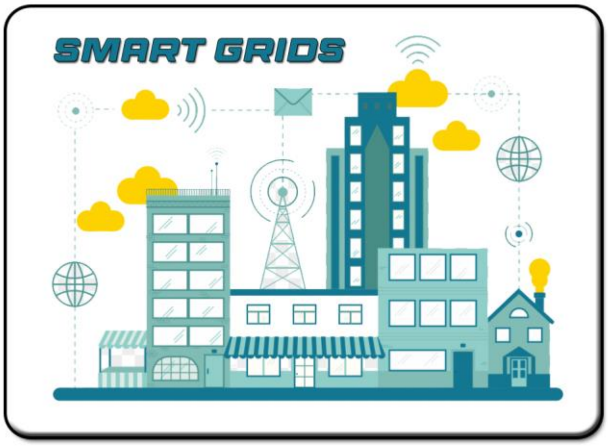

Smart Grids

(Including Deployment and Status In Puerto Rico)

Vortex Energy Group LLC
www.VortexEnergyGroup.com

Smart Grids and Outage Prevention

1. What is a Smart Grid?

A **smart grid** is an advanced electricity network that integrates digital communication, sensors, automation, and real-time data analytics with traditional power infrastructure. Unlike conventional “one-way” grids (power plants → transmission lines → consumers), smart grids enable **two-way communication** between utilities and end-users, allowing for monitoring, prediction, and adaptive control of energy flows.

Key features:

- **Real-time monitoring** with smart meters, sensors, and IoT devices.
- **Automation** for fault detection and self-healing.
- **Integration of distributed energy resources (DERs)** like solar, wind, battery storage, and microgrids.
- **Data-driven demand response** to balance loads.

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2. How Smart Grids Prevent Outages

Smart grids improve reliability and resilience in several ways:

a) Fault Detection and Self-Healing

- Sensors identify faults (downed lines, overloads, equipment failures) within seconds.
- Automated switches re-route power to isolate the faulted section while keeping the rest of the grid active.
- This minimizes blackouts and reduces outage durations from hours to minutes.

b) Demand Response and Load Balancing

- Smart grids monitor electricity demand in real-time.
- During peak loads, they can reduce strain by:
  - Signaling smart appliances or industrial users to temporarily reduce consumption.
  - Drawing on distributed storage (batteries, EVs).
- Prevents overload conditions that cause cascading blackouts.

c) Integration of Renewable Energy & Microgrids

- Smart grids incorporate local generation (solar panels, wind turbines, biomass, or WtE systems like yours).
- If the main grid fails, microgrids can **island** (separate) and continue powering critical facilities (hospitals, police stations, etc.).
- Reduces reliance on vulnerable long-distance transmission lines.

d) Predictive Maintenance

- Machine learning and sensor data predict when transformers, breakers, or lines are likely to fail.
- Proactive repairs prevent sudden equipment breakdowns.

e) Enhanced Communication with Consumers

- Smart meters notify utilities of outages instantly (no need to wait for customers to report).
- Customers can see their usage, adjust demand, and even sell excess energy back into the grid.

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3. Benefits of Smart Grids for Outage Prevention

- **Reduced outage frequency and duration** (SAIDI and SAIFI reliability metrics improve by up to 40%).
- **Resilience against natural disasters**: Smart grids can sectionalize damaged areas while keeping power flowing elsewhere.
- **Cybersecurity layers** help prevent malicious disruptions.
- **Energy efficiency**: Real-time optimization reduces waste and enhances grid capacity.

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4. Real-World Examples

- **Puerto Rico (after Hurricane Maria, 2017):** Smart microgrids are being installed to reduce reliance on vulnerable centralized transmission. Hospitals now use **solar + battery microgrids** for continuous operation.
- **Italy (ENEL Smart Grid):** Reduced outage duration by >50% using automation and self-healing grids.
- **U.S. (DOE Smart Grid Investment Program):** Grid operators now use predictive analytics to anticipate outages during storms, saving billions annually.

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5. Challenges

- **High upfront cost** of installing smart meters, control systems, and communication networks.
- **Cybersecurity risks** due to increased connectivity.
- **Interoperability**: Integrating legacy grid systems with new digital technologies can be complex.

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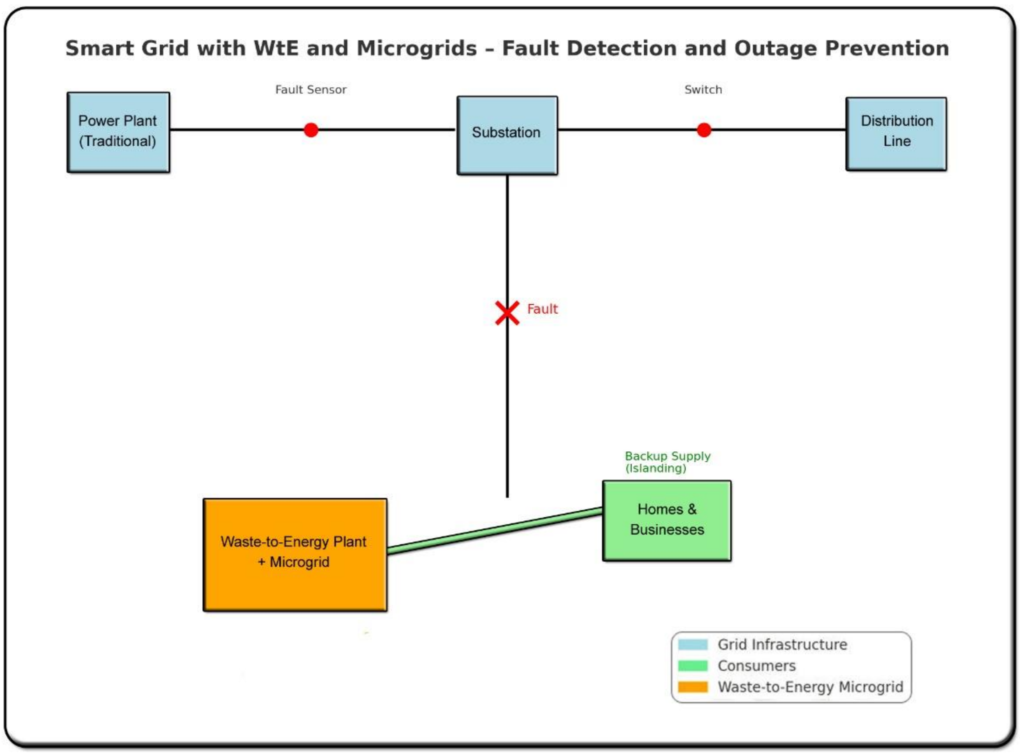
6. Smart Grid + Your Waste-to-Energy Systems

For your **Thermal Vortex WtE projects**, smart grid integration provides:

- **Priority dispatch**: WtE generation can supply power during outages.
- **Load balancing**: Heat recovery + steam turbine generation can stabilize voltage/frequency.
- **Microgrid resilience**: Hospitals and emergency centers in Puerto Rico could tie into your WtE-powered smart microgrids, maintaining power even if the central grid collapses.

✅ **Bottom line**: Smart grids transform the electrical system from reactive to **predictive and adaptive**, dramatically reducing outages and enabling more resilient communities.

Smart Grid with WtE and Microgrids – Fault Detection and Outage Prevention



This diagram shows how a **smart grid detects faults, re-routes power, and integrates a WtE microgrid** as backup during outages.

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

AP

Push to eliminate renewable energy goals in Puerto Rico sparks outrage as outages persist

The Puerto Rican flag flies in front of the Capitol building in San Juan, Puerto Rico, July 29, 2015. (AP Photo/Ricardo Arduengo, File)

By DÁNICA COTO

Updated 2:53 PM EDT, February 10, 2025

SAN JUAN, Puerto Rico (AP) — Puerto Rico legislators on Monday held a contentious public hearing on a governor-backed bill that would eliminate renewable energy goals and extend operations of the island's lone coal-fired plant, long accused of polluting low-income communities.

The bill challenges Puerto Rico's four-year renewable energy push, supported by U.S. federal funding, to help ease chronic power outages on an island trying to wean itself off fossil fuels.

But with that support expected to vanish under U.S. President Donald Trump, coupled with concerns that limited renewable energy projects are not helping offset outages, Puerto Rico's newly elected Gov. Jenniffer González, a Trump supporter, recently filed a bill to scrap a law calling for renewable energy to meet 40% of the U.S. territory's needs by 2025 and 60% by 2040.

"Once we have electricity, we can talk about resuming meeting the objectives," González said late last week.

But environmentalists and health officials are pushing back.

"We are alarmed that this project is being considered," said Nadya Rivera, of Puerto Rico Clinicians for Climate Action, who warned of the consequences of burning coal on people's health.

Puerto Rico has one of the world's highest asthma rates, and medical doctors have testified in public hearings that they've seen a "significant" increase in various types of cancers and other diseases in the island's southern region since the plant began operating.

A push to keep burning coal

Josué Colón, Puerto Rico's newly appointed "energy czar," recently said that burning coal for energy should continue through 2035 even though public policy dictates that the island stop burning coal in 2028.

The coal-burning plant located in the southern coastal town of Guayama produces up to 20% of power consumed in Puerto Rico, generating an average of 510 megawatts a year, said Jesús Bolinaga, president of AES Puerto Rico, which runs the plant.

Officials have claimed that shutting down the plant as legally mandated by late 2027 would result in a power generation deficit. But environmentalists argue otherwise.

During Monday's hearing, legislators questioned why AES Puerto Rico and the government did not take steps to convert the coal-burning plant since the renewable energy public policy was approved in 2019.

"On our behalf, we made all the efforts that were necessary," Bolinaga said.

Rep. Héctor Ferrer and other legislators condemned the island's government for not acting sooner.

"These government officials not only failed the (island)…but all of its people," he said.

Legislators said there are no studies on the cost or viability of converting the plant into one that would use clean energy, with Bolinaga noting it took eight years to build the current plant.

"If Puerto Rico wants those megawatts, we have to move quickly," he said of extending operations of the coal-burning plant, warning it was given only the necessary maintenance to last until late 2027.

A call to delay renewable energy goals

The project submitted by the governor upholds a 2050 goal that renewable energy meet 100% of Puerto Rico power needs, but eliminating the other goals means that final one will not be achieved, said Pedro Saadé, a Puerto Rico attorney who is an expert in environmental law.

"This bill means the death of renewable energy in Puerto Rico," he said, suggesting that the near- and mid-term goals be delayed, not eliminated.

In addition to the push to authorize another 10 years of coal burning on Puerto Rico, other fossil-fuel projects are being considered.

Mary Carmen Zapata, director of Puerto Rico's Electric Power Authority, recently told El Nuevo Día newspaper that she believes a new fossil fuel-based plant in the island's southern region is needed in addition to a natural gas plant being built in Puerto Rico's capital that is expected to start operating in 2028.

Despite the push to eliminate certain renewable energy goals, the governor announced Sunday a $767 million contract with Tesla funded by the U.S. government to buy 430 megawatts in energy storage systems, which she said would help stabilize Puerto Rico's power grid. The project was initiated under previous administrations in the U.S. and Puerto Rico.

The length of power outages in Puerto Rico increased 11% last year as the island struggles to rebuild an electric grid that already lacked maintenance and investment when it was razed by Hurricane Maria, a Category 4 storm that struck in September 2017.

The latest mass outage to hit Puerto Rico was an island-wide blackout that left 1.2 million clients without power on Dec. 31.

On Monday, Puerto Rico's representative in Congress, Pablo José Hernández, urged Trump to declare a federal emergency on the island's energy crisis.

"It is a problem, and it needs a solution," he said.

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Reuters

More than 40% of Puerto Rico customers without power after island-wide blackout

By Scott Disavino and Laila Kearney

April 17, 20257:02 PM EDTUpdated April 17, 2025

People walk through a dark street after Puerto Rico was hit with a massive power outage where energy plants across the island unexpectedly shut down, in San Juan, Puerto Rico April 16, 2025. REUTERS/Ricardo Arduengo

Summary

- Puerto Rico's grid struggles since 2017 hurricanes
- Luma Energy aims to restore 90% power in 48 hours
- Outage caused by protection system failure and vegetation on lines

April 17 (Reuters) - Nearly half of the homes and businesses in Puerto Rico that receive electricity from the commonwealth's main utility were still without power on Thursday, a day after a widespread blackout struck the island, Luma Energy said in a statement.

Hospitals, airports and prisons were among the structures still out.

The Reuters Power Up newsletter provides everything you need to know about the global energy industry. Sign up here.

Puerto Rico's electrical system has continued to falter since two powerful hurricanes devastated Puerto Rico in 2017, decimating the grid and killing nearly 3,000 people, according to official estimates. On New Year's Eve last year an underground power line was the most recent failure that led to island-wide blackouts.

As of 6 p.m. EST on Thursday, 844,973 Luma customers, or 57.6% of its total, had power restored.

"We continue on track with our initial projection of restoring service to at least 90% of customers in the next 48 hours, conditions permitting and generation is available," the company said in a statement.

It also added that some customers who have had service restored may experience temporary system outages throughout the day, and possibly tomorrow.

This time, a power line is also believed to have triggered outages.

Following overnight aerial patrols with helicopters, Luma said a preliminary analysis suggested a number of factors had caused the power outage.

It cited a protection system failure as the trigger, followed by the presence of vegetation on a transmission line between Cambalache and Manatí in the north of the island.

"As part of our response efforts, we are investigating the cause of this incident, including what role and effect the long-recognized impact of the fragility of the system had on this island-wide outage," Luma said.

Luma, which started operating the Puerto Rico power grid in 2021, is a joint venture between units of Canadian energy firm ATCO (ACOx.TO), opens new tab and U.S. construction and engineering firm Quanta Services (PWR.N), opens new tab.

Reporting by Scott DiSavino and Laila Kearney in New York and Noel John and Anmol Choubey in Bengaluru; Editing by Ros Russell, Barbara Lewis and Sandra Maler

Our Standards: The Thomson Reuters Trust Principles., opens new tab

Scott Disavino
Thomson Reuters
Covers the North American power and natural gas markets.

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.

How Smart Grid Companies are making Power Grids Intelligent

Author
[Vipin Singh](#)
Demand Gen Specialist

As energy crises and prices sharply increase, we are witnessing some amazing innovation trends in the energy storage sector. One such trend we discuss in this post is "Smart Grid technology," which allows electrical networks to operate more efficiently.

The energy grid is where the crises mentioned above meet. Creating a smart grid is vital in delivering energy resources in the face of supply disruptions while optimizing usage for a healthier planet.

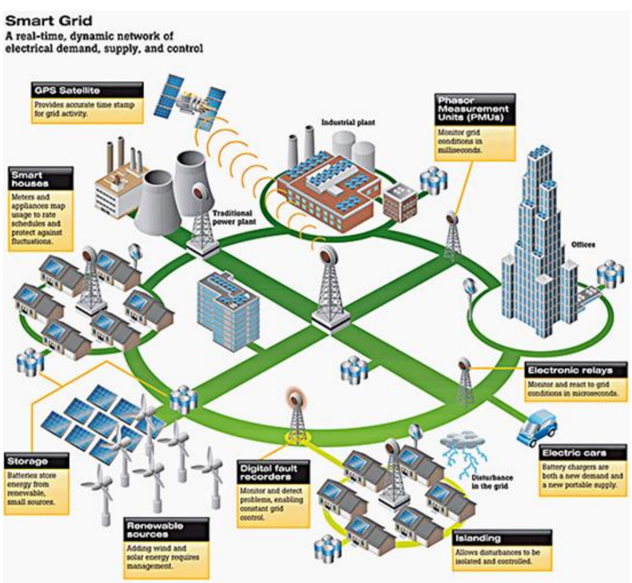
The smart grid electricity network lets devices connect. Thus, allowing them to control demand, safeguard the distribution network, save energy, and drive down costs.

The current energy grid structure provides little flexibility or support for new renewable technologies. Traditional energy grids allow for a one-way power flow from centralized sources like coal, nuclear, and gas to places of consumption such as homes, businesses, and data centers. The need for more power is met by building another power plant.

Hence the need for smart grids.

A smart grid is a highly distributed network of clean, renewable energy deployed at the edge of the existing grid.

It requires an advanced level of computing to manage and optimize the highly distributed intermittent loads introduced. It also requires a "total system" approach to effectively balance multiple fluctuating energy sources, consumption levels, and new renewable technologies.



Real-Time Dynamic Network of a Smart Grid

Smart Grid Market Size

In 2021, the global smart grid market size was valued at $43.10 billion. Analysts believe it'll increase and reach $206.25 billion by 2030. The market will grow at an approximate CAGR of 19% during the forecasted period.

In 2021, the North American region held the largest share of 35% of the global smart grid market.

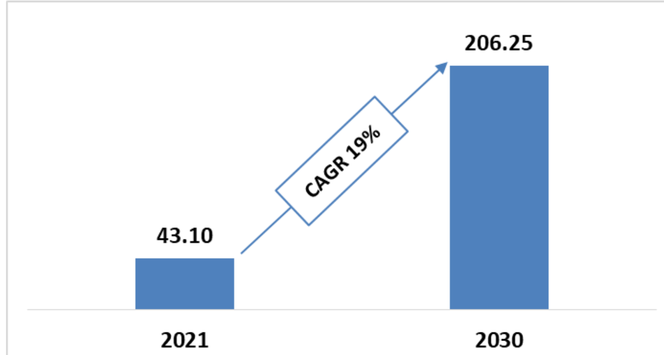
The growing need for smart infrastructure and the ever-increasing smart city projects were some of the critical factors driving the growth of the smart grid market in North America.

Global Smart Grid Market Size during 2021-2030 ($Billion)

Canada's Ministry of Natural Resources introduced the Renewable and Electrical Pathways Program in 2020, a four-year scheme that aided in the roll-out of smart grids. With $4.8 billion received in funding, the project aims to improve the dependability and capacity of its smart grids.

North America was an early user of smart grid technology, and the potential benefits of smart grids encouraged investments in the region's smart grid infrastructure implementation.

In June 2021, Poland's power grid operator PSE announced plans to invest $1.23 billion by 2030 across its network in the country's north to distribute electricity from planned Baltic offshore wind turbines to clients.

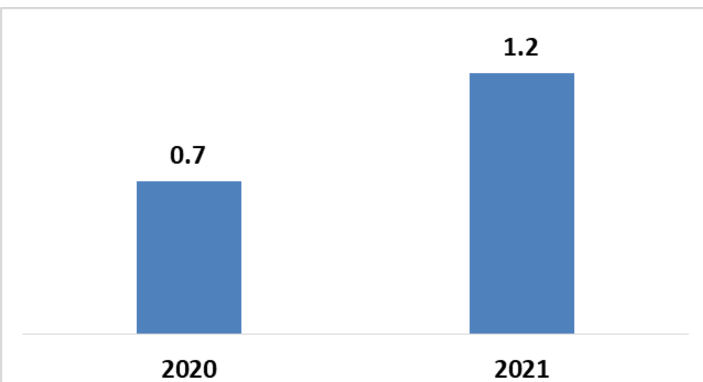


VC Investments in Smart Grid

In 2021, smart grid startups raised $1.2 billion in 35 rounds of venture capital funding, a 55% increase from the $748 million raised in 2020. With $789 million in 18 deals, smart charging firms received the most venture capital funding in 2021. The smart grid sector documented 19 M&A deals in 2021, compared to 21 in 2020.

Smart Grid VC Funding during 2020-2021 ($Billion)

Smart Grid Advantages



Load Balancing on Automatic Mode – A primary advantage of a smart electrical grid is automatic load balancing, which minimizes the likelihood of equipment failure. Companies must make manual modifications since electricity load varies depending on external variables. A smart grid employs technology that analyzes consumption trends to manage loads. This decreases strain on electrical equipment, particularly at peak periods.

Increased Efficiency of Electrical Transmission – Smart grids can regulate electrical transmissions because they use intelligent technologies to reduce electrical wastage during distribution. This boosts the efficiency of electrical transmission, which benefits all stakeholders.

Enhanced Utilization of Renewable Energy – Smart grids offer better choices for integrating renewable energy into the grid. Renewable energy sources, such as residential solar and battery storage, will play a more significant role in future smart grids, supplying regular base-load electricity and responding to demand surges.

Smart Grid Challenges

High Initial Costs for Deployment of Smart Grid Technology – The early stage of smart grid adoption requires a significant investment. Therefore, the involvement of local and national governments in modernizing energy infrastructure is critical. In addition, smart grid technology necessitates significant initial investments to establish transmission networks that allow two-way communication between the utility and the customers.

Storing and Managing Complicated Smart Grid Infrastructure Data – The adoption of smart grid technologies has created vast amounts of complex data. The data is largely unstructured and needs analysis to acquire critical insights. Smart grid solution suppliers need help storing and managing network node-generated data.

Smart Grid Companies

1. Itron, Inc.

Itron, Inc., based in the United States, assists utilities and cities in managing energy and water more effectively. Its smart grid solutions provide measurable benefits. These smart grid solutions are adaptable to different operating environments, business priorities, and investment objectives. Itron solutions combine information and operations technologies to offer customers unprecedented visibility into measurement and control activities, network management, system operations, data management, and analysis.

Acquisition

In 2017, Itron, Inc. announced the acquisition of Silver Spring Networks, a provider of smart grid products, for $830 million. The acquisition's goal was to accelerate Itron's Smart Grid and Smart City innovation growth.

2. Siemens

Siemens provides energy intelligence for a more flexible, sustainable power grid. Smart grids utilize digital technologies and IoT solutions to respond and adapt to changes in the grid intelligently. The key to leveraging data in the grid is incorporating energy intelligence into the Siemens Xcelerator for Grids portfolio. This enables grid operators to make grid operations more reliable, cost-effective, flexible, safe, and thus sustainable.

Using Smart Grid Compass methodology, Siemens has designed a road map for NB Power to incorporate its Demand Response Management System (DRMS) and Decentralized Energy Management Suite (DEMS). Thus, enabling the utility to manage electricity distribution in a more flexible, intelligent, and efficient manner.

Important Collaborations

In 2022, Siemens Smart Infrastructure partnered with Esri, the global leader in geographic information systems (GIS) and location intelligence. The collaboration aims to broaden Siemens' ecosystem of partners for its grid software business. The cooperation improves grid operators' power network planning, operations, and maintenance capabilities by combining Esri's robust mapping and spatial analytics software with Siemens' electrical topology expertise.

3. Cisco

Cisco has been working on Smart grids for a long time. Its Distribution Automation solutions use data communication infrastructure to remotely monitor and control various components of the electrical distribution grid, such as substations and feeders. This allows grid operators to collect and analyze real-time power distribution and consumption data and provide predictive information and recommendations to utilities, suppliers, and customers.

Important Collaborations

In 2022, Cisco collaborated with Schneider Electric to provide smart grid solutions in Egypt. The duo is constructing a highly efficient and cyber-secure network that would control and assist in integrating traditional and renewable energy sources by utilizing the latest Artificial Intelligence (AI) and Internet of Things (IoT) technologies.

Cisco will supply the IP and security infrastructure, including Cisco routers and switches, as well as various cyber security equipment and tools such as the Cisco Secure Firewall and Cisco Secure Network Analytics. On-site, the grid will be outfitted with Cisco IR1101 5G-ready industrial routers to assist in secure and efficient communication with the control centers. (Source)

Smart Grid Startups

1. AmpereHour Energy

AmpereHour Energy was formed by IIT Bombay alumni and power sector specialists to make an environmental and social difference via technical advancement in energy storage. Off-grid mini-grid solutions from AmpereHour comprise a 3-phase or 1-phase core power storage structure capable of both diesel generator and PV integration.

AmpereHour's Ah-Stack is a portable, scalable Li-ion energy storage stack. Ah-Stack systems have been deployed in rural off-grid micro-grids, distribution networks, co-located with behind-the-meter solar, and as independent systems. Their power management software, ELINA, enables customers to track and manage storage and mini-grid assets continuously.

2. SparkMeter

SparkMeter provides complete low-cost metering systems ranging from rural microgrids to existing urban central grid utilities. Through various features, including flexible billing, customer communications, and remote monitoring and control, its simple plug-and-play solution empowers microgrids and distribution utilities to enhance operations and attain financial stability.

SparkMeter's cloud-based grid management platforms, such as Koios and ThunderCloud, transfer data from the smart grid's edge to the cloud and back in low-bandwidth areas with sporadic Internet connectivity.

Microgrid utilities can minimize operating expenses with their software by automating customer service and invoicing operations via remote communication.

3. SYNDEM

Syndem is a forerunner in developing technologies that strengthen all power electronics-interfaced suppliers. Its goal is to bring together power system stakeholders and create synchronized and equal smart grids worldwide by using power electronic converters as synchronous virtual machines on the supply side, in the network, and on the load side.

The Syndem smart grid research and educational package is a multipurpose power electronic converter. It can enhance grid integration research and education for diverse renewable energy sources. It also has a household solar converter with a 3 kVA capacity and several inverters.

Important Collaborations

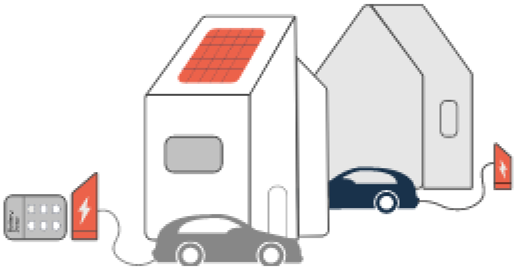
In 2020, the U.S. Department of Energy chose Syndem to collaborate and serve as a vendor for a project, 'The Solar Energy Technologies Office Fiscal Year 2020'. This initiative created a two-stage hybrid PV plant control framework that allowed the coordination of many hybrid PV plants with unpredictable production and improved grid stability via grid-forming inverter controls.

4. ENLİL (Deveci Tech)

ENLIL develops a smart vertical axis wind turbine that converts highways into renewable energy sources by utilizing city dynamics, thereby giving an additional source of power generation within a Smart City. ENLIL's wind turbine, installed on highways, provides energy by using both the wind caused by the flow of automobiles and natural winds.

Enlil has an integrated SMART system that allows for the addition of modules such as CO_2 measurement tools, data collecting via its IoT platform, traffic management systems, earthquake detection, connectivity for autonomous vehicles, and a built-in Wi-Fi station.

5. EdgeGrid



Edgegrid is an Indian smart grid startup that delivers clean energy using its digitally connected energy network. Its clean-tech platform connects sellers with individuals, businesses, and distribution companies that need energy services. With their apps, organizations can take control of their consumption, supply possibilities, costs, new income opportunities, and impact on the climate.

Conclusion

The International Energy Agency estimates that investment in electricity grids must average around $600 billion annually through 2030 for the global energy sector to achieve net-zero carbon emissions by 2050.

And one of the best ways to invest such a considerable amount is through collaborations. One such collaboration is Edge for Smart Secondary Substation Alliance (E4S), a partnership of eight major electric utilities providers that Intel and other companies are working with to develop a smart grid.

Intel is also collaborating with California providers to transform electrical substation relays into virtualized applications and with Malaysia's largest energy provider to digitalize its electric grid.

Big countries like China are accelerating investment in smart grids. For the first time, the State Grid Corporation of China announced spending more than CNY 500 billion and focusing on power grids.

Smart grids will get more exposure and recognition as the companies are optimistic about this energy storage trend.

SMART UTILITY

DTE Energy’s Smart Grid Devices Prevent More Than 16,000 Outages Throughout its Service Territory So Far in 2025

DTE is committed to reducing outages by 30%, cutting outage time in half by 2029.

Sept. 8, 2025 3 min read

DTE Energy’s, a Detroit-based diversified energy company involved in the development and management of energy-related businesses and services nationwide, smart grid devices have prevented more than 16,000 outages throughout DTE’s electric service territory so far in 2025.

Accelerating the deployment of these smart devices is an important component of DTE’s five-year, $10 billion plan to build the electric grid of the future and deliver on its commitment to reduce power outages by 30% and cut outage time in half by the end of 2029.

“We're building an electric grid that is smarter, stronger and more reliable," said Matt Paul, president, DTE Electric. “This technology gives us the ability to automatically reroute power and get crews to trouble spots faster, which means more reliable electricity for our customers."

- 16,019 power outages have been prevented since the beginning of 2025.
- 675+ new reclosing devices will be installed by the end of 2025, more than doubling the number of reclosers on the system since 2023. Reclosers can speed restoration by providing crews with an exact location of damage during an outage as well as rerouting power so more customers have service while crews make repairs.
- This is part of a five-year, $10 billion plan to improve electric reliability.
- DTE is committed to reducing outages by 30%, cutting outage time in half by 2029.

DTE’s smart grid is an interconnected system including the company’s Advanced Distribution Management System software, Systems Operation Center, substation equipment, automated smart devices, smart meters and more. The automated smart devices allow the company to remotely monitor, operate and control the grid across the communities that DTE serves, minimizing service interruptions for customers.

DTE will add more than 675 devices to its electric grid by the end of 2025, more than doubling the number of devices already on the system since the automation program started in 2023.

DTE’s commitment to fully automating the grid by 2029 will provide the following benefits:

- Improved safety: Smart grid devices can automatically detect and de-energize downed wires, helping to keep people safe.
- Fewer outages: Smart devices are designed to isolate areas of damage and reroute power, so the lights stay on for many customers while crews make repairs.
- Shorter outages and quicker restoration: Smart devices can quickly identify the location of the damaged equipment, so crews can arrive at the location faster and begin making repairs.

Transitioning to a smart grid is one part of DTE’s broader plan to build the grid of the future, which also includes upgrading existing infrastructure, rebuilding significant portions of the grid and trimming or removing trees.

Source URL: https://www.tdworld.com/smart-utility/news/55314988/dte-energys-smart-grid-devices-prevent-more-than-16000-outages-throughout-its-service-territory-so-far-in-2025

OVERHEAD TRANSMISSION

Strengthening the Grid: Rethinking Utility Pole Restoration as a Capital Investment

Utilities are shifting from traditional pole replacement to strategic reinforcement, emphasizing regulatory frameworks, cost management, and innovative technologies to enhance grid resilience amid climate threats.

Talieh Zargar Sept. 4, 2025 5 min read

Key Highlights

- Utilities are increasingly adopting pole reinforcement strategies to improve resilience against wildfires, storms, and aging infrastructure, moving beyond simple replacement.
- Regulatory bodies like the CPUC are differentiating between operational expenses and capital investments, favoring reinvestment that extends asset life and enhances safety.
- Innovative reinforcement technologies can extend pole lifespan by up to thirty years at a lower cost, supporting sustainable and cost-effective grid hardening efforts.

As utilities confront threats from wildfires, severe weather, and aging infrastructure, innovative strategies for strengthening distribution and transmission assets are gaining renewed urgency. Wooden utility poles remain vulnerable to damage from woodpeckers, storms, vehicle collisions, and heat-driven degradation. Pole programs, traditionally treated as providing limited alternatives to replacement, are now a focal point to bolstering long-term grid resilience planning. With limited capital budgets and ever vigilant regulatory scrutiny, utilities must plan and design the pole replacement and restoration programs to optimize performance and resiliency while appropriately budgeting costs by balancing between maintenance expenses and capital re-investment.

A Case Study in Action: Investor-Owned Utilities in California

To gain a better understanding of whether utility pole restoration qualifies as an operational expense or capital expenditure, Midgard Consulting conducted a review of investor-owned utilities operating in California and their expenditures of pole related monetary outlays caused by car accidents, storm and grid hardening, woodpecker damage and/or wildfire protection (including prevention measures).

In California, electric utility pole replacements are governed primarily by General Orders issued by the California Public Utilities Commission, along with utility accounting practices governed by Federal Energy Regulatory Commission accounting rules and CPUC General Rate Case decisions. Table 1 presents a breakdown of the rules and regulations governing pole replacements, with emphasis on when costs are expended versus capitalized.

Standard	Capitalize (e.g., Account 364)	Expense (e.g., Account 593)
FERC	New/replacement poles extending service life or capacity	Minor repairs, inspections, non-life-extending
CPUC	Projects above certain cost threshold or extending life/capacity; GRC-reviewed	Reactive/emergency fixes without upgrades
NARUC	Planned asset upgrades or new installations	Routine maintenance, patch work, minor component fixes

Differentiating between the alternative accounting treatments comes down to the nature of the expenditure, the resulting impact the expenditure has on the condition assessment of the asset, and the precedent and accounting treatment the utility has used previously for similar work. Work planned and incorporated within a larger expenditure program with the objective of extending the economic and effective lives of the assets has high confidence of being treated as capital expenditure. Unlike operating expenses that are immediately deducted from revenue in the year in which they are incurred, capitalized investments are added to the rate base and depreciated over the useful life of the asset.

Precedent in Practice: What the CPUC Is Teaching the Sector

Recent proceedings before the California Public Utilities Commission (CPUC) show how regulatory bodies are parsing these distinctions.

In its 2023 General Rate Case, Pacific Gas & Electric (PG&E) introduced a pole asset management strategy that classified severely damaged poles as capital replacements, especially those in High Fire Threat Districts. The utility was authorized to recover costs under capital accounts for systematic upgrades, despite pushback on unit costs and timing. Notably, PG&E had faced regulatory criticism following the 2021 Brewer Fire, which was linked to a pole patched (rather than replaced) despite known woodpecker damage5.

In Southern California Edison’s 2021 GRC6, the CPUC reaffirmed the principle that preventative maintenance under structured programs may qualify as capital, while emergency or reactive work typically remains an operational expense. SCE's “Pole Loading” and “Deteriorated Pole” programs were cited as examples where capital tracking and systematic planning enable life-extending interventions to qualify for long-term recovery.

These examples point to a regulatory appetite for re-investment subject to improved resilience as part of a disciplined, documented capital expenditure program.

The Case for Grid Hardening as a Capital Measure

According to Midgard Consulting's report, utilities capitalize investments where the application increases structural integrity, extends service life, and/or reduces environmental vulnerability.

This has implications beyond one product and signals a shift in how utilities might approach alternative reinforcement strategies, such as when a short-term repair may be transformed into a strategic asset investment.

A new utility pole reinforcement technology has been developed to extend the service life of existing wooden poles while improving their resilience against wildfire, severe weather, pest damage, and natural aging. Unlike temporary measures such as patching or bracing, this solution provides both structural strengthening and fire protection in one application. It can extend the lifespan of poles by up to thirty years at a fraction of the cost of full replacement, making it a cost-effective and sustainable alternative. By combining durability, resilience, and enhanced load-bearing capacity, reinforcement solutions represent a strategic investment for utilities, supporting grid modernization and wildfire mitigation programs.

The key litmus test for utilities' accounting treatment of their expenditures as capital versus maintenance expense is planning and intent. When pole reinforcement is programmatic, preventative, and performance-enhancing, regulators are expected to concur to treat infrastructure investment as an increase to utility rate base.

Resilience, Reimagined

As utilities face mounting pressures from regulators, insurers, and the public to prevent outages and fire-related liabilities, asset reinforcement is no longer a marginal consideration. It's a central piece of modern grid management.

Technologies are giving utilities a new toolkit to close the gap between full replacement and temporary repair. When used strategically, they represent not just savings, but long-term reliability and risk mitigation. More importantly, they fit into a broader rethinking of what grid hardening means in an era of climate disruption.

For asset managers, engineers, and regulatory professionals alike, the takeaway is clear: the line between expense and investment is moving—and reinforcing the grid may be one of the most capital-worthy decisions utilities can make.

For access to Midgard's full report, please contact davoud@gridwrap.com

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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

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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