Puerto Rico Grid Resilience and Transitions to 100% Renewable Energy Study (PR100): Six-Month Progress Update

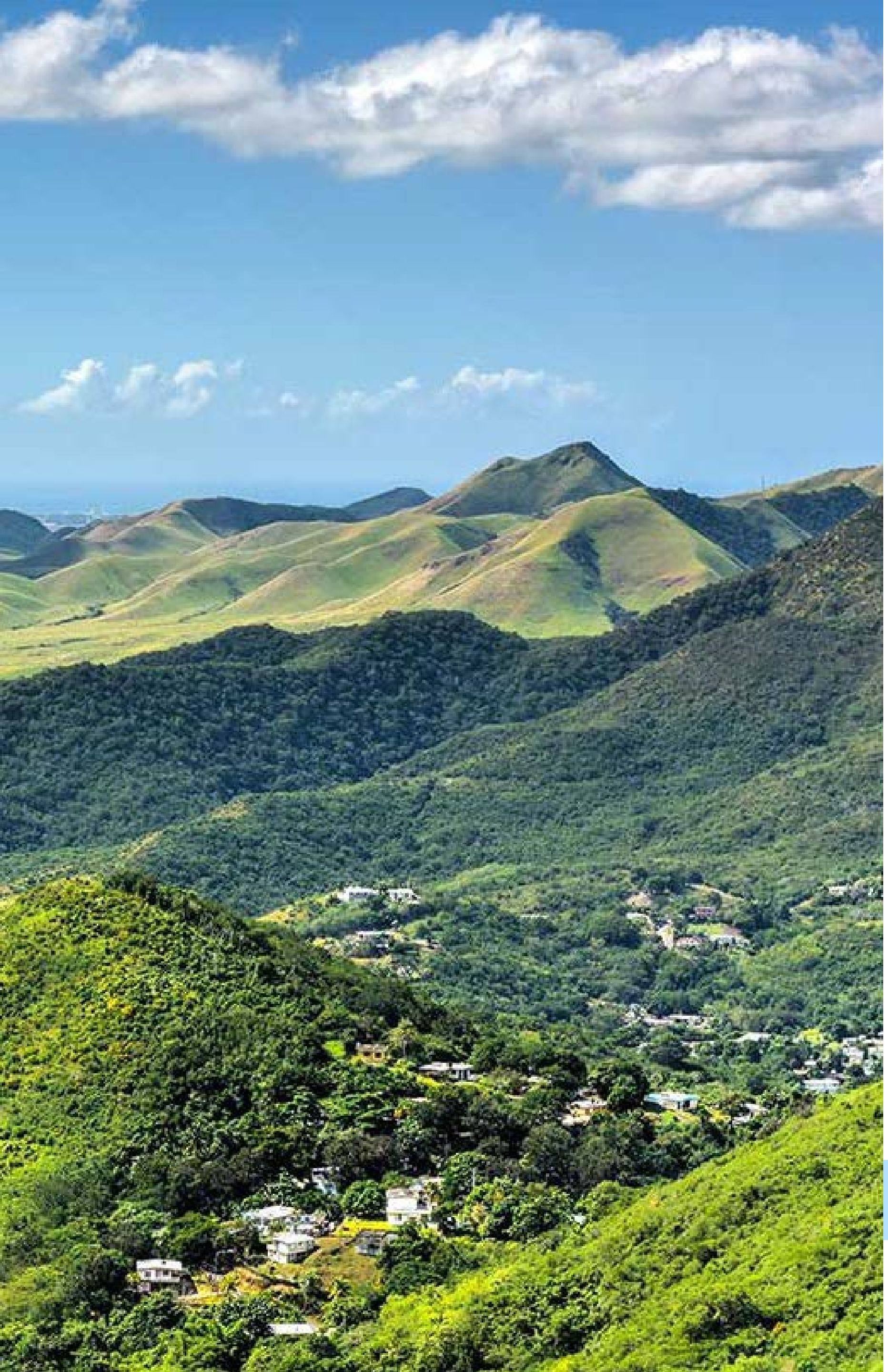
Public Webinar on July 21, 2022, from 11 a.m. – 12:30 p.m. AST

Welcome

Charlotte Gossett Navarro
Puerto Rico Chief Director
Hispanic Federation

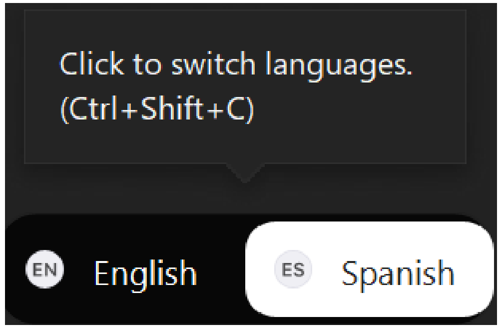
Agenda

1. Welcome
2. Opening Remarks: PR100 Study Context
   - Marisol Bonnet, U.S. Department of Energy (DOE)
   - José Baquero, Federal Emergency Management Agency (FEMA)
   - Manuel Laboy, Puerto Rico Central Office for Recovery, Reconstruction and Resilience (COR3)
   - Laura Rivera-Carrión, U.S. Department of Housing and Urban Development (HUD)
   - Carlos Yamín, Esq., Office of the Governor of Puerto Rico
3. PR100 Study Overview and Timeline
4. PR100 Study Progress Update
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

Marisol Bonnet
Recovery Coordinator for Puerto Rico
DOE

Jose Baquero
Federal Disaster Recovery Coordinator, Puerto Rico
FEMA

Manuel Laboy
Director
COR3

Laura Rivera-Carrion
Coordinating Officer for Disaster Recovery, Caribbean Region
HUD

Carlos Yamín, Esq.
Deputy Chief of Staff to the Governor of Puerto Rico

Poll Question #1

Click link in the chat.

How familiar are you with the PR100 Study?

- Not at all, but ready to learn!
- Somewhat. I've read about the study or attended the public launch in February.
- Very. I'm a member of the Advisory Group, Steering Committee, or project team.

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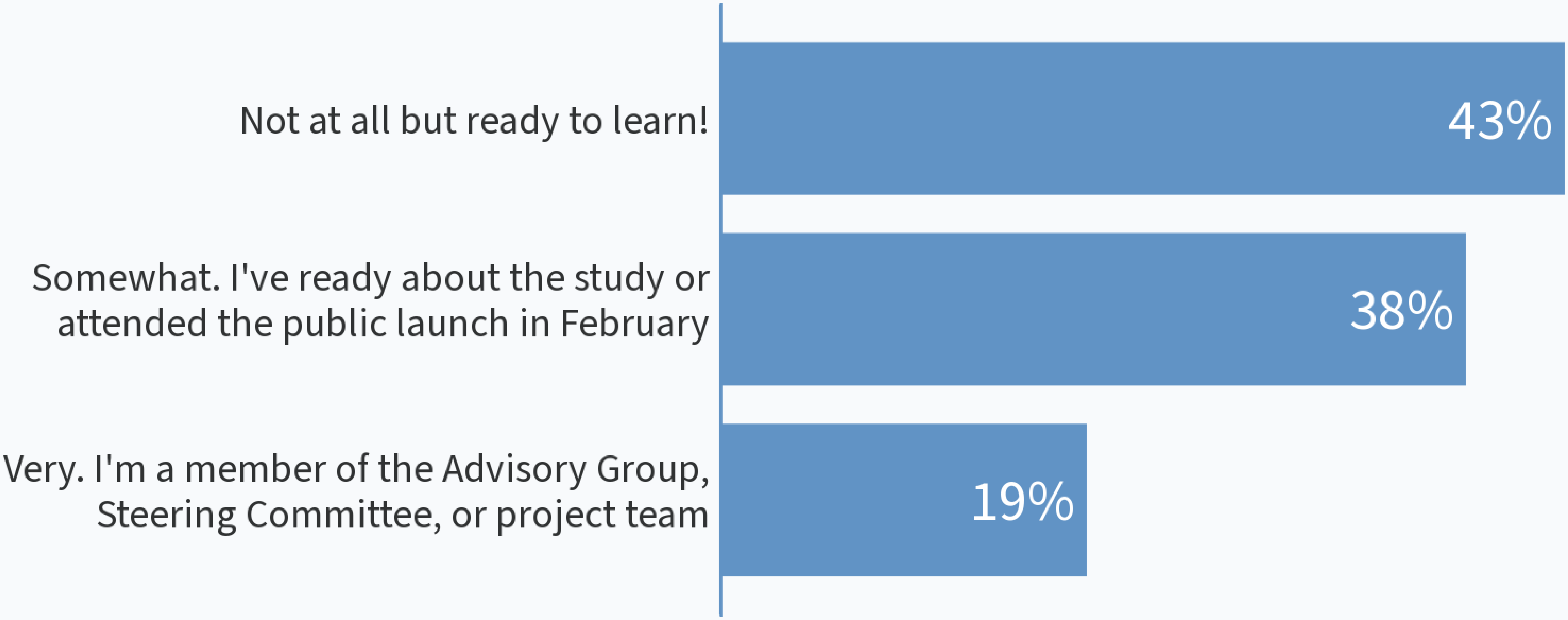
Text **NRELWEBINARS303** to **22333** once to join

How familiar are you with the PR100 Study?



PR100 Study Overview and Timeline

Presented by:

Robin Burton, 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.

PR100 Scope

In scope

In this study, the project team will:

- Model pathways and analyze impacts
- Conduct analysis to inform potential investment decisions
- Produce a roadmap with recommended near- and long-term actions to transition to renewable resources
- Facilitate stakeholder interaction and information exchange to create foundation for future implementation
- Publish and disseminate results, including high-resolution datasets and open-source models

Out of scope

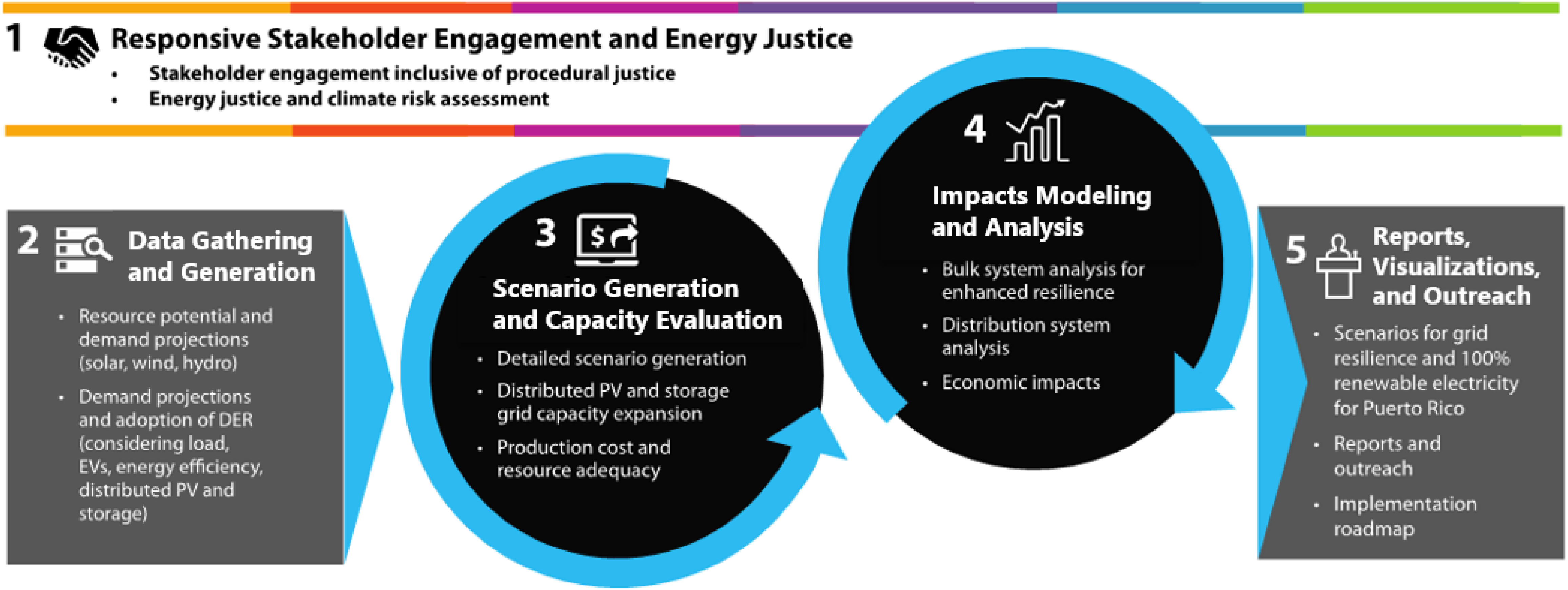
The study will not:

- Make policy recommendations
- Develop a detailed implementation plan
- Make specific investment recommendations
- Address economy-wide decarbonization
- Replace mandated capital investment planning processes such as the Integrated Resource Plan (IRP)

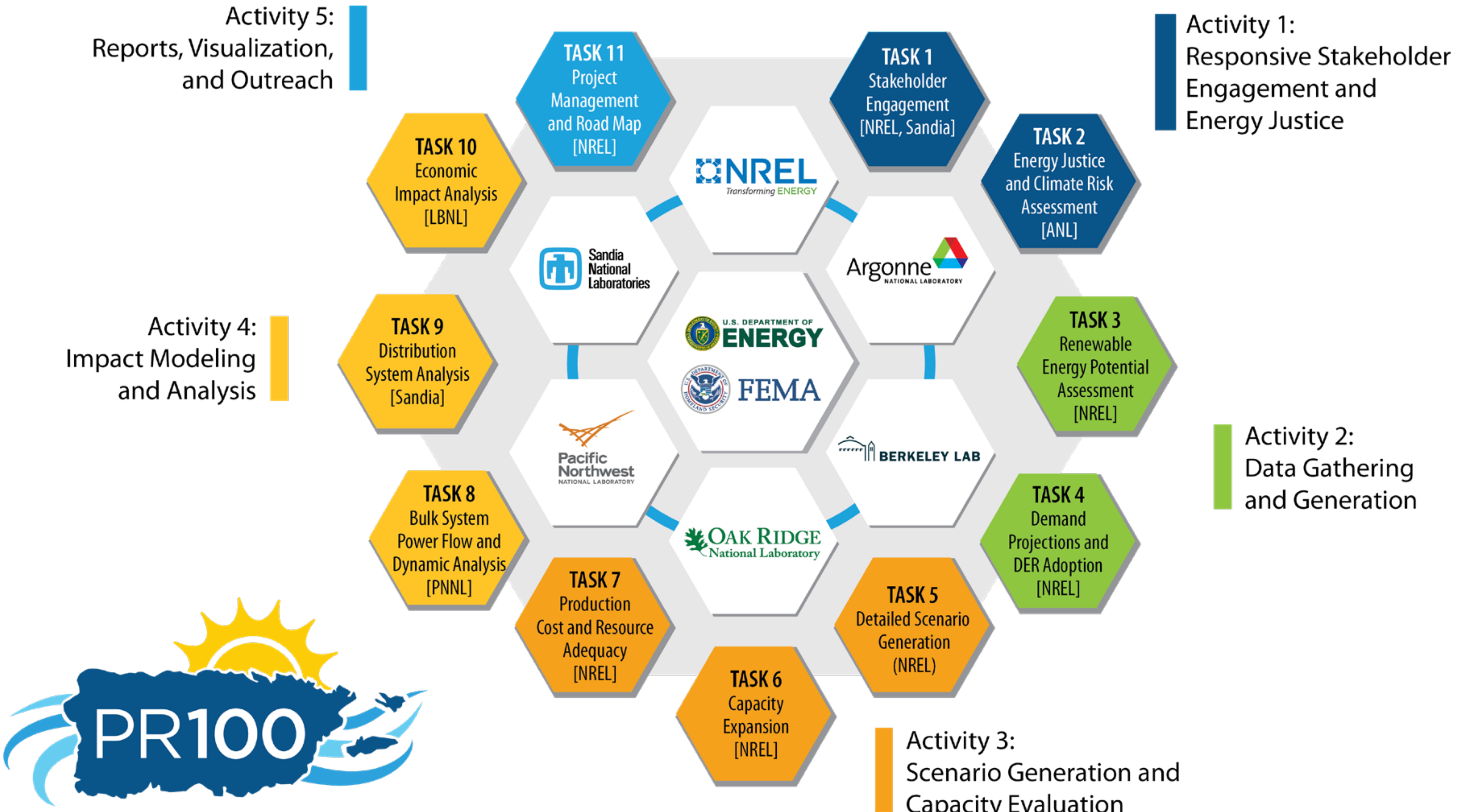
How Stakeholders Can Use PR100 Study Results

- 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



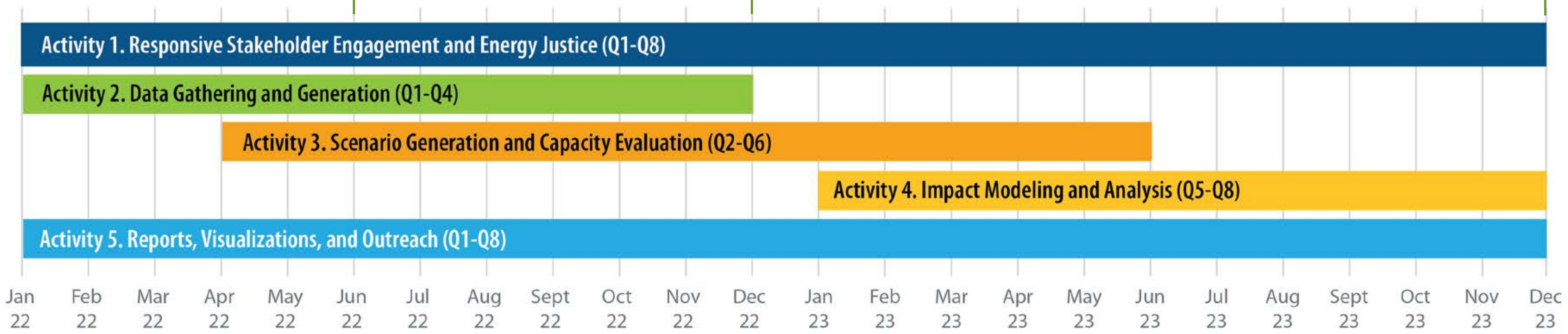
Activity 5:
Reports, Visualization, and Outreach
Activity 1:
Responsive Stakeholder Engagement and Energy Justice
Activity 4:
Impact Modeling and Analysis
Activity 2:
Data Gathering and Generation
Activity 3:
Scenario Generation and Capacity Evaluation
TASK 11 Project Management and Road Map [NREL]
TASK 1 Stakeholder Engagement [NREL, Sandia]
TASK 2 Energy Justice and Climate Risk Assessment [ANL]
TASK 10 Economic Impact Analysis [LBNL]
TASK 9 Distribution System Analysis [Sandia]
TASK 3 Renewable Energy Potential Assessment [NREL]
TASK 8 Bulk System Power Flow and Dynamic Analysis [PNNL]
TASK 4 Demand Projections and DER Adoption [NREL]
TASK 7 Production Cost and Resource Adequacy [NREL]
TASK 5 Detailed Scenario Generation (NREL)
TASK 6 Capacity Expansion [NREL]
NREL Transforming ENERGY
Sandia National Laboratories
Argonne NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY
FEMA
Pacific Northwest NATIONAL LABORATORY
BERKELEY LAB
OAK RIDGE National Laboratory
PR100

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

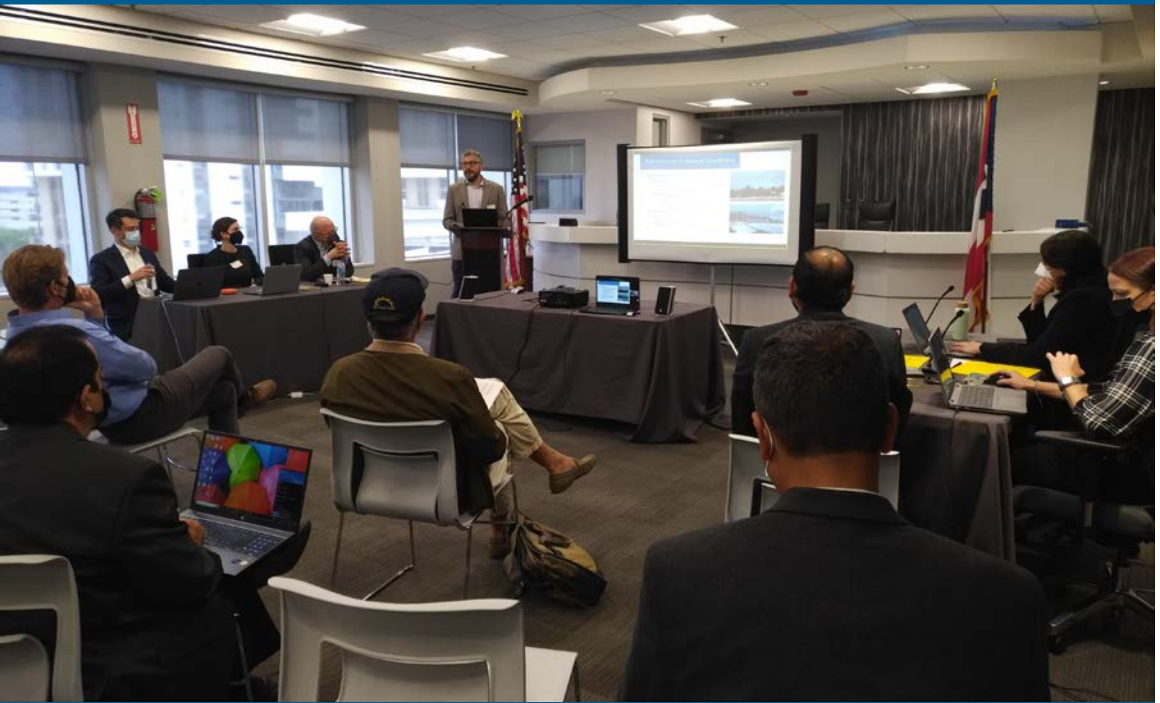


PR100 Study
Progress Update

Stakeholder Engagement and Energy Justice

Presented by:
Matthew Lave, Sandia
John Murphy, ANL

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.

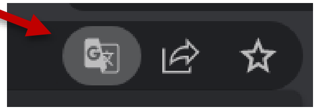
Discussion topics:

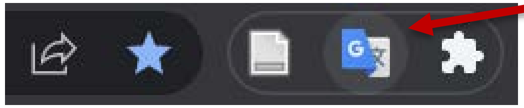
- Priorities for Puerto Rico's energy future
- Scenario frameworks and electricity demand levels
- Energy justice priorities
- Data inputs including land use and technology cost.

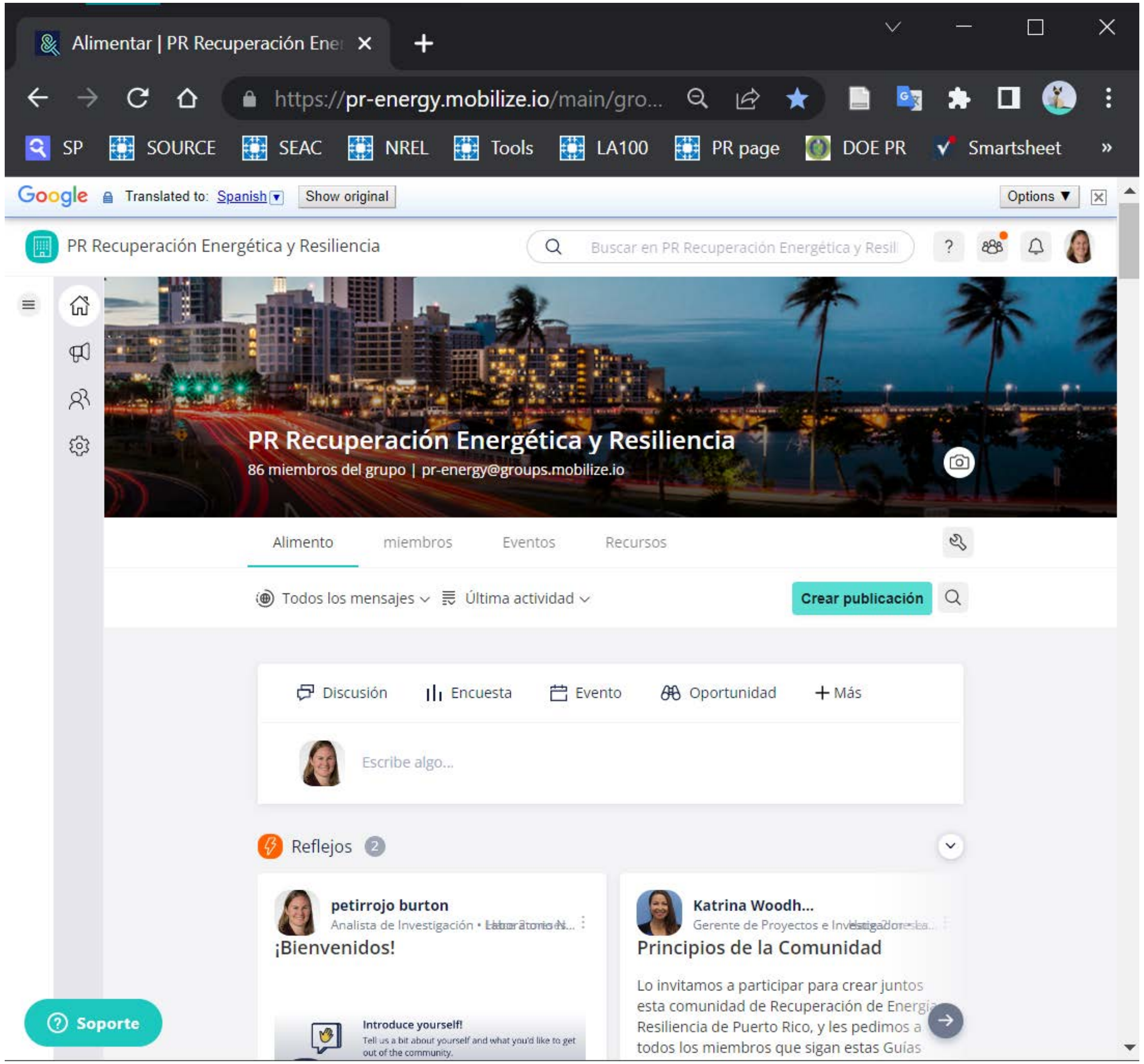
Presentation during hybrid Advisory Group meeting held in San Juan, Puerto Rico in May 2022. Photo by Robin Burton, NREL

Information Exchange

- Launched online community on Mobilize for networking and information exchange with Advisory Group members and the public
- What is Mobilize?
  - Web-based platform where Puerto Rico energy system stakeholders can come together and share ideas
  - Space for DOE and national labs to provide project updates and gather feedback, and for all users to share resources and network
  - Foundation for implementation of pathways to 100% renewable energy
- Register to join the online community!
- **Tip:** To view the site in Spanish, access the site using Google Chrome and click the Translate feature in the search bar or install the extension:







Capacity Building

- **The objectives of this task are to:**
  - Facilitate university participation in scenario development, technical support, and analysis
  - Support the use of lab data, tools, and analysis by university and other partners to build local capacity.

- **Progress: University of Puerto Rico Mayagüez (UPRM) subcontract**
  - During the first six months, DOE and the labs met regularly with UPRM faculty resulting in a subcontract for UPRM faculty and students to participate as members of the PR100 team.
  - Between June 2022 and July 2023, UPRM will:
    - Advise the PR100 team on the development of methods, inputs, and assumptions to accurately represent rooftop solar resources across models
    - Produce new data through a comprehensive survey to improve the PR100 team's understanding of residential solar systems
    - Assist in the development of energy justice metrics based on outage restoration data from Hurricane Maria
    - Coordinate with parallel research efforts.

Energy Justice Definition and Themes From the Literature

Energy Justice:

- Achieving equity in social and economic participation in the energy system, while remediating social, economic, and health burdens on those historically harmed by the energy system.
- Connects to and builds upon scholarly and grassroots traditions of environmental justice and climate change movements.

Energy Access

Infrastructure Interdependencies

Land Use and Siting

Economic and Workforce Development

Environmental and Health Impacts

Academic Frameworks

Utility Actions

Energy Democracy

Access a database of energy justice literature by theme compiled during this phase of the PR100 study in the Resources section of Mobilize.

Source (definition): Baker, Shalanda, Subin DeVar, and Shiva Prakash. 2019. The Energy Justice Workbook. Initiative for Energy Justice.

Energy Justice in PR100

Procedural Justice

- Ensure stakeholder access to planning process by convening Advisory Group of members with diverse perspectives representing a breadth of sectors
- Recognize and incorporate local knowledge into the study
- Share results in a way that everyone can understand them.

Metrics-based Energy Justice Analysis

- Evaluate societal “cost” of long-duration outages and disparities in social burden
- Evaluate energy justice impacts of modeled scenarios.

Infrastructure Interdependency Assessment

- Identify and characterize electric power interdependencies of other critical infrastructure (i.e., communications, IT, transportation, water), community lifeline assets, etc.
- Evaluate the extent to which energy injustices have resulted in other resource justice concerns.

Climate Risk Assessment and Adaptation Strategies

- Project where changing climate conditions will present future risks to infrastructure and the communities it supports
- Inform siting and operational needs of infrastructure to avoid premature obsolescence.

Climate Risk Assessment

Team leveraged climate modeling capabilities to develop 4-km grid and dataset for a range of climate variables projected for mid-century and end-of-century, including:

- Surface parameters (e.g., accumulated total precipitation, daily minimum and maximum temperatures, etc.)
- Atmospheric parameters (e.g., wind speeds, cloud fraction, relative humidity, etc.)
- Soil parameters (e.g., soil temperature, moisture, liquid water, etc.)
- Hydrologic parameters (e.g., sea level rise, inland waterway level rise, etc.).

Poll Question #2

Click link in the chat.

How much do you think annual daily average precipitation is projected to change by 2045 (in millimeters [mm] per day)?

- ○ +1.2 mm
- ○ +0.5 mm
- ○ -0.5 mm
- ○ -1.2 mm

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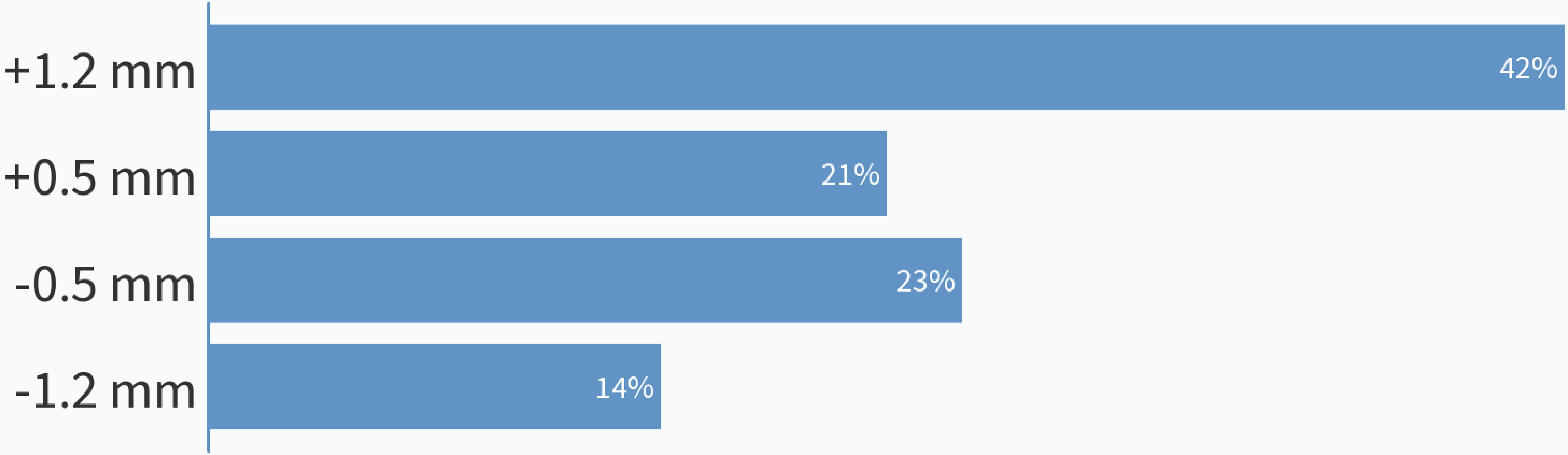
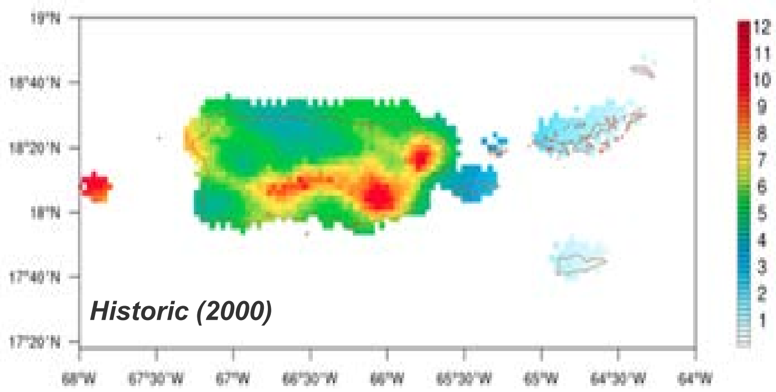
How much to you think annual daily average precipitation is projected to change by 2045 (in millimeters [mm] per day)



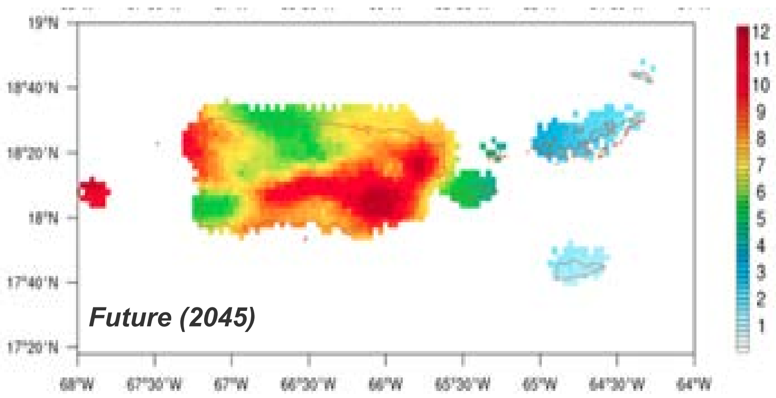
Climate Risk Assessment

Poll Answer: -1.2 mm

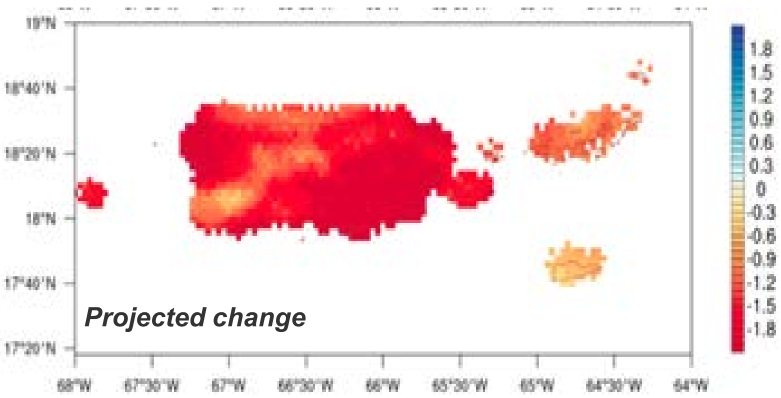
This is an 8% decrease per year in total rainfall by 2045 (preliminary results)



Preliminary downscaled modeling of historic annual daily average precipitation amount (mm/day) (graphic from Argonne)



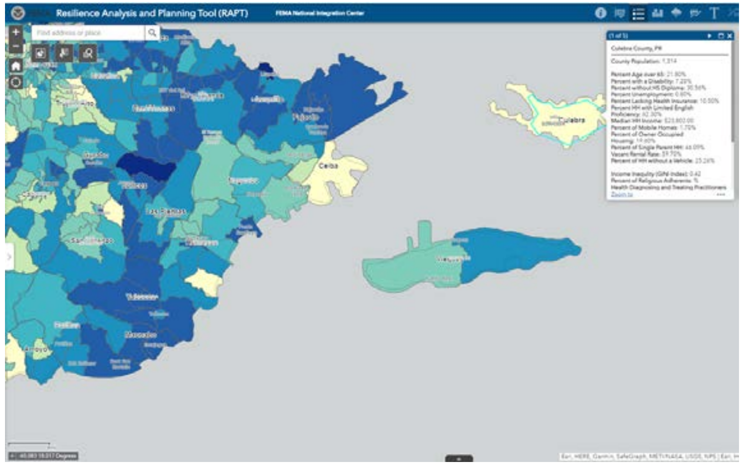
Preliminary downscaled modeling of future annual daily average precipitation amount (mm/day) (graphic from Argonne)



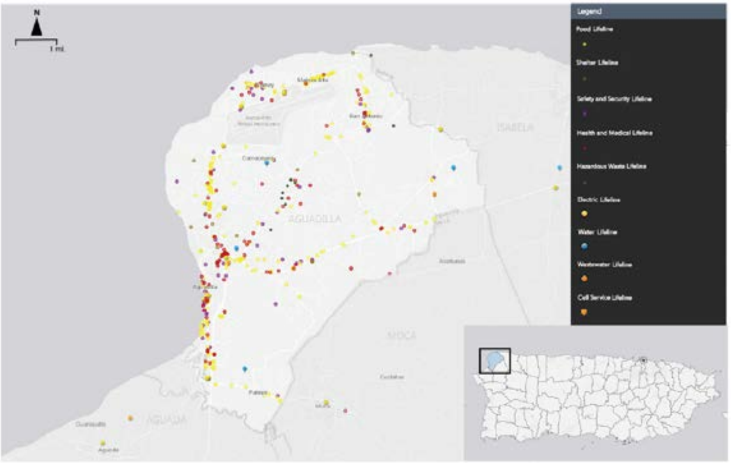
Preliminary downscaled modeling of projected climate-driven change to annual daily average precipitation amount (mm/day) (graphic from Argonne)

Infrastructure Interdependency Assessment

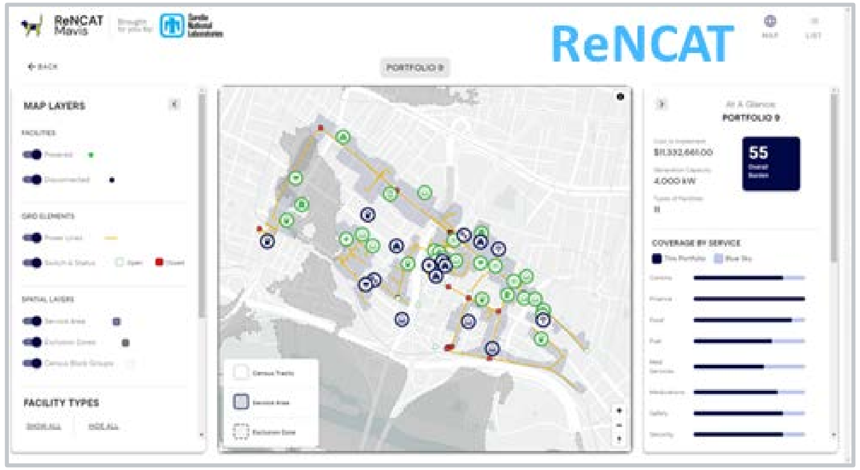
- Progress with the Puerto Rico Infrastructure Interdependency Assessment (PRIIA):
  - Completed modeling of service areas for electricity-dependent critical infrastructure across Puerto Rico (i.e., all 38-kv substations, cellular transmission towers, water treatment plants, and wastewater treatment plants)
  - Developed GIS dataset and visualization of critical infrastructure dependencies for each distribution substation



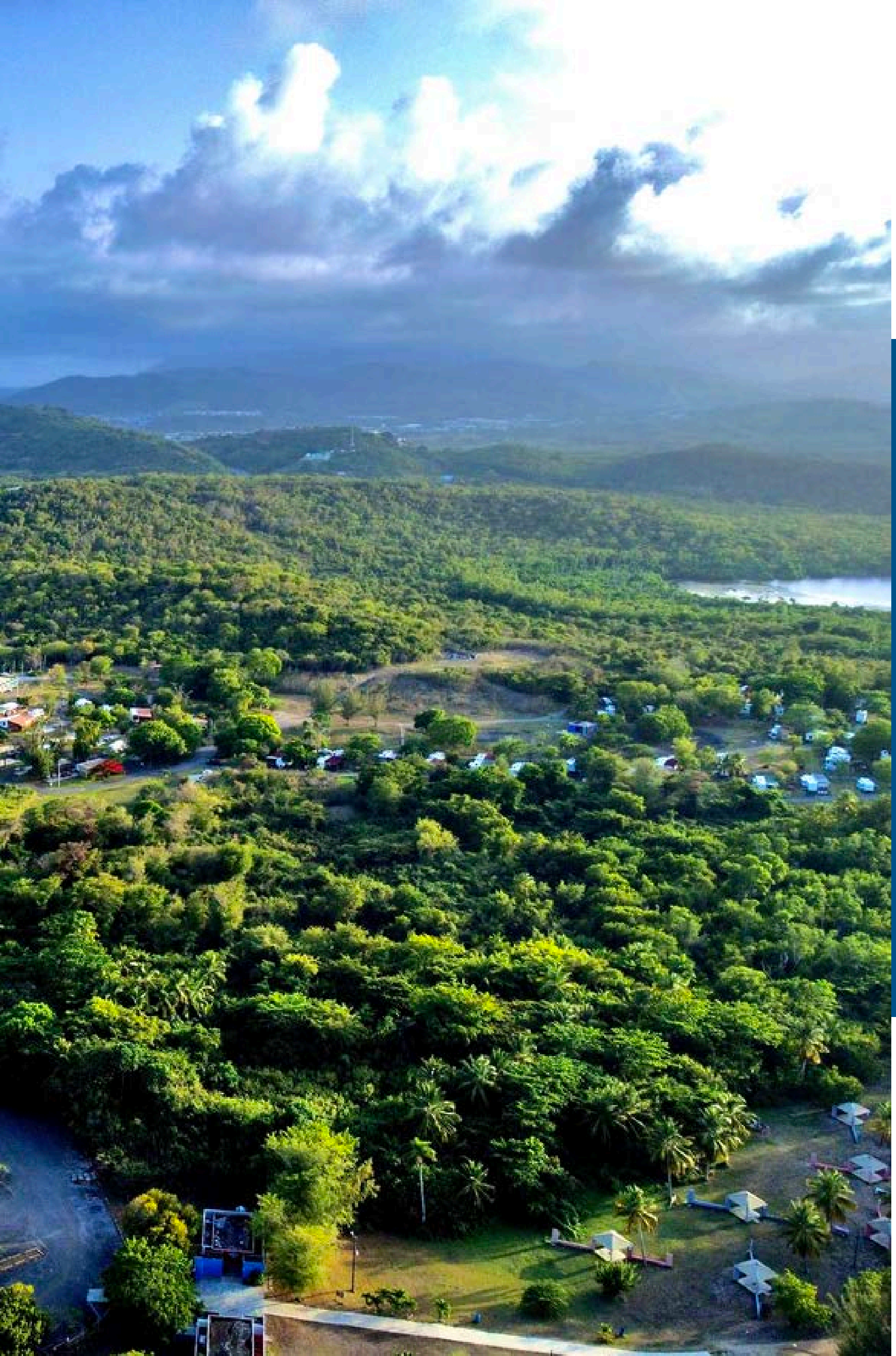
Community resilience indicators in RAPT (graphic from Argonne)



Identification of community lifelines in RAPT (graphic from Argonne)



Social burden analysis in ReNCAT (graphic from Sandia)

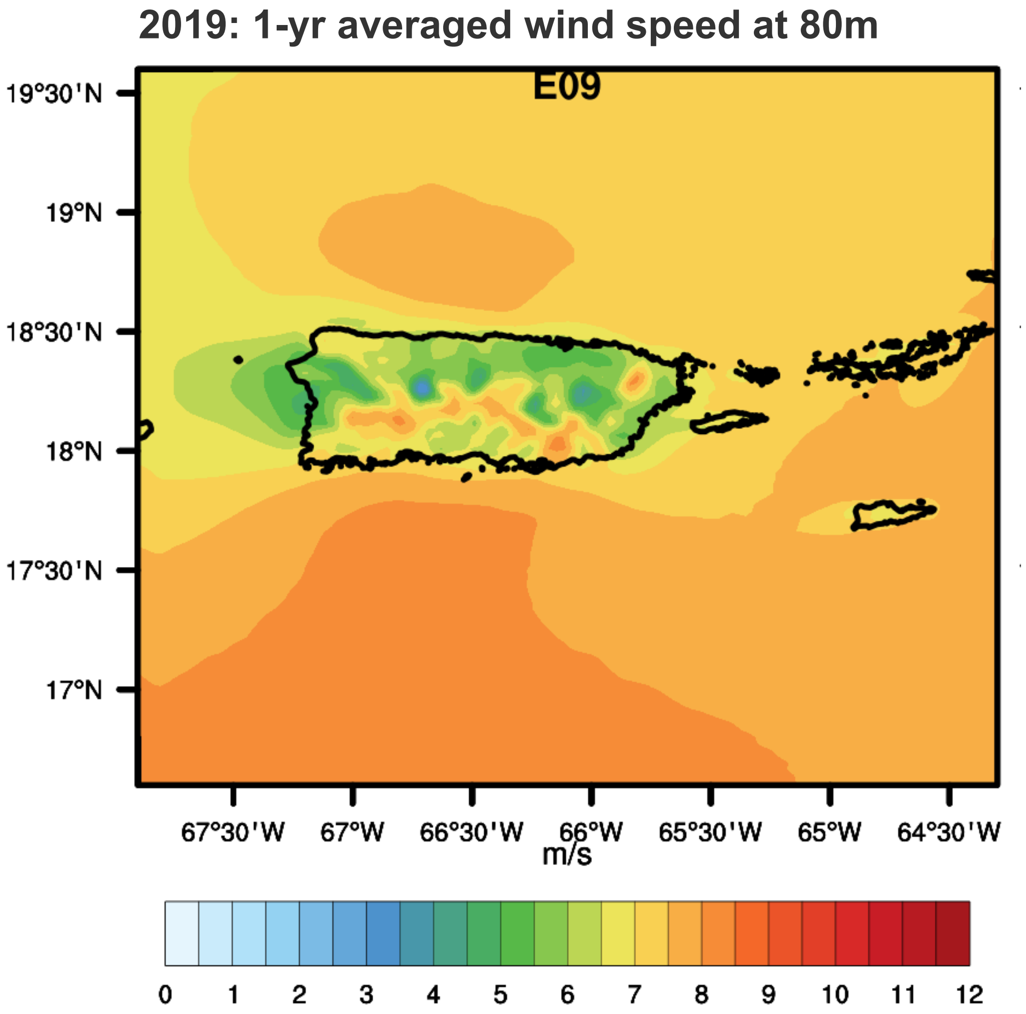


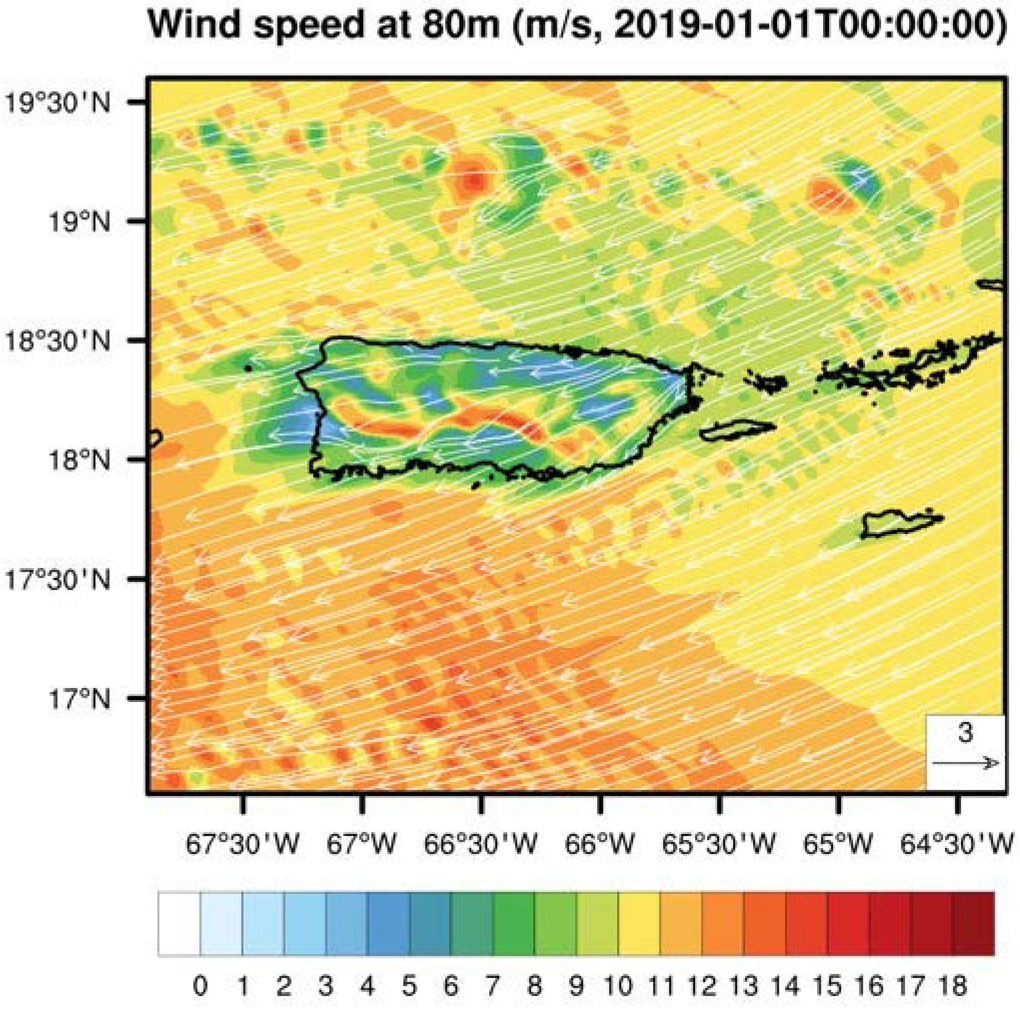
Renewable Energy Resource Assessment

Presented by:
Manajit Sengupta, NREL

Wind Resource in Puerto Rico

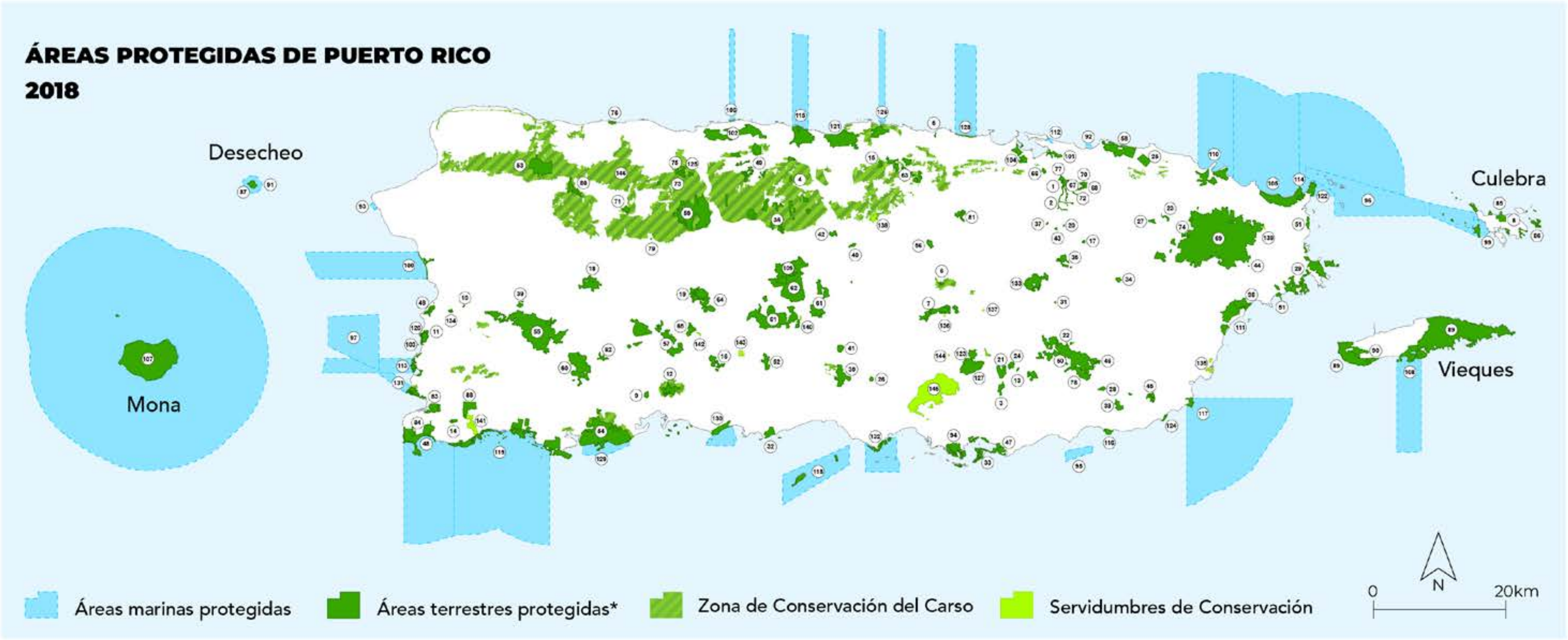
20 years of high-resolution offshore and onshore wind data was developed.





Map from NREL

Technical Potential for Land-based Wind



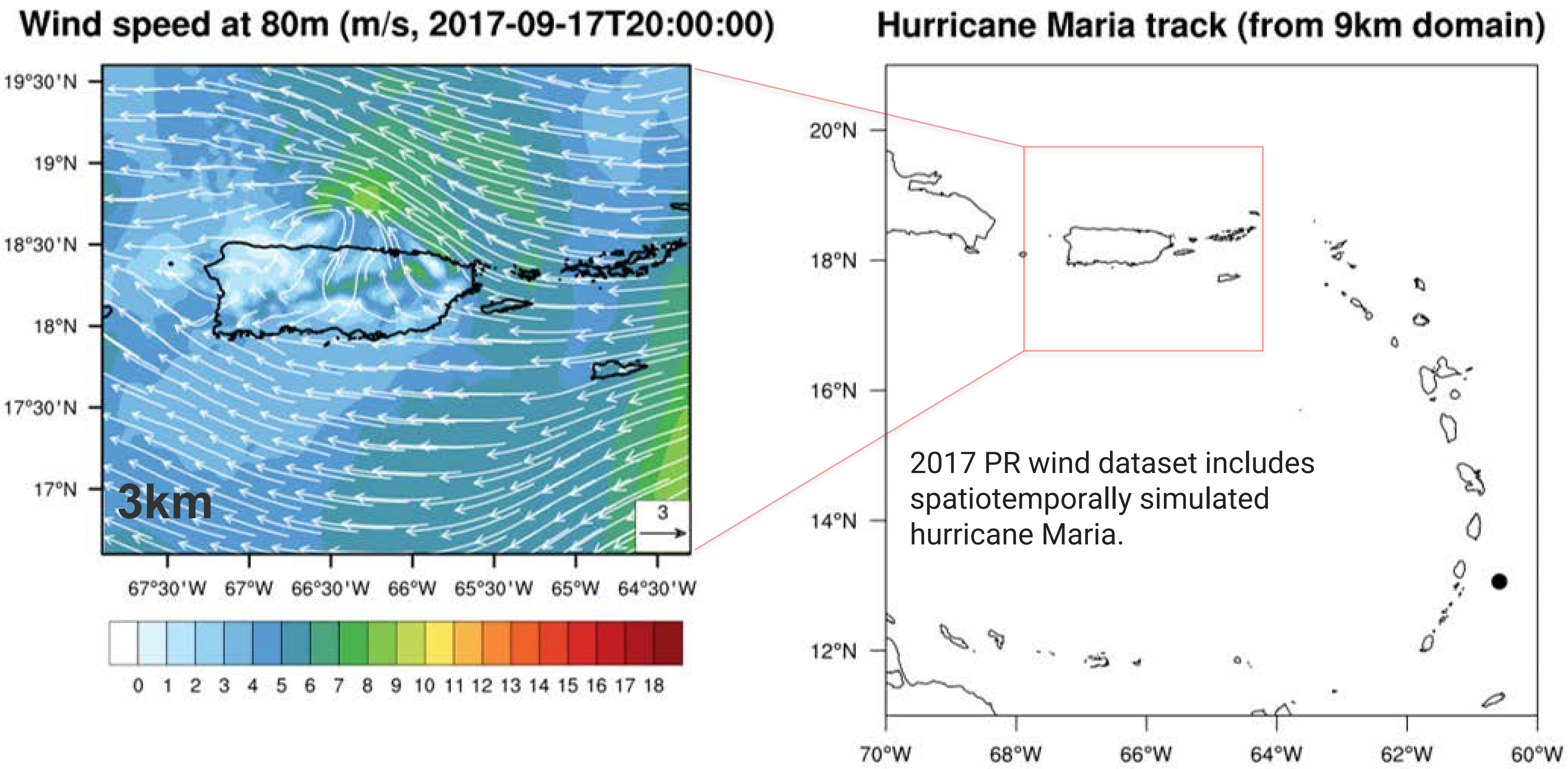
Protected areas that are excluded for land-based and offshore wind.

- Preliminary Finding: 2,150 km^2 to 2,640 km^2 of developable area
- Assuming 3 MW/km^2 for wind density, preliminary technical potential for land-based wind ranges from 6,400 to 7,900 MW

Source: U.S. Department of Agriculture Forest Service. Natural Areas of Puerto Rico 2018. https://www.fs.usda.gov/detailfull/iitf/home/?cid=fseprd667356&width=fullProtected.

Representations of Severe Weather

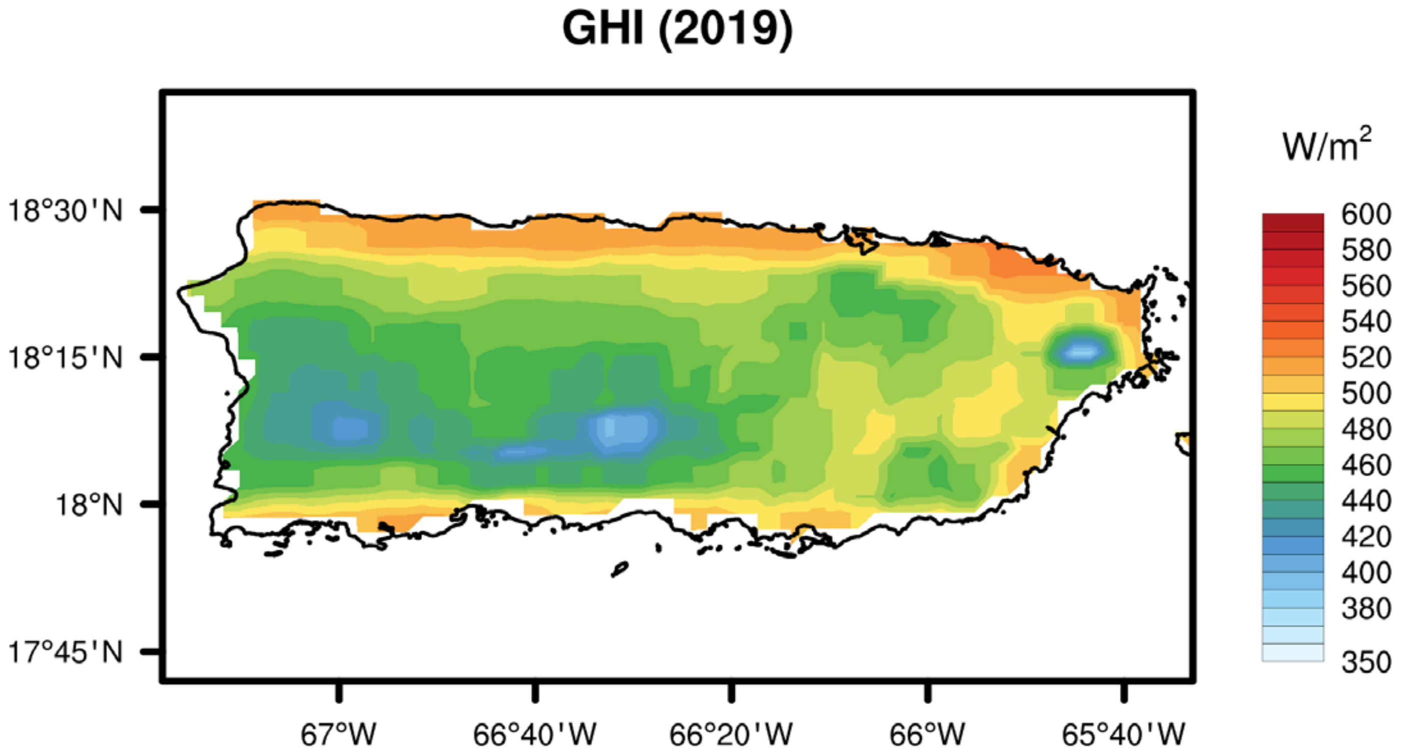
Wind data used to assess storm impacts on renewable generation resources, demand, and power system outages.



2017 PR wind dataset includes spatiotemporally simulated hurricane Maria.

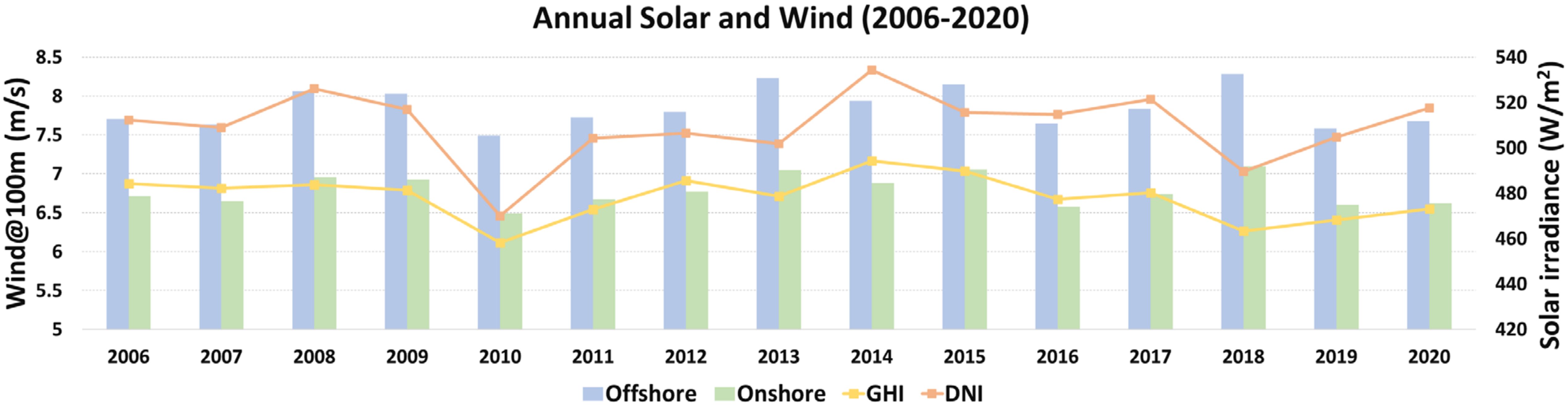
Map from NREL

Solar Resource in Puerto Rico



- National Solar Radiation Database (NSRDB) provides a serially complete database of solar irradiance and meteorological information across the United States and is the source of solar resource and ancillary data for solar modeling for PR100.
- Average solar global horizontal irradiance (GHI) for 2019 shows that most of the main island, especially coastal regions, has high solar resource.
- Solar datasets are being added for 2018-2020.

Map from NREL



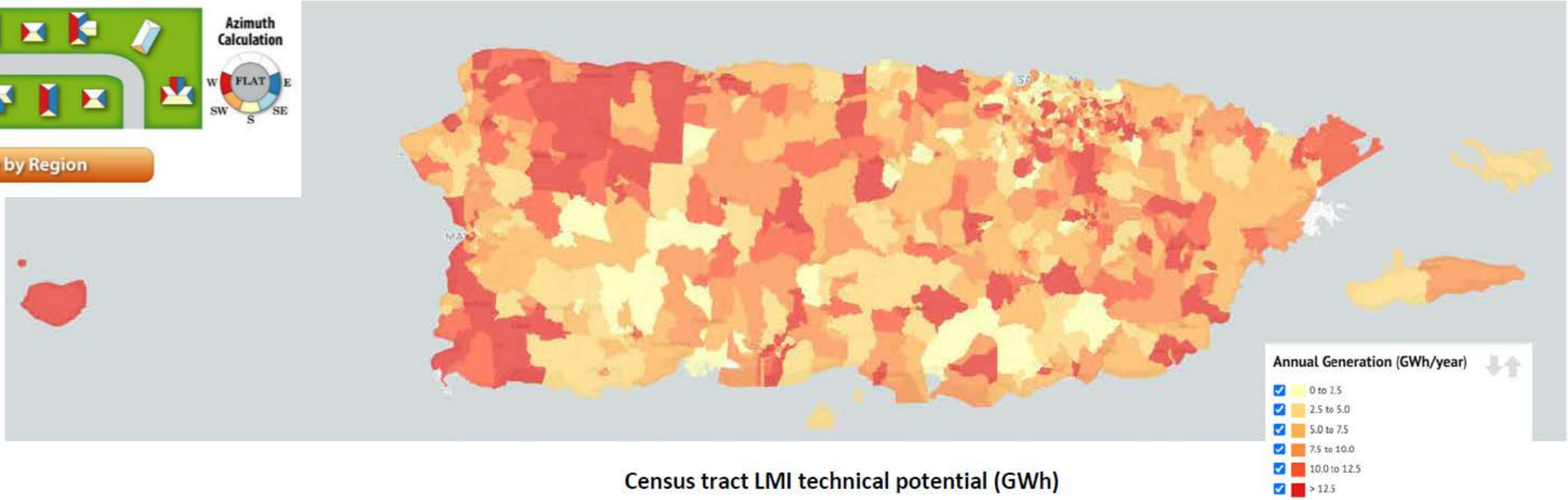
Wind and Solar Resource Comparison

- For system reliability, it is important to analyze the year-to-year variability of wind and solar resources.
- For Puerto Rico, annual solar and wind resources were analyzed (standard deviation for analyzed years
  - Offshore: 0.24m/s; Onshore: 0.19m/s; GHI: 9.41W/m2; DNI: 14.92W/m2).
- The year of 2018 shows the most abundant wind resource, and the sunniest year was 2014.
- The year of 2010 exhibits the lowest wind/solar resources compared to the other years.
  As expected, offshore includes more wind resources compared to onshore.

Data from NREL

Residential Rooftop Solar Potential in Puerto

Preliminary distributed rooftop PV technical potential is 20 GW or more.



Census tract LMI technical potential (GWh)

Source: Mooney, Meghan and Katy Waechter. 2020. Puerto Rico Low-to-Moderate Income Rooftop PV and Solar Savings Potential. NREL. https://www.nrel.gov/docs/fy21osti/78756.pdf

What Additional Renewable Energy Resources are Being Considered in the PR100 Study?



Through year one and into year two of the study, the team will evaluate hydropower and pumped hydro storage, marine energy, and may address additional technologies such as floating solar PV, bioenergy, and ocean thermal technology conversions.

Poll Question #3

Click link in the chat.

What renewable energy resources are you excited to see represented in the PR100 Study?

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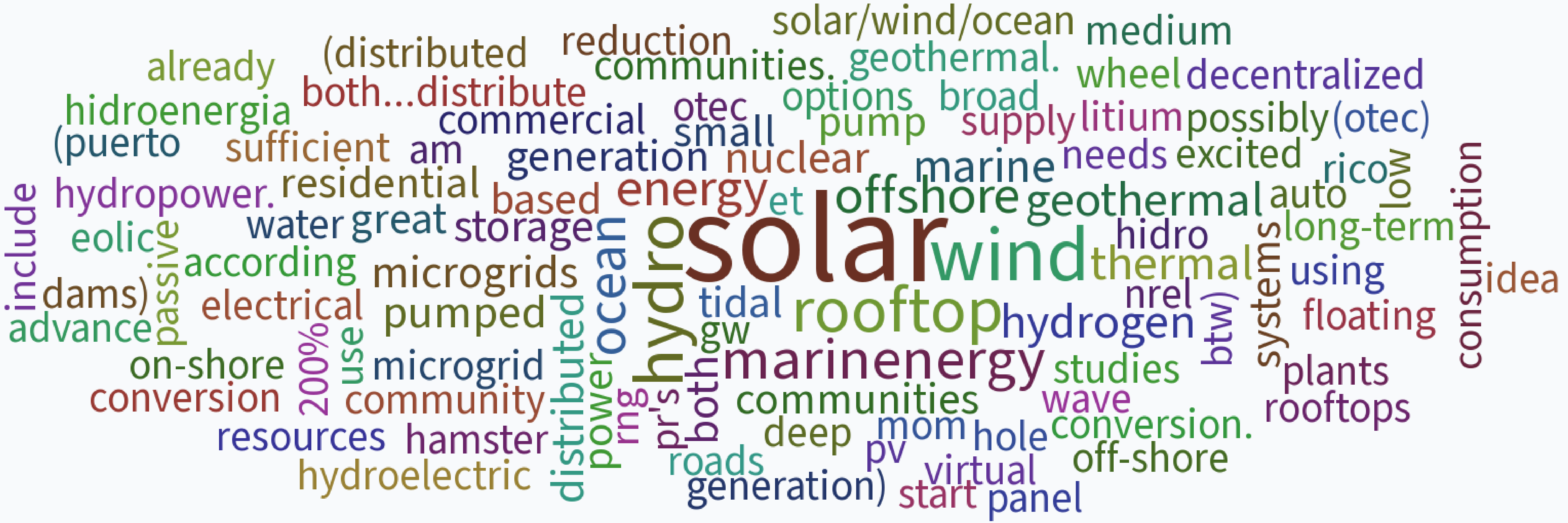
What renewable energy resources are you excited to see represented in the PR100 Study?



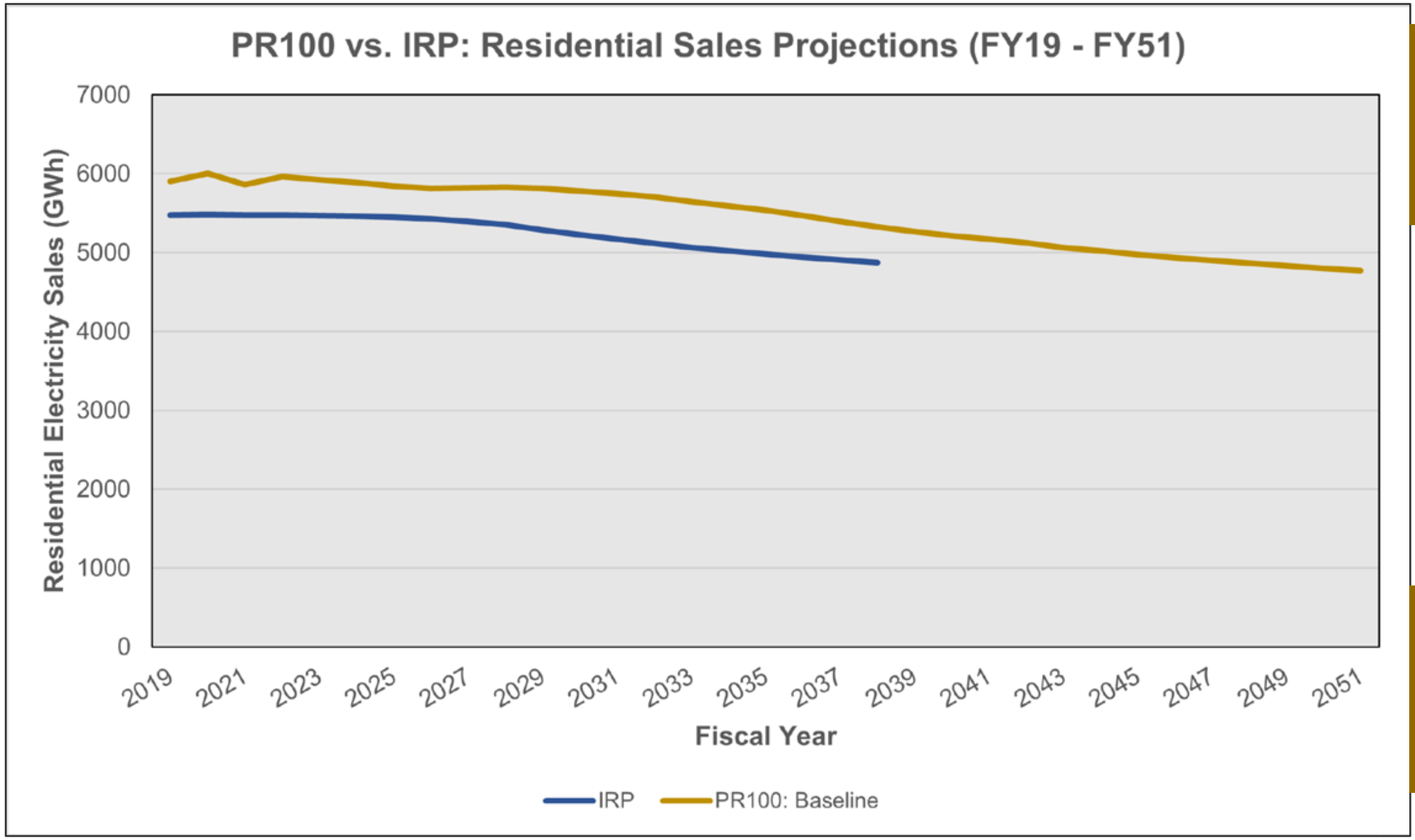
Electricity Demand and Distributed Energy Resource Adoption Projections

Presented by:
Paritosh Das, NREL

Electricity Demand Impacts

- 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 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 renewable energy sources.

Residential Sector



Graphic from NREL

PR100: New Input Data
Population
Real GNP
CDD

IRP: Old Input Data
Population
Real GNP
CDD

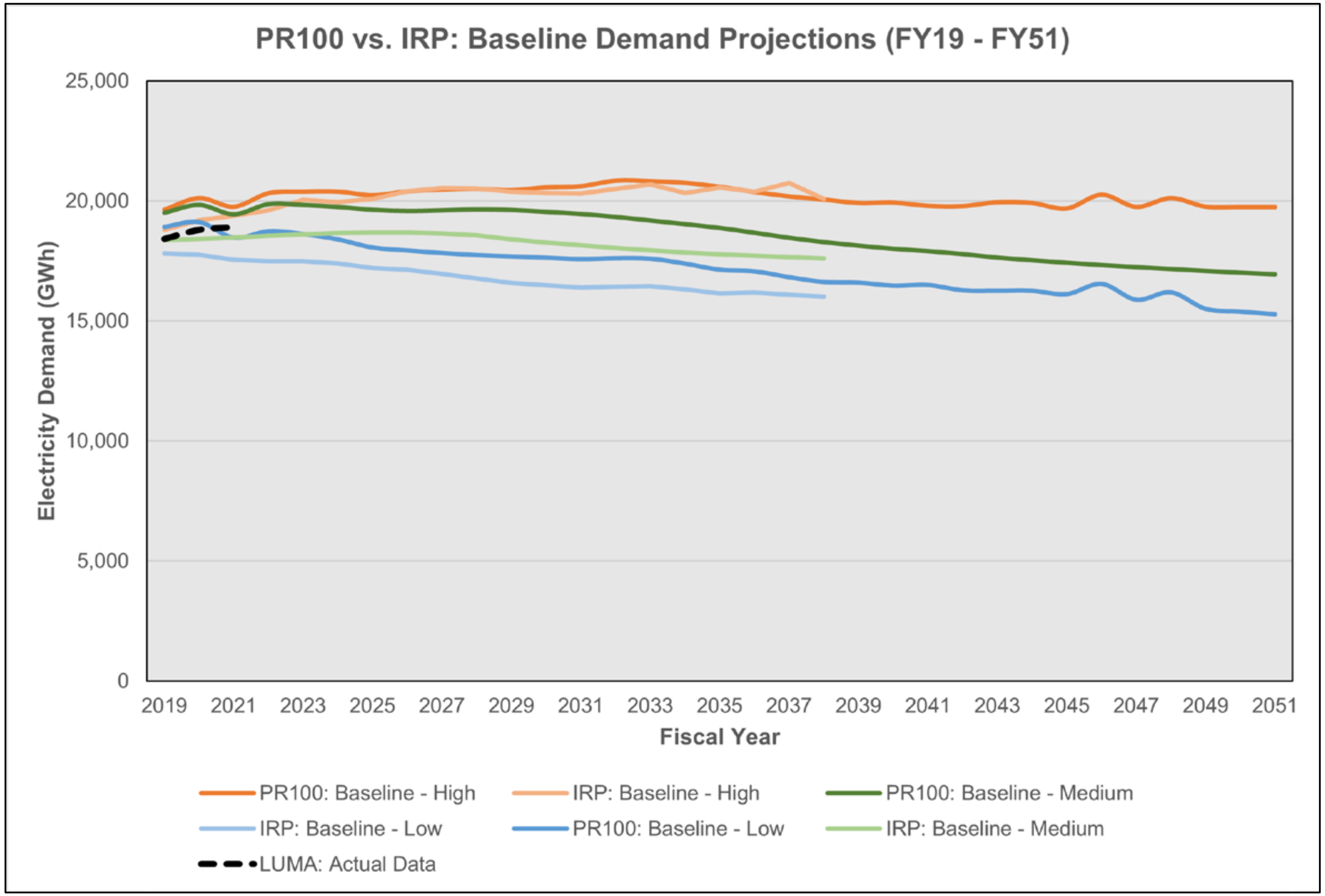
IRP: Linear Regression Equation
Historical Data from 2000–2017

PR100: New Projection
Residential Sector
Electricity Sales
(FY 2019–FY51)

IRP: Old Projection
Residential Sector
Electricity Sales
(FY 2019–FY 2038)

Definitions: CDD: Cooling Degree Days; GNP: Gross National Product; IRP: Integrated Resource Plan

Baseline "High," "Medium," and "Low" Projections



Graphic from NREL

IRP Projections (FY 2019–FY 2038):

"85% – Stochastic" = **"Baseline – High"**
"Base Case – Deterministic = **"Baseline – Medium"**
"25% – Stochastic" = **"Baseline – Low"**

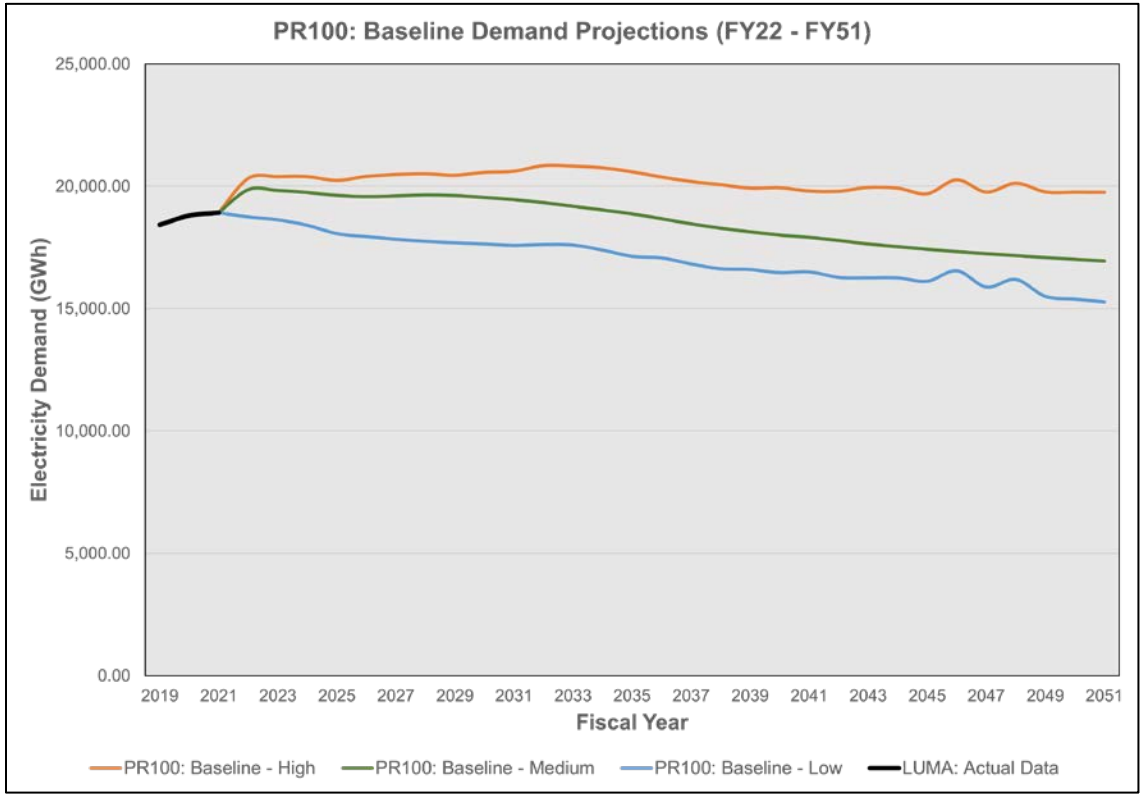
PR100 Projections (FY 2022–FY 2051):

"75% – Stochastic" = **"Baseline – High"**
"Base Case - Deterministic" = **"Baseline – Medium"**
"25% – Stochastic" = **"Baseline – Low"**

NOTE: the "IRP: 25% - Stochastic" projection is not equivalent to the "PR100: 25% - Stochastic" projection because the "Base Case – Deterministic" projections differ as described in previous slides.

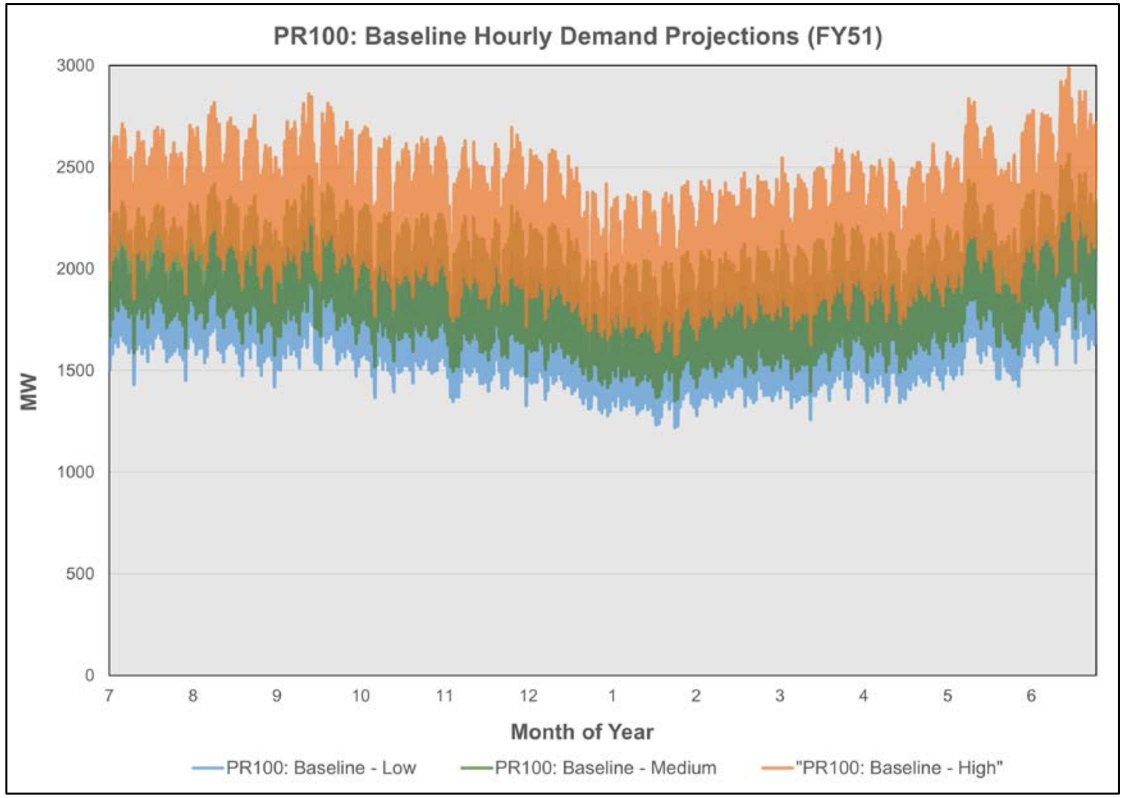
Hourly Demand Projections

Annual Projections for FY 2022–FY 2051



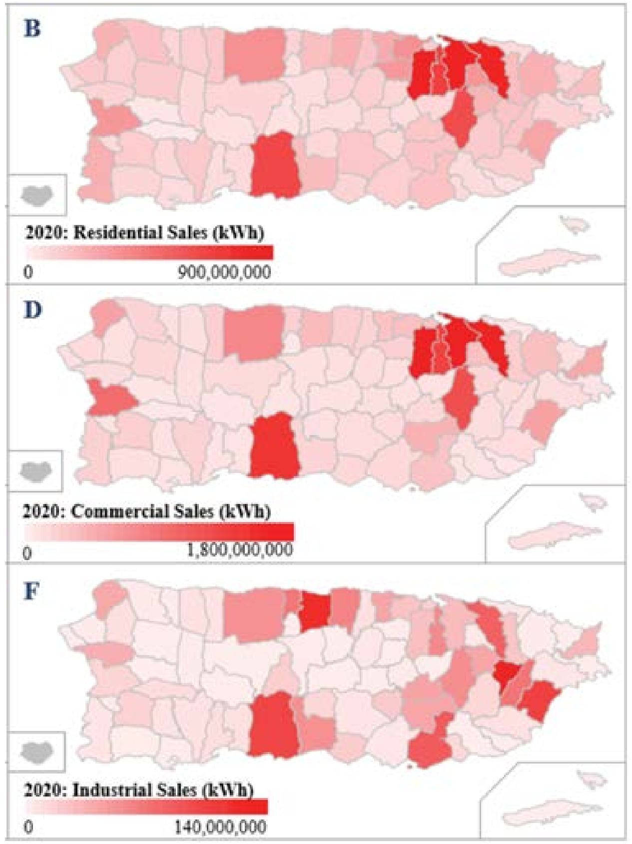
Graphics from NREL

Hourly Projections for FY 2022–FY 2051



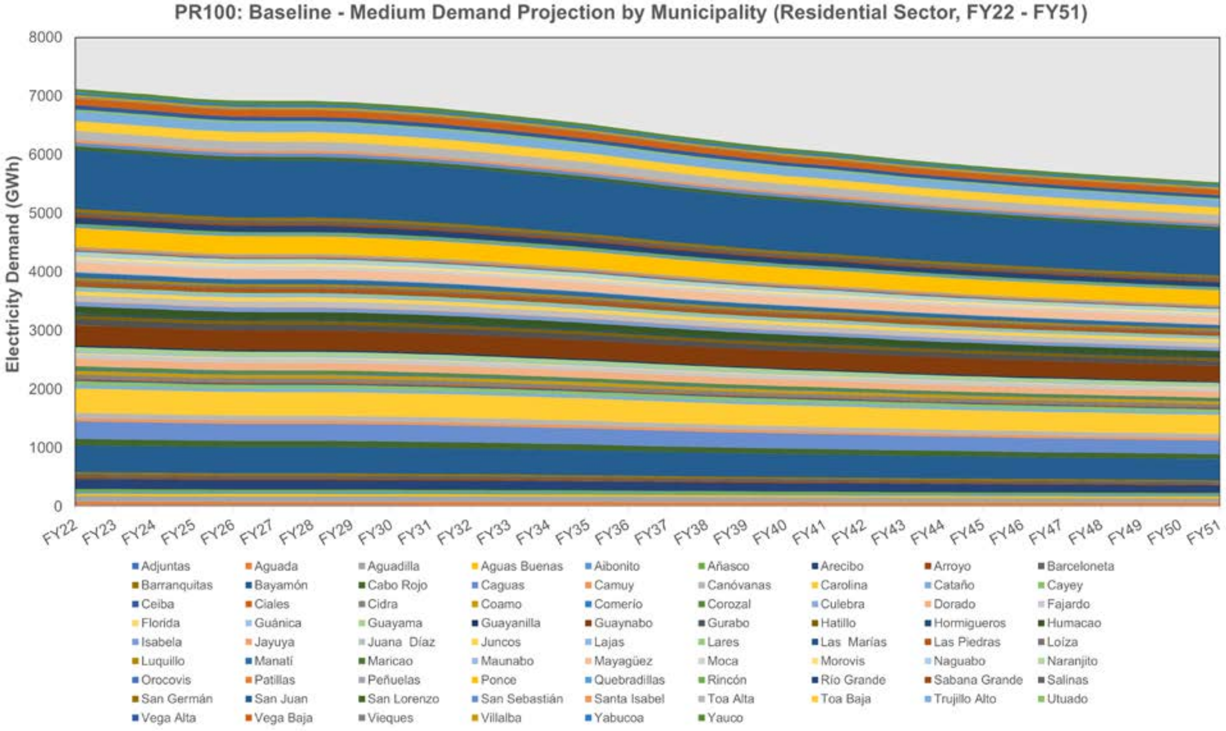
Hourly Demand Projections by Region

FY20: Distribution of Electricity Sales by Municipality



Data from PREPA 2021 Fiscal Plan

Percentage breakdowns assumed to remain constant from FY22 to FY51



FY22–FY51

Hourly electricity demand projections disaggregated by:

- Sector (residential, commercial, industrial, other)
- Region (78 municipalities)

Electric Vehicle Spatial-Temporal Projections

Spatial EV Adoption Model:

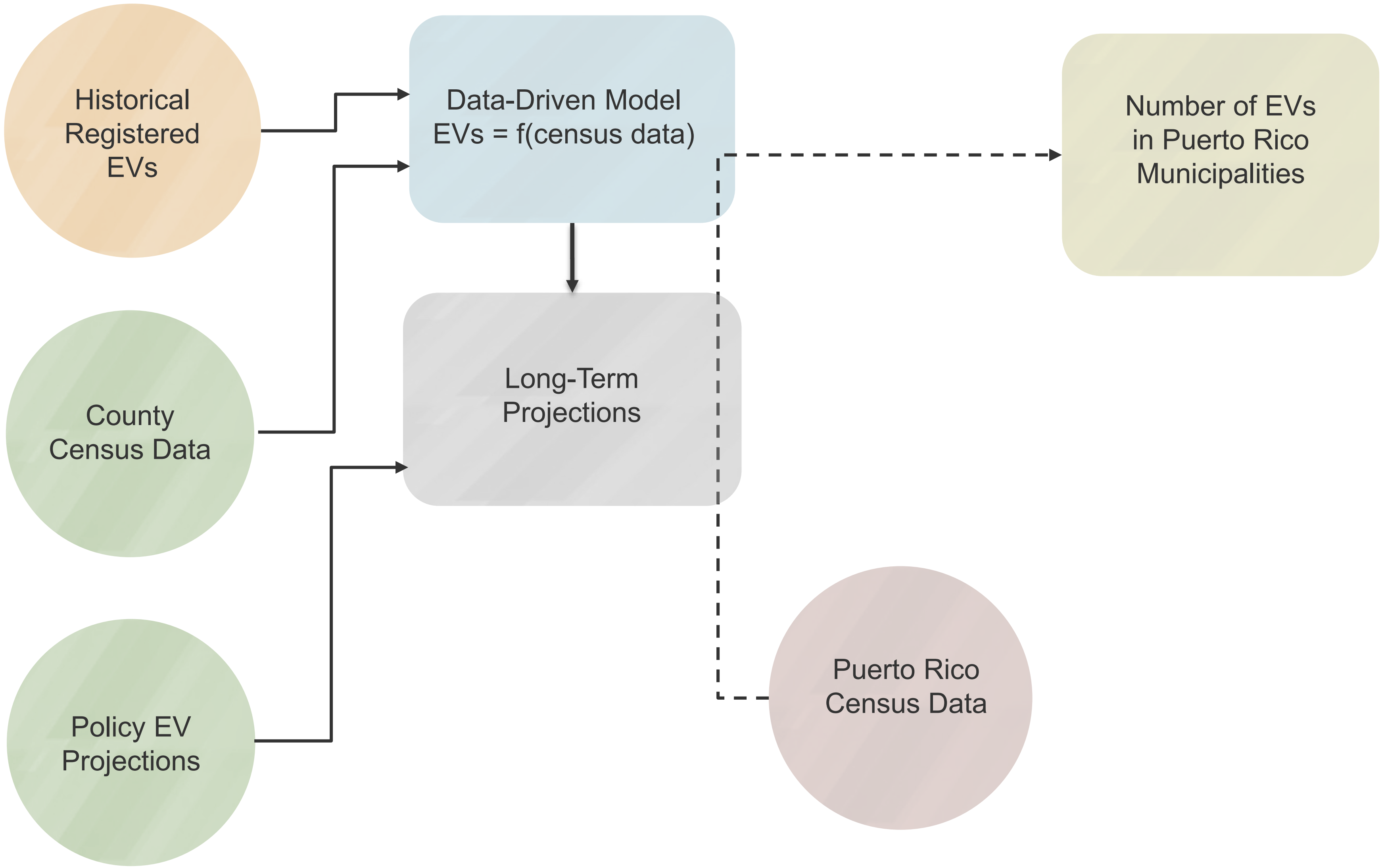
- Input historical EV data and census data
- Output spatial diversity of EV adoptions.

Temporal EV Adoptions:

- Use forecast developed by Energy Policy Solutions for U.S. and other states.

Model Deployment

- Input Puerto Rico Census data
- Output Number of EVs in each Municipio from 2020 to 2050.



Graphic from LBNL

Energy Efficiency Savings Sources

Source of energy efficiency savings	Default	Stress
Programs	Programs (both transition period and permanent) are implemented as contemplated in current energy efficiency proceedings	No new programs are implemented, likely due to a lack of available funding for the planned programs
Building energy codes	Puerto Rico adopts increasingly stringent building energy codes and enforces them sufficiently to produce savings	Little to no savings from codes, either because Puerto Rico does not adopt more stringent codes or is unable to enforce them sufficiently
Appliance and equipment standards	Puerto Rico receives savings from the implementation of increasingly stringent federal standards	Same as default except that federal standards adoption is somewhat slower, reducing savings
Net impact	Energy efficiency decreases load	Energy efficiency is only sufficient to offset demand, resulting in flat net load

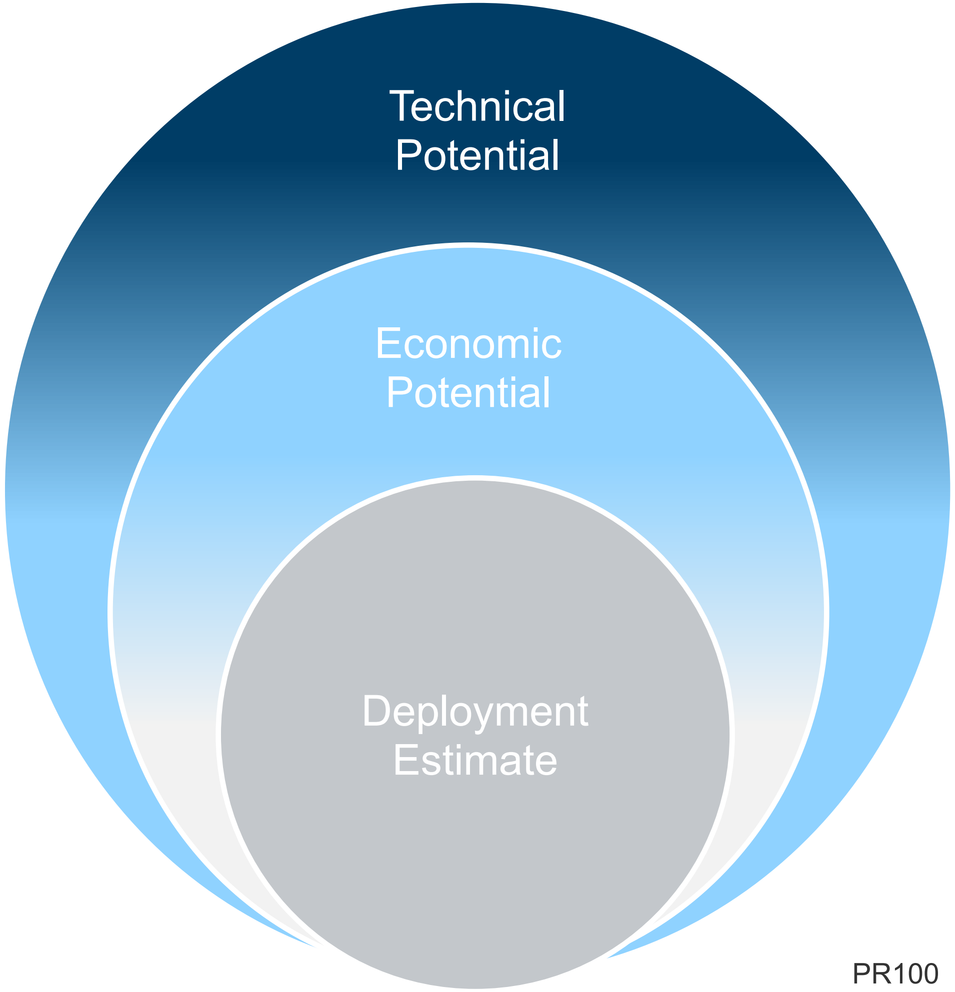
Energy efficiency sources and variations in the default and stress scenarios

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)

dGen

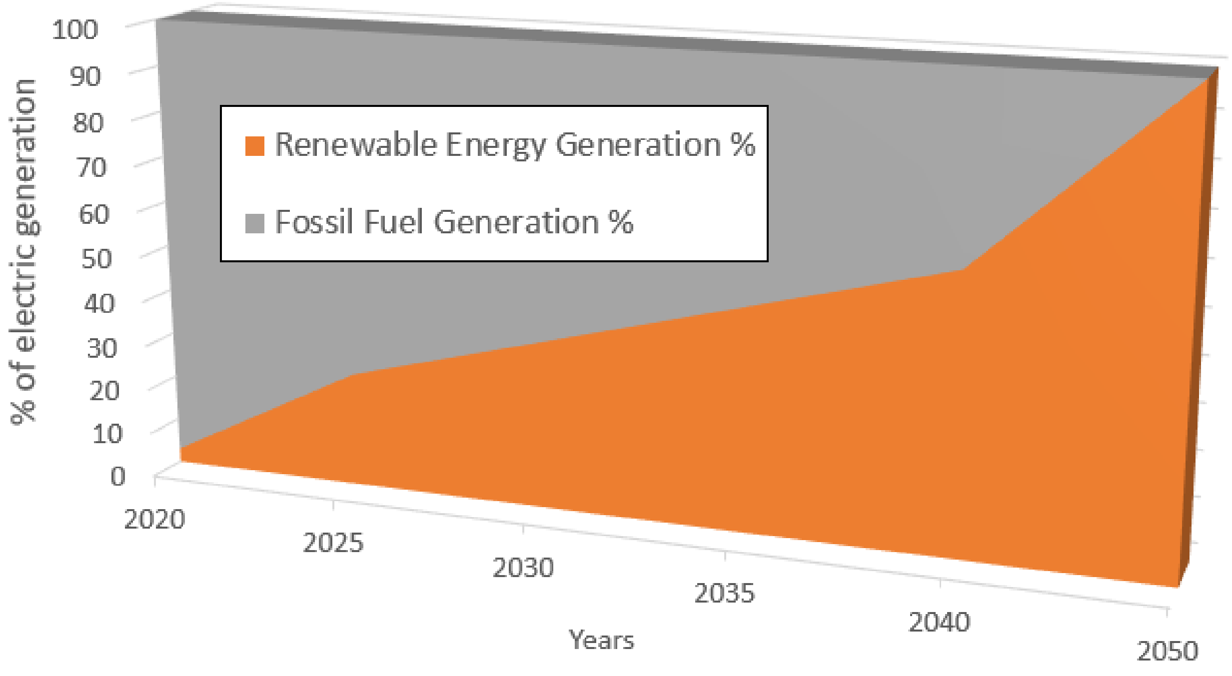


Four Initial Scenario Definitions

Presented by:
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

Similar Examples:

PR100 modeling is based on a research standard, but it is not one size fits all. Different communities have different priorities, conditions, and local legislation.

Hawai'i Clean Energy Initiative

- ✓ High energy consumption
- ✓ Land availability
- ✓ Competing maritime interests

LA100

- ✓ Compliance with CA Senate Bill
- ✓ Transmission focus
- ✓ Biofuel opportunities
- ✓ Customer electricity demand

Solar Futures Study

- ✓ Changes in policy
- ✓ Deep decarbonization
- ✓ Increased electrification

PR100

- ✓ Grid recovery
- ✓ Resilience in extreme storms
- ✓ Land availability

Images left to right: Dennis Schroeder / NREL 57777, Microsoft Images, Dennis Schroeder / NREL 40820, Werner Slocum / NREL 53641

Initial Scenario Definitions

- 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

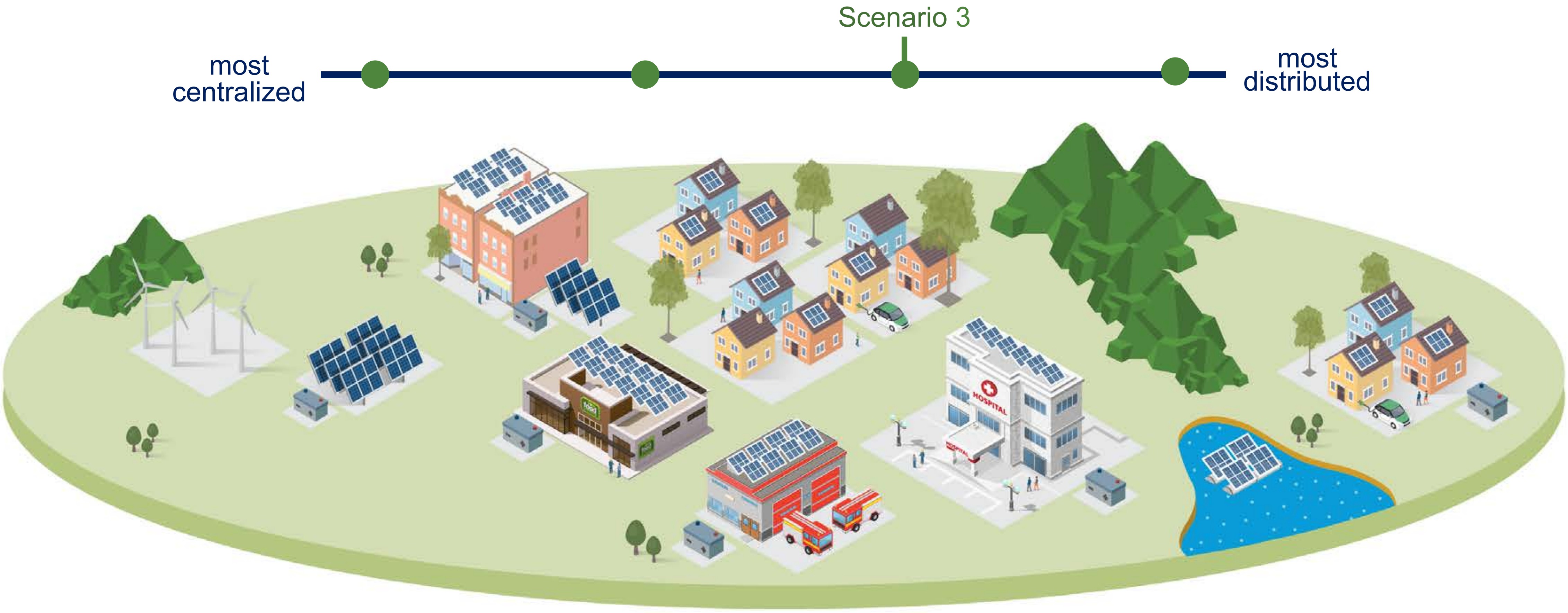
Electricity system is modeled to achieve 100% renewable energy by 2050

Scenario 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

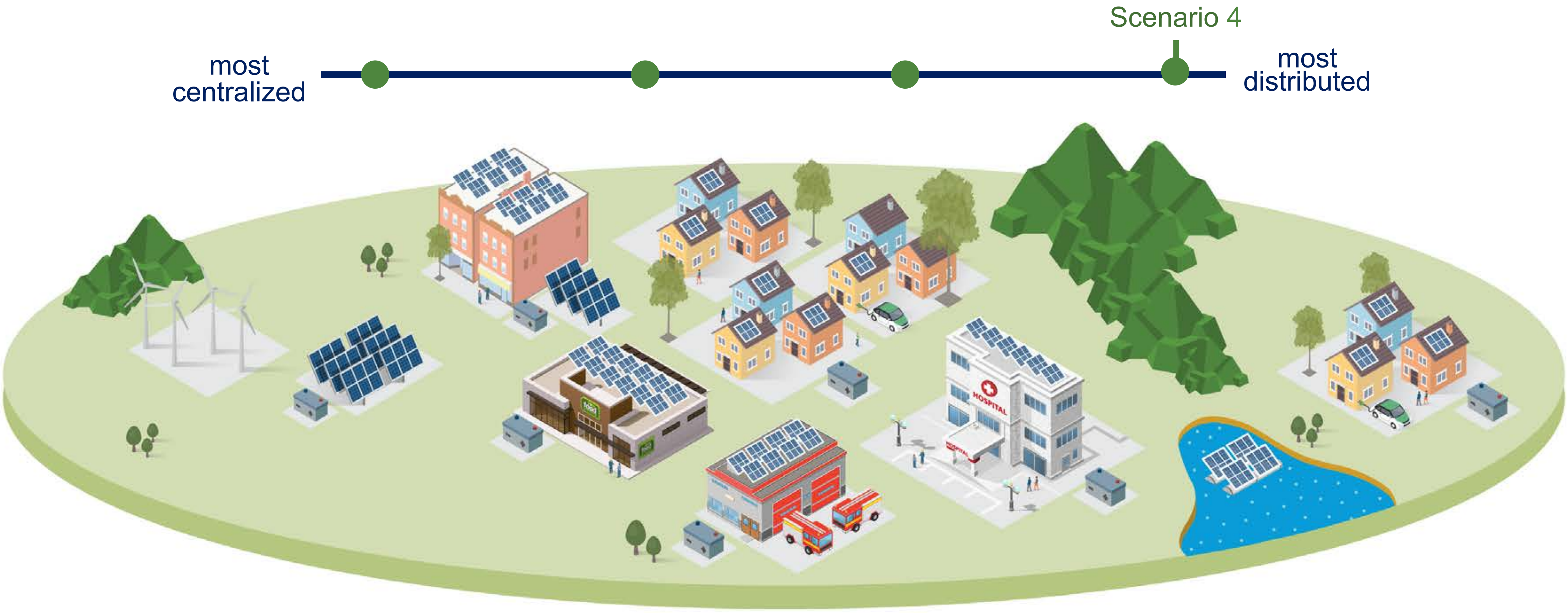
Scenario 3. Equitable Deployment of Distributed Energy Resources

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



Scenario 4. Maximum Deployment of Distributed Energy Resources

Distributed solar and storage is added to all suitable rooftops

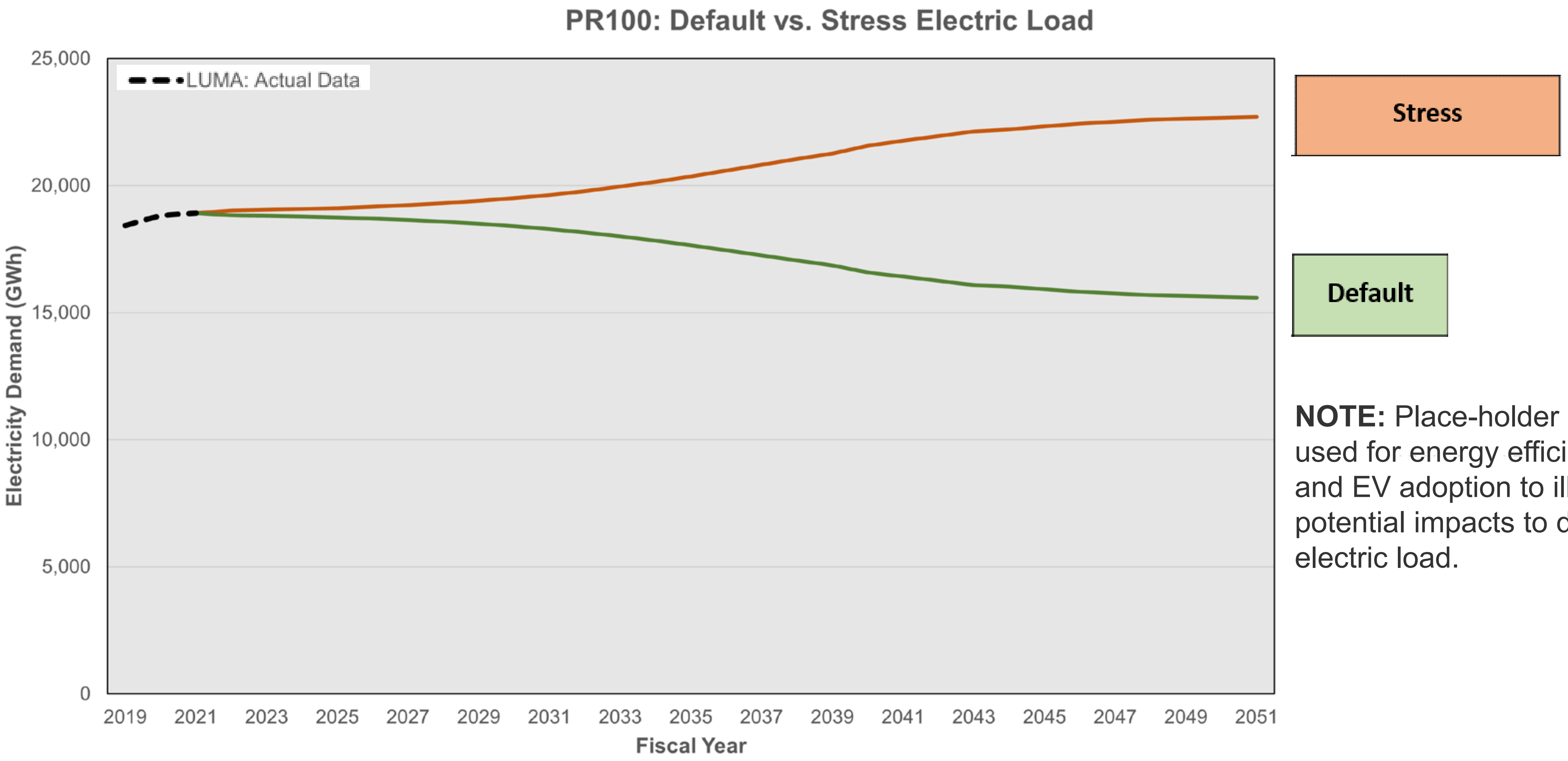


Key Driver: Electric Load Variations

	Default	Stress
End Use Loads	Inputs include gross national product, population, cooling degree days, and manufacturing jobs	Combination of end-use loads and energy efficiency result in a flat net annual load
Energy Efficiency	Mid-case: Impact of reduced energy waste	
EV Adoption	Moderate EV adoption	High EV adoption (uncontrolled)

- Load components can be combined with the other scenarios to examine impact of variations in load.
- The “stress” scenario would result in the highest loads. It includes largest electric system build-out and largest likely land use.

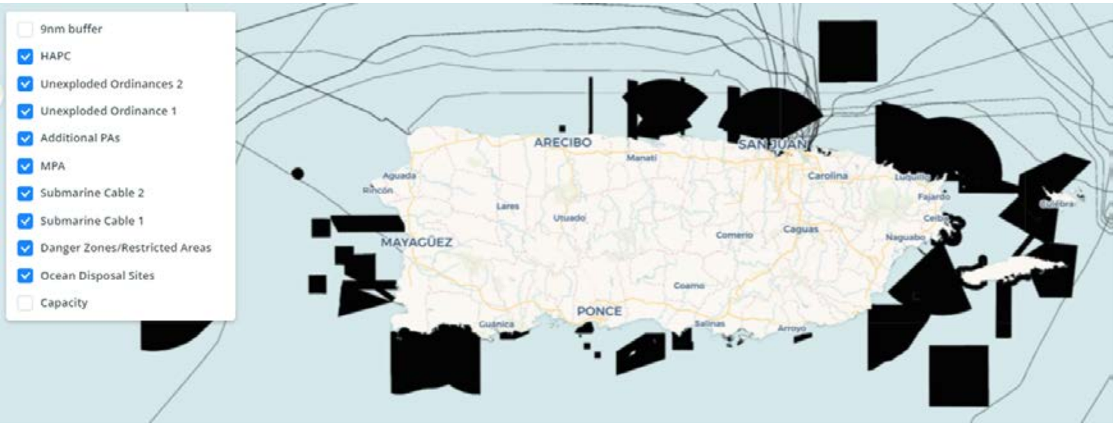
Potential Electric Load Variations



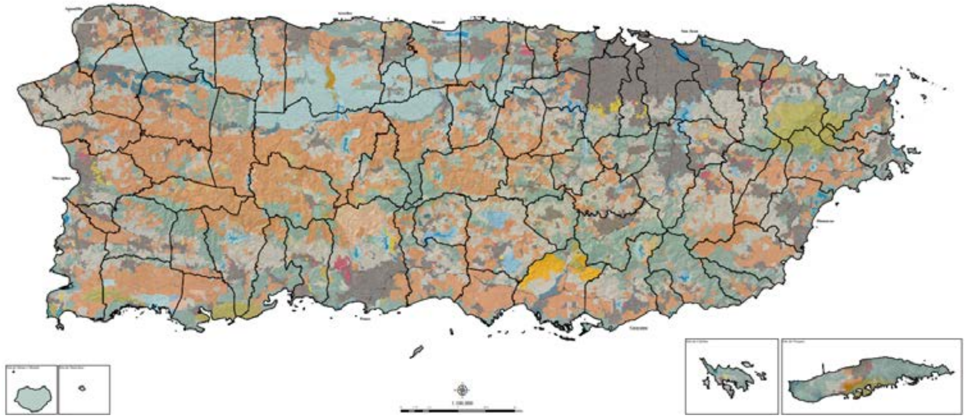
NOTE: Place-holder data used for energy efficiency and EV adoption to illustrate potential impacts to default electric load.

Graph by NREL

Key Driver: Marine and Land Exclusion Variations



Available Offshore Wind Areas after Known Possible Exclusions



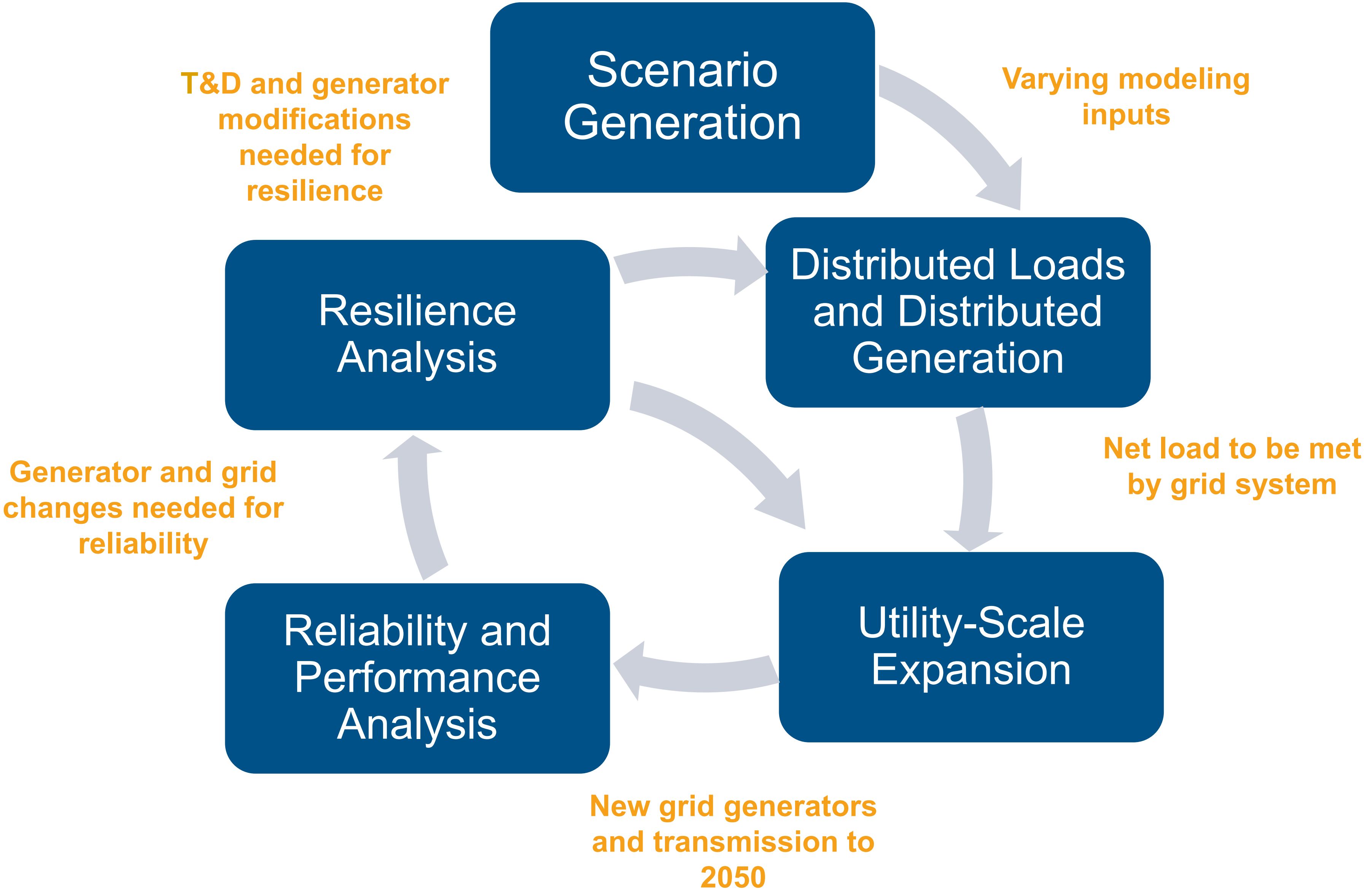
Puerto Rico Land Use Plan will inform land use constraints for onshore wind and solar

Many layers of marine and land use data have been gathered. Two possible exclusion variations will be applied to the scenarios:

- Less Constrained: Allow land and marine use for utility-scale renewables consistent with current use
- More Constrained: Allow less land and marine use for utility-scale renewables based on stakeholder input

Graphic at left by NREL; Source of map at right: Puerto Rico Planning Board. 2015. Land Classification Map, Puerto Rico Land Use Plan. https://jp.pr.gov/wp-content/uploads/2021/09/Mapa-PUT-Vigente.pdf.

Reliability and Resilience Modeled in All Scenarios



Next Steps

Six Months (by June 2022):

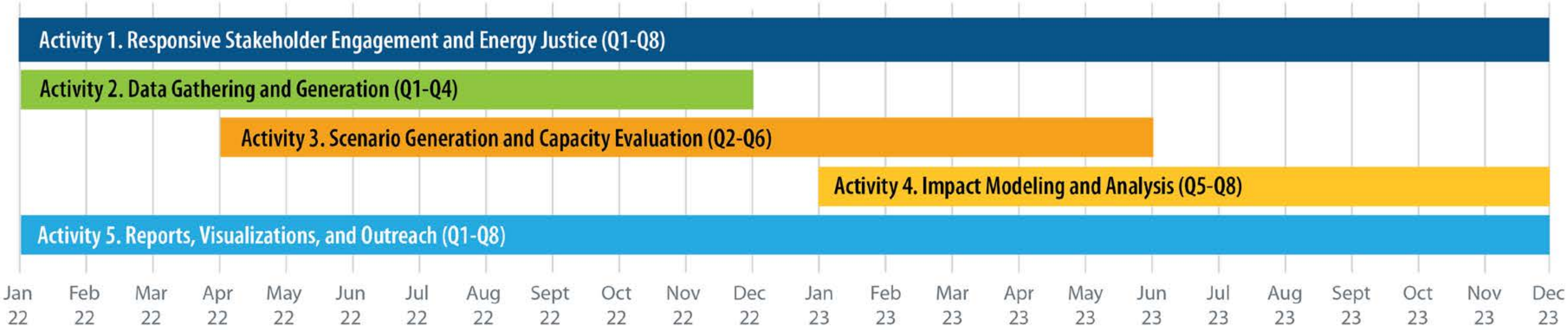
- Established stakeholder group meets monthly to inform scenarios
- Defined four initial scenarios to achieve Puerto Rico's goals.

Year One (by December 2022):

- High-resolution data sets for wind and solar resource for 10 years
- Three feasible scenarios with high-level pathways

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% renewable energy 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?
- How resilient is each scenario under extreme weather events?
- What are the economic impacts, such as changes to retail rates?



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: https://public.govdelivery.com/accounts/USDOEELECTRICITY/subscriber/new
- For questions on our efforts in Puerto Rico, contact prprojects@nrel.gov.

Additional Resources

- **PR100 Six-Month Progress Update:** https://www.nrel.gov/docs/fy22osti/83432.pdf
- **Recent Events**
  - 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 Energy Recovery and Resilience
  - DOE: PR100 Study
  - NREL: Multilab Energy Planning Support for Puerto Rico

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