Emergency Management: Effective Planning for Hurricane Damage Response In Puerto Rico

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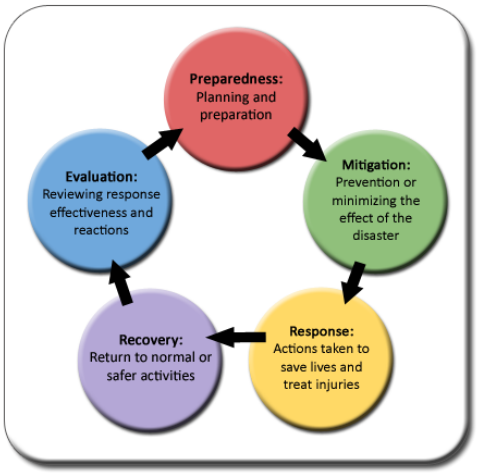
Emergency Management



One of the most important tasks to handle emergencies, specifically natural disasters, is to prepare extensively. It's important to establish parameters, coordinate with all parties involved, run drills, evaluate your responses, and then do it all again.

All throughout our history, we make attempts to be prepared, often condensing the time we give to this process, cut corners, and fight the all too prevalent issue of ambivalence. But with emergency management, every detail can literally mean life or death.

Our particular focus is on emergency management related to hurricanes in Puerto Rico and throughout the Caribbean Basin. Numerous hurricanes have left extensive damage in their wakes, but oftentimes more human damage is done post storm. For instance, the cost to repair and restore the electric grid in Puerto Rico following Hurricane Maria in 2017, was over $10 billion. However, the loss of life reached nearly 3,000, with some estimates as high as 4,600 deaths. But, these tragedies weren't caused by the storm itself, but were due to the extensive power outages.

Rarely do we have an opportunity to actually get it right. And now we have that chance. Thanks to Luciano Castillo, a Kenninger Professor of Renewable Energy and Power Systems at Purdue University, who put together an incredible collection of subject matter experts, researchers, analysts, scientists, as well as industry experts on various issues and topics related to emergency management and restoration. With a proven track record of putting together projects to identify and establish planning criteria, Dr. Castillo has worked tirelessly to provide innovative solutions.

Between his consortium, local elected officials, industry groups, and federal agencies, for the first time in modern history, Puerto Rico has an incredible opportunity to have sustainable solutions that are also eco-friendly, and will not only save money in the long run, but have a potential to produce revenues that will help expand the solutions island wide, and even throughout the Caribbean Basin.

The following pages lay out in detail the necessary steps to be taken in preparation, as well as in response to a natural disaster. Using this information as a guide, other documents related to costs and timelines will help create an extensive blueprint for proper emergency planning and overall management.

Key Priority Sites for Rapid Restoration

Even though the swirl of damage after a major hurricane like Hurricane Maria (Puerto Rico, 2017) can feel chaotic, there is a clear "triage" of buildings, facilities and systems that must be restored **first** if one wants to stabilize the situation and begin full recovery. Below is a structured breakdown of the most-critical assets to keep open, why they matter, and how one might prioritize (and metaphorically "underground" the weakest links) in the immediate aftermath.

Here are the facility types that should go to the top of the agenda — each with the rationale, typical damage challenges, and "what to check" items.

1. Electric power generation & distribution (grid, substations, poles)



Why critical: Without power we cripple almost all other critical sectors (water/wastewater, communications, healthcare, refrigeration, etc.). The Cybersecurity & Infrastructure Security Agency (CISA) identifies the energy sector as one of the 16 designated "critical infrastructure" sectors whose disruption has cascading effects. PNNL
Typical damage from hurricanes: Overhead lines knocked down, poles snapped, substations flooded or wind-damaged, vegetation/trees down across distribution lines.
Priority check-list:

- Are major transmission lines and substations operational?
- Can essential circuits (hospitals, shelters, water plants) be energized?
- Clear debris blocking access to repair crews.
- Temporary power (generators, micro-grids) in place for essential services.

2. Water supply, wastewater and sewage (treatment plants, pumping stations)



Why critical: Clean water for drinking, firefighting, hygiene and sanitation is foundational. Loss of water + power = public-health disaster.

Damage issues: Pump stations without power, flooding of treatment plants, broken pipelines, contamination of supply.
What to prioritize:

- Restore power/backup power at major water/wastewater plants.
- Check integrity of major pipelines and valves.
- Provide interim potable water supply (tankers, bottled) while repairs underway.
- Ensure sewage still flows or is temporarily diverted—avoiding massive public-health problems.

3. Healthcare facilities (hospitals, clinics, emergency services)



Why critical: The injured, ill and vulnerable cannot wait. Also, hospitals often serve as hubs for coordination and sheltering.
Damage issues: Hospitals may lose power, lose potable water, be structurally compromised, or be inaccessible due to debris or flooding.
Priority checks:

- Does the hospital have backup generators fueled and working?
- Are critical systems (ventilation, sterile environment, pharmaceuticals) intact?
- Access routes to hospital are clear.
- Communication links from hospital to emergency command are functioning.

4. Transportation and access (roads, bridges, airports, ports)



Why critical: Without the “supply arteries”, people, equipment and goods cannot move—so relief and repair operations stall.
Damage examples: Washed-out roads, collapsed bridges, airports damaged, ports blocked with debris.
What to restore first:

- Clear main evacuation/relief routes.
- Restore access to ports and airports (so supplies can arrive).
- Ensure at least one reliable route in/out of affected area.

5. Communications (telecom, internet, emergency radio)



Why critical: Coordination of emergency response, public information, and business continuity all depend on communications.
Damage issues: Cell towers down, fiber-optic lines broken, power outage at key telecom hubs.
Priority tasks:

- Restore power/backup power to key telecom hubs.
- Deploy mobile or satellite communications if primary networks are down.
- Establish emergency broadcast/alert systems for public.

6. Fuel supply and distribution (gas stations, fuel terminals)


Why critical: Without fuel we can't run generators, vehicles, heavy equipment, transport goods. It's a logistic "oxygen" for the system.
Damage issues: Power loss at fuel terminals, fuel contamination, blocked access roads, damaged storage tanks.
What to act on:

- Prioritize restoring fuel terminals that service emergency vehicles, utility trucks, and heavy equipment.
- Ensure safe storage, delivery routes, and that fuel is available for critical missions.

7. Shelters and emergency services / command centers



Why critical: People displaced by the storm need shelter and care; the command centers coordinate all restoration efforts.

Key concerns: Building may be damaged, power/HVAC down, communications cut, supplies lacking.
Action steps:

- Confirm operational shelters with power, sanitation, communications.
- Set up interim command centers if main ones are compromised.
- Link shelters, hospitals and utilities in a common incident management network.

Prioritization and "Restoration Ladder"

Here's a suggested ordering of efforts (a kind of "triage ladder") for post-hurricane environments. Think of this as "digging down" into the underground of recovery and restoring the foundation before building back up the structure.

1. **Ensure life safety** – search & rescue, medical triage, ensure shelter, prevent secondary disasters (fire, flood, collapse).
2. **Stabilize the foundational utility systems** – power, water/wastewater, communications. Without these, nothing else functions.
3. **Restore transportation and fuel logistics** – get crews, materials and supplies moving.
4. **Re-activate critical facilities** – hospitals, emergency operations centers, major shelters.
5. **Restore supply chain & commerce basics** – fuel, ports, markets, basic business functions.
6. **Reopen community services and structures** – schools, local businesses, municipal services.
7. **Rebuild and enhance resilience** – "better than before" design, hardened infrastructure, redundancy.

In the context of Hurricane Maria (and other similar disasters), many of the delays in recovery were caused by: power grid collapse, water/wastewater systems vulnerable, communications down, fuel logistics disrupted, and critical roads/bridges out. For example, in Puerto Rico the existing grid was old and damaged and the disaster exposed how the energy / distribution system was the bottleneck.

Special considerations for our work (waste-to-energy / sargassum disposal)

Since we're working in the waste-to-energy, landfill reclamation, sargassum disposal domain, these implications tie into our "undergrounding + hardening" concept:

- Without power, our thermal systems (vortex combustors, steam turbines) cannot operate — so ensure the power grid restoration is a higher upstream priority than our plant startup.
- Water/wastewater systems matter for cooling systems, scrubbing, emissions controls. If the municipal supply is compromised, our plant cannot run safely.
- Transportation access (for waste, sargassum, equipment) and fuel/energy logistics are critical — if roads are blocked or fuel is unavailable for mobile units, our system is stuck.
- Communications + command oversight: our project may need to coordinate with emergency management agencies and other infrastructure teams — we need reliable links.
- Think of our facility as a **node** in the larger "critical infrastructure mesh" — it depends on the upstream utilities and supports downstream services (energy, waste disposal, local economy). When rebuilding or designing for resilience, treat it as both consumer and provider in that mesh.
- When we propose or budget for recovery/upgrade, we can emphasize **resilience**: e.g., self-sufficient power (micro-grid, solar + storage), water reuse, redundant access roads — so our facility remains operative when upstream fail.

Here's a **ranked list of 12 key facility and system-types** that should be at the top of the restoration ladder after a major hurricane (e.g., in a setting like Hurricane Maria). For each a brief description is included, typical damage issues and a rough indication of how quickly they should be restored (recognizing real-world timing will depend on resources, logistics, and local conditions). Think of this as the "foundation stones" our recovery-undergrounding strategy must prioritize.

#	Facility/System Type	Why it's critical	Typical damage issues	Approximate restoration timeframe*
1	Electric power generation / transmission / substations	Without reliable electricity, nearly all other systems (water, communications, health, transport) are severely hampered.	Downed poles/lines, flooded substations, trees on lines, loss of fuel for generators. American Public Power Association	**Hours to a few days** for key nodes; full grid may take weeks/months.
2	Water supply / treatment / wastewater systems	Clean water and sanitation are essential for public health, firefighting, facility operations.	Pump failure (due to no power), flooding of treatment plants, pipeline breaks, contamination. FDEP	**1-3 days** for critical service (hospitals, shelters); weeks for full system.
3	Communications networks (telecom/cell/internet/emergency radio)	Enables coordination of relief, public warning, business continuity, access to help.	Tower damage, fibre cuts, power loss to hubs, access blocked for repair crews. Government Accountability Office	**Days** for core emergency comms; full commercial service may take longer.
4	Transportation infrastructure (roads, bridges, airports, ports)	Supplies, crews, equipment cannot move without access; evacuation/rescue depend on mobility.	Washed-out roads, debris blocking, collapsed bridges, damaged runways. FHWA Operations	**Days to a week** to clear main routes; full restoration weeks/months.
5	Fuel supply & distribution (terminals, storage, gas stations)	Fuel drives generators, vehicles, heavy equipment — a logistic "backbone" of recovery.	Terminals without power, access roads blocked, damaged tanks, supply interruptions.	**Days** to get fuel to priority zones; full retail service may take longer.
6	Hospitals, clinics and medical facilities	The ill and injured must be treated and facilities act as hubs in recovery.	Loss of power, water, access, damage to structures, loss of staff.	**Hours to few days** for emergency capacity; full operations days/weeks.
7	Emergency operations centers / shelters / command & coordination sites	These are the "nerve centers" for response and recovery-management.	Facility damage, power/internet loss, access issues, staff shortage.	**Within first 24-48 hours** ideally.

#	Facility/System Type	Why it's critical	Typical damage issues	Approximate restoration timeframe*
8	Food/grocery supply and pharmacies (commercial infrastructure)	Basic survival: food, medicine, and commerce must be resumed to stabilize community.	Supply chain disruption, store damage, distribution/logistics blocked.	**Within first few days** for basics; full services over weeks.
9	Waste management / debris removal / sanitation services	Without these, secondary public-health and logistic crises emerge (blocked roads, disease, pests).	Debris on roads, trucks inaccessible, landfill or transfer station damage.	**First week** very critical; ongoing for weeks/months.
10	Educational facilities / community centers (if used as shelters)	While not immediately life-critical, reopening these helps community normalcy, sheltering, and recovery morale.	Roof/wall damage, utilities down, access problems.	**Within 1-3 weeks** for partial reopening; full recovery later.
11	Commercial/business infrastructure (banks, communications hubs, major employers)	Economic recovery depends on business continuity; these facilities support jobs, income, and services.	Office damage, IT systems down, power/internet out, access disruption.	**Weeks** to get key business hubs operational; full business ecosystem months.
12	Environmental/waste-to-energy and specialized infrastructure (e.g., our sargassum disposal, MSW facilities)	These are often downstream dependencies: they rely on upstream utilities (power/water/access) and support long-term resilience.	Equipment damage, power/water loss, access/logistics blocked; may be lower priority for immediate life-safety.	**Weeks to months** depending on size and complexity; but we want to push earlier if we focus on resilience.

**** "Approximate restoration timeframe" is indicative: actual times vary hugely with damage extent, island vs mainland setting, resource availability, logistic constraints (especially after major hurricanes).***

Some additional notes & "swirl" metaphors for our field

- Think of the infrastructure as a "foundation grid" under the building of recovery. If we **underground** (i.e., shore up) the weakest foundational links early (like power, water, access), we prevent the structure above from collapsing.
- Pay special attention to **interdependencies**: e.g., we can't restore wastewater treatment if power is still out; we can't get crews to a substation if roads are blocked. Models show that restoring traffic signals or access speeds up power restoration. arXiv
- For our waste-to-energy/sargassum disposal work: while it may sit lower on the immediate life-safety list, it moves up quickly in the resilience phase. If we design it to **kick in** as soon as upstream utilities are stabilized, we advance from the "recovery" phase into the "better-than-before" resilience phase faster.
- Documentation and prioritization matter: utilities guides emphasize mapping priority customers (hospitals, shelters) and making them part of the first-restoration list. EPA
- Use the "triage ladder" approach: immediate life-safety → core utilities & access → medical/communications → logistics/fuel → commerce/community services → long-term resilience.