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

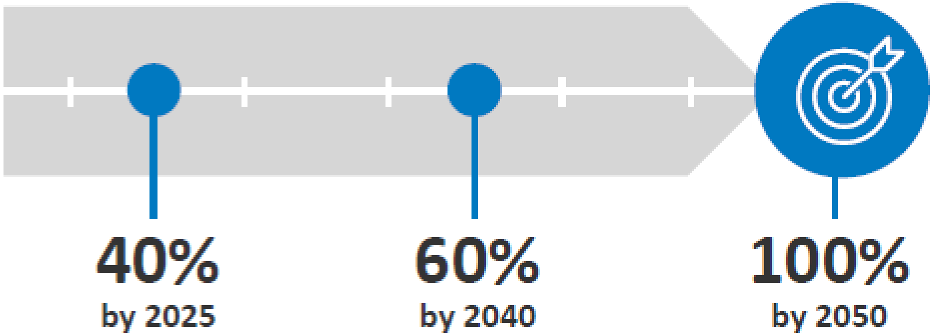
Muhidin (Dino) Lelic

October 4, 2022

Introduction

Puerto Rico has committed to meeting its electricity needs with 100% renewable energy by 2050, along with realizing interim goals of 40% by 2025, 60% by 2040, the phase-out of coal-fired generation by 2028, and a 30% improvement in energy efficiency by 2040, as established in Puerto Rico Energy Public Policy Act (Act 17).

PREPA is required to procure the following portions of its power needs through renewable energy:



Other requirements:

- **Reduce energy use by 30%** by 2050
- **Replace100% of public lighting with LED** by 2030
- **Eliminate coal-fired generation** by January 1, 2028

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

What is PR100 Study

- PR100 is a comprehensive analysis of stakeholder-driven pathways for Puerto Rico to achieve its goal of 100% renewable energy by 2050.
- A coordinated effort led by FEMA, DOE and NREL, leveraging the unique tools and capabilities of five additional national laboratories.

Key Activities

- Community Engagement
  - Scenario Generation and Modeling Demand Projections
  - Distributed and Central Generation
- Impact Analysis

Key Considerations

- Energy Justice –Equitable Access to Planning Process and Benefits
- Affordability, Reliability, and Resilience
- Climate Risk Assessment
- Economic Impact and Jobs

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?

DOE Role in Energy Sector Recovery

Interagency Agreement with FEMA

DOE and its national laboratories will provide support to:

1. Conduct **technical analyses and modeling** to support the successful interconnection, integration, and operation of federally funded distributed and utility-scale energy generation on the PR grid system;
2. Assist in **planning to meet performance goals** designed to enhance the resilience of the power system, including review of technology types and sizes along with optimal dispatch schedules;
3. Develop and review **feasibility studies, RFPs, and responses** for federally funded projects identified to support the resilient recovery of the PR power system.

Argonne National Laboratory
Berkeley Lab
NREL
Oak Ridge National Laboratory
Pacific Northwest National Laboratory
Sandia National Laboratories

Funding Sources for Energy Sector Recovery

FEMA Hazard Mitigation Grant Program	FEMA Public Assistance	HUD CDBG–Disaster Recovery: Electric Grid	Other HUD CDBG-DR and CDBG-MIT disaster assistance programs
Amount: $832.5M Purpose: Improve the resilience of disaster-damaged or undamaged facilities. Recipient: Central Office for Recovery, Reconstruction and Resiliency (COR3) Subrecipient: PREPA (and LUMA as an agent)	Amount: $9.5B Purpose: Restoration and hazard mitigation for disaster-damaged public utilities. Recipient: Central Office for Recovery, Reconstruction and Resiliency (COR3) Subrecipient: PREPA (and LUMA as an agent)	Amount: $1.9B Purpose: Unmet needs after FEMA funds, insurance, and other federal or private sources are accounted for. Mitigate risks and improve resilience, sustainability, and financial viability for electrical power systems. Recipient: Puerto Rico Department of Housing (PRDOH) Subrecipients: Grantees of PR DOH Grant Programs, including local agencies, authorities, trusts, and governing boards; municipalities and local governments; private, for-profit entities; nonprofits, and homeowners.	Community Energy and Water Resilience Installations ($300M): Support resilient design and improvements that incorporate modern technology for life-sustaining purposes. R3 eligible. Community Energy and Water Resilience Installations ($500M): Same as above, but from CDBG-MIT with broader eligibility City Revitalization Program ($1.29B): Funding directly to municipalities for repairs of urban centers

More information: https://cdbg-dr.pr.gov/en/download/cdbg-dr-action-plan-for-the-electrical-systems-enhancements/

PR100 Project Background

<u>PUERTO RICO GRID RESILIENCE AND TRANSITIONS TO 100% RENEWABLE ENERGY (PR100)</u>

The PR100 study will endeavor to develop a path that fulfills Puerto Rico Energy Public Policy Act (Act 17) mandate

TRANSFORMS THE PR GRID FROM WHERE IT IS TODAY TO ITS 2050 CONFIGURATION

so as to

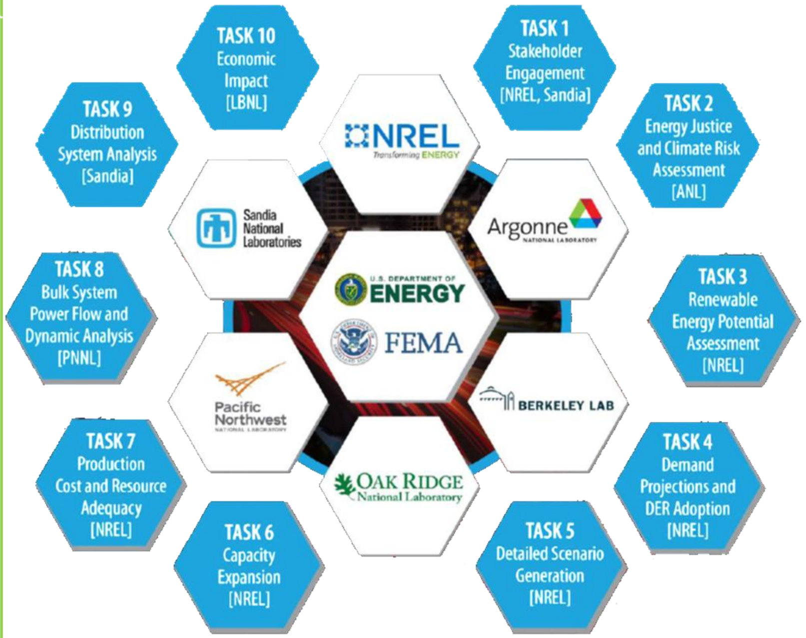
- **Accommodate**
  - ✓ **100% renewable energy by 2050,**
  - ✓ **40% by 2025,**
  - ✓ **60% by 2040,**
- **Phaseout coal-fired generation by 2028,**
- **Achieve 30% improvement in energy efficiency by 2040.**

In addition to addressing traditional G/T/D issues, it also includes all *CUSTOMER INTERFACES, FLEXIBLE LOADS, AND EE/DR/EV* measures and programs.

MAJOR STUDY

- Over $12M, 2 years
- 11 Tasks
- 6 DOE National Labs

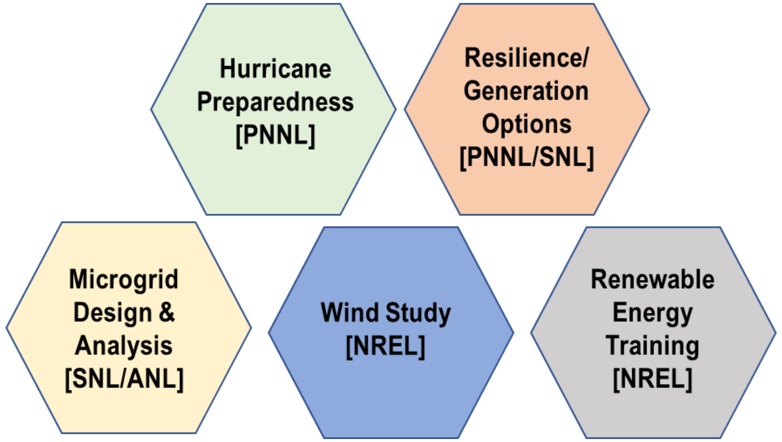
DOE thinking about approach continues to evolve



DOE Office of Electricity:
PUERTO RICO ENERGY RECOVERY TEAM

- Marisol Bonnet
- Eric Britton
- Ernesto Rivera

- Several related projects conducted in parallel with PR100.

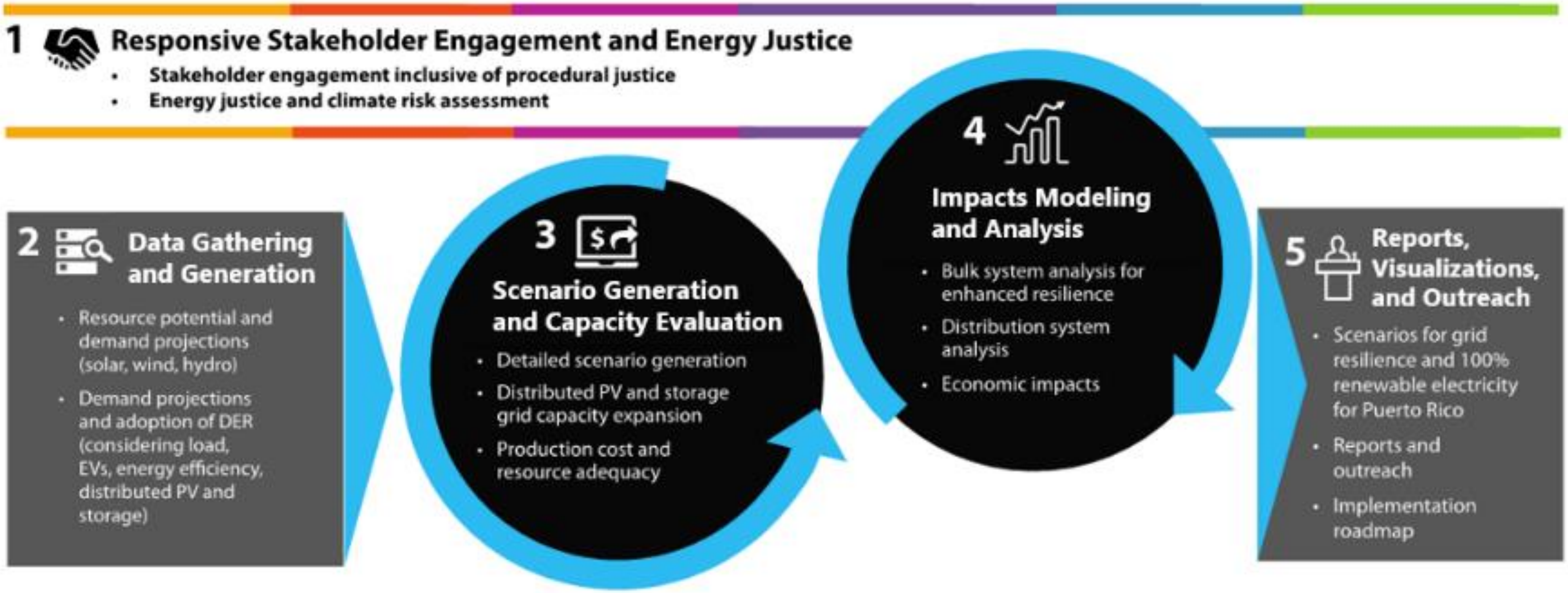


- Other related work may be carried out directly w/PREB, e.g., LBL providing ongoing support to PREB on EE regulation

How Stakeholders can use PR100 Study Results

- The PR100 study will produce a set of results including data and models that outline alternatives for how Puerto Rico can achieve its resilience and renewable energy goals.
- The results are intended to answer stakeholder questions and inform decision making. It will be up to Puerto Rico energy system stakeholders to decide a path forward and implement it.
- Goals of the study are to help the people of Puerto Rico make more informed choices about their energy future based on world class data, modeling, and analysis.

Phases in PR100 Renewable Energy Study



Graphics by NREL

Community Engagement and Energy Justice

Energy justice: Enlisting broad community participation to reflect local priorities and model pathways to equitable distribution of benefits and burdens associated with the energy transition

Steering Committee

Steering Committee guides technical assistance. Engagement is essential for generating scenarios that are reflective of existing or anticipated policies for potential funding and implementation.

Members include:

- Federal recovery funders: FEMA, HUD
- Local public implementers: PREPA, LUMA, PREB, PRDOH, and COR3

Advisory Group

Advisory Group (AG) provides input to DOE & national labs. AG members (87 members representing 56 organizations as of 7/11/22) are engaged early for input on scenario formulation and data gathering. Working groups provide input to modeling and impact analysis tasks throughout the study.

Represented sectors include:

- Academia
- Business community and professional associations
- Community-based and environmental organizations
- Generation owners, solar and storage developers
- Municipalities; Puerto Rico and federal government agencies not represented on steering committee.

PR100 Snapshot: Tasks & Roles

LUMAPUERTORICO.COM

LUMA

PR100 Tasks & Schedule

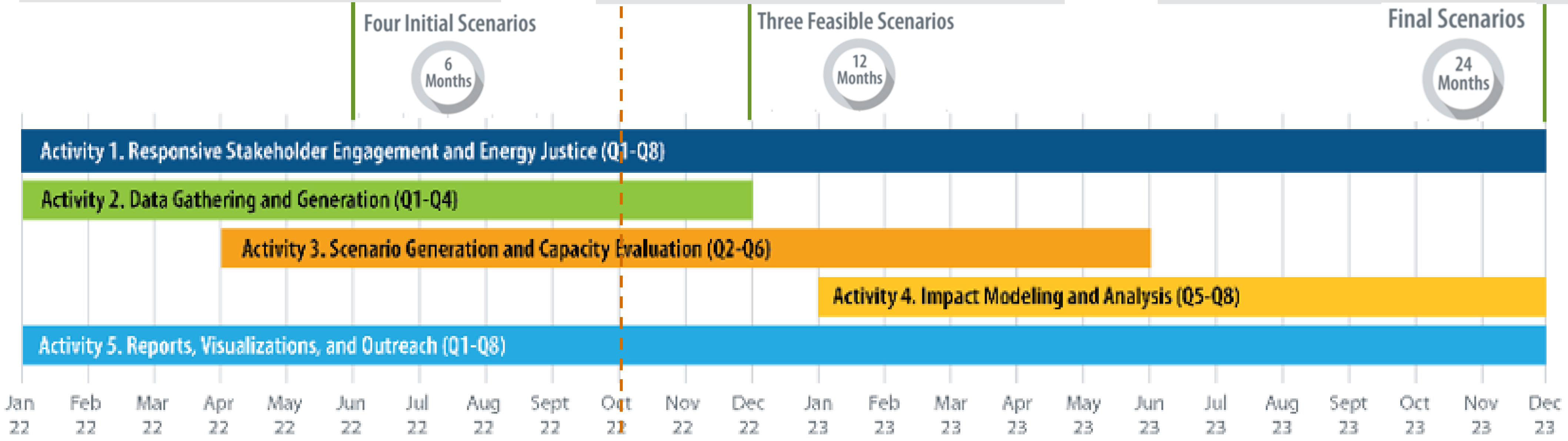
Task / Lead	Start Date	End Date
1. Stakeholder Engagement Leads: NREL and Sandia	Q1/2022	Q4/2023
2. Energy Justice and Climate Risk Assessment Lead: ANL	Q1/2022	Q4/2023
3. Renewable Energy Assessment Lead: NREL	Q1/2022	Q4/2023
4. Demand Projections Lead: NREL	Q1/2022	Q2/2023
5. Scenario Generation Lead: NREL	Q3/2022	Q4/2022
6. Capacity Expansion Lead: NREL	Q3/2022	Q2/2023
7. Production Cost Lead: NREL.	Q3/2022	Q2/2023
8. Power Flow and Dynamic Analysis Lead: PNNL	Q1/2022	Q4/2023
9. Distribution System Analysis Lead: Sandia	Q3/2022	Q4/2023
10. Economic Impact Lead: LBNL	Q3/2022	Q4/2023
11. Project Management, Data Management, Outreach, and Reporting Lead: NREL	Q1/2022	Q4/2023

PR100 High-Level Timeline & Status

6 Months (by June 2022):
Established stakeholder group meets monthly to inform scenarios
Defined four initial scenarios to achieve Puerto Rico's goals.

Year One (by December 2022):
- High-resolution data sets for wind and solar resource for 10 years
- Three feasible scenarios with high-level pathways.

Year Two (by December 2023):
- Comprehensive report and web-based visualizations
- Outreach and public engagement.



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.

Project Summary – LUMA Perspective

Title	**LUMA Interface and Coordination with U.S. DOE project PUERTO RICO GRID RESILIENCE AND TRANSITION TO 100% RENEWABLE ENERGY (PR100)**
Timeline	January 2022 - December 2023
Scope	Implement all elements needed to maintain cognizance of PR100 opportunities and interface needs so that LUMA can work with DOE towards a mutually beneficial outcome. 1. Maintain understanding of PR100 and related project tasks and responsibilities 2. Obtain data necessary to conduct PR100 tasks and coordinate transfers to the National Labs teams; Coordinate the dissemination of the deliverables from the labs 3. Develop and maintain a catalogue of LUMA projects and contacts potentially impacted by PR100 4. Ensure no PR100 task duplicates efforts with projects conducted by LUMA, and vice-versa 5. Guide all PR100 studies to maximize their benefits to LUMA's projects and their execution 6. Establish a communications and coordination process 7. Reporting & Review Approach/Tasks

LUMA Objectives

- Guiding the DOE Team to perform analyses that meet LUMA's needs, including delivery of tasks needed for the Integrated Resource Planning (IRP) and value-added products that complement LUMA's projects.
- Urging the DOE to deliver PR100 results in a format and to a schedule that will be useful for input to LUMA T&D planning needs, IRP, regulatory filings, and other pertinent LUMA studies
- Working with LUMA staff to understand the expected deliverables and milestones from PR100 that may benefit LUMA efforts
- Coordinating and communicating all internal LUMA decisions that are made in relation to PR100
- Keeping key LUMA stakeholders informed about the progress, milestones, interim results, and issues in the PR100 project
- Facilitating communication between the LUMA teams and the DOE for the rapid sharing of interim findings and results for both LUMA and DOE efforts.

Six-Months Progress Status

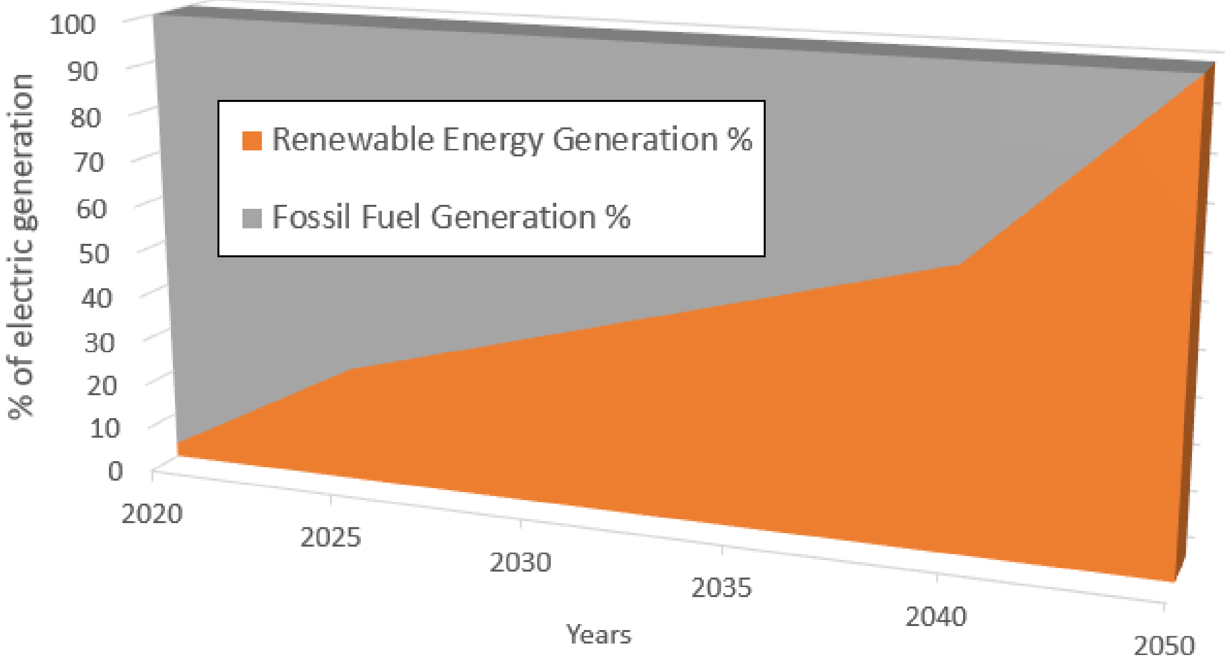
- Guiding the DOE Team to perform analyses that meet LUMA's needs, including delivery of tasks needed for the Integrated Resource Planning (IRP) and value-added products that complement LUMA's projects.
- Urging the DOE to deliver PR100 results in a format and to a schedule that will be useful for input to LUMA T&D planning needs, IRP, regulatory filings, and other pertinent LUMA studies
- Working with LUMA staff to understand the expected deliverables and milestones from PR100 that may benefit LUMA efforts
- Coordinating and communicating all internal LUMA decisions that are made in relation to PR100
- Keeping key LUMA stakeholders informed about the progress, milestones, interim results, and issues in the PR100 project
- Facilitating communication between the LUMA teams and the DOE for the rapid sharing of interim findings and results for both LUMA and DOE efforts.

Initial Scenario Definition

- The project team worked closely with the Advisory Group during the first six months of the study to define four initial scenarios to model.
- The primary distinction between the four scenarios is varying levels of distributed energy resources, such as rooftop solar and energy storage.
- Variations of load and land use will also be applied to select scenarios.

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

LUMAPUERTORICO.COM

DER Adoption: Initial Scenario Definition

- The project team worked closely with the Advisory Group during the first six months of the study to define four initial scenarios to model based on these priorities:
    - Energy access and affordability
    - Reliability and resilience (under both normal and extreme weather conditions)
    - Siting, land use, environmental and health effects
    - Economic and workforce development
- The primary distinction between the four scenarios is varying levels of distributed energy resources, such as rooftop solar and energy storage.
- Variations of electric load and land use, as well as transmission and distribution expansion, will be incorporated in each scenario.

Scenario 1. Economic Adoption of Distributed Energy Resources

Electricity system is modeled to achieve 100% renewable energy by 2050

Graphic by NREL

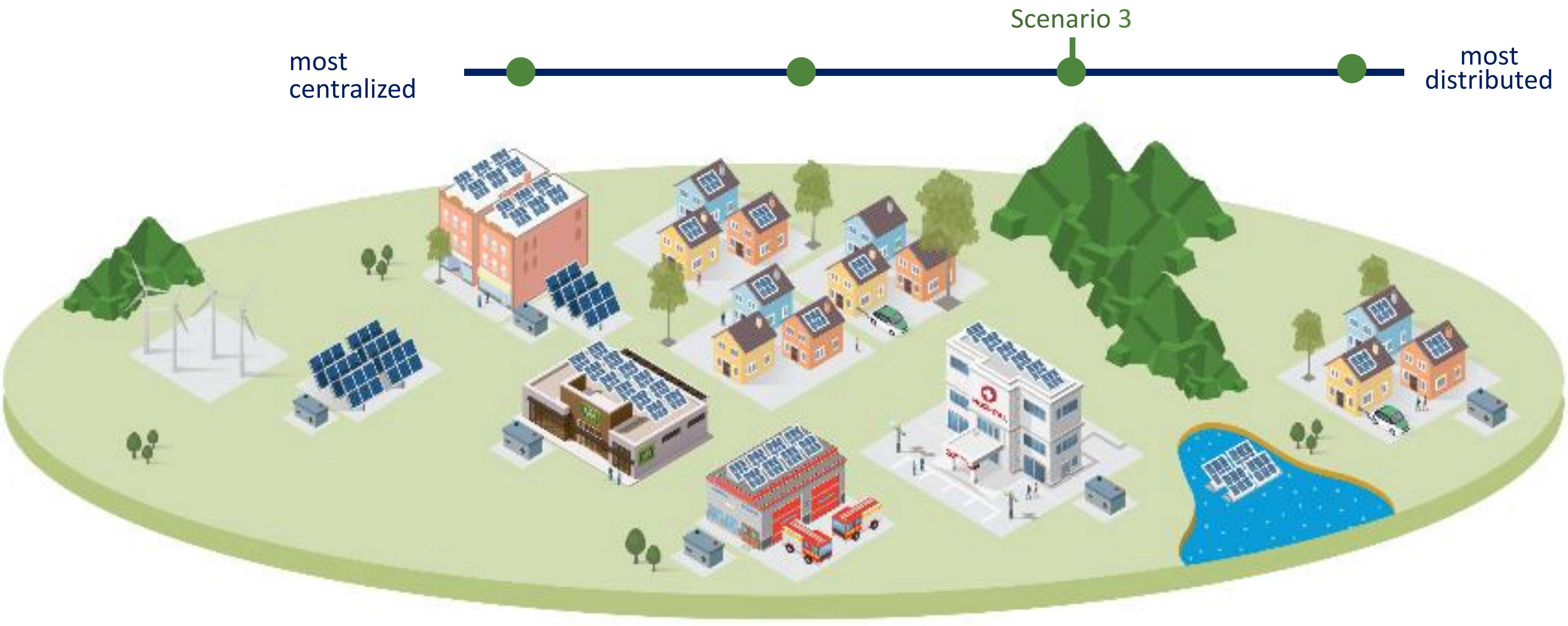
Scenario 2. Deployment of Distributed Energy Resources for Critical Services

Distributed energy resources installed beyond Scenario 1 for critical services like hospitals, fire stations, and grocery stores

Graphic by NREL

Scenario 3. Equitable Deployment of Distributed Energy Resources

Installation of distributed energy resources is prioritized beyond Scenario 2 for remote and low- and moderate-income households



Graphic by NREL

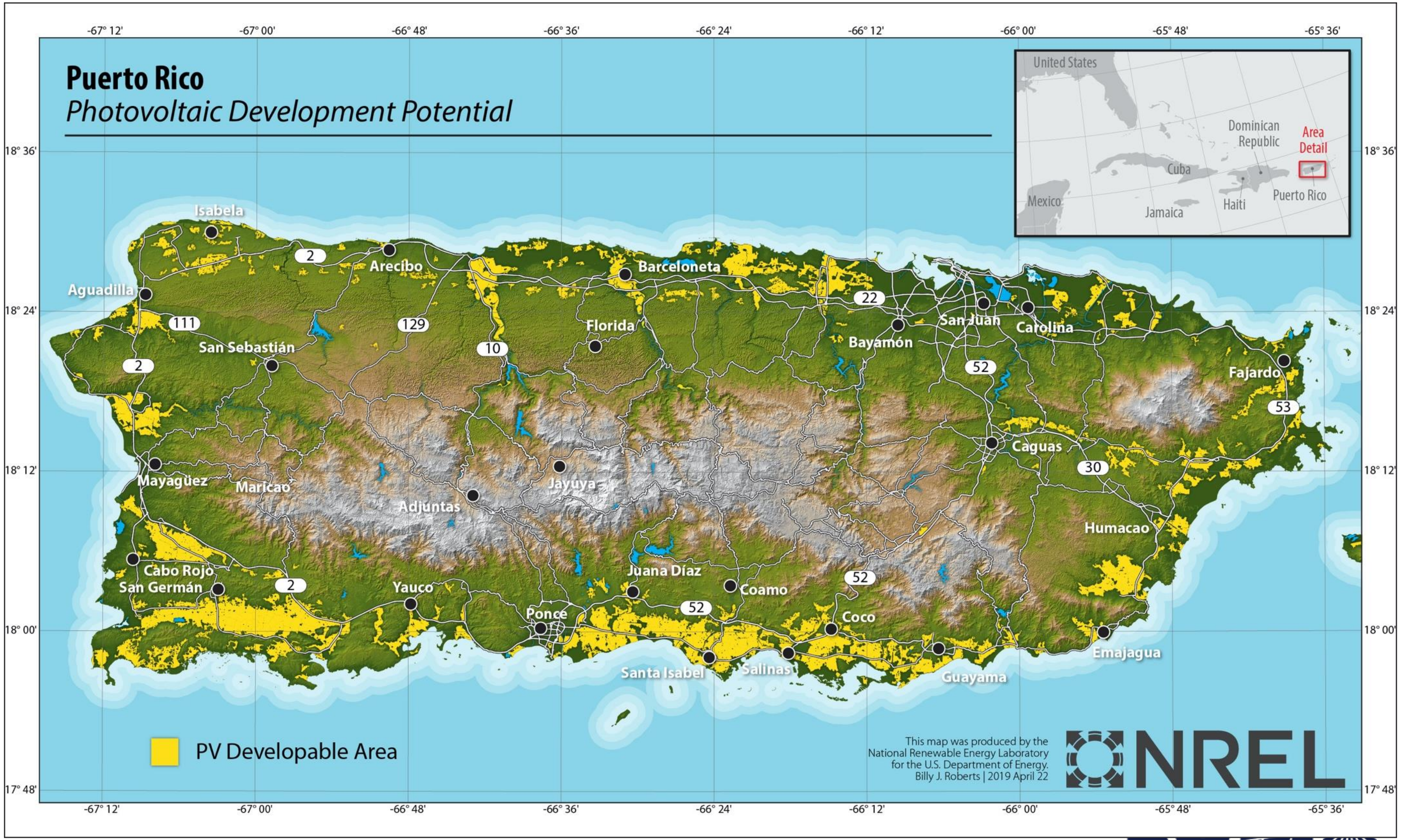
Scenario 4. Maximum Deployment of Distributed Energy Resources

Distributed solar and storage is added to all suitable rooftops

Graphic by NREL

Utility-Scale Solar PV Development Potential

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

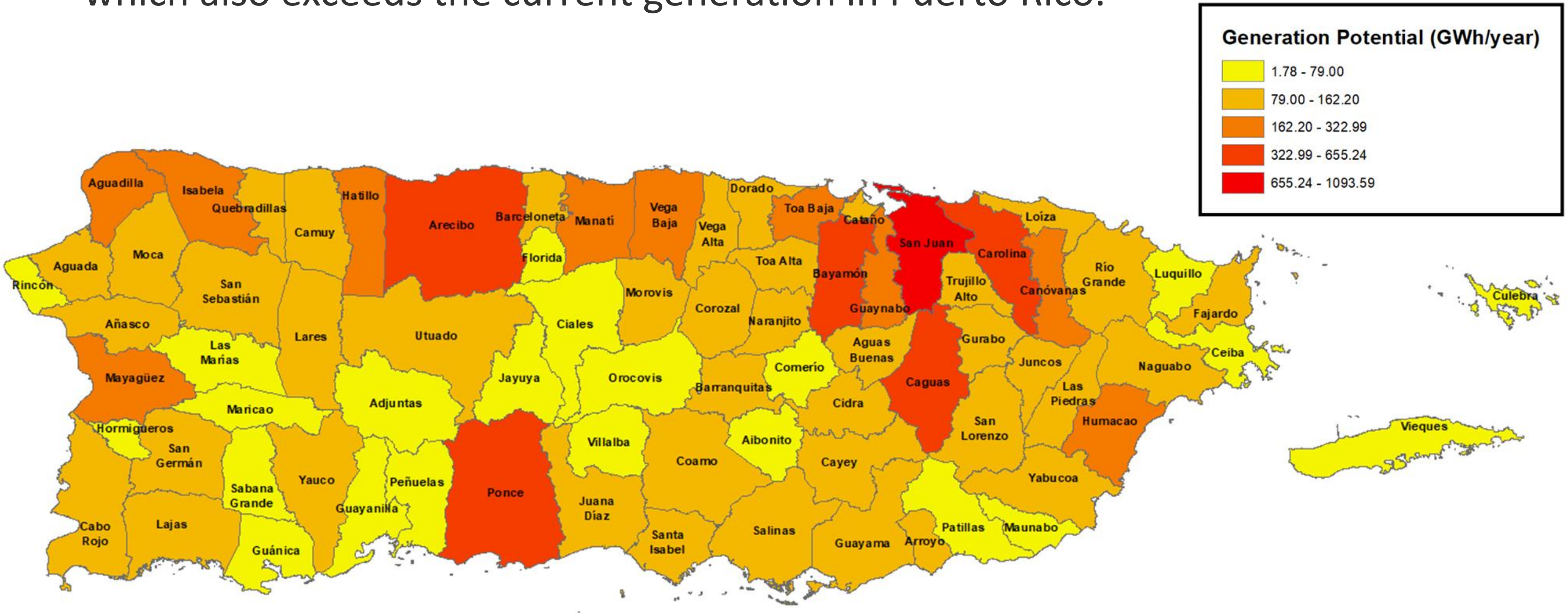


Sources: Grue at al. (2019), Solar Resource and Technical Potential Modeling (NREL Presentation); Grue et al. (2021), Quantifying the Solar Energy Resource for Puerto Rico (NREL Technical Report)

LUMAPUERTORICO.COM

Residential Rooftop Solar Potential by County

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



Data Sources: Visualization generated using NREL's Distributed Generation Market Demand (dGenTM) model; Residential rooftop solar PV potential for Puerto Rico from Mooney and Waechter (2020), Puerto Rico Low-to-Moderate Income Rooftop PV and Solar Savings Potential

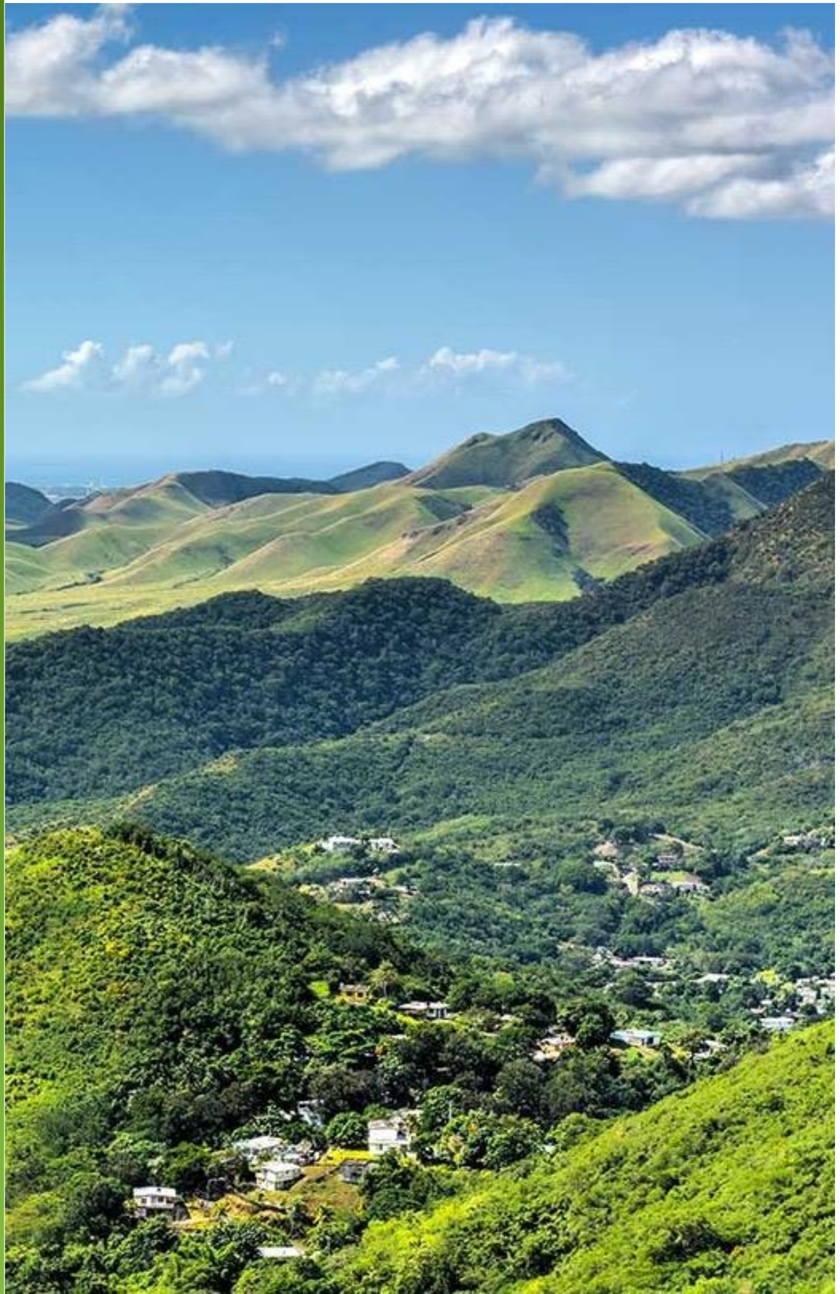
Other Generation Options

LUMAPUERTORICO.COM

Demand Impacts

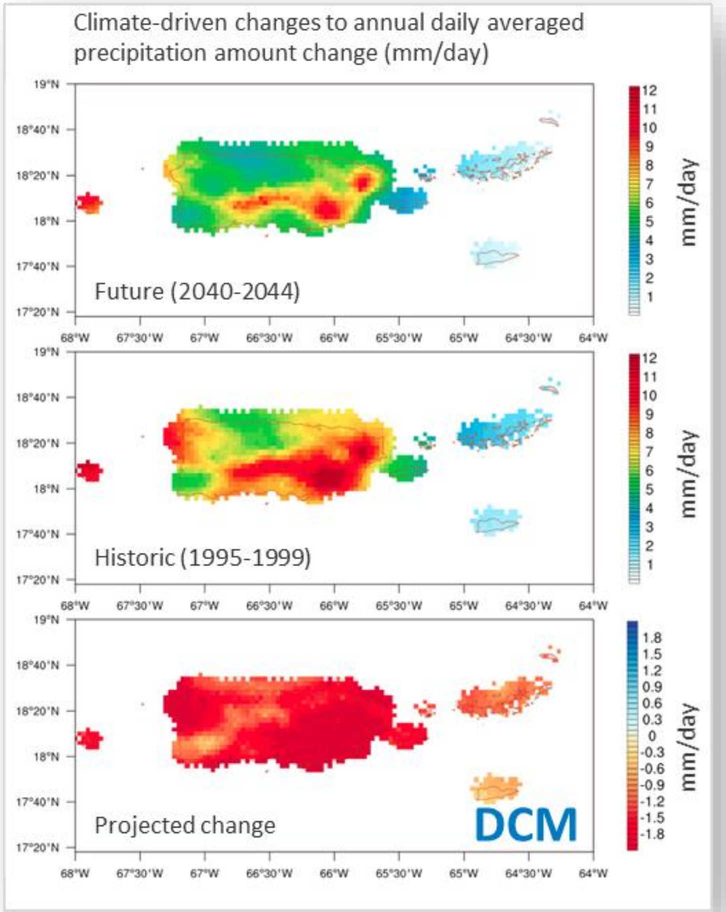
- ↔ The electric usage on the island from estimates in the 2019 IRP.
- ↓ The electric usage will be reduced by energy efficiency improvements.
- ↑ The electric usage will be increased by modeled electric vehicle adoption.
- ↓ The electric usage will be reduced by adoption of distributed solar and storage.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

Summary of Example Scenarios

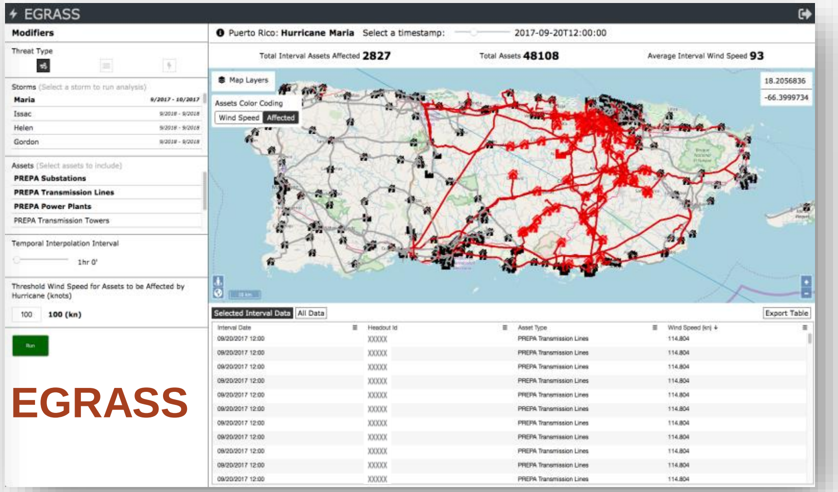


- System cost vs. Resilience
  - Expectation: Full resilience at the building level will be more expensive than larger plants with transmission
- System cost vs. Full RE goal
  - Expectation: It will be cheaper to get to 90% clean energy than 100%
- Local control vs. Lower cost (utility scale)
- Land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

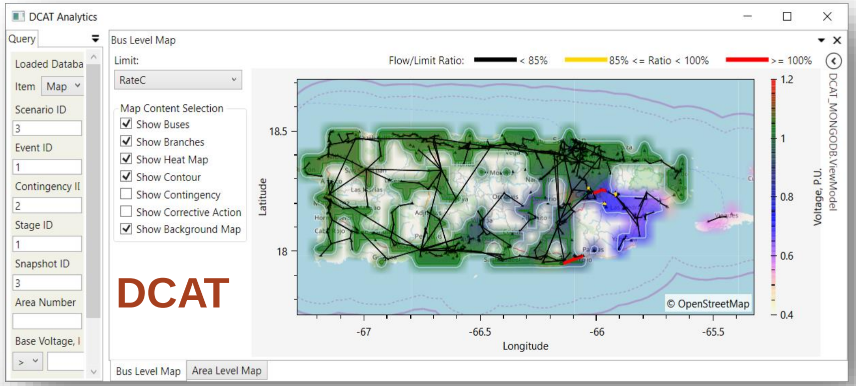
Impact Analysis: Weather to Grid Consequences
Transmission & Distribution & Community Resilience Analysis



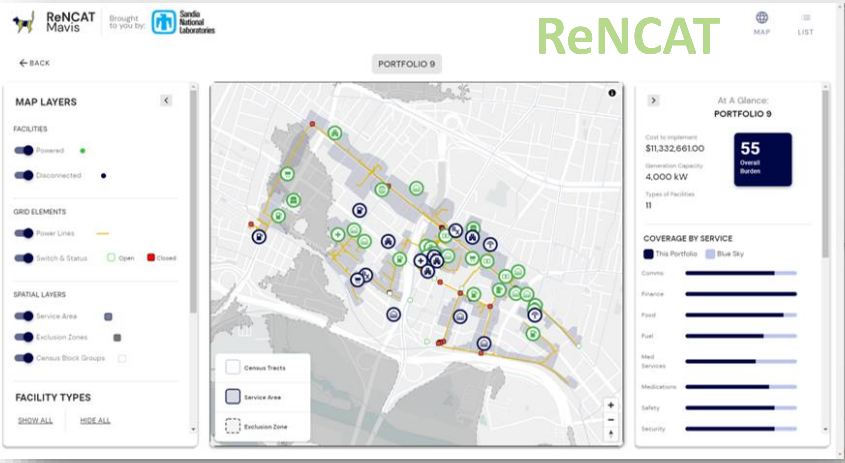
Downscaled climate model



Asset's failure models



Transmission resilience



Distribution resilience

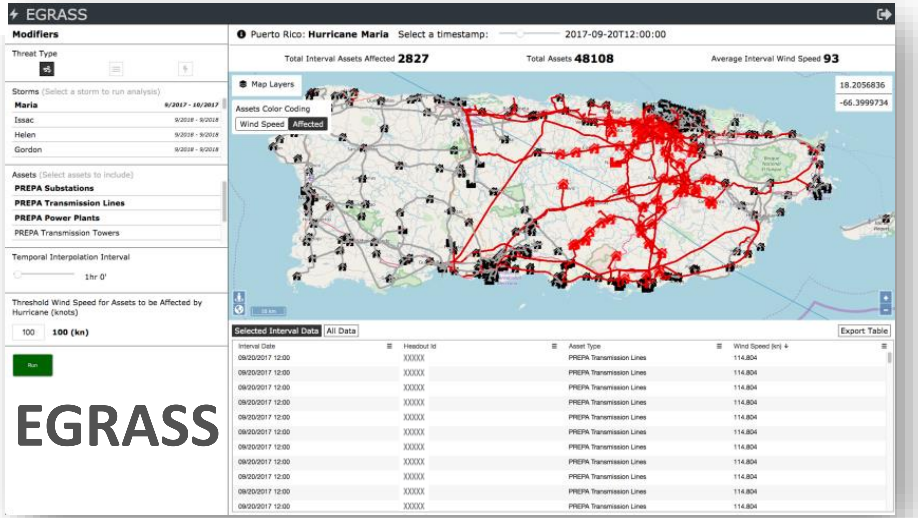
LUMAPUERTORICO.COM

Transmission Resilience Analysis

Pacific Northwest NATIONAL LABORATORY

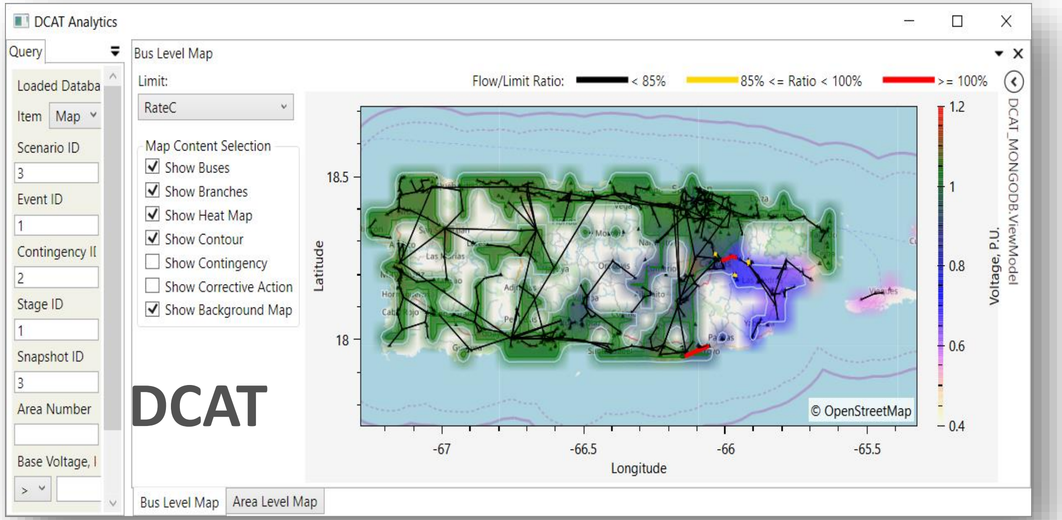
NOAA

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

LUMA

DCAT Application to Puerto Rico

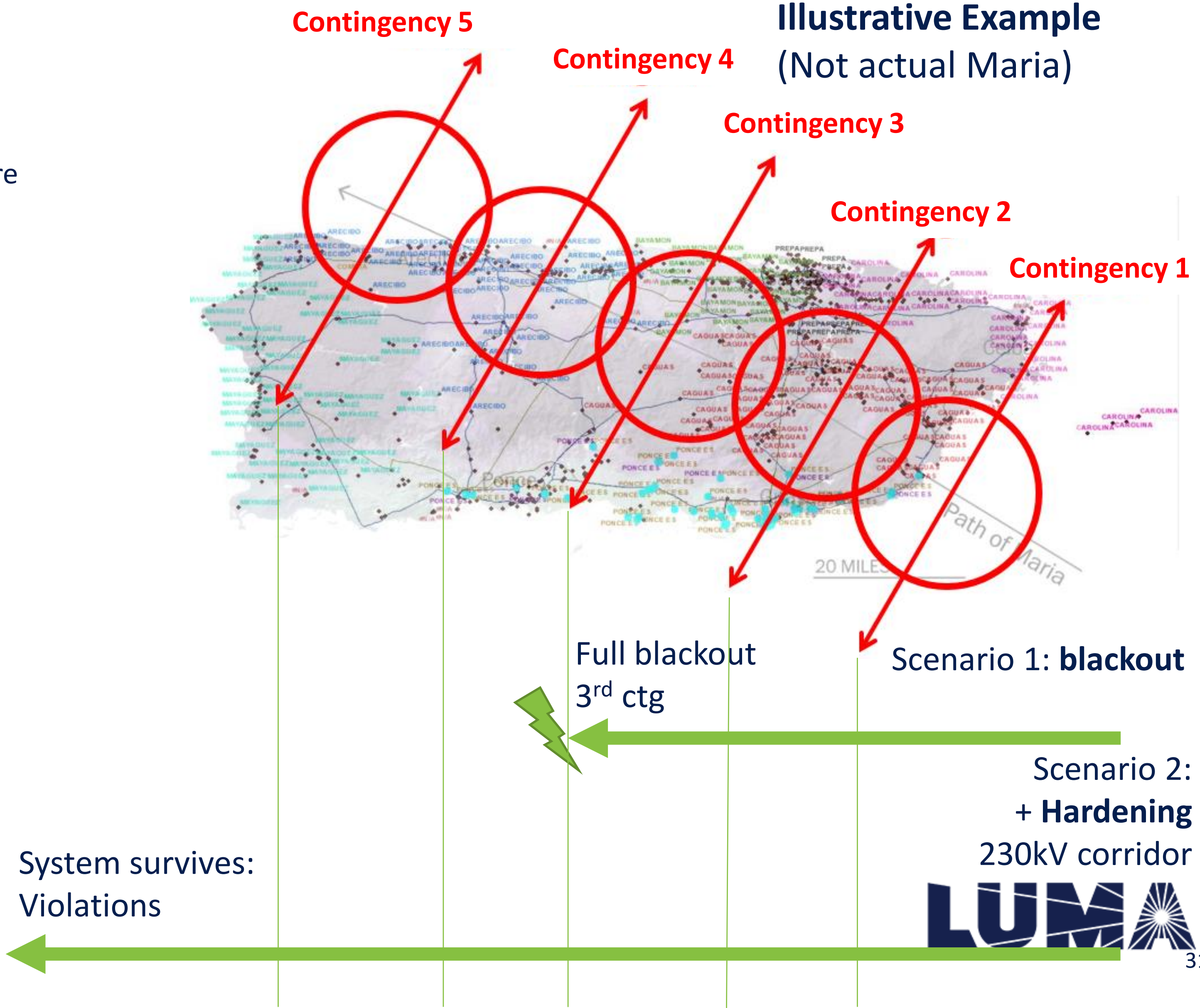
Pacific Northwest
NATIONAL LABORATORY

- 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

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

Illustrative Example
(Not actual Maria)

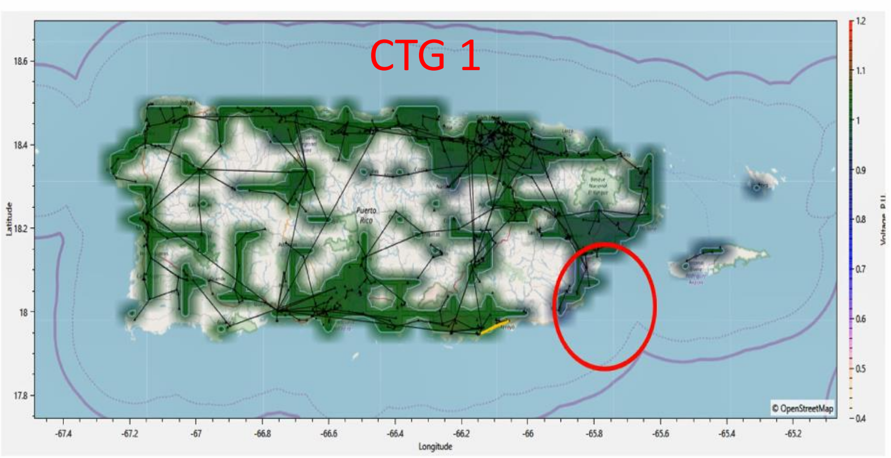


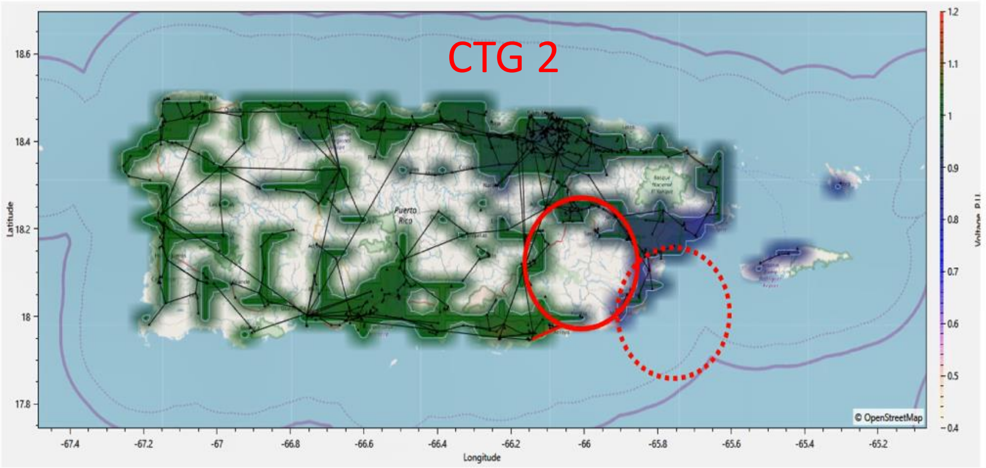
LUMAPUERTORICO.COM

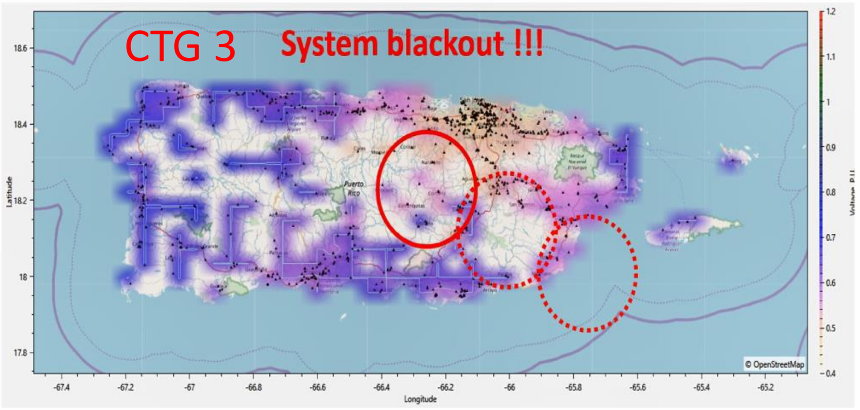
LUMA

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

Pacific Northwest
NATIONAL LABORATORY

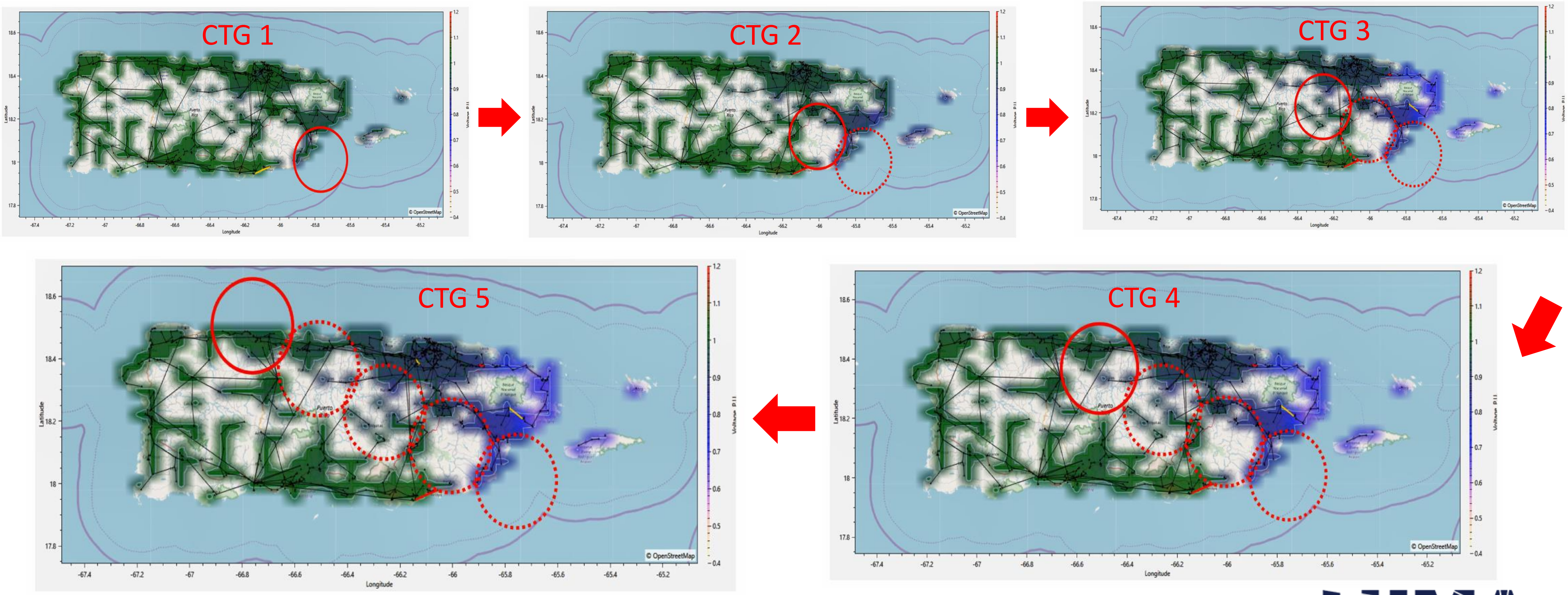






Puerto Rico Illustrative Example: Scenario 2 – Hardening Only

Pacific Northwest
NATIONAL LABORATORY

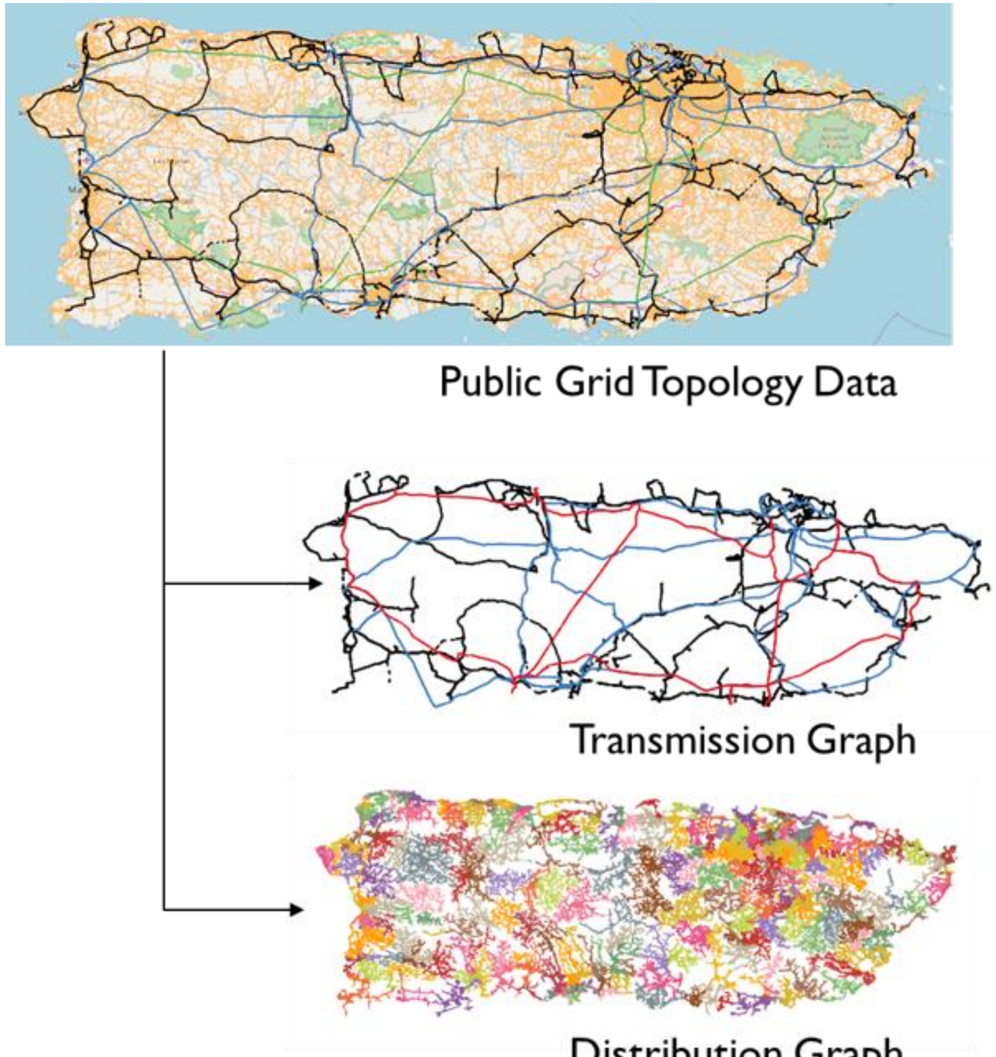


Distribution System Analysis

- 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

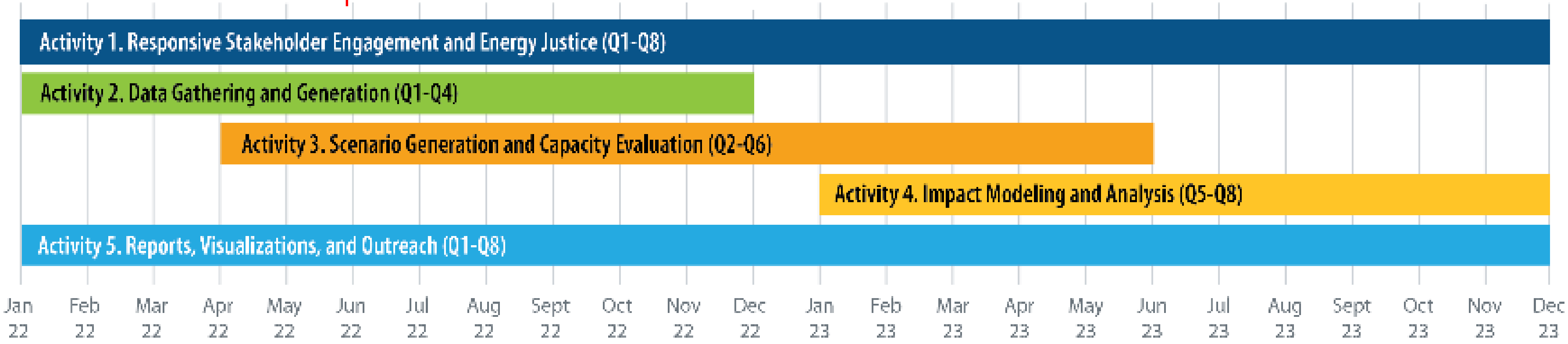


PR100 Timeline

6 Months (by June 2022):
Established stakeholder group meets monthly to inform scenarios
Defined four initial scenarios to achieve Puerto Rico’s goals.

Next Steps -- Each scenario will be modeled to understand:

- What new capacity gets built, where, and at what cost?
- What are the fixed and variable costs of operating the system?
- Does reaching 100% mean big changes locally—like building new transmission lines or increasing hosting capacity of the distribution system?
- If Puerto Ricans adopt energy technologies like EVs, how might that change total demand for electricity?
- Are scenarios resilient under extreme weather events?
- What are the economic impacts, such as changes to retail rates?



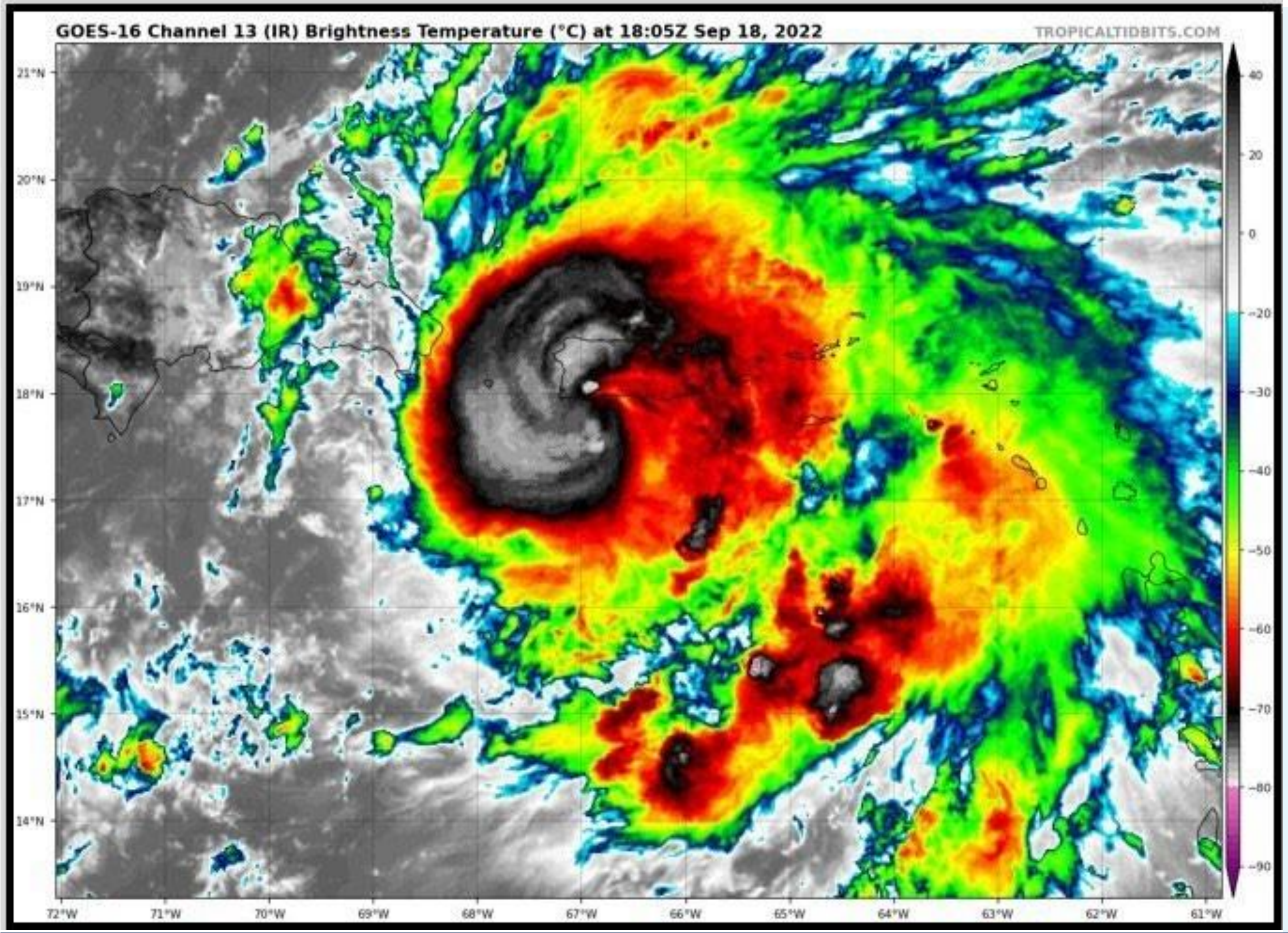
Declaration and Preparation

On September 17, 2022, President Biden, declared that an emergency exists in Puerto Rico and ordered Federal assistance to supplement Commonwealth and local response efforts due to the emergency conditions resulting from Hurricane Fiona.

- Consistent with LUMA standards, we mobilized the LUMA Emergency Operations Center (LEOC), and our Region's began preparing for the storm's arrival
- Preparations and planning for the storm included, but not limited to:
  - Determining the level of resources required to support restorations
  - Standing up the Regional Operations Control Centers (ROCCs)
  - Staging initial crews and materials at sites
  - Continuing to monitor the path of the storm
- LUMA ensured clear paths of communications with regulatory bodies, government agencies, and officials such as the PREB, P3A, Governor's Office, and more

Note: President Biden issued a major disaster declaration on for Puerto Rico on September 21

Hurricane Impact and Measures



Category 1

12-30+ inches of rain

85-113 mph winds

Widespread Flooding | ELECTRIC GRID BLACKOUT

Hurricane Fiona Customer Restoration Update

Data as of 04.10.2022 8:00 AM

Customers Restored

1,375,988

Generation Produced *(MW)*

2,180

% Customers Restored

Customers Restored by Region (map below)

Region	Customers Restored	% Restored
1 - Arecibo	>95%	
2 - Bayamón	>95%	
3 - Caguas	>95%	
4 - Mayagüez	159,652	74%
5 - Ponce	>90%	
6 - San Juan	>95%	

LUMAPUERTORICO.COM

Muhidin (Dino) Lelic

Muhidin.Lelic@lumapr.com

MLelic@quanta-technology.com

Mobile: (919) 274-1375

LUMA