Enhancing U.S. Coast Guard Mission Resilience and Energy Security Through Microgrids: A Scalable Pilot at Base San Juan

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Background:

Problem Statement: U.S. Coast Guard Base San Juan is mission critical in supporting maritime safety, security, emergency response in an expansive area of responsibility (AOR) covering approximately 1.3 million square nautical miles in the Eastern Caribbean but is met with constant electricity instability and extreme weather with a strain of a constantly changing climate and subpar energy infrastructure. Puerto Rico's actively degrading power grid subjects customers to outages seven times more frequent and fifteen times longer than the U.S. national median, a baseline that worsened further in early 2026 with an additional 16.2% increase in blackout duration and a 3.3% increase in frequency. Currently dependent on grid power and diesel generators, the base faces significant and frequent blackout periods that place pressure on fuel supply chains and effects mission readiness especially during adverse weather events.

Desired Solution: Improve Base San Juan's energy resilience with the capability to operate independently of the electrical grid for a minimum of two weeks with 99.99% certainty through use of microgrids, generators and alternative energy sources (PV, BESS). This provides a scalable techno-economic model ready to improve Coast Guard base energy resiliency nationwide.

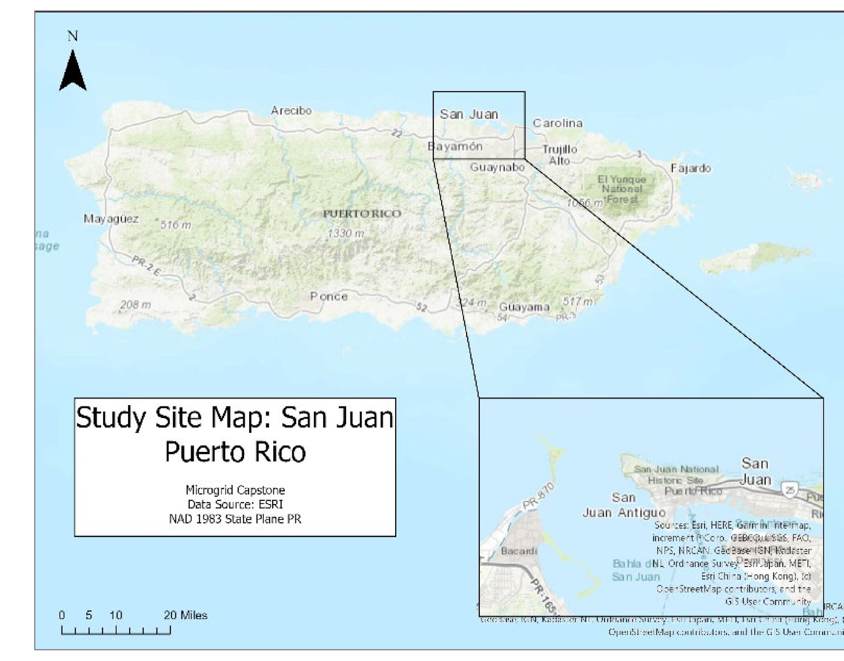

Figure 1: Study Site

Methods:

- Conducted solar radiation and wind energy potential analysis
- Mapped FEMA flood plains
- Ran ReOPT simulations to determine current performance, scenario simulation, resiliency analysis, internal Rate of Returns and more
- Created ArcGIS suitability model to determine placement for additional generators and battery energy storage
- Ran 20 REopt ERP scenarios across 6 families (baseline, fuel-constrained, single generator, degraded maintenance, battery sizing, four-nines target) to isolate each technology's resilience contribution
- Ran 9 REopt financial configurations to evaluate NPV, IRR, payback, and life cycle cost
- Developed hurricane hardening specifications from RMI Solar Under Storm and NREL forensic data

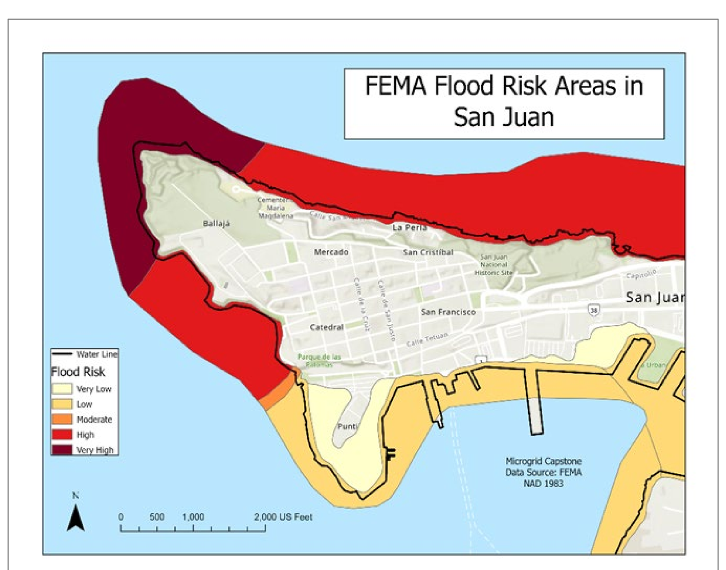

Figure 2: FEMA Risk Area Assessment

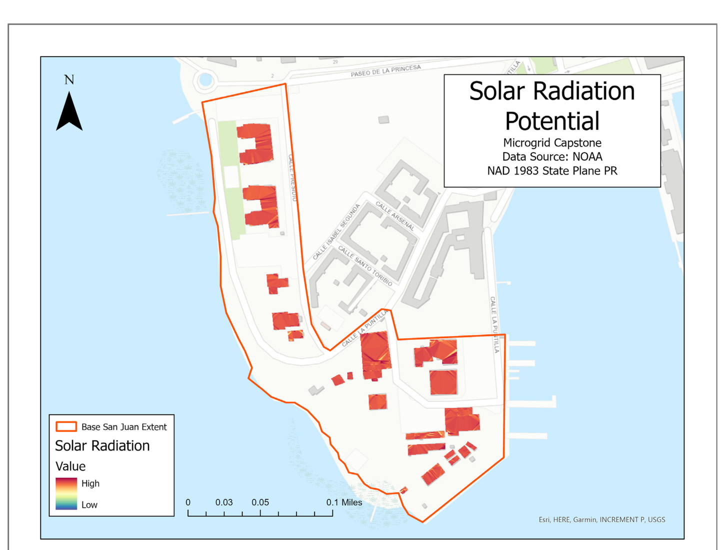

Figure 3: Solar Radiation Potential at Base San Juan

Figure 6: Suitability Analysis for Battery Storage and Generators

Results:

- Areas that are suitable for battery storage are highlighted in green on Figure 4.
- The amount of space on Coast Guard Base San Juan is suitable for a half to full container sized BESS.
- Baseline scenario (3 generators, 40k gal fuel) have 99.11% ERP at 14 days, which falls short of the 99.9% three-nines standard.
- Photovoltaic systems (PV) and BESS add negligible resilience improvement under normal fuel conditions.
- Under fuel-constrained conditions (10k gal), PV extend period of 99.9% ERP by 70 hours through extending fuel endurance.
- Battery raises hour-1 survival from 96.9% to 99.4% on single-generator buildings by bridging startup failures. Effect fades by hour 2.
- Maintenance quality (well-maintained vs degraded) is 70x more impactful than PV and battery combined.
- Four-nines (99.99%) requires 6 generators. 5 generators reach 99.96%
- PV alone returns +$3.85M in Net Present Value (18.8% IRR, 5.65-yr payback). Without PV, every configuration is NPV-negative.
- Recommended: 5 gen + PV + 1 MWh battery at +$529k NPV (three-nines), or 6 gen + PV + 1 MWh battery at -$505k NPV (four-nines). BESS system can be replaced with an Uninterruptible Power Supplies (UPS) system for more cost savings.

All resilience and financial results generated by the authors using NLR's REopt (Cutler et al., 2017)

Discussion

- No single technology provides full resilience. Generators sustain long-duration runtime. PV extends fuel endurance. Battery bridges startup failures. Maintenance prevents premature mechanical failure. Each covers a failure mode the others cannot
- PV is the economic engine: its $234k/yr utility savings fund the entire resilience upgrade. Without PV, adding generators costs $2-3M over 25 years. With PV, the same upgrade is NPV-positive
- Batteries are a compliance and bridging asset, not an economic one. The REopt optimizer selected zero batteries when unconstrained. Right-sizing at 1 MWh captures the bridging benefit while retaining returns.
- ERP results are conservative: REopt assumes no generator repair during outages. Actual reliability with on-site technicians and battery bridging is likely higher than modeled
- Hurricane-hardened PV (5,400 Pa modules, mechanical attachment, Zone 1 placement) adds only 5% to total capital costs. Systems built to these specs survived Maria and Fiona at 100% capacity

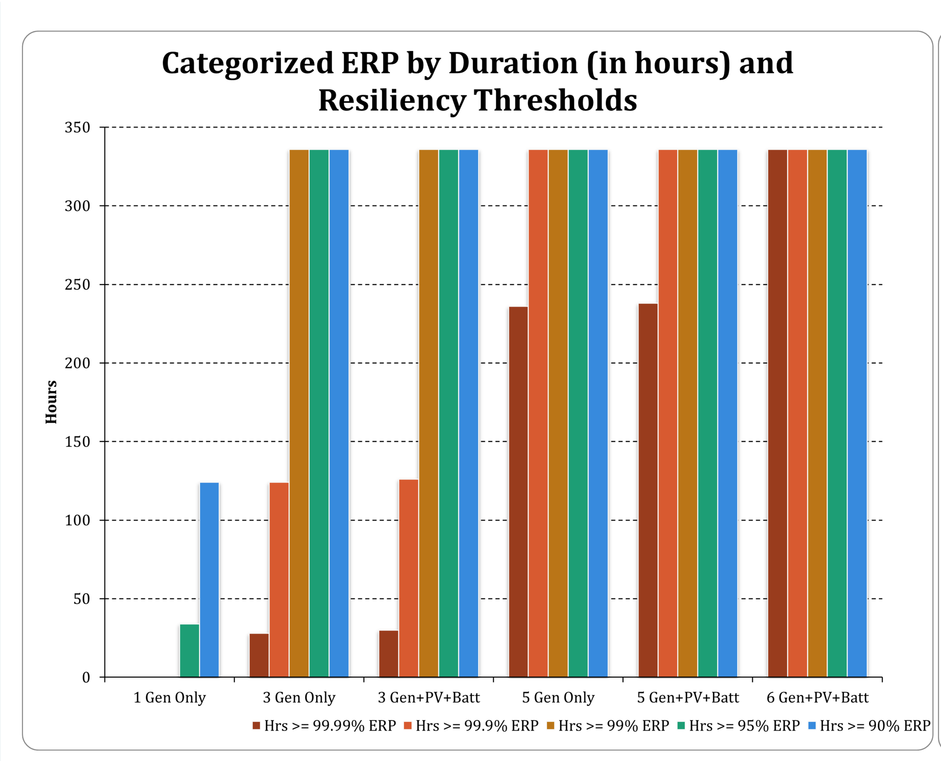

Figure 4: Categorized Energy Resilience Performance (ERP) by Duration and Resiliency Thresholds

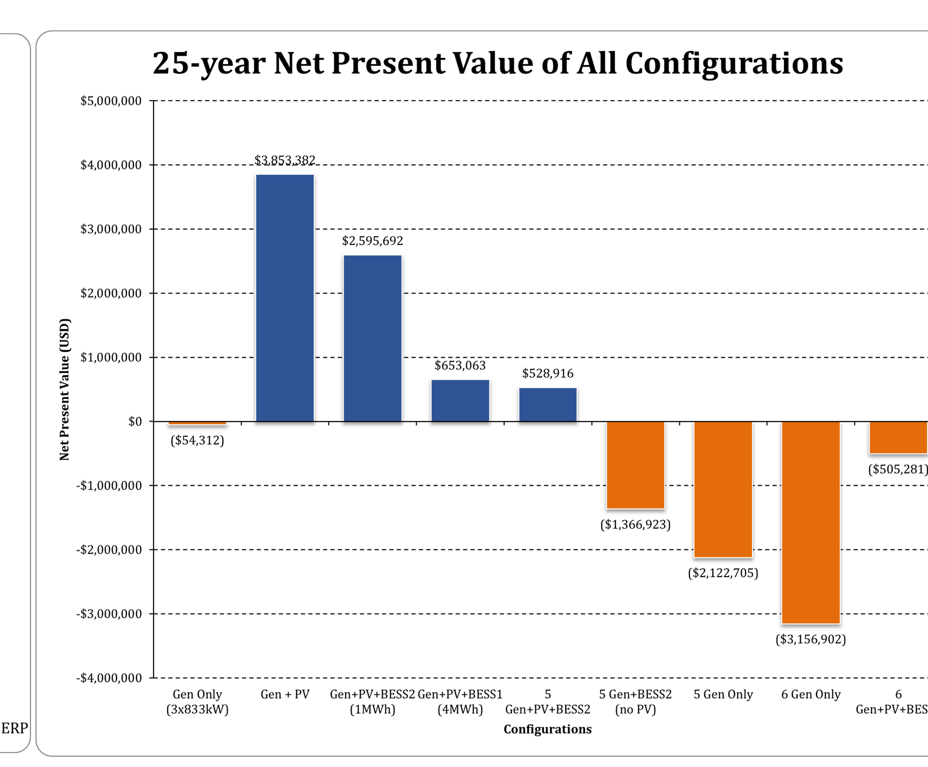

Figure 5: 25-year Net Present Value Analysis

Conclusion: Through quantitative and qualitative analysis, our study was able to determine that the current survivability of Base San Juan is substandard and is affecting our mission critical workload. Optimization of microgrids, a PV power source, a system of energy storage, and an increase in generators would significantly increase the overall resiliency of the base. A PV source provides the savings for all components. An energy storage provides instantaneous continuity of operations. Additionally, the generators increase the energy resiliency performance. All of these systems can be safely and resiliently installed to survive adverse weather conditions by following geospatial analysis recommendation and rigorous adherence to engineering standards.

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