What is the Cost of Delay or Inaction?
What is the cost of doing the wrong thing?

Vortex Energy Group LLC
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I find myself asking a very simple question nowadays: “What is the cost of delay or inaction?” Or even: “What is the cost of doing the wrong thing?”

I have a friend that used to be on a committee in California tasked with finding a solution to the deteriorating condition of the Salton Sea, the largest inland lake in California. There were actually a couple of different groups that all seemed to want to look for a solution, but never find one. They were paid handsomely for only a few meetings per year, with three of them being in-person. If they actually found a solution, they would all lose their cushy income.

In 2024, the U.S. Department of Energy announced $861 million for two solar farms in Puerto Rico. Don’t get me wrong, solar farms are great for producing clean energy, but they offer intermittent generation, and will most likely never offset the amount of fossil fuels used in the manufacturing and deployment. The ROI is over 20 years. The other problem is protecting them from the elements. Recently, a solar farm in Nebraska had over 14,000 solar panels destroyed in a hail storm. With the constant threat of hurricanes in Puerto Rico, solar farms and wind farms are not a good investment.

In early 2025, the U.S. Department of Energy committed to $1.2 billion for renewable projects in Puerto Rico. There is a lot of hope that these funds will go to projects that will actually make a difference, such as reinforcing and hardening the current power grid, including burying transmission lines, replacing poles with steel towers, and Cat 5 hurricane-proof buildings protecting the energy generation facilities.

The following pages outline some of those predictable costs, but one that is never calculated is the cost to residents without power. A colleague in Puerto Rico told me about being without power for 2 months following Hurricane Maria in September 2017. His daughter was diabetic and required insulin that had to be kept refrigerated. They spent most of their time early on driving around each day looking for enough ice to keep the medicine cold. Another person said that she was without power for almost 8 months. It affected her physically, because of not being able to keep cool during the hot and humid weather.

There is so much government wasteful spending, which often prevents good projects from receiving needed funding. Senator Rand Paul publishes what he calls Festivus Reports, citing some of the more ridiculous expenditures. Examples from Festivus Report 2022:

➢ Watching hamsters fight on steroids (NIH)	$3,000,000
➢ Encouraging Ethiopians to wear shoes (NIH)	$2,100,000
➢ Training mice to binge drink alcohol (NIH)	$1,100,000
Total	$6,200,000

The cost of a complete waste-to-energy (WtE) facility ***$6,150,000***

Wouldn’t it make more sense to put money into projects that will actually have a measurable impact, as well as being able to generate income that will more than cover operating costs? We think so too!

Puerto Rico: Economic and Social Costs of Poor Energy Infrastructure & Blackouts

Executive Summary

Puerto Rico faces recurring and severe costs from poor energy infrastructure, repeated blackouts (including hurricane-induced island-wide outages), and delayed implementation of storm-readiness measures. Direct customer interruption costs (CICs) reach approximately $1 billion for a 1-day blackout, $5 billion for a 14-day outage, and nearly $29 billion for a 30-day loss of service. These estimates exclude repair costs, health impacts, and broader economic drag. In 2023, the average customer experienced 27 hours of service loss (SAIDI ~1,572 minutes)—far above the U.S. average.

Estimated Customer Interruption Costs (Puerto Rico-Specific)

Outage Duration	Territory-Wide Cost Estimate
1 day	$1 billion
14 days	$5 billion
30 days	$29 billion

Direct Costs to Customers & Businesses

Households face spoiled food, lost productivity, and generator fuel costs. Businesses lose revenue, inventory, and equipment function, with median costs rising sharply as outages lengthen. For large facilities, a 14-day outage can cause median losses exceeding $180,000.

Health & Safety Impacts

Hurricane Maria caused an estimated 2,975–4,645 excess deaths, largely from prolonged power loss to medical services, refrigeration, and communications. Hurricane Fiona in 2022 again triggered island-wide blackouts with cascading public health consequences.

Utility-Side & Systemic Costs

Failures such as the Costa Sur substation fire (2022) and the April 2025 blackout linked to vegetation contact with transmission lines highlight repair and emergency generation costs. Puerto Rico's residential electricity rate remains among the highest in U.S. jurisdictions (~24–25 ¢/kWh).

Macroeconomic Drag & Migration

Unreliable and costly power deters manufacturing and tourism investment. Households pay high generator fuel bills and face deteriorating living conditions, pushing migration to the U.S. mainland.

Delays in Storm-Readiness

Despite $23+ billion in obligated FEMA funds, less than 10% had been spent as of mid-2023. Each missed hurricane season adds risk exposure. LUMA reports automation projects already deliver millions of avoided interruption minutes—proving rapid benefits when investments are implemented.

High-Impact Storm-Readiness Measures

- Transmission line vegetation management and protection relay upgrades on top 10 risk corridors.
- Substation modernization with arc-flash detection, spare parts, and flood barriers.
- Feeder automation: reclosers, sectionalizers, and fault indicators, prioritizing feeders for hospitals and water plants.
- Microgrids with PV + BESS + genset for hospitals, shelters, and police/EMS hubs.
- Accelerated FEMA-to-construction conversion with standardized designs and transparent reporting.

Cost of Delay and Inaction with the Energy Infrastructure in Puerto Rico

Following is a report on the real (and often hidden) costs Puerto Rico bears from poor energy infrastructure, blackout events (including hurricanes), and delays in storm-readiness. This includes the newest Puerto Rico–specific outage-cost study to quantify impacts.

Executive summary (what the numbers say)

- **Direct economic cost of blackouts** (best current Puerto Rico–specific estimates): territory-wide outages cost **≈ $1B for 1 day**, **≈ $5B for 14 days**, and **≈ $29B for 30 days**—and those figures **exclude** utility repair costs and broader societal harm (health/mortality). In 2023 the typical customer still lost **~27 hours** of service (SAIDI 1,572 minutes), far above the U.S. average. eta-publications.lbl.gov
- **System fragility today:** Puerto Rico has suffered repeated large-scale outages, including the **Costa Sur substation failure (Apr 6, 2022)**, a **New Year's Eve island-wide blackout (Dec 31, 2024)**, and an **island-wide blackout (Apr 16, 2025)**. energia.pr.gov The Wall Street Journal The Washington Post
- **Storm impacts:** Hurricanes **Maria (2017)** and **Fiona (2022)** caused island-wide power loss and long restoration tails; Maria is linked to **~2,975 to ~4,645 excess deaths**—a stark reminder that outage costs are not only economic. NIST New England Journal of Medicine
- **Customer bills & macro drag:** Puerto Rico's electricity prices remain among the highest in U.S. jurisdictions (e.g., **residential ~24–25 ¢/kWh** in 2025), compounding economic losses from interruptions. U.S. Energy Information Administration
- **Delayed resilience build-out:** Billions are obligated for grid recovery, yet **<10% of >$23B** in FEMA public-assistance funds had been spent as of mid-2023; GAO flags cost escalation and project delays—each hurricane season that passes without hardening increases expected losses.
  U.S. Government Accountability Office

The cost stack: where losses actually arise

1) Direct customer & business interruption costs

- **Residential & small/medium businesses:** Lost perishables, productivity, spoiled inventory, equipment damage, generator fuel/maintenance, overtime. Puerto Rico-specific modeling shows rapidly escalating costs as outages move from days to weeks. eta-publications.lbl.gov
- **Large industrial & public sector:** Lost revenue, process upsets, equipment damage, contract penalties, safety/environmental incidents, and service backlogs (hospitals, water utilities). Median business costs reported in the LBNL study rise from **~$15k (1-day)** to **~$180k (14-day)** and **~$520k (30-day)** for large non-residential/public facilities (many reported much higher). eta-publications.lbl.gov
- **Territory-wide scale:** Using Puerto Rico-specific customer damage functions, **1-day LDWI ≈ $1B**, **14-day ≈ $5B**, **30-day ≈ $29B** in **direct** costs—again **not** counting repairs or health impacts.
  eta-publications.lbl.gov

2) Health & safety impacts (social costs often ignored in benefit/cost)

- **Excess mortality from protracted outages:** Peer-reviewed and official studies estimate **~2,975** to **~4,645** excess deaths after Maria, driven largely by prolonged loss of power to medical services, refrigeration (meds/insulin), pumps, and communications. NIST New England Journal of Medicine
- **Public health during Fiona (2022) & later events:** Island-wide outage with days-to-weeks restoration; cascading failures affected water and heat exposure, increasing emergency risks. The Department of Energy's Energy.gov Earth Observatory

3) Utility-side & systemic costs

- **Repair, replacement & emergency generation:** Substation fires/breakers (e.g., **Costa Sur 2022**) and major plant trips trigger forensic investigations, parts replacement, and rental gensets—costs that don't show up in customer-side CICs. energia.pr.gov
- **Lost energy + inefficiencies:** High reliance on imported fuels + volatile fuel riders compound the cost of **technical/non-technical losses** and re-dispatch during restoration; end-user rates routinely sit well above U.S. averages. U.S. Energy Information Administration
- **Reliability metrics understate reality:** PREB notes **load-shed and generation shortfall events are not counted** in reported distribution reliability metrics—masking the lived outage burden. In 2024, **35 generation shortfall** events averaged **~192 minutes**, plus **82 load-shed** events averaged **~29 minutes**. energia.pr.gov

4) Macroeconomic drag & migration

- **Investment deterrence:** Unreliable, expensive power raises hurdle rates for manufacturing, tourism, cold-chain, and data-centric businesses.
- **Household welfare & migration:** Recurrent LDWIs raise the cost of living (genset fuel, appliance turnover) and push skilled labor to the mainland—effects repeatedly highlighted in fiscal and policy analyses. ntc-prod-public-pdfs.s3.us-east-2.amazonaws.com grupocne.org

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Hurricanes & major blackout case notes (cost relevance)

- **Maria (Sep 2017):** Longest U.S. blackout; **$90B+** damages; massive grid rebuild need; thousands of excess deaths underscore life-safety cost of slow restoration. NREL Docs
- **Fiona (Sep 2022): Island-wide outage**; peak **~1.47M customers** out; restoration spanned days to weeks in some regions—typical of LDWI cost growth curves. The Department of Energy's Energy.gov The Washington Post
- **Dec 31, 2024 – Jan 2025:** Major island-wide blackout from underground cable/protection failures; 1.2M+ impacted; restoration over 24–48+ hours. The Wall Street Journal AP News

- **Apr 16, 2025: Island-wide blackout** tied to protection failure + vegetation on transmission line; power plant trips cascaded; 48–72-hour restoration window. The Washington Post

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Why delays in storm-readiness are so costly

1. **Compounding risk per season:** Each hurricane season that passes without hardening (vegetation management, protection schemes, sectionalizing/automation, flood-hardening) raises expected outage-day counts—and therefore expected annual losses. PREB has also flagged gaps between what's measured and what customers experience (generation shortfalls). energia.pr.gov
2. **Funding bottlenecks & cost inflation:** GAO shows Puerto Rico had **>$23B** in Public Assistance obligations for post-2017 disasters, but **spending remained <10%** as of mid-2023; inflation and supply-chain shocks erode purchasing power and delay benefits. U.S. Government Accountability Office
3. **Missed reliability dividends:** LUMA reports millions of **customer-interruption minutes avoided** where automation was deployed—i.e., rapid, tangible benefits when projects actually land. Luma Energy

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Opportunity: what pays for itself (fast) in Puerto Rico

Based on Puerto Rico-specific CICs and recent outage history, the following tend to **self-fund** through avoided losses:

- **Transmission protection upgrades + aggressive vegetation management** on critical corridors (Cambalache–Manatí type risks). The Washington Post
- **Substation fire-hardening & modern breakers** (Costa Sur-type failures). energia.pr.gov
- **Distribution automation + sectionalizing** (LUMA reports large interruption-minute reductions where deployed). Luma Energy
- **Resilience for critical services** (hospitals, water, comms) with BESS + on-site renewables to cut LDWI tail risk—aligned with **PR100** pathways to lower fuel spend and risk exposure.
  The Department of Energy's Energy.gov
- **Faster FEMA-to-construction conversion** (owner's-rep discipline, packaged scopes, standard designs) to overcome the spend bottleneck documented by GAO. U.S. Government Accountability Office

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Context you can cite in proposals & briefs

- **PR-specific outage costs**: $1B (1-day), $5B (14-day), $29B (30-day), SAIDI 1,572 min (2023). eta-publications.lbl.gov

- **Blackout case studies**: Costa Sur substation failure (2022); NYE 2024 blackout; Apr 2025 island-wide blackout. energia.pr.gov The Wall Street Journal The Washington Post
- **Health impacts**: **2,975** (GWU) to **4,645** (NEJM) excess deaths after Maria. NIST New England Journal of Medicine
- **High retail rates** (drag on economy): PR residential ~24–25 ¢/kWh (mid-2025 snapshot). U.S. Energy Information Administration
- **Recovery funding gaps & delays**: >$23B PA obligated; <10% spent as of 6/2023; "a lot of work remains." U.S. Government Accountability Office
- **Policy/trajectory**: Act 17 (2019) targets (40% by 2025; 60% by 2040; 100% by 2050); **PR100** confirms feasibility if investments proceed. grupocne.org The Department of Energy's Energy.gov

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Suggested "ready to implement" storm-readiness package (Puerto Rico)

1. **Critical-path T-line corridors:** vegetation + protection relays + remote switching (start with top 10 high-risk lines by historical trips). The Washington Post
2. **Substation modernization:** replace legacy OCBs, add arc-flash detection, flood barriers, and spare-parts caches (Costa Sur lesson). energia.pr.gov
3. **Feeder automation blitz:** reclosers, sectionalizers, fault indicators; prioritize feeders serving hospitals, water plants, telecom hubs; publish before/after SAIDI/SAIFI. Luma Energy
4. **Critical-services microgrids (PV+BESS+genset):** standardized designs for hospitals, shelters, police/EMS; leverage DOE/FEMA programs aligned to PR100. The Department of Energy's Energy.gov
5. **Programmatic delivery & reporting:** track **avoided customer-interruption minutes** and apply the Puerto Rico CICs to show monthly economic benefits (turn this into your ROI story). eta-publications.lbl.gov

The US government announces $861 million for two solar farms in Puerto Rico

Updated 12:03 PM EDT, October 16, 2024

SAN JUAN, Puerto Rico (AP) — The U.S. Department of Energy announced an $861 million loan guarantee on Wednesday to build two solar photovoltaic farms in Puerto Rico as persistent power outages plague the U.S. territory.

The project would be located in the southern coastal towns of Guayama and Salinas and backed by Clean Flexible Energy LLC, a subsidiary of The AES Corporation and TotalEenrgies Holdings USA Inc.

It would add up to 200 megawatts of solar generation and another 285 megawatts of storage capacity to Puerto Rico's grid, according to U.S. Energy Secretary Jennifer M. Granholm.

The solar photovoltaic project is expected to generate about 460,000 megawatts of energy, enough to power some 43,000 homes, officials say.

The announcement comes as Puerto Rico continues to struggle with ongoing outages blamed on a crumbling electric grid that was razed by Hurricane Maria when it hit the island as a powerful Category 4 storm in September 2017.

The grid, which is still being rebuilt, was in a fragile state even before the storm hit due to a lack of investment and maintenance.

Fossil fuels currently generate 94% of Puerto Rico's electricity, with the island tasked with obtaining 40% of its energy from renewable sources by next year and 60% by 2040.

Progress of Smart Grid and Grid Modernization Efforts in Puerto Rico

Here's a comprehensive update on the **progress of smart grid and grid modernization efforts in Puerto Rico** since Hurricane Maria devastated the island in 2017:

1. Early Recovery & Post-Maria Challenges

- **Severe damage & slow recovery**: Hurricane Maria in September 2017 caused the largest blackout in U.S. history, taking about 11 months to fully restore power for all customers with safe structures ABC News Government Accountability Office.
- **Grid fragility exposed repeatedly**: Even by 2022, Hurricane Fiona triggered a near-total blackout, highlighting persistent weaknesses in the grid infrastructure The Department of Energy's Energy.gov Scientific American ABC News.

2. Growing Resilience via Distributed Solar & Storage

- **Community-led resilience**: By 2022, more than 40,000 households had installed rooftop solar systems—accumulating over **250 MW**—often paired with battery storage to back up power during outages IEEFA.

3. Federal Support & Smart Meter Rollout

- **Major federal funding unlocked**: Since 2021, the Biden Administration freed up billions in disaster recovery funds — enabling:
    - Replacement of **1.5 million meters with smart technology**, to enable faster detection of service interruptions.
    - Deployment of **430 MW of 4-hour battery storage systems** to improve grid stability The White House.
- **Private investment and renewables**: In early 2025, DOE committed **$1.2 billion** toward renewable projects:
    - A **100 MW solar + 55 MW battery** in four cities.
    - Up to **455 MW of combined storage capacity** across multiple towns AP News.

4. LUMA Energy's Role & Infrastructure Upgrades

- **New operator since 2021**: LUMA Energy took over transmission and distribution from PREPA in mid-2021 under a long-term privatization effort
- **Physical infrastructure improvements**:
    - Replaced over **17,000 poles**, including **17,850 hurricane-resistant poles**, plus upgrades to over **1,800 breakers**.
    - Submitted **460 FEMA-funded projects**, with 144 under construction—and 8 major substations approved.

- Initiated vegetation clearing: Around **4,800 miles cleared** so far, with plans to cover **16,000 miles over four years**.

- **Modernizing substations**:
  - As of January 2025, **23 substations** are being upgraded (equipment replacement, redesign), impacting over **650,000 customers**, via a **$620 million** initiative.

5. Renewable Integration & Smart Grid Transformation

- **Massive clean energy scaling**:
  - LUMA plans nearly **1 GW of renewables** and **700 MW of storage**, supported by ~$4 billion in private investment.
  - Agreements set up **nine interconnection points** to facilitate integration of solar and storage assets.

- **Long-term planning**:
  - An **Integrated Resource Plan (IRP)** was filed in late 2024, mapping scenarios for Puerto Rico's future energy mix over two decades.

6. Continuing Challenges & Recent Outages

- **Ongoing outages remain a concern**: Between 2021–2024, customers experienced around **27 hours of outages annually** even without storms—vastly more than mainland U.S.'s ~2 hours Canary Media.

- **April 2025 blackout**:
  - A protection system failure combined with vegetation interference triggered a cascading island-wide blackout affecting over 1.15 million customers — signal that vulnerability persists The Washington Post Reuters.

- **Political and regulatory tensions**:
  - Moves by the Puerto Rico governor to rescind renewable targets, and efforts to terminate LUMA's contract, reflect challenges in governance and energy policymaking.

Summary Table: Progress at a Glance

Area	Progress & Status
Smart Meters & Monitoring	1.5 million smart meters planned; rollout underway
Battery Storage	430 MW deployed; >455 MW planned via federal funding projects

Area	Progress & Status
Physical Grid Infrastructure	Thousands of poles and breakers replaced; substations upgraded; vegetation clearing ongoing
Renewable & Clean Integration	~1 GW renewables and 700 MW storage planned; interconnection points established
Distributed Rooftop Solar	250 MW installed across 40,000+ homes
Resilience Improvements	Signs of progress, yet major outages continue; grid remains fragile
Governance & Policy Landscape	Political friction affecting energy targets and operator contracts

Bottom Line

Puerto Rico has made **notable strides in modernizing its grid**—through smart technologies, infrastructure upgrades, and renewable integration. Major funding and partnerships are fueling transformation. However, **systemic weaknesses** persist, evidenced by recurring widespread outages and grid instability. Smart grid elements are being introduced, but **true resilience remains a work in progress**, requiring continued investment, policy alignment, and implementation momentum.

What the 2019 law required (Act 17-2019)

- **Renewable Portfolio Standard (RPS):** 40% by **2025**, 60% by **2040**, and 100% by **2050**. It also set a **coal phase-out by 2028** and called for **30% energy-efficiency improvement by 2040**. NEPR

Big change in 2025: interim targets were eliminated

- In **March 2025**, **Act 1-2025** amended the energy laws and **eliminated the 40% (2025) and 60% (2040) interim RPS targets**, while **keeping the 100% by 2050 goal**. Puerto Rico's Energy Bureau and the Governor's office both describe this change; English and Spanish texts are available. NEPR Bvirtual OGP fortaleza.pr.gov

- Legal/industry summaries note Act 1-2025 also allows **continued coal operations** beyond 2028 (AES Guayama) and reorients near-term reliability planning. McConnell Valdés

Progress to date (renewables share & buildout)

- **Actual renewable generation:** PREPA reported **~2%** of total generation from renewables in **FY2023** (year ending June 30, 2023). U.S. Energy Information Administration

- **Distributed (rooftop) solar:** Rapid growth—**~900 MW** of residential rooftop PV capacity by **Dec 2024** (driven by net metering & incentives). Note this is capacity, not energy share. U.S. Energy Information Administration

- **Utility-scale additions:** As of 2024, only very limited new utility-scale solar/wind had entered service; multiple tranches approved earlier were **not online** by mid-2023. U.S. Energy Information Administration

- **Pipeline & storage:** DOE/NREL's **PR100** study concluded the **planned tranches were insufficient** to reach **40% by 2025**. Federal support is funding large **solar+storage** projects and hundreds of **MW** of batteries, but these roll in over several years. The Department of Energy's Energy.gov nrel.gov

Reality vs. the original 2019 milestones

Milestone	Original target	Observed / status
Renewable share by 2025	**40%**	**~2% in FY2023**; interim 40% target **eliminated in 2025**. U.S. Energy Information Administration NEPR
Renewable share by 2040	**60%**	Target **eliminated** in 2025; long-term planning continues under new framework. NEPR
Coal phase-out	**by 2028**	Act 1-2025 enables **extension** (AES Guayama) for reliability; details under PREB proceedings. McConnell Valdés
100% renewables	**by 2050**	**Still the law of the land**; DOE/NREL say it is technically achievable with sustained investment and policy support. Bvirtual NREL

Odds of meeting the goals (my best evidence-based assessment)

These are estimates based on the current law/pipeline, historical build rates, and DOE/NREL findings—not official forecasts.

- **40% by 2025: 0%** (goal already eliminated; deployment was far short). NEPR U.S. Energy Information Administration

- **60% by 2040 (original):** Without a binding interim target, hitting ~60% by 2040 would require **multi-GW** of utility PV plus large storage and faster interconnection than Puerto Rico has achieved so far. Given recent policy shifts and execution pace, I'd rate it **unlikely** under status quo. (Call it **<30% probability**)—but it could improve if procurement, siting, and grid upgrades accelerate markedly in the late 2020s. docs.nrel.gov U.S. Energy Information Administration

- **100% by 2050: Plausible but challenging.** NREL's PR100 shows **technical feasibility** with aggressive distributed + utility PV, storage, and grid modernization. Achieving it will hinge on **stable policy, execution capacity, and financing**. I'd put this at **40–60% probability** today—

swinging higher if current storage and solar programs scale on schedule and governance remains supportive. docs.nrel.gov NREL

Key takeaways

- The **2019 interim benchmarks (40% by 2025, 60% by 2040)** framed the transition but were **removed in 2025**, reflecting reliability and implementation concerns. NEPR
- **Renewable penetration remains very low** in the official generation mix (~2% FY2023), despite fast growth in **rooftop PV capacity**. Turning capacity into high renewable **energy share** requires **utility-scale buildout, storage, and interconnection reforms**.
  U.S. Energy Information Administration
- **2050 (100%)** is still Puerto Rico's statutory destination; federal studies say it's doable, but it demands **sustained, accelerated execution** in the 2025–2035 window. docs.nrel.gov

Value Proposition:
Sargassum Management & Energy Strategy for Puerto Rico

The following describes available solutions to the growing invasion of Sargassum along the beaches of Puerto Rico. These solutions represent several years of intensive research and ongoing assessment regarding the Sargassum issue in Palmas del Mar, Puerto Rico through a program lead by Castillo Cabrera Research Group LLC, in partnership with Vortex Energy Group LLC, Blue Integrated Partnership, UPR Bayamon, UPR Humacao, Office of Naval Research, and the Palmas Homeowners Association.

Overview

Puerto Rico faces an escalating crisis due to the massive influx of sargassum seaweed along its coastal regions. Left unmanaged, sargassum disrupts marine ecosystems, damages tourism infrastructure, and emits harmful gases such as hydrogen sulfide during decomposition. To address this multifaceted challenge, a two-tiered strategy is proposed—delivering immediate mitigation while laying the foundation for long-term environmental and energy resilience.

Short-Term Solutions: Agricultural Repurposing

In the near term, the project proposes the collection and repurposing of sargassum as:

- ✓ Cattle Feedstock: Following appropriate treatment to reduce salt and heavy metal content, sargassum can be blended with conventional forage to support local livestock operations.
- ✓ Organic Fertilizer: Rich in minerals and organic compounds, processed sargassum can be transformed into soil amendments and organic fertilizers.

These immediate uses serve to reduce environmental load, create rural economic value, and divert waste from landfills or coastal decay.

Long-Term Solution: Waste-to-Energy via Thermal Vortex Combustion

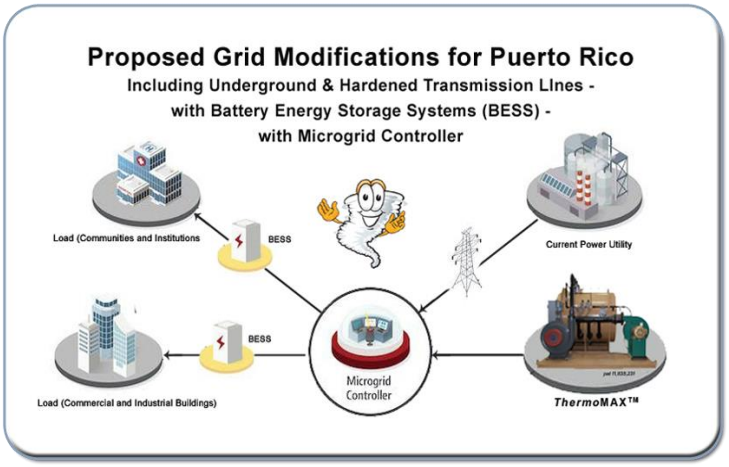
The cornerstone of the long-term solution is the deployment of a Waste-to-Energy (WtE) facility powered by Vortex Energy Group LLC's patented Thermal Vortex Combustion (TVC) system. This cutting-edge technology:

- ✓ Ensures complete and efficient combustion of sargassum biomass, including moisture-laden and mineral-rich material.
- ✓ Produces no ash material or other particulate matter, and eliminates harmful emissions, including dioxins, NOx, and CO_2 through the use of external scrubber systems as the exhaust exits the chamber.

To maximize energy recovery, the system integrates:

- ✓ A Waste Heat Boiler to capture superheated exhaust from the post-combustion thermal process, also known as thermal energy to produce steam.
- ✓ A Steam Turbine Generator Set to convert steam into consistent, grid-compatible electrical power.

Proposed Microgrid Modifications



The most efficient solution that can be initiated for the short-term and long-term plans is to integrate Battery Energy Storage Systems, or BESS. These will offer critical backup power for those essential sites, such as hospitals, some commercial buildings, and other emergency response locations. These utility sized units can be deployed at or very close to the facilities, and can offer up to 10 to 12 hours of backup electricity.

Strategic Impact

This phased approach addresses both immediate environmental hazards and the structural energy vulnerabilities Puerto Rico faces:

- ✓ ***Dramatically reduce the cost to generate electricity, which allows the customer to pay significantly less for their electricity.*** *(Extremely beneficial since ~80% of the population falls under the classification of Low to Moderate Income or LMI)*
- ✓ Reduces coastal and marine pollution
- ✓ Aids in the sargassum mitigation process to avoid ongoing beach erosion
- ✓ Ensures energy security by the generation of renewable, sustainable baseload energy (protects against blackouts that have plagued the island from the dilapidated energy infrastructure)
- ✓ The entire energy infrastructure will be enclosed within a Category 5 hurricane-resistant facility, ensuring resilience, energy security, and uninterrupted operation.
- ✓ Creates year-round employment opportunities
- ✓ Multiple waste materials can be used, even mixed and matched in the same process. This will dramatically help with the municipal solid waste (MSW), which is the collected garbage, as well as the landfill crisis.
- ✓ Ensures national security through guarantee of open coastal waterways

Conclusion

Through the combined use of agricultural reuse and advanced waste-to-energy conversion, Puerto Rico can transform a pressing ecological crisis into a sustainable economic and energy opportunity. This solution aligns with both local needs and global climate goals, positioning the island as a leader in innovative sargassum management and renewable energy development.