

# Powerless: Puerto Rico's Grid Collapse, Recovery, and the Quest for Resilience After Hurricane Maria



May 31, 2018: Powerlines and debris cover a road after Hurricane Maria hit Puerto Rico. Photo: [Carlos Giusti, AP Images, WNYC](#)

**Author:** Kalain Hosein, Columbia Climate School,  
MA Climate and Society Student

## Summary

The 2017 Atlantic hurricane season exposed catastrophic vulnerabilities in Puerto Rico's energy infrastructure, governance systems, and disaster preparedness framework. This case study examines how a convergence of economic collapse, aging infrastructure, and climate shocks created the longest blackout in U.S. history (328 days until the last affected neighborhood had power restored). At the same time, subsequent earthquakes and cyclones revealed persistent systemic failures (Zahn, 2022). With approximately \$55 billion in FEMA funds allocated, but only \$24.5 billion spent by 2025 (*Official Transparency Portal of the Government of Puerto Rico, 2025*), the island's struggle exemplifies the challenges of rebuilding colonial-era systems under 21st-century climate pressures.

## Keywords

Cascading Failures  
Climate Resilience  
Disaster Recovery  
Disaster Risk Reduction (DRR)  
Earthquake Impacts  
Energy Equity  
Energy Infrastructure  
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Hurricane Fiona  
Hurricane Maria  
LUMA Energy  
Microgrids  
Privatization of Utilities  
Puerto Rico Energy Grid  
Renewable Energy Transition

## Pre-Maria Conditions: A System Primed for Failure

### Colonial Legacy and Economic Collapse

Puerto Rico is a semi-self-governing archipelago with 3.2 million U.S. citizens across 78 municipalities. The U.S. territory is subject to a multitude of hazards, spanning tropical cyclones and their accompanying severe weather, drought, and wildfires, as well as geological hazards like earthquakes and tsunamis. Puerto Rico's status as a U.S. territory created structural disadvantages: inability to access Chapter 9 bankruptcy protections, exclusion from federal disaster mitigation programs, and lack of voting representation in Congress (Kevane & Pachulski Stang Ziehl & Jones LLP, 2016; Whiting, 2019). Puerto Rico's industrialization depended increasingly on tax incentives, particularly the Possession Tax Credit, Section 936, which exempted federal income tax profits earned by U.S. companies in Puerto Rico and other possessions under certain conditions. From the 1970s, this credit launched an era of capital- and knowledge-intensive operations in electronics, medical devices, and pharmaceuticals. In 1995, at the height of the Section 936 bonanza, manufacturing accounted for 42% of GDP, created more than 30% of deposits in the island's banking system, and directly generated 17% of total employment. However, a phase-out of this tax incentive began in 1996 and was completed in 2006, triggering an economic freefall, with GDP declining 13.6% from 2006 to 2017 (Citizens for Tax Justice & Mendelson, 2016).

### Grid Architecture Vulnerabilities

Puerto Rico's electrical system was developed in the early 1900s by businessmen, municipal corporations, and the central government through the Department of the Interior. These piecemeal regional and local electric power companies were unified by 1941 when the Puerto Rico Electric Power Authority (PREPA) was formed (Agosto Flores, 2017). By 2017, Puerto Rico's electric system had a generation capacity of 5,839 megawatts (MW) with a mix of technologies mainly based on burning fossil fuels (steam, combustion, combined cycle, and diesel). The territory's main power plants were Costa Sur, Aguirre, and AES, located in southern Puerto Rico, and Cambalache, Palo Seco, and San Juan north of the island (Kwasinski et al., 2019). However, these generation plants were old, with 60% of the installed systems dating back about 50 years and with a relatively low efficiency of at most 30% (Kwasinski et al., 2019; 117th Congress (2021-2022) & House Committee on Natural Resources, 2021).

80% of PREPA's generation capacity was concentrated on Puerto Rico's south coast. This led to an electrical system with 2,478 miles of transmission lines, including a single transmission corridor crossing the 4,000-foot Cordillera Central Mountains (Kwasinski et al., 2019). In addition, Quiniones et al. (2017) indicated that only 15% of the lines would withstand winds from a category four hurricane.

Approximately 40% of the territory's population lives in its capital, San Juan, located north of the island. This larger population has the highest electricity demand, meaning the north-south transmission lines were critical. The terrain made the grid exceptionally vulnerable to landslides, particularly through the mountainous choke points.

Financially, a 2016 austerity plan cut PREPA's maintenance budget by 30% (Sanzillo & Kunkel, 2016), leaving vegetation overgrowth on 60% of transmission lines (Zhorov, 2018). The system operated without North American Electric Reliability Corporation standards, with 80,000 customers experiencing outages before Maria (Gheorghiu, 2019). In the lead-up to the 2017 Atlantic hurricane season, this vertically integrated electric power company carried U.S. \$9 billion in debt after decades of political patronage (Mufson, 2017) and electricity theft (Valdivieso, 2015).

## The 2017 Hurricane Season: Cascading Failures

### Hurricane Irma's Warning Shot (September 6th)

Though missing Puerto Rico by 50 miles, Hurricane Irma was a category five hurricane on the Saffir Simpson Hurricane Wind Scale with tropical-storm-force winds and hurricane-force gusts affecting much of the northern and western portions of mainland Puerto Rico (Cangialosi et al., 2021), devastating Vieques and Culebra – dependencies of Puerto Rico, as well as the U.S. Virgin Islands (Federal Emergency Management Agency, 2018b). As a result, nearly 1.1 million of Puerto Rico's population were left without power (Johnson et al., 2017), while Irma's rainfall led to widespread riverine and flash flooding, as well as landslides (Cangialosi et al., 2021). A state of emergency was declared on September 4th, before Irma's passage, and the U.S. Federal Emergency Management Agency (FEMA) was deployed by September 6th.

Given that Vieques, Culebra, and the U.S. Virgin Islands were all declared disaster zones (Federal Emergency Management Agency, 2017), FEMA's Caribbean Distribution Center deployed 90% of the stockpiled tarps/water to the U.S. Virgin Islands, leaving only 17% of inventory for subsequent events (Federal Emergency Management Agency, 2018a). DHS Office of Inspector General (2020) found that FEMA mismanaged the commodity distribution process in response to Hurricanes Irma and Maria.

By September 9th, over one million people were still without electricity, hospitals operated on generators, and the government struggled to establish contact with Vieques and Culebra (Ferré-Sadurní, 2017). Two weeks later, Puerto Rico was staring down the barrel of another category-five hurricane, but this time, a direct hit was anticipated.

## **Maria's Catastrophic Impact (September 20th)**

Hurricane Maria made landfall near Yabucoa, on Puerto Rico's southeastern coast, around 10:15 UTC on September 20th, moving from the southeast to the northwest (Pasch et al., 2023) with maximum sustained winds of 135 knots (155 mph) at category four strength. Maria became the strongest hurricane to make landfall in Puerto Rico since a category-five hurricane in 1928, with U.S. \$116.1 billion (2025 Consumer Price Index adjusted) in damage and 3,059 deaths, of which an estimated 2,975 occurred in Puerto Rico (Taylor et al., 2018), the hurricane ranks as the fourth costliest and third deadliest in U.S. history (NOAA's National Centers for Environmental Information & National Hurricane Center, 2018). The powerful storm produced hurricane-force winds across the territory, combined with torrential rainfall and significant storm surge along the coasts (Pasch et al., 2023).

Strong winds also resulted in 166,000 residential buildings being damaged or destroyed and 472,000 housing units receiving major damage or destruction (Federal Emergency Management Agency, 2018b).

Approximately 37.9 inches of rainfall triggered an estimated 40,000 landslides across Puerto Rico, nearly 100 times the historical average (Besette-Kirton et al., 2019). Maria's winds and landslides knocked down 80% of Puerto Rico's utility poles and all transmission lines, resulting in the largest power outage in U.S. history, with all 3.4 million residents without power, water, or cell phone service (Anagnostakos et al., 2023).

## **Collapse Dynamics: Institutional Breakdown**

### **Cascading System Failures**

Following Hurricane Maria, damage to power generation plants was considered minor compared to other assets (Kwasinski et al., 2019), though many experienced flooding, particularly in Cambalache. Puerto Rico also has renewable energy comprising its generation capacity, and post-Maria, one of the two industrial wind farms suffered damage to all its turbines. In addition, all five utility-scale photovoltaic plants suffered damage. While generation capacity remained somewhat available, the most significant damage was to Puerto Rico's transmission and distribution infrastructure.

Of the 2,478 miles of transmission lines, only 98 miles are underground, and 55 miles are submarine (Kwasinski et al., 2019). In addition to the 342 substations, 80% of the above-ground transmission was downed, damaged, or destroyed in Maria. These overhead transmission lines, supported by approximately 75,000 wooden, concrete, or metal poles, were destroyed due to a combination of winds, trees, and flying debris (Quiniones et al., 2017).

It is estimated that Puerto Rico has over 30,000 miles of distribution lines (all above ground), and more than half a million poles were used to support this network. Kwasinski et al. (2019) found that while no exact figures were produced by PREPA, at least 10% of these poles were damaged, considerably higher than the 1-3% in areas affected by past hurricanes (Krishnamurthy & Kwasinski, 2013).

## **Controversial Response Efforts**

As Puerto Rico remained in darkness, power plants were gradually returned online (Mayaguez on September 25th, Costa Sur on October 2nd, Cambalache on October 4th, and Aguirre on October 5th) while transmission and distribution networks were repaired or replaced. One month after Maria's landfall, 89% of Puerto Rico still had no power, 44% had no water, and 58% had no phone service (Bump, 2017). As Maria's contested death toll rose, 25 of the territory's 69 hospitals were still not reconnected to the power grid (Liautaud, 2017). The lack of power, clean water, and adequate health facilities led to a deadly combination of unsanitary conditions in areas with minimal access to aid. For the first time since Hurricane Katrina in 2005, Oxfam, an international relief organization, intervened on American soil (Holmes, 2017).

PREPA decided not to invoke mutual aid agreements with other public utilities the way Florida did for Irma out of a lack of ability to repay, according to PREPA CEO Ricardo Ramos. Instead, Puerto Rico's government signed agreements with private contractors, and almost half were awarded without bidding (Bade, 2017). On October 19th, Whitefish Energy announced it had signed a \$300 million contract with PREPA to repair and reconstruct large portions of the electrical infrastructure. The subcontracting company, a subsidiary of Brazil's Comtrafo S.A., employed only two people when Maria made landfall and was based in Whitefish, Montana, the hometown of the then-Interior Secretary Ryan Zinke. The contract, paying \$319/hour for linemen versus \$63/hour under mutual aid agreements, a \$332/day meal allowance, and prohibited audits, drew scrutiny and criticism from Congress (Campbell & Irfan, 2017). On October 27th, FEMA, which controlled government reimbursements, said it had "significant concerns" about how Whitefish secured the contract. The contract led to investigations by Congress and the FBI. PREPA's CEO resigned in the wake of the debacle in November (Campbell, 2017).

As 2017 came to a close, 45% of Puerto Ricans were still without power – an estimated 1.5 million people, with 14% without tap water, but over 90% of the cell service was restored (Holmes, 2017). Puerto Rico experienced two more island-wide blackouts in 2018 and even entered the 2018 Atlantic hurricane season with approximately 11,000 households without power, even after an estimated \$3.8 billion was spent on power grid repair (CBS News, 2018).

By 2025, of the \$91.5 billion allocated to Puerto Rico for recovery, reconstruction, and resilience through FEMA, U.S. Department of Housing and Urban Development, the CARES Act, the American Rescue Plan Act, and other funds, only \$39.1 billion has been disbursed (*Official Transparency Portal of the Government of Puerto Rico*, 2025). The delayed funding, particularly FEMA-related funding, has been hindered due to a lack of clarity on what is eligible for funding (United States Government Accountability Office, 2019). During the FEMA administration that predates the second Trump presidency, FEMA had new authorities to fund projects that enhance resilience and restore grid infrastructure to the latest industry standard. However, it did not define resilience or acceptable standards (United States Government Accountability Office, 2019).

## Recovery and Rebuilding: Missed Opportunities

### Privatization Debates

On January 22nd, 2018, then-Puerto Rican Governor Ricardo Rossello announced that PREPA would be privatized (ABC News, 2018) as part of Puerto Rico's Financial Oversight and Management Board reforms to restructure the territory's debt. However, PREPA was still fraught with controversy. From accepting a \$1.5 billion fossil fuel contract during Hurricane Maria (Sanzillo et al., 2020) to not adhering to applicable laws, which led to financial loss, contracting irregularities, and major project mismanagement (Puerto Rico's Office of the Comptroller, 2020), PREPA accumulated over \$9 billion in debt.

PREPA signed a controversial \$1.5 billion contract with LUMA Energy, a Canadian-American private power company, in June 2020, nearly 6 months after the company was founded (Capella, 2021). The 300-page contract, which was approved within 43 minutes, allowed LUMA Energy to manage PREPA's damaged transmission and distribution network for a period of 15 years (León, 2021).

LUMA Energy officially took over on June 1, 2021, and, like with PREPA, controversies and service failures followed. Electricity rates increased by 18% despite 12-hour daily outages in 2022, disproportionately affecting households spending 30% of their income on energy. LUMA also cut 30% of PREPA's unionized workforce, outsourcing maintenance to \$1,200/day contractors (O'Connell-Domenech, 2022). Kunkel et al. (2021) found that LUMA Energy may spend more than \$1 billion on off-island consultants, nearly triple what was being spent on grid hardening, which left the territory vulnerable to future tropical cyclones.

In March 2019, another deal approved a \$1.5 billion contract to New Fortress Energy to supply natural gas to PREPA and convert the San Juan power plant from diesel to gas, attempting to use “cheaper and cleaner fuel,” reducing monthly costs (Gallucci, 2022). However, like many deals that preceded this new contract, it was mired in irregularities, insufficient legal review and financial oversight, and locked in fossil fuels for Puerto Rico’s energy future (Sanzillo & Vila-Biaggi, 2020).

## **Renewable Energy Push**

The Puerto Rico Energy Public Policy Act (Act 17) set a goal for the territory to produce its electricity with 100% renewable energy by 2050, with an interim target of 40% by 2025. Nearly half of the \$1 billion Puerto Rico Energy Resilience Fund through the U.S. Department of Energy is meant to install rooftop solar and battery backup systems on the homes of vulnerable residents in Puerto Rico (Angueira, 2023), overcoming the high upfront costs and credit requirements, which typically leave low-income municipalities underserved.

While government funding is slowly mobilized, one community, Adjuntas, is a trailblazer in boosting Puerto Rico's energy resiliency. The community of 17,600 residents in the island's mountainous western interior has the territory's first cooperatively managed solar microgrid. The 187 kW solar and battery system powers 50+ clinics and businesses in Adjuntas. It was developed independently of federal programs and supported by the Honnold Foundation and Rivian (Winters, 2023).

## **Subsequent Disasters: Compounding Crises**

### **2019-2020 Puerto Rico Earthquakes**

On January 7th, 2020, a magnitude 6.4 earthquake struck Puerto Rico's southwestern coast at 8:24 UTC following weeks of hundreds of foreshocks (U.S. Department of the Interior & U.S. Geological Survey, 2020). This damaging earthquake knocked out the Costa Sur power plant, which produced 40% of Puerto Rico's electricity. The earthquake caused extensive damage, initially causing an island-wide outage, but at least 250,000 customers were without power for a week (Cancel, 2020), exposing LUMA's failure to seismic-proof substations. In the following weeks, thousands of aftershocks led to delays in restoration (Mazzei, 2020).

As of 2025, Costa Sur has received over \$125 million in FEMA funding to replace equipment damaged by Hurricane Maria and the 2019-2020 earthquakes (Federal Emergency Management Agency, 2024). In addition, FEMA assigned \$238 million to help cover costs related to backup units that were used to meet the demand previously covered by Costa Sur.

## Hurricane Fiona (2022)

On September 18th, 2022, Hurricane Fiona, a Category one hurricane at the time, moved across Puerto Rico's southeastern corner, drenching the island with rainfall totals as high as 32.40 inches, accompanied by hurricane-force wind gusts as high as 103 mph (Pasch, Reinhart, et al., 2023). Winds and rains once more affected the territory's grid with wind damage, flying debris, and widespread flooding and landslides, causing another island-wide power outage (Ravipati, 2022). 100,00 customers remained without power for two weeks (Sullivan, 2022). LUMA took 18 days to restore 95% service, drawing criticism for prioritizing urban centers like San Juan over rural municipalities (LUMA Energy, 2022). However, Casa Pueblo's microgrid in Adjuntas maintained electricity for nine days while the surrounding areas remained in the dark (Office of Energy Efficiency & Renewable Energy, 2023). At this point in Puerto Rico's rebuilding post-Hurricane Maria, only \$40.3 million in FEMA funds for the island in the category of "utilities" has been spent, even though more than \$12 billion in FEMA funds have been allocated for the reconstruction of the grid (Sanzillo, 2022).

## Lessons in Cascading Failure

Puerto Rico's energy crisis stems from colonial policies (Section 936's 1996–2006 phaseout), climate (and other natural hazard) denial, and austerity. As climate models show more intense and slower-moving hurricanes (Emanuel, 1987; Knutson et al., 2010; Intergovernmental Panel on Climate Change, 2023), decentralized solar microgrids—like Adjuntas's 700-panel cooperative—offer resilience. However, dismantling LUMA's legacy debt and PREPA's bureaucracy requires Congressional action to reallocate stalled funding toward community-led projects.

## Discussion Questions:

1. How did Puerto Rico's colonial economic policies (e.g., Section 936 phaseouts) and infrastructure austerity measures create cascading vulnerabilities that transformed Hurricane Maria from a natural hazard into a humanitarian disaster?
2. Evaluate the tension between rapid grid restoration ("spaghetti lines") and climate-resilient rebuilding in Puerto Rico. What metrics would you use to balance immediate needs against 50-year infrastructure lifespans?
3. Analyze why only \$24.5 billion of FEMA-provided funding was spent by 2025 despite urgent needs. How might disaster agencies redesign procurement rules to accelerate projects without compromising environmental/anti-corruption safeguards?
4. Casa Pueblo's microgrid powered 50+ clinics during Fiona, while LUMA failed. What policy mechanisms could scale grassroots energy models without co-opting them into centralized systems?
5. Puerto Rico's experience with hurricanes, earthquakes, and financial crises highlights the need for multi-hazard risk assessment. How can other disaster-prone regions develop infrastructure and governance systems that are robust to multiple, overlapping hazards, rather than planning for one type of event at a time?
6. How do colonial histories and territorial status impact disaster preparedness, response, and long-term recovery in other regions (e.g., U.S. Virgin Islands, French Caribbean, Pacific territories)? What parallels or differences can be drawn with Puerto Rico's experience after Hurricane Maria?

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