# PR100: Puerto Rico Grid Resilience and Transition to 100% Renewable Energy

## Preventing and Responding to Extreme Events

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Technical Committee: Analytic Methods for Power Systems (AMPS)

# Results of Hurricane Maria Landfall in PR

- Landfall on Sep 20, 2017
- Incapacitated  power system
- Entire island left without electricity and access to fresh water
- Some parts are still recovering
- **A resilient electric grid is vital to Puerto Rico's security, economy, and way of life**


# Puerto Rico Energy Public Policy

Act 17 2019 requires PREPA to procure the following portions of its power needs through renewable energy:

| 40% | 60% | 100% |
|---|---|---|
| by 2025 | by 2040 | by 2050 |

## 2020 Integrated Resource Plan (IRP)

- **Retire a significant number of oil-fired thermal units** in the next 5 years
- **Retire the AES coal-fired power plant** by 2027
- **Retire Aguirre diesel-fired combined cycle units** 1 and 2 by 2030
- **Limit the development of new gas turbine peaking units** to 81 MW
- **Integrate renewable generation projects** to achieve the renewable portfolio standard in Act 17

# PR100 Seeks To Answer These Complex Questions

- What are the pathways to achieving Puerto Rico's 100% renewable energy target by 2050?
- Does reaching 100% mean big changes locally—like building new transmission lines?
- If Puerto Ricans adopt energy technologies like electric vehicles (EVs) and expand air-conditioning, how might that change total demand for electricity?
- How can Puerto Rico assure that the new system is reliable during extreme weather events?
- What are the impacts on jobs and the local economy?
- What needs to be done to support an equitable energy transition for all Puerto Ricans?
- What might this all cost?
- And what investments and actions are needed in the near term to enable Puerto Rico's long-term objectives?

# Phases of Puerto Rico 100% Renewable Energy Study

### 1 Responsive Stakeholder Engagement and Energy Justice

- Stakeholder engagement inclusive of procedural justice
- Energy justice and climate risk assessment

### 2 Data Gathering and Generation

- Resource potential and demand projections (solar, wind, hydro)
- Demand projections and adoption of DER (considering load, EVs, energy efficiency, distributed PV and storage)

### 3 Scenario Generation and Capacity Evaluation

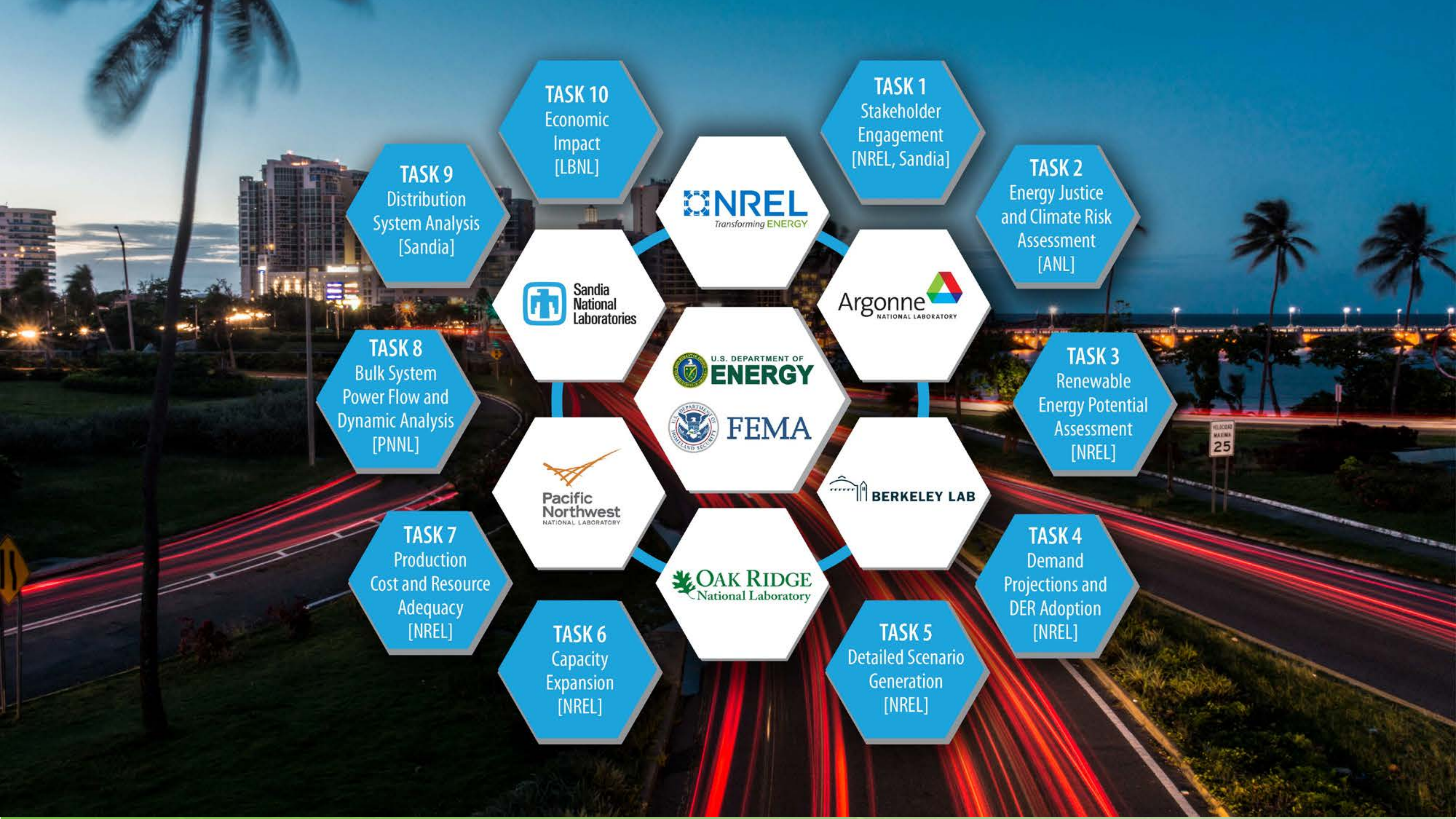
- Detailed scenario generation
- Distributed PV and storage grid capacity expansion
- Production cost and resource adequacy

### 4 Impacts Modeling and Analysis

- Bulk system analysis for enhanced resilience
- Distribution system analysis
- Economic impacts

### 5 Reports, Visualizations, and Outreach

- Scenarios for grid resilience and 100% renewable electricity for Puerto Rico
- Reports and outreach
- Implementation roadmap


TASK 1
Stakeholder Engagement [NREL, Sandia]
TASK 2
Energy Justice and Climate Risk Assessment [ANL]
TASK 3
Renewable Energy Potential Assessment [NREL]
TASK 4
Demand Projections and DER Adoption [NREL]
TASK 5
Detailed Scenario Generation [NREL]
TASK 6
Capacity Expansion [NREL]
TASK 7
Production Cost and Resource Adequacy [NREL]
TASK 8
Bulk System Power Flow and Dynamic Analysis [PNNL]
TASK 9
Distribution System Analysis [Sandia]
TASK 10
Economic Impact [LBNL]
NREL Transforming ENERGY
Argonne NATIONAL LABORATORY
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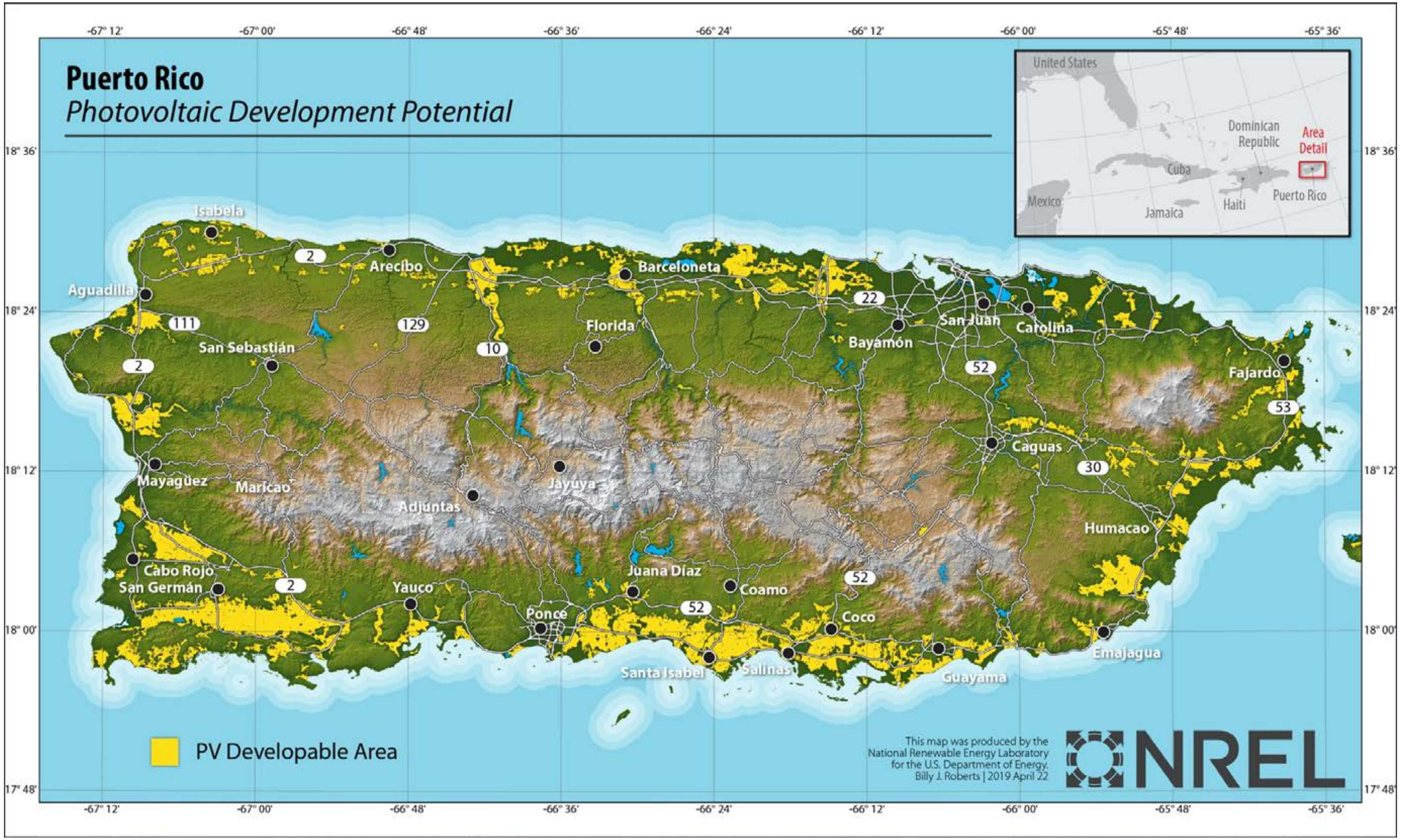
OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY
Sandia National Laboratories
U.S. DEPARTMENT OF ENERGY
FEMA

# Utility-Scale Solar PV Development Potential

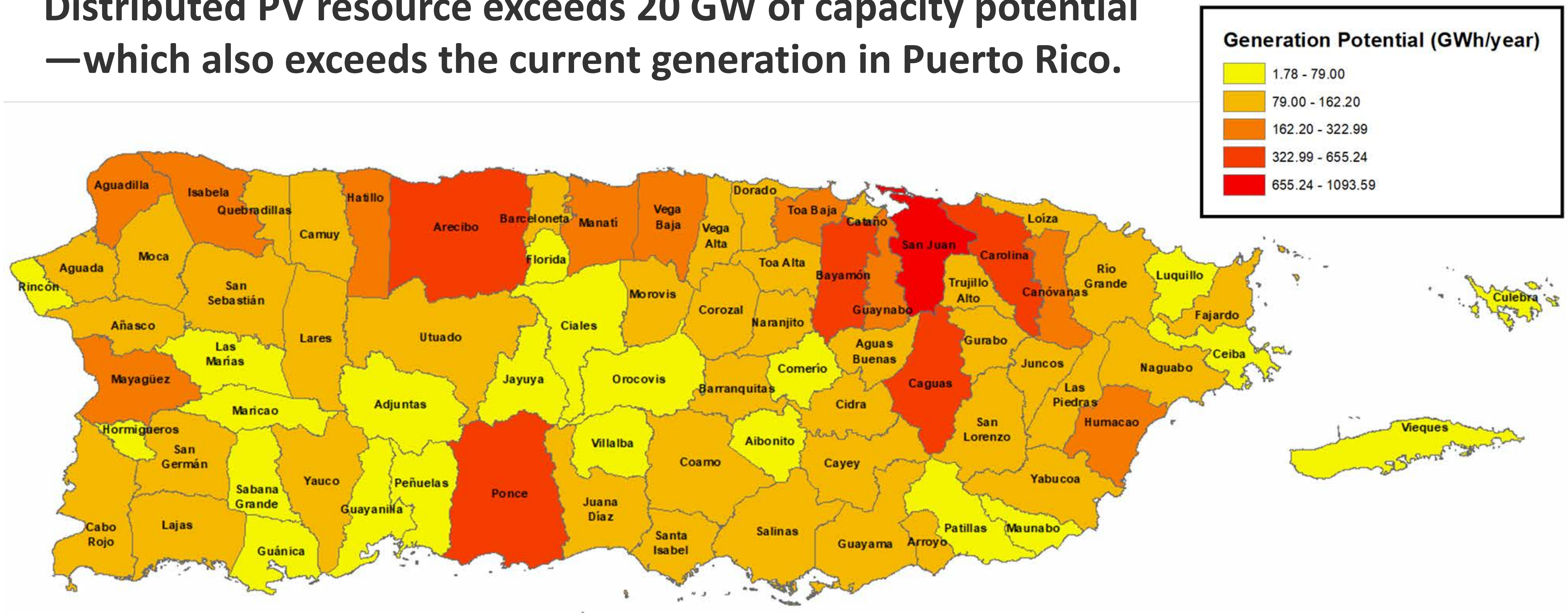
## NREL Analysis of Utility-Scale Solar PV Development Potential Found Greater Than 20 GW Total

*Sources: Grue at al. (2019), [Solar Resource and Technical Potential Modeling](#) (NREL Presentation); Grue et al. (2021), [Quantifying the Solar Energy Resource for Puerto Rico](#) (NREL Technical Report)*



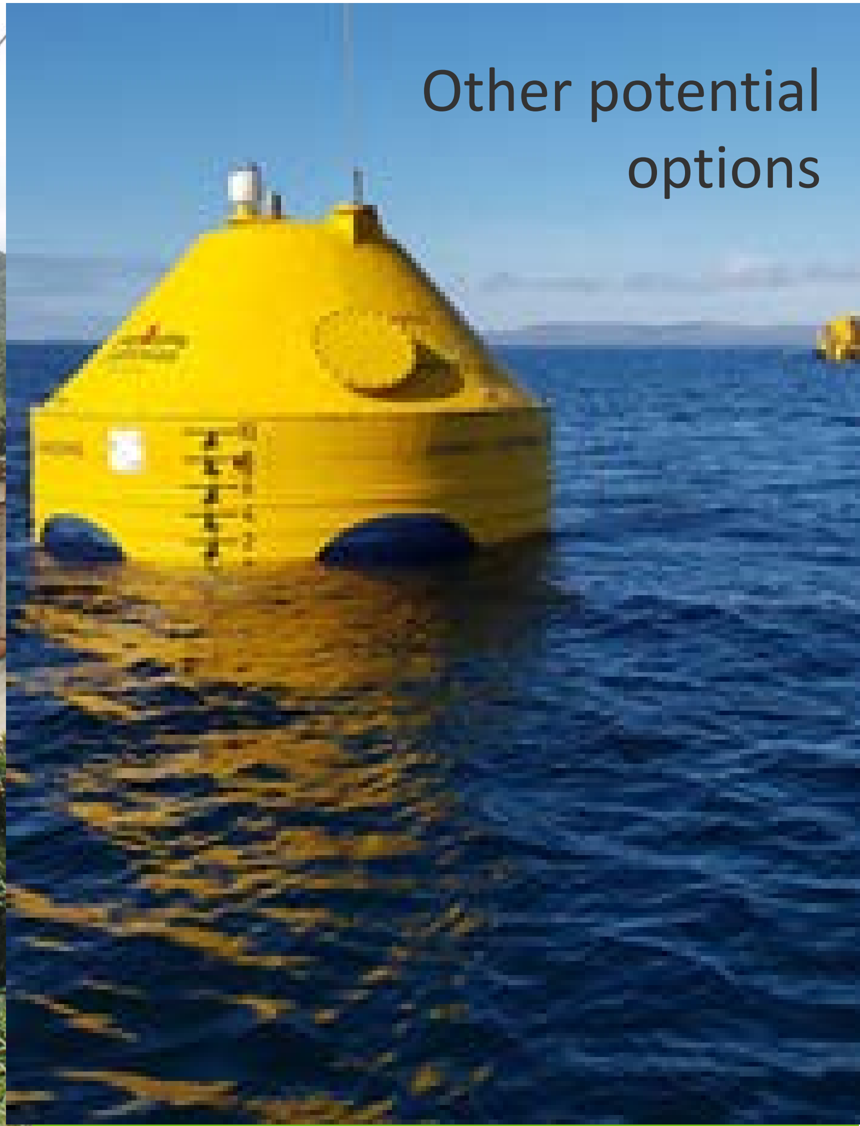
# Residential Rooftop Solar Potential by County

**Distributed PV resource exceeds 20 GW of capacity potential —which also exceeds the current generation in Puerto Rico.**



# Other Generation Options



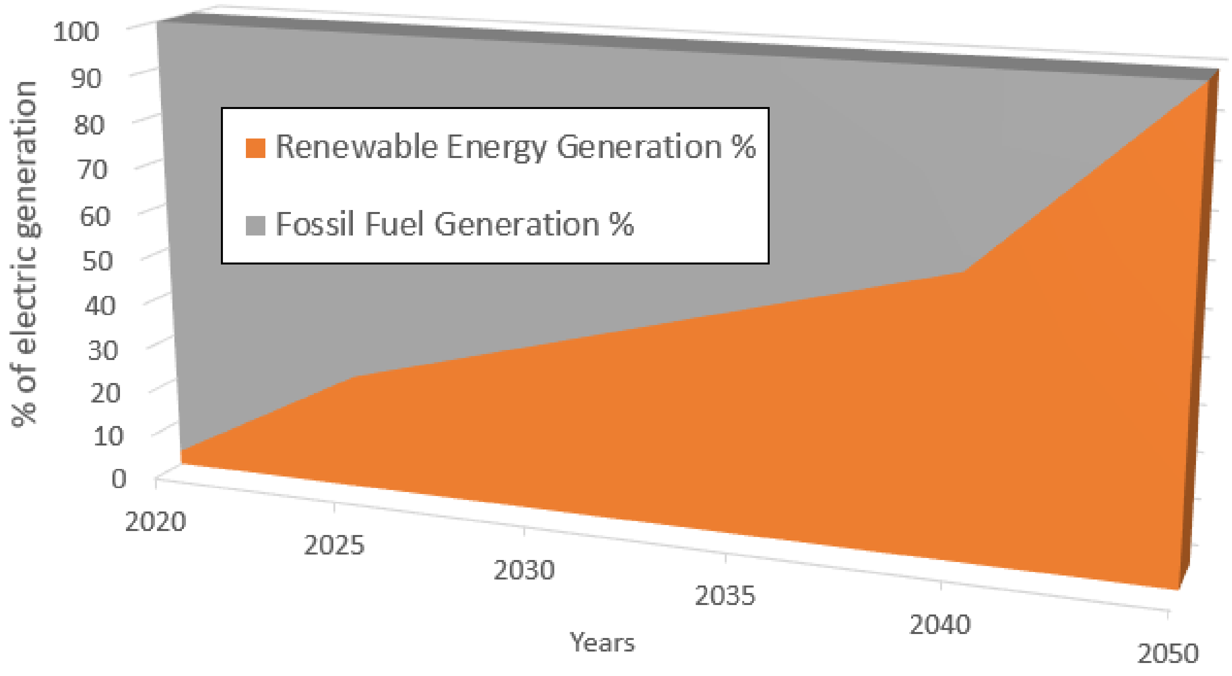


# Demand Impacts

- The electric usage on the island from estimates in the 2019 IRP.
- The electric usage will be reduced by energy efficiency improvements.
- The electric usage will be increased by modeled electric vehicle adoption.
- The electric usage will be reduced by adoption of distributed solar and storage.
- The remaining (net) electric usage will be met by large solar, wind and other RE sources.

# Scenario Modeling: What Is a Scenario?

**A scenario is a possible pathway toward a clean energy future driven by a set of inputs.**




## Variable Scenario Inputs (examples):

**Energy Demand**

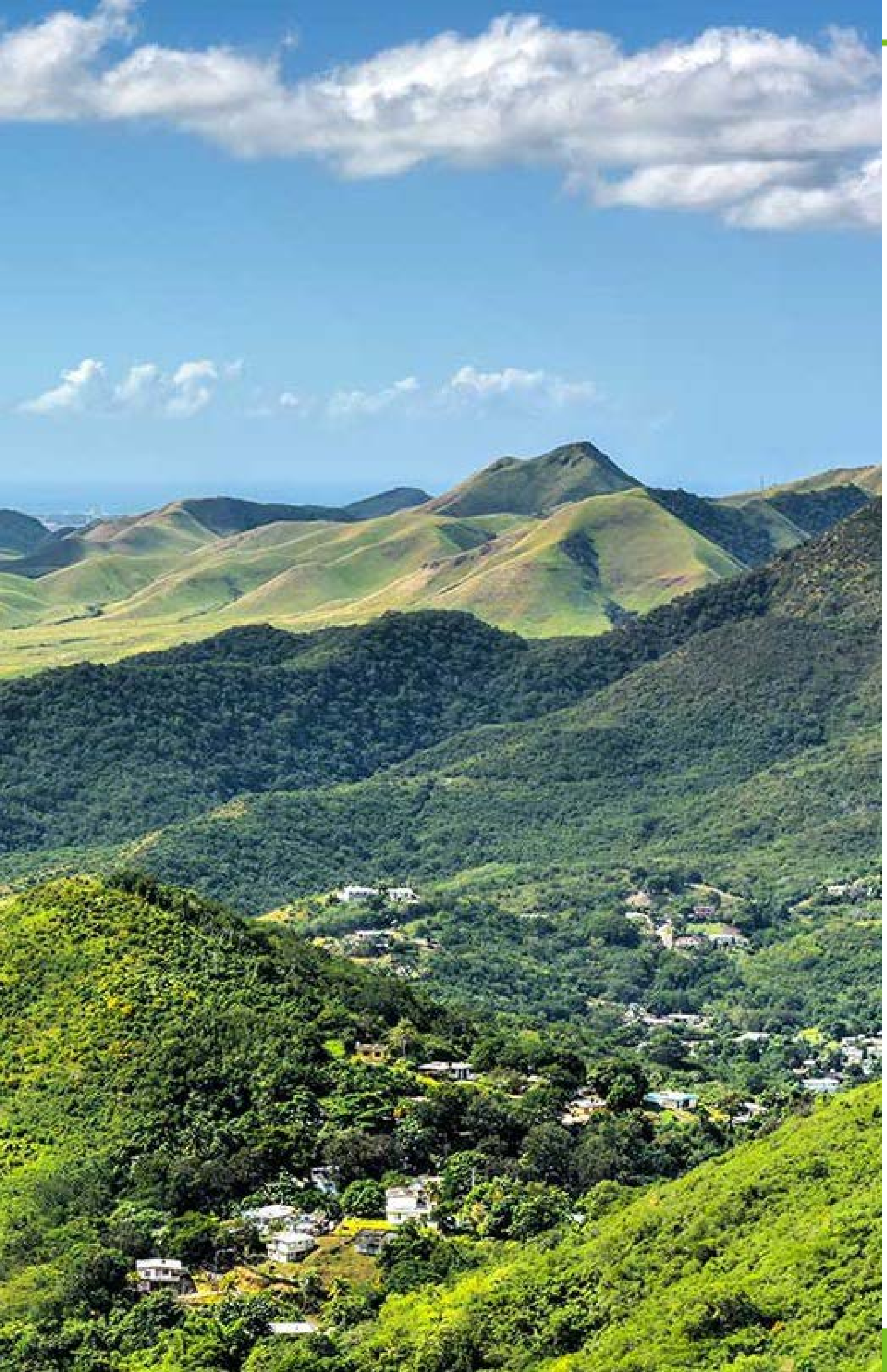
How will demand for electricity change over time?

- Economic inputs
- Expected energy efficiency and EV adoption
- Value of backup power

**Energy Supply**

How will demand be met with 100% renewable energy?

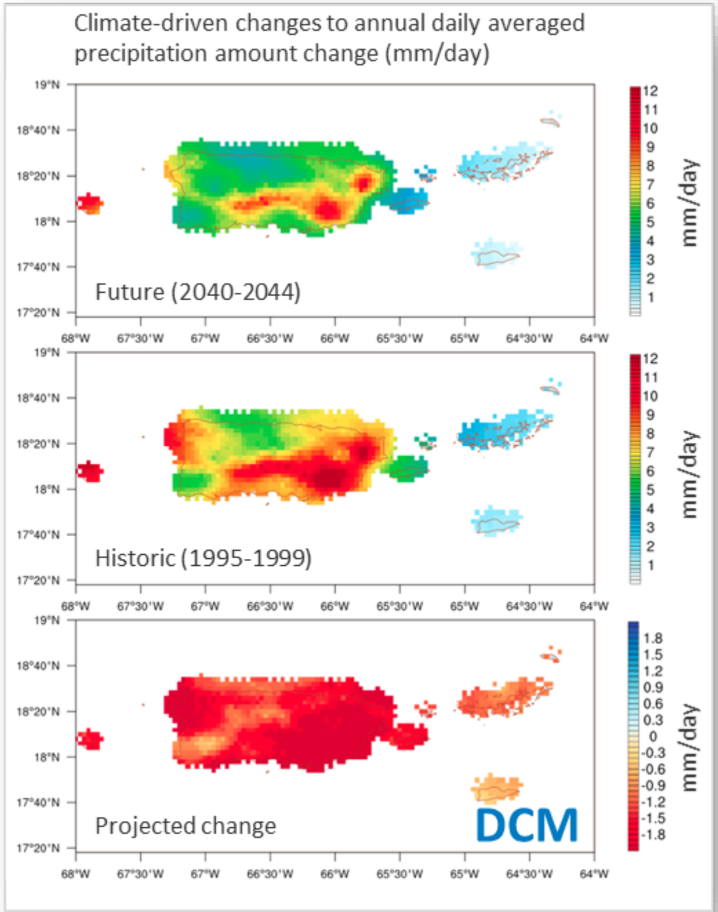
- Distributed solar and storage
- Large scale solar, wind, etc.
- Public Policy (like Act 17)
- Resiliency requirements
- Transmission cost



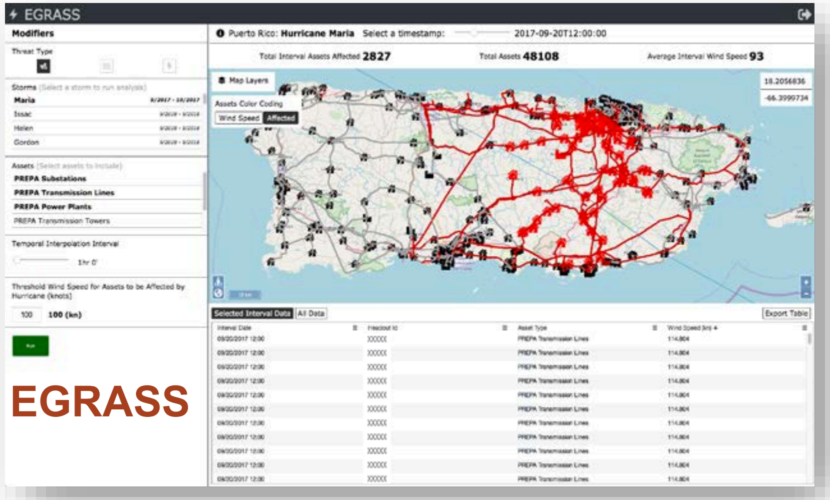
# Summary of Example Scenarios

- System cost vs. Resilience
  - Expectation: Full resilience at the building level will be more expensive than larger plants with transmission
- System cost vs. Full RE goal
  - Expectation: It will be cheaper to get to 90% clean energy than 100%
- Local control vs. Lower cost (utility scale)
- Land use constraints vs. more large-scale renewables
- More Jobs vs. Cheaper technology

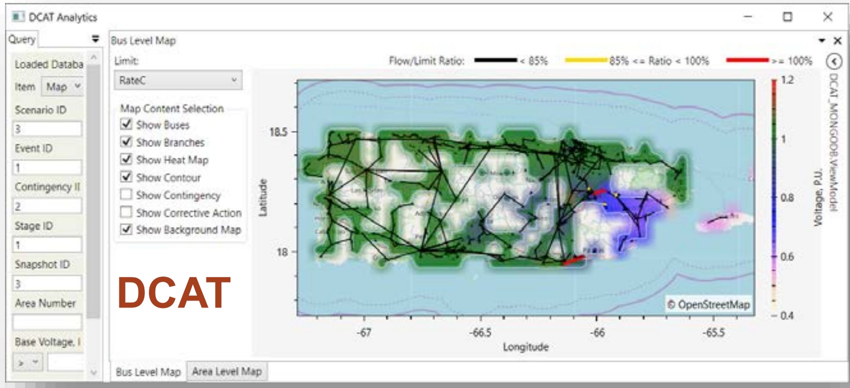
# Impact Analysis: Weather to Grid Consequences Transmission & Distribution & Community Resilience Analysis



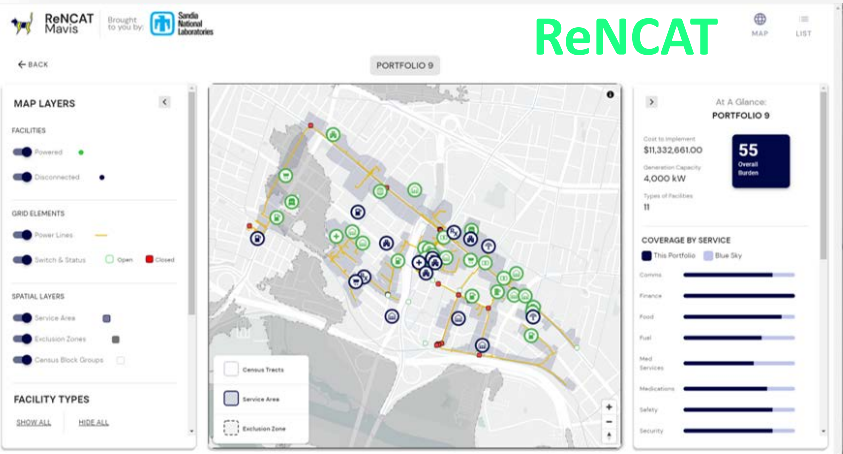

Downscaled climate model




Asset's failure models



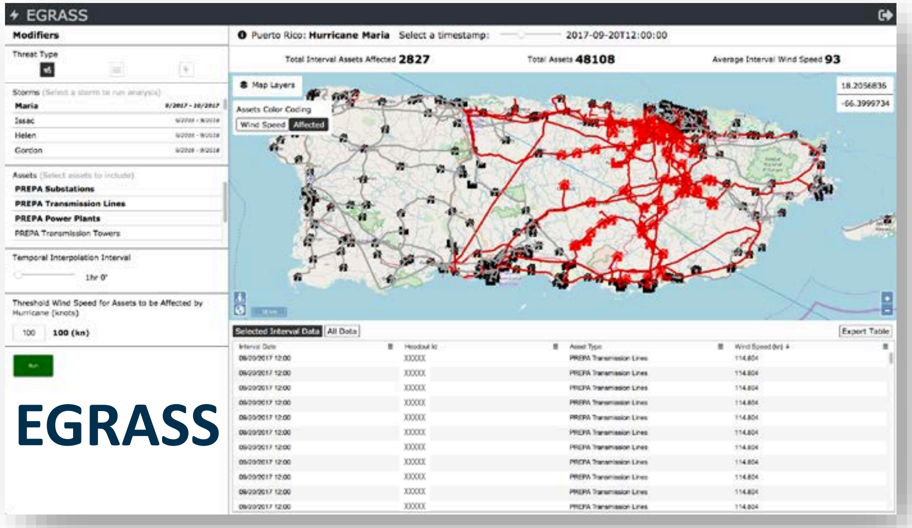

Transmission resilience




Distribution resilience

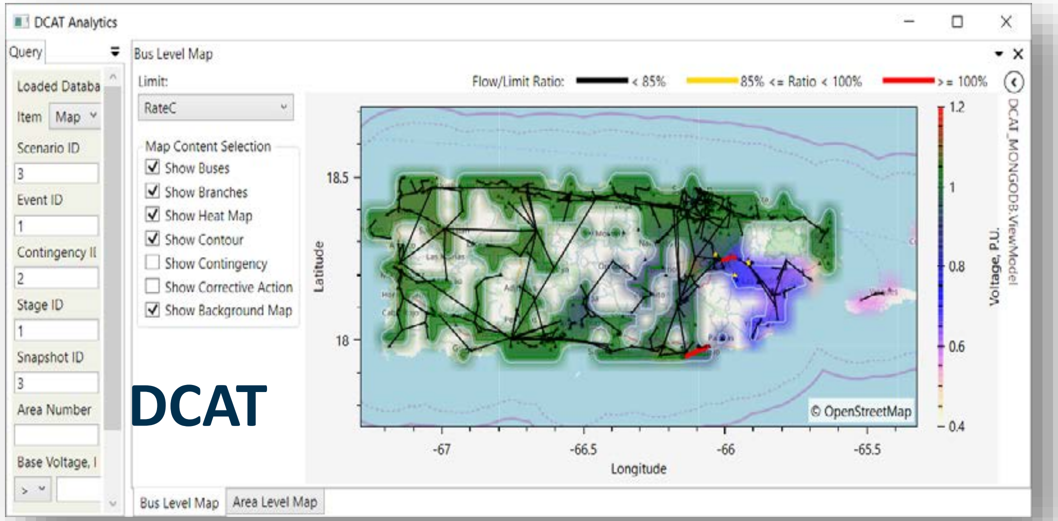
# Transmission Resilience Analysis

National hurricane center data




Electrical Grid Resilience and Assessment System (EGRASS)

- Infrastructure probability of failure
- Monte Carlo generation of N-k sequences




Dynamic Contingency Analysis Tool (DCAT)

- Dynamic cascading failure analysis
- Vulnerability with multiple N-k sequences

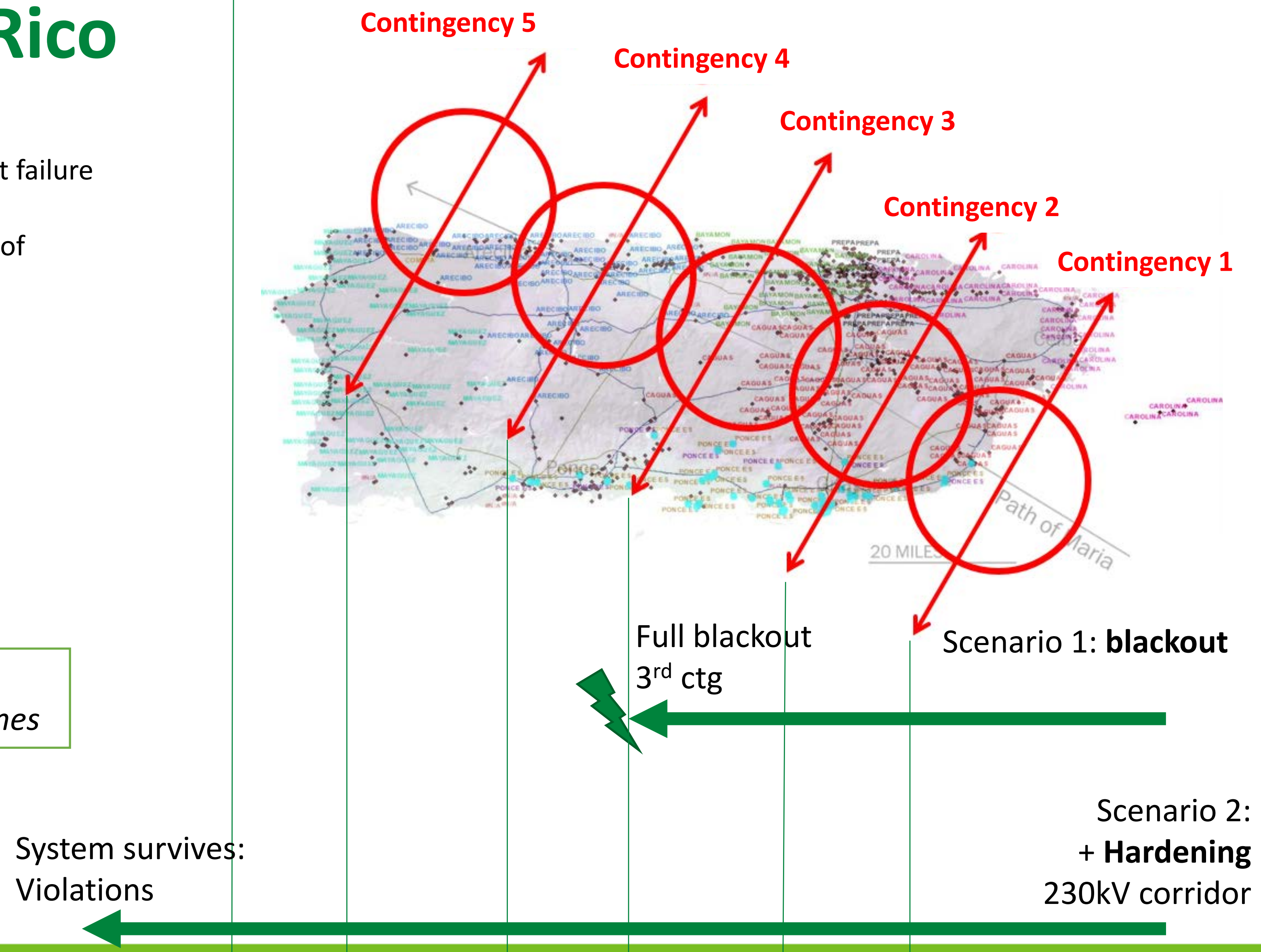
- EGRASS-DCAT used for Puerto Rico
  - Resilience evaluation of new generation scenarios
  - Scenarios comparing underground versus overhead transmission resilience
- DCAT applied to Texas, Western and Eastern Interconnections

# DCAT Application to Puerto Rico

- Large amount of results data
  - 78,000+ contingencies on component failure analysis
  - Hurricane scenarios – time sequence of contingencies
- Deriving recommendations
  - Priority transmission assets
  - Transmission hardening
  - Protection coordination
  - Voltage support
  - Preventive operational actions
  - High solar scenarios

*Developing DCAT capabilities for efficient planning and operation for upcoming hurricanes*

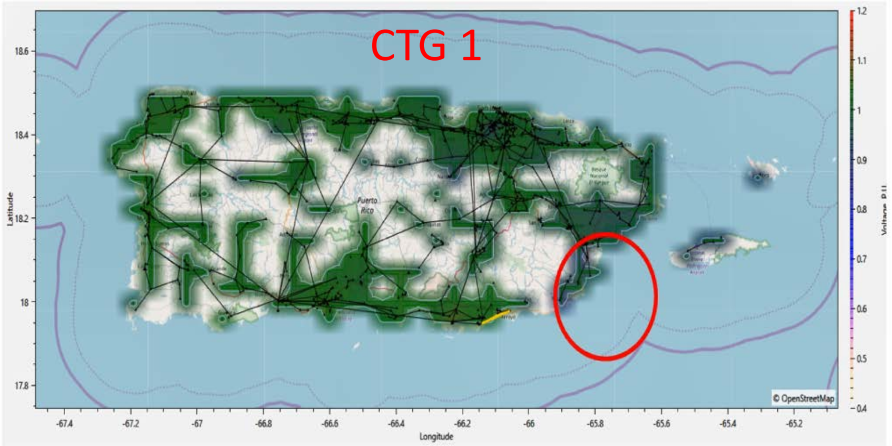
**Illustrative Example**
(Not actual Maria)

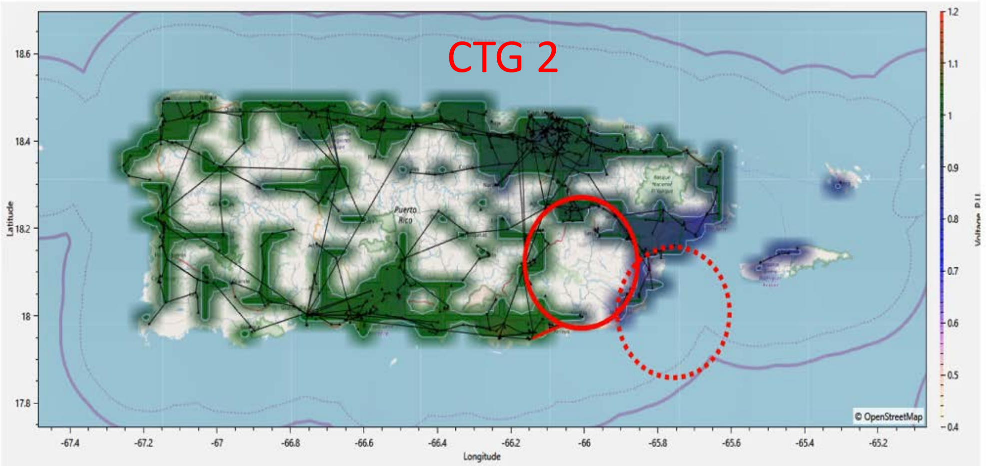


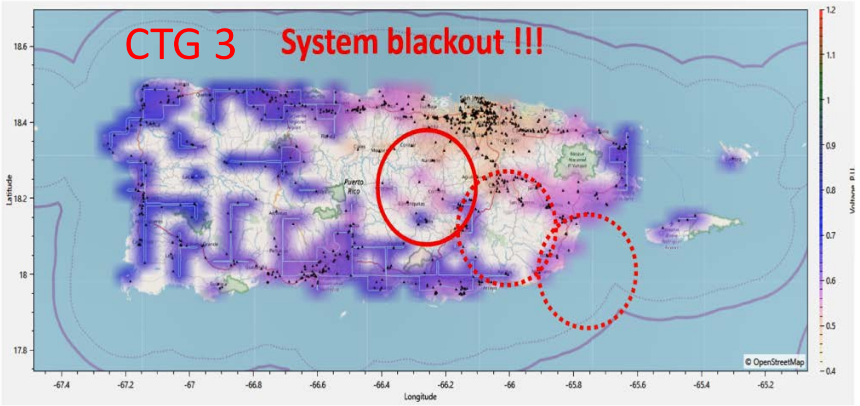


M Elizondo, X Fan, S Davis, B Vyakaranam, E Barrett, S Newman, P Royer, P Etingov, A Tbaileh, H Wang, U Agrawal, W Du, P Weidert, D Lewis, T Franklin, N Samaan, YV Makarov, J Dagle. *Risk-Based Dynamic Contingency Analysis Applied to Puerto Rico Electric Infrastructure*. PNNL-29985. Richland, WA, Pacific Northwest National Laboratory, May 2020 - https://www.osti.gov/biblio/1771798

# Puerto Rico Illustrative Example: Scenario 1 – No Hardening nor Corrective Actions



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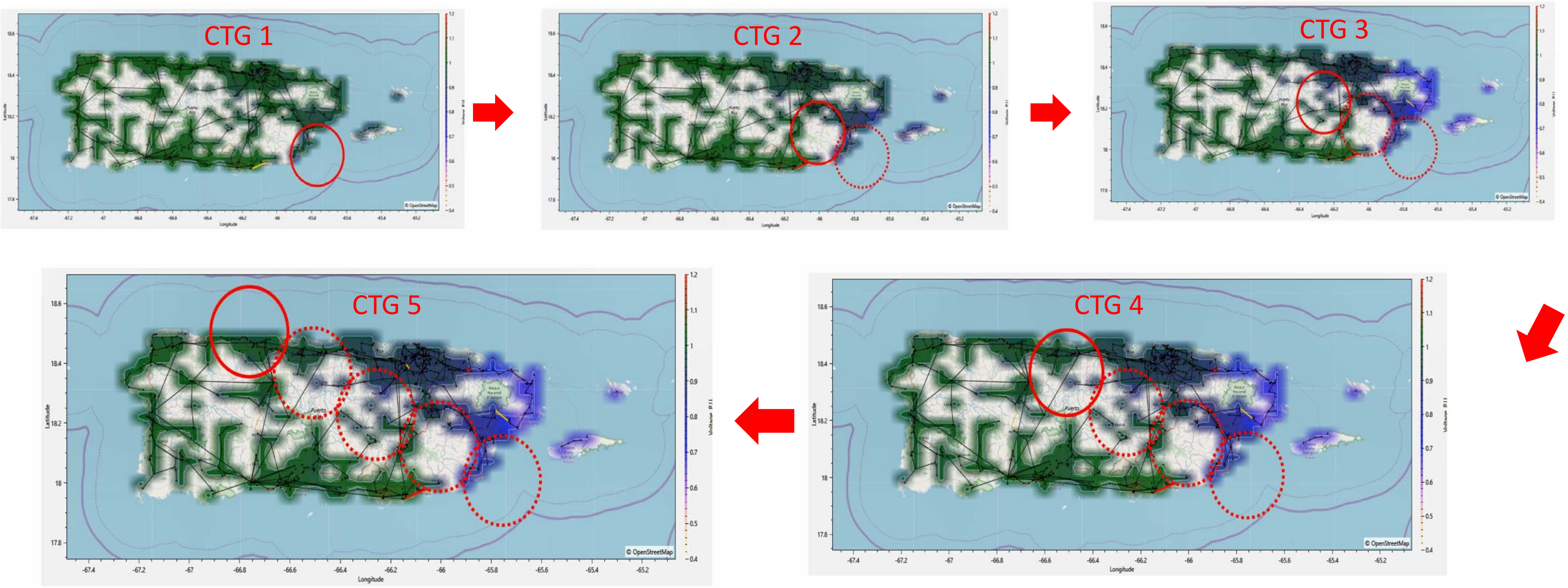
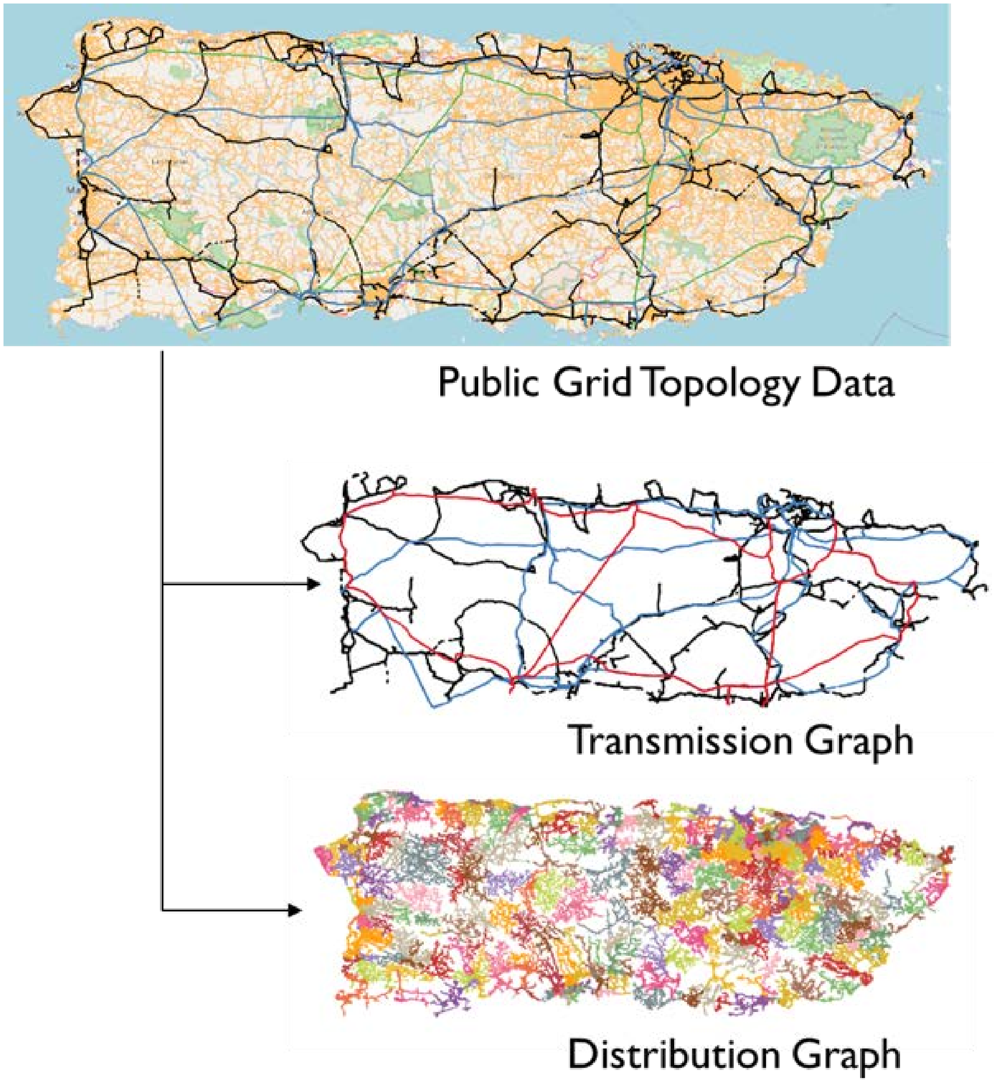
# Puerto Rico Illustrative Example: Scenario 2 – Hardening Only



# Distribution System Analysis

- Resilience benefits under the 100% renewables scenarios, including opportunities for microgrid formation
- Strategies for changes to operating strategies, controls, or infrastructure to enable higher renewable capacity
- Comparison of system resilience to more common faults and more rare natural disasters with traditional generation versus equivalent amounts of DERs with effective distribution-level control strategies

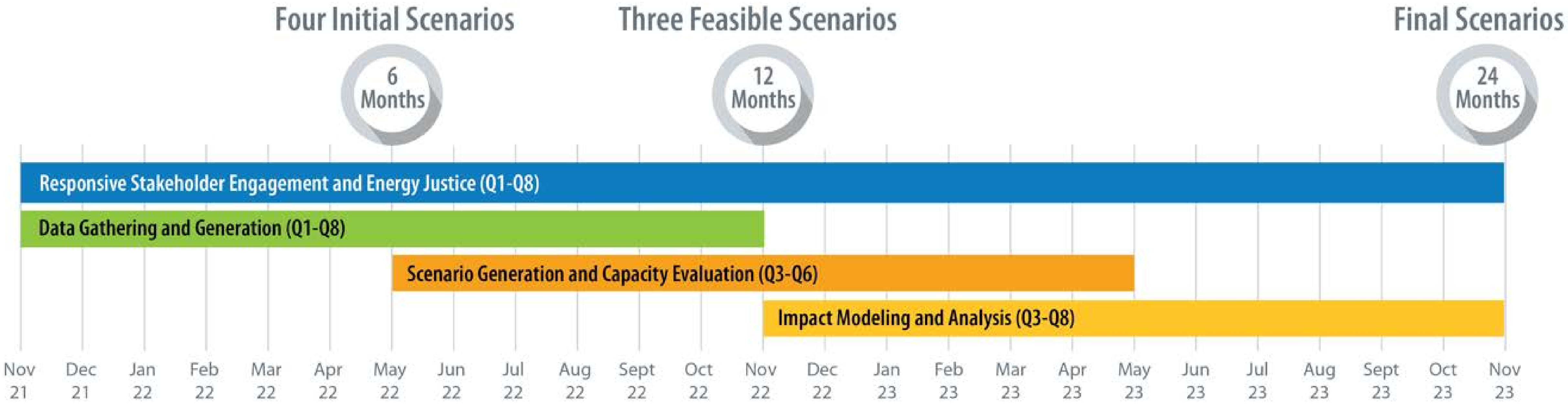


# Economic Impact

- With a schedule of customer/sector level rates in hand, as well as the macroeconomic impacts, PREPA, LUMA, and policymakers will have a more informed picture of the economic implications associated with different approaches to meeting energy goals. IRPs typically do not directly include retail rate or macroeconomic impacts.

- Estimated net and gross impacts on earnings, jobs, and GDP presented to AG to determine how a reliable, resilient, and clean grid can help provide economic stability for Puerto Rico

# Project Timeline




Key Outputs:

- **Four initial scenarios** to achieve Puerto Rico goals
- **Three feasible scenarios** with high-level pathways, refined from the original four
- **Comprehensive report** and associated outreach materials by end of year 2, including workshops, web-based communications, and immersive visualizations, presenting the results of the component tasks and describing possible scenarios.

# Questions?

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## Thank you

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