

Puerto Rico

Distributed Energy Resource Integration Study

March 23, 2021



Institute for Energy Economics
and Financial Analysis
IEEFA.org



T E L O S E N E R G Y



Filantropía
Puerto Rico



ENERGIZING NEXT
GEN SOLUTIONS

Basis for the study

Queremos Sol

- 50% renewable generation by 2035, 100% by 2050
- 25% energy efficiency by 2035
- Clear public policy based on:
 - (1) Efficiency, conservation, demand management;
 - (2) Distributed renewable, emphasizing rooftop solar and storage;
 - (3) Accelerated fossil fuel phase out;
 - (4) Transforming PREPA as a public utility.



How was the study conducted?

Data

- Electrical system data was provided by PREPA.*



TELOS ENERGY

Expertise

- Performed by experts in transmission, distribution, and electrical resource planning.



ENERGIZING NEXT
GEN SOLUTIONS

Participation

- Used **Queremos Sol** as basis in consultation with labor, environmental and community groups that support the proposal.



Dr. Agustín Irizarry Rivera

*Although data used was provided by PREPA the model has been independently developed by consultants on behalf of CAMBIO and in no way represents any proposal, projection or representation of the Puerto Rico Electric Power Authority

Project objectives

- ✓ Provide a detailed economic and technical analysis evaluating a **radically different energy mix** than Puerto Rico has today as proposed in Queremos Sol.
- ✓ Illustrate a future grid integrating with high levels of **distributed energy resources**, prioritizing rooftop solar and storage, following the Queremos Sol proposal.
- ✓ Evaluate to meet PR's **renewable, resiliency, reliability, and economic** goals.
- ✓ Understand the **operational, transmission, and distribution** opportunities and challenges associated with DER integration and evaluate possible mitigations.

Study confirms that Puerto Rico has viable and cost-effective alternative

- Results demonstrate that objectives can be attained ensuring:
 - ✓ Affordability
 - ✓ Service reliability
 - ✓ Efficiency in the use of endogenous, renewable resources
 - ✓ Resiliency for homes and businesses.

Scenarios analyze up to 75% renewable energy in Puerto Rico by 2035

SCENARIO 1

25%

Renewable

50%

Resilient Homes*

~1500 MW

PV & Batteries

SCENARIO 2

50%

Renewable

75%

Resilient Homes

~3200 MW

PV & Batteries

SCENARIO 3

75% ♦

Renewable

100%

Resilient Homes

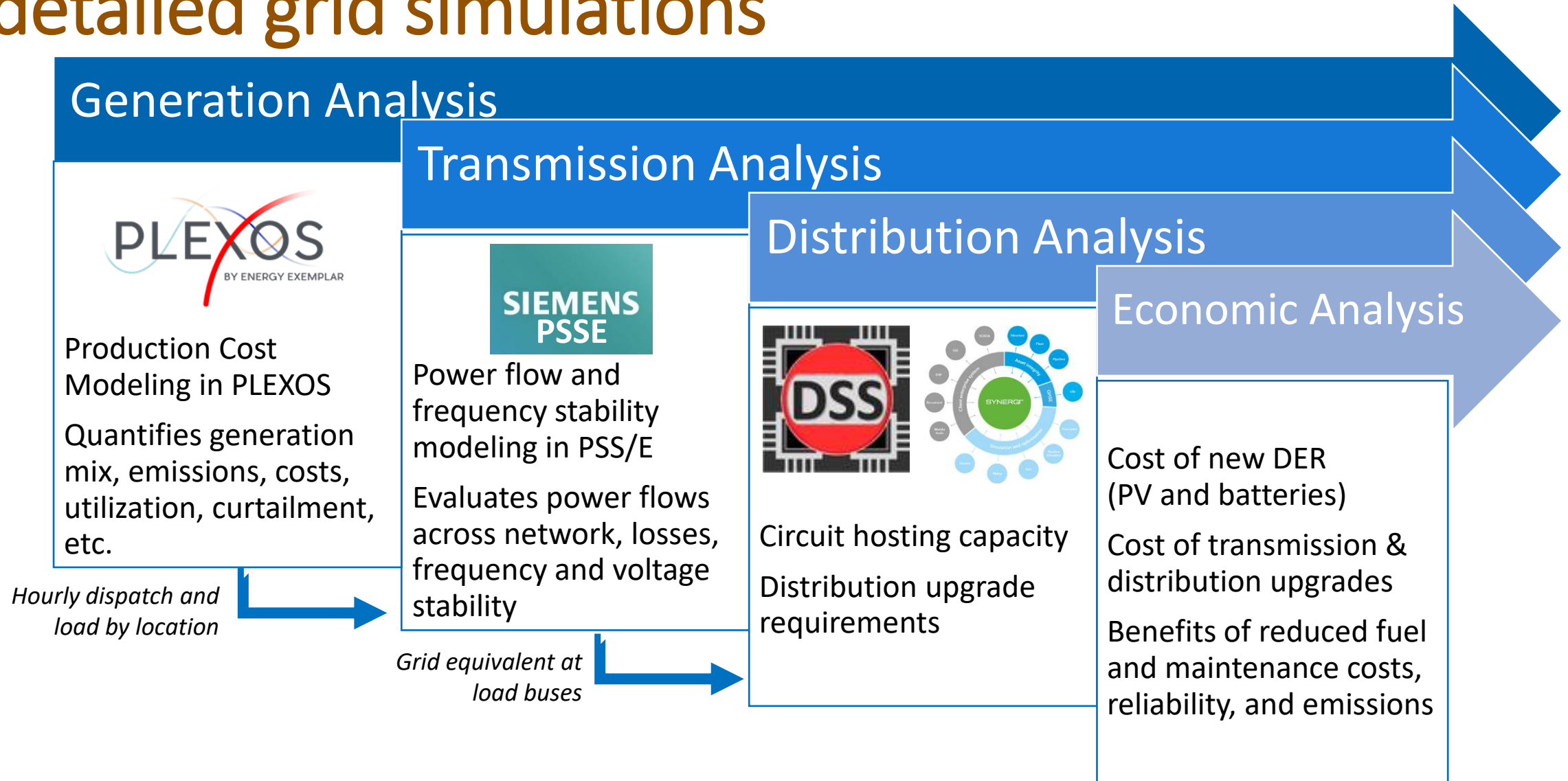
~5000 MW

PV & Batteries

*Resilient Homes: Defined as homes suitable for rooftop PV (with average size of 2.7 kW and 12.6 kWh of batteries)

♦ Requires distributed photovoltaic (PV) generation and batteries in commercial installations: roofs and parking lots

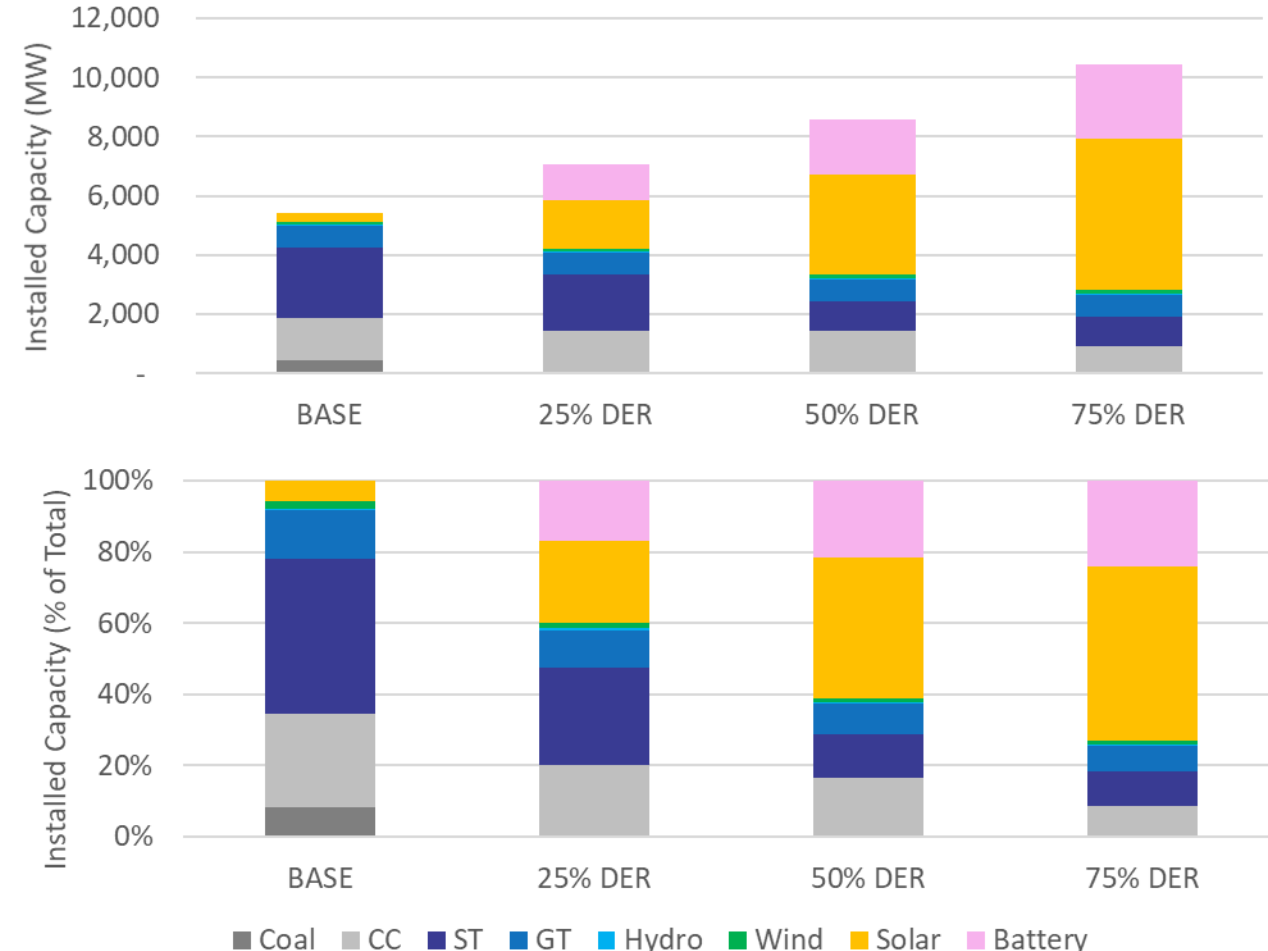
Integrated modeling tools provide detailed grid simulations



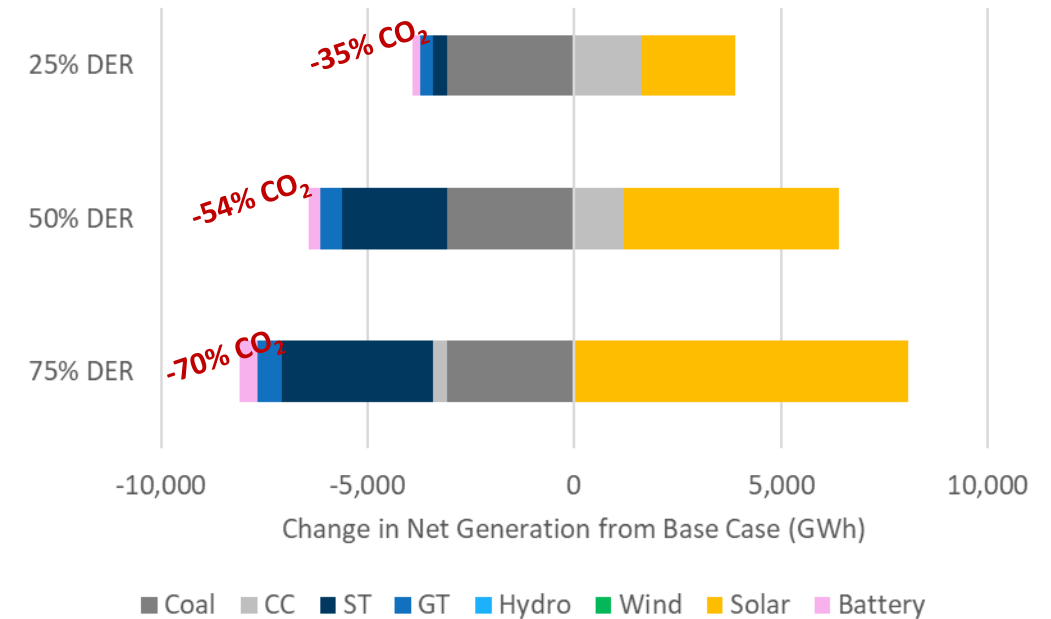
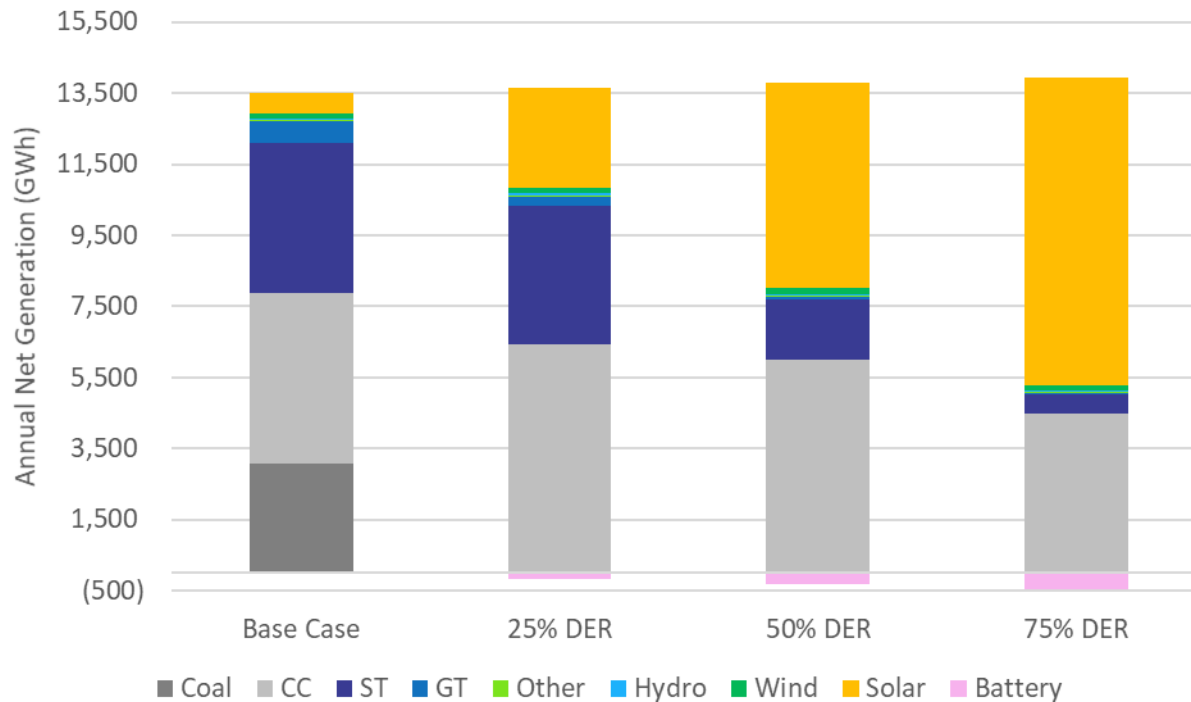
Future DER system would significantly change the resource mix on Puerto Rico

- Solar additions reach 5,000 MW (over 2x peak load!)
- Battery buildout ranges from ~5,300 MWh to 11,400 MWh
- DER (Solar + Batteries) become the largest component of the grid in the highest scenarios, reaching over 70% of installed capacity
- Fossil steam turbine fleet (oil and coal-fired) is significantly reduced via retirements

Case	Units Retired	Incremental Capacity (MW)	Cumulative Capacity (MW)
Base Case	Not Applicable	0	0
25% DER	AES 1 & 2 and Palo Seco Steam 3 & 4	886	886
50% DER	Aguirre Steam 1 & 2	900	1,786
75% DER	Aguirre CC 1 & 2	520	2,306

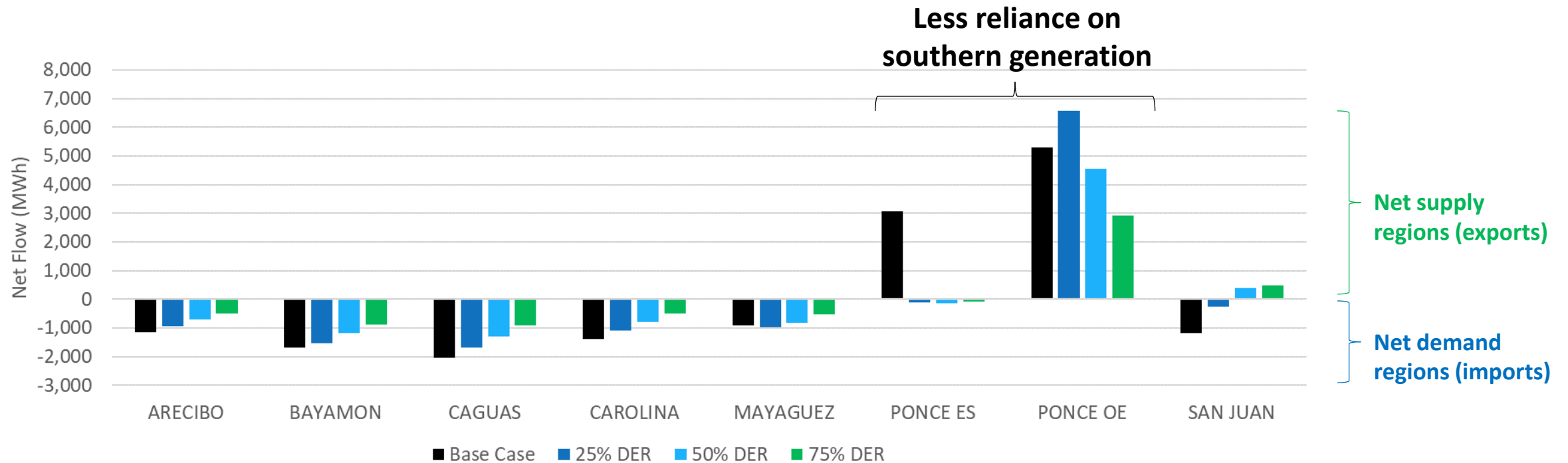


Puerto Rico's Generation Mix in a High DER Future



- ✓ Curtailment is limited to no less than 1% in all scenarios evaluated!
- ✓ Most displacement is from the ST Coal fleet (25% DER), and the ST Oil fleet (50 -75% DER)
- ✓ Combined cycle fleet (LNG & oil-fired) continue to support the grid, although use is considerably reduced.

DER reduces flows across the transmission system

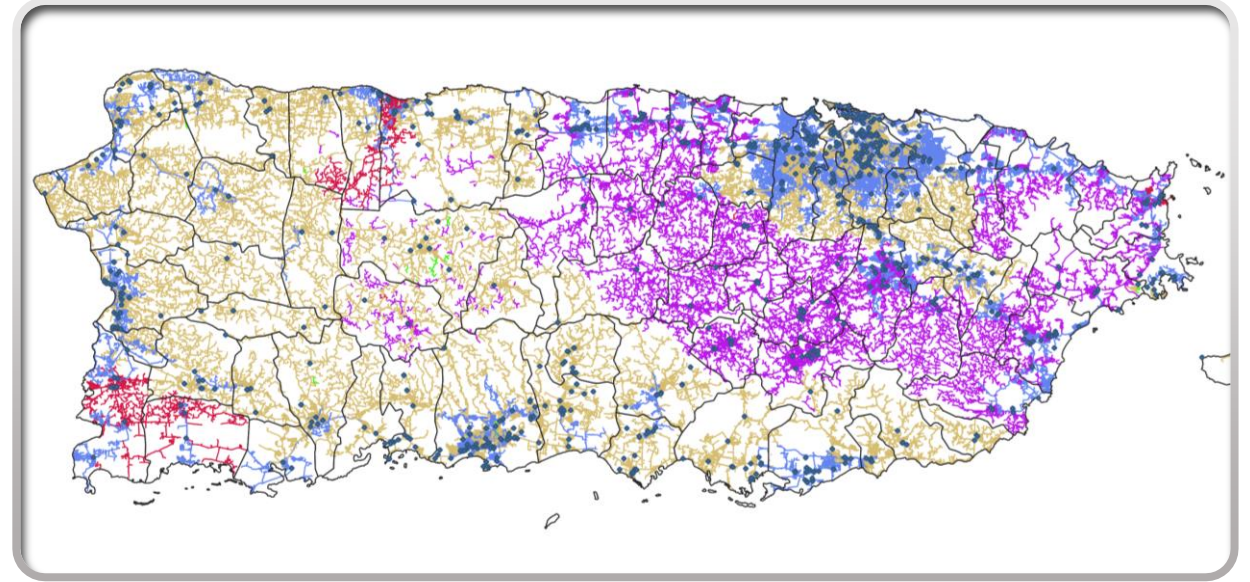


- ✓ DER is located directly at the loads, reducing the need for power to flow from South to North
- ✓ Reduces the total amount of energy that flows across the transmission network
- ✓ Leads to increased reliability, resiliency, and avoided transmission losses
- ✓ Ponce ES experiences a dramatic drop in exports with the retirement of the AES coal plant
- ✓ Ponce OE exports less to other regions as they become more self-sufficient with increased DER

Distribution system analysis

PREPA provided models for 7 feeders, we created models for 89% of feeders

- EE Plus used GIS data provided by PREPA to prepare OpenDSS models of the distribution substations and feeders.
- EE Plus modeled a total of 987 Feeders, 28,954 line miles representing approximately 89%.
- The study includes Vieques and Culebra.

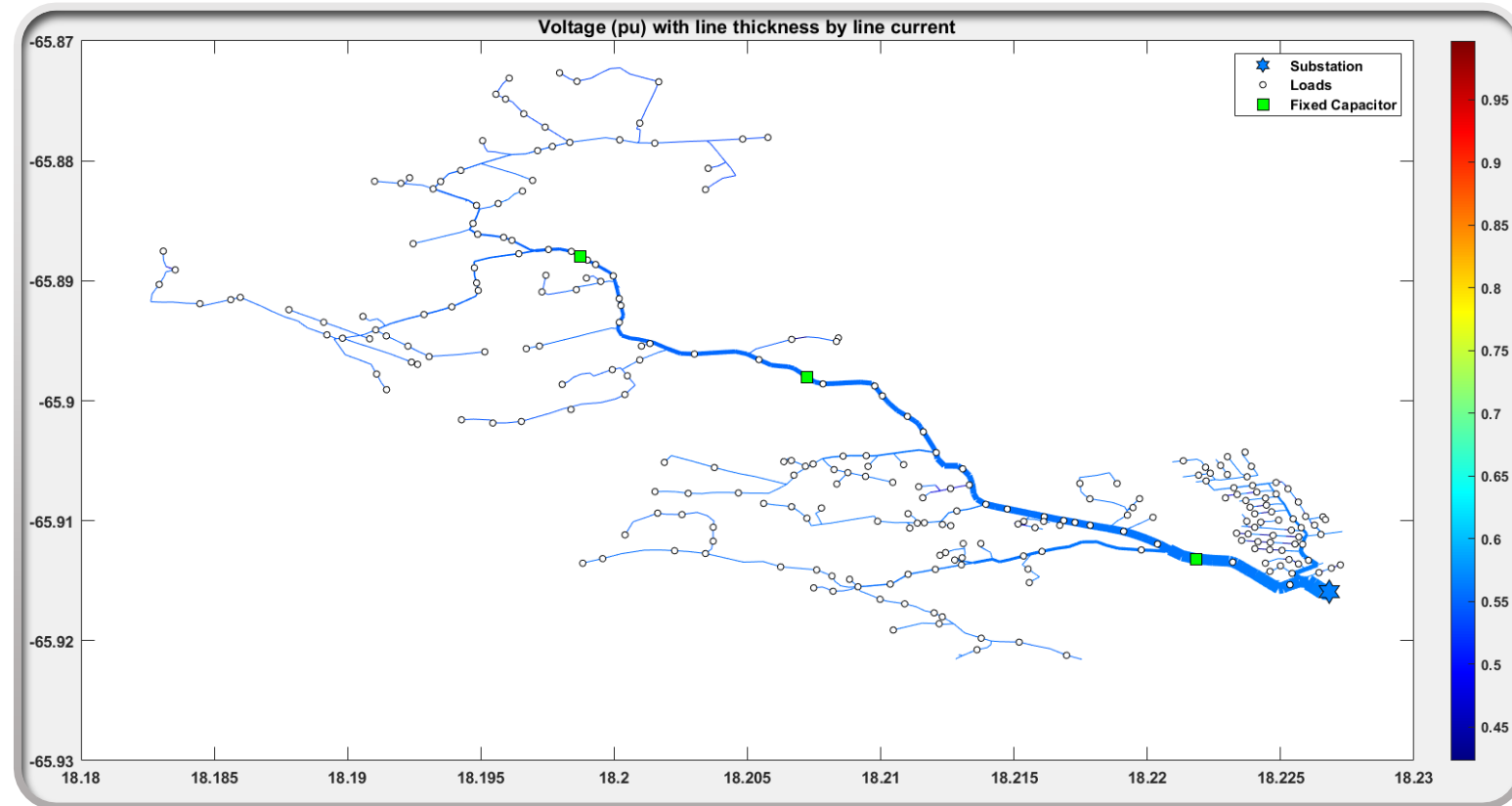


OpenDSS – is an Open-Source distribution modeling tool developed by Electric Power Research Institute (EPRI).

Distribution system analysis coordinated with transmission

- Each distribution line modeled was studied up to the corresponding transformers.
 - PV systems connected to existing Transformers in multiples of 2.7 kW consistent with resilient homes.
- Demand in each feeder was coordinated with transmission modeling.

Example of distribution line and substation



Improvements were identified as well as voltage and overheating problems and solutions for these.

Improvements at distribution to reach 75% DER

- Mitigation of both thermal & voltage violations are based on:
 - Upgrading existing facilities to meet the needs / requirements of the 75% scenario
 - Perform line upgrades.
 - Identify potential transformer loading issues.
- Line upgrades are based on:
 - If conductor size increase is no more 2 conductor sizes – reconductor
 - If conductor size increase is greater than 2 conductor sizes – rebuild
- Transformer issues / upgrades
 - If transformer reverse power overloads are less than 125% for no more than 500 hours annually – no upgrade
 - Power flows greater than 125% of their rating or for more than 500 hours annually - replace

Encouraging Results: Distribution System Analysis

Distribution system can support high renewable penetration levels with modest upgrades

- While there are several reverse power flow, voltage and thermal violations associated with the development scenarios, in general:
 - The distributed nature of the deployment limits these violations to lower than anticipated levels.
 - Associated mitigation costs are generally limited to rebuilding / reconductoring of existing lines (~15%), with modest substation transformer upgrades (~4%).

75% scenario upgrades

Region	Total Line Miles	Line Miles Reconductored	Line Miles Rebuilt	% Mitigation	Transformer Upgrades (MVA)
Arecibo	4,790	32.7	697.7	15.2%	15
Bayamon	2,442	196.1	237.6	17.8%	22
Caguas	6,761	328.5	701.3	15.2%	30
Carolina	3,310	241.7	313.1	16.8%	15
Mayaguez	5,482	90.4	669.6	13.9%	18
Ponce ES	2,828	29	287.7	11.2%	11
Ponce OE	2,526	48.2	302.8	13.9%	10
San Juan	2,908	64.1	228.6	10.1%	28
Vieques	166	1.8	24.9	16.1%	0
Culebra	68	2.2	6	12.1%	0

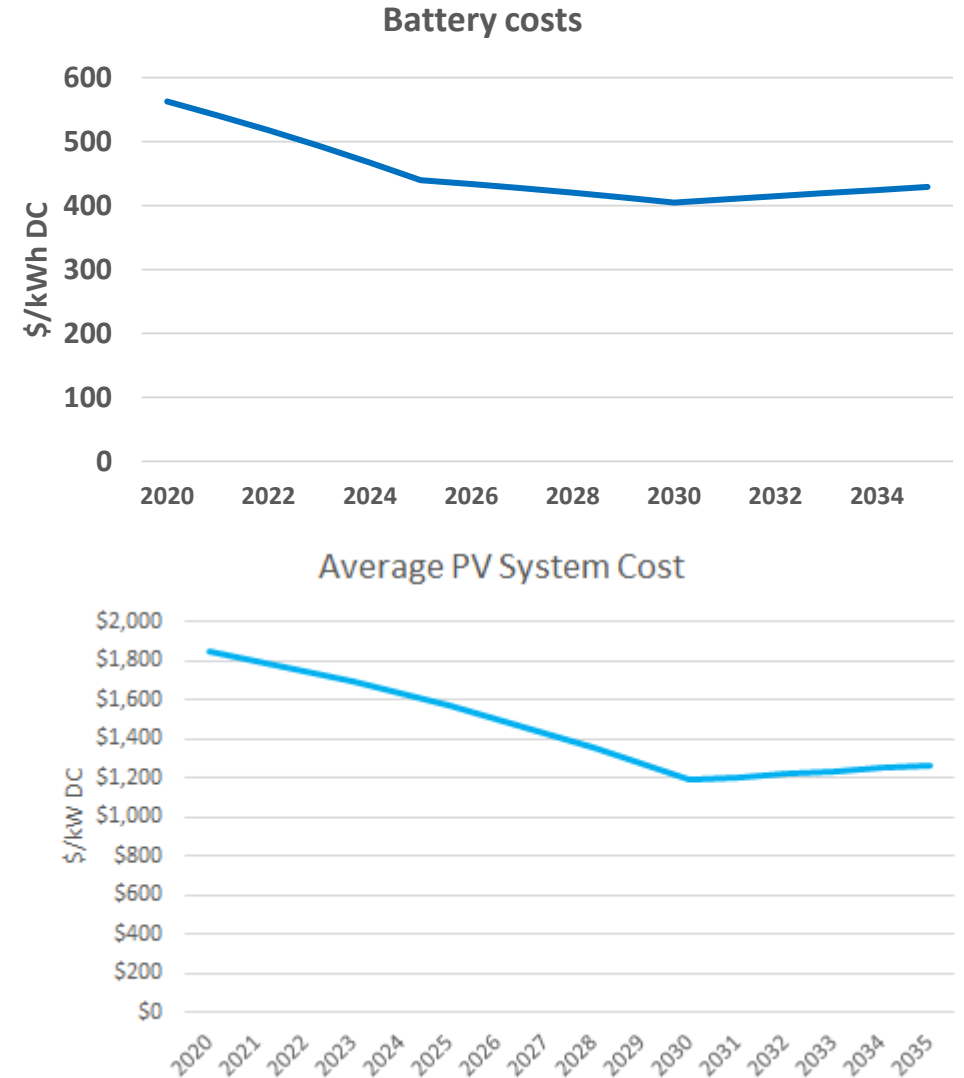
Encouraging Results: Distribution System Analysis

- Previous experiences with high penetration renewables were based on large-scale projects and have required significant investments in infrastructure improvements. This is not the case here, because:
 - The strategy pursued by Queremos Sol of locating systems on roofs and storage behind the meter (in residences) minimizes the use of the distribution system and therefore the need for improvements.
 - The coordinated deployment of PV systems and batteries in which PV systems charge batteries at peak hours minimizes voltage shocks.
 - The use of individual small systems that shift local demand, instead of exporting to the grid, mitigates overheating of lines and transformers.



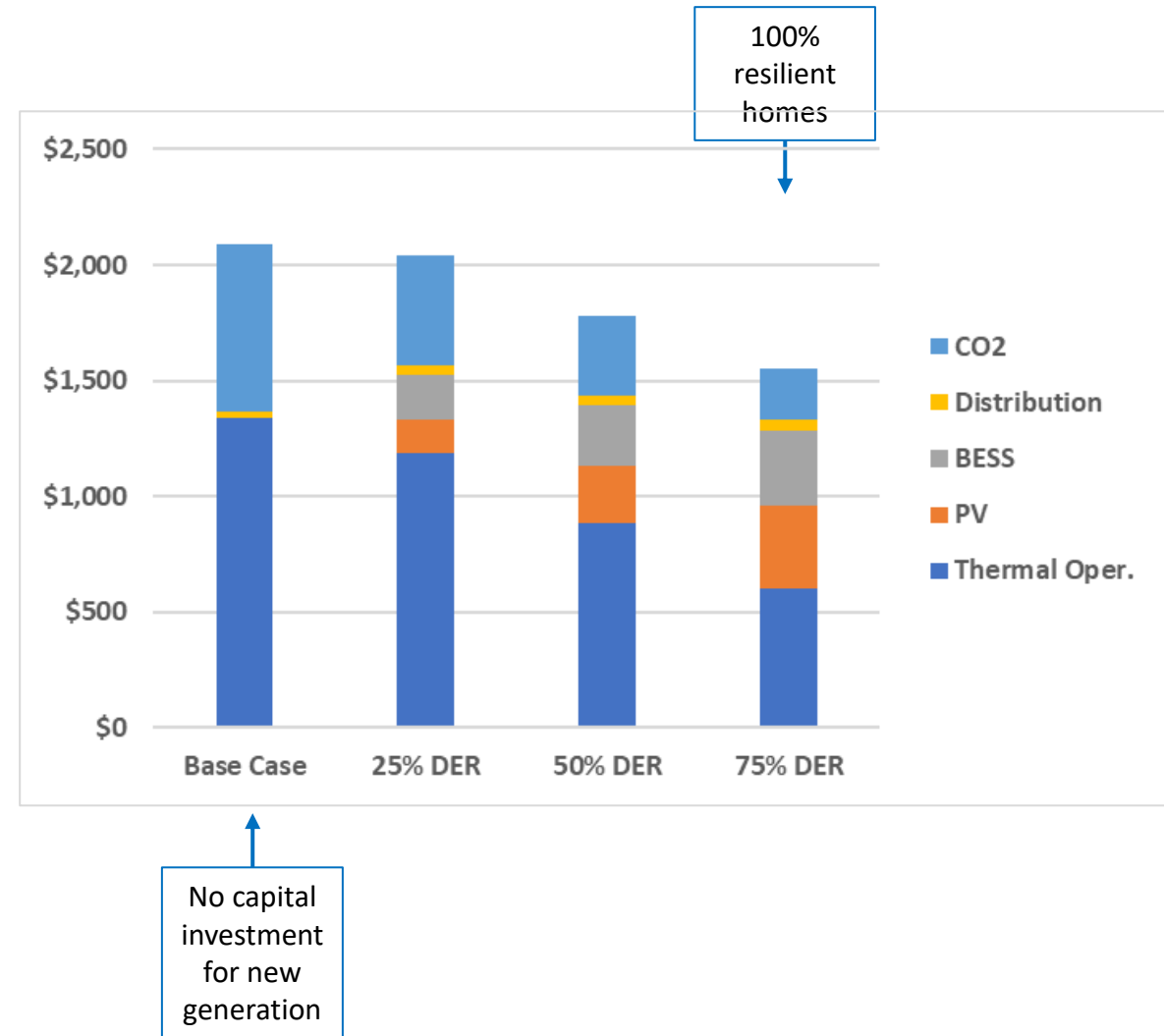
PV and BESS Costs

- 2020 costs reflect actual prices obtained from quotes in Puerto Rico.
- Applied ATB cost decline curves to produce forward trajectory.
- A more aggressive scenario was also modeled.



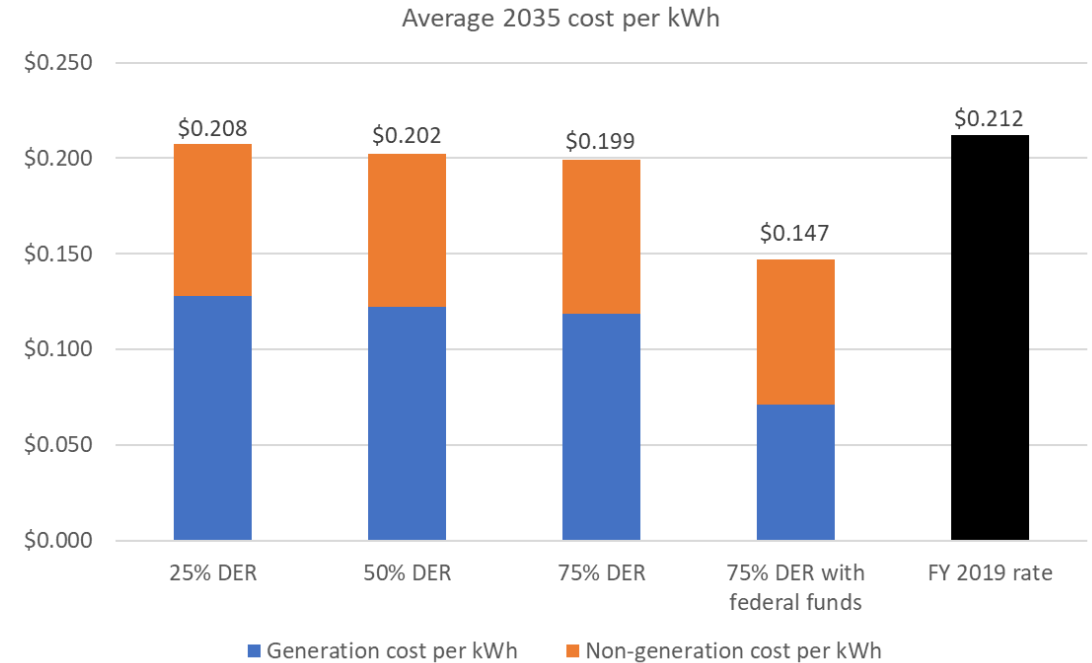
System costs --2035

- Includes operational costs (fuel, maintenance), distribution system improvements and annual cost for financing PV and BESS at 6.5%.
- “Base Case” does not include capital investment for new generation.
- Even given this the 75% DER scenario is ~ \$500 million lower than the “Base Case”.
- Distributed generation scenarios require capital investment:
 - Opportunity to use federal funds to lower costs and considerably improve resiliency conditions.



System costs --2035

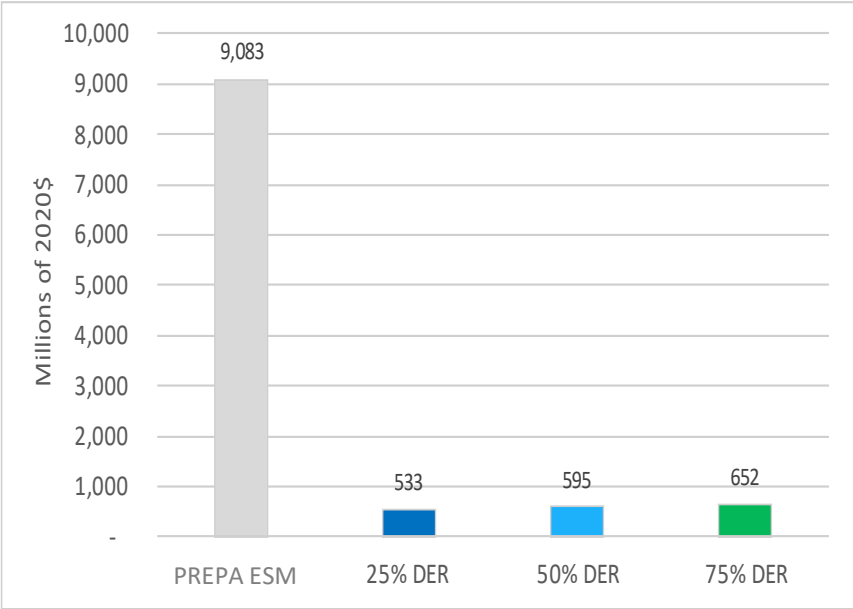
- Final scenario 75% includes \$9.65 billion in federal funds
 - \$9 billion for solar and batteries and \$650 million in improvements to the distribution system.
- FEMA 404 and 428, HUD funds.
- Scenarios reflect the average cost of the system.
- No specific ratemaking proposal is assumed.



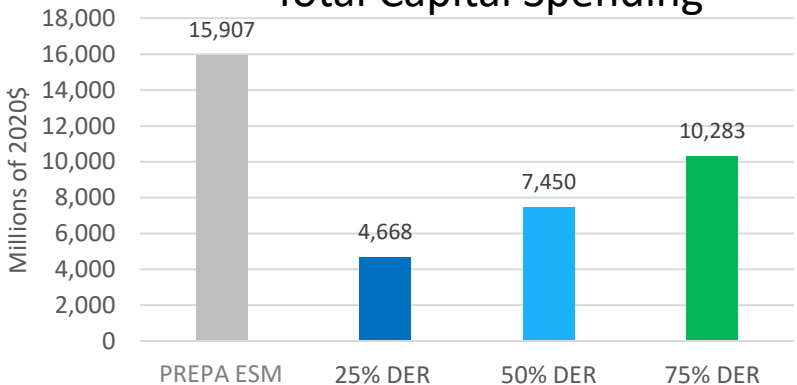
- ✓ Does not include debt payments or other payments such as pensions.

Comparison to PREPA's ESM Plan

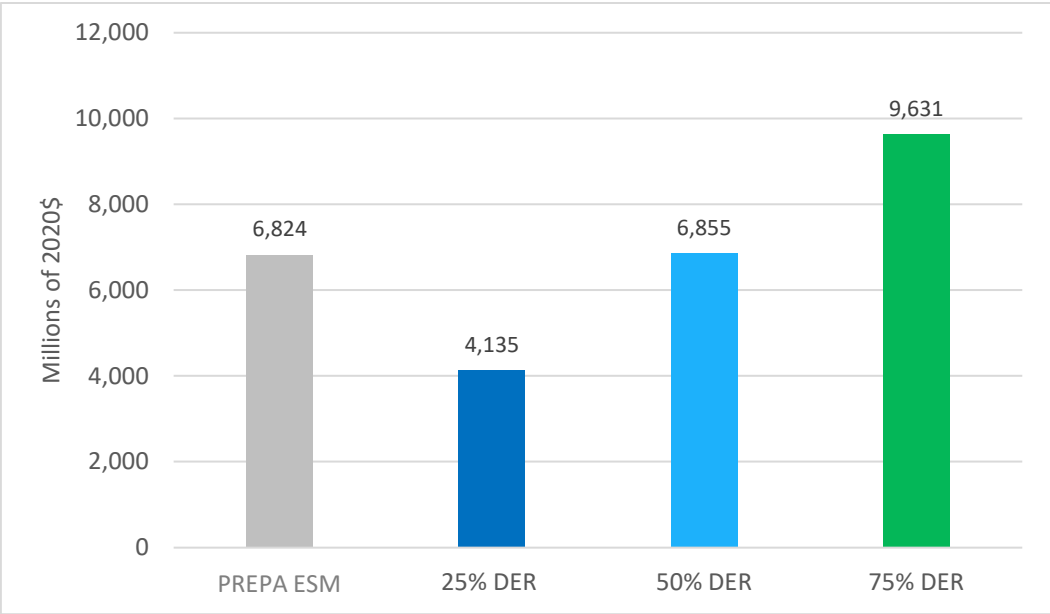
Transmission and Distribution System Investment



Total Capital Spending



Generation Investment



Main conclusions

- **FEASIBLE**

- A high penetration of renewable energy (rooftop solar and storage) is feasible with modest improvements to the distribution system.

- **RESILIENT**

- Equipping 1 million homes with rooftop solar and battery backup can provide 2,700 MW of power to Puerto Rico's grid, which is complemented by commercial renewable generation to achieve 75% renewable energy penetration. In 15 years resiliency conditions could be dramatically different.

- **NO NEW FOSSIL FUEL INVESTMENT**

- The study demonstrates there is no need for new fossil fuel plants or for conversion of existing plants.

- **FOSSIL FUEL PHASE OUT**

- Under the 75% scenario, the vast majority of PREPA's current generation fleet would no longer be used, including the AES coal plant, which can be shut down in the next 4 years.*

- **REDUCE DEPENDENCY ON TRANSMISSION**

- Thus, reducing a recognized vulnerability.

Main conclusions

- **70% REDUCTION OF CO₂ EMISSIONS** (75% scenario)
 - Significant progress improving environmental and health conditions for communities.
 - Positions Puerto Rico at the forefront—addressing climate change with urgency.
- **75% SCENARIO LESS EXPENSIVE THAN CURRENT GRID**
 - Reduce imported fossil fuel costs by nearly \$600 million each year relative to the current generation system.
 - PREPA can purchase the equipment and install with employees, supplementing with local contractors.
- **SYSTEMS COSTS \leq 20 CENTS/KWH**
 - Puerto Rico's future electricity rates face significant uncertainty. Excluding debt, the 50% and 75% distributed power scenarios result in system costs equal to or less than 20 cents/kWh.
- **SYSTEMS COSTS \leq 15 CENTS/KWH, IF FEDERAL FUNDS USED**
 - \$9.65 billion in federal funds available to achieve the 75% scenario.
- **POSITIVE IMPACT ON PEOPLE AND ECONOMY**
 - Volatility in rates due to fluctuations in the fossil fuel market is reduced.

Benefits



- The study provides new and useful information to guide the radical transformation of Puerto Rico's energy model and the use of federal funds.
- The results show that this transformation is viable, reliable and cost-effective for citizens, the economy and PREPA itself.
- This model ensures that lower-income communities share in the benefits of renewable energy with rooftop solar and storage ... and that no one is left behind.

The alternative modeled is in line with the federal government's climate, energy and economic plan.

75% for 2035

- A distributed energy future for the island is technically achievable, affordable, and would provide **real resiliency** to Puerto Rico's homes and businesses.
- The study can help inform discussions/process for **defining federal funds investments**.
- Could aid PREPA in **targeting more effectively upgrades for solar integration** and strategies that can aid PREPA in complying and exceeding adopted RPS.
- Provides a pathway for maximizing federal funds to ensure risks and vulnerabilities are mitigated and that **resiliency is evenly distributed** across the population.
- Could **launch PREPA as a 21st century utility**.



www.queremossolpr.com