

## RALI Series: Promoting Solutions for Low Emission Development

# Power System and Municipal Resilience in the Dominican Republic: Learning in Real-Time Following Hurricanes Irma and Maria

The RALI Series is a collection of papers developed by the RALI project to share examples of low emission development in practice. The series features case studies, tools, and innovative new approaches in this space, highlighting user benefits and lessons learned. To learn more about the RALI project, visit <https://www.climatelinks.org/projects/rali>.

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## INTRODUCTION

As developing countries work to reduce poverty, strengthen economic development, and develop sustainable pathways for future growth, the impacts of extreme events can produce devastating setbacks. These impacts can be particularly severe in rapidly growing urban areas where local governments are already challenged to meet residents' increasing demands for services, including electricity and other critical services. Work to improve the capacity of urban centers to prepare for these events is still in its infancy, and not enough is known about whether the actions that have been taken to begin to build municipal resilience are effective.

In September 2017, as the USAID Planning for Climate Adaptation (ClimaPlan) project was supporting efforts to increase resilience with pilot municipalities in the Dominican Republic, hurricanes Irma and Maria were forecast to hit one of these cities, Las Terrenas. Located on the northern coast of Hispaniola (the Caribbean island shared by the Dominican Republic and Haiti), Las Terrenas was in the hurricane track for both storms. The ClimaPlan team recognized that these impending hurricanes afforded an opportunity to evaluate in real time the climate-related vulnerabilities of the resources, people, and assets of Las Terrenas—and that these storms could be used to identify both existing strengths and opportunities for improving the resilience and adaptive capacity of the municipality. To capture these lessons, the ClimaPlan team conducted a Post-Event Assessment of Resilience (PEAR) to document the impacts of the two

### USAID Planning for Climate Adaptation Project

The Dominican Republic has been declared one of the 10 countries in the world most vulnerable to climate change. Climate impacts ranging from tropical storms and intense precipitation to extreme heat and drought are stressing the country's current services and exacerbating problems with existing infrastructure, including its power system. Communities across the Dominican Republic also face multiple stresses that threaten citizen security: poverty is widespread, gender inequality is significant, and economic development is stymied. In response to the country's vulnerability, USAID formalized the ClimaPlan project in 2015 to increase the resilience of Dominican Republic municipalities by incorporating climate change considerations into municipal strategies and land use planning processes.

ClimaPlan, led by the International City/County Management Association (ICMA) in partnership with ICF, worked with four pilot cities to identify the climate-related risks confronting each municipality. This ClimaPlan team then developed adaptation strategies that could be integrated in the cities' municipal and land use plans to address these risks and to build their resilience. From the work conducted with the pilot cities, the team ultimately produced guidance and tools that other communities across the country can replicate. The coastal city of Las Terrenas was one of the four pilot cities that developed climate-resilient land use plans under this program.

hurricanes; the sensitivity of the people, the power system, and other municipal assets to the storms; the degree of effectiveness of implemented preparedness measures; and how the level of resilience varied across the community.<sup>1</sup>

This paper highlights the findings of this PEAR assessment, with an emphasis on the vulnerabilities of the municipality's power distribution system as part of a broader examination that surveyed the resilience of a range of the municipality's infrastructure and services. The sections below describe the:

- 1) Impacts of the storms on power services to the affected community,
- 2) Measures taken by the power utility, the municipality, and other entities to prepare for, respond to, and recover from service disruptions, and
- 3) Lessons learned about strategies to increase the resilience of energy services to climate events.

Although these findings are relevant to service distribution of both low-emission and carbon-based electricity, understanding the relationship between severe events and electricity services is critical to low-emission development providers to ensure reliable, sustainable service.

The PEAR assessment built on prior ClimaPlan project research and activities undertaken collaboratively with stakeholders from Las Terrenas. These include a Climate Change Vulnerability Assessment, a Climate Change Adaptation Plan, and the draft Municipal Land Use Plan. Employing this knowledge and through engagement with stakeholders, the ClimaPlan team developed working hypotheses regarding the specific vulnerabilities and resilience of Las Terrenas and tested these suppositions through additional evidence collection, including two PEAR site visits (one after each hurricane). During each of these visits, the team conducted a series of interviews, documented storm impacts, and gathered recorded data. The team compared findings from various data sources (e.g., desk reviews, interviews) to validate and identify those findings that could be confirmed in multiple ways.

The key objectives of the PEAR assessment in Las Terrenas were to:

- 1) Assess the impacts of hurricanes Irma and Maria on the people, natural resources, infrastructure services, and business operations in Las Terrenas,
- 2) Determine whether these impacts were captured in the municipality's preliminary Climate Change Vulnerability Assessment and Land Use Plan,
- 3) Evaluate the effectiveness of pre-event planning, post-event recovery, and any resilience measures in place to protect assets and services, and
- 4) Identify and recommend improvements to strengthen the municipality's Land Use Plan to better build the long-term resilience of Las Terrenas.

## KEY HYPOTHESES

- Las Terrenas' short-term emergency preparedness measures implemented in advance of predicted storms would likely result in a reduction of impacts to people and power services, particularly in the event of a less powerful hurricane.
- These emergency preparedness measures would be less effective in preventing significant damages in the event of a powerful hurricane due to Las Terrenas' geography, the existing condition of the built environment, and existing vulnerabilities.
- To sustainably reduce impacts from coastal and riverine flooding and high winds, long-term solutions and investments are required and should be integrated into the Municipal Land Use Plan.

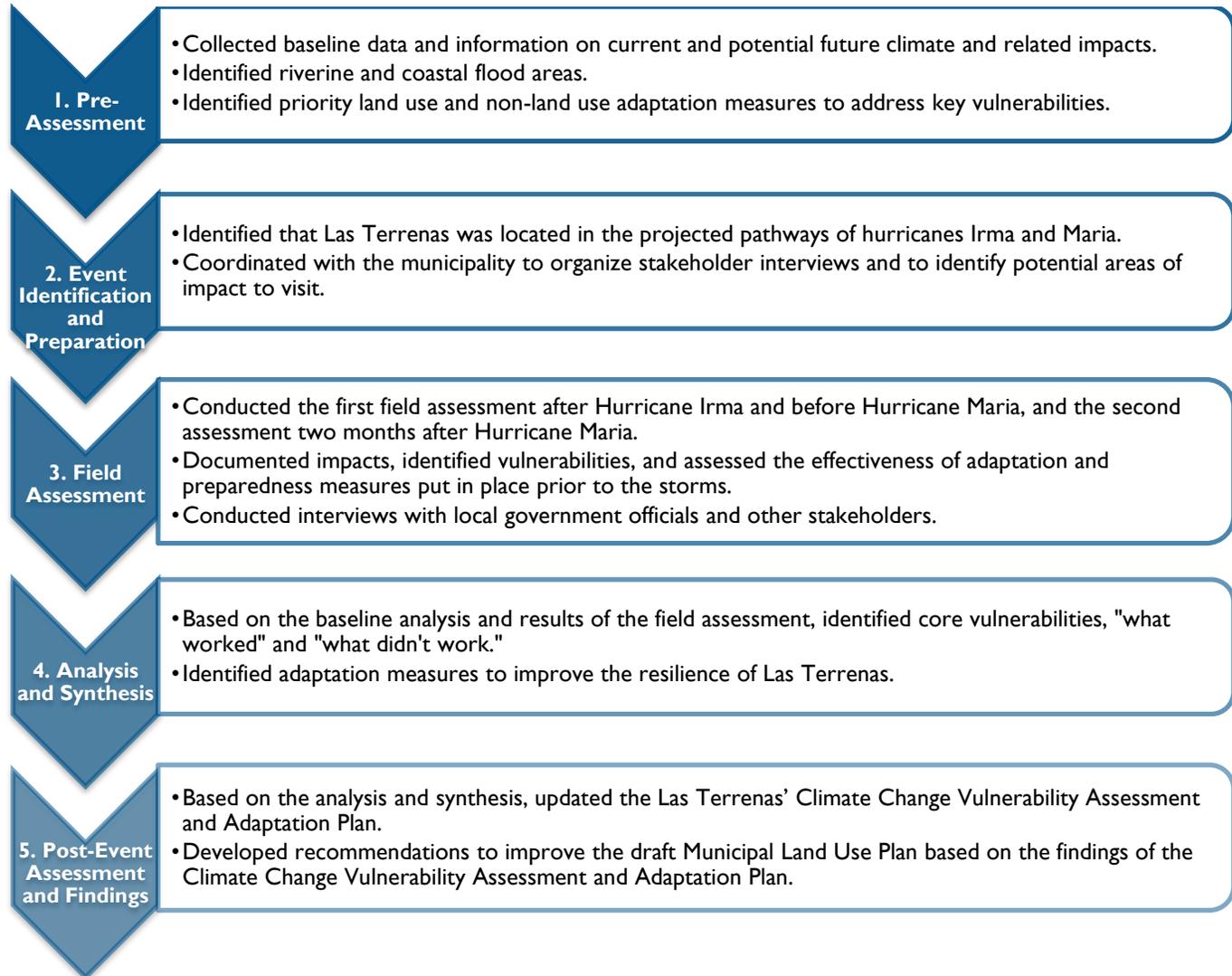
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<sup>1</sup> PEAR is an approach developed by ICF under the USAID Climate Change Resilient Development activity and subsequently implemented by ICF following Hurricane Sandy in 2012 and the flooding in the Carolinas in 2015.

## THE PEAR PROCESS IN LAS TERRENAS

PEAR has roots in pre-event planning for post-event recovery (PEPPER) and more recently established pre-disaster recovery planning (PDRP). PEAR involves a rapid assessment of post event vulnerabilities and seeks to identify transformational adaptation measures to better plan for a future that is different than the past. PEAR entails five steps (see Figure 1), beginning with a pre-event assessment of potential vulnerabilities and adaptation options, and ending with a post-event assessment of actual vulnerabilities and adaptive capacity revealed by the event.

Figure 1. The PEAR Process



### I. PRE-ASSESSMENT

#### Current and Potential Future Vulnerability

Las Terrenas is highly vulnerable to current and future climate variability and change. The municipality is particularly vulnerable to heavy rainfall and coastal erosion, which can have significant impacts on power and other municipal services and infrastructure as well as on roads, housing, and beaches. The steady increase in new development — sometimes constructed in vulnerable areas or without regard for potential climate-related impacts — is exacerbating this vulnerability and threatening the long-term sustainability of new development investments.

## Vulnerability of Electricity Distribution

The private company responsible for the distribution of electricity in the area, Compañía de Luz y Fuerza de Las Terrenas, S.A. (Light and Power), serves approximately 9,500 households, of which 80 percent are currently active contracts (FEDOMU, 2013). Prior to 2015, high electricity tariffs, due in part to the high cost of generation, resulted in protests and vandalism, including in 2014 when damage to power lines resulted in power outages. In addition, the lighting and distribution system poles have been criticized as having “messy overhead electrical wiring,” being poorly located and in substandard condition (FEDOMU, 2013). In 2015, electricity tariffs were substantially decreased due to a government-supported interconnection between Luz y Fuerza’s distribution network and the state-operated National Interconnected Electric System (SENI) (at Sanchez substation). As a result, there are no operational large-scale power generation resources located within the municipal boundaries of Las Terrenas. Luz y Fuerza does own backup diesel generators in case of an emergency.

Luz y Fuerza is responsible for operation and maintenance of the distribution network in Las Terrenas. Therefore, this assessment focused primarily on the local distribution network, though the transmission and distribution network and generation resources that supply Las Terrenas are also vulnerable to climate risks. In particular, if the transmission lines that feed into Sanchez substation, and the distribution lines that feed into Las Terrenas substation from Sanchez, are damaged, Las Terrenas will experience outages.

Luz y Fuerza is already challenged by weather-related disruptions to its distribution network. Heavy winds routinely down trees and power lines, and flooding and inundation of distribution poles have led to power outages, exacerbating existing community tensions and economic impacts. In the future, potential increases in extreme rainfall, sea level rise, storm surge, and hurricane intensity could lead to increased damages to substations, transmission and distribution infrastructure, and disruptions to service; these impacts broadly affect the economy but also lead to higher direct capital and maintenance costs of power systems. Higher temperatures are also a concern. Expected increases in extreme temperatures can cause thermal expansion of power lines and lead to line sag and potential service disruption. Additionally, increases in extreme temperatures can increase energy demand for air conditioning from both residents and tourists, potentially stressing the system.

## Vulnerability Across Municipal Services

Electricity distribution is one of several critical services in the community that are vulnerable to climate change. A comprehensive set of potential direct impacts, categorized by municipal sector or service, is provided in Table 1. Together, the quality and reliability of these services is fundamental to the ability of Las Terrenas to achieve its development objectives. Because interruptions in electricity service have cascading impacts—impacts that affect all other services—disruptions to the electricity distribution network are particularly significant.

**Table 1. Matrix of Potential Climate Change Impacts to Sectors Vital to the Development Objectives of the Municipality of Las Terrenas**

MUNICIPAL PRIORITY	SUPPORTING SECTORS	POTENTIAL IMPACTS BY CLIMATE CHANGE STRESSOR		
		TEMPERATURE INCREASE	SEA LEVEL RISE AND STORM SURGE	CHANGES IN RAINFALL AND EXTREME WEATHER EVENTS
<b>Quality municipal services</b>	Electricity	<ul style="list-style-type: none"> <li>Thermal expansion of power lines, reducing the amount of power that can be securely transported, risk of line sag and power outages</li> <li>Increased energy demand for cooling</li> </ul>	<ul style="list-style-type: none"> <li>Downed power lines, inundated distribution assets</li> <li>Coastal road damage restricts access to assets</li> </ul>	<ul style="list-style-type: none"> <li>Restricted access for line maintenance, or transport of alternate energy supplies</li> <li>Downed power lines</li> <li>Energy service disruption, de-energizing flooded lines</li> <li>Increased capital and maintenance costs</li> </ul>
	Water supply and treatment	<ul style="list-style-type: none"> <li>Higher evaporation losses</li> <li>Changes in water quality</li> </ul>	<ul style="list-style-type: none"> <li>Salt water intrusion</li> </ul>	<ul style="list-style-type: none"> <li>Changes in water quality, water availability</li> <li>Damage to water treatment, storage, and distribution infrastructure</li> </ul>
	Sewage systems and storm water drainage	<ul style="list-style-type: none"> <li>Lower wastewater quality due to increased algal blooms and pathogen concentrations, and lower dissolved oxygen</li> </ul>	<ul style="list-style-type: none"> <li>Flooding of roads that serve as drainage</li> <li>Inundation of sewage system</li> </ul>	<ul style="list-style-type: none"> <li>Flooding of roads that serve as drainage</li> <li>Sewer overflows that pollute the environment and expose the population to pathogens</li> <li>Damage to infrastructure</li> <li>Increase of debris that can further block drainage</li> </ul>
	Roads	<ul style="list-style-type: none"> <li>More rapid road asphalt deterioration</li> <li>Increased maintenance and construction costs</li> </ul>	<ul style="list-style-type: none"> <li>Erosion of road base</li> <li>Permanent inundation</li> </ul>	<ul style="list-style-type: none"> <li>Flooding and damage of roadways</li> <li>Closure of facilities due to debris and damage to infrastructure</li> </ul>
	Solid waste management	<ul style="list-style-type: none"> <li>Increased odor, requiring more frequent waste collection and rigorous landfill management</li> <li>Altered decomposition rates</li> <li>Overheating of collection vehicles</li> <li>Increase of flies around organic waste, increasing risk of infectious diseases</li> </ul>	<ul style="list-style-type: none"> <li>Narrowed collection routes</li> </ul>	<ul style="list-style-type: none"> <li>Flooding of collection routes</li> <li>Dispersal of waste</li> <li>More garbage deposited into rivers</li> <li>Damage and debris along collection routes</li> </ul>
	Human health and safety	<ul style="list-style-type: none"> <li>Increased heat stress and increase in the spread of pathogens</li> </ul>	<ul style="list-style-type: none"> <li>Flooding of critical roadways</li> </ul>	<ul style="list-style-type: none"> <li>Flooding of roadways, limiting access to hospital and evacuation route</li> <li>Flooding of central hospital</li> <li>Injuries and loss of life</li> <li>Increased demand for emergency response services</li> <li>Physical damage to public health infrastructure</li> </ul>

MUNICIPAL PRIORITY	SUPPORTING SECTORS	POTENTIAL IMPACTS BY CLIMATE CHANGE STRESSOR		
		TEMPERATURE INCREASE	SEA LEVEL RISE AND STORM SURGE	CHANGES IN RAINFALL AND EXTREME WEATHER EVENTS
<b>Sustainable tourism and natural resources</b>	Built infrastructure	<ul style="list-style-type: none"> <li>Higher cooling costs</li> </ul>	<ul style="list-style-type: none"> <li>Inundation or physical damage</li> </ul>	<ul style="list-style-type: none"> <li>Inundation or physical damage to tourism infrastructure</li> </ul>
	Natural resources	<ul style="list-style-type: none"> <li>Coral bleaching due to ocean acidification</li> <li>Heat stress on vegetation and wildlife</li> <li>Increase of seaweed on the beach (specifically Sargassum)</li> </ul>	<ul style="list-style-type: none"> <li>Submersion of coastal forests</li> <li>Loss of wetlands</li> <li>Increased erosion on the beach</li> <li>Possible reduction of reef growth</li> </ul>	<ul style="list-style-type: none"> <li>Possible alteration of natural forest structure and composition</li> <li>Changes in nutrient balance and increased sedimentation</li> <li>Physical damage to forests, with greater impact on coastal forests by large storm waves</li> <li>Physical damage to marshes and mangroves</li> <li>Physical damage to coral reefs, especially barriers and shallow reefs</li> </ul>
	Tourist activities	<ul style="list-style-type: none"> <li>Reduced volume and demand for diving due to loss of coral reefs</li> </ul>	<ul style="list-style-type: none"> <li>Loss of beach area for recreational use</li> <li>Reduced activity due to loss of reefs whose vertical growth rate does not exceed that of sea level rise</li> </ul>	<ul style="list-style-type: none"> <li>Reduced activity due to loss of coral reefs resulting from changes in salinity, nutrient balance, direct damage, and increased sedimentation</li> </ul>
<b>Fishing and agriculture</b>	Fishing	<ul style="list-style-type: none"> <li>Heat stress on fish and marine ecosystem</li> <li>Impacts on productivity of fisheries</li> <li>Impacts on corals and shellfish due to ocean acidification</li> </ul>	<ul style="list-style-type: none"> <li>Possible reduction of reef growth</li> <li>Physical damage to fishing landing sites</li> </ul>	<ul style="list-style-type: none"> <li>Changes in nutrient balance and increased sedimentation</li> <li>Physical damage to fish breeding sites and coral reefs, especially barriers and shallow reefs</li> <li>Reduction of fishing time</li> </ul>
	Agriculture	<ul style="list-style-type: none"> <li>Heat stress on crops and agriculture infrastructure</li> <li>Reduced production</li> <li>Shifts of pests</li> </ul>	<ul style="list-style-type: none"> <li>Salt water intrusion of soil</li> </ul>	<ul style="list-style-type: none"> <li>Changes in the timing and amount of precipitation for rain-fed agriculture</li> <li>Damage to crops and agriculture infrastructure</li> </ul>
<b>Participatory governance</b>	Various	<ul style="list-style-type: none"> <li>Climate impacts to livelihoods and disruptions to municipal services; increasing pressure on the municipality to better include the community in its governance and decision-making processes</li> </ul>		
<b>Harmonious land use</b>	Various	<ul style="list-style-type: none"> <li>Undermining of the efficiency and effectiveness of investments and spatial planning that do not take changes in climate into account</li> </ul>		

Source: ICMA/ICF/FEDOMUI/AMLT (2017a).

## Adaptation Measures

### Cross-Cutting Adaptation Measures

Las Terrenas' Land Use Plan and Adaptation Plan present several adaptation strategies that are primarily focused on addressing riverine and coastal flooding and related impacts (see Table 2). Each of these adaptation strategies is cross-cutting, aimed at improving the resilience of the overall community and infrastructure rather than at specifically improving the resilience of the electricity sector. By taking an integrated, systems-level approach to adaptation, the community can achieve greater resilience across all sectors.

**Table 2. Adaptation Strategies in Las Terrenas' Land Use and Adaptation Plan**

#	Adaptation Strategy
1	<b>Development planning.</b> Avoid urbanization and development in vulnerable areas affected by rising sea levels, storm surge, saltwater infiltration, beach erosion, and riverine and coastal flooding. Focus on ecosystem protection and preservation (e.g., riparian areas, beaches, mangroves, and coral reefs). Settlements shall be prevented through zoning and leaving these spaces free for public projects under the Urban Regulatory Plan.
2	<b>Structural measures.</b> Reduce/eliminate the impact of coastal and riverine flooding from extreme rainfall events on populations and infrastructure in vulnerable sites through structural measures such as improved design and engineering, and flood management and control technologies.
3	<b>Non-structural measures.</b> Implement programs and policies to reduce the impact of flooding in vulnerable locations through measures such as early warning systems to support emergency evacuation and improved dam management to control flows. Consider resettlement in the medium- or long-term.
4	<b>Ecosystem-based measures.</b> Preserve, restore, and take advantage of terrestrial, riparian, and coastal environments to address degradation and loss of ecosystems that mitigate flood risks and have biodiversity and ecotourism co-benefits.
5	<b>Improved municipal services.</b> Improve basic services such as solid waste, wastewater, power and water services to reduce/avoid the negative synergies between climate and non-climate stressors. For example, improve solid waste management to improve drainage and reduce contamination of water sources; ensure reliable electricity service to power-dependent services; reduce water supply losses and leakage to help compensate for rainfall variability.
6	<b>Strengthened institutional coordination.</b> Create relationships and alliances with the public and fortify interinstitutional and intersectoral mechanisms for effective adaptation.
7	<b>Improved data and information.</b> Address priority information needs (historic and projected climate, spatial, and socioeconomic) to improve understanding of vulnerabilities and to align land use and development planning with municipal climate change adaptation goals.
8	<b>Public engagement.</b> Increase education and awareness at all levels (citizens, businesses) to address land use planning needs, climate risks, and natural resource protection in the municipality.

Source: Adapted from ICMA/ICF/FEDOMUI/AMLT (2017a).

### Sector-Specific Adaptation Measures for Power Distribution

In addition to these cross-cutting adaptation strategies, sector-specific actions can be deployed to increase the resilience of power transmission and distribution systems. These actions can include structural and non-structural measures (e.g., policy and planning, technological, and operational actions) and can be incorporated at different points in the development and management cycle: during siting, design, or operations. In Las Terrenas, it is important for distribution infrastructure to be resilient to sea level rise and storm surge, extreme rainfall, and high winds during tropical storms. Examples of measures that can be taken by the utility to protect transmission and distribution from climate risks are listed in Table 3.

**Table 3. Example Adaptation Measures for Electricity Transmission and Distribution**

TRANSMISSION & DISTRIBUTION	ADAPTATION TYPE
Build additional transmission and distribution capacity to cope with increased loads and to increase resilience to direct physical impacts.	Structural
Place transmission lines underground (to avoid high winds).	Structural
Install new types of cooling and heat-tolerant materials/technology at substations.	Structural

Install cooling systems for transformers.	Structural
Elevate substation control rooms to reduce potential flooding hazards.	Structural
Increase fire and wind corridors around transmission and distribution lines.	Land use planning
Use transmission line materials that can withstand high temperatures.	Structural
Map landslide risk along transmission line right-of-way.	Policy and Planning
Construct levees, berms, floodwalls, and storm surge barriers to protect exposed transmission and distribution infrastructure.	Structural
Elevate or relocate substations.	Structural
Consider extreme events threats in new siting.	Policy and Planning
Relocate, or reinforce, or replace towers/poles with stronger or more flexible materials or additional supports to make them less susceptible to wind and flood damage.	Structural
Increase resources for more frequent maintenance.	Financial, Operational
Regularly inspect vulnerable infrastructure such as wooden utility poles.	Operational
Regularly trim trees within transmission and distribution corridors.	Operational
Update aging transmission and distribution equipment.	Structural
Use submersible equipment in vulnerable locations.	Structural

Source: Modified from ICMA/ICF/FEDOMUI/AMLT (2017a).

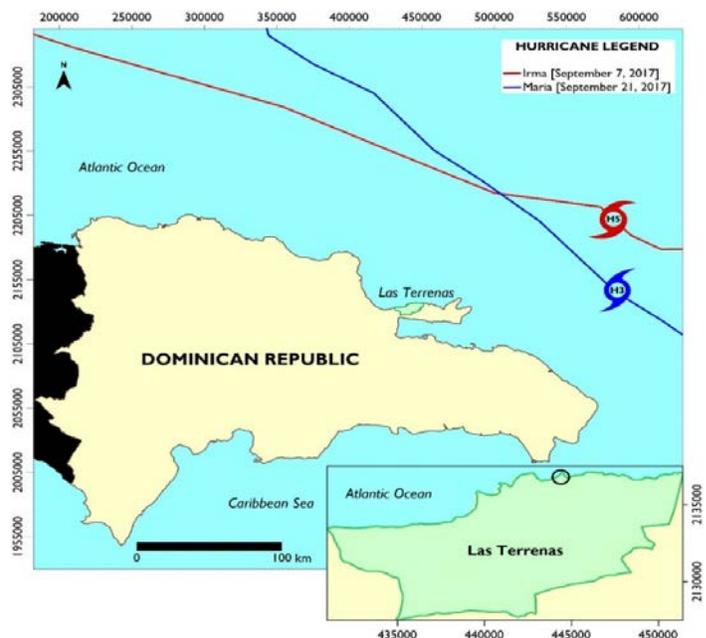
## 2. EVENT IDENTIFICATION AND PREPARATION: HURRICANES IRMA AND MARIA

Las Terrenas was in the projected pathways of hurricanes Irma and Maria. The municipality was interested in learning from the hurricane events to better understand climate-related vulnerabilities, and to improve Las Terrenas' resilience through improved land use and municipal planning. The PEAR team coordinated with the municipality to develop agendas for two site visits to Las Terrenas, which included organization of key stakeholder interviews and visits to vulnerable locations.

The projected storm surge heights were 0.9–1.5 meters above normal tide levels for Irma (NHC 2017a) and 1.2–1.8 meters above normal tide levels for Maria (NHC 2017b). Fortunately, neither Hurricane Irma nor Maria made landfall in Las Terrenas (see Figure 2). Although the actual storm surge heights were not recorded, based on observation, they were on the lower range of the projections. Rainfall levels were significant. The rainfall over the two-day period for each hurricane was 155 mm for Irma, and 259 mm for Maria, and total rainfall recorded for the month of September 2017 was more than three times the monthly average for September. At nearby Catey station, the winds for Hurricane Irma were recorded at 63 km per hour, with gusts up to 111 km per hour, while the winds for Hurricane Maria were recorded at 75 km per hour, with gusts up to 121 km per hour (personal communication, National Meteorological Office, October 2017).

Hurricanes events such as Irma and Maria are not isolated events for communities in the Dominican Republic; hurricanes and tropical storms will continue to affect the country, and their impacts are likely to become more serious over time. Historically, cyclone and hurricane landfall frequencies over the Dominican Republic average once every two years, occurring primarily during the months of August, September, and October. From 1851 to 2014, 22 cyclones or hurricanes came within 50 kilometers of Las Terrenas, with two making landfall in the municipality. Of these, the most recent to make landfall

Figure 1. Path of Hurricanes Irma and Maria



was Hurricane Jeanne in September 2004 (NOAA, 2016). Climate warming is likely to increase hurricane intensity, precipitation rates, and frequency of very intense (Saffir-Simpson Category 4–5) hurricanes in the Atlantic Basin, though the total number of tropical storms may remain the same or decrease in frequency by the end of the century. Sea level rise will increase storm surge heights when tropical cyclones do occur.

### 3. FIELD ASSESSMENTS

The team traveled to Las Terrenas in advance of the hurricanes as part of its work under the ClimaPlan project to support the vulnerability assessment and adaptation planning processes. This work provided the foundation for the PEAR assessment, as team members developed a better understanding of vulnerabilities and preparedness measures being put into place, increased familiarity with the area, and established relationships with key stakeholders. An additional trip, conducted between the two hurricanes, combined a post-event assessment after Irma with additional reconnaissance in advance of Maria. The assessments included numerous interviews with stakeholders, as well as on-site observations.

#### Preparedness Strategies Implemented Prior to Hurricanes Irma and Maria

The PEAR team interviewed a variety of stakeholders in Las Terrenas, including the Mayor and representatives from the government disaster management agency, civil defense, the Committee for Prevention, Mitigation, and Response to Disasters (CPMR), the Ministry of Tourism, the power utility Luz y Fuerza, and the local newspaper. These stakeholders outlined the measures that were taken in advance of the hurricanes.

##### *Cross-Cutting Preparedness Measures*

CPMR coordinated an action plan for before, during, and after each event. The municipality's preparedness measures were focused foremost on ensuring the safety of residents and visitors, including setting up and stocking shelters for at-risk people and evacuating tourists. Las Terrenas also raised awareness through broadcasting preparedness messages through various media channels, including via speakers mounted on a truck that drove throughout the municipality. To mitigate riverine flooding and debris scattering, the municipality collected debris prior to the storm and dredged Las Terrenas River (See Picture 1). However, during the first site visit it was noted that the materials from dredging were not contained and protected from rainfall, but rather piled up on the shore of the river. One week prior to Irma, the municipality partially enforced regulations requiring no-build zones within 60 meters of the beach, and 30 meters of the river, removing small businesses along the coast, and houses that were considered particularly vulnerable to riverine flooding. The forced removal of small businesses resulted in some public unrest, including protests and temporary street blockages in Las Terrenas. After the hurricanes, CPMR worked to rehabilitate impact areas, prioritizing the clearance of access routes.



**Picture 1. Las Terrenas River after dredging.**  
Photo: M. Hellmuth, September 13, 2017.

##### *Sector-Specific Preparedness Measures for Power Distribution*

The power utility Luz y Fuerza undertook several measures to protect its assets in advance of the hurricanes, and to prepare for recovery in their aftermath. These included de-energizing areas known to experience significant flooding to avoid asset damage and prevent electrocutions. In addition, steps were taken to secure backup diesel generators. The utility also indicated they had practiced routine and continuous trimming of trees—necessary due to their rapid growth—to reduce interference with the power lines. Throughout the preparedness process, the utility coordinated with disaster management agencies and kept an inventory of critical equipment and vehicles in stock in case damaged assets needed replacement. Staff members and their families were encouraged to stay at the utility headquarters, which was considered to be more safely constructed than other options and located away from flood-risk zones. This

arrangement allowed for utility workers to be quickly deployed to assess damage as soon as the storm permitted. The utility implemented a phased approach to service assessment and restoration; the first priority area was the urban zone where critical services are located (e.g., police stations, hospitals, private clinics, and the civil defense). During recovery, the utility used a private communications network to ensure reliable communications.

## Post-Hurricane Impacts Identified Through PEAR

### Cross-Cutting Impacts

The areas of Las Terrenas that experienced the greatest impacts during hurricanes Irma and Maria were at low elevation, near rivers and coastal areas, and/or in the urban zone of the municipality. The level of physical damage was less severe than expected because neither hurricane made landfall. Most impacts were concentrated in the coastal area where sections of the beach road were covered in sand and stones, eroded away, flooded, or blocked by fallen trees, and where many street lamps had fallen. Las Terrenas also experienced impacts related to sewage and solid waste. During the hurricanes, water blew out of sewer drains due to poor drainage. The beach was also inundated with polluted river water that had been released into the ocean and washed back onshore. Small, temporary business structures adjacent to the ocean that were not removed in advance of the storms were damaged by the hurricanes (see Picture 2). The area suffered economic impacts due to the hurricanes as well. The local tourism industry reported lost business due to tourists leaving and cancelling reservations; the timing of the hurricanes was particularly problematic as many tourists typically visit Las Terrenas in September.



**Picture 2. Coastal small business structure undergoing demolition.**

Photo: M. Hellmuth, September 13, 2017

### Power System Impacts



**Picture 3. Downed power lines.**

Photo: M. Hellmuth, Sept. 13, 2017

Hurricane Irma resulted in flood- and wind-related impacts specific to the power system, whereas Hurricane Maria's strong winds affected both local distribution lines and other parts of the Interconnected National Electric System (SENI) outside of Las Terrenas. Following Hurricane Irma, 12 distribution posts were destroyed, more than 30 medium-tension power lines were damaged by falling trees, and 150 secondary lines were reported on the ground (El Nuevo Diario, 2017) (see Picture 3). In the central business zone, some distribution poles were inundated (at flood depths of up to 1.6 meters), requiring the utility to disconnect service until water levels receded. After repairing the lines, the utility re-energized them. During Hurricane Maria, an estimated 9-10 distribution posts were knocked down, causing power outages on the outskirts of town. In addition, a municipality-wide power outage was caused by interruptions to SENI in areas outside of Las Terrenas, though power was restored within five hours. The overall impact to customers was considered minimal, as power was restored in less than a day following both hurricanes.

## 4. ANALYSIS AND SYNTHESIS

The municipality and Luz y Fuerza implemented several measures designed to mitigate and/or reduce the potential impacts of the hurricanes that had some success in reducing loss and service disruption. Ultimately, impacts to the distribution system were primarily due to strong wind gusts from hurricanes Irma and Maria, but also due to some flooding in the urban zone. Power was restored within 14 hours after both hurricanes. However, had either hurricane made landfall, the level of destruction and service disruption would have been much more severe.

During post-event interviews with the utility staff, the PEAR team discussed several potential adaptation measures that can be deployed to reduce risks to the distribution networks. These measures, and the utility’s comments about each measure’s potential usefulness to their operation, are summarized in Table 4. These comments highlight the fact that the efficacy of climate change adaptation measures is highly dependent on local conditions.

**Table 4. Potential Adaptation Measures to Increase Climate Resilience of Transmission and Distribution Networks, and their Relevance to the Luz y Fuerza System in Las Terrenas**

Adaptation Measures that may Increase Climate Resilience of Electricity Distribution	Comments from Luz y Fuerza Utility on Applicability of Measure to Network*
Build additional capacity to cope with increased loads and to increase resilience to direct physical impacts.	New distribution lines are being planned. It is challenging to meet demand due to vandalism and illegal tapping of electricity.
Install new types of cooling and heat tolerant materials/technology at substations.	Heat is not considered a major concern.
Elevate substation and control rooms to reduce potential flooding hazards.	Currently, the substation is not at risk of flooding.
Adopt vegetation management programs that are more aggressive than the industry norm due to tropical growth.	This is an important measure, but is a challenge given how quickly the vegetation grows; in addition, the utility noted that cutting trees located on private property can be challenging.
Use distribution line materials that can withstand high temperatures.	Efficiency losses in the lines due to high temperatures is not considered a major issue. The lines are periodically re-strung to reduce sag.
Map landslide risk along transmission line rights of way.	Landslides can be a concern, particularly to the transmission lines located outside of Las Terrenas.
Take a targeted approach to re-siting or flood-proofing exposed distribution infrastructure to reduce power disruptions.	Several distribution poles in the urban zone are at risk from flooding; implementing these measures would provide broader benefits.
Consider threats of extreme events in new siting.	Could be incorporated into new expansion plans.
Relocate, reinforce, or replace towers/poles with stronger materials or additional supports to make them less susceptible to wind and flood damage.	Wooden poles are more resilient to strong winds, as they typically “bend,” whereas metal poles break under similar wind stress.
Increase resources for more frequent maintenance.	Maintenance is an ongoing challenge, but it has a significant effect on resilience.
Maintain an inventory of spare parts to reduce response times.	The utility has an inventory in place, and parts can be rapidly deployed in the event of damaged poles.

\*Source: PEAR team interviews with Luz y Fuerza personnel.

## 5. POST-EVENT ASSESSMENT AND FINDINGS

The real-time assessment resulted in several findings about Las Terrenas’ vulnerabilities and its adaptive capacity. Based on these findings, the team identified strategies the municipality could implement to increase the resilience of the power sector and other municipal services to climate events. Key findings and recommendations are summarized below.

**Increase the focus on long-term preparedness strategies to reduce the need for recurring emergency measures.** The municipality undertook a suite of preparedness efforts prior to the hurricanes, which effectively reduced potential flood damages and impacts. However, many of these only mitigate impacts in the short term; they do nothing to prevent the impacts from recurring. For instance, dredging Las Terrenas’ rivers did mitigate flooding for hurricanes Irma and Maria, but did not abate the solid waste disposal and erosion that necessitates the dredging. The

draft Municipal Land Use Plan, when implemented, will support the municipality in more sustainably addressing impacts like those experienced during hurricanes Irma and Maria. The draft plan includes strategies that would increase resilience over the longer term, achieving better and more cost-effective results over time compared to short-term hurricane preparedness strategies implemented prior to every potential new storm or hurricane. The land use strategies include creating buffer zones in flood-risk areas through zoning and regulations; limiting development near riverbanks; reducing erosion through green infrastructure; reducing the impact of flooding on infrastructure through improved structural and non-structural measures; and reducing flooding through improved solid waste management and disposal practices. Additional measures should include ensuring transmission and distribution right of ways.

**Establish and enforce climate-resilient zoning to steer development away from high-risk locations.**

Stakeholders expressed a strong belief that Las Terrenas' draft Municipal Land Use Plan offers a transformational opportunity to improve resilience, and that it is critical to employ zoning to keep people and assets out of harm's way. Currently, development in Las Terrenas is occurring in a risky and unsustainable manner—for example, some developers constructing too close to the coast—and the municipality has limited ability to restrict this development. However, zoning restrictions in Las Terrenas' draft Municipal Land Use Plan would empower the municipality to ensure that Las Terrenas is developed in a sustainable and resilient manner.

**Apply regulations consistently to ensure fair and equitable treatment of businesses and property owners and to promote buy-in.** Some preparedness strategies resulted in dissatisfaction and resentment by some members of the community. For instance, the destruction of buildings within the no-build zone caused anger among business owners who lost their businesses, including those who claimed that they had received a permit from the government. When implementing the Municipal Land Use Plan's adaptation strategies, involving the community early on and ensuring consistency across government departments could mitigate civil unrest and foster community buy-in.

**Address gaps in information to support informed risk management decisions across all sectors.** While Las Terrenas' Climate Change Vulnerability Assessment captured many of the actual impacts observed from hurricanes Irma and Maria—many of which were due to high winds, flooding, and erosion—new information about electricity, transport, and waste system impacts and bluff erosion should be incorporated to provide a fuller picture of potential risks. More complete information will help managers make better decisions about the investments needed to protect their assets and services. For instance, the draft Municipal Land Use Plan should note the areas that routinely flood, and as a result, the power utility must de-energize these areas until water levels recede. Similarly, the plan should include information regarding potential traffic blockages and road damage from sand, stone, and fallen trees. In addition, the plan should note that flooding can cause the sewer to overflow and regurgitate wastewater into the streets. Finally, it should be noted that waves from storms and hurricanes can cause severe erosion to sand bluffs, and damage to structures on top of bluffs.

**Protect and maintain evacuation routes and shelters to ensure public safety.** The Climate Change Adaptation Plan includes several land use adaptation measures that achieve the same objectives as the municipality's hurricane preparedness measures, but provide more sustainable, longer-term mitigation of these impacts. Emergency response will continue to be a critical component of preparedness, however. The location of critical evacuation routes and shelters in low-risk areas should be incorporated into the draft Municipal Land Use Plan.

**Incorporate future climate conditions into all policies and regulations to ensure long-term resilience.**

Currently, adaptation measures for coastal and riparian areas in the draft Municipal Land Use Plan focus on adhering to existing regulations. However, these do not account for sea level rise and the associated increase in storm surge during hurricanes and storms, and do not address changing conditions. By establishing a process to update policies and regulations based on the most recent climate projections, Las Terrenas would institutionalize an adaptive management approach to ensure that municipal requirements are sufficient to address future risks.

**Consider local generation options to increase energy resilience of the community.** Because Las Terrenas has no local source of electricity generation, the community is dependent on the national grid. The security of power supply is therefore dependent upon stable transmission and generation outside of the boundaries of Las Terrenas. Work in Puerto Rico following Hurricane Maria may illustrate some useful approaches to addressing this risk. A holistic approach to rebuild Puerto Rico's transmission and distribution system has been proposed that integrates technology, distributed

generation, and energy storage; this includes an electric distribution system designed to readily integrate distributed energy resources and maintain service continuity to critical customers.<sup>2</sup>

In Las Terrenas, diversification of energy sources to include solar or wind generation could increase the resilience of the area to outages, and of critical services. This approach is being tested by some area businesses. For example, one local hotel has installed a 210kW solar power plant at Cosón beach in Las Terrenas to supply energy to its properties and to help develop the area.<sup>3</sup> Net metering regulations stipulated in the Dominican Republic's national Renewable Energy Law 57-07 allow for customers who own generation based on renewable energy sources to be compensated for the energy that they export to the system of the electricity distribution company.

## CONCLUSION

The PEAR assessment was designed and implemented to improve the understanding of the differentiated vulnerabilities of Las Terrenas to extreme weather events, and to assess the effectiveness of the preparedness and resilience measures that were put in place. Las Terrenas' draft Municipal Land Use Plan includes a range of measures designed to increase resilience, and when adopted, will empower the municipal government to enforce them. Because hurricanes Maria and Irma did not make landfall, Las Terrenas was largely spared from more severe and prolonged impacts, and the implemented preparedness measures were for the most part effective in protecting people and assets. At the same time, impacts from the hurricanes resulted in some damaged infrastructure, including power service disruptions. Future storms are likely to continue to become increasingly intense due to climate change, and urbanization is expected to continue at a rapid pace, ensuring that flooding will likely continue in the absence of improved land use management and planning.

As a result, strategies are needed both to make future storms and floods less damaging when they do occur, and to improve the ability of Las Terrenas to rebound when storms do happen. The draft Municipal Land Use Plan provides an opportunity to enhance resilience of the municipality and its assets by delineating clear buffer zones, restoring natural defenses, creating green spaces for water, and ensuring that new urban development occurs outside of flood zones and does not contribute to flood risk. This will also benefit the power sector, but additional measures to ensure power system resilience will be required to better manage future storm and flood risk.

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<sup>2</sup> Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico, 2017.

<sup>3</sup> SolarServer: <https://www.solarserver.de/solar-magazin/aus-den-unternehmen/presse-meldungen/soventix-caribbean-srl-brings-solar-power-to-viva-wyndham-samana.html>

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## Contact

USAID  
Amanda Valenta  
Climate and Energy Specialist  
[avalenta@usaid.gov](mailto:avalenta@usaid.gov)

ICF  
Marian Van Pelt  
RALI Project Director  
[marian.vanpelt@icf.com](mailto:marian.vanpelt@icf.com)

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