

### **EPRR TASK A:** Black Sky Playbook Use Cases













### **CASE CLASSIFICATION**



## Class A

Class A denotes a true Black Sky event, affecting power, communications, and water, with cascading and lasting impacts.



Class B events come close to becoming Black Sky, but fall just short due to a given variable, such as duration, that enables event mitigation.



Class C events contain one or several elements of Black Sky events.

### **CASE SELECTION**



#### Hurricane Maria '17

Class A Black Sky Scenario

#### Winter Storm Uri '21

Class B Black Sky Scenario

#### **California Wildfires**

Class C: Black Sky Components

Southwest Arizona -California Blackout

Class C: Black Sky Components

#### 2003 Northeast Blackout Class C: Black Sky Components

### Hurricane Katrina

Class C: Black Sky Components

#### **Superstorm Sandy**

Class C: Black Sky Components

### HURRICANE MARIA September 16 - October 2, 2017



#### **Overview:**

Hurricane Maria devastated the northeastern Caribbean in September 2017, particularly Dominica, Saint Croix, and Puerto Rico. It is regarded as the worst natural disaster in recorded history to affect those islands.



### **Total fatalities:**

3,057/Harvard University Study, puts the death toll at 4,645\*



Highest wind speed: 174 mph



Severity: Category 5 Hurricane (SSHWS)

#### **Bottom line:**

Maria was a full scale Black Sky Event (BSE) that destroyed or critically impacted the electric grid, water infrastructure, telecommunications networks and nearly all other forms of modern society. The island's infrastructure was weak and vulnerable to storms well before Maria. But the government's efforts to respond were slow, insufficient, and lacking transparency.

### MARIA | THE LARGEST BLACKOUT IN US HISTORY



- Puerto Rico faced extensive and deep-rooted stressors prior to the 2017 hurricane season

- Puerto Rico experienced a decade of economic decline and a debt crisis

- Puerto Rico has struggled to provide effective and transparent governance

- Hurricane Maria destroyed much of the commonwealth's electricity grid

- Nearly all 3.4 million residents lost power

- Approximately 90 percent of households applied for post-disaster assistance

- Deaths in Puerto Rico were 62 percent higher in the three months after the hurricane than during the same period in 2016



The Storm Track - Maria essentially bi-sected the island

### MARIA CASCADING CONSEQUENCES



### Cascading consequences of electricity loss in healthcare included:



- Loss of vital medical equipment like dialysis machines
- Spoiling of medicines like insulin
- Loss of water pumps
- Consumption of contaminated water sources by residents
- Failure of sanitation networks
- A major outbreak of leptospirosis across multiple communities
- Overwhelming of hospitals and health care agencies

### MARIA BREAKDOWN BY EVENT PHASE



	Pre-Event Mitigation	Event Response		Post-Event Restoration	
Critical Moments	Minimal to no pre-disaster Mitigation to the island infrastructure. Decades of sub-standard investment.	Complicated by the Island, lack of communications, poorly managed harbor and lack of unified response		The last neighborhood that lost electricity after Hurricane Maria — 328 days after the Category 4 storm hit the island	
Significance	Nearly non-existence of command and control initially.	Complete loss of an electrical grid that could not be restored, required rebuild and re-engineering		Unbounded cascading outages	
	Inability to prioritize and action within internal resources. No tested or validated response plans.	Water ended up being the most important resource that impacted the island communities	The restoration and recovery plan was conflicted by mixed priorities, resource shortages	No clear vision of the appropriate direction in a timely manner shorten the restoration of Cl.	
	No interchange available			Inept contracting bordering on criminal in some cases. A Federal investigation was initiated over contracting irregularities.	
Alternative Actions	Closer alignment between the local, state and federal government with close coordination with private sector organizations. This is actually what it took to get the restoration jump started, but it took too long. Improved planning for response and restoration. Increased funding for resilience and hardening of key infrastructure elements. Improved grid design, redundancy in fuel supplies (mixed environment), improved cross-sector planning (none existed).				

**CLASS** 

# MARIA REGULATORY AND GRID BACKGROUND INFORMATION (Rand Report, 2020)

Puerto Rico relies primarily on large fossil fuel power plants and long transmission lines to carry electricity into mountains, coastlines, and urban centers. Five of PREPA's eight major power plants were constructed before 1980.

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Approximately 57 percent of Puerto Rico's electricity is produced from petroleum (fuel oil), 31 percent from NG, 18 percent from coal, and 3 percent from renewable energy sources (wind, solar, biomass, and hydroelectricity)



In 1981, PREPA (**Puerto Rico Electric Power Authority**) assumed control of all Puerto Rico-owned electric-power systems in Puerto Rico



PREPA is governed by a nine-seat board: Six seats are appointed by the governor of Puerto Rico, two seats are elected by power consumers, and one seat is reserved for the Secretary of the Department of Transportation and Public Works

# MARIA REGULATORY AND GRID BACKGROUND INFORMATION (Rand Report, 2020)

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PREPA is one of the largest publicly owned utility companies in the United States. From 1941 until 2014, PREPA operated independently of any regulatory oversight other than direct legislative control.



In 2014, PREPA ranked **first** among U.S. publicly owned utilities in terms of both customers served (1.5 million) and electricity revenue (\$4.6 billion) and ranked ninth in terms of power generation (12.7 million mWh)



In 2014, following a <u>series of complaints about management and</u> <u>electricity service</u>, the government of Puerto Rico passed the **Puerto Rico Energy Transformation and Relief Act**, which created PREB (Puerto Rico Energy Bureau).



PREB is an independent oversight board and regulatory authority managed by a commission president and two associated commissioners.. PREB was given powers to oversee PREPA's energy rates, power generation, and interconnection matters, as well as implementation of the standards for renewable energy production (as adopted in 2010).

## MARIA | IMPLICATIONS FOR REGULATORS

### What Lessons to Take Away

### Precedent

- Puerto Rico has endured over 50 named Hurricanes in recent recorded history.
- Climate change will increase the odds of these events occurring at an ever increasing rate with a greater level of severity.

### Challenge

- Is it possible to fully prepare/ harden avoid a BSE on an island?
- Can grid modernization be accomplished in a potentially compromised contracting environment?
- How to best accomplish critical pre-planning response and restoration planning.



- Fully harden both the generation and essential elements of the transmission network.
- Decentralize generation plants
- Implement dual-fuel micro-grids at essential CI locations(\*)
- Mandate response and restoration planning



- Fuel diversity and duel-fuel requirements
- Develop creative investment strategies to incentivize Private Sector Investment.
- Mandate Transparency in all Contracting for CI and Public Services.



### WINTER STORM URI | Texas 2021 Blackout





### **URI** THE MARGIN OF ERROR IS SMALLER THAN YOU THINK



CLASS B 13



### **URI BREAKDOWN BY EVENT PHASE**



	<b>Pre-Event Mitigation</b>	Event Response		<b>Post-Event Restoration</b>	
Critical Moments	Winterization of generation assets	Load Shedding		4 minutes and 37 Seconds	
	Higher than anticipated failure rates	Exceeded pre-planned loads		Unbounded cascading outages	
Significance	Compromised fuel resources	Water facilities	DoD Installations	Weeks to months	
	No interchange available			Water "re-start" compromised	
Alternative Actions	Economic incentives for proactive hardening and protection				

### **URI** CASCADING CONSEQUENCES



### Cascading consequences of electricity loss:



\$16 billion in additional service charge for electricity

12/14 DoD installations with power interruptions

Extensive disruptions to natural gas pipeline systems

Consumption of contaminated water sources by residents

Failure of sanitation and water treatment networks

Communications outages with short-duration backups

### **LESSONS "LEARNED" < LESSONS APPLIED**



## Bottom line Black Sky component: Lack of interchange and capacity availability puts Texas at increased risk for extended blackouts

### Data & Variables

First in a series of winter blackouts
 Loss of 1710 MW of firm load
 Poor load forecast played a significant role

#### Data & Variables

 Loss of 4,900 MW of firm load
 Poor load forecast, insufficient generation capacity and lack of interchange played the most significant role



### **URI** IMPLICATIONS FOR REGULATORS





- When is a low-probability event certain?
- How much is resilience worth?
- Estimated property damage \$195.6 billion
- Role of mandatory standards for regulation

#### **Needs Assessment**

- Historical trend of events ('89, '01, '11, '21 - see slide 24)
- Rising cold weather load peaks and declining generation reserve margins
- Recent events establish baseline for avoided cost model to determine resilience value



#### Roles

- Real-time cost "ceiling" for rates based on extreme conditions
- Generation performance regulation and hardening requirements



### Capacity

- Capacity performance markets
- Duel-fuel requirements for Black Start generators
- Interconnection
  minimums
- Load prioritization criteria

### Regulators play a vital role in every stage of Black Sky

### **CLASS C: CRITICAL COMPONENTS CASES**



Even when an event does not meet the threshold of a Black Sky event, impacts can demonstrate a single component of Black Sky that teaches us more about the potential for consequences when they are combined. Each Class C events shows a specific component.



### **CALIFORNIA WILDFIRES**



### California: A Bellwether State - Is PSPS coming to you?

Situation:	California suffered back-to-back record-breaking fires in 2017 and 2018.
Utility Business Decision:	PG&E sells a product, electricity, at a government-set price. "And when that price is not worth the wildfire risk associated with providing service, or when the price does not support the investment necessary to make the service safe, the utility turns off the service to particular sets of consumers avoid the potential liability.
Result:	PG&E <b>filed for bankruptcy</b> after the utility was found liable for igniting multiple fires, including the <b>Camp Fire</b> that spread over 150,000 acres, destroyed the town of Paradise, and killed 86 people.
Impacts:	A Public Safety Power Shutoff (PSPS) for a representative 600k accounts that lasts just 24hrs <u>could</u> <u>cost</u> in excess of \$1.8 billion in costs incurred and opportunities lost. The highest tolls of PSPS outages may be borne by the most vulnerable: People who depend on medical equipment at home, whose jobs will be closed, and who face food insecurity without refrigeration
Mitigation	Trimming trees around power lines and removing dead vegetation are costly, especially over PG&E's vast 70,000-square-mile service territory. Reporting showed that PG&E knew about the hazards of its aging infrastructure for years and neglected maintenance.

### **CALIFORNIA WILDFIRES** | IMPLICATIONS FOR REGULATORS





Gaps

- Aging infrastructure
- Neglected
  maintenance
- Unrestricted population growth, economic impacts
- Operating the "Duck Curve"
- Transmission constraints and availability

#### **Needs Assessment**

- Realistic impact to the service territory based on multiple factors including:
  - Climate change (both fires and floods)
  - Population impacted and average income (mobility)
  - Economic Impact and Investment Potential



#### Roles

- Unique coordination requirements between PUC/State and private utility
- Local Community mandates
- Economic drivers for change



- Open the market to more outside competition
- Harden services to customers in high-risk areas (cost shift)
- Economic, "avoided cost" model of investment

The environment is changing, forward looking resilience investments are mandatory to avoid BSE type events.

### **2011 SOUTHWEST BLACKOUT | OVERVIEW**

CONVERGE STRATEGIES

On September 8, 2011, a hot day in Southwest Arizona saw relatively high loads and exports to Southern California. The loss of a single 500 kV transmission line initiated cascading outages that left some 2.7 million customers without power, amounting to about 7,835 MW. Parts of Arizona, Southern California, and Baja California, Mexico, all lost power, including the entirety of San Diego.

Customer outages persisted for 8-12 hours depending on the service territory, but restoration was generally rapid owning to the lack of damage to assets. However, generation took substantially longer to restore following a trip. While two units came back on-line within 5 hours, the remaining 94% of generation not able to come back on-line for at least 56-87 hours.

This event showed that the system was not being operated in a secure N-1 state. This failure stemmed primarily from weaknesses in two broad areas — operations planning and real-time situational awareness. Ultimately the margin of error was reduced to the loss of a single asset and the cascade was all but inevitable once a vital transmission line failed.



CLAS:

### SOUTHWEST ARIZONA / CALIFORNIA 2011 BLACKOUT | IMPLICATIONS FOR REGULATORS





### The margin of error for N-1

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- error for N-1 operation is too small
- Real-time visibility is essential to preventing/ reducing outages

#### **Needs Assessment**

- Expanded criteria for infrastructure planning and contingency analysis
- Improved visibility on the "seams" of system operators/ ISOs
- Generators cannot be turned on like light switches



#### Roles

 "Trust but verify" remains an essential function of regulators on utility operations



Resilience planning criteria remains an area of emphasis going forward

### N-1 is the bare minimum, not the end goal



### 2003 NORTHEAST BLACKOUT OVERVIEW



On August 14, 2003, a high-voltage power line in northern Ohio brushed against some overgrown trees and shut down. Over the next hour and a half, as system operators tried to understand what was happening, three other lines sagged into trees and switched off, forcing other power lines to shoulder an extra burden. Overtaxed, they cut out by 4:05 P.M., tripping a cascade of failures throughout southeastern Canada and eight northeastern states until 50 million people had lost power in a matter of hours.

This event represents the largest blackout in North American history, resulting in 11 deaths and an economic impact of \$6 billion dollars due to a lack of electricity for 48-72 hours in sections of the impacted area.

Overall, this was a watershed moment for grid operations that produced a report with 46 recommendations to reduce the risk of future blackouts. These recommendations comprise the fundamental aspects of grid reliability criteria today and ushered in a new era of how the grid would be regulated and operated to reduce the changes of similar events occurring again.



# **2003 NORTHEAST BLACKOUT | IMPLICATIONS FOR REGULATORS**





The small things (vegetation management) matter

• System visibility and regional coordination

• There are no "plans" for outages of this scale

- Needs Assessment
- Intersection of reliability and resilience
- Seems between grid systems and operators
- Operational shortfalls



#### Roles

- Multi-state impacts require multi-state coordination across the board
- There is no "federal" grid even during a national event



- Regulation plays a vital role in mitigation
- Resulted in the development and approval of 96 new reliability standards

### Events drive regulation, but we must be proactive



#### CLASS C 25

HURRICANE KATRINA OVERVIEW

Hurricane Katrina formed on August 23, 2005, and in less than a week grew from a tropical depression into a category 4 hurricane. When Katrina made landfall on August 29 near New Orleans on the U.S. Gulf Coast, it brought widespread destruction and flooding with it.

Katrina was the most destructive storm to strike the United States and the costliest storm in U.S. history, causing \$125 billion in total damages, according to the National Oceanic and Atmospheric Administration

Overall, more than 1,800 people lost their lives as a result of Hurricane Katrina. More than 1,500 death occurred in Louisiana, around 230 in Mississippi, and 14 in Florida. Katrina is the third deadliest hurricane in U.S. history. The flooding and widespread damage from Katrina delayed rescue and aid efforts for days. Besides the death toll, hurricane Katrina left many people homeless as more than 800,000 housing units were destroyed or damaged in the storm.





## KATRINA MAJOR CHARACTERISTICS & CONSEQUENCES





#### Poor initial Situational Awareness

Predictable cascading consequences

Health impacts - resulting loss of life

Local, State and Federal Coordination Issues

Mass evacuation/migration of constituents

Michael D. Brown, director of FEMA, forced to resign

Amazing coordination of the Electrical Sector to restore power

Entergy Corp. companies, providing power in Arkansas, Louisiana, Mississippi and Texas, suffered damage from Katrina and Rita to 28,900 distribution poles, 522 transmission lines and 706 substations. The storm made landfall in the area on Aug. 29, 2005, and all customers had access to power by Oct. 15, said Philip Allison, Entergy spokesperson.

### **KATRINA** ON THE GROUND



""[There was] no clear designation of who was in charge, telling reporters, "The state and federal government are doing a two-step dance."" New Orleans Mayor Ray Nagin

New Orleans Mayor Ray Nagin "We wanted soldiers, helicopters, food and water," "They wanted to negotiate an organizational chart." Gov. Kathleen Babineaux Blanco\*

Conflicting views and priorities - unity of action is required!



### **KATRINA | IMPLICATIONS FOR REGULATORS**





#### Gaps

- Accurate Risk Assessments
- Public Messaging
- Pre-planned solutions for Sheltering, restoration\* and Whole of Community Coordination

### **Needs Assessment**

- Long and near term market incentives (Bonds)
- Processes and procedures for response mission prioritization
  - Resource Management tactics and techniques for catastrophe response - people, stuff and capabilities



#### Roles

- Effective Emergency Managers at all levels of government (more than a title)
- Effective cross-sector liaisons
- Market impact and incentives



- Reorganization and realignment of local and state emergency response agencies
- Trained, Cross-Sector Liaisons
- Effective, integrated restoration plans for both public and private sector

### States should build up their internal resource pool

### SUPERSTORM SANDY OCTOBER 22, 2012 - NOVEMBER 2, 2012



Actually several storms wrapped together, which made it one of the most damaging hurricanes ever to make landfall in the U.S.

Over 8 million people lost power during the storm.

Power outages from Sandy were experienced as far west as Michigan.

Outages were seen for days in some major cities, while outlying areas were without power for weeks.

In the nine days that Sandy raged, it killed 70 people in the Caribbean and almost 150 people in the U.S.

An unusual combination of hurricane conditions and cold fronts contributed to Sandy's potency.

More than 600,000 housing units were destroyed in New Jersey and New York.

Sandy is considered the fourth most expensive storm in U.S. history.

The government of New York City estimates that \$19 billion in damages was inflicted on the city alone. The National Oceanic and Atmospheric Administration estimates Sandy caused at least \$70 billion in damages.



### **SUPERSTORM SANDY** IMPACTS & MAIN FEATURES

CONVERGE STRATEGIES

Climate change driven intensity - dubbed a Frankenstorm

Massive in size, scope, and duration

**Critical Infrastructure Impacts** 

- Electric Grid (8 million without power days to weeks)
- Transportation Grid (Subway Systems South Ferry Station Lost)
- Communications Grid
- Homes destroyed and damaged

#### **Fuel Issues**

- Flooding shut down two refineries and numerous terminals; and power outages, which disabled gas stations and the area's biggest pipeline.
- The problem was not so much a lack of gasoline as an inability to transport it to the right place.

### **SANDY** | IMPLICATIONS FOR REGULATORS





Resilience planning for storms of a new magnitude: --Electric Grid -Comm Grid -Fuel Systems

 Recovery options focused on efficiency and effectiveness -Housing -Infrastructure

#### **Needs Assessment**

- Vetting of restoration and recovery contractors
- Improved housing options for catastrophe recovery
- Streamlined certification for Mutual Aid Teams



#### Roles

- Public Interest Watch Dogs for Restoration and Recovery Contracting
- Integrated Resilience Officers at the community and critical infrastructure level



- Effective Planning Scenarios for Black Sky level events
- Improved resilience investment for flooding
- Enhanced Energy Assurance Fuel Plans at the local and state level

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### **USE STUDIES | TAKEAWAYS FOR COMMISSIONERS**



