We Want Sun and We Want More

75% Distributed Renewable Generation in 15 Years in Puerto Rico
Is Achievable and Affordable

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Executive Summary

In 2018, Queremos Sol ("We Want Sun"), a multi-sectoral coalition of Puerto Rican community, environmental and labor organizations, put forward a policy proposal for the renewable energy transformation of Puerto Rico's electrical system under a reformed public ownership model. The proposal emphasized efficiency and distributed renewable energy, particularly rooftop solar and behind-the-meter storage, as a strategy to provide resilience to households in future blackouts, to reduce the impact on agricultural and ecologically valuable lands from utility-scale renewable energy projects, and to reduce the island's dependence on imported fossil fuels and extensive transmission systems. Queremos Sol proposes a transformation that is equitable, affordable and that ensures a transition to renewables that is fair to PREPA workers.

In this report, we summarize the result of in-depth grid modeling studies completed in early 2021 to investigate specific technical aspects of the Queremos Sol proposal. Specifically, Telos Energy and EE Plus performed modeling of the Puerto Rico Electric Power Authority's generation, transmission and distribution infrastructure, using data obtained from PREPA, to analyze scenarios of increasing penetration of renewable energy, up to 75% (with over half of that from residential installations) of total electricity consumption by 2035. Energy Futures Group used these grid modeling results to estimate costs. Key results of this analysis are:

- Achieving 75% distributed renewable energy generation in 15 years is feasible with minimal upgrades to the distribution system.
- Equipping 100% of homes with 2.7 kW PV and 12.6 kWh battery backup can provide 2700 MW of power to the Puerto Rico grid, which would need to be supplemented by solar installations at commercial sites (rooftops and parking lots) to reach 75% renewable energy penetration.
- Seventy-five percent distributed renewable energy by 2035 would cut imported fossil fuel costs to $430 million/year (relative to recent expenditures over $1.4 billion/year) and reduce carbon dioxide emissions by more than 70%.
- The distributed energy scenarios demonstrate there is no need for new fossil fuel generation or conversions of existing units to natural gas. It is possible to move directly to the widespread deployment of distributed solar and storage technologies, rather than locking in decades of new natural gas infrastructure.

- Under the 75% distributed renewable energy scenario, the vast majority of PREPA's current power plants would no longer be used, included the AES coal plant, which can be retired in the next 4 years.[1]
- The 75% distributed renewable energy scenario is less expensive than the base case of PREPA's current grid.

Puerto Rico's future electric rates face significant uncertainty due to federal funding, privatization contracts and PREPA's ongoing debt restructuring. Without including legacy debt, the 50% and 75% distributed energy scenarios modelized here result in average system costs equal or less than 20 cents per kWh. The study does not assume any specific ratemaking policy. **If $9.6 billion in federal funding is used to cover necessary distribution system improvements and to invest in distributed solar and battery systems as proposed by Queremos Sol and modeled, the average system cost is less than 15 cents/kWh in 2035.** Moreover, Puerto Rico's dependency on fluctuating fossil fuel prices would be dramatically reduced providing greater stability in rates.

After the 2017 hurricanes, high-level rhetoric has emphasized transitioning to a renewable energy-based, resilient electrical system, while money has flowed to privatization, centralized generation and natural gas infrastructure. Most recently, PREPA's 10-Year Infrastructure Plan calls for spending about $10 billion in federal funds to harden PREPA's centralized transmission and distribution systems and to build out new natural gas infrastructure, with zero dollars directed towards renewable energy and storage. Decisions over the use of billions of dollars in federal funding will shape Puerto Rico's grid for decades to come.

A distributed energy future for the island is technically achievable, affordable and would provide real resiliency to Puerto Rico homes and businesses. In this report, we make the case for policy development and prioritization of federal funding to widely deploy rooftop solar and storage, coupled with energy efficiency, across Puerto Rico.

[1] Retirement of AES modeled follows substitution of its generation capacity with roof-top solar and PV. However, Queremos Sol's demand for immediate retirement of AES can also be attained through other operational modifications.

Background

The future of Puerto Rico's oil-dependent, poorly maintained and bankrupt electrical system has been highly contested. In the aftermath of Hurricanes Irma and Maria in 2017, this debate received much greater attention island-wide and in the continental United States. At a high level, there has been significant recognition of the role that distributed renewable energy could play in enhancing resiliency.

Law 17-2019, Puerto Rico's Energy Public Policy Act envisions an electrical system "that empowers the consumer to be part of the energy resources portfolio through the adoption of energy efficiency strategies, demand response, the installation of distributed generators."[2]

However, in the three years since the hurricane, distributed energy resources have not played a central role in the transformation process, which continues to perpetuate a centralized generation model.

PREPA's twenty-year Integrated Resource Plan (IRP) - the long-term plan for the island's generation system approved by its regulator, the Puerto Rico Energy Bureau – is supposed to be the guiding document for investments in the generation system.[3] PREPA's IRP was based on electric generation capacity expansion modeling that evaluated the cost of adding new capacity and retiring existing capacity to arrive at the least-cost trajectory for transforming the island's generation mix. However, the capacity expansion model was not capable of simulating distribution system investments and simply assumed a certain penetration of rooftop solar resources (13% by 2035[4]). While this is common practice in integrated resource planning in the continental United States, it is an impediment to achieving the desired widespread penetration of distributed energy resources in Puerto Rico.

Additionally, despite the alleged primacy of the IRP in guiding the development of Puerto Rico's electrical system, investments in the generation system have moved forward outside of the IRP process. Notably, PREPA entered into a contract with New Fortress Energy subsidiary NFEnergia for the conversion of units 5 and 6 of the San Juan power plant to natural gas and for a five-year supply of natural gas (with possible extension up to 20 years).[5] The deal has been criticized for its lack of clarity on savings to ratepayers, for taking place outside of the IRP process, for NFE's failure to gain approval from the Federal Energy Regulatory Commission for its project, for failing to notify and consult neighboring communities, and for numerous red flags in the contracting process itself.[6]

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[2] Act 17-2019, Article 1.5(2)(e).
[3] Act 57-2014, Article 6.23.
[4] PREPA's workpaper for the Energy System Modernization scenario (its preferred IRP scenario) in 2035 shows 1,508 GWh of customer-owned PV generation out of a total generation of 11,780 GWh. (See PREPA file "ESM_Metrics_Base_SII-mm with action plan tab" filed with the Puerto Rico Energy Bureau in Case No. CEPR-AP-2018-0001 on June 28, 2019).
[5] Gerardo E. Alvarado León, "La AEE y NFEnergía firman contrato de combustible," El Nuevo Día, March 5, 2019.
[6] Tom Sanzillo and Ingrid Vila-Biaggi, "Is Puerto Rico's Energy Future Rigged?", Institute for Energy Economics and Financial Analysis, June 2020.

Most recently, PREPA has earmarked federal funding to build new natural gas infrastructure that was rejected by the Energy Bureau in the IRP proceeding. Specifically, PREPA plans to spend over $500 million in federal funds to construct a 400 MW natural gas plant near San Juan in 2024, despite the fact that this was not approved in the IRP.[7] PREPA does not plan to spend any FEMA grid reconstruction funds on renewable energy or storage.

The laws passed by the Puerto Rico legislature since Hurricane Maria are aimed primarily at privatizing the electrical system (Law 120-2018 and Law 17-2019). These laws set up a streamlined and non-transparent process for the lease of PREPA's T&D system to a private operator and for the sale or lease of generation assets to private buyers. In the absence of clear prioritization of distributed renewable energy, this legislation has facilitated natural gas interests (like NFEnergia) pushing centralized natural gas infrastructure in Puerto Rico.

Finally, ongoing negotiations with PREPA's creditors to restructure PREPA's $9 billion in legacy debt are likely to have a material impact on future investment in the electrical system. The most recent debt restructuring agreement (RSA) seeks to recover legacy debt from a surcharge on rates for the next 47 years. The debt charge, which grows to 4.552 cents/kWh over that period, would also be applied to electricity generated by distributed solar panels installed after September 2020.[8] This structure thwarts the goal of incentivizing distributed generation on the island. As of February 2021, the RSA has not received court approval because the 2020 earthquakes and pandemic have dramatically worsened economic conditions in Puerto Rico.

In short, the transformation process post-hurricane Maria has been fraught with contradictions that, so far, have furthered more of the same: politically-driven contracting focused on centralized generation, particularly natural gas. Yet there is still much that is uncertain about the future of the power system. PREPA's proposals for new natural gas infrastructure were largely rejected by the Energy Bureau in its latest IRP, despite PREPA's ongoing attempts to circumvent the Bureau. The outcome of debt restructuring negotiations are still uncertain. The recent concession of PREPA's operations (excluding generation) to a private third-party has drawn stiff opposition. The imminent disbursement of over $10 billion in FEMA funds for the electrical system, plus the potential future disbursement of nearly $2 billion in HUD funds, will shape the grid for decades to come.[9]

Queremos Sol Modeling Initiative

In this context, Queremos Sol ("We Want Sun"), a multi-sectoral coalition of Puerto Rican community, environmental and labor organizations, put forward a policy proposal for the renewable energy transformation of Puerto Rico's electrical system under a reformed public ownership model in 2018. Queremos Sol explicitly rejected the push for privatization of the electrical system and centered energy efficiency and distributed renewable energy in its vision.

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[7] See: Puerto Rico Electric Power Authority, Revised 10-Year Infrastructure Plan, February 2021. And Puerto Rico Energy Bureau, Final Resolution and Order, Case No. CEPR-AP-2018-0001, August 21, 2020, paragraph 620.

[8] Definitive Restructuring Support Agreement, May 3, 2019. (See Appendix C: Recovery Plan Term Sheet).

[9] José Delgado, "FEMA aprueba cerca de $13,000 millones para reconstruir la red eléctrica y el sistema educativo," El Nuevo Día, September 18, 2020.

The vision included specific goals of 25% energy efficiency by 2035, 50% renewable energy by 2035 and 100% by 2050. Queremos Sol specifically advanced the proposal of providing 75% of homes in Puerto Rico with a minimum level of energy security, in the form of solar with battery back-up, by 2035. Queremos Sol also rejected the development of new natural gas infrastructure on the island.[10]

In this report, we present the results of modeling conducted on behalf of CAMBIO to lend more analytical detail to the Queremos Sol proposal. A key focus of this modeling was analyzing the costs and technical operations of a grid heavily based on decentralized renewable energy (rooftop solar and storage). As noted above, this type of modeling was absent from PREPA's most recent IRP. The modeling analyzed three scenarios of increasing penetration of decentralized renewable energy to find out what that would mean in terms of: (a) generation mix; (b) costs; and (c) upgrades required to maintain grid stability and reliability.

The modeling was conducted by Telos Energy and EE Plus, using data provided to CAMBIO and the Institute for Energy Economics and Financial Analysis (IEEFA) as a result of a public records request.[11] Energy Futures Group used these grid modeling results to estimate costs. The modeling evaluated four scenarios for the Puerto Rico grid in 2035: a base case scenario that projects today's grid and generation mix into 2035, and three scenarios with increasing levels of renewable energy penetration. As shown in Table 1, these scenarios meet 25, 50 and 75% of Puerto Rico's assumed 2035 electricity consumption with renewable energy and assume that 50, 75 and 100% of residential homes are equipped with 2.7 kW solar panels and 12.6 kWh battery backup, respectively.[12]

Table 1: Summary of Renewable Energy Scenarios[13]

		25% DPV	50% DPV	75% DPV
Renewable Share	% of Total Generation	25%	50%	75%
Resilient Homes	% of Resilient Homes	50%	75%	100%
Distributed PV Capacity (MW)*	Residential	1,350	2,025	2,700
	Commercial	143	1,212	2,282
	Total	1,493	3,237	4,982
Distributed BESS Capacity	Power Rating (MW)	1,178	1,853	2,528
	Energy Rating (MWh)	5,301	8,339	11,376
	Duration (hrs)	4.5	4.5	4.5

*Includes existing distributed PV

[10] For more details, see queremossolpr.com

[11] 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.

[12] 100% of homes refers to 1,000,000 homes that are projected to be inhabited by 2035. Multi-family units, or houses where PV installation is not possible, are assumed to be served by nearby home, community or commercial installations.

[13] Telos report, Table 1.

These scenarios were evaluated using a production cost model (PLEXOS) that optimized the use of generation resources on the grid in each scenario, according to assumptions about solar availability, fuel prices, and operations and maintenance costs for each generating unit. The full details of this analysis are found in the report of Telos Energy (hereafter "Telos report"). Telos also ran a transmission model (PSS/E) that simulated the flow of power on PREPA's transmission network in each scenario. This showed how the integration of increasing amounts of distributed renewable energy changes PREPA's traditional reliance on south-to-north transmission lines to bring power from generators in the south to population centers in the north. It also provided an opportunity to analyze the stability of the grid under increasing amounts of renewable energy systems, which do not respond to disruptions to the grid (generator or transmission outages) in the same way as traditional fossil fuel-based generators.

EE Plus used the transmission system power flow modeling output from the Telos analysis to model power flows on the distribution system using OpenDSS. EE Plus analyzed 976 feeders (89% of PREPA's distribution system mileage) to determine which distribution lines would need to be rebuilt or reconductored in order to accommodate increasing amounts of rooftop solar interconnected directly to the distribution system.

Energy Futures Group analyzed the energy efficiency measures that could be used to meet Queremos Sol's vision of 25% energy efficiency by 2035 and forecasted the 2035 island-wide electricity demand that was input into the Telos and EE Plus modeling. Energy Futures Group also modeled the total costs of each scenario, including the costs of acquiring the solar and battery storage resources.

Modeling Results

No New Natural Gas Infrastructure Is Needed to Achieve High Penetrations of Renewable Energy

The modeling analysis conducted here shows that it is possible to skip over natural gas as a "bridge fuel" and move directly to the widespread deployment of distributed solar and storage technologies, rather than locking in decades of new natural gas infrastructure. The modeling shows there is no need for the construction of any new natural gas infrastructure or for the conversion of existing plants to gas. In contrast, the integrated resource plan (IRP) presented by PREPA to the Energy Bureau included substantial investment in new natural gas infrastructure. Although many of these proposals were rejected by the Bureau, the Bureau did authorize PREPA to move forward with preliminary permitting activities and studies for a 300 MW natural gas plant at Palo Seco and also stated that it would consider the conversion of the AES coal plant to natural gas as part of the next IRP cycle.[14] Moreover, PREPA's 10-Year Infrastructure Plan also calls for the use of FEMA funding to build new natural gas infrastructure, although the

[14] Puerto Rico Energy Bureau, Final Resolution and Order, Case No. CEPR-AP-2018-0001, August 21, 2020, p. 284.

Bureau has ordered PREPA not to move forward with implementation of this initiative beyond $5 million for preliminary studies.[15]

The Scenarios Allow for the Retirement of the AES Coal Plant and Varying Amounts of Oil and Natural Gas Capacity

In the modeled scenarios, increasing amounts of distributed renewable energy displace the current fossil-based generation and allow for the retirement of existing units. Telos used a weighted ranking – that included age, cost, emissions, flexibility, forced outage rate, and location – to prioritize units for retirement.

The 25% DER scenario allows for the retirement of the AES coal plant and Palo Seco units 3 & 4.[16] If pursued starting in 2021, this scenario can be attained by 2024. The 50% DER scenario allows for the additional retirement of the Aguirre steam units 1 & 2. And the 75% DER scenario allows for the additional retirement of the Aguirre combined cycle plant, for a total of 2,306 MW of conventional generation retired. This is shown in the following table:

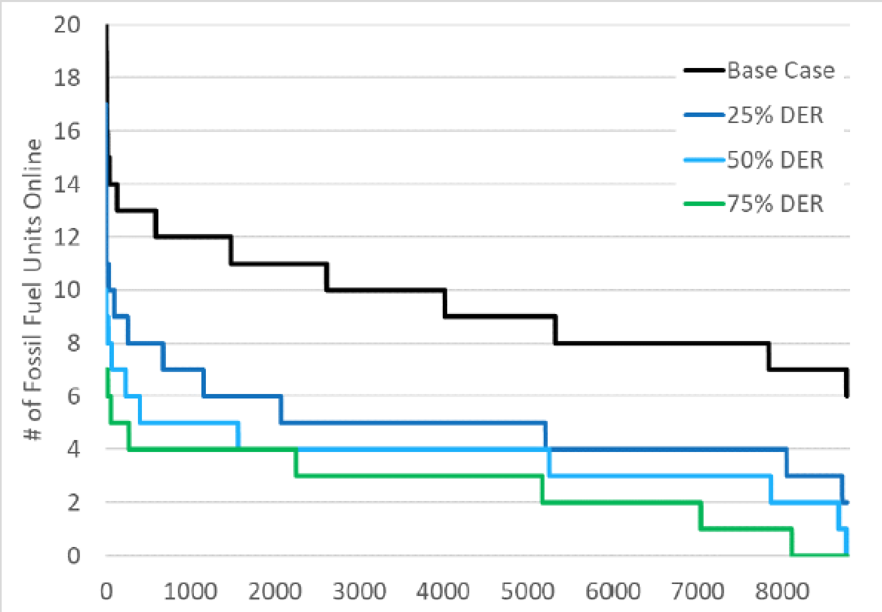
Table 2: Unit Retirements Under Distributed Renewable Energy Scenarios[17]

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

It is worth noting that in the 75% DER scenario, the majority of the fossil generation units remaining on the system are rarely, if ever, used. As shown in the following figure, a maximum of 7 fossil generating units (out of a current total of 39) are generating power during the 75% DER scenario. A more detailed resource adequacy analysis could likely identify additional units that could be retired.

[15] PREPA, "Response to Resolution and Order Entered on January 25, 2021 and Request for Approval of Revised 10-Year Infrastructure Plan," Puerto Rico Energy Bureau Case No. NEPR-MI-2021-0002, February 16, 2021.
[16] Retirement of AES modeled follows substitution of its generation capacity with roof-top solar and PV. However, Queremos Sol's demand for immediate retirement of AES can also be attained through other operational modifications.
[17] Telos report, Table 2

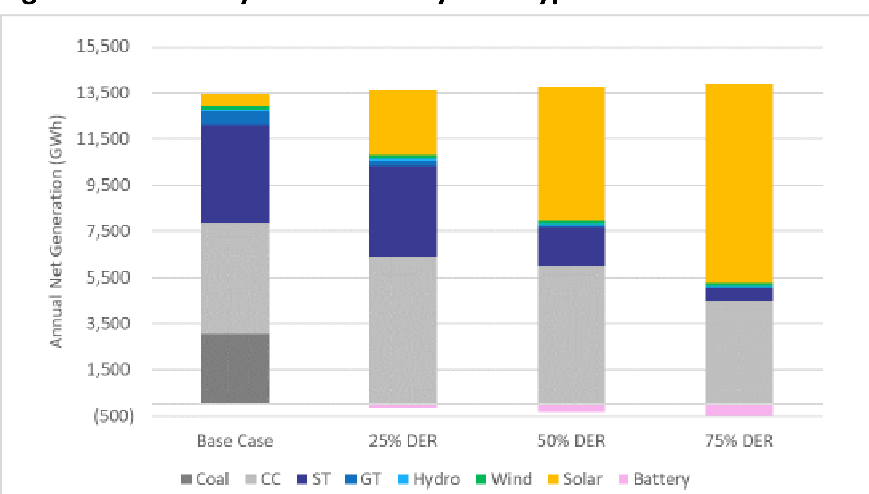
Figure 1: Number of Fossil Fuel Units Generating Power Per Hour of the Year in 2035[18]



Decreased reliance on PREPA's unreliable power plants, which are a frequent cause of power outages, also provides a reliability benefit for the distributed energy scenarios.

Figure 2 shows Puerto Rico's energy generation mix under the modeled scenarios. There is no coal generation in any of the DER scenarios since the AES coal plant is retired. The natural gas- and oil-fired units (blue and light grey bars) initially increase to compensate for some of the lost coal generation, but are ultimately partially displaced by solar. In the 75% DER scenario, both oil and natural gas consumption have declined by more than 50% relative to the current grid. The San Juan 5 and 6 units were modeled as operating with fuel oil in 2035.

Figure 2: Electricity Generation by Fuel Type in 2035[19]



[18] Telos report, Figure 30
[19] Telos report, Figure 15.

The amount of renewable energy resources built out in the 75% DER scenario is comparable to the S3S2B scenario in PREPA's IRP, which was the most aggressive renewable energy scenario that PREPA analyzed for implementation over a 20-year period. The 75% DER scenario achieves 8,802 GWh of renewable energy generation, over half of which is from residential rooftop installations.[20] The S3S2B scenario presented by PREPA achieves 7,613 GWh of utility-scale renewable energy and 1,508 GWh of residential rooftop solar by 2035.[21] The key difference is that the 75% DER scenario is based on distributed resources rather than utility-scale solar generation and therefore provides a much greater level of household-level resiliency and reduced dependency on transmission.

The Modeled Scenarios Cut Puerto Rico's Imported Fuel Bill by Close to $600 Million per Year

As a result of the decreased reliance on fossil fuels, Puerto Rico is able to dramatically decrease its bill for imported fossil fuels (i.e. all fossil fuels) across the modeled scenarios. Table 3 shows total operating costs (not including capital costs) for the fossil fuel units across all of the scenarios. Using modeled 2035 fuel prices from PREPA's integrated resource plan, the distributed energy scenarios save close to $600 million in fuel costs in 2035 relative to Puerto Rico's current grid. The 75% renewable energy by 2035 scenario would cut imported fossil fuel costs to $432 million/year (relative to recent expenditures over $1.4 billion/year)

Table 3: Costs of Operating Fossil Fuel Units in Each Scenario[22]

Case	Base	25% DER	50% DER	75% DER
Fuel Costs	$1,003	$926	$677	$432
Fixed O&M + Cap. Maint.	$255	$198	$151	$130
Variable O&M	$59	$32	$21	$13
Startup Costs	$24	$31	$34	$28
Total Costs	**$1,341**	**$1,188**	**$883**	**$603**

Distributed Energy Scenarios Both Reduce Puerto Rico's Contribution to Climate Change and Enhance Resilience to Future Storms

By 2035, the 75% DER scenario results in a 70% reduction in carbon dioxide emissions relative to the base case from 8.9 million tons per year to 2.6 million tons per year. [23] This is a direct result of reduced consumption of fossil fuels.

At the same time as the much greater reliance on distributed renewable energy reduces Puerto Rico's contribution to climate change, it also greatly enhances household resiliency to more severe storms. In the 75% DER scenario, all households have a 2.7 kW rooftop solar system with

[20] See Table 17 of Telos report.
[21] PREPA IRP workpaper "S3S2B_Metrics_Base_SII" filed with the Puerto Rico Energy Bureau in Case No. CEPR-AP-2018-0001.
[22] EFG Report, Table 12.
[23] Telos report, p. 38.

12.6 kWh battery storage to serve critical loads, providing continued access to electricity even if the transmission system is severely damaged by a hurricane.

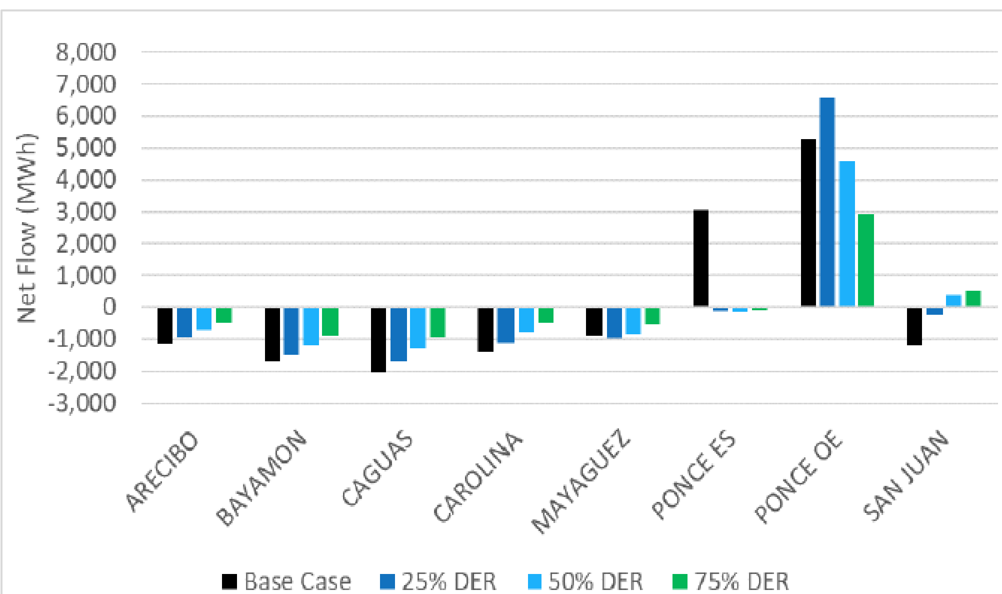
The strategy pursued by Queremos Sol and modeled here would place Puerto Rico at the forefront of worldwide climate change mitigation objectives while adopting a cost-effecting approach to much needed adaptation, in order to reduce vulnerabilities.

Increased Reliance on Distributed Renewable Energy Dramatically Reduces Reliance on South-To-North Transmission

One of the vulnerabilities of Puerto Rico's current grid configuration, which was dramatically exposed by hurricane Maria, is its over-reliance on south-to-north transmission because the majority of the power plants are located in the south and the main population center (the San Juan metropolitan area) is in the north. This is shown in Figure 3, where the black bars (the current grid configuration) show large net power flows out of the two Ponce transmission zones located along the south coast.

In the modeled scenarios, solar is distributed evenly across the island's eight transmission zones, roughly proportional to population within each zone. As a result of the location of more power generation in the north, power imports decline across all of the northern transmission zones (Arecibo, Bayamon, Carolina, and San Juan). Power export declines dramatically out of the eastern Ponce zone ("PONCE ES") because of the retirement of the AES coal plant in all DER scenarios. Power export actually increases out of the western Ponce zone ("PONCE OE") to compensate for the AES retirement in the 25% DER scenario, but then power exports decrease as more distributed solar is integrated to the grid.[24]

Figure 3: Net Annual Flow of Power Out of Each Transmission Zone[25]



[24] Telos report, pp. 40-41.

[25] Telos report, Figure 22.

Energy Efficiency Programs Can Be Scaled to Meet 25% of Puerto Rico's Demand by 2035

Energy Futures Group identified several areas where energy efficiency programs could be scaled to meet the goal of meeting 25% of projected 2035 electricity demand through energy efficiency. However, EFG's projection of 2035 sales does not depend entirely on specific energy efficiency programs. Efficiency gains are a combination of: natural energy efficiency (savings that occur without additional policy intervention through the tightening of appliance energy efficiency standards); energy efficiency programs administered by the utility; and the conversion of 70% of residential electric water heaters to solar water heaters.[26] Utility-sponsored energy efficiency programs include incentive programs to improve the efficiency of residential lighting, residential air conditioning, commercial lighting, commercial refrigeration, commercial lighting controls and more.[27]

Operational Changes to Achieving 75% Renewable Energy Grid by 2035 Can Be Addressed

One of the critical results of the Telos study is that achieving high levels of distributed renewable energy penetration (75%) on the Puerto Rican grid is technically feasible by 2035. Solar is different from traditional power plant generation in that it is only available when the sun is shining. The addition of batteries allows solar power to be stored for use to meet electricity demand at other times. But even so, solar plus battery storage at high levels of penetration changes grid operations. The Telos study explored these changes at length, modeling how a grid with increasing amounts of distributed renewable energy would respond to different disruptive events like a generator outage or a transmission line fault. The study identified mitigation options, including introducing Fast Frequency Response (FFR), synchronous condensers, and grid forming inverters, to result in a reliable grid with 75% renewable energy penetration by 2035.

Little Investment in the Distribution System Is Required to Achieve High Levels of Renewable Energy Penetration; No Investment Required in Transmission

The EE Plus study modeled 89% of the distribution system including Vieques and Culebra. It identified distribution feeder lines that would need to be rebuilt or reconductored in order to avoid overheating of lines and equipment, and to maintain voltages within the needed range, in the distribution system as a result of integrating renewable energy generation at the distribution level. In the 75% DER penetration scenario, this analysis found that 4,504 miles of distribution lines would need to be reconductored or rebuilt (about 14% of the total line-miles

[26] EFG Report, p. 7-8.

[27] The baseline load forecast assumed for modeling is slightly higher than what PREPA assumed in its integrated resource plan. This modeling assumed, before accounting for energy efficiency, 0% growth in sales by 2035, whereas the IRP modeled a 4% decline in sales by 2038. (Puerto Rico Energy Bureau, Final Resolution and Order, Case No. CEPR-AP-2018-0001, August 21, 2020, p. 47).

of Puerto Rico's distribution system), and 149 MVA of transformers upgraded.[28] The cost of these upgrades are estimated in Table 4.

Table 4: Cost of Distribution System Upgrades in 75% DER Scenario[29]

Scenario	Transformer Upgrade Cost	Line Reconductor Cost	Line Rebuild Cost	Total Cost
Base	$0	$41,141,424	$243,592,659	$284,734,084
25% DER	$0	$77,545,581	$455,887,200	$533,432,781
50% DER	$2,410,800	$76,269,071	$516,119,531	$594,799,403
75% DER	$7,330,800	$97,837,352	$546,739,997	$651,908,149

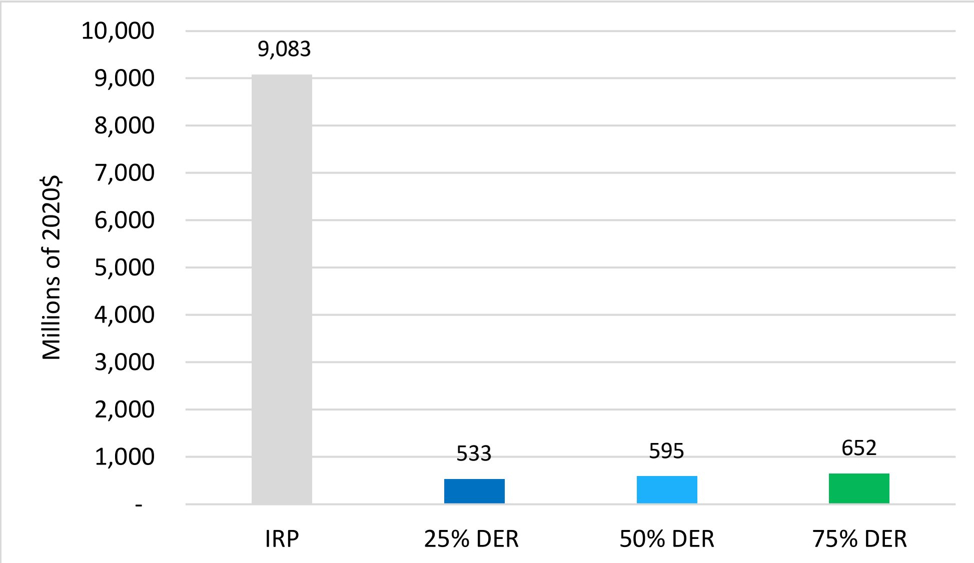
Two factors contribute to the relatively low level of distribution system improvements needed to integrate this high level of distributed generation. One is the fact that highly distributed, rooftop systems allow for a large amount of generation to be consumed on site, minimizing use of the distribution system. The second is the coordinated deployment of rooftop solar with battery storage, which helps to minimize impact on system voltage.[30]

No additional upgrades to the transmission system were identified in the Telos study for integration of renewables.

These levels of transmission and distribution system investment are much lower than proposed by PREPA in its most recent integrated resource plan. PREPA's IRP devoted more than $5 billion to its minigrid concept. Beyond this, the IRP included over $3 billion for hardening of existing infrastructure and bringing it up to standards. Because we lacked data on the current condition of distribution system assets, the EE Plus study does not include costs to bring this infrastructure up to standard. It may be that at least some of the $3+ billion in upgrades and urgent improvements of existing transmission and distribution system infrastructure are needed. Even with such costs included, transmission and distribution system capital investments would still be over $5 billion less than proposed by PREPA in its IRP.

[28] EE Plus report, p. 22.
[29] EFG report, Table 10.
[30] EE Plus report, p. 5.

Figure 4: Total Transmission & Distribution System Capital Costs[31]



Investment in Solar and Storage Required to Achieve High Penetrations of Distribution Renewable Energy Is Comparable to Generation System Investment Proposed by PREPA for a Centralized System

Even though the high distributed energy scenarios require significant capital investment in PV and battery storage technologies, total capital costs in those scenarios are still comparable with capital investment in new generation proposed by PREPA in its IRP. Figure 4 compares the total amount of generation system capital investment in each DER scenario to PREPA's preferred scenario in its IRP. Note that PREPA's IRP did not include the cost of the 848 MW of distributed solar that it assumed customers would install; adding that cost would raise the cost of the IRP scenario by roughly $1 billion to over $7.5 billion.

On the other hand, as mentioned earlier there is a dramatic difference in investment proposed for distribution and transmission by PREPA and the investment required in the 75% scenario. When adding all components (generation, transmission & distribution), Figure 6 shows that even the 75% scenario of distributed renewable generation is over $5 billion less than PREPA's preferred IRP scenario.

[31] EFG Report, Figure 14.

Figure 5: Total Generation System Capital Costs, 2020-2035[32]

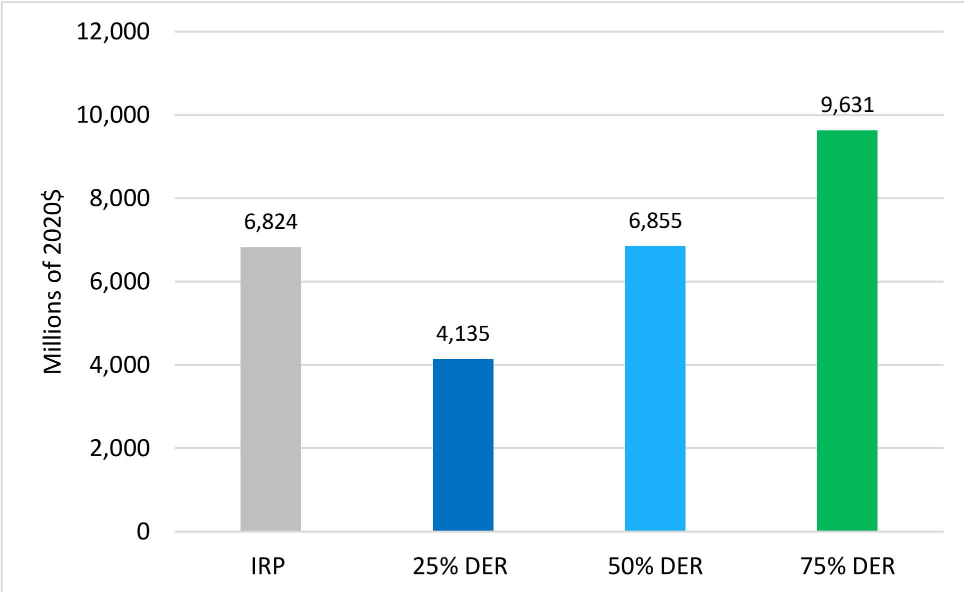
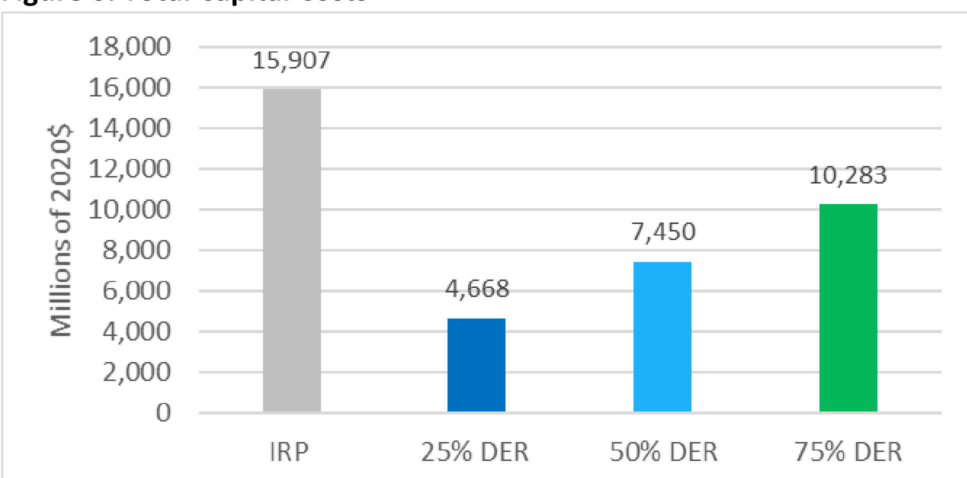


Figure 6: Total Capital Costs[33]



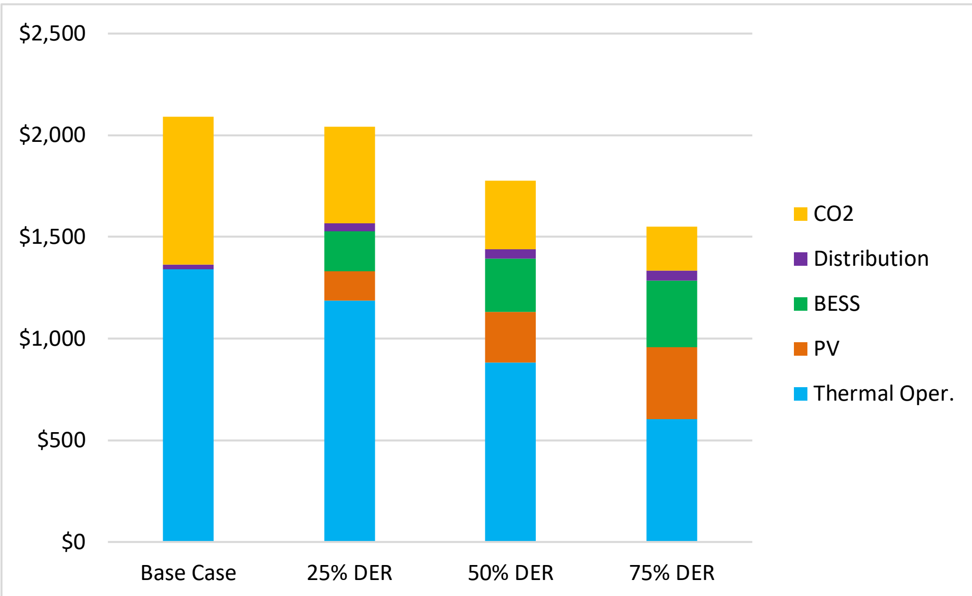
Overall 2035 Costs Are Lower in the 75% DER Scenario

Figure 7 shows the total costs of the scenarios in 2035, including both operational costs and the annualized cost of solar and battery storage systems. The base case includes no capital costs for new generation which represents a conservative approach. Capital costs are modeled assuming a 6.5% cost of capital, an estimate that assumes that PREPA is responsible for financing of solar and battery storage systems.[34] The figure also includes a carbon cost to take into account the climate change damage caused by burning fossil fuels. Including carbon costs, all of the DER

[32] Source: EFG Report, Figure 12.
[33] Fuente, Informe EFG
[34] PREPA's most recent long-term debt issuances prior to bankruptcy had interest rates in the 5-7% range. EFG modelled financing costs using a value that was conservatively high compared to the interest rates faced by other public power utilities.

scenarios are progressively less expensive than the base case. Even without the carbon cost, and without capital costs for new generation in the base case, the 75% DER cost scenario is slightly less expensive than the base case, as increasing capital costs are balanced by declining fuel import costs.

Figure 7: Total System Costs (Millions of 2020$) in 2035[35]



Impact on Electric Rates

To evaluate the affordability of these scenarios, we derived an estimate of the electric rate in each DER scenario in 2035. Generation costs shown in Figure 8 include thermal unit operational costs and the annualized capital costs for PV and storage, assuming that PREPA finances the installation of these systems.[36] Non-generation costs are based on PREPA's certified FY 2021 budget, but excluding costs related to the privatization of the system and to PREPA's bankruptcy process, under the assumptions that PREPA remains a public utility and emerges from bankruptcy well before 2035.[37] The non-generation system costs also include the annualized cost of financing the distribution system capital upgrades identified in the EE Plus study. We further include a scenario in which Puerto Rico is able to direct $9 billion in grid reconstruction funding towards distributed energy resources and $650 million to distribution

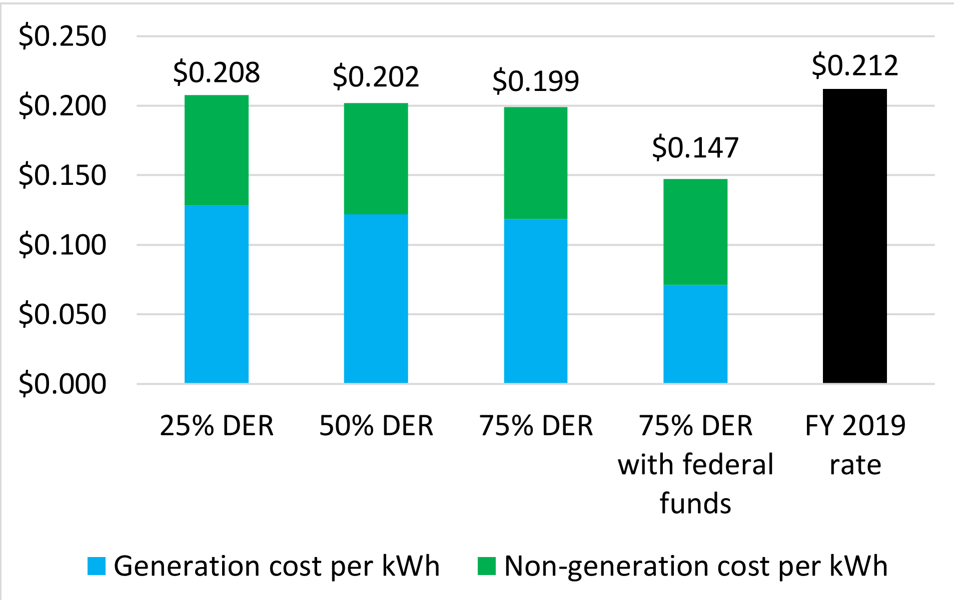
[35] EFG Report, Figure 6.

[36] Our analysis assumes that PREPA customers in 2035 are paying the debt service on prior years' installations. As a sensitivity, we analyzed the impact on rates if PREPA finances these installations at 8.5%, not 6.5%. In that case, the cost of the 75% DER scenario only increases by about 1 cent to 21.1 cents/kWh.

[37] Specifically, our non-generation cost estimate is derived from PREPA's FY 2021 Certified Budget. Labor costs were adjusted based on the ratio of non-generation to total employees. Generation maintenance expenses as well as line items for "PREPA Restructuring & Title III," "FOMB Advisor Costs allocated to PREPA", "P3 Authority Transaction Costs" and "T&D Operator Costs" were also excluded. Finally, we included an estimate of energy efficiency program costs based on PREPA's IRP modeling.

system upgrades to achieve the 75% DER scenario.[38] We arrive at total system costs at or below 20 cents per kWh in the 50% and 75% DER scenarios, and below 15 cents/kWh in the scenario with federal funding. It is worth noting that 20 cents per kWh is the rate set as desirable target in PREPA's Fiscal Plans and defined in the Preamble of Law 17-2019.

Figure 8: Average Costs in 2035 per kWh (in 2020 dollars)



These scenarios compare favorably with recent PREPA rates, shown in the black bar in Figure 7. We emphasize that electric rates in the DER scenarios will be much less subject to fuel price volatility than current rates.

It is worth highlighting that the scenarios evaluated for modeling were never cost-optimized. That is, the scenarios were developed to explore the operation of the Puerto Rico grid at pre-defined high levels of distributed renewable energy penetration, with renewable energy and household resiliency goals in mind. They were not developed to minimize total system cost (and decisions about which units to retire included factors such as emissions rates, age, flexibility and location, in addition to cost). Therefore, it is particularly significant that we find that the high-penetration DER scenarios are affordable, as defined by Law 17-2019.

It is also important to note that the non-generation costs in the above figure do not reflect any costs related to PREPA's legacy debt or its underfunded pension liability. The May 2019 PREPA Restructuring Support Agreement would impose a surcharge on electric rates of 2.6 cents/kWh

[38] This assumption takes into account $1.9 billion in forthcoming HUD funding for grid reconstruction work, an existing allocation of $850 million in FEMA 404 funding for natural gas plants that could be repurposed and the fact that PREPA has proposed to spend $8.4 billion in FEMA 428 funding on its transmission and distribution systems despite only receiving Energy Bureau approval to spend about $2 billion over the next 5 years.

in 2035,[39] which would push rates above 20 cents/kWh in all but the last of the scenarios show in Figure 7, without any provision for PREPA's pension liability.

Finally, we highlight that Figure 8 reflects average cost of the system; no specific ratemaking policy is assumed. The cost of residential and commercial rooftop solar and battery installations will decline over time, and it should be a goal of public policy to ensure that rates for all customers are just and reasonable. This would require decisions about how to allocate subsidies across income levels to ensure an equitable transition in which low-income households are able to participate in energy resiliency solutions.

Achieving the Queremos Sol Scenario

The Queremos Sol high penetration scenario (75% distributed renewable energy by 2035) is the most cost-effective strategy modeled thus far for PREPA to achieve RPS goals, mitigate risks due to grid failure, lower CO_2 emissions and attain reasonable and more stable rates. PREPA's current path will not achieve these goals or the DER scenarios proposed by 2035. PREPA has been ordered by the Energy Bureau to procure a large amount of renewable energy and storage over the next several years (3750 MW of solar by 2023), but the focus is not on rooftop solar systems.

If PREPA were to aim specifically for a higher penetration of distributed renewable energy, it could implement an on-bill financing program in which customers could install solar and battery systems and pay back their investment through their electric bills. PREPA could directly offer the systems to customers, using PREPA employees and a network of local contractors, as needed, to perform the installations. A well-designed program should make use of community partners to market the program to households. If it is a requirement of federal funding that PREPA retain ownership of the systems, PREPA could lease the systems to customers.

It is clear that federal funds present a unique opportunity to lower overall systems costs while implementing DER scenarios modeled. In light of the experience of Hurricane Maria, there is a clear case to be made that siting generation at points of consumption (rather than relying on long-distance transmission) and enabling households to become self-sufficient in energy production will save lives in future severe storms. Significant federal funding is available (around $12 billion)[40], although thus far PREPA has proposed to use those funds towards rebuilding a centralized generation system reliant on fossil fuels.[41] In contrast, $9-$10 billion in federal funding could be deployed towards implementing high DER scenarios that would result in real resiliency, e.g. through deployment of rooftop PV and storage to serve critical loads. This level of funding leaves $2-$3 billion of federal funds available to address upgrades that require urgent attention at the transmission and distribution level.

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[39] The Restructuring Support Agreement provides for 3.76 cents/kWh in FY 2035, which we have converted to 2020 dollars for consistency with Figure 6.

[40] Including FEMA 404 and 428 funds, and HUD CDBG funds

[41] PREPA currently proposes to spend over $800 million in FEMA 404 funds for a new natural gas plant near San Juan and new peaker generation. PREPA has also proposed to spend $8.4 billion in FEMA 428 funds on upgrades to its transmission and distribution systems.

Other jurisdictions provide examples of policies that have successfully achieved higher levels of distributed renewable energy penetration than PREPA is currently seeking to achieve. For example, more than 21% of households in Australia have rooftop solar installations.[42] Initially, feed-in tariffs helped drive the market for rooftop solar, but they have now been phased out. Rebates are still available to cover roughly one-third of upfront costs.[43] High electric rates (above US $0.20/kWh) have helped make rooftop solar an economic choice for households. Hawaii has achieved even higher penetrations of rooftop solar, with one-third of homes on the island of Oahu having rooftop solar.[44] With the highest electric rates in the United States, rooftop solar makes economic sense in Hawaii and has also been driven by supportive policies to compensate homeowners for power exported to the grid.[45]

Additionally, achieving the Queremos Sol scenario also requires significant investment in energy efficiency, which PREPA has already been ordered to do by the Energy Bureau.[46] There are many examples in the United States of ratepayer funded energy efficiency programs to achieve the levels of energy savings described in the EFG study. Such programs offer financial incentives to customers to install more efficient lighting, refrigeration, air conditioning, and other products, as well as solar hot water heaters, to encourage the adoption of efficient technologies. Although such programs cost money and are funded through electric rates, they ultimately save money for all customers because they are cheaper than the cost of investing in new generation. An important first step would be to conduct an energy efficiency potential study to inform the design of cost-effective energy efficiency programs.

Areas for Future Work

The modeling conducted for this study reveals several opportunities for future work:

- The Telos study was conservative in its decisions about which existing power plants could be retired. A more detailed study of resource adequacy would show which additional units would be candidates for retirement or conversion to synchronous condensers.
- Both the Telos and EE Plus studies recommended additional studies and modeling tools to evaluate other options for grid stability at the 75% DER scenario.
- A residential appliance saturation study, and a similar study to determine baseline commercial energy consumption, should be undertaken to better understand current energy consumption. This would inform the design of effective energy efficiency programs to achieve the desired savings.[47]

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[42] Australian Department of Industry, Science, Energy and Resources, “Solar PV and Batteries,” https://www.energy.gov.au/households/solar-pv-and-batteries, last accessed January 26, 2021.

[43] Jason Deign, “What the U.S. can learn from Australia’s roaring rooftop solar market,” Greentech Media, August 3, 2020.

[44] Hawaiian Electric, “2019 saw 21% jump in solar generation capacity,” January 17, 2020.

[45] Hawaiian Electric, “Private Rooftop Solar,” last accessed January 26, 2021.

[46] The Energy Bureau ordered PREPA to “Support all necessary steps to establish EE programs at 2%/year savings including quick-start programs.” (Puerto Rico Energy Bureau, Final Resolution and Order, Case No. CEPR-AP-2018-0001, August 21, 2020, p. 283.)

[47] EFG report, p. 8.

- Additional avenues for future study are outlined in Section 10 of the Telos report.

In addition to technical modeling needs, more work must be done to identify workforce development and training needs and to identify possible sources of federal funding to support worker training. Additional investigation is also needed to develop a plan for recycling of PV and battery systems at the end of their useful lives.

Conclusions

In 2018, Queremos Sol put forth a vision of Puerto Rico’s electrical system based on efficiency and decentralized, renewable energy. The modeling summarized in this report has shown that achieving 75% distributed renewable energy in 2035, with 100% of households equipped with solar and battery storage to address critical loads, is both technically and economically feasible. This scenario would result in a grid that is far less dependent on long-distance south-to-north transmission, that does not rely extensively on imported fossil fuels and that does not lock Puerto Rico into new natural gas infrastructure. Achieving this scenario will require a change of course in policy to truly prioritize rooftop solar and storage systems. Puerto Rico has a historic opportunity to use billions of dollars of federal grid reconstruction funding to redesign an electrical grid to promote real resiliency, an opportunity which is unlikely to come again.

About the Authors

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Ingrid M. Vila-Biaggi is co-founder and President of CAMBIO, a non-profit organization based in Puerto Rico that designs, promotes and implements sustainable policies and practices. She has held several government positions, including Chief of Staff for the Commonwealth of Puerto Rico where she oversaw policy development and implementation of over 100 agencies and corporations and served as liaison to the Puerto Rico White House Task Force. She collaborates and coordinates Queremos Sol, an alliance of environmental, labor, community groups and energy experts, aimed at transforming Puerto Rico's energy sector, establishing a 100% clean renewable path. She also works with the Caño Martín Peña communities as Urban Waters Ambassador. Vila-Biaggi is a former Open Society Leadership in Government Fellow and recently joined the Institute for Energy Economics and Financial Analysis' Board. Vila-Biaggi has a bachelor's degree in Civil and Environmental Engineering from Cornell University and a master's degree in Environmental Engineering from Stanford University.

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