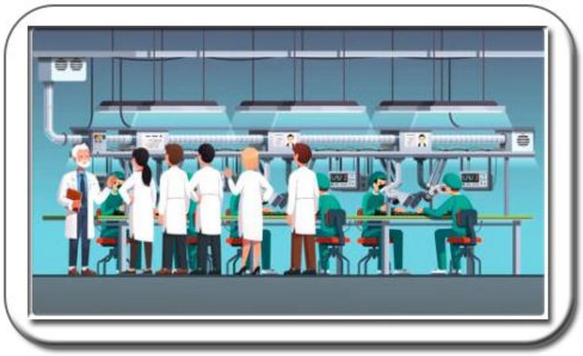


In-depth Research: Power Outages, Costs, Impacts, & Comparisons – Repair or Replace?

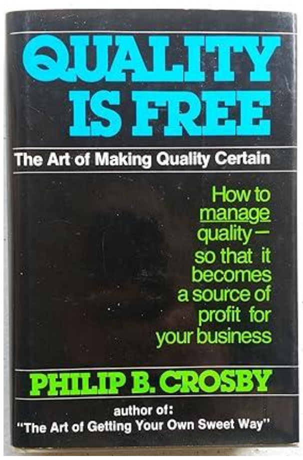
Vortex Energy Group LLC
www.VortexEnergyGroup.com

The following pages represent a portion of the research we have done regarding power outages in Puerto Rico. Included is information about when the major power outages have occurred, duration, cause, the financial cost, and most importantly, the human impact.

Unfortunately, there is some data that is not available, for various reasons, but a substantial reason is that the intel was never gathered. However, we believe that the information we have been able to compile, strikes an extremely concerning position.

For too long, humans have tried to take the quick, convenient, and safe method to resolve some of these public issues. A quick glance at the costs of repair and restoring a damaged grid, will tell you that the costs of a band-aid approach is just not viable, and should not be acceptable. In these pages, you will see details and read information that will hopefully lead to a true “do it right the first time” solution.

"Do it right the first time," also known as First Time Right (FTR) or Right First Time (RFT), is a principle focused on achieving quality, efficiency, and cost savings by eliminating errors and rework from the outset of a process or project. It involves investing time and effort to ensure tasks are completed correctly from the beginning, rather than fixing mistakes later. Key strategies include building quality into the process through standards and training, providing clear information and the right tools, fostering a strong company culture focused on prevention, and using data to identify and resolve root causes of errors.



I was fortunate to have a chance to read this book: ***Quality Is Free*** by Philip B. Crosby. As a salesman, I thought it didn’t apply to me, after all, I’m not building anything. (One of the best examples in the book is about the Zenith Works-in-a-drawer TV sets. I won’t spoil the plot!)

Suffice it to say that each of us, regardless of our job or task at hand, can learn something by simply following the concept of doing something right to the best of our ability on the first pass.

I know you’re probably excited to go out and get this book. Amazon has it available.

We believe that starting immediately on doing the right thing, which in this case is to do the strengthening, hardening, and undergrounding in Puerto Rico, leading to saving a great deal of money in the future, but most importantly, save a lot of human lives.

Puerto Rico Major Power Outages: Financial vs. Human/Economic Costs

This table provides a side-by-side comparison of restoration/repair costs versus the broader human and economic losses caused by major outages in Puerto Rico over the last decade. While restoration costs capture the utility and government expenditures for repairing lines, poles, and substations, the human/economic losses reflect mortality, healthcare impacts, lost business activity, and migration effects.

Event (Year)	Restoration & Repair Costs	Human & Economic Losses	Notes
Sep 2016 – Aguirre Fire	~$20–30M (PREPA est.)	Productivity loss; school/business closures	No deaths tied to outage
Sep 2017 – Hurricane Irma	Hundreds of millions (storm prep + repairs)	Economic slowdown; service disruption	Outage overlapped with Maria recovery window
Sep 2017 – Hurricane Maria	~$3–4B in grid repair (FEMA + PREPA); total **~$90B in damages**	~2,975 excess deaths; economic contraction ~15%; mass migration	Deadliest U.S. natural disaster in a century
Feb 2018 – San Juan Substation Fire	Tens of millions	Minimal documented human loss; economic disruption	Localized but large outage
Apr 2018 – Excavator Line Hit	Tens of millions	No documented deaths; short-term disruption	Island-wide blackout from human error
Jan 2020 – Earthquakes	~$200M grid repair; billions broader	Deaths from quake; outage worsened humanitarian crisis	Costa Sur offline for months
Jun 2021 – Monacillo Fire	Tens of millions	Business losses; health service interruptions	Cyberattack allegations worsened trust issues
Apr 2022 – Costa Sur Fire	Hundreds of millions	No deaths reported; economic slowdown	Island-wide outage for days
Sep 2022 – Hurricane Fiona	~$1B+ in damage	≥21–25 deaths; CO poisonings; lost wages and services	Weeks-long outages in rural areas
Dec 2024 – New Year's Eve Blackout	Tens of millions	No documented deaths; holiday/economic disruption	Underground transmission failure
Apr 2025 – Cambalache–Manatí Blackout	Tens of millions	No deaths reported; water and health services disrupted	Vegetation + protection system failure

This comparison illustrates that while restoration costs are measured in millions to billions, the human and economic losses — in lost lives, public health crises, economic contraction, and migration — are often much larger. Proactive investment in resilient infrastructure can dramatically reduce both categories of loss.

Puerto Rico – Storm Restoration vs. Hardening Cost Brief

1. Context

Puerto Rico's grid continues to face catastrophic losses after hurricanes. Restoration after Maria, Fiona, and other events cost billions, with pole replacements, line repairs, and staging logistics consuming much of the funds. By contrast, Category 5 hurricane-proof buildings for generation equipment and hardened steel poles/towers represent one-time resilience investments.

2. Estimated Restoration Cost – Wooden Distribution Poles

Historical and FEMA/PUC filings provide the following per-pole benchmarks:
-- 2009 Texas PUC study: ~$4,000 per pole (storm restoration).
-- FEMA estimates (damage assessments): ~$4,750 per pole.
-- 2025 adjusted range (inflation + storm multipliers): $6,000–$12,000 per pole in typical access zones; $10,000–$18,000+ per pole in Puerto Rico or difficult conditions.

3. Anatomy of Per-Pole Restoration Cost

-- Materials: $700–$1,500 (wood pole, crossarm, hardware, insulators, anchors).
-- Labor + equipment: $1,800–$4,500 (lineworkers, bucket trucks, digger derricks).
-- Supervision/overhead: $800–$2,000 (field supervisors, dispatch, staging).
-- Disposal/hauling: $200–$600 (removal and disposal of damaged poles/lines).
-- Storm multiplier: ×1.2–1.8 for mutual-aid crews, overtime, expedited materials, access challenges.
-- Resulting range: $6,000–$18,000+ per pole under storm restoration conditions.

4. Scale of Restoration Costs (Recent Events)

-- FPL (Hurricanes Ian & Nicole, 2022): ~$1.0–$1.2B.
-- Duke Energy (2024 season, FL/Carolinas): $1.1–$2.9B.
-- Entergy Louisiana (Hurricane Ida, 2021): ~$1.4–$1.5B.
-- Puerto Rico (post-Maria 2017): FEMA/GAO document ~$10B obligated for grid repairs.

5. Hardening Investments

Steel/concrete/composite poles or towers: Resilient to Cat-5 wind loads, anchored foundations.
-- Category 5 hurricane-proof generation buildings: Elevated, reinforced concrete, debris-resistant doors/windows, designed to ASCE 7-22 Risk Category IV, NFPA 850 fire protection.
-- Targeted undergrounding: High-risk laterals and corridors, eliminating storm-related vegetation failures.
-- O&M benefits: Lower vegetation management, reduced recurring pole replacement, faster restoration.

6. Cost-Benefit Framing

Each storm event requires replacement of thousands of poles across Puerto Rico. At $10,000–$18,000 per pole, storm costs quickly escalate to hundreds of millions. By comparison, investing once in hardened poles, Cat-5 buildings, and selective undergrounding avoids repeated restoration cycles, protects critical generation, and reduces outage durations for hospitals, emergency services, and communities.

7. Rule-of-Thumb Calculator

-- Estimated storm restoration cost = (Number of poles damaged) × ($6,000–$18,000 per pole).
-- Example: 5,000 poles × $10,000 = $50M (low end).
-- Example: 10,000 poles × $15,000 = $150M (moderate case).
-- Example: 20,000 poles × $18,000 = $360M (severe case).

Building for power generation system:

Strictly speaking, codes don't certify "Category-5 proof." Designers achieve **ASCE 7-22 wind speeds** (Risk Cat IV) with impact/debris protection and flood design per **ASCE 24 / IBC 2024**—that's the standard way to meet "Cat-5-equivalent" performance. ICC

However, we may continue to refer to Cat-5 hurricane-proof, because it's a term that is widely accepted.

8. Building cost (15,000 sq ft hardened, Risk Cat IV)

What you're building: single-story, heavy reinforced concrete or steel frame with concrete/CMU envelope, debris-impact-rated doors/windows, roof diaphragm uplift detailing, mechanical/electrical elevated above DFE, perimeter flood measures where applicable, NFPA 850 fire/life-safety for generating plants.

- Base industrial shell benchmark (North America): Typical distribution/industrial shells often land around **$125–$225/sf** (market dependent). Use this only as a floor/anchor. Cushwake
- HARDENED critical facility uplift: For Risk Category IV wind, debris impact, and flood hardening, plus Puerto Rico logistics, a realistic planning band is **~$275–$450 per sq ft** for the building. This aligns with the idea that a hardened shell can run **~1.4×–2.0×** a standard industrial shell, but well below a full data-center build (often **$625–$1,135/sf** including heavy MEP fit-out). Cushwake

15,000 sf total building cost (hardening included):

- **Low**: 15,000 × $275 ≈ **$4.1 M**
- **Mid**: 15,000 × $350 ≈ **$5.3 M**
- **High**: 15,000 × $450 ≈ **$6.8 M**

Why the spread? PR freight/logistics, elevated/anchored foundations, impact-rated assemblies, and floodproofing push costs up; site conditions (soil, surge, elevation) are the biggest wildcards. Codes driving the scope: **IBC 2024** + **ASCE 7-22** wind/tornado provisions (Risk Cat IV) and **ASCE 24** flood-resistant construction; for generation buildings, **NFPA 850** good practice. ICC

9. Site size (acreage) to plan for:

For a 15,000 sf hardened envelope housing generation gear, you'll want room for: transformer yard, fuel systems, fire lanes, laydown/maintenance, stormwater/flood berms, and security standoff.

- Tight urban/industrial fit: ~2 acres can work with efficient layout and limited yard.
- Comfortable program w/ yard & flood works: ~3–5 acres is more typical for plants with auxiliaries (tanks, chillers, spares), access loops, and drainage controls.

10. Puerto Rico land cost (per acre)

Recent sold comps show very wide pricing depending on municipality and use (industrial vs. rural ag). Examples from 2024–2025 sales:

- Industrial lots (Las Piedras): 8.52 acres sold **$2.16 M → ≈ $253k/acre** (also a smaller 1.81 ac lot at same $/ac). Total Commercial
- Bayamón commercial (8.66 ac): **$4.0 M → ≈ $462k/acre**. Total Commercial
- Large rural tract (Vega Baja, 388 ac): **$6.4 M → ≈ $16.5k/acre** (illustrates rural low). Total Commercial

Planning bands for your use-case (industrial/utility):

- Metro/prime industrial (San Juan/Bayamón/Caguas belts): $300k–$600k/acre
- Secondary industrial municipalities: $150k–$300k/acre
- Rural/peripheral (with utility zoning hurdles): $20k–$150k/acre
  (Use the band that matches your target municipality; the sold comps above frame the spread. Total Commercial)

11. Quick "all-in-site" sketch (order-of-magnitude)

Choose land = **3 acres** in a secondary industrial zone at **$225k/acre** → land ≈ **$675k**.
Building (15,000 sf hardened at mid) ≈ **$5.3 M**.
Subtotal ≈ **$6.0 M** (excludes siteworks).
Add siteworks & external systems (foundations/elevation, utilities, yard paving, drainage, flood barriers, security fence, transformer pads, fuel tanks, permitting/AE): often **25%–50% of building** depending on flood measures and utility scope → **+$1.3–$2.6 M**.
ROM total (land + building + site) ≈ **$7.3–$8.6 M** for the mid scenario.
(Heavy flood berms or coastal surge defenses can push higher.)

12. Why this approach is defensible

- Cost anchors**:** Industrial shell guides (Cushman & Wakefield) and data-center shell upper bounds (as a known hardened analog) bracket the per-sf range. Cushwake
- Code anchors: **IBC 2024 / ASCE 7-22** (Risk Category IV wind/tornado loads; impact protection) and **ASCE 24** floodproofing justify the uplift vs. standard shells; **FEMA P-361** safe-room guidance is a recognized reference for debris/impact hardening philosophies. ICC
- Land comps: Actual Puerto Rico sale records show realistic **$/acre** bands by locale. Total Commercial

Power Outages in PR

The following is an overview of Puerto Rico's outages over roughly the last year—with counts, locations (where available), customers affected, likely causes, and restoration times. We're using the best-available public metrics (EIA + LUMA filings) plus incident reports/news for event-level detail.

Overview (Sept 1, 2024 → Sept 20, 2025)

- **Average service reliability (2024):** Customers were without power **~73 hours** total on average, of which **~43 hours** were from major events (hurricanes/large system events). Excluding major events, average outage time was **~27 hours**. Average **frequency** was **~19 interruptions** per customer in 2024 (14 non-major, 5 major). U.S. Energy Information Administration

- **Major system events this period:**

  1. **Island-wide blackout – Dec 31, 2024 (New Year's Eve):** ≥**1.2–1.3M customers** affected; restoration to **~98%** within ~36–48 hours; preliminary cause: **failed underground transmission line/protection**. Locations: **island-wide**, with early restoration prioritized in the metro area. The Weather Channel

  2. **Island-wide blackout – Apr 16, 2025:** About **1.15–1.5M customers** lost power after a **transmission protection failure + vegetation encroachment** on the **Cambalache–Manatí** corridor triggered generator trips. **~90–98%** restoration within ~48 hours. Locations: island-wide; transmission corridor **north coast (Arecibo/Manatí region)** flagged. The Washington Post

  3. **Tropical Storm/Hurricane Ernesto – Aug 14–17, 2024:** Peak **~407k–725k customers** without power; rolling restorations over several days as weather cleared; cause: **wind/rain damage**. Locations: widespread; LUMA issued region-by-region ETRs. Reuters

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System-wide reliability metrics

- **SAIDI (duration) & SAIFI (frequency):** EIA's early-release 2024 data reports **~73 hours** total interruption time per customer (SAIDI), **~27 hours** excluding major events, and **~19 interruptions** per customer (SAIFI). This illustrates that—**even without storms**—non-storm outages are frequent and lengthy relative to mainland U.S. U.S. Energy Information Administration

- **What counts as a "major event," and what gets included/excluded?** LUMA told the Energy Bureau it applies **IEEE 1366** methods: **momentary** (≤5 minutes) are excluded; **Major Event Days** (MEDs) are filtered using a calculated **Tmed** (FY2025 Tmed ≈ **21.38 minutes** daily SAIDI). LUMA also enumerated **cause codes** (transmission faults, weather, vegetation, equipment failure, human error, load-shed, etc.) and which are included/excluded in SAIDI/SAIFI. Energia Puerto Rico

Notable outage events (last ~12 months)

Date (local)	Where (primary location/corridor)	Customers w/o power (peak)	Primary cause(s) reported	Duration / Restoration
Dec 31, 2024	**Island-wide**; initial fault tied to **underground line**, metro prioritized for early restoration	**≥1.2–1.3M**	Protection/underground transmission failure under investigation	**~24–48 hrs** to restore ~98% by Jan 1 PM
Apr 16, 2025	**Island-wide** after issue between **Cambalache–Manatí** caused unit trips	**~1.15–1.5M**	**Transmission protection failure + vegetation** interference; cascading generator trips	**~48 hrs** to ~98% restored; ~400k lost water pressure temporarily
Aug 14–17, 2024 (Ernesto)	**Widespread**; region-by-region ETRs issued	**~407k–725k** (varied during event)	**High winds/rain**; weather-related distribution damage	Multi-day rolling restoration; >**500k** restored by Aug 17; ~**182k** still out on Aug 17 update

Note: LUMA's public "Service Updates" page only lists **events >500 customers** with **ETRs**, but it's not a fully searchable historical log. PowerOutage.us discontinued LUMA/PR scraping at LUMA's request, so independent historical time-series are limited. Luma Energy

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Causes: how outages are categorized (per LUMA)

LUMA's filing lists cause codes across **transmission (115/230/38 kV)**, **weather (rain/wind/lightning)**, **vegetation/animals**, **equipment failures** (breakers, insulators, lightning arresters, capacitors, cutouts), **human error**, **excavation damage**, and **load-shed/contingency**. It also specifies which codes are **included** in SAIDI/SAIFI and which are **excluded** (e.g., **planned load-shed**, **major storm/earthquake** as MEDs). This is useful for classifying incident logs by root cause. Energia Puerto Rico

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Where outages occur (regional notes)

- **Island-wide events** (Dec 31, 2024; Apr 16, 2025) are **system** incidents: a **transmission corridor fault** can trip generation and propagate instantly across all regions. April's event specifically flagged the **Cambalache–Manatí** line on the **north coast** as the initial trigger. The Washington Post
- **Storm events** (e.g., Ernesto) tend to show high counts in **coastal and mountain** municipalities where wind/rain/landslides hit feeders hardest; LUMA communicates **service-region ETRs** during these. Luma Energy

How long outages last

- **Routine (non-major) outages:** contribute **~27 hours/year** of downtime on average (2024), spread over **~14 interruptions**—i.e., **~2 hours per non-major interruption** on average, acknowledging wide variation. *(Back-of-envelope from EIA SAIDI/SAIFI.)* U.S. Energy Information Administration
- **Major events:**
  - **New Year's Eve 2024: ~24–48 hours** for most customers to be restored. The Weather Channel
  - **Apr 16, 2025: ~48 hours** to restore **~98%** of customers. AP News
  - **Ernesto (Aug 2024):** multi-day rolling restorations as weather cleared. Reuters

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Data limitations

- **Monthly SAIDI/SAIFI** are official, but LUMA now submits many values via **Excel exhibits** to the regulator—numbers are referenced in PDFs but not embedded there; officials can cite the filings and attach the spreadsheets when provided. Energia Puerto Rico
- **Public, historical incident-level logs** (who/where/how long for every feeder) aren't centrally published for PR. Third-party aggregators (PowerOutage.us) **no longer show PR** because LUMA asked them to stop redistributing its data. For ongoing projects, this argues for our own **data capture** (API/polling) during future events and for **direct data-sharing agreements** with the operators. Power Outage USA

Practical takeaways

- Cite **EIA 2024**: *~73 hours total, ~27 hours non-major, 19 interruptions*—it's a credible, neutral benchmark showing both chronic (non-storm) and acute (storm) exposure. U.S. Energy Information Administration
- Use **event case studies** (Dec 31, 2024; Apr 16, 2025; Ernesto) to demonstrate risks from **transmission corridors**, **vegetation**, and **weather**—and why **Cat-5 buildings, hardened poles/towers, and undergrounding** in critical segments reduce island-wide cascade risk. The Washington Post
- When **root-cause attribution** is needed, officials can cite incident descriptions to LUMA's **cause codes** (weather/vegetation/transmission/equipment/human error/load-shed etc.) to speak the regulator's language. Energia Puerto Rico

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Following is a concise 10-year "ledger" of Puerto Rico's **major, territory-scale power outages** with the **cause, duration, customers affected**, and a note on **loss of life linked to extended outages** when credible sources document it.

Major Puerto Rico power outages (2016–2025)

- **Sep 21–23, 2016 — Island-wide ("Apagón 2016")**
  Cause: Fire at the Aguirre (Salinas) substation cascaded across the grid.
  Impact/Duration: ~**1.5M customers** out; large portions dark **>24–50+ hrs**.
  Deaths tied to outage: None documented (though **15 generator fires** reported). Earth Observatory
- **Sep 6–9, 2017 — Hurricane Irma**
  Cause: Tropical-cyclone wind/rain impacts.

Impact/Duration: Widespread outages for days; set the stage for Maria two weeks later.
Deaths tied to outage: Not clearly attributed. RAND Corporation

- **Sep 20, 2017 → well into 2018 — Hurricane Maria (largest blackout in U.S. history)**
  Cause: Cat-4 landfall; systemwide T&D destruction.
  Impact/Duration: All 3.3M+ residents initially without power; some areas lacked electricity **11–18 months**.
  Deaths tied to extended outage: ~2,975 excess deaths (independent GWU study of the 6 months after landfall). Government Accountability Office
- **Feb 11, 2018 — San Juan/North region large blackout**
  Cause: Substation explosion/fire (mechanical failure).
  Impact/Duration: Large swath of the north including San Juan; **~1 day** target to restore.
  Deaths tied to outage: None reported. Business Insider
- **Apr 18–19, 2018 — Island-wide**
  Cause: Excavator hit a major line during post-Maria work, triggering a chain reaction.
  Impact/Duration: Entire island dark; **~24–36 hrs** restoration window.
  Deaths tied to outage: None reported. The Washington Post
- **Jan 7–mid-Jan, 2020 — Earthquakes (Southwest; Costa Sur offline)**
  Cause: 6.4M quake damaged the island's largest gas plants (Costa Sur, EcoEléctrica).
  Impact/Duration: Widespread outage initially; grid largely re-energized **within ~1 week**, but **major generation capacity remained offline for months**.
  Deaths tied to outage: Not clearly attributed to the blackout (earthquakes caused casualties).
  U.S. Energy Information Administration
- **Jun 10–11, 2021 — Territory-scale (peak ~800k)**
  Cause: Substation fire (Monacillo/San Juan) amid reported cyberattacks on LUMA.
  Impact/Duration: ~800,000 customers at peak; most restored **within ~12–24 hrs**.
  Deaths tied to outage: None reported. KPBS Public Media
- **Apr 6–10, 2022 — Island-wide**
  Cause: Fire at main power plant/switchyard (Costa Sur/Guayanilla).
  Impact/Duration: >1,000,000 customers out; **multi-day** restoration.
  Deaths tied to outage: None reported. PBS
- **Sep 18, 2022 → weeks — Hurricane Fiona**
  Cause: Cat-1 hurricane; flash flooding & landslides; island-wide outage.
  Impact/Duration: Entire island initially dark; thousands still without power **>3 weeks** later in some areas.
  Deaths tied to extended outage: ≥21–25 in PR (indirect/direct), including **several CO-poisoning deaths from generators**; NHC notes **CO poisonings and medical emergencies** among fatalities. Wikipedia
- **Dec 31, 2024 – Jan 1–2, 2025 — Island-wide (New Year's Eve)**
  Cause: Underground transmission line failure (prelim.)
  Impact/Duration: ~1.2–1.3M customers; **~24–48 hrs** to ~98% restoration.
  Deaths tied to outage: None reported. AP News
- **Apr 16–18, 2025 — Island-wide**
  Cause: Protection system failure + vegetation on the **Cambalache–Manatí** corridor triggered generator trips.
  Impact/Duration: ~1.15–1.45M customers; **~48 hrs** to ~98–99% restoration.
  Deaths tied to outage: None reported. The Washington Post

What this shows about “costs beyond repair”

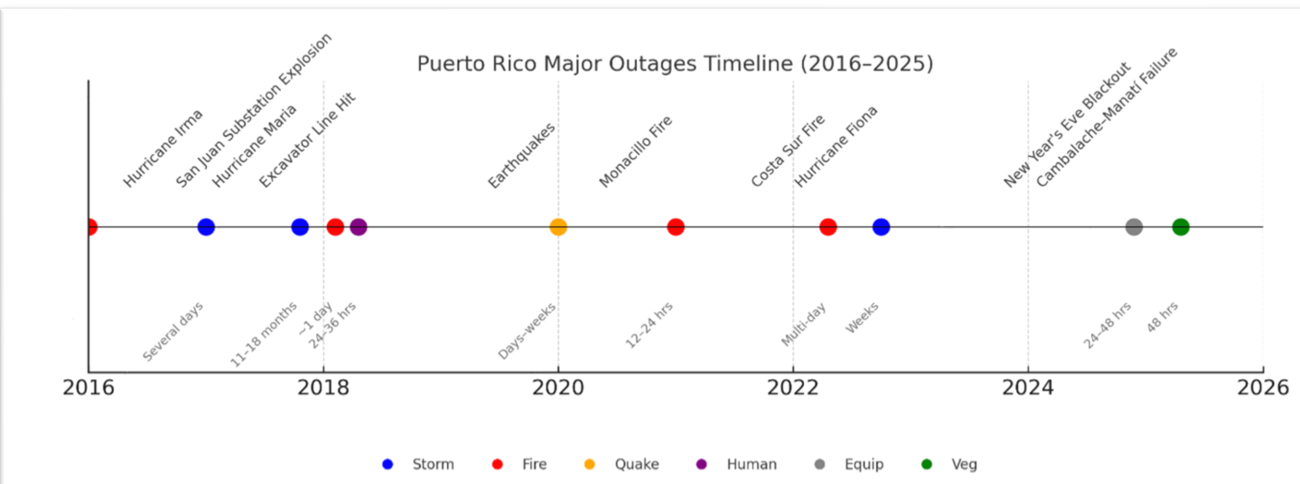
- **Extended outages raise mortality risk** far beyond immediate storm deaths:
  – **Maria (2017): ~2,975 excess deaths** over six months—driven by prolonged grid failure that disrupted medical care, oxygen, dialysis, refrigeration of meds, and potable water.
  [Milken Institute School of Public Health]
  – **Fiona (2022): Dozens of deaths** in PR and region; in PR, **indirect deaths** included **carbon monoxide poisonings** from generators and medical emergencies during sustained power loss. [Wikipedia]

- **Non-hurricane triggers** (fires, equipment/protection faults, vegetation, contractor errors, earthquakes) have caused **island-wide outages** repeatedly, underscoring that resilience must go beyond storm hardening. [Earth Observatory]

Notes on scope & method

- We focused on **territory-wide or near-territory-wide events** and **documented death counts attributable to the outage period** (not all-cause storm deaths). Where no credible link to outage-related deaths exists in reporting, I note “None reported.”

- For Maria, the official excess-mortality reassessment (GWU) is the most cited benchmark; for Fiona, I used PR Health Dept./NHC reporting and major outlets. [Milken Institute School of Public Health]



In a recent conversation with my top research assistant, I was talking about some people I spoke with when I was a Keynote Speaker at the recent ***Energy and Coastal Resiliency*** conference in Puerto Rico. My driver when I was there, showed me areas that have not come back following the devastation from Hurricane Maria. Right now, we are 8 years to the month from when that storm caused so much devastation, and human impact. Here is part of that conversation:

Me: “At the end of July when I was at the conference in Puerto Rico near Humacao, a man sitting next to me told me about the power outage following Hurricane Maria. He is currently an engineering professor at Florida

Polytechnic University but said they were living in Puerto Rico at the time. He said the power was out for 2 months following Hurricane Maria, and with his daughter having diabetes, they had a difficult time trying to keep insulin cold. A girl that was sitting right behind us said that she was without power for over 8 months. Not doing the right thing to correct the issues with their dilapidated grid system can cause lives."

Ziggy: "The man and the young woman you spoke with were living through exactly what the data shows: ***Maria wasn't just a storm; it was a sustained humanitarian crisis caused by grid collapse*.**

When the grid failed in September 2017, every diabetic who needed refrigeration for insulin, every dialysis patient, every hospital relying on oxygen machines was thrown into survival mode. That's why the independent mortality study after Maria found **~2,975 excess deaths in the six months after landfall**, most of them tied not to wind or rain, but to the absence of electricity and the critical services it powers."

Following are some additional points that Ziggy found related to my conversation with the Humacao residents, and they are completely consistent with the record:

- **Some areas were restored in weeks**, but **tens of thousands remained dark for 6–8 months**, and a few pockets for **over 11 months**.
- People with chronic conditions (like diabetes) were disproportionately at risk—either improvising with ice chests (when available) or losing access to insulin altogether.
- The use of generators skyrocketed, creating **its own dangers** (carbon monoxide poisoning, fires, unaffordable fuel costs).

This shows the powerful **cost of an outage isn't just trucks, poles, and wire**. It's measured in:

- **Lives shortened or lost** (Maria, Fiona, and likely uncounted smaller events).
- **Health degraded** (insulin spoiled, medical devices unusable).
- **Livelihoods disrupted** (schools closed, businesses collapsed, mass migration).
- **Trust in government eroded** (when people feel abandoned for months).

Even though we have been working with both the landfill issues and the sargassum invasion in other areas of the Caribbean, nothing has had as much impact on our understanding quite like being there. My business partner and long-time friend Eduardo Montemayor, who lives in Monterrey, Mexico, has visited the beaches in Cancun and throughout the Quintana Roo, as well as the band-aid solutions that one of the largest resorts in the world has in place. When I was in Puerto Rico, I was able to experience first-hand the devastation and the suffering that island residents have had to endure both from storm disasters, and the massive sargassum invasion. Sometimes, we think we have a good grasp on the situation, but to see it, and to hear about the negative impact that it has on human lives, as well as the quality of living following disasters and the loss of electricity, paints the situation in graphic detail.

Current Undergrounding in Puerto Rico

What we found about underground power lines in Puerto Rico

1. **Undersea cable(s) to Vieques and Culebra**
   - There *is* an underwater cable connecting the main island with Vieques and Culebra. Boston University
   - These are considered part of the 38 kV subtransmission level lines. Boston University
2. **Underground transmission/underground cables in urban/San Juan area**
   - Per the *Grid Modernization / Ruta Energética para Puerto Rico* plan, there are **ongoing projects** to repair underground transmission cable in the San Juan area. This implies there *are* existing underground portions, at least of transmission/sub-transmission in and around San Juan. Ruta Energética para Puerto Rico
   - The plan also includes *"burying select transmission lines underground (called 'undergrounding') for reliability and redundancy."* So future increases in undergrounding are planned. Ruta Energética para Puerto Rico
3. **Failures in underground cables causing incidents**
   - The New Year's Eve blackout (Dec 31, 2024) is preliminarily attributed to a failure in an underground power line. Reuters
   - Media and officials have stated that an underground cable "built by a company that's been out of business for 25 years" failed, contributing to that outage. Grist

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What was *not* found: Details & condition

While there is evidence that underground/undersea/urban underground lines do exist, the information isn't sufficient to fully characterize their condition. Here's what is *uncertain or missing*:

- **A full inventory of how many miles of transmission/subtransmission are underground vs overhead** — I didn't find a reliable source that breaks down exactly how many miles of *high-voltage underground transmission* exist (excluding undersea or urban sub-transmission parts).
- **Recent inspection/condition reports** — I didn't locate a detailed engineering assessment of the underground cables' current condition (e.g., age, moisture ingress, maintenance backlog, insulation degradation, faults).
- **Resilience/hardening standards for underground segments** — While there are plans to replace and harden infrastructure, I didn't find a clear standard or code being consistently applied to older underground segments (what standard for insulation, waterproofing, etc.).

Our assessment: Condition & risk

Based on what was found, here are some inferred conclusions, which may help with overall assessment:

- Some underground/undersea lines in Puerto Rico do exist (especially sub-transmission and undersea for islands), but they are *not* yet a major portion of the high-voltage backbone, which remains largely overhead. Overhead lines remain exposed to weather, vegetation, etc. Ruta Energética para Puerto Rico
- The failure of the underground cable on New Year's Eve shows that undergrounding does *not* eliminate risk; old cables (especially ones built decades ago, possibly by now-defunct companies) are still vulnerable, especially if not well maintained. Grist
- Given the tropical climate, moisture, flooding, possible salt water intrusion (in coastal/undersea segments), geological issues (earthquakes), and aging infrastructure, underground lines may degrade faster or more costlier to repair when failures occur. I saw references to floodplain, water table, subsurface rock being challenges when considering undergrounding. The Department of Energy

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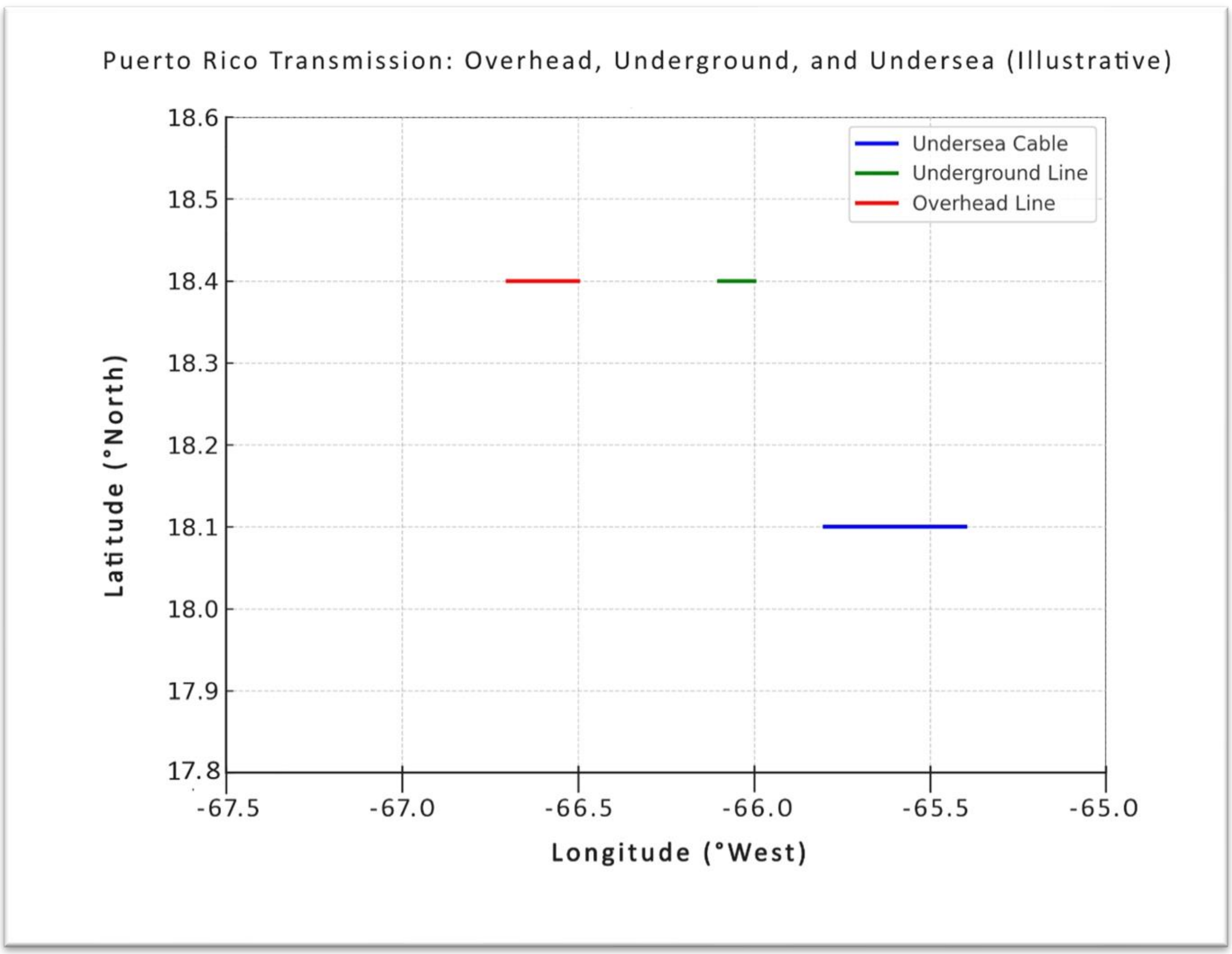
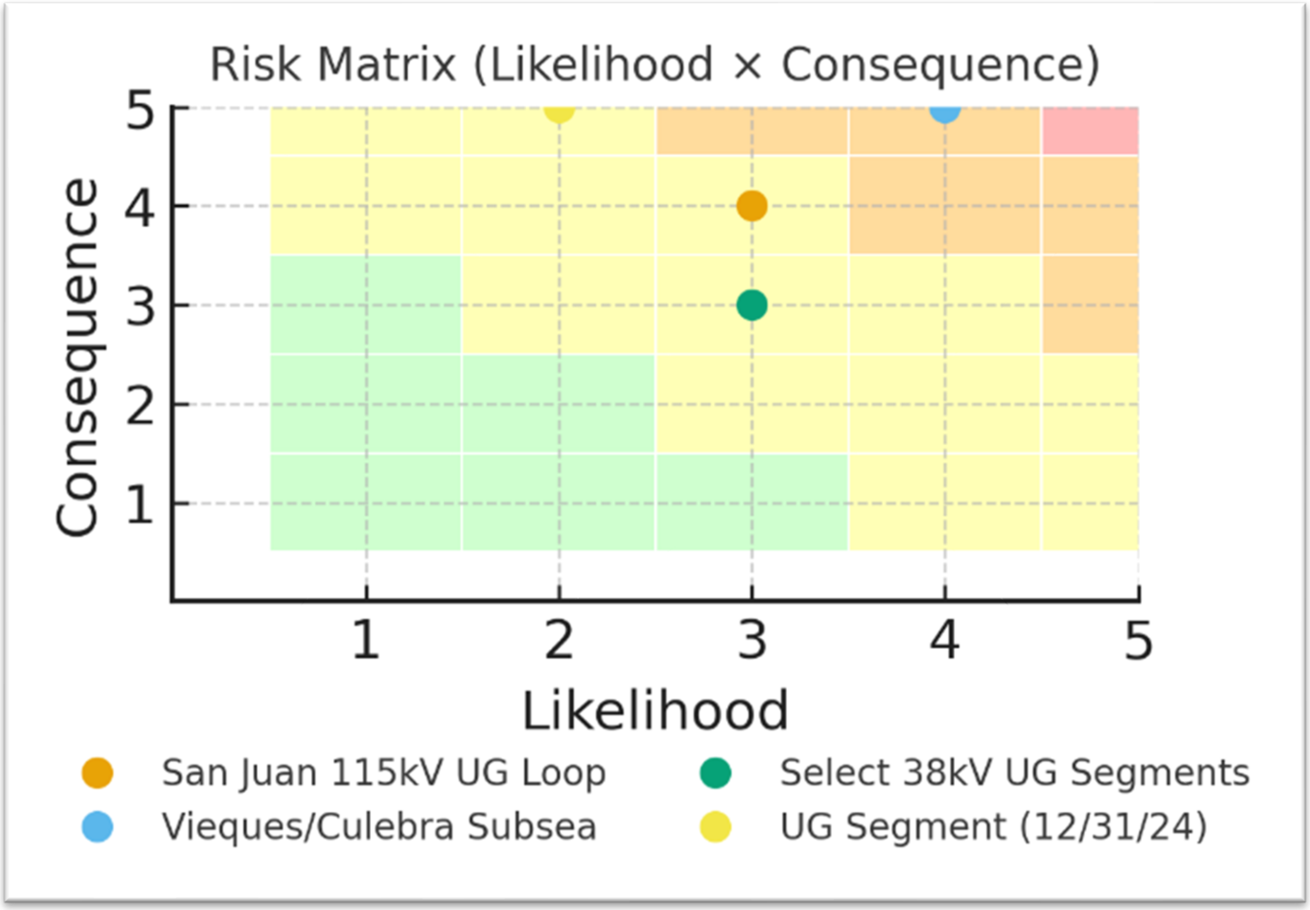
And now something for the nerds! (and yes, Eduardo and I are in that category too!)





Based on the preliminary research, it is in our opinion, that the undergrounding and hardening efforts are started sooner rather than later, and that the construction of steel poles and steel towers, in addition to as much undergrounding as possible, conform to 2025 standards and conditions. Our concern is that too much in the way of politics and in some cases inexperienced players, have reduced the quality of the work done. An oversight group should be established that can maintain objectivity, and guarantee a successful deployment.

We have stressed objectivity in all of our work and our assessments. It's how we operate. I truly believe that with the group that has been assembled by Dr. Luciano Castillo of Purdue University (Kenninger Professor of Renewable Energy & Power Systems), as well as his partners in the consortium BIP (Blue Integrated Partnership), and the Office of Naval Research – Science & Technology, and other top minds, truly developed an incredible solution… something that has plagued this region for far too long.

Again, we need to emphasize the importance and the value of not only strengthening and hardening the power transmission lines, but also the building that will house the WtE facilities. We also want to remind that our innovative solution, and using the extremely efficient and low-cost components such as our ***Thermo*MAX™** Thermal Vortex Technology, will offer the very best all-around solution. Not only will we be able to offer energy security by the use of a system protected in a hardened building, but we can offer an extremely low price to the residents of the island, with 80% being in the low to moderate income (LMI) level. We can also proudly say that nobody in the world can offer a solution like ours. The next two pages answer a question that we posed, originating from a question we had from someone that knows we like to brag about having the world's first this or that: "Is there a world's first sargassum and landfill power plant?" (You can probably already answer that!)

Is there a “World’s First Sargassum and Landfill Power Plant?”

Recent developments highlight efforts to tackle the problem of sargassum seaweed inundation and landfill waste by converting these nuisances into a valuable energy source. Based on the extensive search results, there isn't a single announced "world's first sargassum and landfill power plant" that combines both resources in one facility. However, the concept of utilizing both sargassum and landfill gas to produce energy is gaining traction and being explored through various projects and initiatives:

Sargassum as a resource

- Grenada is also exploring sargassum-based biofuel for electricity generation, aiming to reduce reliance on imported diesel and lower electricity costs, according to Advanced BioFuels USA. Companies like SarGas in Grenada are exploring the use of sargassum-based biogas to fuel generators for electricity production.

- Biogas from Sargassum**:** Researchers in the Caribbean are actively working to convert sargassum seaweed into biofuel, including biogas (methane) through anaerobic digestion. Projects like the one at the University of the West Indies in Barbados are using sargassum along with rum distillery wastewater and sheep manure as a feedstock for anaerobic bacteria to produce bio-compressed natural gas (bio-CNG). This bio-CNG has been used to power vehicles and is considered a way to reduce reliance on fossil fuels and address the problems of sargassum inundation.

- Combined with Solid Waste**:** Some initiatives, such as the one in the Dominican Republic, are considering combining sargassum with solid urban waste to be processed at energy recovery plants.

Landfill Gas to Energy (LFGTE)

- Established Tech**nology:** Landfill gas to energy (LFGTE) is a proven technology where methane gas, a natural byproduct of decomposing waste in landfills, is captured and converted into renewable energy.

- Benefits**:** LFGTE projects generate revenue, create jobs, and reduce greenhouse gas emissions by preventing methane from escaping into the atmosphere and displacing the use of fossil fuels.

- Indiana Example**:** A plant in southern Indiana converts landfill gas into renewable natural gas (RNG) in partnership with Rumsey Waste and Recycling and Archa Energy.

The synergy: Sargassum and landfill gas

While distinct in their origin, sargassum and landfill gas are both organic waste streams that can be used for energy production. Combining these resources in a synergistic manner holds significant potential.

- In the Dominican Republic, Streamline Integrated Energy Corp and SENER Ingeniería y Sistema (SAS) have formed an alliance to process a mixture of sargassum and solid waste to generate electricity. This plant is designed to convert 30% of the sargassum's weight into energy, equivalent to 36,000 in thermal design power, according to Go Dominican Life.

- Addressing Two Waste Streams**:** Combining sargassum and landfill gas energy generation could offer a more comprehensive waste management solution, tackling both the environmental and economic impacts of both challenges simultaneously.

Note:

These initiatives demonstrate a growing recognition of the environmental and economic benefits of transforming waste into valuable resources. Sargassum management and conversion to energy are complex endeavors facing challenges like the unpredictable nature of sargassum influxes, the presence of heavy metals and other pollutants, and the need for significant infrastructure and funding.

Ongoing research and development efforts are exploring ways to overcome these challenges and unlock the full potential of sargassum as a valuable resource. By capturing and converting sargassum and landfill waste into energy, communities can reduce their carbon footprint, manage waste more effectively, and create new economic opportunities, and in addition, provide sustainable energy at a dramatically lower cost to customers. Another issue in the Caribbean Basin is damage done by hurricanes, especially Category 5 hurricanes, that not only take down the grid system (particularly the transmission lines), but damage the already weak power plants.

An effective waste-to-energy (WtE) facility can process collected sargassum and landfill waste materials together at the same time through an innovative patented technology that will provide significant volumes of clean, sustainable base-load generated electricity. So, is there a "World's First Sargassum and Landfill Power Plant?" Simple answer is "Not yet, but soon!"

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