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

PR100 One-Year Progress Update: Preliminary Modeling Results and High-Resolution Solar and Wind Data Sets

Public Webinar

Monday, January 23, 2023

12 p.m. - 1:15 p.m. (AST)

Welcome

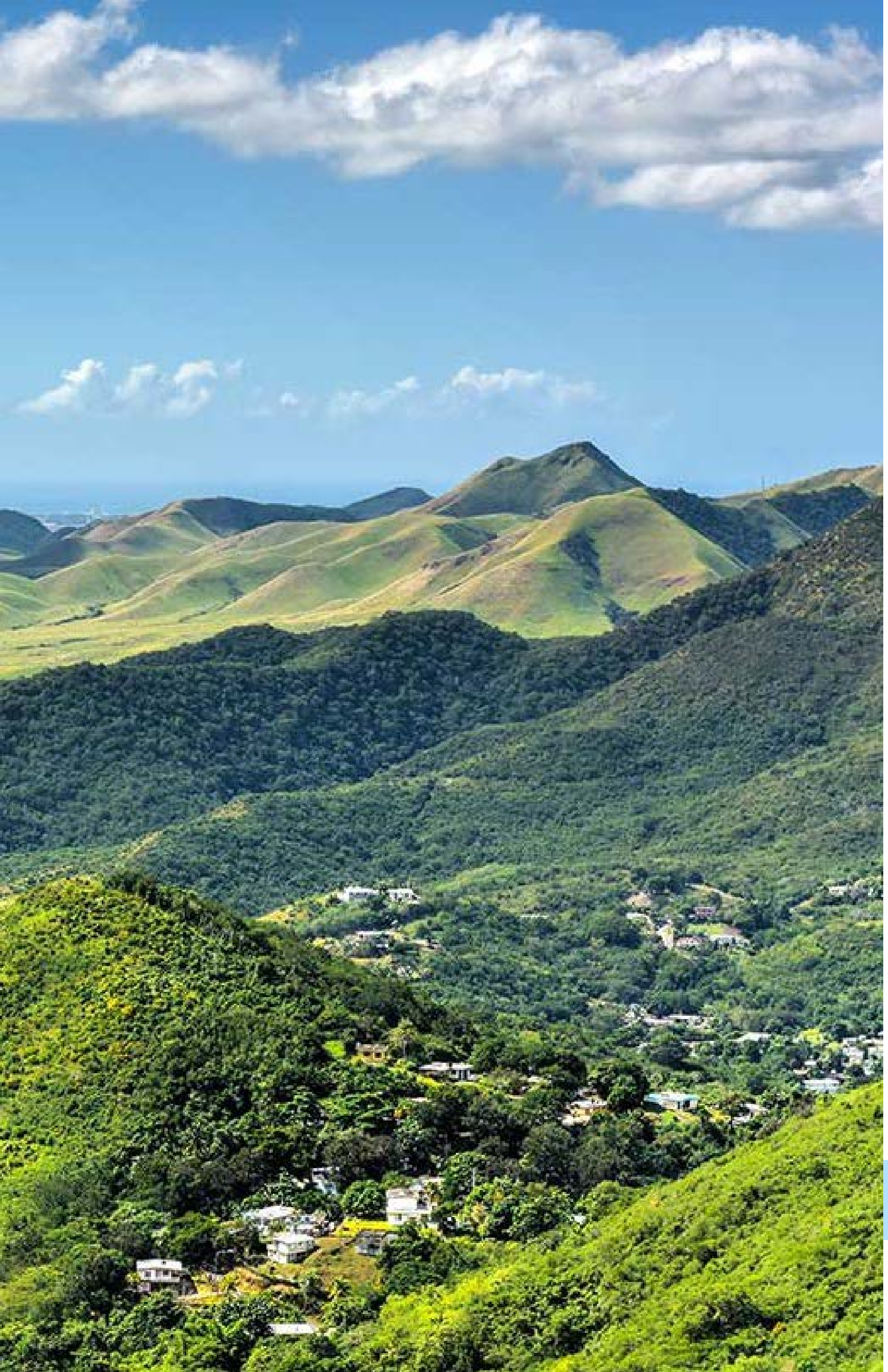
Moderator

Charlotte Gossett Navarro

Puerto Rico Chief Director Hispanic Federation

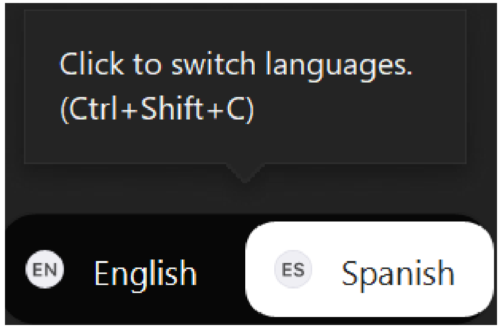
Agenda

1. Welcome
2. Opening Remarks
   - Dr. Martin Keller, National Renewable Energy Laboratory (NREL)
   - Secretary Jennifer Granholm, U.S. Department of Energy (DOE)
3. PR100 One-Year Update
4. Discussion
   - Secretary Jennifer Granholm, DOE
   - Administrator Deanne Criswell, Federal Emergency Management Agency (FEMA)
   - Puerto Rico Governor Pedro Pierluisi
5. Q&A



Housekeeping

- Toggle to Spanish for live interpretation.
- American Sign Language interpretation is provided.
- Audio and video are muted for participants.
- Ask questions in the Q&A box throughout the presentation. We will answer some questions in writing and discuss others at the end.



Note: Today's event is being recorded.

Opening Remarks

Director Martin Keller

National Renewable
Energy Laboratory (NREL)

Secretary Jennifer Granholm

U.S. Department of Energy
(DOE)

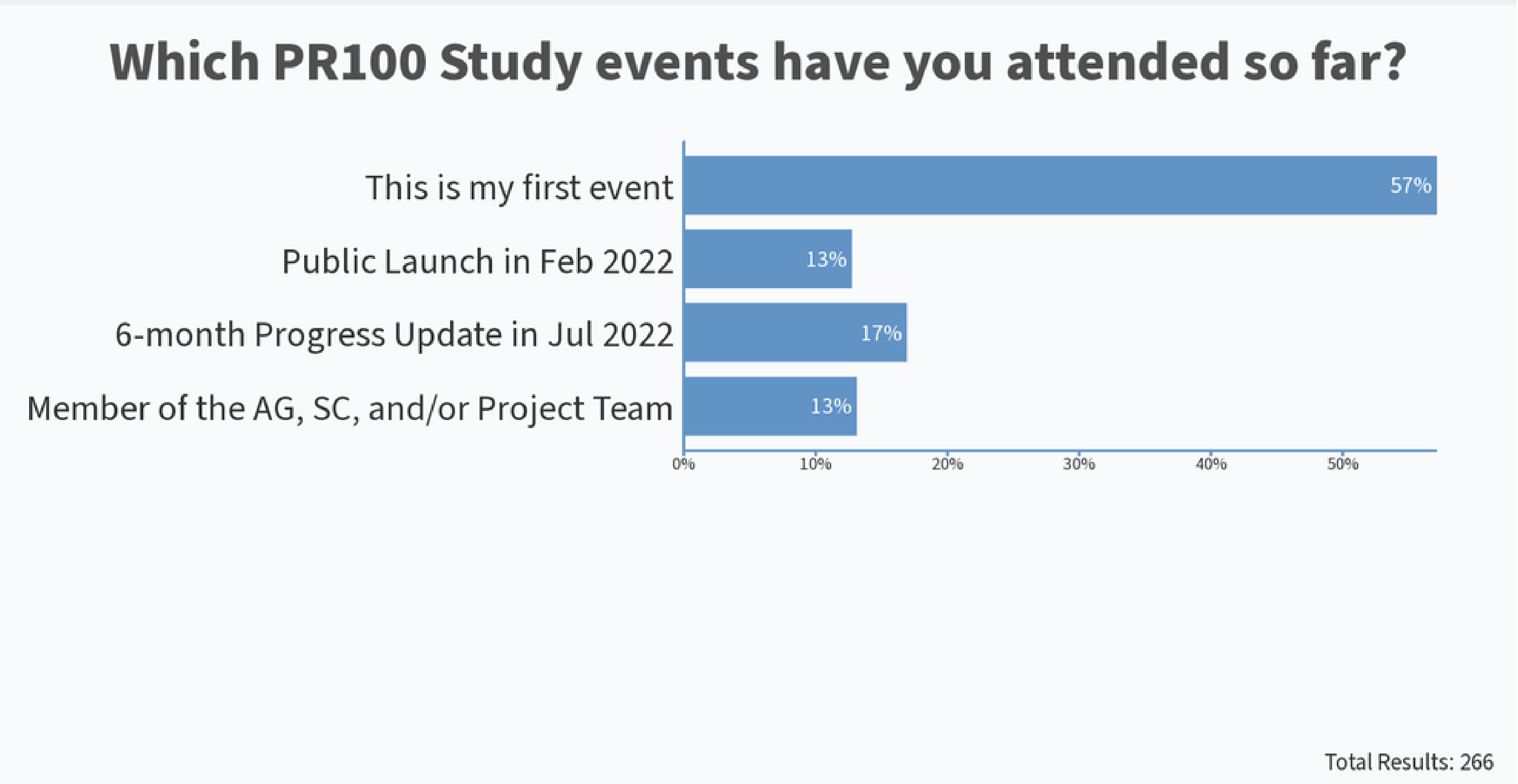
Poll Question #1

Click link in the chat.

Which PR100 Study events have you attended so far?

- This is my first event
- Study launch webinar in February 2022
- Six-month progress update webinar in July 2022
- Advisory Group or Steering Committee meetings (for members of these groups).

Poll Question #1



PR100 Year 1 Update

Robin Burton
NREL

Nate Blair
NREL

Tom Harris
NREL

Marcelo Elizondo
PNNL

PR100 Study Overview

Robin Burton
National Renewable Energy Laboratory (NREL)

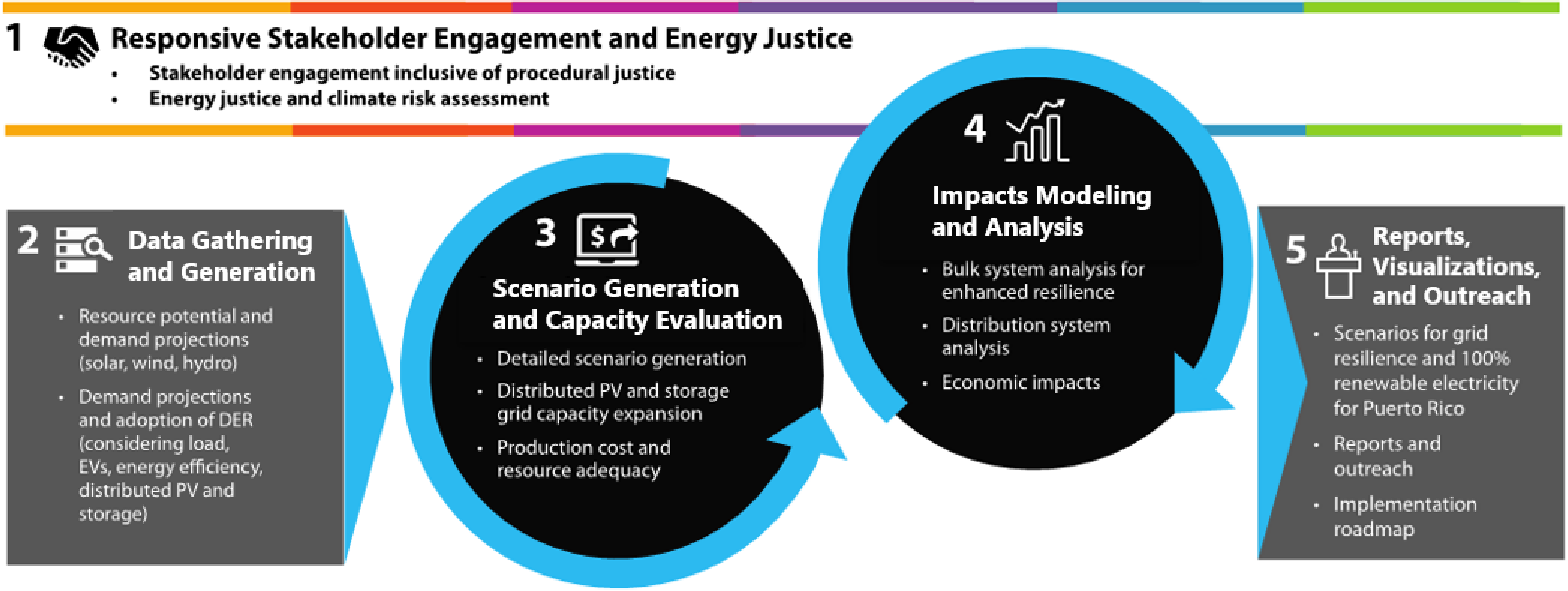
What Is the PR100 Study?

- 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 coordinated effort led by FEMA, DOE, and NREL, leveraging the unique tools and capabilities of five additional national laboratories.

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 using world-class data, modeling, and analysis.
- It will be up to Puerto Rico energy system stakeholders to choose a path forward and implement it.

Activities of Puerto Rico 100% Renewable Energy Study



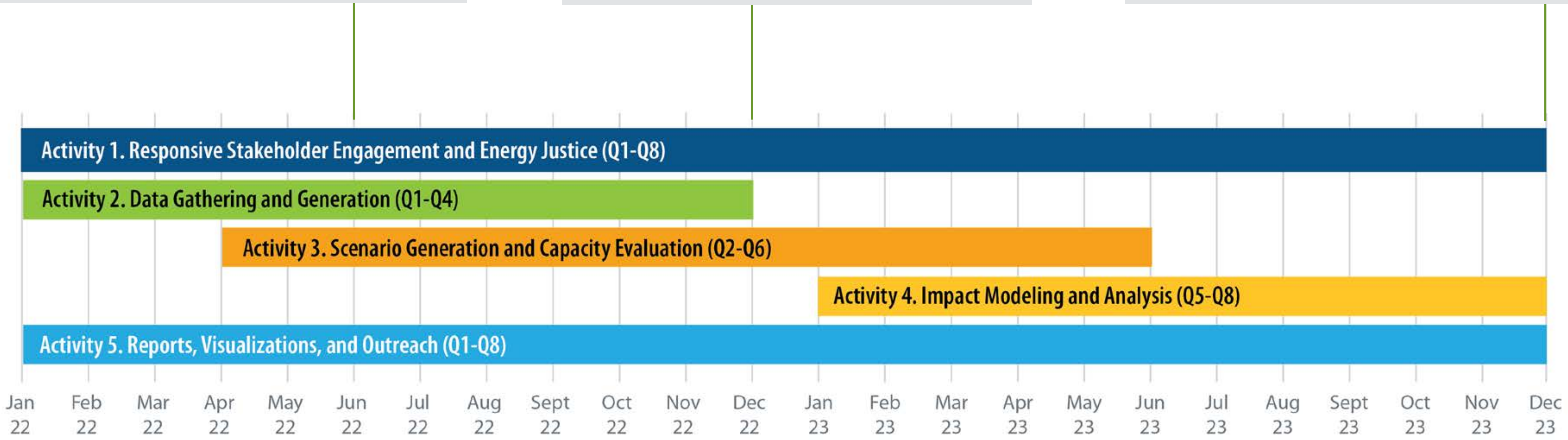
Graphic by NREL

PR100 Timeline

6 Months (by June 2022):
- Established stakeholder group meets monthly to inform scenarios.
- 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.

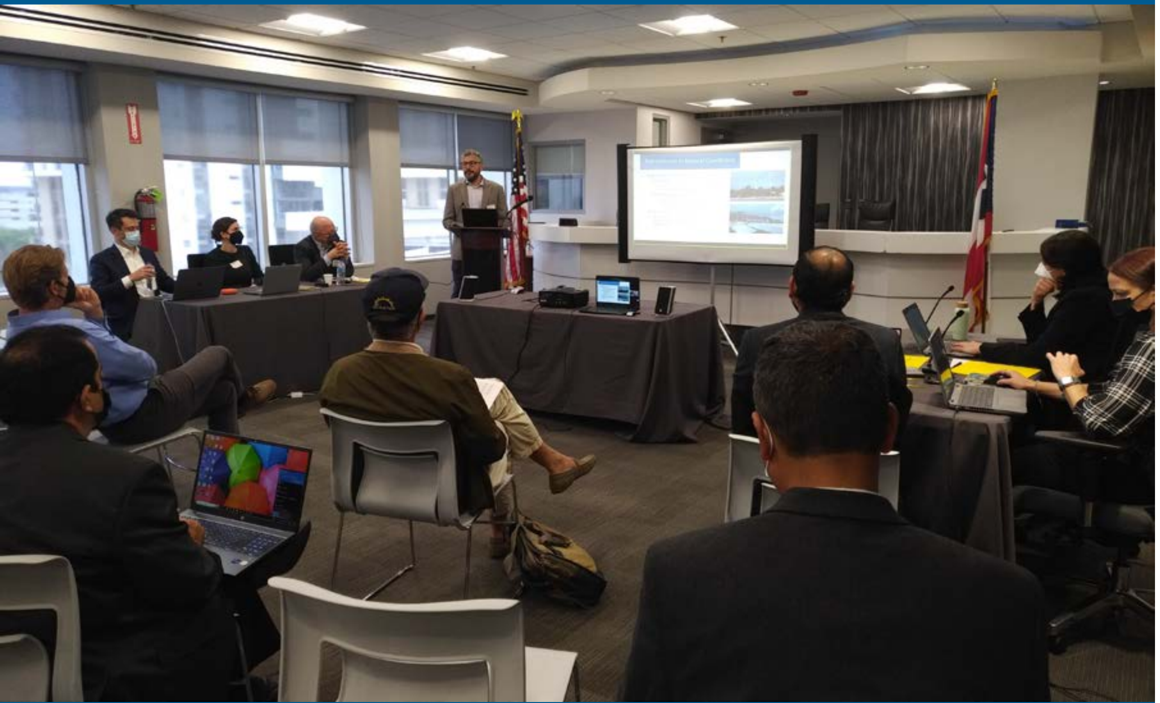


Questions Answered in One-Year Update

- Does Puerto Rico have enough renewable resources to meet its electricity demand (load), now and through 2050?
- How is energy demand expected to change in the future?
- How much rooftop solar and storage capacity is projected to be deployed through 2050, based on scenario assumptions?
- How does the system perform now compared to national standards?
- What are the areas most impacted by hurricanes?
- What do Puerto Ricans prioritize in the transition to renewable energy?

Preliminary Findings and Key Considerations: Stakeholder Engagement and Energy Justice

Advisory Group Formation and Engagement

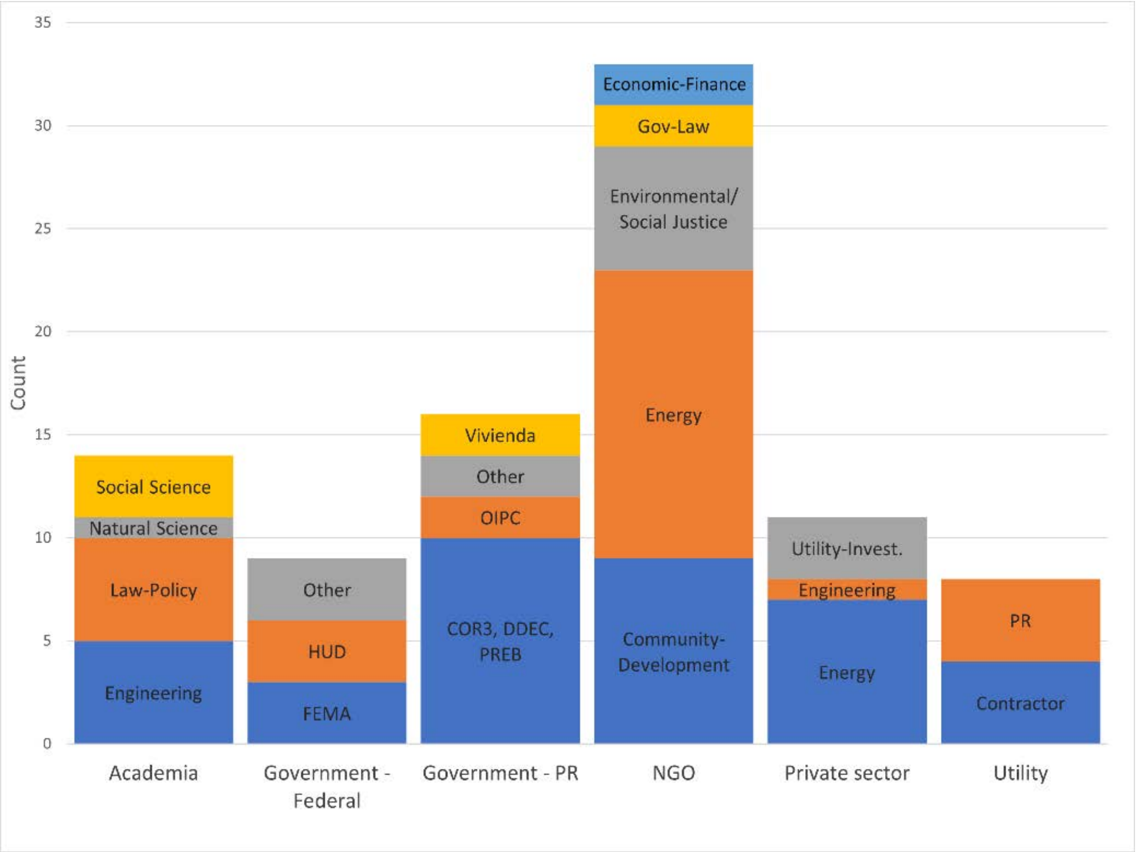


- Formed an Advisory Group of nearly 100 members, representing nearly 60 organizations from public, private, and nonprofit sectors, including academia, community-based and environmental organizations, solar and storage developers, local government agencies, and others
- Met monthly from February–July 2022; bi-monthly or quarterly 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.

Presentation during hybrid Advisory Group meeting held in San Juan, Puerto Rico in May 2022. Photo by Robin Burton, NREL

Preliminary Findings on *Stakeholder Engagement and Energy Justice*

- Advisory Group members **value PR100 as a neutral forum** where stakeholders with a diverse set of perspectives can discuss Puerto Rico's energy future.
- **Energy justice themes** prioritized by Advisory Group members include:
  - Energy access, affordability, reliability, and resilience
  - Community participation
  - Economic and workforce development
  - Siting and land use
  - Environmental and health effects
  - Public sector implementation.
- Baseline social burden analysis highlights **inequitable access to critical services** across geographic areas during normal grid operations.
- Initial climate risk assessment results illustrate a **temperature increase of 1.5°–2.0°C and a precipitation decrease of up to 20%** across the entire archipelago by 2055.



Distribution of sectors represented by nearly 100 individual members of the Advisory Group. *Graphic by ORNL.*

Key Considerations

Energy Justice

- Energy justice involves **prioritizing access to affordable, resilient electricity and high-quality energy sector jobs and economic opportunities for the most vulnerable utility customers**, such as rural, remote, low-income, and people with disabilities.
- An important way to work toward energy justice is by developing a process to **ensure broad and meaningful stakeholder participation in the planning, decision-making, and implementation** of the pathway to 100% renewable energy.

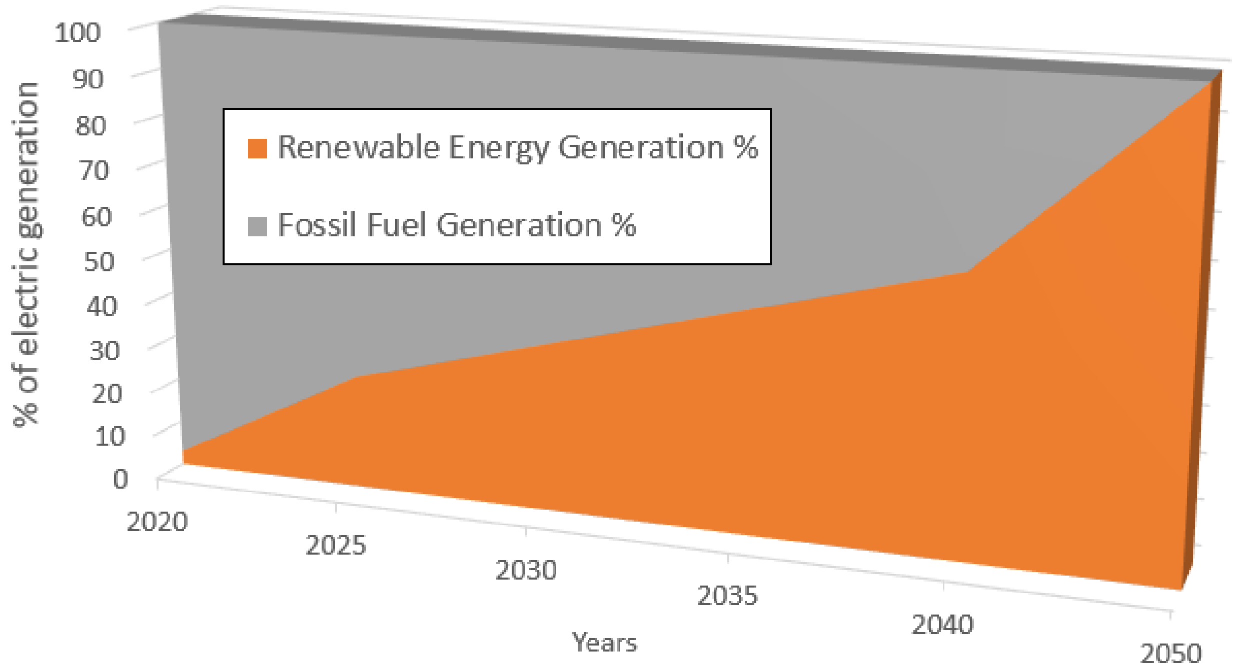
Presentation during hybrid Advisory Group meeting held in San Juan, Puerto Rico in October 2022. Photo by Marisol Bonnet, DOE.

Preliminary Findings and Key Considerations: Feasible Scenarios

Nate Blair, NREL

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.

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.

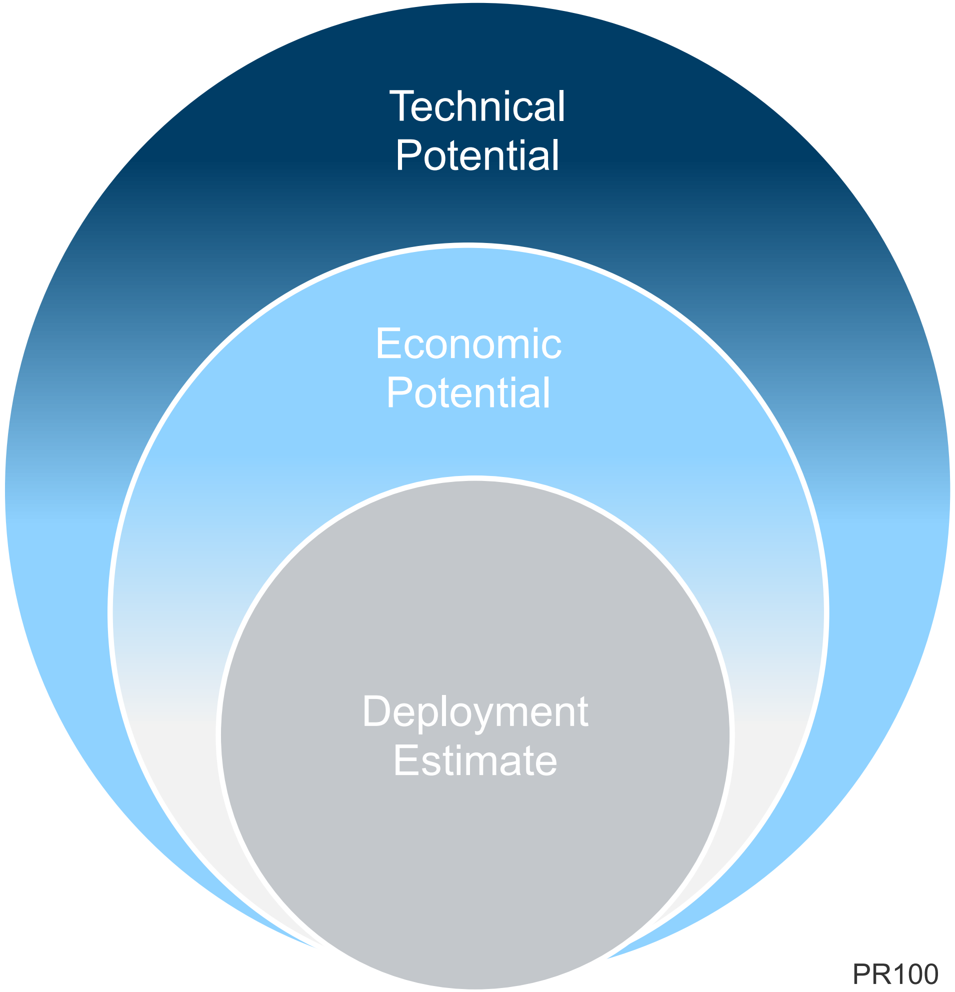
Initial Scenarios Based on Distributed Solar and Storage

Scenario #	Scenario Name	Description	Short Name (based on DER adoption level)
1	Economic adoption of distributed energy resources	Distributed energy resource adoption is based on financial savings to building owners.	**Economic**
2	Deployment of distributed energy resources for critical services	Installation of distributed energy resources is prioritized beyond Scenario 1 for critical services like hospitals, fire stations, and grocery stores.	**Critical**
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.	**Equitable**
4	Maximum (prescribed) deployment of distributed energy resources	Distributed solar and storage is added to all suitable rooftops.	**Maximum**

Modeling Adoption of Distributed Energy Resources

Adoption of rooftop solar is modeled using NREL's [Distributed Generation Market Demand (dGenTM)]() model through an agent-based approach that includes four steps:

1. **Generating agents** (i.e., potential customers) and assigning them attributes based on a probabilistic representation of individual customer types
2. Applying **technical and siting restrictions**, such as resource quality, rooftop availability (solar), and quality for each agent
3. Performing **economic calculations** using cash flow analysis, incorporating project costs, prevailing retail rates, incentives, and net metering considerations
4. Estimating total rooftop solar deployment by applying **market diffusion estimates** (i.e., not all sites with economic potential will be deployed).



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.

Three Feasible Scenarios

Scenario 1 & 2. Economic & Critical

Distributed energy resource adoption is based on financial savings to building owners as well as critical services like hospitals, fire stations, and grocery stores.

Scenario 3. Equitable

Installation of distributed energy resources for remote and low- and moderate-income households, beyond the economic adoption seen in Scenario 1 & 2.

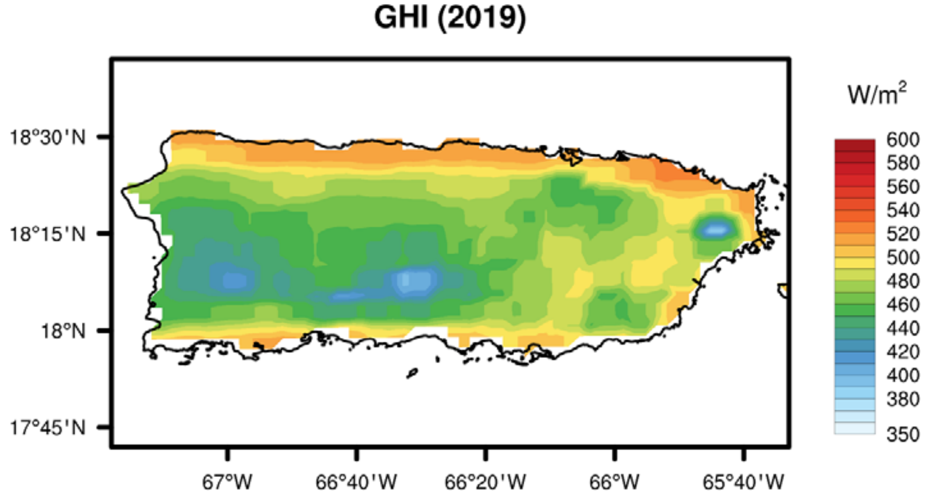
Scenario 4. Maximum

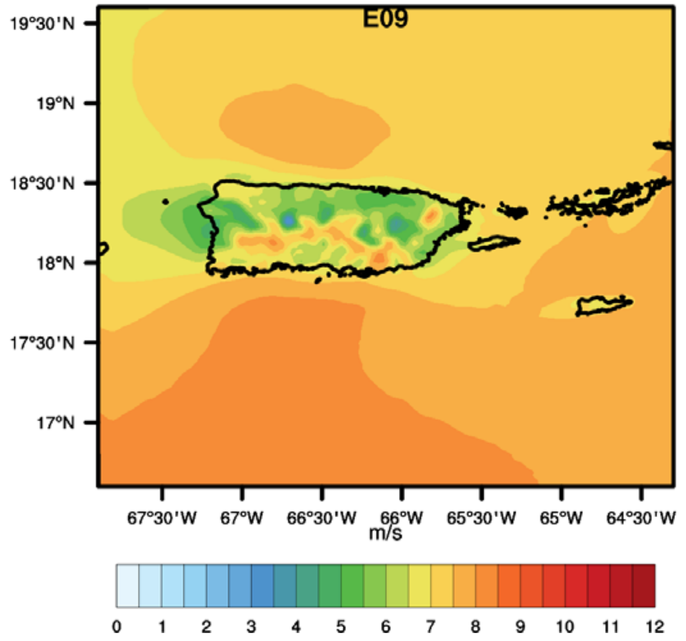
Distributed solar and storage is added to all suitable rooftops.

Graphics by NREL

Renewable Energy Potential in Puerto Rico

- Conducted renewable energy potential assessments for a variety of resources in Puerto Rico.
- Generated high-resolution, multiyear resource data sets for land-based wind, offshore wind, and solar, as well as wind and solar forecast data:
  - Solar resource data from 1998–2021: https://nsrdb.nrel.gov
  - Wind resource data from 2000–2021: https://www.nrel.gov/grid/wind-toolkit.html.
- Marine, hydropower, and pumped storage hydropower assessments are in progress; data sets will be made available.
- Other resources will be considered (either for local production or the cost of import) as they emerge in the study.





Average solar global horizontal irradiance (GHI) for 2019 (at right, above); 1-yr averaged wind speed at 80m in 2019 (at right, below). ***Graphics by NREL.***

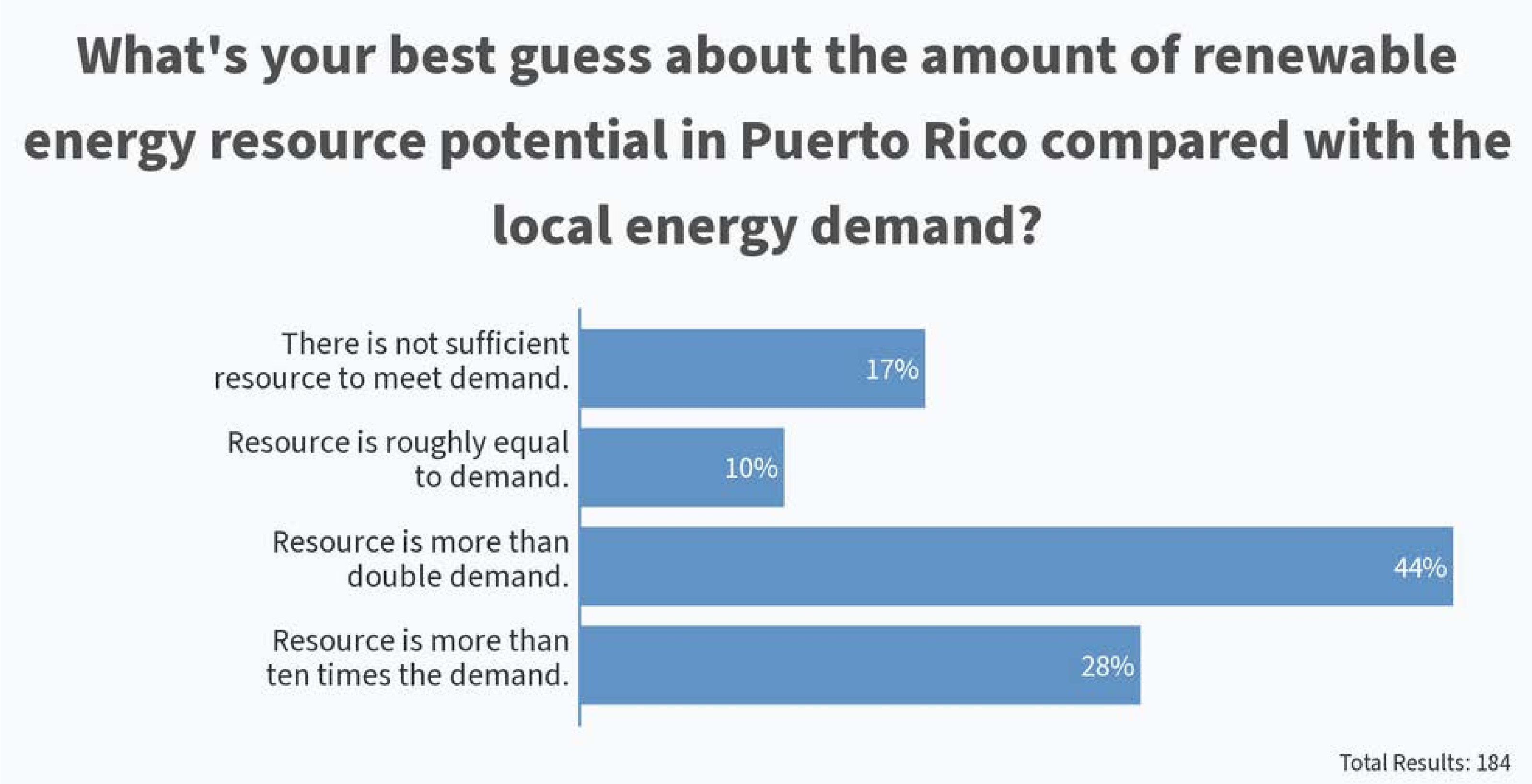
Poll Question #2

Click link in the chat.

What's your best guess about the amount of renewable energy resource potential in Puerto Rico compared with the local energy demand?

- There is not sufficient resource to meet demand.
- Resource is roughly equal to demand.
- Resource is more than double demand.
- Resource is more than ten times the demand.

Poll Question #2



Correct answer: Resource is more than ten times the demand.

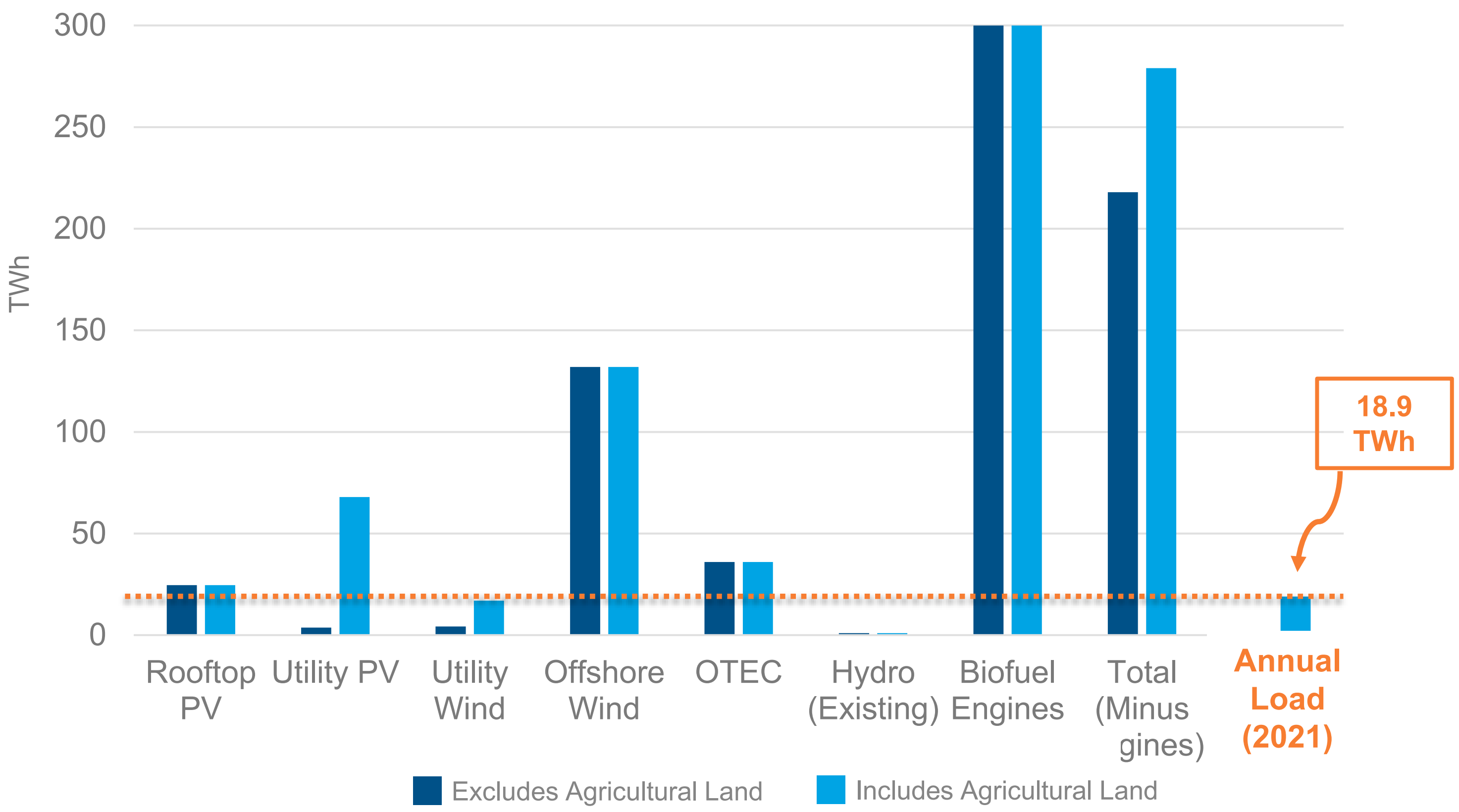
Preliminary Findings From *Renewable Energy Potential and Distributed Energy Resource Adoption*

Answer:

- Resource is more than ten times the demand.

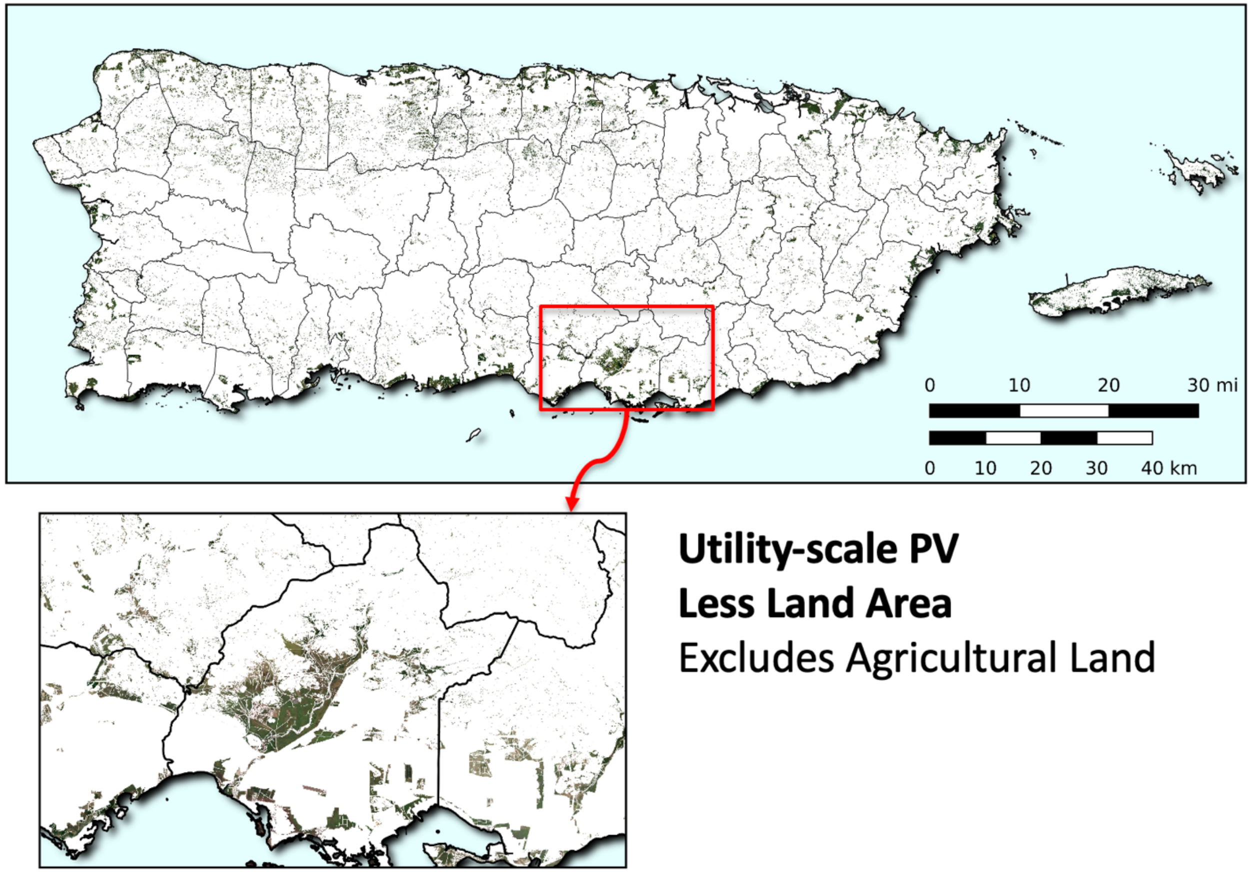
Preliminary Findings:

- The **renewable energy technical resource in Puerto Rico significantly exceeds** the current and projected total annual loads through 2050.
- Adoption of **distributed solar and storage is projected to increase** considerably in all scenarios.

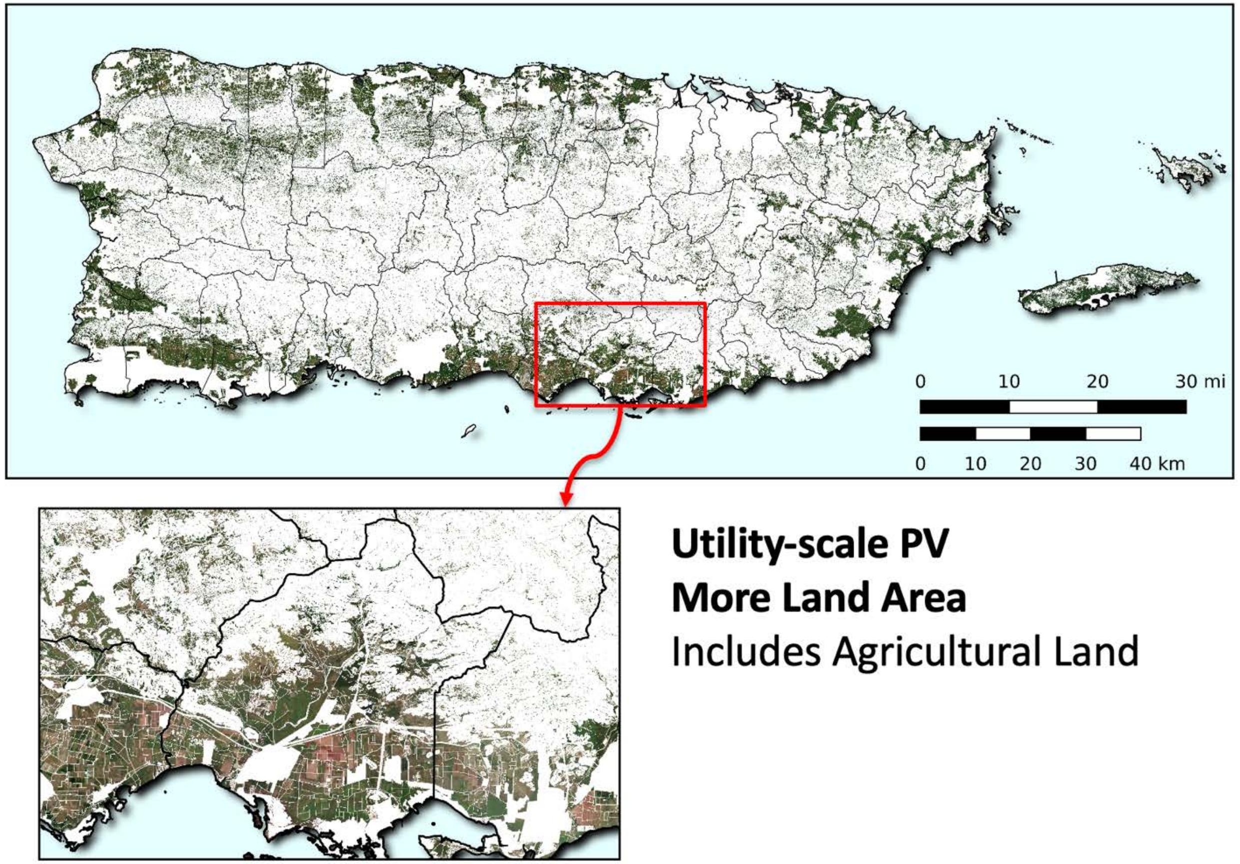


Potential annual generation in TWh of various renewable technologies compared to load (in 2021). ***Graphic by NREL.***

Land Availability: Solar Deployment



Utility-scale PV
Less Land Area
Excludes Agricultural Land

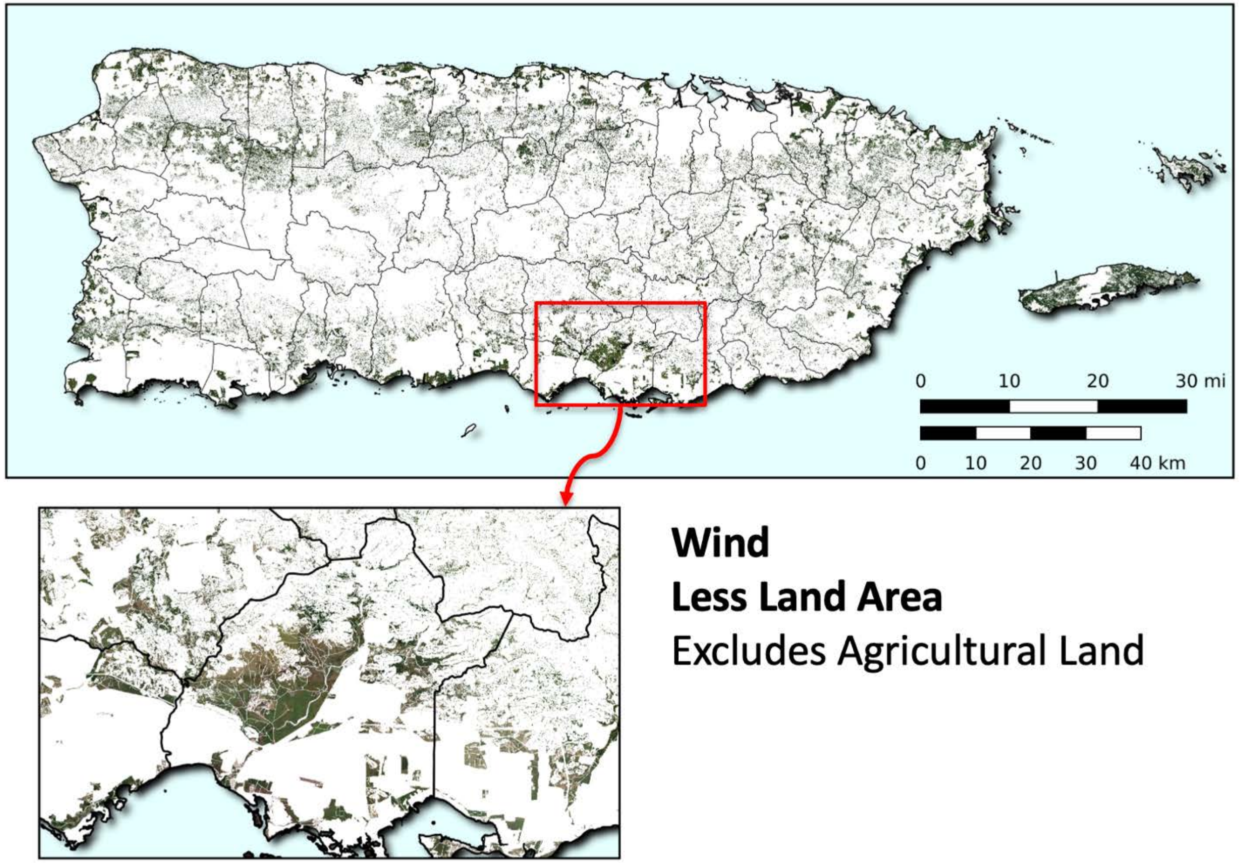


Utility-scale PV
More Land Area
Includes Agricultural Land

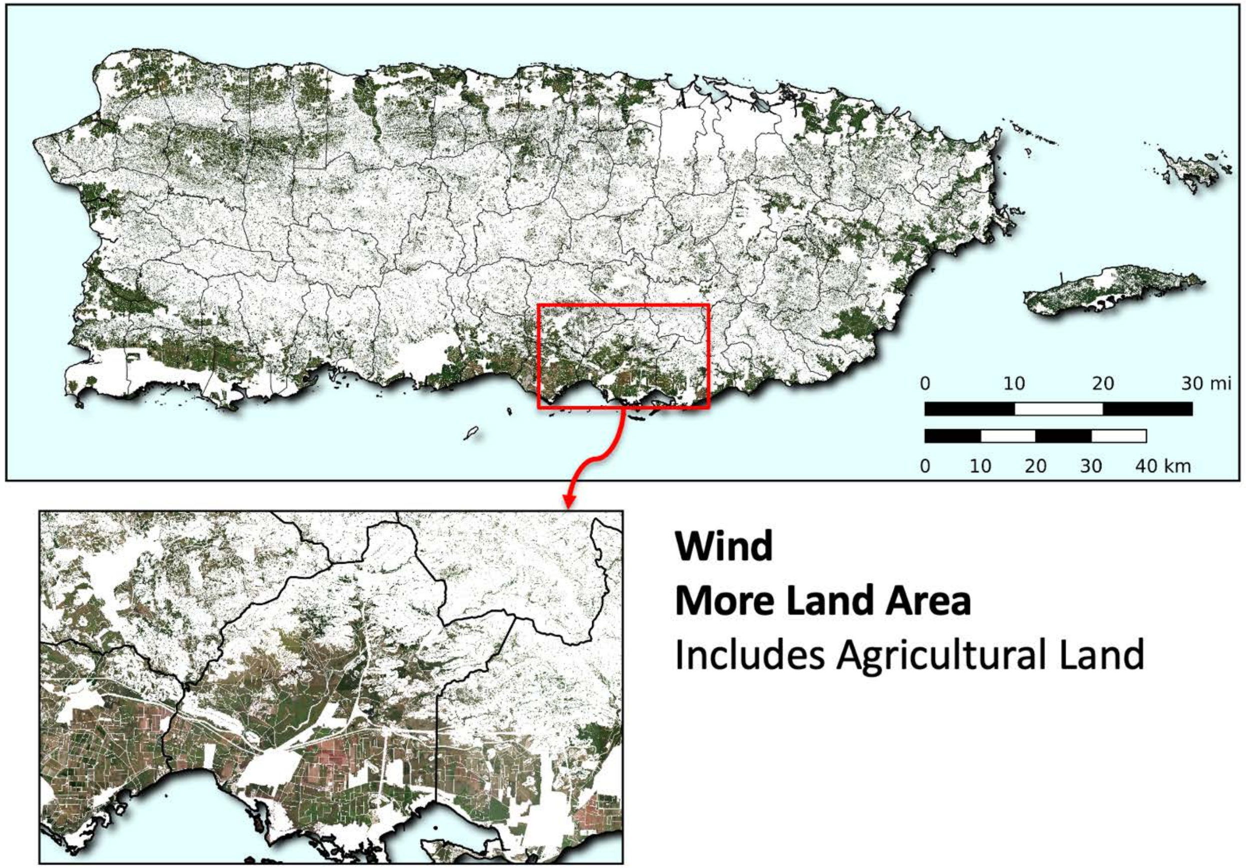
Legend: White = excluded area; green = developable area

Graphics by NREL

Land Availability: Land-Based Wind Deployment



Wind
Less Land Area
Excludes Agricultural Land



Wind
More Land Area
Includes Agricultural Land

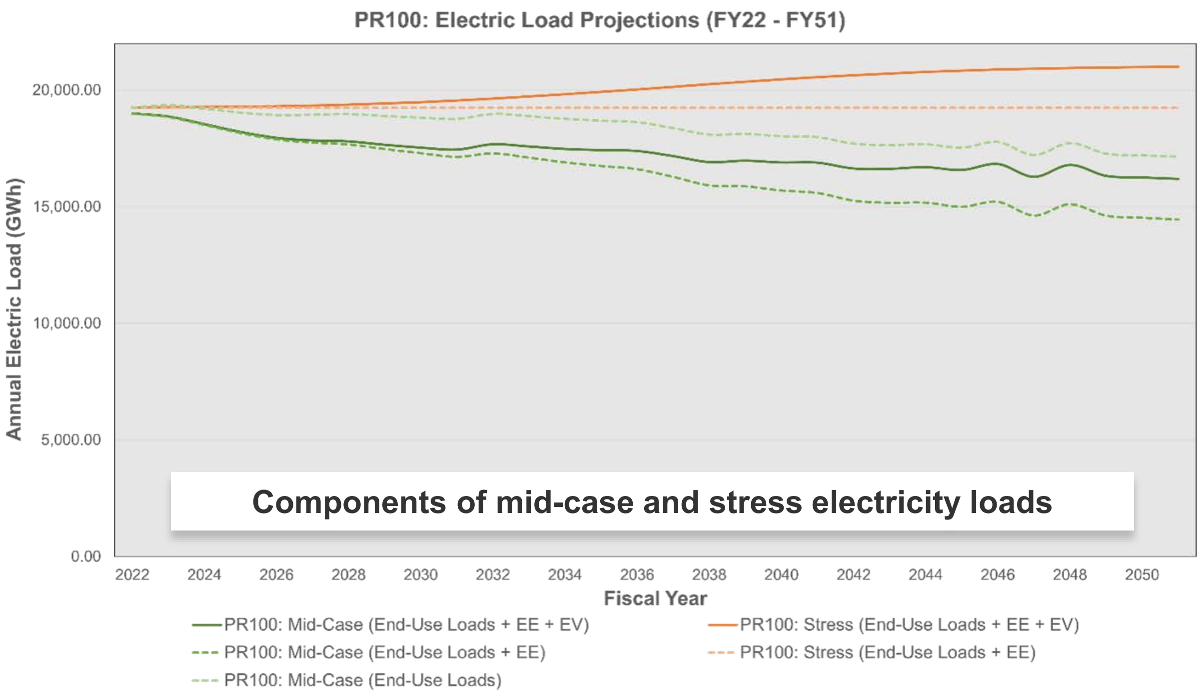
Legend: White = excluded area; green = developable area

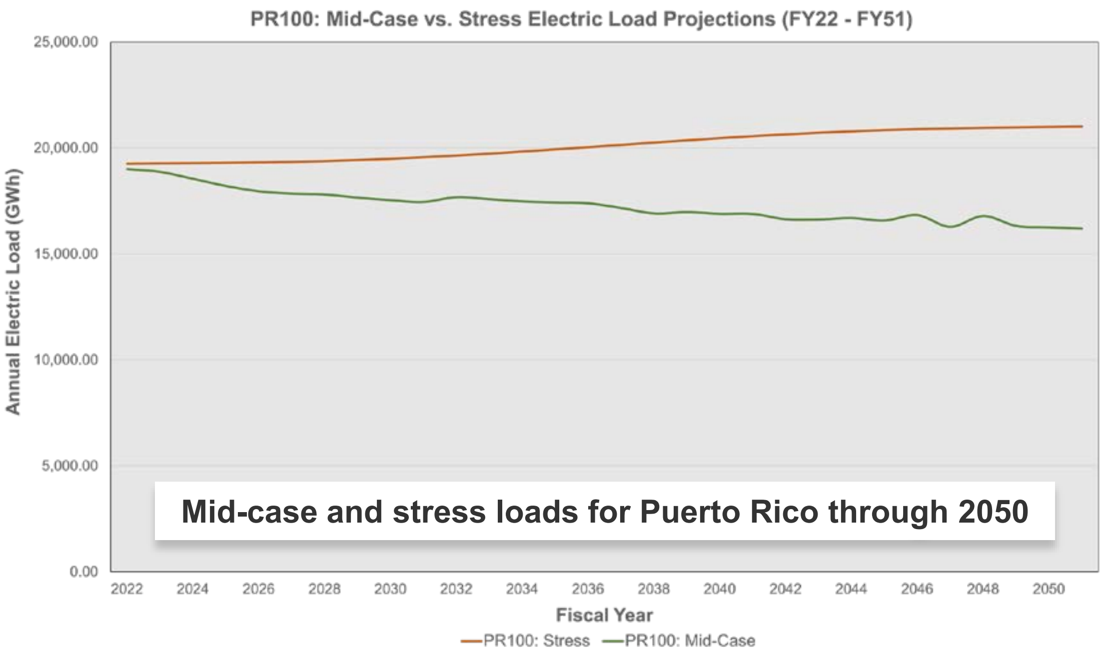
Graphics by NREL

Preliminary Findings for *Land Availability*

- 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.

Preliminary Findings for *Electricity Demand (Load)*





- The end-use electric usage is based on prior methods with updated data.
- The electric usage will be reduced by energy efficiency improvements.
- The electric usage will be increased by modeled electric vehicle adoption.
- The remaining (net) electric usage will be met by distributed generation and utility-scale renewable sources.

Preliminary Finding:
Net load, or combination of projected load increases and decreases, is likely to decline through 2050.

Graphics by NREL

Preliminary Findings and Key Considerations: Scenario Modeling

Tom Harris, NREL

Engage Capacity Expansion Modeling

Existing System Representation
The baseline system
Planned Deployments and Retirements
PV, wind, and battery storage procurements; fossil generation retirements
Distributed Energy Resources Capacities

Future System Technology Options
Technologies the model can build to meet projected demand

Technologies
- *Generators:* thermal generators, renewable energy-based generators, fuel production
- *Transmission:* electric lines, fuel pipelines & transport,
- *Storage:* fuel storage, batteries, pumped storage.

Technology Attributes
Efficiencies, renewable resource potential, fuel mix requirements, land requirements, costs, emissions.

Additional Requirements & Limits
- Spatial/land-use constraints
- Renewable portfolio requirements
- Other emissions/externalities constraints
- Reliability requirements.

engage

Generation and Transmission Capacity Planning via Economic Optimization

Electricity Load and End-Use Projections

Least-cost system that meets the load, respecting all requirements and limits

Optimized assets
Generation, transmission, and storage capacities by region

Resulting costs
- Overall investment (capital) costs through time
- System operating costs
- Fuel costs.

Other
- Production, consumption, and export profiles
- Surface area (land, maritime) use
- Externalities: resources used, emissions, etc.

Inputs
Input entities and attributes
Optimization task
Optimization result
Result detail

Graphics by NREL

Preliminary Findings From *Scenario Modeling*

In addition to modeling distributed generation, we conducted modeling to find the lowest-cost future grid system for each scenario while meeting reliability and resilience requirements.

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.**
- **Additional generation capacity is needed immediately**—on the scale of hundreds of megawatts—to maintain reliability standards.

Key Considerations

Accelerated Deployment

- Due to the building-level resilience that rooftop PV and storage provides, **accelerating deployment of rooftop PV and storage** is likely to increase reliability and resilience locally.
- Because aggregators and virtual power plants allow a grid operator to dispatch battery storage to support the overall system, prioritizing the **deployment of more virtual power plants** would support greater reliability and provide resilience across the system.
- **Accelerated deployment of utility-scale solar and wind energy** will reduce near-term system investment and operational costs because new utility-scale solar and wind energy is less costly to build than to operate existing fossil-fueled capacity, given current and projected fuel costs.
- Deployment of solar and wind renewable energy technologies and storage has the potential to provide or contribute to **economic, resource adequacy, system stability, and resilience benefits**.

Key Considerations

Investment Planning

- **Rapid deployment of solar PV and storage projects approved in Tranche 1 of PREPA's procurement plan** would begin to address, but not completely alleviate, the immediate need for additional capacity on the system.
- **Planned tranches are inadequate to reach 40% renewable energy generation by 2025**, assuming utility-scale PV or similar.
- **Defining tranches in units of generation (MWh) rather than capacity (MW) would provide greater clarity in the procurement process** (capacity factors vary from 20% to 90% across technologies in tranches). Both are needed in proposals, but setting goals in MWh would be more technology-agnostic.
- Investment decisions informed by long-term system planning are critical because **rapid deployment now of both fossil fuel and renewable technologies could lead to stranded assets** if distributed generation is adopted more slowly but eventually dominates the energy supply.

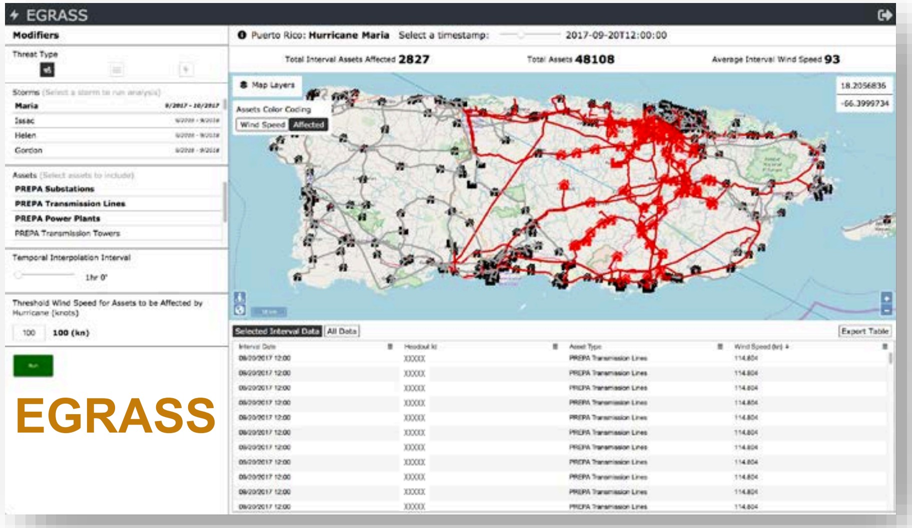
Preliminary Findings and Key Considerations: Bulk Power System Analysis

Marcelo Elizondo, PNNL

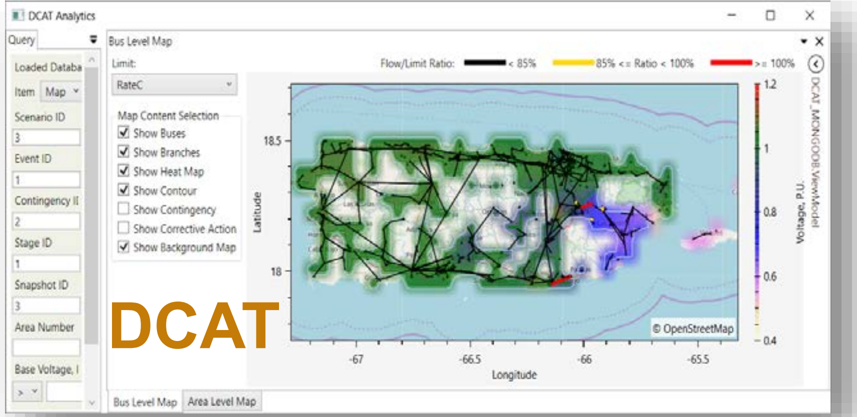
Transmission Resilience Analysis

Pacific Northwest
NATIONAL LABORATORY

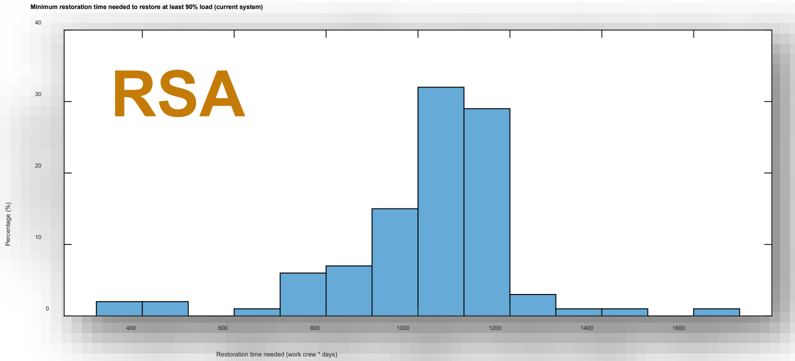
National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center Data



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.



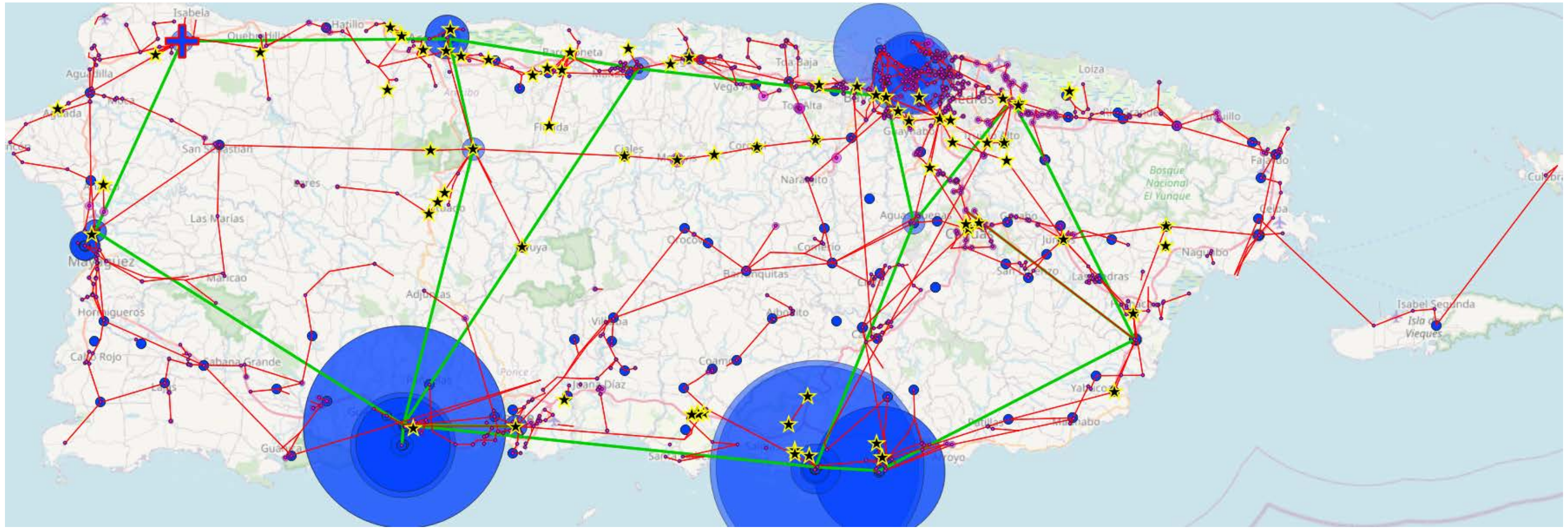
Recovery Simulator and Analysis (RSA)
- Estimated **time and effort to recover** system
- Last substations to be recovered.

- EGRASS-DCAT-RSA used for Puerto Rico:
  - **Resilience evaluation of new generation options**
  - Resilience evaluation of underground versus overhead transmission.

Graphics by PNNL

Preliminary Findings From *Impact Analysis*

- The modeled future system with smaller renewable resources spread across the system tends to **recover power faster than the current system**, which consists of fewer and larger power plants.
- **Last loads recovered** in all simulations tend to be in **mountainous and rural regions** as well as in the areas where a hurricane makes landfall.
- **Black-start capabilities of inverters** can significantly reduce recovery time, by up to 3 times.



The transmission substations that take the longest to recover are mainly in mountainous/rural areas and where a hurricane makes landfall.

Graphic by PNNL

Key Considerations

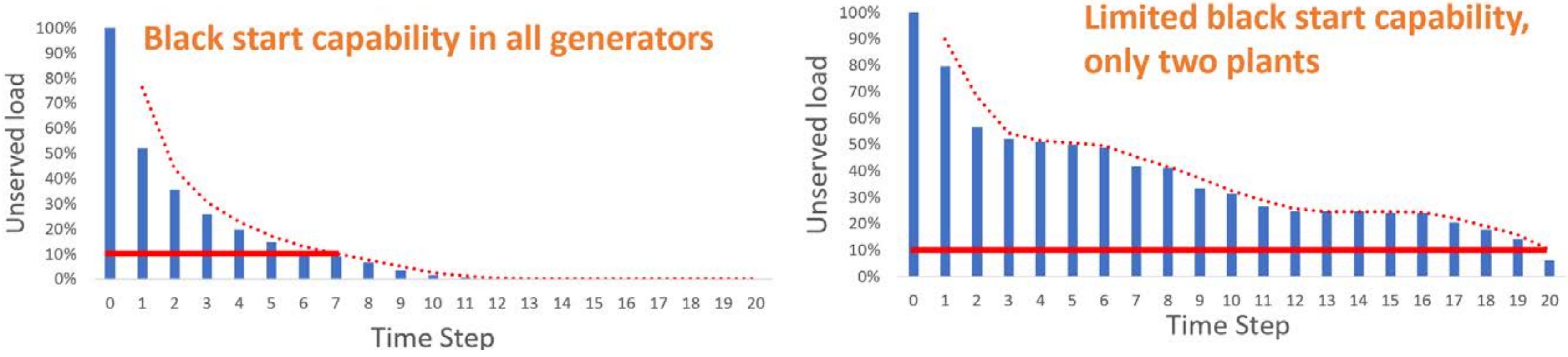
Grid Upgrades and Storage

- In the near term (next 5–15 years), the **transmission system can accommodate the projected growth in renewables**; in the long term, **upgrades are needed to accommodate additional utility-scale generation** resources on the bulk power system, especially for offshore wind.
- **Distribution feeder upgrades** are needed to accommodate anticipated growth in distributed energy production, distributed storage, and electric vehicle adoption, and to enable increased power flow on certain lines, additional variable voltage profiles, and more complex control schemes.
- Deployment of **utility-scale battery energy storage** in the very near term can **support bulk power system resilience** to extreme weather events, as well as day-to-day reliability, if properly sized and fitted with black-start capability.
- **Improved system protection would provide better stability during severe faults.** Inverter controls, such as batteries with grid-forming inverters, could significantly improve system reliability immediately.

Key Considerations

Grid Modernization

- **Implementation of real-time high-resolution grid measurement systems** can facilitate model validation and help provide critical situational awareness.
- **Enhancing the accuracy of generator governor models** can increase system stability and improve reliability in the current system.
- **High-fidelity models**, such as those in electromagnetic simulations software, can **help power grid planners gain confidence in simulating scenarios with inverter-based resources** like renewables and battery energy storage systems.



Comparison of system recovery time with black-start capability of multiple generators.
Graphs by PNNL.

Graphic by PNNL

Poll Question #3

Click link in the chat.

Which organizations do you think need to be involved in implementing Puerto Rico's energy transition?

Poll Question #3

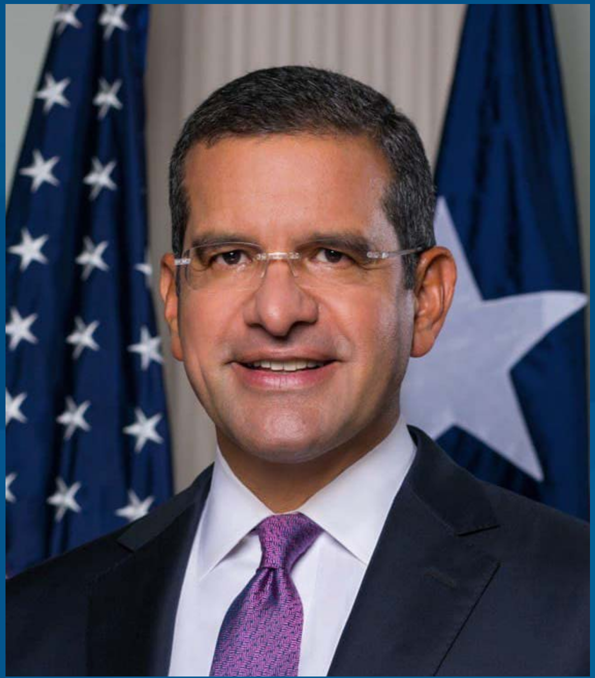
Which organizations do you think need to be involved in implementing Puerto Rico's energy transition?

Implementation Discussion Panel

Agustín Carbó
DOE Director of Puerto Rico Grid Modernization and Recovery Team

Jennifer Granholm
DOE Secretary

Deanne Criswell
FEMA Administrator



Pedro Pierluisi
Governor of Puerto Rico

Q&A

- Please type your questions in the Q&A box.

Contact Us

- Join Mobilize online community to connect with PR100 team and PR energy planning network: https://pr-energy.mobilize.io/registrations/groups/49360.
- Sign up for updates: DOE Grid Deployment Office (govdelivery.com)
- For questions or our efforts in Puerto Rico, contact prprojects@nrel.gov.

Additional Resources

- **Progress Reports**
  - PR100 Six-Month Progress Update (English Version) (Español Versión).
- **Recent Events**
  - PR100 Webinar: 6-month Progress Update (July 21, 2022)
  - PR100 Webinar: Public Launch (February 16, 2022)
  - DOE Press Release: DOE, DHS, HUD Launch Joint Effort with Puerto Rico to Modernize Energy Grid (February 2, 2022)
  - MOU among DOE, DHS, HUD and the Government Of Puerto Rico, Collaboration for the Recovery and Resilience of Puerto Rico's Energy Sector (February 2, 2022).
- **Web Pages**
  - DOE: Puerto Rico Grid Recovery and Modernization
  - DOE: PR100 Study
  - NREL: Multilab Energy Planning Support for Puerto Rico.

Thank you

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Authors

Dozens of talented researchers from the six participating national laboratories contribute to the PR100 Study. This presentation was authored by:

- **National Renewable Energy Laboratory (NREL):** Nate Blair, Robin Burton, Murali Baggu, Haiku Sky, Tom Harris, Clayton Barrows, Vahan Gevorgian, Jeremy Keen, Manajit Sengupta, Cameron Weiner, James Morris, Paritosh Das, James Elsworth, Prateek Joshi, Joseph McKinsey, Surya Dhulipala
- **Argonne National Laboratory (ANL):** Lawrence Paul Lewis, John Murphy
- **Lawrence Berkeley National Laboratory (LBNL):** Peter Cappers, Sydney Forrester, Jeff Deason, Margaret Pigman
- **Oak Ridge National Laboratory (ORNL):** Ben Ollis, Thomaz Carvalhaes
- **Pacific Northwest National Laboratory (PNNL):** Marcelo Elizondo, Xiaoyuan Fan, Patrick Maloney, Vishvas Chalishazar
- **Sandia National Laboratories:** Matthew Lave, Amanda Wachtel
- **Colorado State University:** Harvey Cutler and Martin Shields
- **Michele Chait LLC:** Michele Chait