Enhanced Reliability and Resiliency for the Dominican Republic's Electric Grid: Microgrids Against Climate-Driven Events

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Executive Summary
Recent severe power outages caused by increasingly frequent **climate-driven events** have highlighted the urgency to improve grid resilience worldwide. Traditional approaches to grid restoration face limitations when severe damage occurs, posing challenges in supplying critical loads (*hospitals, military bases, water treatment plants, etc*.) during blackouts. Here is where **microgrids/minigrids (MGs)** present a promising solution, offering a quick and effective recovery alternative to the resilience dilemma.

Key findings:

- Through the geospatial analysis of high seismic exposure zones, climate vulnerability (including hurricanes, droughts, and floods), socio-economic indicators of community resilience (such as poverty rates and population density), and energy infrastructure data (including generation and transmission), the analysis revealed that the provinces of **Santiago, San Cristobal, Santo Domingo, San Pedro de Macoris, and Samana are particularly vulnerable,** thus where strategic energy resilience planning should take place.

- Dominican Republic´s distribution network topology (including substations, distribution lines, transformers, and other assets) is well maintained using Geographic Information Systems (GIS). However, ***non-georeferenced base maps*** hinder seamless integration with services like *Energy Access Explorer (EAE) and* Energy Modelling and Simulation in Open-Source Software.

Recommendations:

- **Include microgrid regulatory frameworks in the National Energy Plan updates:** Study the regulatory frameworks around microgrid development worldwide, looking at case studies for success and challenges faced by other countries in implementing and regulating microgrids.

- **Comprehensive Database Integration:** DR's distribution companies should explore opportunities to integrate GIS data with external services like **Vegetation Management**. Managing vegetation near power lines is crucial to preventing outages and ensuring safety.

- **Work on the Association (client – transformer – circuit) in Geographic Information Systems (GIS):** Address the lack of maintenance in the *client-transformer-circuit* association field in GIS. Improving this association is vital for data integrity in intelligence tools used for monitoring and controlling energy losses.

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1. Introduction

1.1. Purpose and Scope

Energy Access Explorer (EAE) and **QGIS** are used to synthesize and analyze over **24 geographic** datasets related to *demographic information, energy supply and demand, infrastructure, and vulnerability indicators* specific to Dominican Republic. Through the application of spatial analysis tools, including multi-criteria analysis from EAE, as well as QGIS, the study aims to overlay and filter these datasets. The primary objective is to **identify and prioritize zones where energy resilience initiatives should be explored**, contributing to strategic energy planning. Additionally, the study aims to pinpoint areas suitable for piloting **microgrids/minigrids,** with a dedicated focus on enhancing the reliability of the Dominican Republic's energy infrastructure in the face of climate-driven events. This approach not only emphasizes the importance of resilience but also seeks to provide actionable insights for strategic energy development.

1.1.1. Synthesize Geographic Data Sets

- **Objective:** Aggregate and synthesize more than 24 geographic datasets related to demographic information, energy supply and demand, infrastructure, and vulnerability indicators specific to Dominican Republic
- **Aim:** Establish a comprehensive understanding of the spatial dynamics of the current energy landscape, incorporating diverse factors such as infrastructure, demographics, and climate risks, contributing to reduce high transaction costs for data aggregation and sharing for strategic energy planning.

1.1.2. Assess Demographic and Climate Risk

- **Objective:** Analyze demographic and climate risk indicators in conjunction with energy infrastructure data.
- **Aim**: Understand the intersection of population demographics and climate risks to develop resilient energy solutions that meet the needs of the affected communities

1.1.3. Identify Energy Resilience Zones

- **Objective:** Overlay and filter geographic data to identify zones requiring focused attention for enhancing energy resilience.
- **Aim:** Pinpoint specific areas where climate-driven events pose a significant threat to energy infrastructure, guiding the formulation of targeted resilience strategies,

2. Methodology

2.1. Modeling Approach/Tool Implemented

Energy Access Explorer and **QGIS** are used as geospatial tools to create a custom multi-criteria analysis to identify and prioritize areas requiring focused attention for enhancing energy resilience. Energy Access Explorer aggregates geospatial data related to both energy demand and supply **in 4 major categories**: demographics, social and productive uses, energy infrastructure and energy resources [1]. A 5th category was added for this approach, vulnerability maps.

Figure 1 - Modelling approach – Energy Access Explorer and QGIS for Multi-Criteria Analysis **Source:** Adapted from (Mentis et all, 2019)

2.2. Data Sources

From these 5 categories and out of the **24 geographic datasets** scoped and created from existing literature, the **13 most relevant** were selected for the proposed scenarios and the data sources documented *(see Appendix 1).*

Demographics:

1. **Population Density:**
   Population density data is crucial for decision-making and to facilitate energy planning for utilities [2]. It is also pivotal to understand the key relationships between communities and the infrastructure that support their well-being.

2. **Relative Wealth Index**
   Data on household wealth can provide useful context for energy planning and be used to show areas with the greatest potential for enhancing energy access, or where citizens require financial assistance [3].

Social and Productive Uses:

3. **Poverty Rates**
   Poverty rates can be used as a proxy for energy poverty, a situation in which households are unable to access essential energy services and products, which in turn translates into vulnerability and energy theft [4].

4. **Schools**
   In the country there are 2,605 established shelters, of which approximately 93% of their capacity is in educational centers and churches [5].

Risk

A combination between Human Empowerment Index [6] and Population Density, was used by [7] to establish a factor that allows an approximation of the vulnerability/capacity of the population. This, combined with the threat level, allowed for approximation of the exposure of the provinces to the main threats:

5. **Hurricane Vulnerability Map**
6. **Flood Vulnerability Map**
7. **Earthquake Vulnerability Map**
8. **Drought Vulnerability Map**

Energy Infrastructure

Proximity to power sources and infrastructure is crucial for planning energy access expansion, influencing supply type selection and investment requirements for future projects [1]. Also pivotal for energy resilience is to understand where energy losses are more acute [8], as well as what circuits have a higher rate of interruption:

9. **Transmission Power Lines**
10. **Distribution Power Lines**
11. **Energy Losses by Province**
12. **Energy Losses by Substation**
13. **Energy Interruptions by Feeder**

Energy Resources

Geospatial data on energy resources is crucial for energy planning because it provides valuable information about the spatial distribution, characteristics, and relationships of energy resources. This can be used to develop effective energy policies for targets, incentives and guiding regulatory frameworks:

14. **Solar Irradiation**
15. **Solar PV-Penetration (Net-Metering)**

2.3. Scenarios

Scenario Label	Scenario Description
Hurricane Risk	This scenario involves overlaying the Hurricane vulnerability map with key factors such as Energy Infrastructure, Population Density, and Poverty Rates to identify areas requiring targeted interventions for enhanced for community and energy resilience.
Flood Risk	This scenario involves overlaying the Flood vulnerability map with key factors such as Energy Infrastructure, Population Density, and Poverty Rates to identify areas requiring targeted interventions for enhanced community and energy resilience.
Earthquake Risk	This scenario involves overlaying the Earthquake vulnerability map with key factors such as Energy Infrastructure, Population Density, and Poverty Rates to identify areas requiring targeted interventions for enhanced for community and energy resilience.
Creation of Geographic Datasets on Energy Indicators	The aim is to create geographic datasets on Energy Indicators, specifically Energy Losses by Province and Solar PV Net Metering Penetration.
Mini/Microgrid Segmentation:	The aim is to identify areas suitable for piloting microgrids/minigrids, with a dedicated focus on enhancing the reliability of the Dominican Republic's energy infrastructure in the face of climate-driven events.

Table 1 – Scenarios

3. Results

3.1. Scenario 1 – Hurricane Vulnerability Map

The analysis of the Critical Points of Vulnerability to Climate Change in the Dominican Republic [9] shows that **13 provinces (around 40% of the country)** present levels of vulnerability from intermediate to high (see Figure 2) to hurricanes. Looking at the energy infrastructure, the National Interconnected Electrical System (SENI)'s installed capacity has the highest level of concentration in the **southwestern and northern regions**, with 28.4% and 25.1%, respectively [10].

Both regions group together all the hydroelectric power plants in the country, as well as thermal power plants. The little thermal generation in the North (***with 30% of the demand***) makes the region extremely dependent on thermal generation located in the east and south. Based on current demand profiles, the East and South areas export a significant amount of energy produced to the Central region. The North area, unlike in previous years (prior to 2020 and due to the change in the generation matrix), has become an energy importing area [11].

Area of interest:

The provinces that have been seriously affected by the latest tropical cyclones have been Puerto Plata, Samaná, San Pedro de Macorís, Santo Domingo and San Cristóbal.

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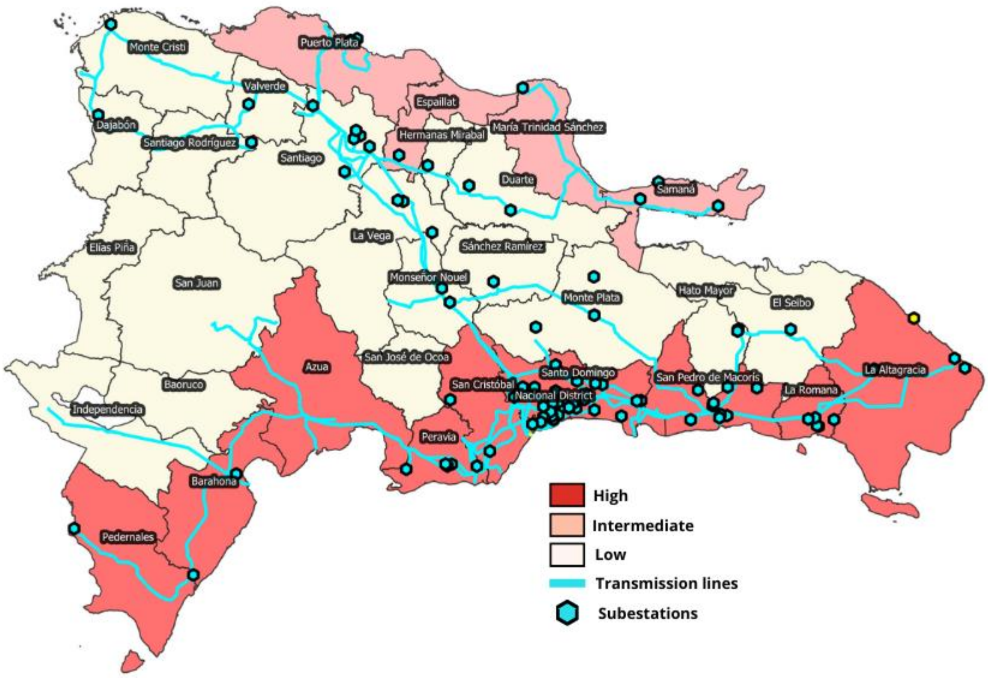

Figure 2 – Hurricane Vulnerability Map by Province, overlaid by Transmission Lines and Substations **Source:** Prepared by the author based on data from (NEO, 2024) and De Travesedo (2009)

3.2. Scenario 2 – Flood Vulnerability Map

The island of Hispaniola is especially sensitive to flood risks, with events occurring throughout the year and not being the direct and exclusive result of tropical cyclones. Figure 3 demonstrates areas most susceptible to alluvial flooding (pink to red) and storm surge (green) [12].

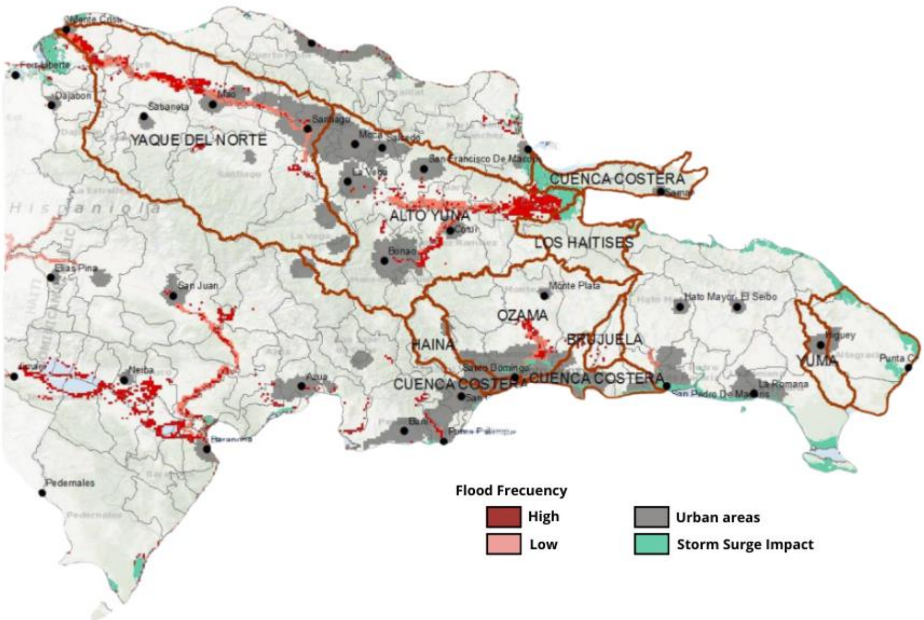

Figure 3 – Areas most susceptible to alluvial flooding (pink and red) and storm surge (green). **Source:** Dominican Republic Climate Change Vulnerability Assessment Report (USAID, 2013)

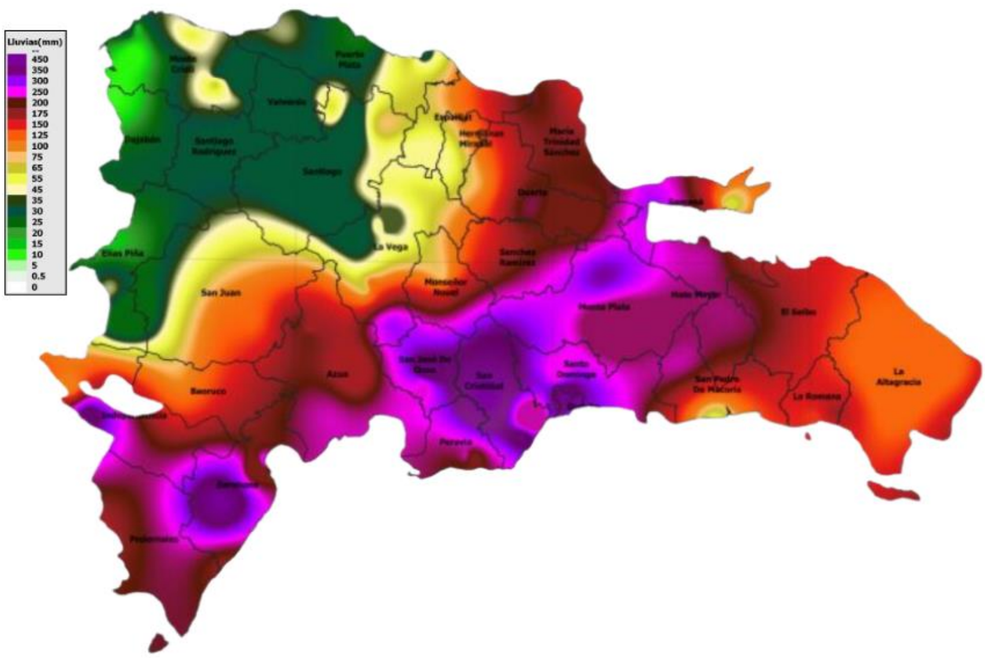

Figure 4 –Accumulated rainfall in the four corresponding days from Thursday, November 16 to Sunday, November 19, 2023. **Source:** National Meteorological Office (ONAMET, 2023)

A recent example occurred on Saturday, November 18, 2023, where accumulated rainfall of 431 millimeters of water was recorded in 24 hours (see Figure 4). It is the **highest rainfall event ever to occur in the Dominican Republic** [13], surpassing the previous record of 266 mm on November 4, 2022. According to official data, 87,442 customers were affected by damage to 24 circuits, and 115 aqueducts in 11 provinces were closed.

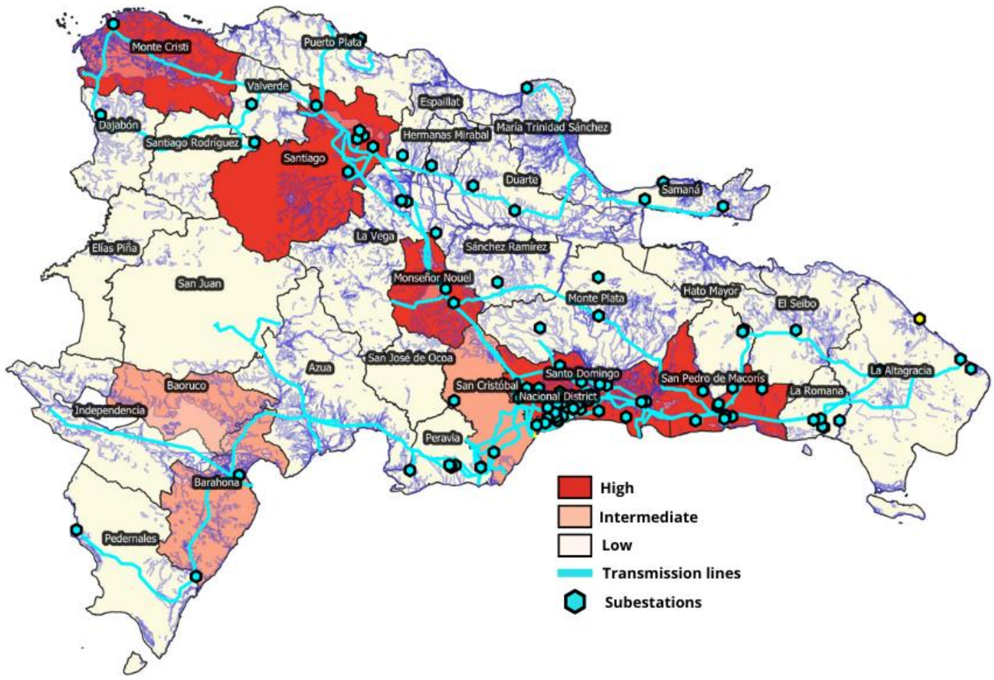

Figure 5 - Flood Vulnerability Map by Province, overlaid by Transmission Lines and Substations**. Source:** Prepared by the author based on data from (NEO, 2024), De Travesedo (2009) and OCHA (2018).

Area of interest:

The regions most affected by floods are those adjacent to the basins of the Yaque del Norte, Yaque del Sur, Yuna, and Soco rivers, as well as the marginal areas along the rivers in the cities of Santo Domingo and Santiago. The provinces with a high degree of flood threat include Santo Domingo, Duarte, Montecristi, Santiago, Valverde, Bahoruco, Barahona, and San Pedro de Macoris [7].

3.3. Scenario 3 – Earthquake Vulnerability Map

Hispaniola is located on the interaction zone between the North American and Caribbean tectonic plate, which causes the entire island to present a high seismic threat, especially the plate fragment made up of the Cibao valley, the Atlantic coast and the Samaná peninsula. In addition, inside the island there are 13 geological faults, that have caused devastating earthquakes in the years 1562, 1783, 1842, 1887, 1904 and 1946.

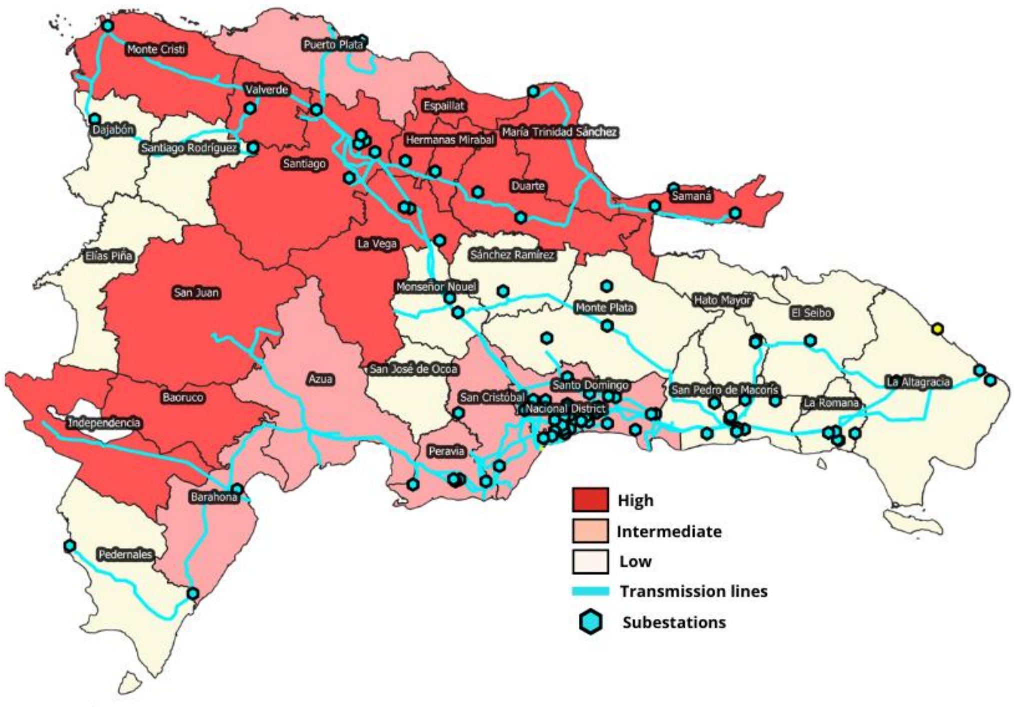

Figure 6 – Earthquake vulnerability Map by Province, overlaid by Transmission Lines and Substations**. Source:** Prepared by the author based on data from (NEO, 2024) and De Travesedo (2009)

Area of Interest

There are many provinces classified as High Seismic Risk, among which Puerto Plata and Santiago stand out for their high population density. Santiago de los Caballeros, also known as the *heart city*, one of the oldest cities in America, has experienced social and natural situations that have led it to be rebuilt over and over again (Earthquake of 1562, Fire of 1863, San Zenón hurricane in 1930, among others), to now be one of the most prosperous metropolises in the nation (18% of GPD in 2015), playing a central role in the economy, politics and culture of the Dominican Republic and the rest of the Caribbean. Recent studies estimated that a hypothetical earthquake in the western segment of the Septentrional fault, with a magnitude of 6.5 and a depth of 9 km, would result in **10 billion dollars in losses, equivalent to 40% of the total economic value** [14].

3.4. Scenario 4 - Creation of Geographic Datasets on Energy Indicators

3.4.1. Energy Losses by Province

Despite the investments made to improve the performance of the electricity sector, loss levels in the Dominican Republic have remained above international reference standards for several decades [21]. According to data from the Superintendence of Electricity (SIE), electricity losses in the distribution sector (around 39.2% in 2023 [15]). This proportion is much higher than the groups of low-income countries (14% to 15%), middle-income countries (13%) and high-income countries of the Organization for Economic Cooperation and Development (OECD), which have fluctuated between 6% and 9% [16].

To put these percentages into perspective, Figure 7 shows electricity losses as a percentage of total electricity production in Latin America and as a percentage of the Gross Domestic Product (GDP) for countries with losses greater than 10% of electricity production. Dominican Republic leads the list with losses that represent 2% of its GDP.

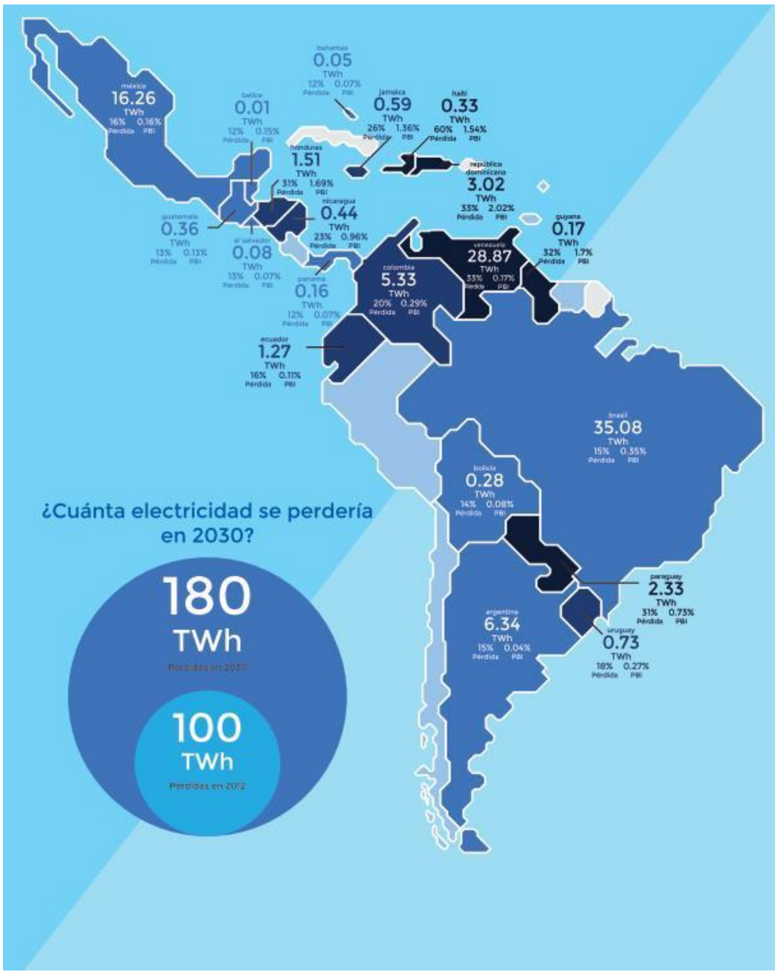

Figure 7 – Map of energy losses in Latin America. **Source:** Adapted from **(IADB, 2014)**

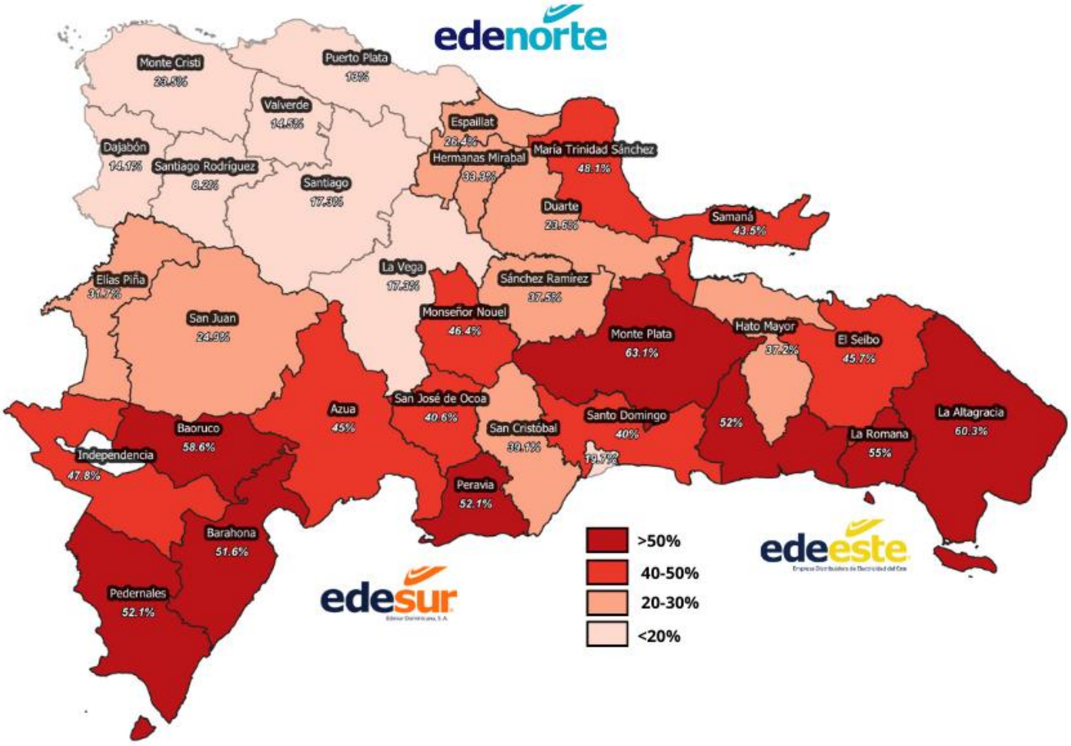

Figure 8 – Map of energy losses by province and distributor**. Source:** Prepared by the author based on data from (Consejo Unificado de las EDES, 2022)

Area of interest:

Historical data reveal that most electricity losses originate in informal circuits, in which customer identification, installation of meters and the normalization of unauthorized consumption have historically not been carried out. Less than a quarter of the total losses arise from rehabilitated circuits that have uninterrupted electricity service 24 hours a day. This finding indicates the existence of two specific elements in the problem of electricity losses: (1) relatively sophisticated fraud and corruption in wealthy areas (circuits A and B), where an adequate quality of service is observed; and (2) opportunistic fraud and non-payment in the most disadvantaged areas that have informal networks (circuits C and D), where the quality of electrical service is poor [17].

3.4.2. Solar PV Penetration by Province

As of October 2023, a total of 338.57 MWp has been installed under the Net Metering Program, distributed among 14,256 users [18]. With 58% being concentrated between Santiago de los Caballeros and Santo Domingo.

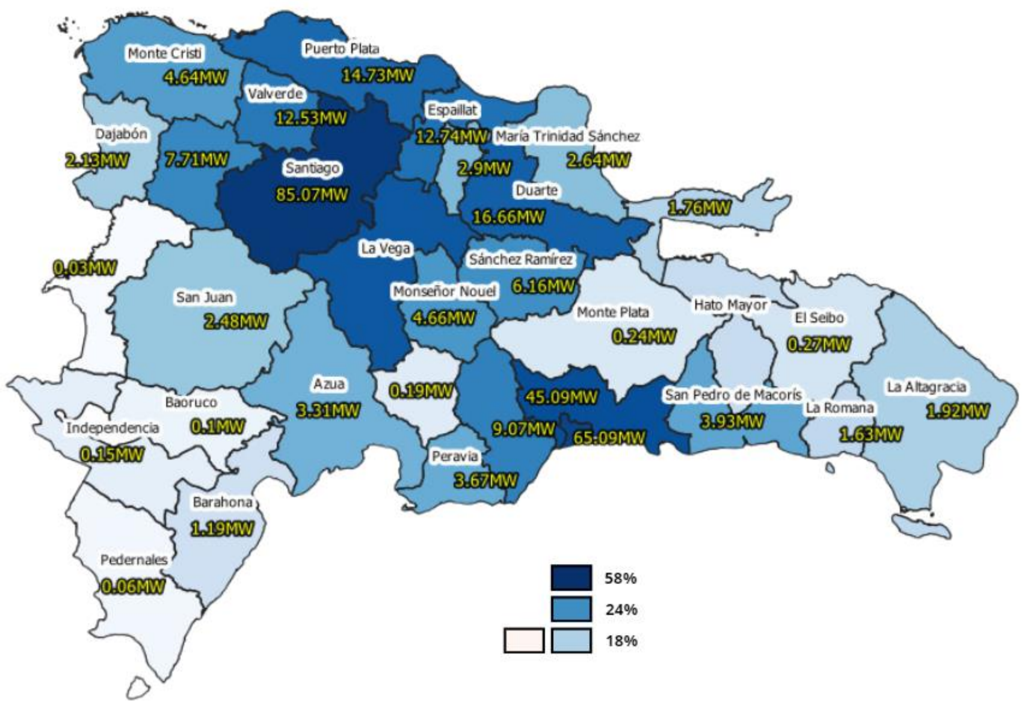

Figure 9 – Solar Net Metering installation in Dominican Republic. Source: Prepared by the author based on data from (CNE, 2023)

Area of interest:

From 2012 to October 2023, a total of 14,256 customers enrolled in the Net Metering Program. This figure accounts for a mere **0.46%** of the total customer base of the distribution companies. Meanwhile, during the same period, the country's energy demand has surged by nearly 50%, absorbing the growth of distributed renewable energies [19].

This indicates that the sales of the distribution companies (EDEs) have increased 25 times more than what net metering users have collectively reduced from grid consumption—a trend expected to intensify with the country's development and the rise of electric mobility.

Considering this, there is a pressing need to increase the share of renewables and eliminate all regulatory, infrastructure, and institutional barriers hindering renewable penetration.

3.5. Scenario 5 – Microgrids/Minigrids

A **minigrid** involves the separation of the existing grid distribution infrastructure into pockets of critical loads served by distributed energy resources and designed to operate in both grid-connected and island mode, being distinguished from **microgrids** in that they utilize existing distribution infrastructure and can be sized much larger than typical microgrids[20].

In this scenario Energy Access Explorer was used to **identify areas requiring focused attention for enhancing energy resilienc**e, where climate-driven events pose a significant threat to communities and the energy infrastructure. Using its multicriteria filters the platform synthesizes data that produces a *“heat map”* of energy access potential, which was used a proxy for minigrid locations.

Case 1: Earthquakes

Dataset	Filter
Earthquake Risk	High
Population Density	Medium (>100)
Global Horizontal Irradiation	Good: 2000-2800 kWh/m2
Energy Losses	High: > 15%

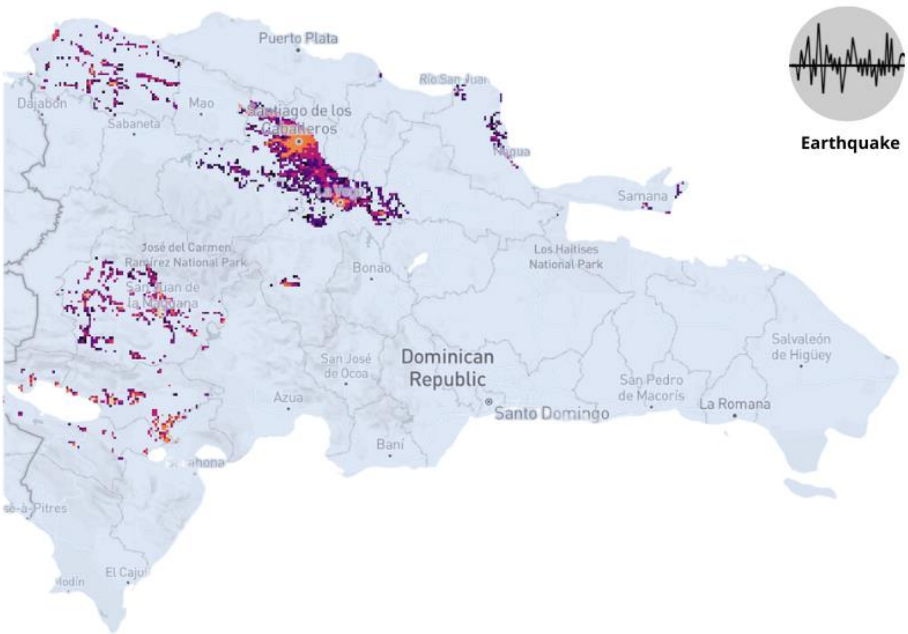

Figure 10 – Identification of areas where minigrids can enhance community resilience against earthquakes.

Areas of interest: Santiago de los Caballeros, Samaná and Montecristi.

Case 2: Floods

Dataset	Filter
Flood Risk	High
Population Density	Medium (>100)
Global Horizontal Irradiation	Good: 2000-2800 kWh/m2
Energy Losses	High: > 15%

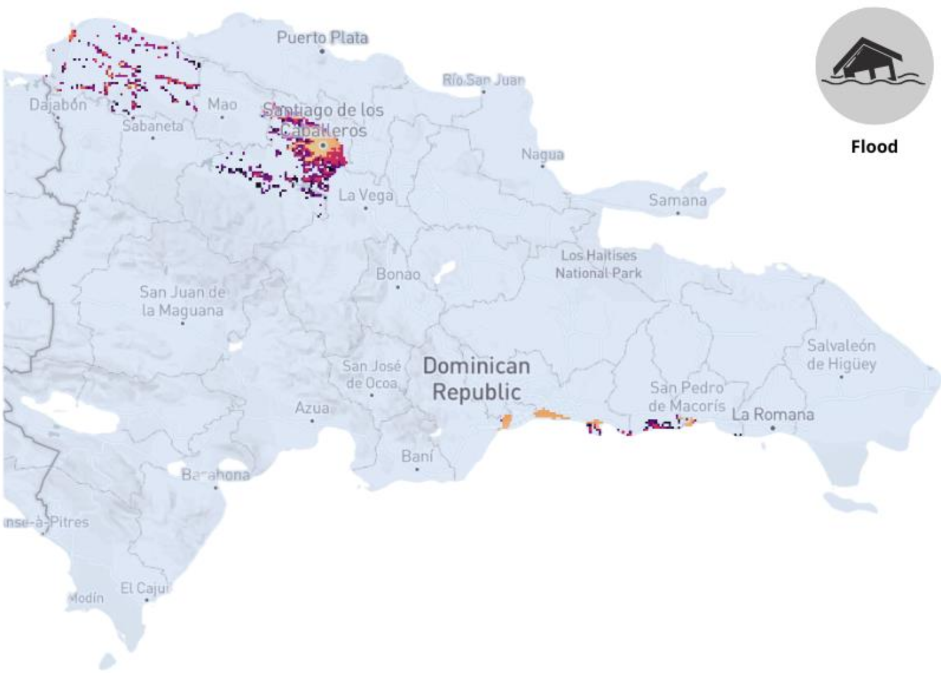

Figure 11 – Identification of areas where minigrids/micrgrids can enhance community resilience against floods.

Areas of interest: Santiago de los Caballeros, Montecristi, Santo Domingo, San Pedro de Macoris.

Case 3: Hurricanes

Dataset	Filter
Hurricane Risk	High
Population Density	Medium (>100)
Global Horizontal Irradiation	Good: 2000-2800 kWh/m2
Energy Losses	High: > 15%

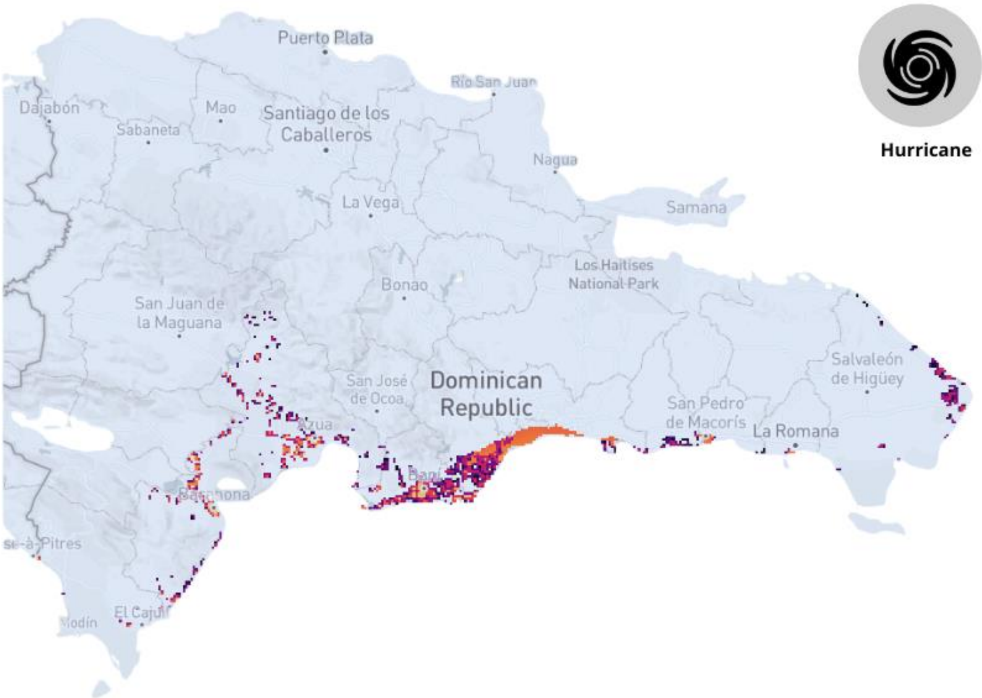

Figure 12 – Identification of areas where minigrids/microgrids can enhance community resilience against hurricanes.

Areas of interest: Santo Domingo, San Cristóbal, Azua, La Romana, Barahona y La Altagracia.

4. Discussion

4.1. Insights and results implications

To better enable system recovery in an extreme weather event and/or black start restoration, there may be operational benefits in segmenting the transmission and distribution system into smaller portions (Mini-Grids). While this would be done out of necessity after a large-scale event, there could be some advantages to **preselecting which segments are likely to survive a future event and proactively planning transmission system segmentation accordingly** [21].

These parts of the system would be identified to include a combination of generation assets, including units with black start capability, along with an appropriately sized load, so that when the distribution system is under restoration activities, there is sufficient load present to constitute the minimum generation, the stable parts of the system could be energized and maintained before the longer transmission lines are repaired and energized. These parts of the system could re-energize each other later in the restoration process.

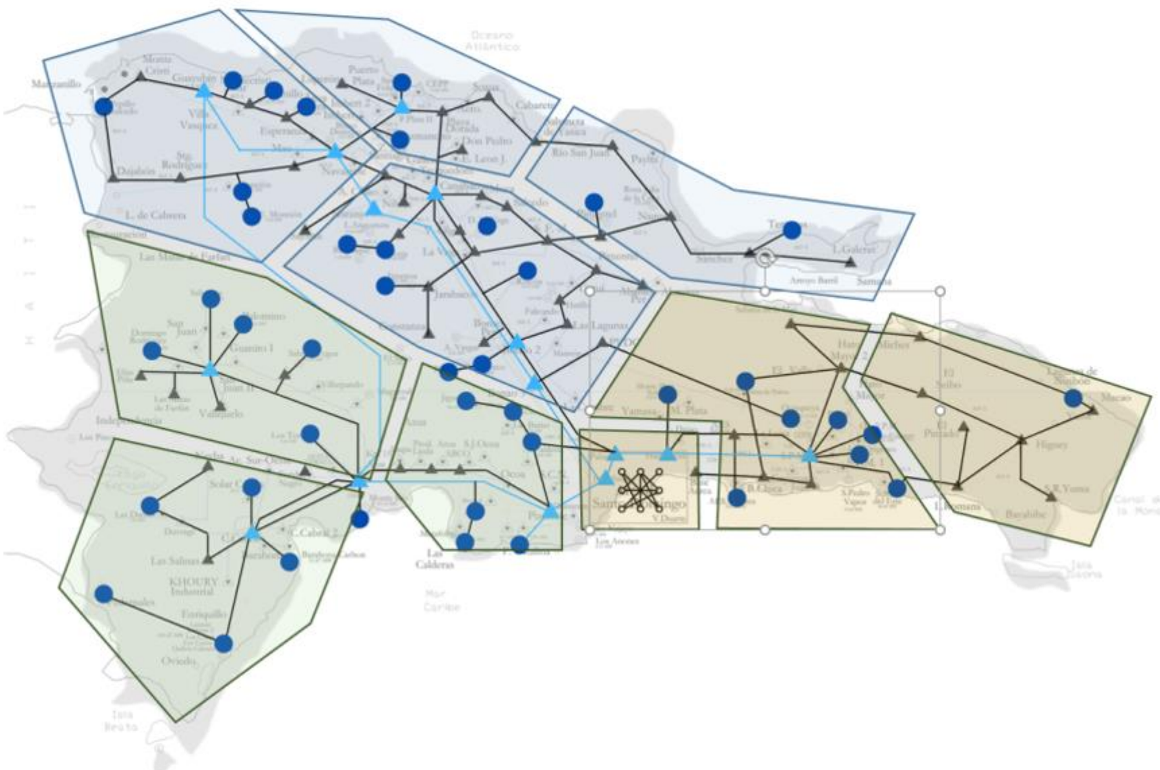

Figura 13 - A vision of Minigrids against Climate-Driven Events in Dominican Republic Source: Energy Resilience and Microgrid Research Group (PUCMM, 2023)

4.2. Policy recommendations

The **Dominican Republic** is one of the most vulnerable countries in the world to climate change (ranked 50th). However, our closest neighbors, **Puerto Rico (1st)** and **Haiti (3rd)**, have been identified among the **10 most affected countries** in the world in the last 20 years, placing the island and the region as one of the ***most vulnerable*** [22].

- **Include microgrid regulatory frameworks in the National Energy Plan updates.** Neighboring Puerto Rico is currently pioneering microgrid legislation, addressing common barriers such as grid interconnection and compensation uncertainties for services provided by microgrids to utilities [23].

4.3. Potential areas for future research

- **Multi-Hazard Assessments:** Investigate the combined impact of multiple hazards (e.g., seismic events, hurricanes, floods) on vulnerability. Develop integrated models that can assess the compounding effects of different hazards to provide a more comprehensive understanding of risk.

5. Conclusion

It is well known that a reliable electrical grid is the backbone of modern society. It plays a key role in all economic activity and ensures the wellbeing of its citizens. This is especially true for nations like the Dominican Republic, which faces the challenges of geographic isolation and the need for self-sufficiency.

Microgrids are poised to play a large role in the future of energy resilience in the world's energy systems. However, these technologies and systems face high **regulatory barriers** tied to the legacy of the 20th-century model of centralized, top-down electricity grid dispatch, so contemporary energy policies and regulations may not fully account for or be tailored to these systems in mind.

Increased demand for reliability and resilience across all productive sectors, combined with falling costs of Battery Energy Storage Systems (BESS) and the affordability of solar PV, are driving the development of microgrids across the world. Capturing and understanding these trends is essential to track regulatory barriers and public policy needs in favor of these technologies, but even more importantly, it is essential to support the country's vision towards the energy transition and its **3D: *Digitalization, Decarbonization and Decentralization.***

6. References

[1] D. Mentis *et al.*, “ENERGY ACCESS EXPLORER: DATA AND METHODS,” 2019. [Online]. Available: www.wri.org/publication/energy-access-explorer.

[2] P. J. Zarco-Periñán, I. M. Zarco-Soto, and Fco. J. Zarco-Soto, “Influence of the Population Density of Cities on Energy Consumption of Their Households,” *Sustainability*, vol. 13, no. 14, p. 7542, Jul. 2021, doi: 10.3390/su13147542.

[3] N. Walter, J. Stockman, C. Odeph, and B. Butler, “Using Meta’s Relative Wealth Index and High Resolution Population Density Data to Help Expand Electricity Access in Uganda.” Accessed: Feb. 01, 2024. [Online]. Available: https://www.wri.org/update/using-metas-relative-wealth-index-and-high-resolution-population-density-data-help-expand

[4] V. Ballesteros-Arjona *et al.*, “What are the effects of energy poverty and interventions to ameliorate it on people’s health and well-being?: A scoping review with an equity lens,” *Energy Res Soc Sci*, vol. 87, p. 102456, May 2022, doi: 10.1016/j.erss.2021.102456.

[5] Oficina Nacional de Estadística (ONE), “Eventos naturales - Una mirada georeferenciada,” Santo Domingo, 2023. Accessed: Feb. 01, 2024. [Online]. Available: https://www.one.gob.do/media/j5enijp3/bolet%C3%ADn-de-estadisticas-ambientales-2023-no-6-eventos-naturales.pdf

[6] PNUD, “Informe sobre Desarrollo Humano - República Dominicana,” 2008.

[7] N. Gómez De Travesedo and P. Saenz Ramírez, “Análisis de riesgos de desastres y vulnerabilidades en la República Dominicana Sistema Nacional de Prevención, Mitigación y Respuesta a Desastres,” 2009. [Online]. Available: http://ec.europa.eu/echo/files/funding/opportunities/interest_dipecho7_Rep_Dominicana.pdf

[8] R. E. De Jesús-Grullón, “Pérdidas de Energía en Distribución: El Agujero Negro del Sector Eléctrico en República Dominicana,” 2023. [Online]. Available: https://ehplus.do/perdidas-de-energia-en-distribucion-el-agujero-negro-del-sector-electrico-en-republica-dominicana/

[9] M. Izzo, L. Rathe, and D. Arias, “Puntos Críticos para la Vulnerabilidad a la Variabilidad y Cambio Climático en la República Dominicana y su Adaptación al mismo,” 2013. [Online]. Available: https://bvearmb.do/bitstream/handle/123456789/561/Puntos-criticos-para-la-Vulnerabiliad-al-cambio-climatico-2013.pdf?sequence=1&isAllowed=y

[10] R. E. De Jesús-Grullón, “Vulnerabilities of the Dominican Republic’s Electric Networks & Catastrophic Risks to Grid Security.” [Online]. Available: https://microgrid.pucmm.edu.do/vulnerabilities-of-the-dominican-republics-electric-networks-and-catastrophic-risks-to-grid-security/

[11] Organismo Coordinador (OC), “Operación en Isla del SENI,” 2020. [Online]. Available: https://www.oc.org.do/DesktopModules/Bring2mind/DMX/API/Entries/Download?Command=Core_Download&EntryId=159365&language=es-ES&PortalId=0&TabId=188

[12] USAID, “Dominican Republic Climate Change Vulnerability Assessment: Executive summary,” no. September, p. 8, 2013, [Online]. Available: https://www.climatelinks.org/resources/dominican-republic-climate-change-vulnerability-assessment-executive-summary

[13] Diario Libre, “Disturbio tropical rompió récord de precipitaciones en 24 horas en el país,” Santo Domingo, Nov. 20, 2023. [Online]. Available:

https://www.diariolibre.com/actualidad/nacional/2023/11/19/inundaciones-en-republica-dominicana-por-record-de-lluvia/2527947
[14] C. Yepes-Estrada and A. Calderon, “Evaluación de Riesgo Sísmico para Santiago de los Caballeros,” 2022.
[15] Ministerio de Energía y Minas (MEM-RD), “Informe de Desempeño - Marzo (2023),” 2023. [Online]. Available: https://mem.gob.do/category/sector-electrico/informe-de-desempeno/
[16] Banco Interamericano de Desarrollo (IADB), “Dimensionando las pérdidas de electricidad en los sistemas de transmisión y distribución en América Latina y el Caribe,” 2014. [Online]. Available: https://publications.iadb.org/es/publicacion/16883/electricidad-perdida-dimensionando-las-perdidas-de-electricidad-en-los-sistemas
[17] Economist Intelligence Unit, “El futuro del sector eléctrico en la República Dominicana Contenido,” *The Economist*, 2015, [Online]. Available: https://www.ces.org.do/images/2015/FunglodeElectricitySectorReportSpanishFINAL.pdf
[18] Comisión Nacional de Energía (CNE), “Estadísticas Programa de Medición Neta.” Accessed: Jan. 31, 2024. [Online]. Available: https://www.cne.gob.do/documentos/medicion-neta-documentos/
[19] Comisión Nacional de Energía, “Plan Energético Nacional República Dominicana 2022 – 2036,” 2022.
[20] Siemens Industry, “Resilient by Design: Enhanced Reliability and Resiliency for Puerto Rico’s Electric Grid Executive Summary,” *Siemens Industry Inc.*, p. 26, 2018.
[21] R. E. De Jesús, R. Batista, and A. Espinal, “Análisis de Resiliencia para el Desarrollo de Arquitectura de Microrredes frente a Eventos Climáticos en los Sistemas Eléctricos de República Dominicana,” PARTNERSHIPS FOR ENHANCED ENGAGEMENT IN RESEARCH (PEER). Accessed: Jan. 17, 2024. [Online]. Available: https://microgrid.pucmm.edu.do/wp-content/uploads/2023/10/PEER-FinallReport-MicrogridResearchPUCMM-1.pdf
[22] D. Eckstein, V. Künzel, and L. Schäfer, “Global climate risk index 2021: who suffers most from extreme weather events? Weather-related loss events in 2019 and 2000–2019,” 2021. [Online]. Available: http://germanwatch.org/en/download/8551.pdf
[23] Comisión de Energía de Puerto Rico (CEPR), “Regulation on Microgrid Development (Proposed Rules).” [Online]. Available: https://energia.pr.gov/wp-content/uploads/sites/7/2018/05/Resolution-Adoptation-of-Microgrid-Regulation.pdfhttps://energia.pr.gov/wp-content/uploads/sites/7/2018/05/Resolution-Adoptation-of-Microgrid-Regulation.pdf

7. Appendix

	Name	Category	Geography	Type	Deployed	Dated	Updated
	agricultural-drought-risk	indicator	Dominican Republic	polygons-valued			2024-01-31 (r.dejesus)
	dom-admin1-regions	boundaries	Dominican Republic	polygons-boundaries			2024-01-23 (Jake.Stockman)
	dom-admin2-provincias	boundaries	Dominican Republic	polygons-boundaries			2024-01-23 (Jake.Stockman)
	dom-admin3-municipios	boundaries	Dominican Republic	polygons-boundaries			2024-01-23 (Jake.Stockman)
	dom-admin4-distritos-municipios	boundaries	Dominican Republic	polygons-boundaries			2024-01-23 (Jake.Stockman)
	dr-admin-tiers-table	admin-tiers	Dominican Republic	table			2024-01-31 (r.dejesus)
	dr-class-crops	lc-class-crops	Dominican Republic	raster			2024-01-31 (r.dejesus)
	dr-distribution-lines	distribution	Dominican Republic	lines			2024-02-01 (r.dejesus)
	dr-drought-risk	indicator	Dominican Republic	polygons-valued			2024-02-01 (r.dejesus)
	dr-earthquake-risk	indicator	Dominican Republic	polygons-valued			2024-01-31 (r.dejesus)
	dr-energy-losses	indicator	Dominican Republic	polygons-valued			2024-01-31 (r.dejesus)
	dr-energy-sector-vulnerability	indicator	Dominican Republic	polygons-valued			2024-02-01 (r.dejesus)
	dr-flood-risk	indicator	Dominican Republic	polygons-valued			2024-01-31 (r.dejesus)
	dr-global-horizontal-irradiation	ghi	Dominican Republic	raster			2024-01-26 (r.dejesus)
	dr-hurricane-risk	indicator	Dominican Republic	polygons-valued			2024-01-31 (r.dejesus)
	dr-island-outline	outline	Dominican Republic	polygons-boundaries			2024-01-31 (r.dejesus)
	dr-landforms	landforms-global	Dominican Republic	raster			2024-01-31 (r.dejesus)
	dr-population-density	population-density	Dominican Republic	raster			2024-01-31 (r.dejesus)
	dr-protected-areas	protected-areas	Dominican Republic	polygons			2024-01-26 (r.dejesus)
	dr-relative-wealth-index	relative-wealth-index	Dominican Republic	raster			2 hours ago (r.dejesus)
	dr-schools	schools	Dominican Republic	points			2024-01-26 (r.dejesus)
	dr-transmission-lines	transmission-lines	Dominican Republic	lines			2024-01-26 (r.dejesus)
	dr-transmission-substations	transmission-substations	Dominican Republic	points			2024-01-26 (r.dejesus)
	povertyrate	indicator	Dominican Republic	polygons-valued			2024-01-26 (r.dejesus)

Table 1 - Geographic Datasets of Dominican Republic

THE WORLD BANK
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2050 PATHWAYS PLATFORM

SFU SIMON FRASER UNIVERSITY

UNIVERSITY OF CAMBRIDGE

ENERGY FOR ALL

uff Universidade Federal Fluminense

UNDP

giz

ESMAP

UKaid

ufjf Universidade Federal de Juiz de Fora

IAEA International Atomic Energy Agency
Atoms for Peace and Development

OpTIMUS

POLITECNICO MILANO 1863

iea

Imperial College London

Centre for Global Equality

Loughborough University

UNIVERSITY OF OXFORD

KTH

The Open University

DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS

Green Grids Initiative

WORLD RESOURCES INSTITUTE