Puerto Rico Grid Resilience and Transitions to 100% Renewable Energy Study (PR100)

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41st Puerto Rico Interdisciplinary Scientific Meeting (PRISM) & 56th ACS Junior Technical Meeting

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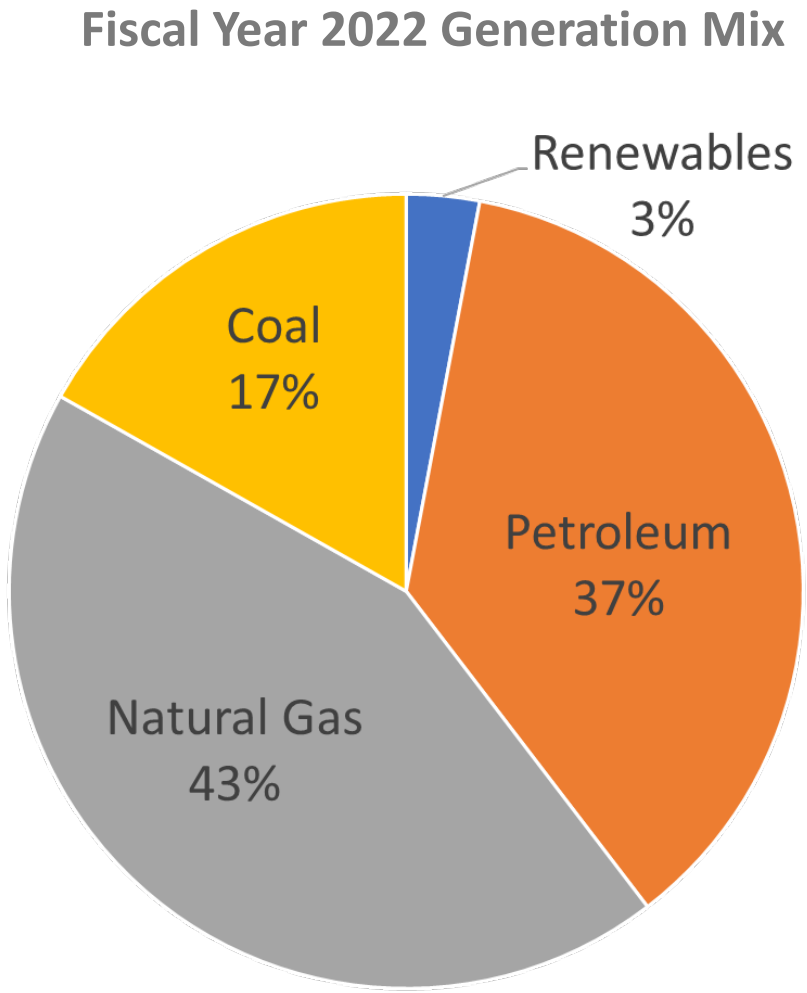
Drivers for the PR100 Study

State of the System

- Puerto Rico **relies almost entirely on imported fossil fuels** with plants along the coast and transmission lines throughout mountainous terrain.
- Puerto Rico's **consumers pay 3 times more for electricity** than U.S. mainland consumers.
- The **average customer loses power at least once every 5 to 6 weeks**, compared to 1 to 2 times per year for mainland customers.
- Some legacy generation plants are **noncompliant** with current air and pollution standards.
- Puerto Rico has **inadequate supply resources** to ensure reasonable system reliability and meet expected demand.
- Puerto Rico experienced one of the **longest power outages in U.S. history** after Hurricane Maria in 2017, which caused billions of dollars in damages and led to nearly 3,000 excess deaths



Data source: www.eia.gov

Energy Sector Recovery: Funding Sources

FEMA Hazard Mitigation

Amount: $7.8B

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)

FEMA Public Assistance

Amount: $9.5B

Purpose: Restoration for disaster-damaged public utilities.

Recipient: Central Office for Recovery, Reconstruction and Resiliency (COR3)

Subrecipient: PREPA (and LUMA as an agent)

HUD CDBG–Disaster Recovery: Electric Grid

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.

Other HUD CDBG-DR and CDBG-MIT disaster assistance programs

Community Energy and Water Resilience Installations ($300M): Support resilient design and improvements that incorporate modern technology for life-sustaining purposes. R3 eligible.

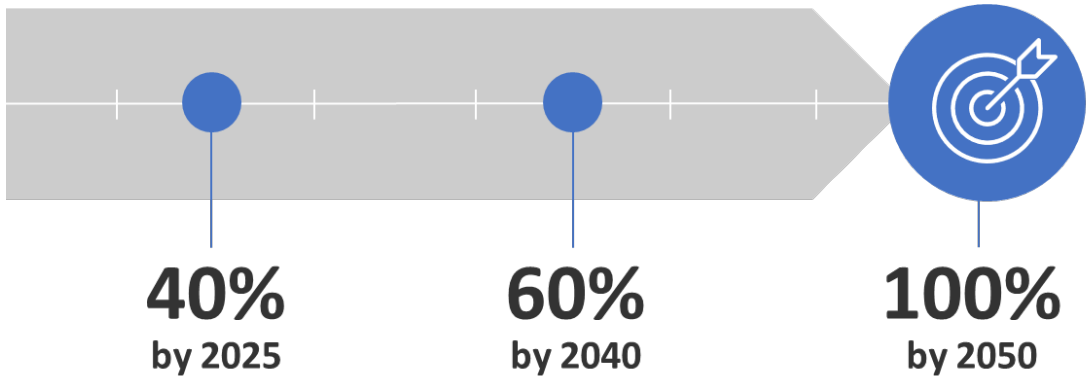
Community Energy and Water Resilience Installations ($500M): Same as above, but from CDBG-MIT with broader eligibility

City Revitalization Program ($1.29B): Funding directly to municipalities for repairs of urban centers

Puerto Rico's Energy Public Policy

Act 17 of 2019

- **Increase generation from renewable energy resources**:



- **Reduce energy use by 30%** by 2040
- **Replace 100% of public lighting with LED** by 2030
- **Eliminate coal-fired generation** by 2028
- **Comply with the Integrated Resource Plan**

2020 IRP

- Retire a significant number of oil-fired thermal units in the next 5 years
- 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.
- To achieve the established target of 40%, PREPA established a plan to issue six requests for proposals for the procurement of 3,750 MW of renewable energy resources + 1,500 MW of storage.

Complex Questions Require Complex Analyses

- 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 or increasing hosting capacity?
- If Puerto Ricans adopt energy technologies like electric vehicles, how might that **change total demand** for electricity?
- How can Puerto Rico assure that the new system is **resilient to 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?
- And what **investments and actions** are needed in the near term to enable Puerto Rico's long-term objectives?

PR100 Study

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

Presentation during hybrid Advisory Group meeting held in San Juan, Puerto Rico in Jan 2023.
Photo by DOE Communications

- A comprehensive analysis of possible pathways for Puerto Rico to achieve its goal of **100% renewable energy by 2050**, based on extensive stakeholder input.
- A two-year coordinated effort led by FEMA, DOE and NREL, leveraging the unique tools and capabilities of five additional national laboratories.
- Publicly launched February 2022

Activities 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, Visualization and Outreach

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

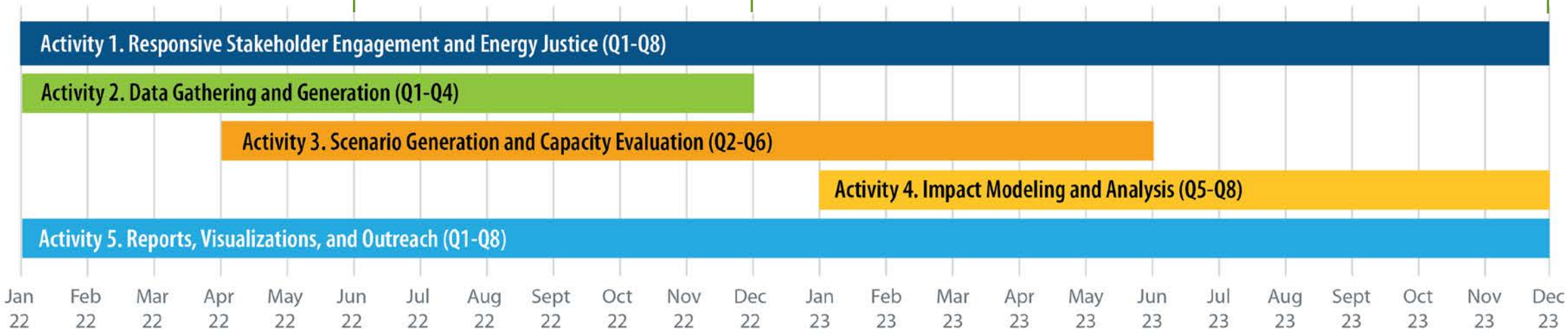
Graphic by NREL

PR100 Timeline

Six 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.



Advisory Group Formation and Engagement

- Formed Advisory Group (AG) of 80+ members from academia, public and private sectors, community-based and environmental organizations, and other sectors. AG provides information on portfolio of technical assistance for Puerto Rico.
- Monthly meetings from February–July 2022 (four remote and two hybrid); bi-monthly or quarterly meetings to be held through December 2023.
- Partnered with Hispanic Federation in Puerto Rico for facilitation and stakeholder engagement support.
- Partnered with University of Puerto Rico Mayagüez (UPRM) to contribute to the study

In January 2023, we kicked off the PR100 Community Engagement Tour (Road Show) to learn from communities across Puerto Rico to better reflect their diverse needs and priorities.

Presentation during Road Show held in Loiza, Puerto Rico in January 2023.
Photo by DOE Communications

Initial Scenario Definitions

- Worked closely with Advisory Group 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.
- 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, are incorporated in each scenario.

Technologies

Distributed
- Rooftop PV + Batteries
- Light-duty EV's
- Energy Efficiency

Utility-Scale
- PV
- Land-based Wind
- Offshore Wind
- Hydro (and Pumped)
- Batteries
- Biofuel Engines
- Hydrogen Storage
- Ocean Thermal

Preliminary Fundings

Initial Scenarios Based on Distributed Solar and Storage

Scenario #	Scenario Name
1	**Economic** adoption of distributed energy resources
2	Deployment of distributed energy resources for **critical** services
3	**Equitable** deployment of distributed energy resources
4	**Maximum** (prescribed) deployment of distributed energy resources

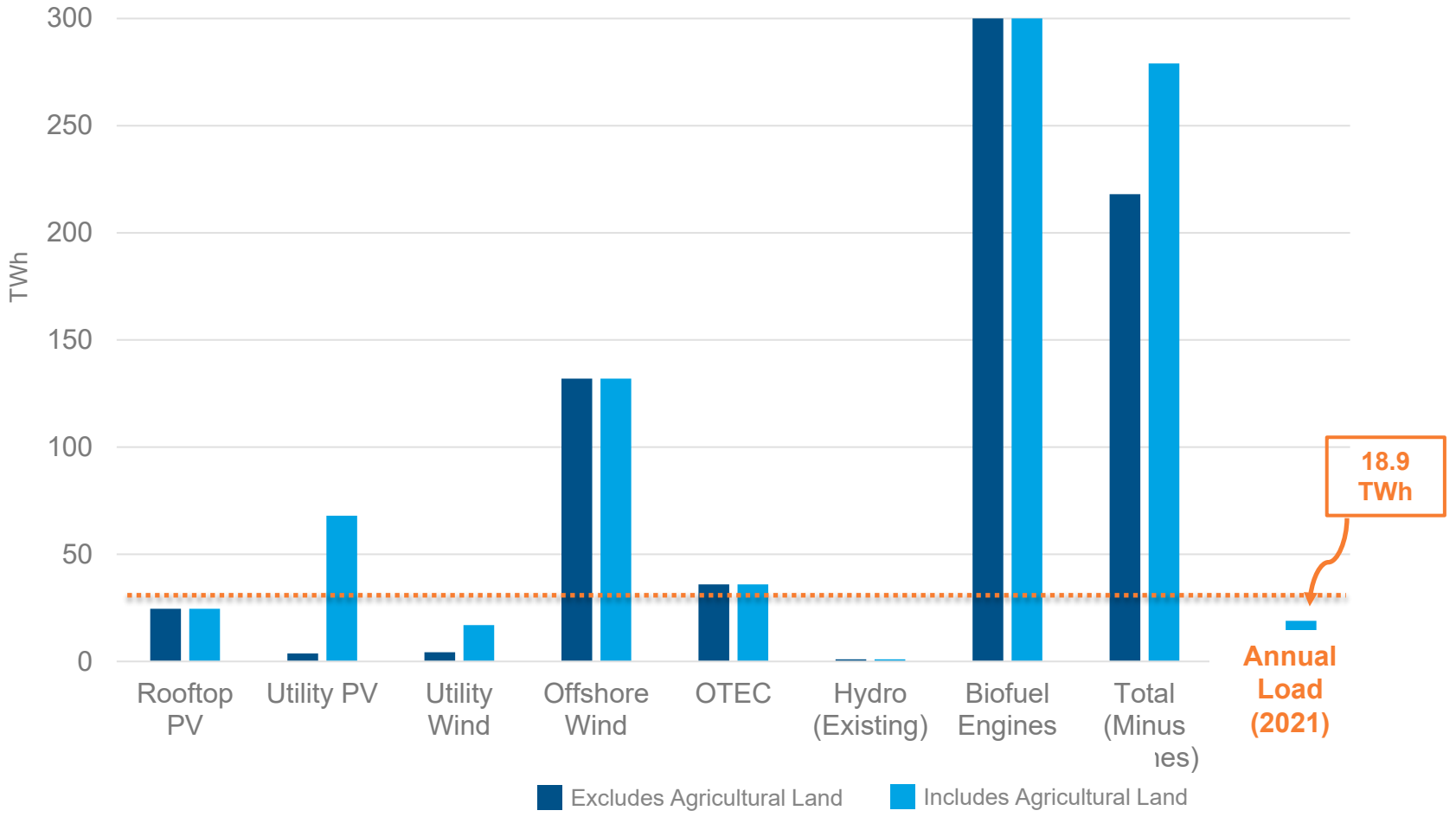
- All scenarios result in a **significant increase** in rooftop solar photovoltaics (PV) and associated battery energy storage systems.
- Preliminary modeling shows that Scenario 1 results in a 6x increase in distributed solar and storage systems between 2022 and 2050, while Scenario 4 results in a 16x increase.
- This "maximum" scenario would be achieved by increasing the current rate of deployment by approximately 4x.
- Preliminary results give a range from 3 GW to nearly 7 GW of rooftop PV and associated storage capacity by 2050.

Preliminary Finding:
Adoption of distributed solar and storage is projected to increase considerably in all scenarios.

Renewable Energy Potential and Distributed Energy Resource Adoption

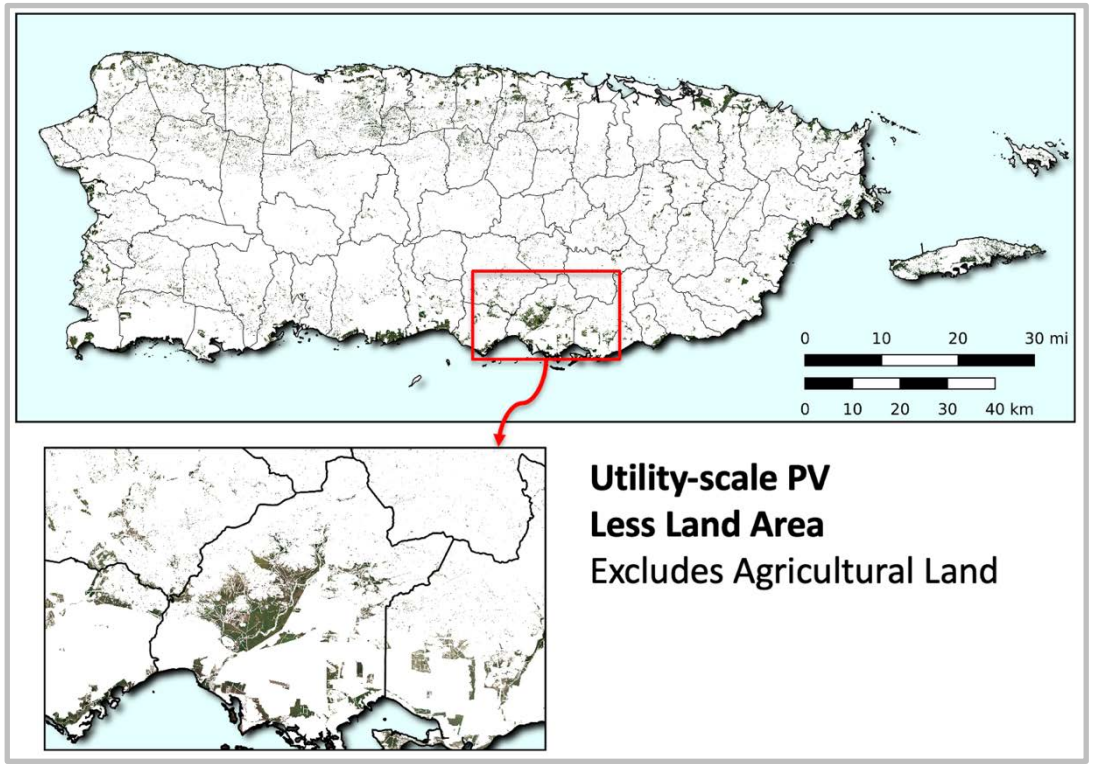
Preliminary Finding:

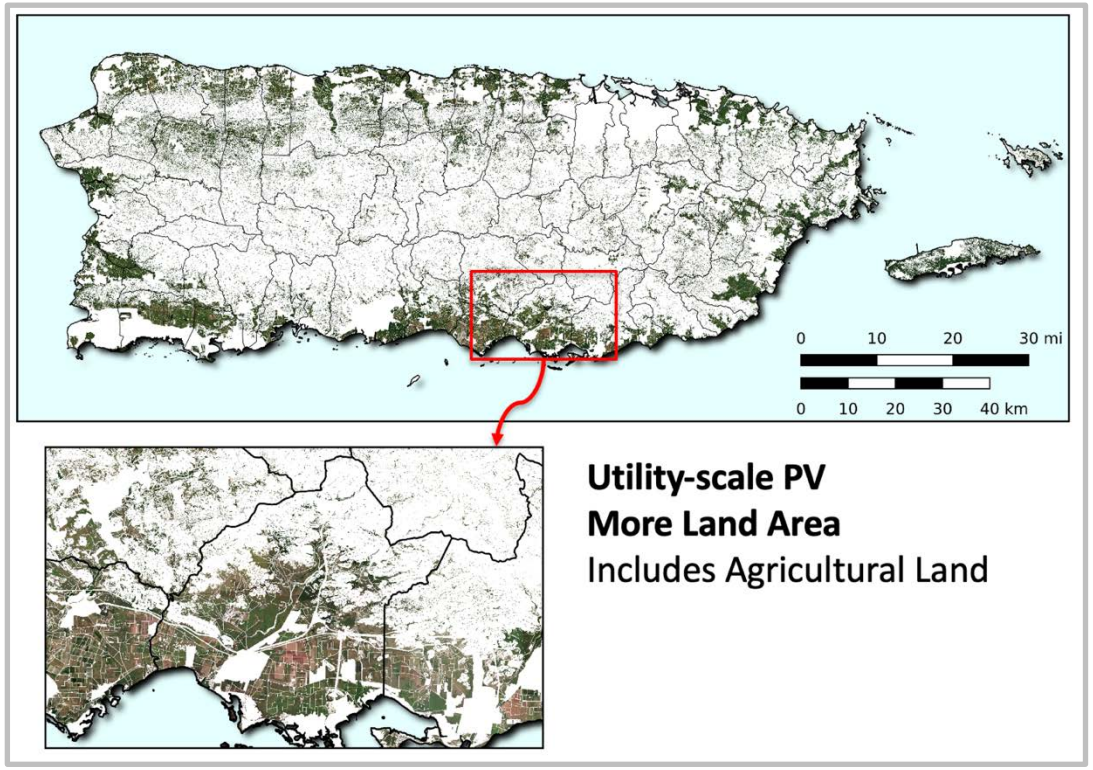
- The renewable energy **technical resource in Puerto Rico significantly exceeds** the current and projected total annual loads through 2050.



Potential annual generation in TWh of various renewable technologies compared to load (in 2021). *Graphic by NREL.*

Land Availability: Solar Deployment



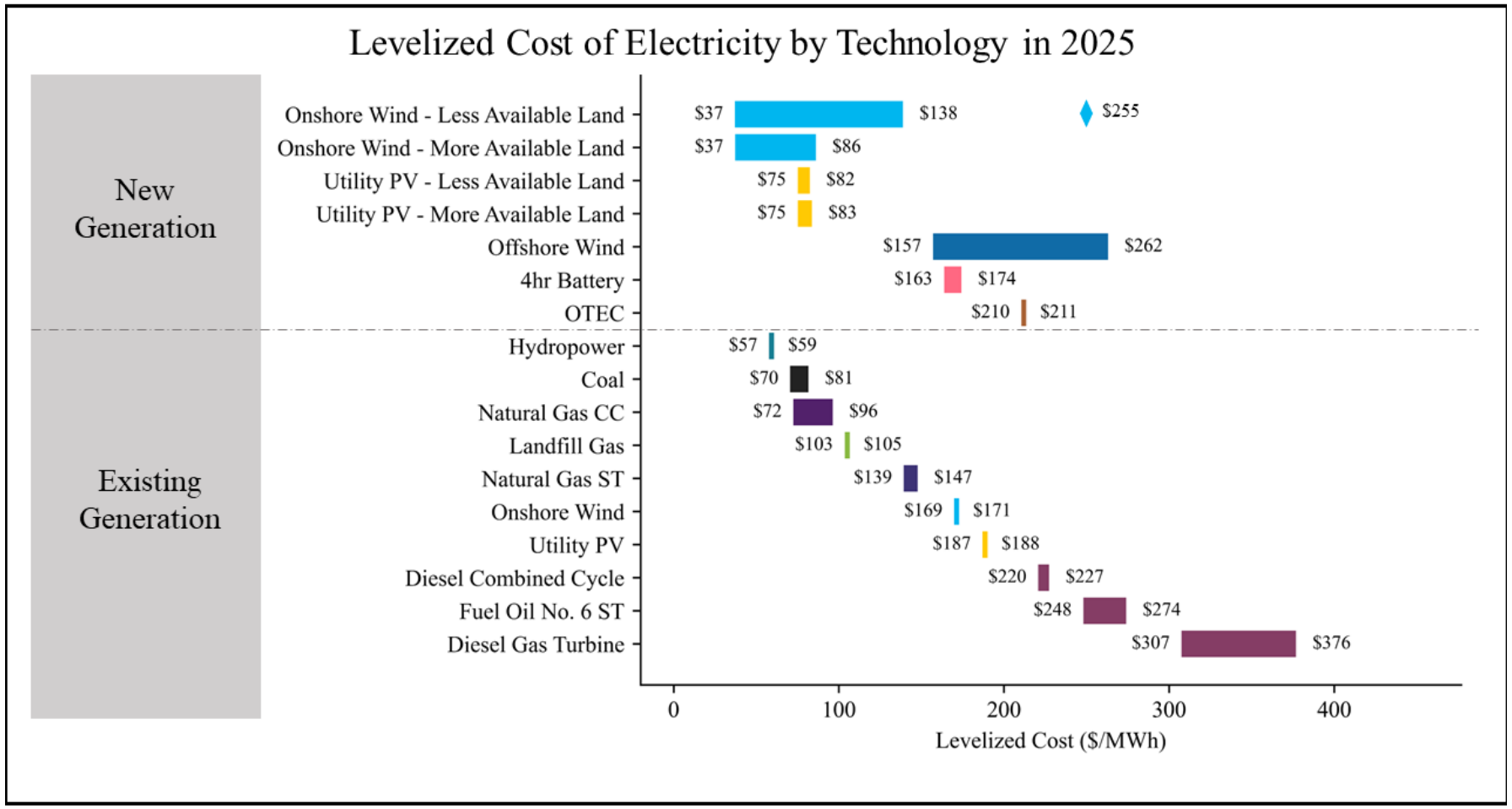


Legend: White = excluded area; green = developable area

Preliminary Findings:

- If **only utility-scale solar and land-based wind** resources were deployed, Puerto Rico **could not meet its renewable capacity targets,** given the amount of land available when agricultural land is excluded.
- Therefore, identifying **alternate system configurations for deployment** on smaller specialized areas could increase developable area for moderate- to large-scale renewable energy projects.

Comparative Costs of Utility Scale Generation Technologies

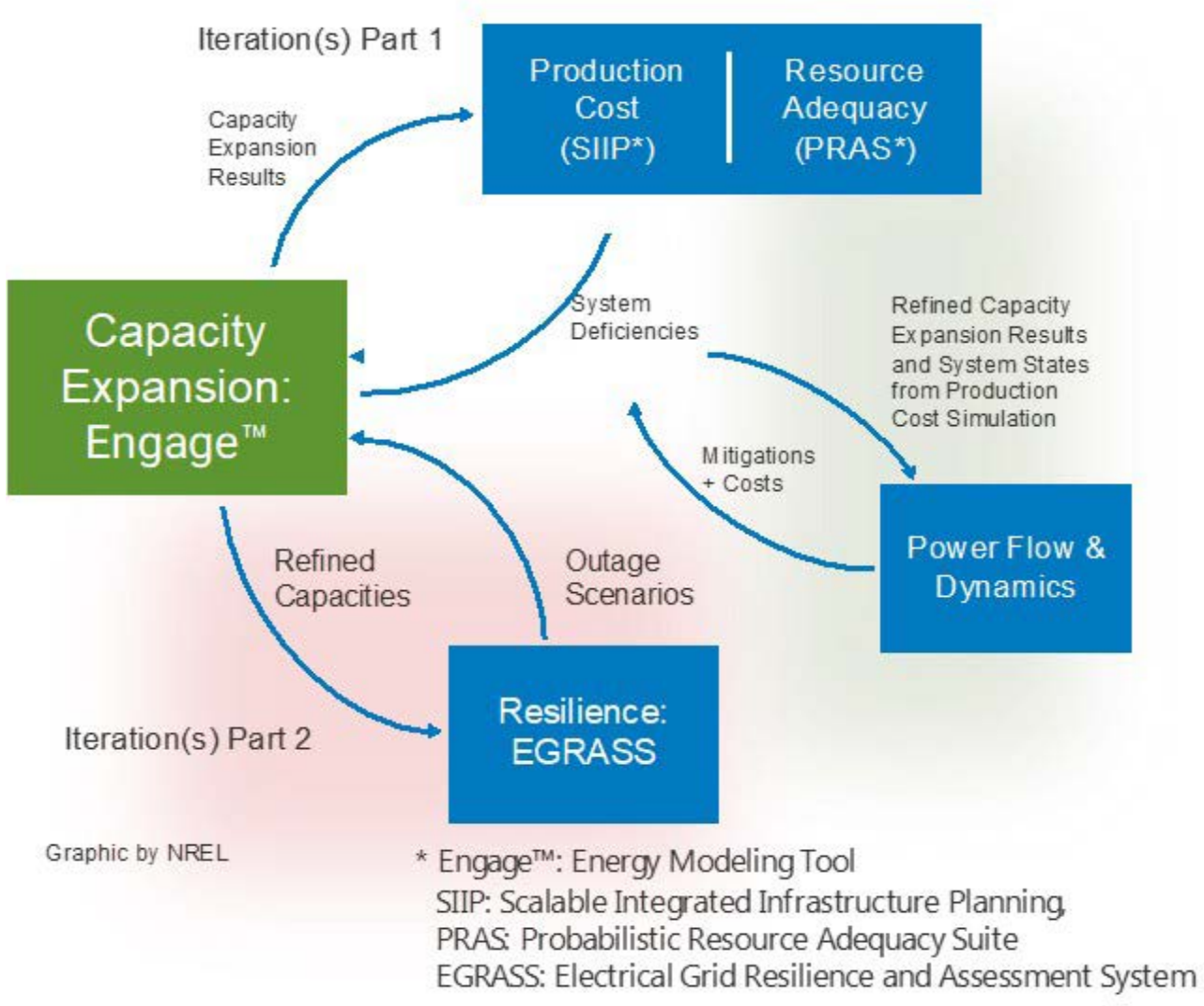


Preliminary Finding:
Implementation of **new utility scale renewables and storage is more cost effective** than the operating costs alone of much of the existing generation by 2025.

Capacity Expansion and Resource Adequacy

Preliminary Findings:

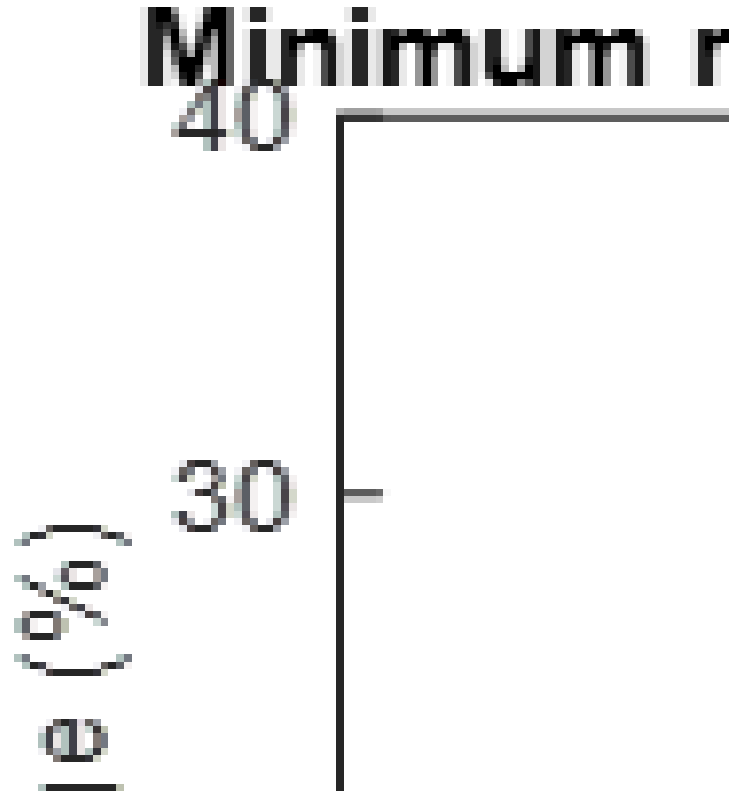
- The **tranche procurements** of renewable energy **are insufficient** to meet the Act 17 2025 40% RPS.
- **Rapid procurement** of large amounts of utility scale wind and solar would save **money vs operating the existing** diesel and fuel-oil generation fleet.
- In the less land scenarios, the **money-saving** by deployment of utility scale solar and wind **exhausts land availability**.
- Due to uncertainties and unscheduled events, even after the near-term implementation of substantial amounts of utility scale wind, PV, and storage, **the system requires additional capacity to meet NERC reliability standards** throughout the 2025-2050 simulation horizon.



Resilience Analysis

- The future simulated model with smaller units spread across the system tends to **recover faster than the current system** that has larger power plants.
- **Last loads recovered** in all simulations tend to be in **mountain regions** as well as in the areas where the hurricane made landfall.
- **Black-start capability** can significantly reduce recovery time, by up to 3 times.
- Renewable Microgrids with storage can be an effective way to **increase energy resilience and reliability.**

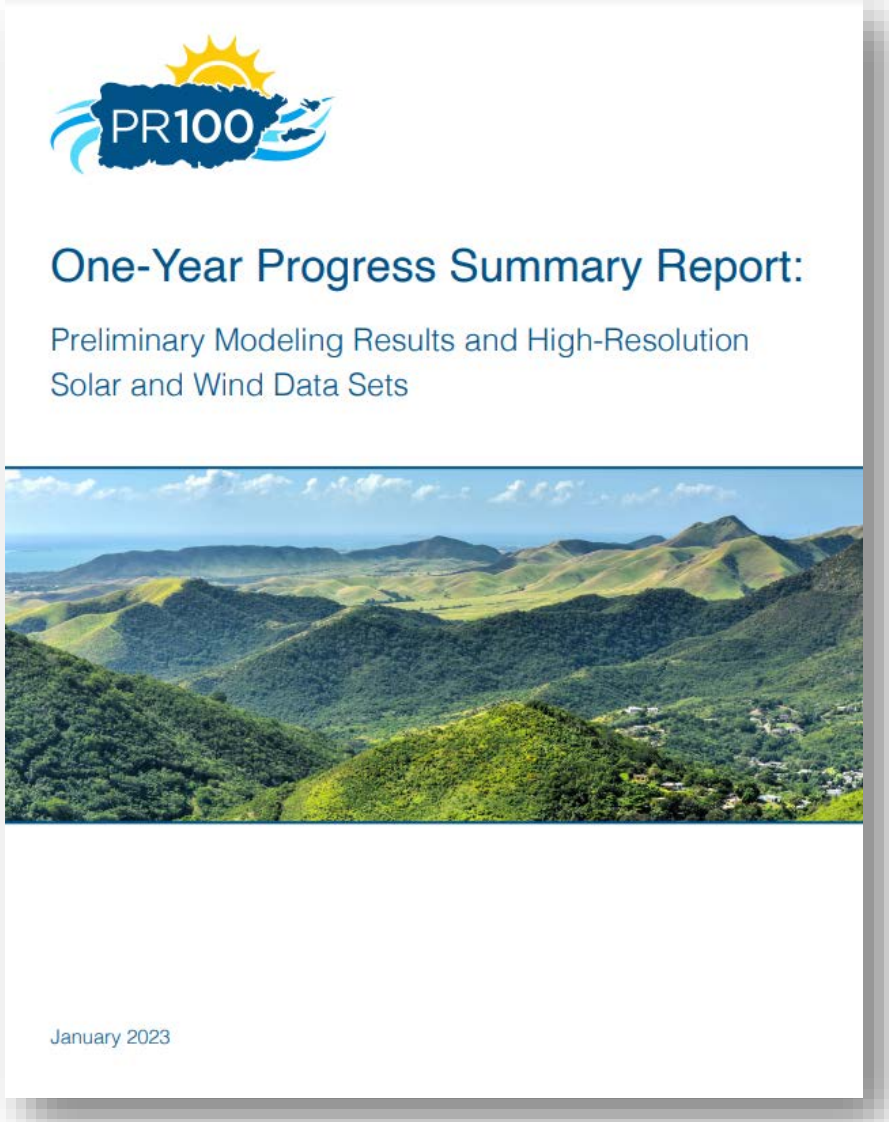
Preliminary Finding:
Smaller, more distributed utility-scale renewables and battery storage **can improve resilience**



Less effort is needed to restore 90% of the system load in the expanded scenario

Main Themes for Considerations from Year 1 Analysis

- **Accelerate deployment** of rooftop solar & storage as well as utility-scale solar and wind (2x current rate reaches our 2050 economic deployment, 4x reaches it by 2035)
- **Improve investment planning** beyond current procurement plans
- **Upgrade transmission and distribution** system to accommodate new renewable generation resources
- **Modernize grid** with high fidelity sensors, models and updated grid codes to support T&D upgrades
- **Prioritize equitable access** to affordable, resilient electricity for the most vulnerable utility customers



Available in English and Spanish

Looking Ahead

- What system **upgrades are needed** to integrate high levels of renewables under each scenario, and how much would they cost?
- What are the **impacts of each scenario** in terms of energy justice, reliability, resilience, emissions, jobs, and electricity rates?
- How can the **resilience** of remote, vulnerable, or “last mile” communities, often the last to have power restored after an outage, be increased?

Year 2 Deliverable (by December 2023)

- Comprehensive report and community outreach:
  - **Results** of detailed modeling of feasible scenarios
  - **Impact analysis** including economic and workforce, resilience, climate risk, bulk power, and distribution system
- Implementation Roadmap to:
  - **Advise stakeholders** on the electric grid operation actions needed in both the near term and long term
  - **Engage with implementers** to understand current organization, technical capabilities, and operations
  - **Support validation** of expansion planning results based on national lab expertise and tools
  - Develop a transition plan and suggest paths for **quick-impact actions** (i.e., near-term wins).

Thank you, Questions?

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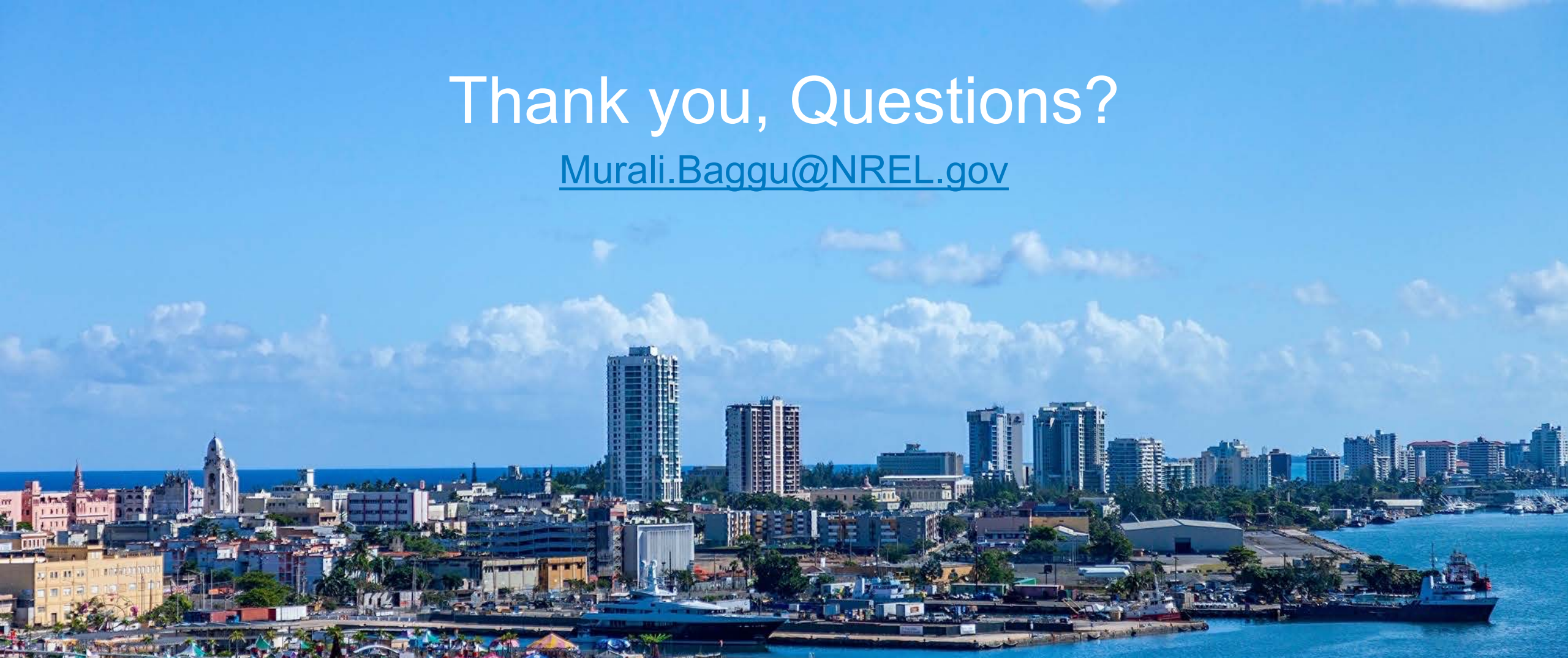

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