitudinal location exposes it to large-scale meteorological phenomena such as ENOS, which is characterized by high-intensity rainfall. In addition, experts predict that the frequency of these events will increase due to climate change. For this reason, this project focuses on the implementation of digital tools (sensors, machine learning/artificial intelligence methods, apps, etc.) in an early warning system (EWS) to increase the reaction time for the timely evacuation of groups of citizens in vulnerable areas, thus contributing to the reduction of human losses. One of the intrinsic consequences of the digitalization of the current EWS process is that it will allow the groups involved, such as contingency teams, technicians, or the citizens themselves, to adapt more efficiently to FEN events in Piura by optimizing communication channels through digital tools (apps).

Optimization of agricultural irrigation systems

The agricultural sector is responsible for the greatest number of jobs in Piura, and water resources are essential for this economic activity. However, due to its geolocation in a desert biome, water availability in Piura is low, with a tendency to be exacerbated by more extensive periods of drought caused by climate change. Therefore, this project seeks to support the city of Piura by optimizing agricultural irrigation systems through technical solutions that aim to reduce water consumption, operating costs, energy consumption in the transport of the precious resource, and, consequently, CO_2 emissions relating to its transport, pumping, and treatment. This optimization is also promising in terms of an increase in the farms' production indicators, quality, and ease of operations. Furthermore, such systems have additional benefits, such as optimized fertilizer use.

Sustainable industrial park

The industrial sector is one of the most relevant sectors in terms of its overall impact on sustainability, from local pollution to GHG emissions. The Piura Futura industrial park and other industrial parks in the region represent a unique opportunity for transforming industry in Piura into a more sustainable model. Through grouping several industrial actors in geographical proximity, sustainable industrial parks could offer a unique opportunity to address them in an organised and simultaneous manner and thus transform the industrial sector.

Implementation of smart technology in public spaces

In order for Piura to become a smart city in the coming years, it is considered appropriate to start with the gradual incorporation of intelligent technology in different parts of the city. Therefore, the use of renewable energies and energy efficiency in public spaces will be implemented and promoted. The main areas where this will be implemented are traffic lights, surveillance cameras, environmental quality sensors, meters, etc.

Floodable recreational park and reforestation of the Piura riverbank

This project is based on the recovery of the banks of the Piura River through a proposal that considers both its landscape potential and the fact that this area of the city is flood-prone.
For this reason, the urban edge of the Piura River as a natural corridor that integrates the districts of Castilla and Piura should be promoted with a variety of uses and programmes such as walkways, resting places, viewpoints, paths with groves, recreational bicycle paths and outdoor areas providing areas where citizens can undertake diverse social activities, taking into account the flood-prone potential that it currently has.
For this project, it will be necessary to present a concept that adapts to both the urban context in non-flood-prone periods and the flooding scenario that occurs in rainy years due to the FEN.

Tactical urbanism, including urban gardens and pocket parks

Through tactical urbanism, the project aims to transform the public spaces of the city of Piura, making them more environmentally friendly and pleasing to the population. In this way, by including urban gardens and the creation of pocket parks, it will, over time, reinforce the idea of an inclusive and sustainable city.

Part of the proposal is to offer job opportunities to the vulnerable and the socially and occupationally excluded population. Through education and training tools, a system of mutual learning will be forged that can be replicated over time, thus contributing to local development and relying on the talent of the community.

The use of viable, sustainable, low-cost, flexible construction systems and methods for reusing greywater has been proposed, since water resources represent another problem in the city.

Considering all of the above, the aim is to ensure that there are quality public spaces for everyone and that over time the radius of reach will be larger, supplying the whole city.

Refrigeration for agro-industry

The regional economy of Piura is firmly based on its agro-industry, which is growing and expanding rapidly on the outskirts of the city. The logistics involved are complex, and must take into account production, storage, the large-scale transport of agricultural products, and the cold storage facilities that are necessary to preserve agricultural products for extended periods. In addition, pumping for agricultural processing requires the supply of energy that is often non-existent in remote areas. This project proposes solar photovoltaics for agricultural refrigeration, food storage, and the pumping of water in remote areas.

5. CONCLUSIONS

This summary report presents the results of City Lab Piura as one of the three pilot cities of the Morgenstadt Global Smart Cities Initiative project. It describes the status quo of Piura with respect to its performance in sustainability and climate change resilience with a focus on the water, energy, and urban planning sectors and presents the most salient challenges to current urban development in Piura. The paper also explores the opportunities in these sectors that have great potential for improving the city's resilience to climate change, solutions, and a sustainability vision for each sector. Complementary to this, the report presents a portfolio of concrete projects developed so that the municipality, together with other stakeholders and interested parties, can develop and advance towards the sustainability guidelines that have been defined for the city.

In this respect, the integrated analysis, assessment of challenges, and improvement potential in each sector, together with a list of concrete project ideas, were developed based on the holistic methodology of the Morgenstadt City Lab. This methodology is based on quantitative and qualitative methods and focuses on the involvement of local stakeholders from the public, private, and academic sectors through expert interviews and workshops. This participatory and co-creation approach ensures that the proposed solutions are tailor-made and have a high degree of local ownership.

As a regional capital, and considering its significant economic and population growth, Piura has the potential to become a model city of good sustainable development practices for other cities with similar demographic characteristics in both the country and the region. While, on the one hand, economic development and improvement in urban quality of life should not lead to an increase in GHG emissions, the impacts of climate change must be assimilated through forward-looking risk assessments and incorporated into urgent planning. This is the recommended focus point for the city's efforts in the near future. Experiences should be made available to other cities in similar conditions, and an intensive exchange of experiences should be initiated.

Urban growth leads to the development of urban infrastructures that last for decades, creating a challenge for the development of infrastructure for essential services, such as electricity grids or road infrastructure, among others, and determining requirements for aspects such as the use of individual vehicles, water management, or the energy consumption of buildings. It is essential to create guidelines to control and manage urban growth in order to encourage the development of high-density urban areas with liveable conditions, mixed land use, traffic planning, and basic service infrastructure. Such developments can be supported by green and blue infrastructure integrated into a public space improvement plan, thus substantially increasing the resource efficiency of the different urban components that structure the city. Improving urban planning concepts also offers a great opportunity for reducing CO_2 emissions and consolidating structures that could have a significant impact on fuel consumption, the emission of CO_2 and local pollutants, and air quality by determining the configuration and ordering of mobility in the city. Another primary climate change mitigation measure beyond the energy sector is the prevention of deforestation and construction in the city's natural ecosystems. The creation of new urban green areas should also be promoted and closely linked to the control and management of the city's growth. Citizen awareness plays a crucial role and is another major challenge facing the city, as there is very limited information among the general population on sustainability, climate change, and environmental issues. However, these issues have been gaining in importance since the 2017 impacts of the FEN, and

thus it is important to implement an effective awareness-raising strategy relating to these issues to ensure the implementation and acceptance of the proposed projects and measures.

From this perspective and through the current project, Piura aims to address the sustainable development challenges it faces. As an intermediate city in the global south, it does not have a global showcase to explore its options and potential to improve the sustainability of its urban environment. The city has demonstrated its interest and commitment to improving the sustainability of its urban environment by implementing smart city projects that seek to optimize resources through digitalization. Proof of this is projects using technological solutions and digital platforms to improve disaster risk management, citizen safety, vehicle traffic, and recycling programs such as Piura Recicla.

However, achieving the sustainability vision developed in this project and beyond will require a long-term commitment to sustainable development. As the first step in this direction, this project has attempted to align the results of the project with other planning instruments, such as the Metropolitan Development Plan. Indeed, the institutional alignment of sustainable developments and the definition of clear future objectives are seen as the way forward in meeting the challenge of continuity in the face of changes in government. In addition, it will be crucial for the city to allocate financial resources to implement sustainable development projects, and thus the formalization of the project portfolio to ensure its implementation is essential. It is also essential that the city defines its monitoring schemes to improve sustainable urban development and decision-making.

It is worth mentioning that the activities of the MGI project do not end with the development of the roadmap presented in this report. As a next step, one of the project ideas will be prioritized in terms of its technical and financial components, its feasibility, its corresponding, quantified GHG emission savings, and its potential concerning climate change adaptation. The pre-project development and its implementation will include discussions with local stakeholders relevant to its implementation to ensure the feasibility of the project and ensure local ownership. It is hoped that all the proposals put forward in the project idea portfolio and the roadmap developed as part of City Lab Piura can be realized, as they offer great potential to foster the transformation of Piura into a sustainable city of the future.

AUTHORS

COORDINATION TEAM

Trinidad Fernández
City Lab Leader
Fraunhofer Institute for Industrial Engineering IAO

Stella Schroeder
City Lab Local Leader
University of Piura

Sonja Stöffler
City Lab Deputy Leader
University of Stuttgart IAT

Jose Carlos García Pérez
Coordination Assistant
Fraunhofer Institute for Industrial Engineering IAO

URBAN PLANNING TEAM

Trinidad Fernández
Urban planning Expert Leader
Fraunhofer Institute for Industrial Engineering IAO

Stella Schroeder
Expert Urban Planning Sector
University of Piura

Joel Antoni Villegas Cornejo
Expert Urban Planning Sector
University of Piura

María Daniela de los Ángeles Zavala Salazar
Research Assistent
University of Piura

WATER TEAM

Diego Eufracio Lucio
Expert Water Sector Leader
Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB

Edson Aldair Atarama Mondragón
Expert Water Sector
University of Piura

Rafael Torres Gómez
Research Assistant
Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB

ENERGY AND CO_2 EMISSIONS

José Antonio Ordóñez
Expert Energy Sector Leader
Fraunhofer Institute for Systems and Innovation Research ISI

Oscar Williams Guillen Herrera
Expert Energy Sector
University of Piura

Prof. Dr. Martin Pudlik
CO_2 Emissions Expert
Fraunhofer Institute for Systems and Innovation Research ISI

Hernando Rodríguez Amorocho
Research Assistant
Fraunhofer Institute for Systems and Innovation Research ISI

CLIMATE RESILENCE TEAM

Sophie Mok
Expert Climate Resilience
Fraunhofer Institute for Industrial Engineering IAO

Gisella Hernández Valle
Expert Climate Resilience
University of Piura

Edsmilda Martínez Hidalgo
Research Associate
University of Piura

CLIMATE FINANCE TEAM

Maria Báez
Financial Expert
Frankfurt School of Finance – UNEP Centre

Gabriel Umana
Financial Expert
Frankfurt School of Finance – UNEP Centre

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CONTACT

info@mgi-iki.com

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