NEPR

Received:

Oct 23, 2019

2:42 PM

COMMONWEALTH OF PUERTO RICO
PUBLIC SERVICE REGULATORY BOARD
PUERTO RICO ENERGY BUREAU

IN RE:

INTEGRATED RESOURCE PLAN
FOR THE PUERTO RICO
ELECTRIC POWER AUTHORITY

NO. CEPR-AP-2018-0001

SUBJECT: PRE-FILED
WRITTEN TESTIMONY

MOTION SUBMITTING EXPERT WITNESS WRITTEN TESTIMONY

TO THE HONORABLE PUERTO RICO ENERGY BUREAU:

COMES NOW Environmental Defense Fund (EDF) and respectfully submits the following Expert Witness Testimony ("Pre-Filed Testimony"), pursuant to Regulation No. 9021, known as the Regulation on Integrated Resource Plan (IRP) for the Puerto Rico Electric Power Authority (PREPA or Company), Regulation 8543, known as the Regulation on Adjudicative, Notice of Noncompliance, Rate Review and Investigation Procedures, and Puerto Rico Energy Bureau's ("PREB") July 3, 2019 Resolution and Order, August 21, 2019 Resolution and Order, and September 23, 2019 Resolution and Order (collectively referred to as "PREB's Resolutions").

Pursuant to PREB's Resolutions, EDF reserves its right to file substantive and legal arguments, based only on information presented during discovery and the evidentiary hearings, at the Final Brief filing, due on December 20, 2019.

EDF submits with this MOTION a duly attested Expert Witness Written Testimony from Dr. Elzabeth A. Stanton.

WHEREFORE, EDF respectfully requests that the Bureau takes notice on the above-mentioned MOTION and accept the testimonies hereby filed.

RESPECTFULLY SUBMITTED,

IN SAN JUAN, PUERTO RICO, THIS 23rd DAY OF OCTOBER, 2019.

ENVIRONMENTAL DEFENSE FUND

__/s/Agustín F. Carbó Lugo______
Agustín F. Carbó Lugo
TSPR-RUA No. 13,801
Attorney for Environmental Defense Fund
257 Park Avenue South
New York, New York 10010
Tel. 214-620-7650
Email: acarbo@edf.org

CERTIFICATION OF FILING AND SERVICE

IT IS HEREBY CERTIFIED that the foregoing was sent to the Puerto Rico Energy Bureau through its electronic filing tool at https://radicacion.energia.pr.gov and to the Puerto Rico Electric Power Authority to the following: Nitza D. Vázquez Rodríguez (n-vazquez@aeepr.com); Astrid I. Rodríguez Cruz (astrid.rodriguez@prepa.com); Jorge R. Ruíz Pabón (jorge.ruiz@prepa.com), Katiuska Bolaños (kbolanos@diazvaz.law), and Maralíz Vázquez (mvazquez@diazvaz.law), and the following intervenors: Javier Rúa-Jovet, Sunrun (javier.ruajovet@sunrun.com); Pedro Saadé-Lloréns, Ruth Santiago and Raghu Murthy, Local Environmental Organizations (pedrosaade5@gmail.com, rstgo2@gmail.com and rmurthy@earthjustice.org); Carlos A. Reyes and Carlos E. Colón-Franceschi, EcoEléctrica (carlos.reyes@ecoelectrica.com and ccf@tcmrslaw.com); Roy Torbert, Rocky Mountain Institute (rtorbert@rmi.org); Víctor L. González and Marc G. Roumain-Prieto, Grupo Windmar (victorluisgonzalez@yahoo.com, mgrpcorp@gmail.com); Hannia B. Rivera-Díaz and Jessica Rivera-Pacheco, Oficina Independiente de Protección al Consumidor (hrivera@oipc.pr.gov, jrivera@cnslpr.com); Manuel Fernández-Mejías, Empire Gas Company (manuelgabrielfernandez@gmail.com); Axel E. Colón-Pérez, AES Puerto Rico (axel.colon@aes.com, mpietrantoni@mpmlawpr.com and apagan@mpmlawpr.com); Alexandra Casellas-Cabrera and Corey Brady, National Public Finance Guarantee (acasellas@amgprlaw.com and corey.brady@weil.com); Mariana Ortíz-Colon and Raúl Negrón-Casanovas, Progression Energy (maortiz@lvprlaw.com and rnegron@dnlawpr.com); Paul De Moudt, Shell (paul.demoudt@shell.com); Eugene Scott-Amy, Wartsila North America (escott@ferraiuoli.com and sproctor@huntonak.com); Jéramfel Lozada-Ramírez, ACONER (aconer.pr@gmail.com); Fernando E. Agrait, Non Profit Intervenors (agraitfe@agraitlawpr.com); Pablo Vázquez-Ruíz, CIAPR (presidente@ciapr.org); Renew Puerto Rico (castrodieppalaw@gmail.com, voxpopulix@gmail.com); Arctas Capital Group (sierra@arctas.com, tonytorres2366@gmail.com); SESA-PR & Caribe GE (cfl@mcvpr.com);

League of Cooperatives of Puerto Rico and AMANESER 2025 (info@liga.coop, amaneser2020@gmail.com).

__*/s/Agustín F. Carbó Lugo*______
Agustín F. Carbó Lugo
TSPR-RUA No. 13,801
Attorney for Environmental Defense Fund
257 Park Avenue South
New York, New York 10010
Tel. 214-620-7650
Email: acarbo@edf.org

Puerto Rico Electric Power Authority (PREPA) Least Cost Integrated Resource Plan

Docket No. CEPR-AP-2018-0001

DIRECT TESTIMONY OF

ELIZABETH A. STANTON, PHD
ON BEHALF OF ENVIRONMENTAL DEFENSE FUND

APPLIED ECONOMICS CLINIC

OCTOBER 23, 2019

A. INTRODUCTION

Q: Please state your name, business address, and job title.

A: My name is Elizabeth A. Stanton, Ph.D. I am the Director and Senior Economist of the Applied Economics Clinic, 1012 Massachusetts Avenue, Arlington MA 02476.

Q: On whose behalf are you testifying in this proceeding?

A: I am testifying on behalf of Environmental Defense Fund.

Q: Dr. Stanton, what is your education and professional background?

A: I am the founder and Director of the Applied Economics Clinic, a non-profit consulting group. The Applied Economics Clinic ("the Clinic") provides expert testimony, analysis, modeling, policy briefs, and reports for public interest groups on the topics of energy, environment, consumer protection, and equity. The Clinic provides training to the next generation of expert technical witnesses and analysts through applied, on-the-job experience for graduate students in related fields and works proactively to support diversity among both student workers and professional staff.

I am a researcher and analyst with more than 18 years of professional experience as a political and environmental economist. I have authored more than 160 reports, policy studies, white papers, journal articles, and book chapters on topics related to energy, the economy, and the environment. My articles have been published in Ecological Economics, Climatic Change, Environmental and Resource Economics, Environmental Science & Technology, and other journals. I have also published books, including *Climate Change and Global Equity* (Anthem Press, 2014) and *Climate Economics: The State of the Art* (Routledge, 2013), which I co-wrote with Frank Ackerman. I am also co-author of *Environment for the People* (Political Economy Research Institute, 2005, with James K. Boyce) and co-editor of *Reclaiming Nature: Worldwide Strategies for Building Natural Assets* (Anthem Press, 2007, with Boyce and Sunita Narain).

My recent work includes Integrated Resource Plan (IRP) and Demand-Side Management (DSM) planning review, analysis and testimony of state climate laws as they relate to proposed capacity additions, and other issues related to consumer and environmental protection in the electric and natural gas sectors. I have submitted expert testimony and comments in state dockets in New Hampshire, Massachusetts, Vermont, Indiana, Illinois, Louisiana, and Minnesota as well as several federal dockets.

In my previous position as a Principal Economist at Synapse Energy Economics, I provided expert testimony in electric and natural gas sector dockets, and led studies examining environmental regulation, cost-benefit analyses, and the economics of energy efficiency and renewable energy. Prior to joining Synapse, I was a Senior Economist with the Stockholm

Environment Institute's (SEI) Climate Economics Group, where I was responsible for leading the organization's work on the Consumption-Based Emissions Inventory (CBEI) model and on water issues and climate change in the western United States. While at SEI, I led domestic and international studies commissioned by the United Nations Development Programme, Friends of the Earth-U.K., and Environmental Defense Fund, among others.

I earned my Ph.D. in economics at the University of Massachusetts-Amherst, and have taught economics at Tufts University, the University of Massachusetts-Amherst, and the College of New Rochelle, among other colleges and universities. My curriculum vitae is attached to this testimony as Exhibit A.

Q: Dr. Stanton, what is your prior experience with Integrated Resource Plans?

A: I have provided comments to the official review processes for Integrated Resource Plans (IRPs) in Indiana (IPL 2016, Vectren 2016, NIPSCO 2016 and 2018, Duke 2018, I&M 2018), and assisted intervenors with IRP review in Minnesota and North Carolina. I have also reviewed and provided comments on gas-sector IRPs and related planning documents in New Hampshire, Massachusetts, and Virginia.

B. OVERVIEW

Q: Please summarize your conclusions.

A: I recommend that the Energy Bureau reject PREPA's June 2019 IRP and require that the Utility resubmit an IRP with the following instructions and conditions:

1. PREPA must constrain all modeling runs to follow Puerto Rican law, including Act 17-2019.

2. PREPA must submit model runs with higher demand forecasts including much lower representations of the pace and extent of build out of customer-owned generation, (b) energy efficiency estimates that meet but do not exceed Act 17 requirements; (c) a combination of both (a) and (b), and (d) a sensitivity showing more modest energy efficiency savings that fail to meet the Act 17 standard.

3. PREPA must issue an all resource (technology neutral) RFP for new generation and peak-shifting resources that is open to both supply and demand-side measures, and must use the costs derived from RFP responses in its resource expansion modeling. It would be inappropriate for such an RFP to be conducted by PREPA's current consultants, and the RFP responses must be made available (under confidentiality agreements) to stakeholders' experts.

4. PREPA must hold more stakeholder meetings for the general public for future IRPs, in various locations and in Spanish.

While my conclusions and recommendations should not be misconstrued as depending on missing information as yet not supplied by PREPA, it is worth noting that many of PREPA's responses to discovery questions were incomplete or non-responsive, including discovery responses indicating that the text of the IRP was incorrect and that other documents or spreadsheets, in fact, contain the correct information.

Q: Please describe the information you reviewed.

A: In my preparation of this testimony, I reviewed PREPA's June 2019 IRP and the associated appendices, attachments, and discovery responses relevant to the topics I discuss here.

Q. Have you performed any other research that has helped form your opinions in this case?

A. Yes. I led a group of energy policy experts at the Applied Economics Clinic who performed a study comparing the energy planning needs in Hawaii with those of Puerto Rico. The result of our work is a report entitled: *Puerto Rico Integrated Resource Plan: Lessons from Hawaii's Electric Sector,* which I co-authored and which was prepared under my supervision and control. A true and accurate copy of the report is attached to my testimony as Exhibit B.

Q. Why is Hawaii's IRP process a valuable comparison for the development of Puerto Rico's IRP?

A. Hawaii's IRP process a valuable comparison for the development of Puerto Rico's IRP because of the parallels that exist between the Hawaiian and Puerto Rican electric sectors:

- Small population (Hawaii has the 11th smallest population and Puerto Rico's is a little smaller than Iowa, the state with the 20th smallest population),
- Substantial fossil fuel dependence (fossil fuels accounted for 83 percent of Hawaii's 2018 total generation and 98 percent of Puerto Rico's 2018 total generation),
- Both Hawaii and Puerto Rico use much more oil for electric generation (70 and 45 percent, respectively) compared to the United States as a whole (<1 percent);
- High electric rates (residents in Hawaii and Puerto Rico pay at least 170 percent more than the average U.S. electric customer),
- Modest electric demand (taken together, Hawaii and Puerto Rico's annual electric generation accounts for less than 1 percent of the U.S. total),
- High potential for solar generation, and
- High vulnerability of coastal infrastructure to large ocean storms and sea level rise. *See* Exhibit B.

Q. Please summarize the lessons learned from Hawaii's IRP that the Bureau should apply in reviewing PREPA's IRP.

A: The Hawaiian utilities' development of their 2016 resource plan points to nine best practices for other utilities seeking to balance strong renewable energy policy requirements with grid resiliency. These important lessons have the potential to improve Puerto Rico's planning process, ensure that PREPA complies with Puerto Rico's climate policies, and provide the lowest possible rates to consumers. These best practices are:

- Develop low-cost renewable resources and battery storage,
- Pursue renewables with the highest certainty of deployment early in the planning period,
- Ensure lowest costs for ratepayers by considering renewables on equal footing with fossil fuels,
- Shift from centralized to distributed energy resources,
- Assess all types of distributed energy resources on equal footing with other capacity expansion opportunities,
- Consider grid services and risk reduction from distributed energy resources relative to other capacity expansion opportunities,
- Reduce generation costs by retiring aging fossil fuel plants,
- Place renewable energy, energy efficiency, demand response and battery storage on equal footing with fossil fuel generation for capacity expansion, and
- Assess the risks of stranded costs, uncertainties, and rate impacts of imported LNG fuels and new fossil generation. *See* Exhibit B.

Q: Please provide an overview of PREPA's IRP, including the time period.

A: PREPA's draft 2018-2019 IRP was submitted in February 2019 (First IRP Filing, Feb. 13, 2019) and rejected by Puerto Rico's Energy Bureau in March 2019 (PREB's March 14, 2019 Resolution and Order). An April 2019 Energy Bureau Order directed PREPA to refile its IRP to present a plan that would be in compliance with Act 17-2019 (PREB's April 5, 2019 Resolution and Order). In June 2019, PREPA refiled its IRP with the Bureau (Second IRP Filing, June 7, 2019). PREPA's June 2019 IRP includes a five-year action plan for 2019 through 2023 and longer-range resource modeling through 2038.

Q: Do you have an opinion as to whether a utility should use a stakeholder process to incorporate input for its IRP?

A**:** In my opinion, participation by stakeholders—including government agencies or officials, businesses, and public interest groups—during the development of an IRP has the potential to improve the document submitted to the utility commission or energy bureau. A well-designed IRP stakeholder process permits public comment and critique at a time best suited to affect change in the planning process and can therefore be more efficient, and less costly, than a process in which an IRP is submitted, rejected, and resubmitted. IRP stakeholder processes are at their most effective when utilities provide transparent access to all modeling inputs and outputs, and access to the modeling tools used, to stakeholders' third-party experts. A detailed review of modeling assumptions and methodologies by experts other than the authors or modelers themselves is essential to quality control and makes an open, in-depth discussion of IRP findings possible.

Q. Did PREPA conduct a stakeholder process to seek input for its IRP?

A. Yes. PREPA held several stakeholder meetings to gather input for its 2019 IRP, as shown in a summary it prepared and published on its website entitled: *Integrated Resource Plan of 2018 Stakeholder Engagement Workshops Summary* (http://energia.pr.gov/wp-content/uploads/2018/09/PREPA-2018-IRP-Stakeholder-Workshop-Summary-June-2018.pdf).

Q. Do you have any recommendations regarding the stakeholder engagement process that PREPA should follow for future IRPs?

A. Yes. The summary showed that PREPA only held one stakeholder engagement meeting for the general public, which was held in San Juan. I recommend that the Bureau require PREPA to hold more stakeholder meetings for the general public for future IRPs, in various locations and in Spanish.

Q. Do you have any concerns with PREPA's selection of Siemens as its consultant for preparing its 2019 IRP?

A. Yes. I am concerned that PREPA's has not resolved issues of bias and "blurred lines" between public interests and Siemens' interests.

In its final resolution and order on PREPA's first IRP in September 2016 (Sept. 23, 2016 Final Resolution and Order, CEPR-AP-2015-0002), the Bureau ordered PREPA to develop and carry out internal procedures to ensure that future IRPs comply with its legal obligations and satisfy professional standards. Starting on page 37, the Bureau lays out its concerns about relying almost entirely on Siemens to prepare the IRP and using gas plants manufactured by Siemens as part of the IRP supply plan. The Bureau noted:

> A key purpose of an IRP is to determine the need for and type of generating units. The purpose of a least-cost resource planning process is to minimize system costs over the long term… The typical approach, therefore, describes resource options in generic terms only.
>
> … a choice of specific manufacturers or project specifications is typically considered only after generic resource choices have been selected; i.e., after the IRP process is concluded. Where the consultant conducting resource planning has a business interest in resource selection, there is a risk of bias… and
>
> In this IRP, Siemens was involved in the selection of both methodology and resources – a role especially influential given PREPA's lack of IRP experience. And the analysis did not speak solely in terms of generic units. Rather, it described specific units manufactured by Siemens, along with those of several other companies. PREPA conducted a screening study that included turbines from seven manufacturers… But the thermal resource selection process conducted by Siemens PTI reviewed closely only three options: one from GE and two from Siemens technologies." Sept. 23, 2016 Final Resolution and Order, CEPR-AP-2015-0002.

Following the above September 2016 Order, PREPA requested the Commission render a finding that Siemens was unbiased and independent arguing that there was a conscious effort to identify various suppliers for all generation options. The Commission denied PREPA's motion in February 2017 (PREB's Feb. 10, 2017 Resolution and Order, rhttp://energia.pr.gov/wp-content/uploads/2017/02/10-feb-2017-Resolution-Ruling-on-PREPAs-Verified-Motion-for-Reconsideration.pdf) for reconsideration and stated that PREPA failed to demonstrate Siemens' independence:

> This included sustaining [PREPA's] burden of proving that nothing in its actions with Siemens could provide even the appearance of a conflict… The IRP recommendations appear to blur the lines between public interest and Siemens' interests. (id. at page 33-4).

Q. What is your recommendation regarding PREPA's use of consultants to prepare this IRP?

A. I recommend that if the Bureau approves a supply plan that calls for any new generating resource, that the Bureau require PREPA to hire an independent party to perform a competitive solicitation process to get the lowest price and to ensure that contracts awarded by utilities serve the public interest. In addition, using an independent party reduces the possibility that the utility will favor a consultant that it has communicated with before. In this context, FERC guidelines offer four principles for RFPs can help ensure that no party has any undue advantage at any stage of an RFP (U.S. Federal Regulatory Commission, Order Granting Authorization to Make Affiliate Sales, Docket No. ER06-777-000, p. 4, May 18, 2006, https://www.ferc.gov/whats-new/comm-meet/051806/E-9.pdf):

1. Transparency: the competitive solicitation process should be open and fair;
2. Definition: the product or products sought through the competitive solicitation should be precisely defined;
3. Evaluation: evaluation criteria should be standardized and applied equally to all bids and bidders;
4. Oversight: an independent third party should design the solicitation, administer bidding, and evaluate bids prior to the company's selection. As discussed below, the Commission finds that the bidding process used here is an example of a process that meets these guidelines.

C. ACT 17-2019 COMPLIANCE

Q: Please provide an overview of Act 17-2019.

A: Signed into law on April 11, 2019, Act 17-2019 is Puerto Rico's Energy Public Policy Act, which establishes "an effective programming that allows for the setting of clear parameters and goals for energy efficiency, the Renewable Portfolio Standard, the interconnection of distributed generators and microgrids, wheeling, and the management of electricity demand." Act 17-2019, Statement of Motives. Act 17 makes Puerto Rico's 2010 Renewable Portfolio Standard (RPS) more stringent by updating the territory's previous renewable generation supple requirements. The new law established the following schedule for RPS compliance: renewable generation must account for 20 percent of PREPA's total energy production by 2022, 40 percent by 2025, 60 percent by 2040 and 100 percent by 2050. *Id*. at sec. 4.2.

The Act also declares that the Government of Puerto Rico must "guarantee that the cost of the electric power service in Puerto Rico be affordable, just, reasonable, and nondiscriminatory for all consumers in Puerto Rico" by mandating that the Energy Bureau review all proposed charges from an electric power company and "evaluate the efforts made by the electric power company to maintain such fees, rents, rates, and any other type of charge as close as possible to the twenty cent ($0.20) per kilowatt-hour goal established in the Certified Fiscal Plan for the Puerto Rico Electric Power Authority." *Id*. at sec. 1.5. 1(a). One way that least-cost energy is to be secured is by requiring that utilities adopt energy efficiency strategies "geared toward achieving efficiency in the generation, transmission, and distribution of electric power so as to guarantee the availability and supply thereof at an affordable, just, and reasonable cost." *Id*. at sec. 1.5.2(3) and 5(f).

Finally, the Act also states that "the award of new contracts and/or the granting of permits to establish power plants that generate energy from coal and its derivatives is hereby prohibited.

Likewise, no permits or amendments to contracts existing as of the approval of the Puerto Rico Energy Public Policy Act may authorize or consider coal burning as a power generation source after January 1, 2028." *Id*. at sec. 1.4.11.

Q: What did the Energy Bureau's April 2019 Order require of PREPA with regards to Act 17-2019?

A: The Energy Bureau's April 2019 Order (PREB's April 5, 2019 Resolution and Order) proffers two "requirements for all modeling runs" in PREPA's IRP that are relevant to Act 17-2019:

1. Include onshore wind resources in its long-term capacity expansion modeling, and not merely in its resource screening analysis;

2. Conform with the level of renewables required by Act 17: 20 percent of total energy production by 2022, 40 percent by 2025, 60 percent by 2040 and 100 percent by 2050.

Q: Does Siemens' modeling in PREPA's June 2019 IRP include wind resources in all long-term capacity expansion modeling runs?

A: Yes. Siemens' June 2019 IRP includes onshore wind resources in all long-term capacity expansion modeling runs but excludes offshore wind at the resource screening stage of its analysis noting that: "Offshore Wind was considered but it [sic] not included since it is expected to have cost higher [sic] than the equivalent Solar PV project." Second IRP Filing, June 7, 2019, at p. 6-42.

While included in Siemens' modeling, onshore wind resources are never selected for inclusion in any of PREPA candidate portfolios. Failing to pursue opportunities to invest in wind resources in early years means that Puerto Rico loses out on benefits from federal tax credits, which may not be renewed in later years.

Q: Does Siemens' offer evidence of the claimed comparatively high cost of offshore wind?

A: Siemens offers the evidence of a single study of Puerto Rico's potential off-shore wind costs published in 2015 on cost estimates for 2014.

Q: How have cost estimates for off-shore wind changed over time?

A: Leading industry experts estimated off-shore wind costs at $162 per megawatt-hour in 2014 dropping steadily to $92 in 2018 (Lazard's Levelized Cost of Energy Analysis, Ver. 8.0, https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf and Ver. 12.0, https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf) — a 43 percent drop over five years.

Q: Do all of Siemens' modeling runs in PREPA's June 2019 IRP conform with the level of renewables required by Act 17-2019?

A: No. Exhibit 1-3 (p.8-8) in PREPA's June 2019 shows that Siemens conducted 35 modeling runs in total; only 26 of those runs achieve 60 percent renewables in 2038 (the final year of Siemens' modeling period). My calculations based on the information presented in the June IRP show that only 28 of the 35 modeling runs achieve 40 percent renewables in 2025. *See* Second IRP Filing, June 7, 2019, at Exhibit C.

Q: Does PREPA's June 2019 IRP "Action Plan" conform with the level of renewable required by Act 17-2019?

A: Yes. Given the caveats regarding demand forecasts discussed below, PREPA's preferred portfolio, or "Action Plan"—the Energy System Modernization (ESM) case—exceeds 60 percent renewables in 2038 (*id.* at Exhibit 1-3, p.8-8) and achieves 40 percent renewables by 2025 and 20 percent renewables by 2022. *Id.* at Exhibit C.

Q: Why is it relevant that all of Siemens' modeling runs comply with Puerto Rico's RPS requirement?

A: It is important for modeling to comply with RPS requirements and all basic mandates imposed on the electric system. To this end, all applicable current laws and regulations should be incorporated into every run as an input or modeling assumption. In this way, all portfolios under consideration have the potential to be selected as an Action Plan and the resulting IRP presents multiple viable choices for future resource portfolios along with information allowing their comparison in terms of their costs, risks, and other impacts.

To instead treat compliance with current law as an output of modeling—as Siemens has done with Act 17-2019 in its modeling for PREPA—results in portfolios that are not viable choices as Action Plans, limiting the range of real possible future portfolios offered for stakeholders' consideration.

Q: What determines whether or not Siemens' modeling runs comply with Act 17-2019 in its long-term capacity expansion modeling for PREPA?

A: Compliance with Act 17-2019 in Siemens' modeling runs requires that renewable generation—including renewable distributed generation—meets or exceeds RPS target levels: 20 percent renewable generation as a share of total energy production by 2022, 40 percent by 2025, 60 percent by 2040, 100 percent by 2050.

Three key factors, therefore, determine whether Siemens' modeling runs comply with Act 17:

a) Projected energy demand

b) Planned utility-scale renewable generation

c) Projected customer-owned renewable generation

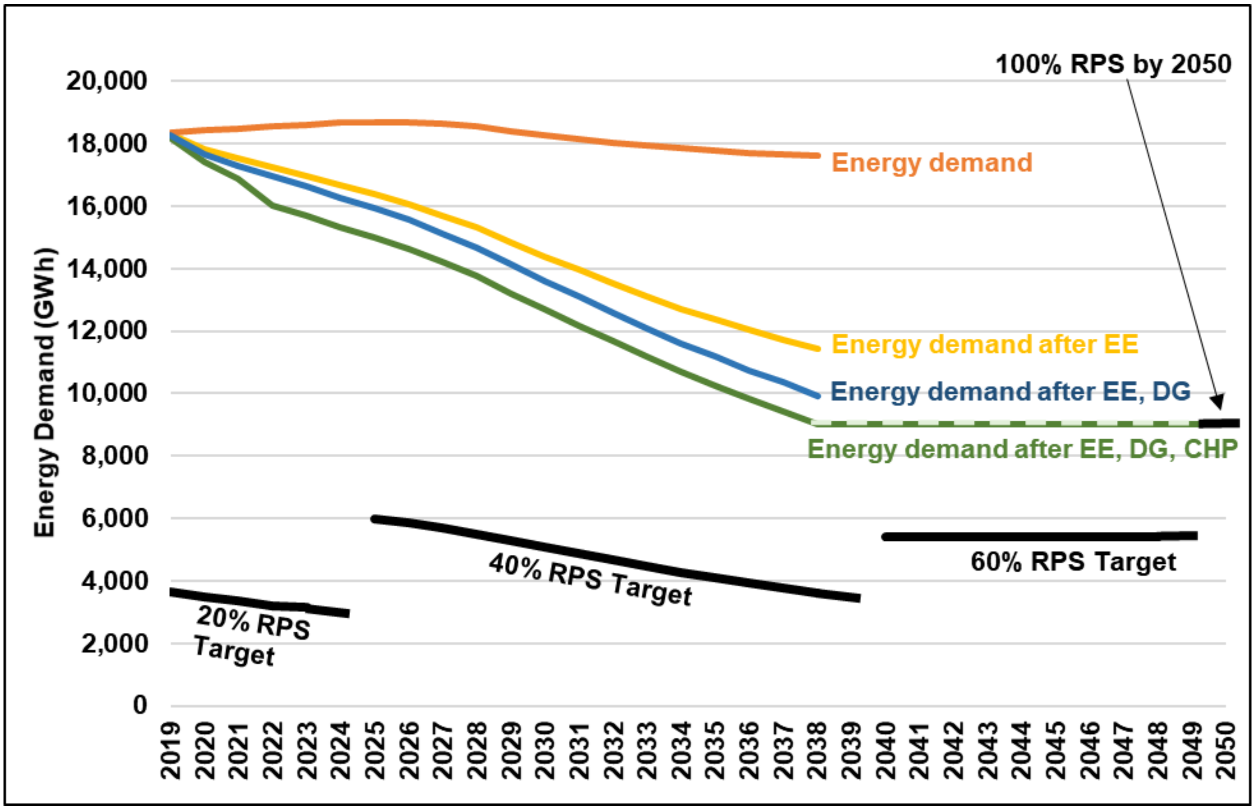
Q: How does projected energy demand impact Act 17-2019 compliance in Siemens' IRP modeling?

A: The lower the expected energy demand in Siemens' IRP modeling, the less renewable generation is needed to meet Act 17-2019 targets. For example, if expected energy demand in 2025 were 20,000 gigawatt-hours (GWh), then 8,000 GWh of renewables would be needed to meet the 40 percent RPS standard. If, instead, expected energy demand in 2025 were 10,000, only 4,000 GWh of renewables would be needed to meet the target.

Q: What forecasts of future energy demand does Siemens use in its IRP modeling for PREPA?

A: Siemens uses base, high and low energy demand forecasts in its IRP modeling for PREPA based on three different forecasts of customer sales. Energy demand is calculated as retail sales less: a 20 percent electric loss factor; energy efficiency savings; customer-owned generation (rooftop solar); and combined-heat and power (CHP) plants. Figure 1 presents Siemens' base case energy demand showing total energy demand (in orange; this is retail sales less electric losses), energy demand less energy efficiency savings (in yellow), energy demand less efficiency savings and customer generation (in blue), and energy demand less efficiency, customer generation, and CHP (in green and, for illustration, shown as remaining constant after 2038).

Figure 1. Siemens' base energy demand forecast with associated RPS targets

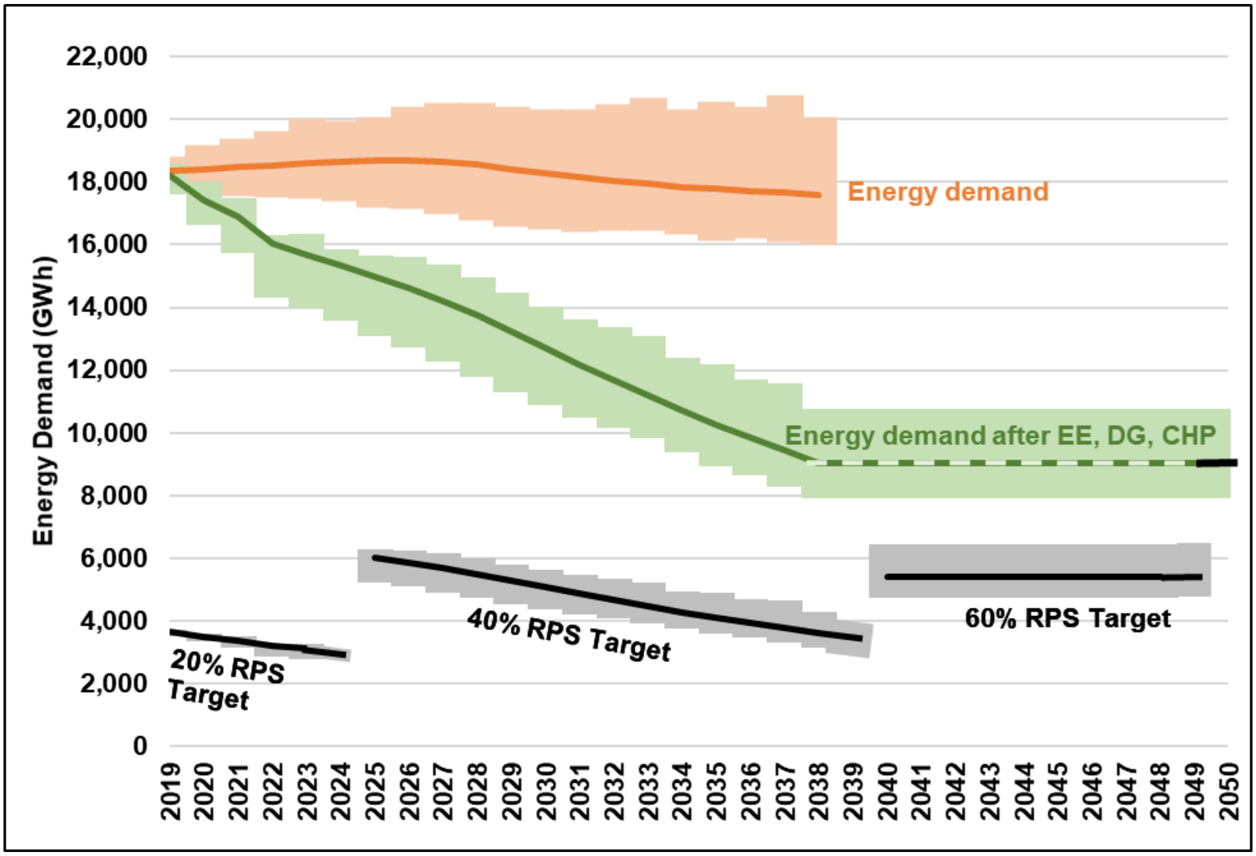


Source: Exhibit C

Under its base load assumptions, Siemens' expects total energy demand to decline very slightly over the 20-year planning period—a 4 percent drop from 2019 to 2038. Net customer demand after taking account of efficiency, customer generation and CHP, however, is forecast by Siemens' to fall to half its current level over the next 20 years, from 18,196 GWh in 2018 to 9,013 GWh in 2038. (Figure 1 also shows the gigawatt-hour RPS targets that result from Siemens' base energy demand forecasts, which decrease as energy demand decreases.)

Figure 2 presents Siemens' base gross energy demand together with the range represented by its high and low energy demand (in orange) and its net energy demand after efficiency, customer generation, and CHP reductions (in green). *Id.* at Exhibit C. Higher energy demand projections lead to higher RPS targets (see range in grey) and lower energy demand projections lead to lower RPS targets.

Figure 2. Siemens' base, high and low energy demand forecasts



Source: Exhibit C

Q: Does Siemens' test its modeling results for their sensitivity to changes in forecasted energy efficiency, customer generation or CHP?

A: No. Siemens does not test its modeling results for their sensitivity to changes in forecasted energy efficiency, customer distributed generation or CHP. Siemens' base, high and low load forecasts all assume an approximately one-half drop in energy demand by 2038.

Q: On what is Siemens' assumption that energy demand will fall to half its current levels based?

A: Siemens' reduction to one-half of current energy demand levels by 2038 is based largely on its (or PREPA's) interpretation of Act 17-2019.

Act 17-2019 requires energy efficiency savings to reach 30 percent by 2040. Act. 17-2019, Sec. 1.6 (11).

Siemens' base load forecast goes beyond this target: Puerto Rico's energy efficiency savings reach 30 percent of <u>gross customer sales</u> (before losses) by 2032 and 42 percent by 2038 (the end of Siemens' modeling period). Energy efficiency savings reach 30 percent of gross customer sales by 2035 in Siemens' high and low load forecasts. Second IRP Filing, June 7, 2019, at Exhibit C.

Energy efficiency savings, customer-owned generation and CHP together reduce 2038 gross energy demand (after losses) by 49 percent. As a share of gross energy demand (customer sales less losses) in 2038:

- Energy efficiency savings are 35 percent of total energy demand
- New customer-owned renewable generation contributes another 9 percent reduction. Siemens assumes that customer-owned DG will account for 30 percent of all renewables (and all RPS compliance) by 2038. *See id*.
- The remaining 5 percent reduction to energy demand comes from Siemens' assumption of 922 GWh of customer-owned CHP generation by 2022. This forecast, presented in PREPA June 2019 IRP Exhibit 3-18, does not appear to be consistent with the expected 71 MW CHP capacity by 2021 discussed in PREPA's Appendix 4. *Id.* at Appendix 4, Exhibit 3-10. PREPA's 71 MW of forecasted CHP includes 12 MW planned capacity, 30 MW of evaluated capacity, and 29 MW of capacity for which there is "incomplete information." *Id*. at Appendix 4, Exhibit 3-5. Even with a 90 percent rate of utilization (called the capacity factor) a 71 MW facility would only be expected to produce 560 GWh annually.

Q: Could a smaller reduction in energy demand still result in compliance with Act 17-2019?

A: Yes. (1) Achieving 30 percent (of customer sales before losses) energy efficiency savings in 2038 (instead of the 42 percent in the ESM plan), (2) assuming that all RPS compliance is met by utility-owned resources, and (3) assuming 12 MW of new CHP capacity operates at a 90 percent capacity factor, would result in 2038 net energy demand that was 30 percent lower than 2018 demand (as compared to the 49 percent lower modeling by Siemens). *Id*. at EAS workbook, Exhibit C.

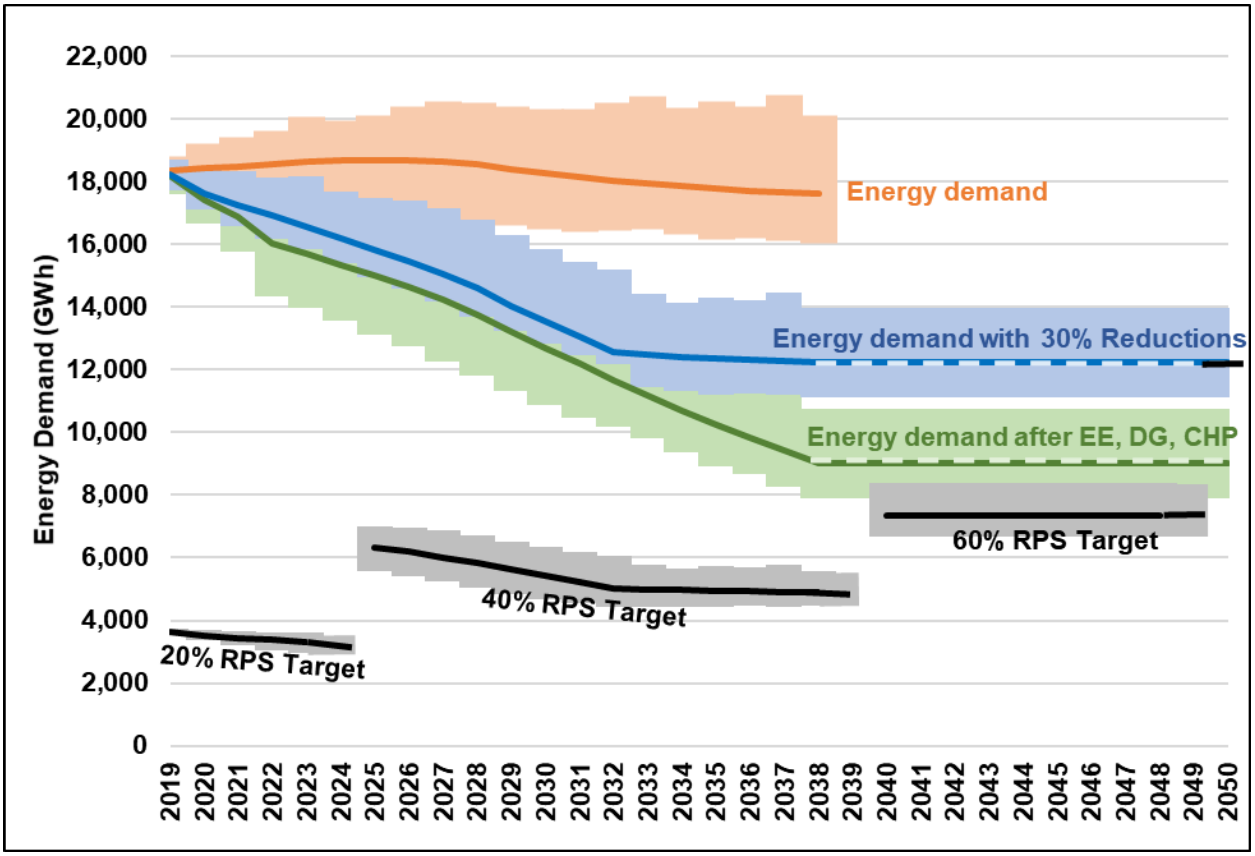
Q: What would examining the sensitivity of Siemens' modeling runs to higher energy demand demonstrate?

A: Lower energy demand requires less renewable generation to comply with the Act 17-2019 RPS standard. Figure 3 presents Siemens' base, high and low load forecasts with its assumed 49 percent reduction in total energy demand by 2038 (in green) and with the lower—but still Act 17 compliant—projection of a 30 percent reduction in total energy demand (in blue).

With a 30 percent reduction in total energy demand (base case in blue line, with shaded area representing high and low load forecasts), the renewable generation needed to comply with the RPS standard (in black line and grey shading) is higher. Under a 30 percent reduction in total energy demand (and under the base load forecast), RPS compliance in 2038 requires 4,893 GWh of renewables—compared to 3,605 required for RPS compliance under a 49 percent reduction in energy demand (and base load forecast). *Id*.

The assumption of a 49 percent reduction in energy demand lowers the renewable generation needed for RPS compliance by 1,288 GWh. That's 26 percent less renewable generation than needed under the—also Act 17-2019 compliant—30 percent energy demand reduction.

Figure 3. Siemens' energy demand forecasts with lower demand reduction



Source: Exhibit C.

Q. Does Siemens energy demand forecast include growth expected from electric vehicles?

A. No, Siemens does not appear to include energy demand from the growing electric vehicle market in its forecasting.

Q. What does PREPA assume regarding current and future electric vehicle levels in Puerto Rico?

A. PREPA assumes that electric vehicle ownership in Puerto Rico will be so small as to have a negligible effect on electric demand: "Electric Vehicles were assessed and found to have a limited impact on the forecast." PREPA's Response No. 52 to Sept. 19, 2019 EDF's Second Set of Interrogatories and Request for Production of Documents and Information.

PREPA's estimates of current-day electric vehicle ownership vary by an order of magnitude from 7,766 in its highest estimate to 453 in its lowest. PREPA further assumes faster growth if today's electric vehicle stock is low (25 percent per year) and slower growth if there are more electric vehicles today (13 percent per year). PREPA's highest growth estimate reaches 2 percent of total electric demand in 2038. *See* PREPA ROI_1_18 Attach 3.xlsx.

Q. What effect does Siemens exclusion of growth in electric vehicle ownership have on its energy demand forecast?

A. The omission of growing demand from electric vehicles results in an underestimate of future energy demand in Puerto Rico.

Q. Has Siemens underestimated Puerto Rico's future electric demand in PREPA's 2019 IRP?

A. Yes, it seems likely that Siemens has underestimated Puerto Rico's future electric demand in PREPA's 2019 IRP by:

- Assuming more energy efficiency savings than called for in Act 17-2019,
- Assuming, without clear justification, that 30 percent of future renewable generation will be supplied by customer-owned generation,
- Modeling more CHP generation than could be produced from expected CHP capacity, and
- Omitting the growing electric demand of new electric vehicles.

Q. What are the consequences of underestimating Puerto Rico's future electric demand in this IRP?

A. As Siemens notes in PREPA's June 2019 IRP: "[I]f energy efficiency gains or customer provided distributed generation do not materialized at the levels modeled, future load could be higher than forecast." Second IRP Filing, June 7, 2019, at p.1-7.

There are two main consequences of underestimating Puerto Rico's future electric demand. First, underestimating demand can lead to underestimation of supply and, therefore, reliability issues. Second, Puerto Rico's Act 17-2019 RPS standard requires renewable generation be supply as a growing share of customer demand. If demand is underestimated, so too is the expected amount of renewable capacity and generation necessary to comply with the RPS. Put simply, undercounting demand leads directly to less planned renewable generation.

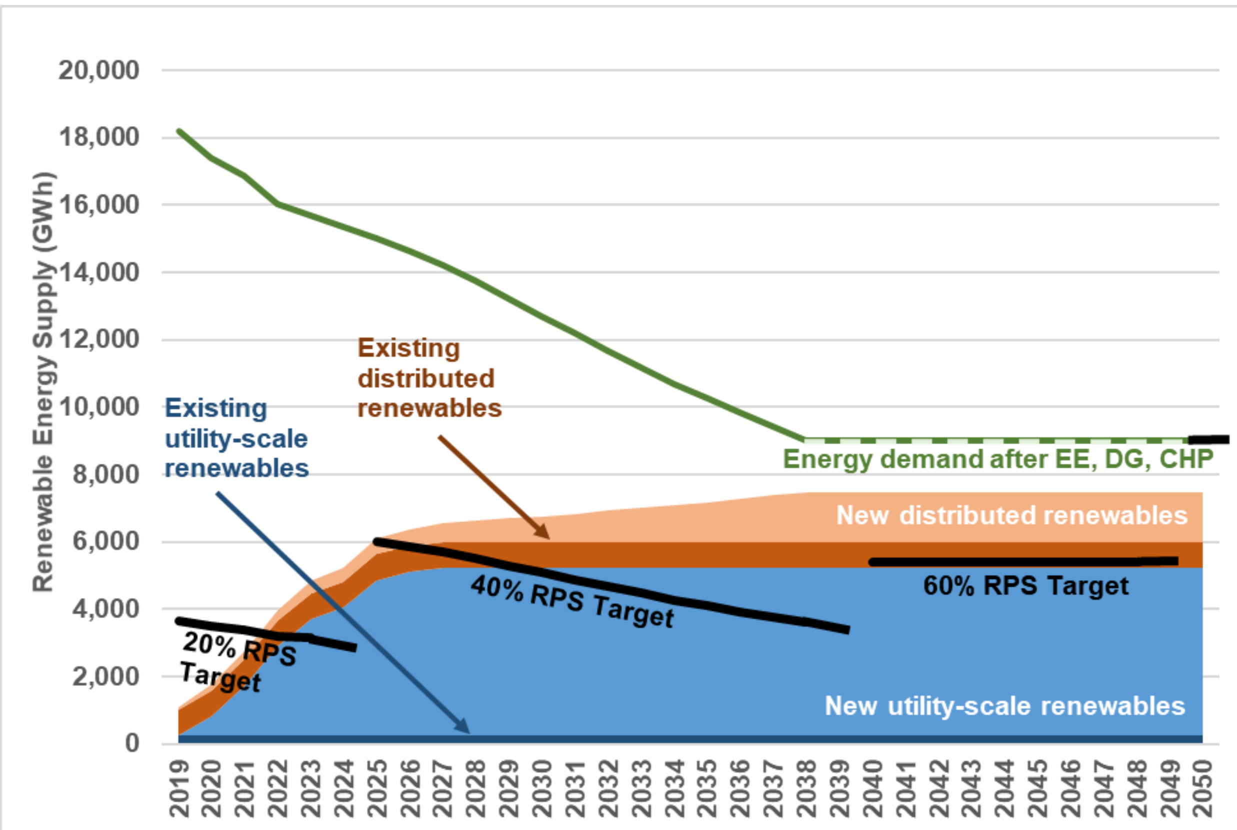
D. RENEWABLE SUPPLY

Q: Are the renewable generating resources proposed in PREPA's June 2019 Action Plan (ESM case) sufficient to comply with the Act 17-2019 RPS standard?

A: Yes, but only using Siemen's assumed rapid energy demand reductions.

The renewable generation resources proposed in PREPA's June 2019 Action Plan (ESM case) are sufficient to comply with the Act 17-2019 RPS standard (see Figure 4). *Id*. at EAS workbook. However, PREPA's RPS compliance relies on its assumed 49 percent demand reduction and assumed 400 MW of new customer-owned renewables.

Figure 4. Energy demand and renewables supply with RPS targets



Source: Exhibit C.

Q: Would PREPA's ESM case comply with Act 17-2019 without its assumed 49 percent reduction in energy demand?

A: No. PREPA's ESM case would not comply with Act 17-2019 without its assumed 49 percent reduction in energy demand. As shown in Table 1, with a (still Act 17-2019 compliant) 30 percent reduction in energy demand by 2038, renewable generation amounts to 38 percent of energy demand in 2025 (compared to the 40 percent target for that year). *Id*.

Table 1. Sensitivity of RPS compliance to demand reduction and customer generation assumptions

	2022	2025	2040
RPS target (share of energy demand)	20%	40%	60%
49% reduction in energy demand (GWh)	16,029	14,997	9,013
30% reduction in energy demand (GWh)	16,902	15,824	12,234
Renewable supply with customer-owned generation (GWh)	3,969	6,091	7,496
(share of total energy demand)	(23% to 25%)	(38% to 41%)	(61% to 83%)
Renewable supply without customer-owned generation (GWh)	2,897	4,863	5,223
(share of total energy demand)	(17% to 18%)	(31% to 32%)	(43% to 58%)

Source: EAS workbook

Q: Would PREPA's ESM case comply with Act 17-2019 without customer-owned renewables?

A: No. PREPA's ESM case would not comply with Act 17-2019 without customer-owned renewables that must be verified and registered for RPS compliance—a process for which procedures do not currently exist in Puerto Rico. As shown in Table 1, without verification and registration of an assumed growing amount of customer-owned renewables, total renewable generation amounts to 43 to 58 percent of energy demand in 2040 (compared to the 60 percent target for that year), depending on the assumed reduction to energy demand. *Id.*

Q: Does Siemens, in its modeling for PREPA, consider renewable resources on equal footing with other capacity expansion opportunities?

A: No. PREPA's June 2019 IRP places annual capacity expansion constraints on solar and battery storage, without limiting fossil fuel resources (see Table 2). For example, in 2022, the model used to determine PREPA's preferred resource plan (ESM case) allows the addition of a maximum of 300 MW of solar resources; the permitted addition of gas resources was unlimited.

Table 2. PREPA June IRP annual installation constraints (MW) for solar and battery storage in its base case, low cost of renewables sensitivity scenario (LCR), and ESM scenario

		Solar	Battery
2019	*Base Case*	0	60-180
	LCR	0	60-180
	ESM	-	20
2020	*Base Case*	300	300
	LCR	300	300
	ESM	-	100
2021	*Base Case*	300	300
	LCR	1,200	1,200
	ESM	240	160
2022-2038	*Base Case*	600	600
	LCR	1,200	1,200
2022	*ESM*	480	160
2023		480	160
2024		300	150

Data source: Siemens Industry. February 12, 2019. Puerto Rico Integrated Resource Plan 2018-2019: Draft for the Review of the Puerto Rico Energy Bureau. Prepared for Puerto Rico Electric Power Authority. Siemens PTI Report Number: RPT-015-19. Exhibit 6-27, Exhibit 6-28, Exhibit 6-29, Exhibit 6-30. Table reproduced from Second IRP Filing, June 7, 2019, Exhibit A.

Q: Describe the timing of the planned renewable buildout proposed by PREPA in its June 2019 IRP Action Plan (ESM case).

A: PREPA's June 2019 ESM case plans for 4,151 GWh of energy efficiency, 800 MW of battery storage, 140 MW of demand response and 1,800 MW of utility-scale solar by 2026. PREPA also reports 1,176 MW of customer-owned generation in 2038.

Q: How long does it take to install solar and wind as compared to fossil power generation?

A: The International Finance Corporation's guide for solar developers states that "solar installations can be built relatively quickly, often in 6–12 months, compared to hydro and fossil fuel projects that require more than 4–5 years to complete." International Finance Corporation, Utility-Scale Solar Photovoltaic Power Plants: A Project Developer's Guide at 3,https://www.ifc.org/wps/wcm/connect/f05d3e00498e0841bb6fbbe54d141794/IFC+Solar +Repor t Web+ 08+05.pdf?MOD=AJPERES. According to the European Wind Energy Association utility-scale wind projects (50 MW) can be built within six months. European Wind Energy Association, https://windeurope.org/about-us/new-identity/)

Q: What are the risks associated with not building out renewable energy generation in the near-term with regards to Act 17-2019 compliance and overall costs?

A: Failing to build out renewables in the near-term will negatively impact Puerto Rico's ability to meet the renewable energy targets contained in Act 17-2019. In 2018, hydro, wind and solar resources made up just 1.4 percent of Puerto Rico's total electric generation (227 GWh of 16,300 MW total). In order to comply with Act 17's target of 20 percent renewable generation by 2022, Puerto Rico must add at least another 3,000 GWh of renewable generation capacity within the next two years. Federal tax credits that are in the process of being phased out are another incentive to build out renewables in the near-term. Finally, the experience of the Hawaiian utilities' development of their 2016 resource plan found that ramping up renewables in the near-term "minimize[d] the potential for making dead-end decisions and stranding assets." The utilities concluded that gas resources were no longer to be included and that they would focused== on the "near-term actions that allow us to make strong progress on achieving our clean energy goals," *Id*. at ES-7, by reducing reliance on imported fossil fuels (and their associated cost risks) and aggressively developing renewable energy resources.

E. GAS GENERATION

Q: Describe the new gas generating plants proposed by PREPA in its June 2019 IRP Action Plan (ESM case).

A: PREPA's preferred portfolio (Energy System Modernization, or "ESM") plans for extensive new gas-fired capacity and supporting infrastructure, including two new 302 MW gas CCGTs at Palo Seco and Yabucoa, the replacement of all existing Frame 5 GT's with 23 MW diesel and gas-fired peakers (418 MW total) by 2021, the conversion to gas of San Juan 5 and 6, the conversion of the Aero Mayagüez units (four 50 MW units, 200 MW total), and a new LNG terminal at Mayagüez. Second IRP Filing, June 7, 2019, at p.8-44, 8-45, 8-48.

Q: When would these gas plants be built?

A: In PREPA's Action Plan (ESM case), the new CCGT at Palo Seco and Yabucoa would be operational by January 2025. The new diesel and gas-fired peakers would be operational by 2021. The conversion of San Juan 5 and 6 to gas would take place by June 2019 and the conversion of the Aero Mayagüez units to gas would take place by 2022. *Id.*, Exhibit 10-5.

Q: What is the normal useful life for a gas generating plant?

A: According to PREPA's June 2019 IRP Exhibit 6-2, the useful life of a gas generating plant ranges from 20 to 28 years—depending on the size of the facility (see Table 3). *Id*. at p. 6-3.

Table 3. PREPA June 2019 IRP Exhibit 6-2 Capital Cost Recovery Factor by Asset Class

Asset Class	Capital Recovery Period (Years)	CCR
Combined Cycle Plant	28	9.5%
Small Combined Cycle	20	10.6%
Existing Unit Fuel Conversion / Switching (San Juan)	21	10.4%
Solar PV /Wind	25	9.8%
Battery Storage	20	10.6%
LNG Terminal	22	9.8%

Source: Reproduced from PREPA June 2019 IRP Exhibit 6-2.

Lazard's *Levelized Cost of Energy Analysis—Version 12.0* reports the economic life of a gas combined cycle plant as 20 years.[1]

Q: What is a stranded asset?

A: As defined in Lloyd's of London's Emerging Risk Report, stranded assets are "assets that have suffered from anticipated or premature write-downs, devaluation or conversion to liabilities". Smith School of Enterprise and the Environment, *Stranded Assets: the transition to a low carbon economy*, Oxford University. Prepared for Lloyd's of London, https://www.lloyds.com/news-and-risk-insight/risk-reports/library/society-and-security/stranded-assets, p. 4 (2017).

Q: When an asset becomes stranded, how does this impact ratepayers?

A: A utility asset that has been approved by the Energy Bureau to enter into rate base will have its capital costs charged to customers gradually throughout the lifetime of the investment. In the event that a rate-based asset no longer has value or is found to have a shorter useful lifetime than had been anticipated at the time of the Bureau's order, customers will nonetheless continue to pay its capital costs throughout its originally anticipated lifetime—unless the Bureau orders otherwise.

If the Bureau's original order stands, electric customers take on the full risk of uneconomic utility investments. For some or all of this risk to instead be assumed by any other part (i.e., the responsibility to pay some or all of the capital costs of stranded assets reverts is assigned

[1] *Lazard's Levelized Cost of Energy Analysis—Version 12.0*, 2018, https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf.

elsewhere) a new commission order would be required. A new cost allocation is typically within utility commissions' purview.

Q: Would the new gas plants become stranded assets when Act 17-2019's RPS standard reaches 100 percent in 2050?

A: Yes. Act 17-2019 requires 100 percent renewable electric generation by 2050. To be clear: by law, PREPA may not run any gas or other non-renewable generation after 2050. PREPA's June IRP ESM case calls for 1,222 MW of new gas generation: 418 MW in 2021, 200 MW in 2022, and 604 MW in 2025. Second IRP Filing, June 7, 2019, Exhibit 8-44. According to PREPA's reported economic lifetimes of these facilities (see Table 3 above), the two 302 MW gas combined cycle plants (Palo Seco and Yabucoa) will have 3 years of remaining useful life in 2050 but cannot operate after that year.

Note that PREPA, in its response to EDF First Set of Interrogatories and Request for Production of Documents and Information, concurs that all thermal assets must be fully recovered by 2050: "[A]ny thermal related investment needs to be fully recovered before 2050. This means that any new thermal generation added of LNG terminal is fully depreciated by that year when Puerto Rico is expected to be supplied only from renewable resources." PREPA Responses to EDF First Set of Interrogatories and Request for Production of Documents and Information, Response No. 5.

Figure 5 shows new gas generation, assuming:

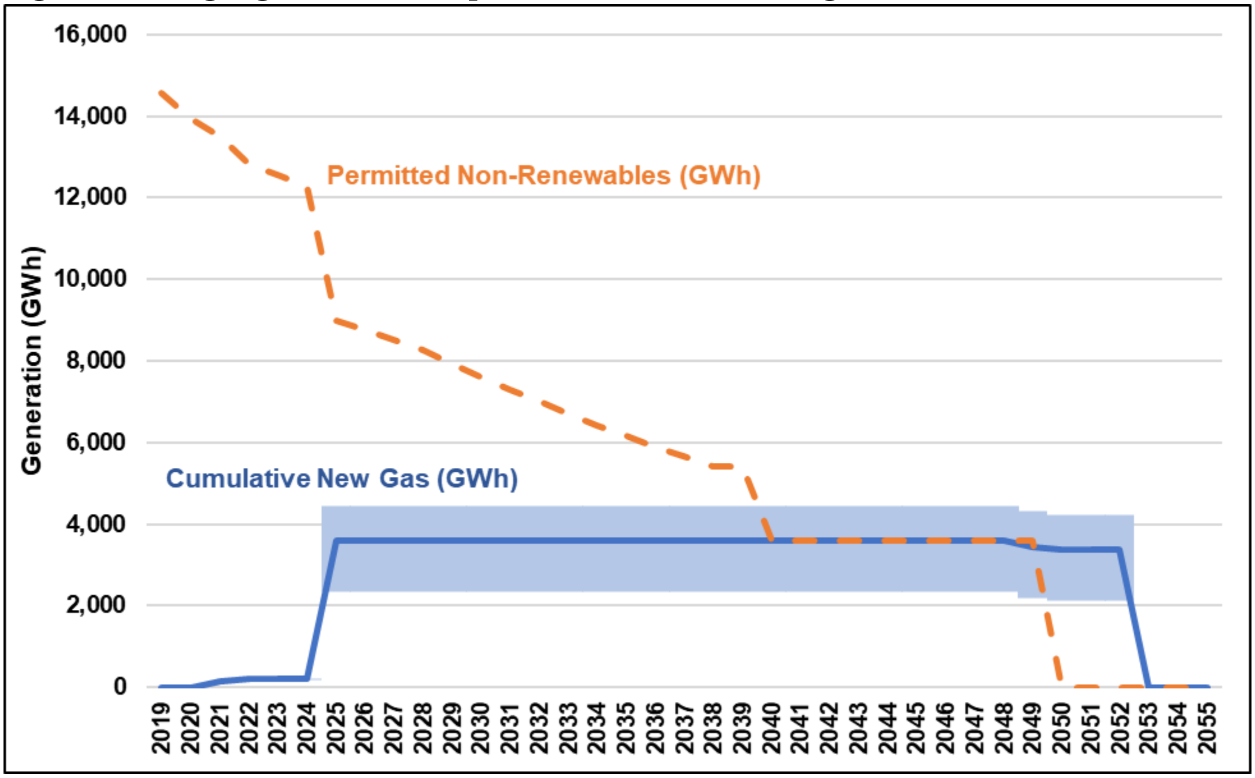
(1) that new gas resources will operate at capacity factors similar to the historical capacity factors of existing resources (4 percent for new gas CTs, based on PREPA's existing GTs; 64 percent for new gas CCs, based on Costa Sur 5&6 and EcoEléctrica), and

(2) that all other non-renewable sources cease generation.

Figure 5 also presents a range of possible generation from new gas given the range of capacity factors for new gas combined cycle presented in PREPA's Exhibit 6-21: 40 to 80 percent.

PREPA's planned gas investments can continue operation through 2050 at the 64 percent capacity factors. *See* Exhibit C. At capacity factors above 64 percent, some share of PREPA's new gas generation will need to be limited starting in 2040. Generation limitations on new resources raise concerns similar to stranded assets and must be taken into consideration when producing cost estimates for modeled portfolios.

Figure 5. New gas generation and permitted non-renewable generation



Source: Exhibit C

Q: Based on Siemens' estimates of the cost of PREPA's proposed new gas plants and the normal useful life of a gas generating plant, can you estimate the amount of the plants' cost that would need to be written off in 2050?

A: Yes. Based on Siemens' estimates of the cost of PREPA's proposed new gas plants and the normal useful life of a gas generating plant, approximately $84 million would still be owed to pay the full cost of these plants in 2050.

PREPA assumes the cost of a new large gas combined cycle will be $994 per kilowatt (kW) (Second IRP Filing, June 7, 2019, Exhibit 6-15) and claims to amortize this value over 29 years: "This same WACC was used to annualize the generation capital considering an asset economic life of 29 years for a large combined cycle plant." *Id.* at p.6-14.

The two gas combined cycle plants planned for 2025 in the ESM case total 604 MW. *Id.* at Exhibit 8-44. At $994 per kW, total costs for these plants amount to $600 million. For the purposes of illustration, calculations to amortize these costs over the 29-year lifetime of the plants can be simplified as: $600 million divided by 29 years, or $21 million per year.

If this $21 million were charged to ratepayers each year for 25 years (from 2025 to 2050), in 2050 another 4 years (or $84 million) would still be needed to pay the full cost of the plants after they are shut down in 2050 in compliance with Act 17-2019.

Q: What is the proper way to calculate the cost of a generating asset in system planning if part of the generating plant's value will be written off in the future?

A: The costs of capital assets must be amortized across the useful lifetime of the asset. In the case of large gas combined cycle units built in Puerto Rico in 2025, this useful lifetime is limited by law because these plants cannot operate in year 2050 or later, per Act 17-2019. Therefore, the useful life of the Palo Seco and Yabucoa plants is only 25 years.

If these assets were amortized over 29 years, their cost to ratepayers would be $21 million per year (before taking account of discount factors or the cost of capital). If instead these assets were correctly amortized over 25 years, their cost to ratepayers would be $24 million per year.

Q: How does PREPA account for stranded costs in its IRP?

A: PREPA does not appear to account for stranded costs in its IRP.

PREPA assesses alternate resource portfolios based on their "NPV" or the "net present value of cash flows" using a 9 percent discount rate. *Id*. at p.1-5. This NPV does not include capital costs: PREPA is comparing system costs based on their fuel, operations and maintenance (O&M), and energy efficiency costs only.

Capital costs are reported separately and are not discounted or amortized across resources' economic lifetimes; instead PREPA's reported capital investment costs sum up the complete costs of all capital investments made within the modeling period having multiplied each year's costs (that is, the full cost of the investment in the planned year of that investment) by a "deflator" that is not explained. *See* June 12, 2019 PREPA's IRP Compliance Filing, https://drive.google.com/drive/folders/1OVN9mMvNdnM-GgX_T_z9mscM4qq_Ji7N.

Using this method, PREPA:

(1) Does not account for any capital costs, stranded or otherwise, in its NPV system cost comparisons, and

(2) Does not account for stranded assets in its separate calculation of capital costs.

Q: If PREPA had properly accounted for stranded gas assets, how would this have affected PREPA's selection of resources for the IRP?

A: If PREPA had properly accounted for stranded gas assets (by including capital costs in its NPV cost assessment and by amortizing capital costs using the correct lifetime for gas assets in Puerto Rico), total system costs would be higher than reported for all scenarios with stranded assets. Going forward, PREPA should amortize resources over their actual viable lifetime, taking into account Puerto Rican laws and regulations.

Q: In addition to the risk of stranded assets did PREPA account for risks associated with financing?

A: PREPA did not consider the risk of failing to attain reasonable interest rates on loans for gas investments. Second IRP Filing, June 7, 2019, at p. 8-28.

Q: Did PREPA prepare any scenarios that do not include new gas infrastructure?

A: Yes. PREPA's Scenario 1 does not include any new gas infrastructure.

Q: Why is the no new gas scenario more expensive?

A: In the June 2019 IRP Siemens states: "Most of the increase in costs comes from higher fuel costs as the plan does not allows [sic] for the incorporation of new CCGT's and in some cases it requires the use of Costa Sur 5&6 for longer periods of time (i.e. until the load declines to levels that it can be retired)." *Id*. at p. 8-62.

PREPA's model, however, does not allow for non-gas resources to compete on a level playing field with gas resources: that is, Scenario 1 did not relax the constraints on annual additions of renewable capacity. As a result, Scenario 1 may have selected a greater amount of peaking generation and entailed greater fuel consumption for existing plants because it was unable to select more renewables than permitted by the renewable capacity constraints. Even so, the Scenario 1 base case was found to be just 3 percent ($423,434) more expensive than the preferred plan. *See* Exhibit B.

Q: Are investments in renewable energy also at risk of becoming stranded assets?

A: Hawaii's PSIPs demonstrate that investments in aggressive build-out of renewable energy, if cost-effective, pose very little risk of becoming stranded assets because renewable fuels (i.e. the wind, the sun, running water) are, and will remain, free—unlike fossil fuels, the prices of which become more uncertain over time. *See id*.

Distributed Energy Resources

Q: What does the PREPA say about the reliance on centralized energy generation?

A: In the June IRP PREPA states that IRP seeks to reduce dependence on an aging, inflexible and not reliable fleet and move away from the reliance on large, concentrated generating plants. Second IRP Filing, June 7, 2019, at secs.5.1 and 5.2.

Q: Why is the need to shift from centralized generation to distributed energy resources particularly acute in Puerto Rico?

A: Islands are at the front lines of vulnerability to climate change. As temperatures rise and we see stronger, more frequent and more forceful hurricanes, Puerto Rico's transmission and distribution system, which cuts across mountainous terrain, is particularly vulnerable as experienced during Hurricane Maria. Distributed energy resources and microgrids can help steer the island towards more decentralized generation and thereby improve resilience for customers and reduce dependence on fossil fuel and large central generating stations. *See* Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico, p. 9, https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/PRERWG_Report_PR_Grid_Resiliency_Report.pdf p. 9.

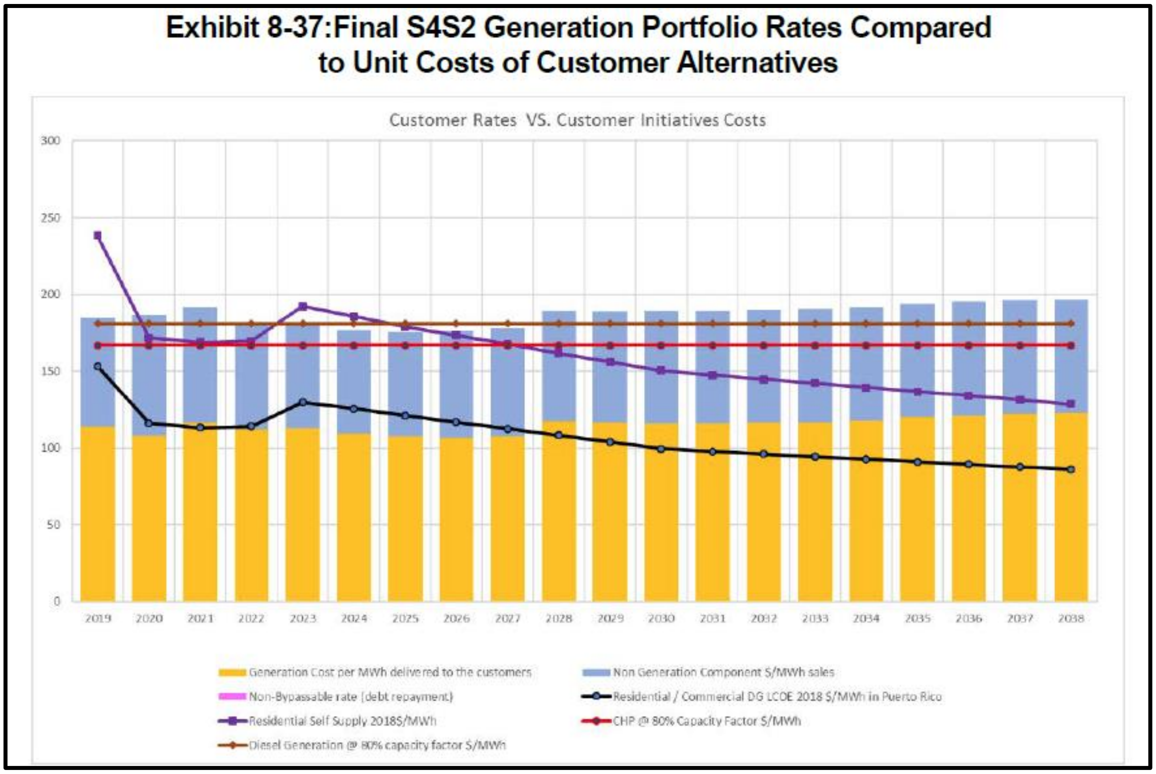
Q: Does PREPA's June 2019 IRP consider energy efficiency and demand response alongside supply-side resources in its capacity expansion modeling?

A: No. Siemen's does not consider energy efficiency and demand response alongside supply-side resources in its capacity expansion modeling. Instead, the expected implementation of these resources is forecast separately and introduced into modeling as a fixed amount. While supply-side resources compete in Siemens' model based on their economics (lower cost resources are selected before those with higher costs), investments in demand-side resources are instead predetermined and cannot out-compete electric generators, no matter how much lower the energy efficiency costs.

Q: Does Siemens offer any comparison of distributed generation in Puerto Rico versus PREPA-owned and operated generation?

A: Yes. In PREPA's June 2019 IRP Siemens explains that the "cost of customer owned generation is significantly lower than the [PREPA-owned and operated] total rate." Second IRP Filing, June 7, 2019, at p. 40. IRP Exhibit 8-37 (*see id*. Figure 6) presents Siemens expectation that customer-owned solar rooftop generation is significantly less expensive than PREPA's own generation, as is generation from customer-owned combined heat and power sources. According to Siemens, even customer-owned diesel back-up generators and complete self-supply (going "off the grid" and losing the benefits of net metering) is less expensive than buying electricity from PREPA in most of the years modeled.

Figure 6. PREPA June 2019 IRP, Exhibit 8-37



F. MINIGRIDS AND MICROGRIDS

Q: Describe PREPA's proposals on minigrids and microgrids.

A: PREPA proposes to divide Puerto Rico into eight, connected regional minigrids that can function interconnectedly or independently, in the event of an extreme weather event. Each minigrid is also broken down into smaller microgrids, which could also function autonomously from the larger grid to generate electricity.

Q: How do minigrids/microgrids impact reliability and resiliency?

A: Minigrids/microgrids have the potential to greatly enhance grid reliability and resiliency by providing a share of Puerto Rico's load from local resources that can be isolated from the rest of the grid during a major event like a hurricane. Minigrids/microgrids allow for greater grid flexibility because they can switch from interconnection to "island" mode. *Id*. at p.1-3. PREPA's June preferred plan itself makes the case that distributed energy resources—in the form of an extensive microgrid system—provide valuable benefits in the form of storm resiliency, especially relative to centralized generation resources: "It is noted that the larger centralized resources aligned with Strategy 1 usually provide lower costs of energy than distributed resources but depend on the reliability of the transmission system during a major event like a hurricane. Considering the experience with the 2017 hurricanes in Puerto Rico, a distributed resources strategy was selected for providing resiliency to the electric service, even though it could result in higher costs." *Id.* at p.9-2.

Q: Do you have an opinion as to whether climate change is causing more severe weather events?

A: Yes, it is my understanding that climate change is causing more severe weather events. The atmosphere has reached 1°C of warming above the pre-industrial level and the ocean "has warmed unabated since 1970 and has taken up more than 90 percent of the excess heat in the climate system" with consequences now apparent in increased ocean acidification, stratification and loss of oxygen. *See* The Ocean and Cryosphere in a Changing Climate, Intergovernmental Panel on Climate Change (IPCC), 2019, https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf. Research has demonstrated that warmer waters strengthen hurricane development and that warmer air holds more water vapor—taken together, these two relationships serve to make hurricanes more intense than they have been in the recorded past. *See* Hurricane Harvey Links to Ocean Heat Content and Climate Change Adaptation, Advancing Earth and Space Science, https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2018EF000825. In addition, the frequency of Category 4 and 5 storms are expected to increase. *See* IPCC AR5 WGI 2013, https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf.

Q: Generally describe the impact of Hurricane Maria on the electric distribution system.

A: Hurricane Maria was the deadliest hurricane to ever hit Puerto Rico and was the tenth-most intense Atlantic hurricane on record. *See* NOAA's Hurricane Research Division, HRD Sonde Archive, https://www.aoml.noaa.gov/hrd/data_sub/dropsonde.html. The official death toll was recorded at 2,975 (*see Ascertainment of the Estimated Excess Mortality from Hurricane María In Puerto Rico*, Milken Institute School of Public Health, George Washington Univ. https://publichealth.gwu.edu/sites/default/files/downloads/projects/PRstudy/Acertainment%20of%20the%20Estimated%20Excess%20Mortality%20from%20Hurricane%20Maria%20in%20Puerto%20Rico.pdf) and the hurricane also caused widespread destruction including that of the entire electric grid: the National Oceanic and Atmospheric Administration (NOAA) reported that Hurricane Maria "destroyed what was still functioning in Puerto Rico's electrical grid after Irma, leaving all residents across the island completely without power." Michon Scott, *Hurricane Maria's devastation of Puerto Rico*, NOAA, https://www.climate.gov/news-features/understanding-climate/hurricane-marias-devastation-puerto-rico.

Q: If customers, communities, and independent third-parties develop microgrids, how does this impact the utility's need for centralized generating plants in its IRP?

A: The larger the share of electric demand that is met by community-developed local generating resources like minigrids/microgrids, the less electric demand that needs to be met by centralized generation resources and the less total renewable generation (in GWh) needed for RPS compliance.

Q: Do you have an opinion as to the best practice for a utility to follow in determining the cost of various supply options for its IRP?

A: Yes. In my opinion, a utility should issue an RFP to determine the most appropriate costs for the supply resources that it will model in its IRP. The use of an RFP will ensure that the utility gets the best, most location specific, and most current information to use in its resource planning.

Q: Did PREPA issue an RFP to determine the actual cost of any supply options for its IRP?

A: No, not to my knowledge.

Q: Does this conclude your testimony?

A: Yes.

ATTESTATION

Commonwealth of Massachusetts)
)
County of Middlesex)

Affiant, Elizabeth A. Stanton, PhD, being first duly sworn, states the following: the Pre-Filed Direct Testimony of Elizabeth A. Stanton, PhD I am sponsoring constitutes the direct testimony of Affiant in the above-styled case. Affiant states that she would give the answers set forth in the Pre-Filed Direct Testimony in the above-styled case. Affiant states that she would give the same answers as set forth in the Pre-Filed Direct Testimony if asked the questions propounded therein at the time of the filing. Affiant further states that, to the best of his knowledge, her statements are true and correct.

Elizabeth A. Stanton, PhD

Acknowledged and subscribed before me by Elizabeth Stanton, in her capacity as Elizabeth Stanton, PhD, who is personally known to me or who identified herself to me by means of driver's license number S75107207 in Somerville, Massachusetts, this 23 day of October, 2019.

Notary Public

Lisa A. O'Leary
My Commission Expires July 10, 2026
NOTARY PUBLIC
COMMONWEALTH OF MASSACHUSETTS

The Commonwealth of Massachusetts

To all to whom these presents shall come, Greeting:

Know Ye, that We, confiding in the ability, discretion and integrity of Lisa O'Leary *of* Medford *in our County of* Middlesex *do hereby, by Our Governor, with the advice and consent of Our Council, assign, constitute and appoint the said*

Lisa O'Leary

to be One of Our ***Notaries Public,*** *within and for the Commonwealth, for and during the term of Seven Years from the date of these Presents if said appointee shall so long behave well in said office.*

And, *we do hereby* ***Authorize*** *and* ***Enjoin*** *said appointee, to execute and perform all the Powers and Duties which, by Our Constitution and Laws, do or may appertain to the said office of Notary Public, so long as said appointee shall hold the same by virtue of these Presents.*

Witness, *His Excellency* **Charles D. Baker,** *Our Governor, and our Great Seal hereunto affixed, at Boston this* tenth *day of* July*, in the year of Our Lord two thousand and* nineteen *and of the Independence of the United States of America, the two hundred and* forty-fourth.

Charles D. Baker

By His Excellency the Governor, with the advice and consent of the Council

William Francis Galvin

WILLIAM FRANCIS GALVIN
Secretary of the Commonwealth

The Commonwealth of Massachusetts

August 16, 2019.

Personally appeared Lisa O'Leary

and took and subscribed the oaths prescribed by the Constitution of this Commonwealth, and a Law of the United States, to qualify the above named to execute the trust reposed in this individual by the foregoing Commission.

Before

St Fleur Roselie Dale Gittens	*Commissioners to Qualify Public Officers*

NOTE. *A Certificate of your qualification should be forwarded to the Secretary of the Commonwealth forthwith, by the officers before whom the oaths are taken.*

OFFICE OF THE SECRETARY, BOSTON.

In case of error occurring in name or residence, immediate notice should be given to the Secretary of the Commonwealth, and the Commission returned for correction.

(SECTION 12 OF CHAPTER 30, GENERAL LAWS)

SECTION 12. A person appointed to an office by the governor with or without the advice and consent of the council shall be notified of his appointment by the state secretary and his commission delivered to him upon qualification, and if he does not, within three months after the date of such appointment, take and subscribe the oaths of office, his appointment shall be void, and the secretary shall forthwith notify him thereof, and shall also certify said facts to the governor. This section shall be printed on every such commission.

(SECTION 9 OF CHAPTER 222, GENERAL LAWS)

SECTION 9. Whoever presumes to act as a justice of the peace or notary public after the expiration of his commission, and after receiving notice of such expiration, shall be punished by a fine of not less than one hundred nor more than five hundred dollars.

Upon change of name by probate, divorce or marriage, commission becomes void until re-registration of change of name is made with the Secretary of the Commonwealth and re-registration fee paid.

FORM 314 Certificate of Official Character

Commonwealth of Massachusetts)
)
County of Middlesex)

I, ____________________, Clerk of the _____________ Court of the County aforesaid in the Commonwealth of Massachusetts, the same being a court of record, certify that Lisa O'Leary whose genuine signature is attached to the foregoing certificate, was at the time of signing the same a Notary Public in and for the Commonwealth of Massachusetts, duly commissioned and qualified, and authorized by virtue of her office to take acknowledgements to deeds and other writings, and to administer oaths under the laws of this state. I further certify that the official acts of Lisa O'Leary are entitled to full faith and credit; that I verily believe her signature to the foregoing proof or acknowledgement to be genuine; and that her attestation is in due form of law. I further certify that the laws of Massachusetts do not require the imprint of the Notary's seal to be filed with the authenticating officer.

In testimony whereof I have set my hand and affixed the seal of the said Court this ____ day of October, 2019.

EXHIBIT A

DIRECT TESTIMONY OF

ELIZABETH A. STANTON, PHD
ON BEHALF OF ENVIRONMENTAL DEFENSE FUND

Elizabeth A. Stanton, Ph.D., Director and Senior Economist

1012 Massachusetts Avenue, Arlington MA 02476 ∞ liz.stanton@aeclinic.org ∞ 781-819-3232

PROFESSIONAL EXPERIENCE

Applied Economics Clinic, Somerville, MA. *Director and Senior Economist*, February 2017 – Present.

The Applied Economics Clinic provides technical expertise to public service organizations working on topics related to the environment, consumer rights, the energy sector, and community equity. Dr. Stanton is the Founder and Director of the Clinic (www.aeclinic.org).

Liz Stanton Consulting, Arlington, MA. *Independent Consultant*, August 2016 – January 2017.

Providing consulting services on the economics of energy, environment and equity.

Synapse Energy Economics Inc., Cambridge, MA. *Principal Economist*, 2012 – 2016.

Consulted on issues of energy economics, environmental impacts, climate change policy, and environmental externalities valuation.

Stockholm Environment Institute - U.S. Center, Somerville, MA. *Senior Economist*, 2010 – 2012; *Economist*, 2008 – 2009.

Wrote extensively for academic, policy, and general audiences, and directed studies for a wide range of government agencies, international organizations, and nonprofit groups.

Global Development and Environment Institute, Tufts University, Medford, MA. *Researcher*, 2006 – 2007.

Political Economy Research Institute, University of Massachusetts-Amherst, Amherst, MA. *Editor and Researcher – Natural Assets Project*, 2002 – 2005.

Center for Popular Economics, **University of Massachusetts-Amherst**, Amherst, MA. *Program Director*, 2001 – 2003.

EDUCATION

University of Massachusetts-Amherst, Amherst, MA

Doctor of Philosophy in Economics, 2007

New Mexico State University, Las Cruces, NM

Master of Arts in Economics, 2000

School for International Training, Brattleboro, VT

Bachelor of International Studies, 1994

AFFILIATIONS

Global Development and Environment Institute, Tufts University, Medford, MA.

Senior Fellow, Visiting Scholar, 2007 – Present

PAPERS AND REPORTS

Stanton, E.A. and Eliandro Tavares. 2019. *An Analysis of the Need for the Atlantic Coast Pipeline Extension to Hampton Roads, Virginia*. Applied Economics Clinic. Prepared for Mothers Out Front. [Online]

Stanton, E.A. and Eliandro Tavares. 2019. *Analysis of the Mountain Valley Pipeline Southgate Project*. Applied Economics Clinic. Prepared for Appalachian Voices. [Online]

Stanton, E.A. 2019. *Update to Pennsylvania Long-Term Renewables Contracts Benefits and Costs*. Applied Economics Clinic. Prepared for Mid-Atlantic Renewable Energy Coalition (MAREC). [Online]

Lopez, R., T. Comings, E.A. Stanton, and E. Tavares. 2019. *Home Heat Pumps in Massachusetts*. Applied Economics Clinic. Prepared for Green Energy Consumers Alliance. [Online]

Woods, B., E.A. Stanton, and E. Tavares. 2019. *Fixing Massachusetts' Gas Leaks Pays for Itself*. Applied Economics Clinic. Prepared for Gas Leak Allies. [Online]

Woods, B. and E.A. Stanton. 2019. *Social Equity Analysis of Carbon Free Boston*. Applied Economics Clinic. Prepared for Green Ribbon Commission. [Online]

Woods, B., E.A. Stanton, and R. Lopez. 2019. *Performance-Based Incentives for Gas Utilities*. Applied Economics Clinic. Prepared for Gas Leak Allies. [Online]

Woods, B. and E.A. Stanton. 2019. *Massachusetts Non-Energy Benefits of Battery Storage.* Applied Economics Clinic. Prepared for Clean Energy Group. [Online]

Stanton, E.A. 2019. *Updated Massachusetts Battery Storage Measures: Benefits and Costs.* Applied Economics Clinic. Prepared for Clean Energy Group. [Online]

Stanton, E.A. 2019. *Testimony on NISPCO's Petition for Approval of Roaming Bison Wind Farm PPA.* Applied Economics Clinic. Prepared for Citizens Action Coalition of Indiana. [Online]

Stanton, E.A. 2019. *Testimony on NIPSCO's Petition for Approval of Jordan Creek Wind Farm PPA.* Applied Economics Clinic. Prepared for Citizens Action Coalition of Indiana. [Online]

Stanton, E.A. 2019. *Testimony in NIPSCO's 2019 Rate Case.* Applied Economics Clinic. Prepared for Citizens Action Coalition of Indiana. [Online]

Comings, T., E.A. Stanton, and E. Tavares. 2019. *Comments on Xcel Energy Minnesota's 2018 Mankato Proposal.* Applied Economics Clinic. Prepared for Sierra Club. [Online]

Comings, T., B. Woods, E.A. Stanton, and E. Tavares. 2019. *Duke Energy Integrated Resource Plans in North Carolina.* Applied Economics Clinic. Prepared for Southern Environmental Law Center. [Online]

Stanton, E.A., B. Woods, A. Sommer, and C. Hotaling. 2019. *Evaluation of Northern Indiana Public Service Company's 2018 Integrated Resource Plan.* Applied Economics Clinic. Prepared for Citizens Action Coalition of Indiana. [Online]

Stanton, E.A. 2018. *Testimony Regarding the Joint Statewide Three-Year Energy Efficiency Plan for Massachusetts, 2019-2021.* Applied Economics Clinic. Prepared for Conservation Law Foundation. [Online]

Stanton, E.A., R. Lopez, and B. Woods. 2018. *Review of Proposed CAFE and CO_2 Standards.* Applied Economics Clinic. Prepared for California Attorney General Office and California Air Resources Board. [Online]

Stanton, E.A., R. Lopez, B. Woods, T. Stasio, and A. Sommer. 2018. *Report on Indiana's 2018 Draft Statewide Analysis of Future Resource Requirements of Electricity*. Applied Economics Clinic. Prepared for Citizens Action Coalition of Indiana. [Online]

Stanton, E.A. 2018. *Massachusetts Comprehensive Energy Plan: Comments on Stakeholder Meeting Presentation.* Applied Economics Clinic. Prepared for Conservation Law Foundation. [Online]

Stanton, E.A. 2018. *Massachusetts Battery Storage Measures: Benefits and Costs.* Applied Economics Clinic. Prepared for Clean Energy Group. [Online]

Stanton, E.A. 2018. *Review of Massachusetts Efficiency Program Administrator's April 2018 Draft 2019-2021 Energy Efficiency Plan.* Applied Economics Clinic. Prepared for Conservation Law Foundation. [Online]

Stanton, E.A., and T. Comings. 2018. *Massachusetts Clean Energy Bill Provisions Boost Jobs.* Applied Economics Clinic. Prepared for Barr Foundation. [Online]

Stanton, E.A., T. Comings, R. Wilson, S. Alisalad, E.N Marzan, C. Schlegel, B. Woods, J. Gifford, E. Snook, and P. Yuen. 2018. *An Analysis of the Massachusetts 2018 'Act to Promote a Clean Energy Future' Report.* Applied Economics Clinic. Prepared for Barr Foundation. [Online]

Woods, B., C. Schlegel, and E.A. Stanton. 2018. *Massachusetts' Clean Energy Policy Overview.* Applied Economics Clinic. Prepared for Barr Foundation. [Online]

Comings, T., E.A. Stanton, and B. Woods. 2018. *The ABCs of Boston CCE*. Applied Economics Clinic. Prepared for Barr Foundation. [Online]

Stanton, E.A., E.N. Marzan, and S. Alisalad. 2018. *Accessing Energy Efficiency in Massachusetts.* Applied Economics Clinic. Prepared for Conservation Law Foundation. [Online]

Stanton, E.A., R. Wilson, and B. Woods. 2018. *Missed Opportunities for Energy Efficiency in Virginia*. Applied Economics Clinic. Prepared for the Consumers Union. [Online]

Stanton, E.A., T. Comings, and A. Sommer. 2018.*The Husker Energy Plan: A New Energy Plan for Nebraska*. Applied Economics Clinic. Prepared for the Nebraska Wildlife Foundation. [Online]

Stanton, E.A., A. Sommer, T. Comings, and R. Wilson. 2017. *Benefits of Long-Term Renewable Contracts for Pennsylvania*. Applied Economics Clinic. Prepared for Mid-Atlantic Renewable Energy Coalition (MAREC). [Online]

Stanton, E.A., A. Sommer, T. Comings, and R. Wilson. 2017. *Pennsylvania Long-Term Renewables Contracts Benefits and Costs*. Applied Economics Clinic. Prepared for Mid-Atlantic Renewable Energy Coalition (MAREC). [Online]

Comings, T., E.A. Stanton, and B. Woods. 2017. *An Analysis of Community Choice Energy for Boston.* Applied Economics Clinic. Prepared for Barr Foundation. [Online]

Wilson, R., T. Comings, and E.A. Stanton. 2017. *Ratepayer Impacts of ConEd's 20-Year Shipping Agreement on the Mountain Valley Pipeline.* Applied Economics Clinic. Prepared for the Environmental Defense Fund. [Online]

Sommer, A. and E.A. Stanton. 2017. *Report on Vectren 2016* IRP. Applied Economics Clinic. Prepared on behalf of Earthjustice, Indiana Distributed Energy Alliance, Sierra Club, and Valley Watch. Submitted to the Indiana Utility Regulatory Commission. [Online]

Sommer, A. and E.A. Stanton. 2017. *Report on Indiana Power & Light 2016* IRP. Applied Economics Clinic. Prepared on behalf of Earthjustice, Indiana Distributed Energy Alliance, Sierra Club, and Valley Watch. Submitted to the Indiana Utility Regulatory Commission. [Online]

Sommer, A. and E.A. Stanton. 2017. *Report on Northern Indiana Public Service Company's 2016* IRP. Applied Economics Clinic. Prepared on behalf of Earthjustice, Indiana Distributed Energy Alliance, Sierra Club, and Valley Watch. Submitted to the Indiana Utility Regulatory Commission. [Online]

Stanton, E.A., P. Knight, P. Luckow, A. Allison, T. Vitolo, J. Barnes, B. Inskeep, and C. Barnes. 2016. *Envisioning Pennsylvania's Energy Future: Powering the Commonwealth's Energy Needs with 100 Percent Renewables by 2050.* Prepared by Synapse Energy Economics and EQ Research for Delaware Riverkeeper Network. [Online]

Wilson, R., S., Fields, P. Knight, E. McGee, W. Ong, N. Santen, T. Vitolo, and E.A. Stanton. 2016. *Are the Atlantic Coast Pipeline and the Mountain Valley Pipeline Necessary?* Prepared by Synapse Energy Economics for Southern Environmental Law Center and Appalachian Mountain Advocates. [Online]

Knight, P. and E.A. Stanton. 2016. *"Sorting Out New England's Pipeline Needs: A Round Up of Recent Studies and What They Mean".* Synapse Energy Economics White Paper. [Online]

Stanton, E.A., P. Knight, A. Allison, T. Comings, A. Horowitz, W. Ong, N. R. Santen, and K. Takahashi. 2016. *The RGGI Opportunity 2.0: RGGI as the Electric Sector Compliance Tool to Achieve 2030 State Climate Targets.* Prepared by Synapse Energy Economics for Sierra Club, Pace Energy and Climate Center, and Chesapeake Climate Action Network. [Online]

Jackson, S., P. Luckow, E.A. Stanton, A. Horowitz, P. Peterson, T. Comings, J. Daniel, and T. Vitolo. 2016. *Reimagining Brayton Point: A Guide to Assessing Reuse Options for the Somerset Community*. Prepared by Synapse Energy Economics for Coalition for Clean Air South Coast, Clean Water Action, and Toxics Action Center. [Online]

Stanton, E. A., P. Knight, A. Allison, T. Comings, A. Horowitz, W. Ong, N. R. Santen, and K. Takahashi. 2016. *The RGGI Opportunity: RGGI as the Electric Sector Compliance Tool to Achieve 2030 State Climate Targets.* Prepared by Synapse Energy Economics for Sierra Club, Pace Energy and Climate Center, and Chesapeake Climate Action Network. [Online]

Luckow, P., E.A. Stanton, S. Fields, W. Ong, B. Biewald, S. Jackson, and J. Fisher. 2016. *Spring 2016 National Carbon Dioxide Price Forecast*. Synapse Energy Economics White Paper. [Online]

Knight, P., A. Allison, W. Ong, N. R. Santen, and E.A. Stanton. 2016. *Cutting Electric Bills with the Clean Power Plan.* Prepared by Synapse Energy Economics for The Energy Foundation. [Online]

Horowitz, A., S. Jackson, A. Allison, and E.A. Stanton. 2016. *Environmental Justice and the Clean Power Plan.* Prepared by Synapse Energy Economics for The Energy Foundation. [Online]

Jackson, S., N. R. Santen, P. Knight, S. Fields, B. Biewald, and E.A. Stanton. 2015. *Clean Power Plan Handbook: A Guide to the Final Rule for Consumer Advocates.* Prepared by Synapse Energy Economics for National Association of State Utility Consumer Advocates. [Online]

Wilson, R., T. Comings, and E.A. Stanton. 2015. *Analysis of the Tongue River Railroad Draft Environmental Impact Statement.* Prepared by Synapse Energy Economics for Sierra Club and Earthjustice. [Online]

Knight, P., S. Fields, S. Jackson, W. Ong, N. R. Santen, B. Biewald, and E.A. Stanton. 2015. *Multi-State Compliance with the Clean Power Plan in CP3T.* Prepared by Synapse Energy Economics for the National Association of State Utility Consumer Advocates. [Online]

Vitolo, T., P. Luckow, S. Fields, P. Knight, B. Biewald, and E.A. Stanton. 2015. *Lower Electric Costs in a Low- Emission Future.* Prepared by Synapse Energy Economics for The Energy Foundation. [Online]

Stanton, E. A., T. Comings, S. Jackson, and E. Karaca. 2015. *Atlantic Coast Pipeline Benefits Review.* Prepared by Synapse Energy Economics for Southern Environmental Law Center. [Online]

Wilson, R., M. Whited, S. Jackson, B. Biewald, and E.A. Stanton. 2015. *Best Practices in Planning for Clean Power Plan Compliance.* Prepared by Synapse Energy Economics for the National Association of State Utility Consumer Advocates. [Online]

Fields, S., S. Jackson, P. Knight, and E.A. Stanton. 2015. *Internal briefing on Clean Power Plan compliance in Ohio.* Prepared by Synapse Energy Economics for Office of the Ohio Consumers' Counsel. [Online]

Luckow, P., E.A. Stanton, S. Fields, B. Biewald, S. Jackson, J. Fisher, and R. Wilson. 2015. *2015 Carbon Dioxide Price Forecast.* Synapse Energy Economics White Paper. [Online]

Knight, P., A. Allison, E.A. Stanton. 2015. *Preliminary Clean Power Plan Analysis for Kentucky.* Prepared by Synapse Energy Economics for Kentuckians for the Commonwealth. [Online]

Stanton, E. A., P. Knight, J. Daniel, B. Fagan, D. Hurley, J. Kallay, E. Karaca, G. Keith, E. Malone, W. Ong, P. Peterson, L. Silvestrini, K. Takahashi, and R. Wilson. 2015. *Massachusetts Low Gas Demand Analysis: Final Report.* Prepared by Synapse Energy Economics for the Massachusetts Department of Energy Resources. [Online]

Fields, S., E.A. Stanton, P. Knight, B. Biewald, J. Daniel, S. Jackson, E. Karaca, J. Rosenkranz, and K. Takahashi. 2014. *Calculating Alabama's 111(d) Target*. Prepared by Synapse Energy Economics for the Southern Environmental Law Center. [Online]

Fields, S., E.A. Stanton, P. Knight, B. Biewald, J. Daniel, S. Jackson, E. Karaca, J. Rosenkranz, and K. Takahashi. 2014. *Calculating Georgia's 111(d) Target*. Prepared by Synapse Energy Economics for the Southern Environmental Law Center. [Online]

Fields, S., E.A. Stanton, P. Knight, B. Biewald, J. Daniel, S. Jackson, E. Karaca, J. Rosenkranz, and K. Takahashi. 2014. *Alternate Scenarios for 111(d) Implementation in North Carolina*. Prepared by Synapse Energy Economics for the Southern Environmental Law Center. [Online]

Stanton, E. A., S. Jackson, B. Biewald, and M. Whited. 2014. *Final Report: Implications of EPA's Proposed "Clean Power Plan."* Prepared by Synapse Energy Economics for the National Association of State Utility Consumer Advocates. [Online]

Stanton, E. A., J. Daniel, T. Vitolo, P. Knight, D. White, and G. Keith. 2014. *Net Metering in Mississippi: Costs, Benefits, and Policy Considerations.* Prepared by Synapse Energy Economics for the Public Service Commission of Mississippi. [Online]

Knight, P., E.A. Stanton, B. Biewald, J. Daniels, S. Fields, S. Jackson, A. Napoleon, J. Rosenkranz, and K. Takahashi. 2014. *Internal briefing on Clean Power Plan implementation in Virginia.* Prepared by Synapse Energy Economics for Sierra Club. [Online]

Jackson, S. and E.A. Stanton. 2014. *Internal briefing on Clean Power Plan implementation in Minnesota.* Prepared by Synapse Energy Economics for Sierra Club. [Online]

Knight, P., E.A. Stanton, B. Biewald, J. Daniels, S. Fields, S. Jackson, A. Napoleon, J. Rosenkranz, and K. Takahashi. 2014. *Internal briefing on Clean Power Plan implementation in Florida.* Prepared by Synapse Energy Economics for Sierra Club. [Online]

E.A. Stanton, S. Jackson, B. Biewald, M. Chang, J. Daniels, S. Fields, P. Knight, A. Napoleon, M. Whited, and K. Takahashi. 2014. *Internal briefing on Clean Power Plan implementation in Arizona, Montana, Nevada, and Utah.* Prepared by Synapse Energy Economics for Sierra Club. [Online]

E.A. Stanton, S. Jackson, B. Biewald, M. Chang, J. Daniels, S. Fields, P. Knight, A. Napoleon, and K. Takahashi. 2014. *Internal briefing on Clean Power Plan implementation Illinois.* Prepared by Synapse Energy Economics for Sierra Club. [Online]

Luckow, P., E.A. Stanton, B. Biewald, S. Fields, S. Jackson, J. Fisher, and F. Ackerman. 2014. *CO_2 Price Report, Spring 2014: Includes 2013 CO_2 Price Forecast.* Synapse Energy Economics White Paper. [Online]

Fisher, J., P. Knight, E.A. Stanton, and B. Biewald. 2014. *Avoided Emissions and Generation Tool (AVERT): User Manual*. *Version 1.0*. Prepared by Synapse Energy Economics for the U.S. Environmental Protection Agency. [Online]

Stanton, E. A., M. Whited, and F. Ackerman. 2014. *Estimating the Cost of Saved Energy in Utility Efficiency Programs.* Prepared by Synapse Energy Economics for the U.S. Environmental Protection Agency. [Online]

Stanton, E. A., F. Ackerman, and J. Daniel. 2013. *Comments on the 2013 Technical Update of the Social Cost of Carbon*. Prepared by Synapse Energy Economics for the Environment, Economics and Society Institute. [Online]

Luckow, P., E.A. Stanton, B. Biewald, J. Fisher, F. Ackerman, and E. Hausman. 2013. *2013 Carbon Dioxide Price Forecast.* Synapse Energy Economics White Paper. [Online]

Stanton, E. A., S. Jackson, G. Keith, E. Malone, D. White, and T. Woolf. 2013. *A Clean Energy Standard for Massachusetts.* Prepared by Synapse Energy Economics for the Massachusetts Clean Energy Center and the Massachusetts Departments of Energy Resources, Environmental Protection, and Public Utilities. [Online]

Knight, P., E.A. Stanton, J. Fisher, and B. Biewald. 2013. *Forecasting Coal Unit Competitiveness: Coal Retirement Assessment Using Synapse's Coal Asset Valuation Tool (CAVT).* Prepared by Synapse Energy Economics for Energy Foundation. [Online]

Hornby, R., P. Chernick, D. White, J. Rosenkranz, R. Denhardt, E. Stanton, J. Glifford, B. Grace, M. Chang, P. Luckow, T. Vitolo, P. Knight, B. Griffiths, and B. Biewald. 2013. *Avoided Energy Supply Costs in New England: 2013 Report.* Prepared by Synapse Energy Economics for the Avoided-Energy-Supply-Component (AESC) Study Group. [Online]

Stanton, E. A., T. Comings, K. Takahashi, P. Knight, T. Vitolo, and E. Hausman. 2013. *Economic Impacts of the NRDC Carbon Standard.* Prepared by Synapse Energy Economics for the Natural Resources Defense Council. [Online]

Stanton, E.A. 2013. Background research, consulting and support related to the Danish Energy Agency, Organisation for Economic Co-operation, and the UNEP Riso Centre's "*National Greenhouse Gas Emissions Baseline Scenarios: Learning from Experiences in Developing Countries.*" [Online]

Whited, M., D. White, S. Jackson, P. Knight, and E.A. Stanton. 2013. *Declining Markets for Montana Coal*. Prepared by Synapse Energy Economics for Northern Plains Resource Council. [Online]

Stanton, E. A. and F. Ackerman. 2013. *Climate Impacts on Agriculture: A Challenge to Complacency?* Global Development and Environment Institute Working Paper 13-01. [Online]

Stanton, E. A., F. Ackerman, T. Comings, P. Knight, T. Vitolo, and E. Hausman. 2013. *Will LNG Exports Benefit the United States Economy?* Prepared by Synapse Energy Economics for the Sierra Club. [Online]

Ackerman, F., T. Vitolo, E. Stanton, and G. Keith. 2013. *Not-so-smart ALEC: Inside the attacks on renewable energy*. Prepared by Synapse Energy Economics for the Civil Society Institute. [Online]

Ackerman, F., E.A. Stanton, and R. Bueno. 2012. *Climate Policy and Development: An Economic Analysis.* Economics for Equity and the Environment (E3 Network) Working Paper. [Online]

Stanton, E. A. and M. Taylor. 2012. *A Good Environment for Jobs.* Economics for Equity and the Environment (E3 Network) Working Paper. [Online]

Stanton, E. A., F. Ackerman, and R. Bueno. 2012. *Reason, Empathy, and Fair Play: The Climate Policy Gap.* UNDESA Working Paper No.113. [Online]

Erickson, P., M. Lazarus, E.A. Stanton, C. Chandler, R. Bueno, F. Ackerman, C. Munitz, and J. Cegan. 2012. *Greenhouse Gas Emissions in King County: An Updated Geographic-plus Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework.* Prepared by Stockholm Environment Institute-U.S. Center for King County, Washington. [Online]

Stanton, E. A., R. Bueno, J. Cegan, and C. Munitz. 2011. *King County Community Greenhouse Gas Emissions Inventory – Consumption Methodology: Technical Report.* Prepared by Stockholm Environment Institute-U.S. Center for King County, Washington. [Online]

Stanton, E. A., J. Cegan, R. Bueno, and F. Ackerman. 2012. *Estimating Regions' Relative Vulnerability to Climate Damages in the CRED Model*. Stockholm Environment Institute-U.S. Center Working Paper WP-US-1103. [Online]

Stanton, E.A. 2012. *Development without Carbon as Climate Policy.* Economics for Equity and the Environment (E3 Network) Working Paper. [Online]

Ackerman, F., E.A. Stanton, and R. Bueno. 2012. *Epstein-Zin utility in DICE: Is risk aversion irrelevant to climate policy?* Economics for Equity and the Environment (E3 Network) Working Paper. [Online]

Stanton, E. A., R. Bueno, and M. Davis. 2011. *Real People, Real Impacts: The Climate Impact Equity Lens.* Stockholm Environment Institute-U.S. Center Report. [Online]

Stanton, E. A. and R. Bueno. 2011. *The CIEL Backgrounder: Understanding the Climate Impact Equity Lens.* Stockholm Environment Institute-U.S. Center Report. [Online]

Stanton E.A. 2011. *Development without Carbon: Climate and the Global Economy through the 21st Century.* Stockholm Environment Institute-U.S. Center Report. [Online]

Erickson, P., M. Lazarus, E.A. Stanton, and F. Ackerman. 2011. *Consumption-Based Greenhouse Gas Emissions Inventory for Oregon – 2005: Summary Report.* Prepared by Stockholm Environment Institute-U.S. Center for the State of Oregon Department of Environmental Quality. [Online]

Stanton, E.A., R. Bueno, F. Ackerman, P. Erickson, R. Hammerschlag, and J. Cegan. 2011. *Consumption-Based Greenhouse Gas Emissions Inventory for Oregon – 2005: Technical Report.* Prepared by Stockholm Environment Institute-U.S. Center for the State of Oregon Department of Environmental Quality. [Online]

Ackerman, F. and E.A. Stanton. 2011. *The Social Cost of Carbon.* Economics for Equity and the Environment (E3 Network) White Paper. [Online]

Stanton, E.A., R. Bueno, J. Cegan, and C. Munitz. 2011. *Consumption-Based Emissions Inventory for San Francisco: Technical Report.* Prepared by Stockholm Environment Institute-U.S. Center for the City of San Francisco, California. [Online]

Stanton, E. A. and F. Ackerman. 2011. *Developing Baselines for Climate Policy Analysis.* Prepared by Stockholm Environment Institute-U.S. Center as additional guidance for *"United Nations Environmental Programme (UNEP) MCA4climate Initiative: A practical framework for planning pro-development climate policies."* [Online]

Ackerman, F. and E.A. Stanton. 2011. *A practical framework for planning pro- development climate policies*. Prepared by Stockholm Environment Institute-U.S. Center as additional guidance for *"United Nations Environmental Programme (UNEP) MCA4climate Initiative: A practical framework for planning pro-development climate policies."* [Online]

Ackerman, F. and E.A. Stanton. 2011. *The Last Drop: Climate Change and the Southwest Water Crisis*. Stockholm Environment Institute-U.S. Center Report funded by the Kresge Foundation. [Online]

Stanton, E. A. and E. Fitzgerald. 2011. *California Water Supply and Demand: Technical Report*. Stockholm Environment Institute-U.S. Center Report funded by the Kresge Foundation. [Online]

Bueno, R. and E.A. Stanton. 2011. *Casting DICE for 350 ppm.* Stockholm Environment Institute-U.S. Center Working Paper WPUS-1101. [Online]

Stanton, E. A. and F. Ackerman. 2010. *Emission Reduction, Interstate Equity, and the Price of Carbon*. Prepared by Stockholm Environment Institute-U.S. Center Economics for Equity and the Environment (E3 Network). [Online]

Stanton, E. A. and F. Ackerman. 2010. *No State Left Behind: A Better Approach to Climate Policy*. Economics for Equity and the Environment (E3 Network) White Paper. [Online]

Ackerman, F., E.A. Stanton, and R. Bueno. 2010. *CRED: A New Model of Climate and Development.* United Nations Department of Economic and Social Affairs Working Paper No.96. [Online]

Stanton, E. A., M. Davis, and A. Fencl. 2010. *Costing Climate Impacts and Adaptation: A Canadian Study on Coastal Zones*. Prepared by Stockholm Environment Institute-U.S. Center for the National Round Table on the Environment and the Economy Economic Risks and Opportunities of Climate Change Program. [Online]

Ackerman, F. and E.A. Stanton. 2010. *The socio-economic implications of climate change on FYR Macedonia and national policy options on adaptation.* United Nations Development Programme (UNDP) Report. [Online]

Ackerman, F., E.A. Stanton, S. DeCanio, E. Goodstein, R. Howarth, R. Norgaard, C. Norman, and K. Sheeran. 2009. *The Economics of 350: The Benefits and Costs of Climate Stabilization*. Economics for Equity and the Environment (E3 Network), Stockholm Environment Institute-U.S. Center, and Ecotrust Report. [Online]

Stanton, E. A., F. Ackerman, and K. Sheeran. 2009. *Understanding Interstate Differences in U.S. Greenhouse Gas Emissions*. Stockholm Environment Institute-U.S. Center Working Paper WP-US-1004. [Online]

Stanton, E. A., F. Ackerman, and K. Sheeran. 2009. *Greenhouse Gases and the American Lifestyle: Understanding Interstate Differences in Emissions*. Economics for Equity and the Environment (E3 Network), and Ecotrust Report. [Online]

Stanton, E. A., F. Ackerman, and F. Resende. 2009. *The Socio-Economic Impact of Climate Change in Armenia*. Stockholm Environment Institute-U.S. Center for the United Nations Development Programme (UNDP). [Online]

Stanton, E. A. and F. Ackerman. 2008. *Generated User Benefits and the Heathrow Expansion: Understanding Consumer Surplus*. Prepared by Stockholm Environment Institute-U.S. Center for Friends of the Earth England, Wales and Northern Ireland. [Online]

Stanton, E. A. and F. Ackerman. 2008. *Out of the Shadows: What's Behind DEFRA's New Approach to the Price of Carbon*. Prepared by Stockholm Environment Institute-U.S. Center for Friends of the Earth England, Wales and Northern Ireland. [Online]

Bueno, R., C. Herzfeld, E.A. Stanton, and F. Ackerman. 2008. *The Caribbean and Climate Change: The Costs of Inaction*. Prepared by Stockholm Environment Institute-U.S. Center for Environmental Defense Fund. [Online]

Ackerman, F. and E.A. Stanton. 2008. *The Cost of Climate Change: What We'll Pay if Global Warming Continues Unchecked*. Prepared by Stockholm Environment Institute-U.S. Center for Natural Resources Defense Council. [Online]

Stanton, E.A. 2008. Literature review of water resources infrastructure and related environmental costs and benefits for "*Default Case Study Values and Management Options for WEAP in Massachusetts."* Prepared by Stockholm Environment Institute-U.S. Center for Keep Water Local, a project of the Massachusetts Riverways Program, Commonwealth of Massachusetts. [Online]

Stanton, E.A. and F. Ackerman. 2007. *Florida and Climate Change: The Costs of Inaction*. Prepared by Global Development and Environmental Institute – Tufts University for Environmental Defense. [Online]

Stanton, E.A. 2007. *United States-Specific Human Development Index: Methodology and Data*. Report commissioned by American Human Development Report Project, as a technical background paper to *The Measure of America: American Human Development Report 2008-2009*. [Online]

Ackerman, F. and E.A. Stanton. 2006. *Climate Change – the Costs of Inaction.* Prepared by Global Development and Environmental Institute – Tufts University for Friends of the Earth England, Wales and Northern Ireland. [Online]

Ackerman, F. and E.A. Stanton. 2006. *Implications of REACH for the Developing Countries*. Global Development and Environmental Institute – Tufts University for European Parliament, Directorate- General for External Policies of the Union. [Online]

Testimony and Expert Comments

Stanton, E.A. 2019. *Comment on Transco's Assessment of Net Greenhouse Gas Emissions from NYC's Proposed NESE Pipeline*. Testimony to the New York State Department of Environmental Conservation on behalf of Natural Resources Defense Council, ID No. 2-9902-00109/00006 WQC. [Online]

Stanton, E.A. and R. Lopez. 2019. *Comment on National Grid's Proposed Off-Peak Charging Rebate*. Testimony to the Massachusetts Department of Public Utilities on behalf of Green Energy Consumers Alliance, Docket No. 18-150. [Online]

Stanton, E.A. 2018. *Minnesota Power EnergyForward Testimony*. Testimony to the Minnesota Public Utilities Commission on behalf of Minnesota Center for Environmental Advocacy and Fresh Energy, PUC Docket No. E-015/GR-17-568. [Online]

Stanton, E.A. 2018. *Testimony Regarding the Joint Statewide Three-Year Energy Efficiency Plan for Massachusetts, 2019-2021.* Testimony to the Commonwealth of Massachusetts Department of Public Utilities on behalf of Conservation Law Foundation, D.P.U. 18-110 – D.P.U. 18-119. [Online]

Stanton, E.A. 2018. *Comment on August 2018 Analysis of the Avoided Costs of Compliance of the MA GWSA*. Applied Economics Clinic. [Online]

Stanton, E.A. 2018. *Testimony Regarding Consistency of Petition with [Eversource] Portfolio Objectives, Adequacy of Alternatives Considered, and Consistency with State Environmental Policies.* Testimony to the Commonwealth of Massachusetts Department of Public Utilities on behalf of the Conservation Law Foundation, Docket No. DPU 17-175. [Online]

Stanton, E.A. 2018. *Testimony Regarding Consistency of Petition with [National Grid] Portfolio Objectives, Adequacy of Alternatives Considered, and Consistency with State Environmental Policies.* Testimony to the Commonwealth of Massachusetts Department of Public Utilities on behalf of the Conservation Law Foundation, Docket No. DPU 17-174. [Online]

Stanton, E.A. 2018. *Testimony Regarding Consistency of Petition with [Columbia Gas] Portfolio Objectives, Adequacy of Alternatives Considered, and Consistency with State Environmental Policies.* Testimony to the Commonwealth of Massachusetts Department of Public Utilities on behalf of the Conservation Law Foundation, Docket No. DPU 17-172. [Online]

Stanton, E.A. 2018. *Testimony Regarding Consistency of Petition with [Berkshire Gas] Portfolio Objectives, Adequacy of Alternatives Considered, and Consistency with State Environmental Policies.* Testimony to the Commonwealth of Massachusetts Department of Public Utilities on behalf of the Conservation Law Foundation, Docket No. DPU 17-145. [Online]

Stanton, E.A. 2017. *Testimony on Entergy New Orleans' Request to Construct New Orleans Power Station.* Testimony to the Council for the City of New Orleans on behalf of Alliance for Affordable Energy, Deep South for Environmental Justice, 350 Louisiana- New Orleans, and the Sierra Club, Docket No. UD-16-02. [Online]

Stanton, E.A. 2017. *Testimony Regarding Natural Gas Price Hedging in Florida.* Testimony to the Florida Public Service Commission on behalf of the Sierra Club, Docket No. 20170057-EI. [Online]

Stanton, E.A. 2017. *Testimony Regarding the Petition of Vectren for Approval of Its Proposed Demand Side Management and Energy Efficiency Programs for 2016-2018.* Testimony to the Indiana Utility Regulatory Commission on behalf of Citizens Action Coalition of Indiana, Cause No.44927 DSM-4. [Online]

Stanton, E.A. 2017. *Testimony Regarding Brockton Power Co., LLC.* Testimony to the Commonwealth of Massachusetts Department of Environmental Protection Office of Appeals and Dispute Resolution on behalf of the Residents of Brockton, West Bridgewater, and East Bridgewater, OADR Docket No. 2011-025 & 026. [Online]

Stanton, E.A. 2017. *Declaration in the matter of Clean Water Action, et al. v. E. Scott Pruitt, regarding the U. S. EPA's Steam Electric Effluent Limitation Guidelines*. Declaration prepared on behalf of Earthjustice and Environmental Integrity.

Stanton, E.A. 2017. *Testimony Regarding Northern Indiana Public Service Company's CPCN for Environmental Compliance Projects.* Testimony to the Indiana Utility Regulatory Commission on behalf of Citizens Action Coalition of Indiana, Cause No.448872.

Stanton, E.A. 2017. *Testimony Regarding the Petition of Duke Energy Indiana, Inc. for Approval of Its Proposed Demand Side Management and Energy Efficiency Programs for 2016-2018.* Testimony to the Indiana Utility Regulatory Commission on behalf of Citizens Action Coalition of Indiana, Cause No.43955 DSM-4. [Online]

Stanton, E.A. 2017. *Expert Comments Regarding Massachusetts' Department of Environmental Protection's Rulemaking Required by Section 3(d) of the Global Warming Solutions Act.* Expert comments submitted by Conservation Law Foundation. [Online]

Stanton, E.A. 2016. *Testimony Regarding the National Grid Analysis of Economic Benefits of Proposed Access Northeast Gas Pipeline.* Testimony to the Massachusetts Department of Public Utilities on behalf of Conservation Law Foundation, Docket No. 16-05. [Online]

Stanton, E.A. 2016. *Testimony Regarding the Eversource Analysis of Economic Benefits of Proposed Access Northeast Gas Pipeline.* Testimony to the Massachusetts Department of Public Utilities on behalf of Conservation Law Foundation, Docket No. 15-181. [Online]

Stanton, E.A. 2016. *Testimony on Byron Fleet Benefits.* Testimony to the Illinois Property Tax Appeal Board on behalf of Whitt Law, Docket Nos. 12-01248 and 12-02297. [Online]

Stanton, E.A., P. Knight, F. Ackerman, and N. R. Santen. 2015. *Byron Fleet Benefit Rebuttal.* Expert comments submitted by Whitt Law to the Illinois Property Tax Appeal Board, Docket Nos. 12-01248 and 12-02297. [Online]

Nogee, A., M. Chang, P. Knight, and E.A. Stanton. 2015. *Electricity Market Restructuring and the Nuclear Industry*. Expert comments submitted by Whitt Law testimony regarding Byron Station to the Illinois Property Tax Appeal Board, Docket Nos. 12-01248 and 12-02297. [Online]

Stanton, E.A. 2015. *Testimony on the Economic Analyses of a Proposed Brockton Power Company Generating Facility*. Testimony before the Massachusetts Department of Environmental Protection on behalf of Alternatives for Community & Environment, Docket No. 2011-025 & 026. [Online]

Stanton, E.A. and P. Knight. 2015. *Testimony in Opposition to HB 208 Repealing the New Hampshire Regional Greenhouse Gas Initiative*. Testimony to the Science, Technology and Energy Committee on behalf of New Hampshire's Office of Consumer Advocate. [Online]

Stanton, E.A. 2014. *Testimony Regarding the Cost of Compliance with the Global Warming Solutions Act*. Testimony to the Commonwealth of Massachusetts Department of Public Utilities on behalf of the Massachusetts Department of Energy Resources and the Department of Environmental Protection, Docket No. DPU 14-86. [Online]

Stanton E.A., F. Ackerman, and J. Daniel. 2014. *Comments on the 2013 Technical Update of the Social Cost of Carbon*. Submitted to the U.S. Office of Management and Budget as part of Environment, Economics, and Society Institute comments, Docket No. OMB-2013-0007. [Online]

Stanton, E.A. 2013. *Testimony Regarding the Prudency of Public Service of New Hampshire's Scrubber Project at Merrimack Station.* Testimony on behalf of the Conservation Law Foundation. Testimony to the New Hampshire Public Utilities Commission, Docket No. DE 11-250. [Online]

Stanton E.A., J. Daniel, F. Ackerman, and S. Jackson. 2013. *Review of EPA's June 2013 Steam Electric Effluent Limitations and Guidelines (40 CFR Part 423).* Submitted as part of Earthjustice/Sierra Club/Environmental Integrity Project testimony, Docket No. EPA-HQ-OW-2009-0819. [Online]

Stanton, E.A., P. Knight, and F. Ackerman. 2013. *LaSalle Fleet Benefit Rebuttal.* Expert comments submitted by Whitt Law to the Illinois Property Tax Appeal Board, Dockets No. 09-04906.001-I-3, 09-04906.002-I-310-03549.001, 10-03549.002, 12-00643.001, 12-00643.002, 12-00643.003. [Online]

Nogee A., M. Chang, P. Knight, and E.A. Stanton. 2013. *Electricity Market Restructuring and the Nuclear Industry.* Expert comments submitted by Whitt Law testimony regarding LaSalle Station to the Illinois Property Tax Appeal Board, Dockets No. 09-04906.001-I-3, 09-04906.002-I-310-03549.001, 10-03549.002, 12-00643.001, 12-00643.002, 12-00643.003. [Online]

Stanton, E.A. 2013. *Testimony Regarding Vermont Gas System's Petition for Authorization to Construct New Natural Gas Transmission Pipeline*. Testimony on behalf of the Conservation Law Foundation to the State of Vermont Public Service Board, Docket No. 7970. [Online]

Ackerman, F., and E.A. Stanton. 2011. *Regulation of Cooling Water Intake Structures at Existing Facilities.* Comments submitted to the U.S. Environmental Protection Agency, Docket ID EPA-HQ-OW-2008-0667. [Online]

Ackerman, F. and E.A. Stanton. 2010. *Testimony on EPA's 'Coal Combustion Residuals: Proposed Rule'.* Comment submitted as part of Earthjustice/Environmental Integrity Project testimony, Docket ID EPA-HQ-RCRA- 2009-6040. [Online]

JOURNAL ARTICLES

Luckow, P., J. Daniel, S. Fields, E.A. Stanton, and B. Biewald. 2014. "CO_2 Price Forecast: Planning for Future Environmental Regulations." *EM Magazine*, *June 2014*, 57-59. [Online]

Stanton, E.A. 2014. "What Carbon Costs Us." *Economists for Peace & Security Quarterly* 27 (4), 7-8. [Online]

Ackerman, F., E.A. Stanton, and R. Bueno. 2013. "Epstein-Zin utility in DICE: Is risk aversion irrelevant to climate policy?" *Environmental and Resource Economics* 56 (1), 73-84. [Online]

Stanton, E.A. 2012. "Modeling Pessimism: Does Climate Stabilization Require a Failure of Development?" *Environmental Development* 3, 65-76. [Online]

Stanton, E.A. 2012. "The Tragedy of Maldistribution: Climate, Sustainability, and Equity." *Sustainability* 4 (3): 394-411. [Online]

Erickson, P., D. Allaway, M. Lazarus, and E.A. Stanton. 2012. "A Consumption-Based GHG Inventory for the U.S. State of Oregon." *Environmental Science & Technology* 46 (7), 3679-3686. [Online]

Ackerman, F., E.A. Stanton, and R. Bueno. 2011. "CRED: A new model of climate and development." *Ecological Economics* 85, 166-176. [Online]

Ackerman, F. and E.A. Stanton. 2012. "Climate Risks and Carbon Prices: Revising the Social Cost of Carbon." *Economics: The Open-Access, Open-Assessment E-Journal* 6 (2012-10), 1-25. [Online]

Ackerman, F., E.A. Stanton, S. DeCanio, E. Goodstein, R. Howarth, R. Norgaard, C. Norman, and K. Sheeran. 2010. "The Economics of 350." *Solutions* 1 (5), 49-56. [Online]

Ackerman, F., E.A. Stanton, and R. Bueno. 2010. "Fat Tails, Exponents, Extreme Uncertainty: Simulating Catastrophe in DICE." *Ecological Economics* 69 (8), 1657-1665. [Online]

Stanton, E.A. and F. Ackerman. 2009. "Climate and development economics: Balancing science, politics and equity." *Natural Resources Forum* 33 (4), 262-273. [Online]

Stanton, E.A., F. Ackerman, and S. Kartha. 2009. "Inside the Integrated Assessment Models: Four Issues in Climate Economics." *Climate and Development* 1 (2), 166-184. [Online]

Stanton, E.A. 2009. "Negishi welfare weights in integrated assessment models: The mathematics of global inequality." *Climatic Change* 107 (3), 417-432. [Online]

Ackerman, F., E.A. Stanton, C. Hope, and S. Alberth. 2009. "Did the Stern Review Underestimate U.S. and Global Climate Damages?" *Energy Policy* 37 (7), 2717-2721. [Online]

Ackerman, F. and E.A. Stanton. 2008. "Can Climate Change Save Lives? A comment on 'Economy-wide estimates of the implications of climate change: Human health'". *Ecological Economics* 66 (1), 8-13. (Previous edition appeared as Global Development and Environment Institute Working Paper No.06-05.) [Online]

Ackerman, F., E.A. Stanton, B. Roach, and A. S. Andersson. 2008. "Implications of REACH for Developing Countries." *European Environment* 18 (1): 16-29. [Online]

Ackerman, F., E.A. Stanton, and R. Massey. 2007. "European Chemical Policy and the United States: The Impacts of REACH." *Renewable Resources Journal* 25 (1). (Previously published as Global Development and Environment Institute Working Paper No.06-06.) [Online]

BOOKS AND BOOK CHAPTERS

Ackerman, F. and E.A. Stanton. 2015. "Climate Impacts on Agriculture: A Challenge to Complacency?". *The Oxford Handbook of the Macroeconomic of Global Warming,* eds. Bernard, L. and W. Semmler. New York: Oxford University Press. (Previous edition appeared as Global Development and Environment Institute Working Paper No.13-01.)

Ackerman, F. and E.A. Stanton. 2014. *Climate and Global Equity*. London: Anthem Press.

Ackerman, F. and E.A. Stanton. 2013. *Climate Economics: The State of the Art (Routledge Studies in Ecological Economics)*. Oxford: Routledge.

Stanton, E.A. 2011. "Greenhouse Gases and Human Well-Being: China in a Global Perspective." *The Economics of Climate Change in China: Towards and Low-Carbon Economy* eds. Gang, F., N. Stern, O. Edenhofer, X. Shanda, K. Eklund, F. Ackerman, L. Lailai, K. Hallding. London: Earthscan. (Previous version appeared as Stockholm Environment Institute-U.S. Center Working Paper WP-US-0907.)

Boyce, J. K., E.A. Stanton, and S. Narain, eds. 2007. *Reclaiming Nature: Worldwide Strategies for Building Natural Assets*. London: Anthem Press.

Boyce, J. K., E.A. Stanton, and S. Narain. 2007. "Land Reform and Sustainable Development." *Reclaiming Nature: Worldwide Strategies for Building Natural Assets,* eds. Boyce, J. K., E.A. Stanton, and S. Narain. London: Anthem Press.

Stanton, E.A. 2007. "Inequality and the Human Development Index." PhD dissertation, University of Massachusetts-Amherst, 2007.

Stanton, E.A. and J. K. Boyce. 2005. *Environment for the People*. Political Economy Research Institute: Amherst, MA.

TEACHING EXPERIENCE

Tufts University, Medford, MA

Adjunct Professor, Department of Urban Environmental Policy and Planning, 2007, 2017, 2018

College of New Rochelle, New Rochelle, NY

Assistant Professor, Department of Social Sciences, 2007 – 2008

Fitchburg State College, Fitchburg, MA

Adjunct Professor, Social Sciences Department, 2006

University of Massachusetts-Amherst, Amherst, MA

Adjunct Professor, Department of Economics, 2003 – 2006

Castleton State College and the Southeast Vermont Community Learning Collaborative, Dummerston, VT

Adjunct Professor, 2005

School for International Training, Brattleboro, VT

Adjunct Professor, Program in Intercultural Management, Leadership, and Service, 2004

Resume dated August 2019

EXHIBIT B

DIRECT TESTIMONY OF

ELIZABETH A. STANTON, PHD
ON BEHALF OF ENVIRONMENTAL DEFENSE FUND

Puerto Rico Integrated Resource Plan: Lessons from Hawaii's Electric Sector

October 22, 2019

Applied Economics Clinic

Authors:
Bryndis Woods
Eliandro Tavares
Sagal Alisalad
Elizabeth A. Stanton, PhD

Executive Summary

The size and scale of the challenge facing Puerto Rico's electric utility, the Puerto Rican Electric Power Authority (PREPA), is difficult to overstate. The destructive force of Hurricanes Irma and Maria in September 2017 left thousands of people dead and caused extensive damage to all kinds of infrastructure, including roads, bridges, buildings and the electric grid—approximately 80 percent of the island's power lines were downed in the hurricanes. In the aftermath of the hurricanes, nearly the entire territory was left without power in the largest blackout in U.S. history, creating an immediate need for extensive re-building of the electric grid in order to restore power to the 1.5 million homes and businesses that lost it. The potential to build a better electric system creates a valuable opportunity for Puerto Rico to minimize future damages from stronger storms.

Puerto Rico need not, however, "reinvent the wheel" as it rebuilds and improves its grid. Hawaii and Puerto Rico are the largest U.S. island groups in population, area and energy consumption and share similar tropical climates, as well as similar emissions and energy policy goals. Hawaii recently undertook a dramatic overhaul of its own electric system and its most recent Integrated Resource Plan (IRP) plans for even more drastic changes to come; Hawaii's experience offers essential lessons for Puerto Rico as it moves forward. Hawaii has already confronted many of the same issues facing Puerto Rico today—such as the need to enhance the flexibility, reliability and resiliency of the electric grid—and has had laudable success in addressing these issues. This Applied Economics Clinic report compares PREPA's most recent version of its Integrated Resource Plan (IRP), released in June 2019, to best practices distilled from the most recent Hawaiian electric sector planning process, which was finalized in 2016 (Table ES-1).

Table ES-1. Best practices for utility resource planning from Hawaii

Emphasis on grid reliability and climate resiliency via:		
Renewable energy	**Distributed energy resources**	**Eliminates gas imports**
Develop low-cost renewable resources and battery storage	Shift from centralized to distributed energy resources	Reduce generation costs by retiring aging fossil fuel plants
Pursue renewables with the highest certainty of deployment early in the planning period	Assess all types of distributed energy resources on equal footing with other capacity expansion opportunities	Place renewable energy, energy efficiency, demand response and battery storage on equal footing with fossil fuel generation for capacity expansion
Ensure lowest costs for ratepayers by considering renewables on equal footing with fossil fuels	Consider grid services and risk reduction from distributed energy resources relative to other capacity expansion opportunities	Assess the risks of stranded costs, uncertainties, and rate impacts of imported LNG fuels and new fossil generation

The current state of Puerto Rico's electric grid

Currently, Puerto Rico's electric grid is dominated by large coal, gas and oil-fired generators that serve the entire island. In 2018, less than 1.5 percent of the island's electric generation came from renewable resources, although Puerto Rican law mandates that renewable energy must account for 20 percent of all generation by 2022 and completely replace fossil fuels by 2050. PREPA's June IRP includes 1,800 MW of planned solar capacity additions (equal to 29 percent of 2018 total installed electric capacity) as well as plans for 2,222 MW of new and converted gas-fired capacity (36 percent of 2018 capacity) and three new liquefied natural gas (LNG) import facilities, all by the end of 2025. PREPA's June IRP also plans for an extensive shift to flexible, distributed generation resources in the form of eight connected regional "minigrids" across the island that are connected to each other but can also operate self-sufficiently.

Hawaii's electric resource planning sets the bar

Puerto Rico needs to re-build its electric grid for flexibility, reliability and resiliency. Our review of the Hawaiian experience highlights three important focus areas to accomplish these goals: renewable energy, distributed energy resources and an elimination of gas imports. This report offers several best practices for each of these focus areas, gleaned from the most recent Hawaiian IRP and the Hawaiian utility commission's feedback during the IRP development process. Hawaii's recent planning process demonstrates the importance of:

- Shifting from centralized, fossil fuel power plants to more widely distributed renewable generation,
- Allowing all resources (including both electric supply and customer demand resources) to complete on equal footing, and
- Fully accounting for potential risks and benefits of various resource options.

Paying due consideration to these lessons from Hawaii has the potential to improve Puerto Rico's resource planning practices, ensure that PREPA can comply with Puerto Rico's climate laws, and provide customers with the lowest possible electric rates.

PREPA's June IRP falls short in its compliance with Puerto Rican renewables requirements and the degree to which it allows renewables to compete on equal footing with fossil fuels. As a consequence of these shortcomings, PREPA's June IRP proposes to substantially increase the island's investment in gas-fired generation and gas import facilities. A policy of continued investment in gas infrastructure fails to adequately account for the important financial risks posed to both PREPA and to all Puerto Rican residents of the island's strict climate law, the potential for stranded assets, or the cost volatility of fossil fuel imports. Given the island's recent history with centralized generation resources during an extreme weather event like a hurricane, it is particularly important that PREPA's resource planning prioritize critical grid benefits like reliability and resiliency. Finally, while PREPA's June IRP includes ambitious plans to develop distributed energy resources, these proposals need to be fleshed out with additional detail regarding the amount and type of planned capacity.

Table of Contents

1. Introduction

As Puerto Rico works to develop its first island-wide integrated resource plan (IRP) since the severe damage to the electric grid caused by Hurricanes Irma and Maria, there are lessons to learn from resource planning in places that share similar constraints and opportunities in their energy systems. This Applied Economics Clinic report compares the most recent IRP from Puerto Rico's electric utility to best practices distilled from the most recent Hawaiian IRP, which was finalized in 2016.

Important parallels exist between the Hawaiian and Puerto Rican energy sectors (see

Table 1 below):

- Small population (Hawaii has the 11th smallest population and Puerto Rico's is a little smaller than Iowa, the state with the 20th smallest population),
- Substantial fossil fuel dependence (fossil fuels accounted for 83 percent of Hawaii's 2018 total generation and 98 percent of Puerto Rico's 2018 total generation),
- Both Hawaii and Puerto Rico use less coal for electric generation (13 and 15 percent, respectively) than the United States does as a whole (27 percent);
- Puerto Rico uses similar amounts of gas for electric generation (38 percent) as the United States as a whole (35 percent), while Hawaii uses much less (< 1 percent);
- Both Hawaii and Puerto Rico use much more oil for electric generation (70 and 45 percent, respectively) compared to the United States as a whole (<1 percent);
- High electric rates (residents in Hawaii and Puerto Rico pay at least 170 percent more than the average U.S. electric customer),
- Modest electric demand (taken together, Hawaii and Puerto Rico's annual electric generation accounts for less than 1 percent of the U.S. total),
- High potential for solar generation,[1] and
- High vulnerability of coastal infrastructure to large ocean storms and sea level rise.[2]

Both Hawaii and Puerto Rico have a 100 percent renewable energy target by mid-century (2045 and 2050, respectively) and both operate electric grid systems without any interconnection to a neighboring system.

---

[1] Solargis. 2019. Solar resource maps of USA and Puerto Rico. Available at: https://solargis.com/maps-and-gis-data/download/usa and https://solargis.com/maps-and-gis-data/download/puerto-rico.

[2] U.S. Department of Energy. 2015. Hawaii and Puerto Rico: Climate Change and the U.S. Energy Sector: Regional vulnerabilities and resilience solutions. Available at: https://www.energy.gov/sites/prod/files/2015/10/f27/Hawaii_and_Puerto_Rico.pdf.

Table 1. Snapshot of Hawaii and Puerto Rico energy systems, with share of total U.S. value

		Hawaii	Puerto Rico
Population (millions)		1.4 (0.4%)	3.3 (1.0%)
Poverty Rate (% of persons in poverty)		9 (75%)	43 (365%)
GDP (billions $)		92 (0.5%)	103 (0.6%)
Electric Rates (cents/kWh)	Residential	34 (260%)	23 (173%)
	Commercial	30 (288%)	26 (247%)
	Industrial	27 (406%)	22 (336%)
2018 total installed electric capacity (GW)		3.1 (0.3%)	6.3 (0.5%)
2018 total electric generation (GWh)		9,802 (0.2%)	16,299 (0.4%)
Coal share of total electric generation (%)		13.4%	15.4%
Gas share of total electric generation (%)		0.6%	37.7%
Oil share of total electric generation (%)		68.8%	45.3%

Note: Latest available data years are inconsistent across variables. Population is from 2017. GDP is from 2015. Electric rates are from 2019. Installed capacity, total generation and generation shares are from 2018.
Sources: (1) U.S. EIA. 2018. Hawaii State Energy Profile. EIA. Available at: https://www.eia.gov/state/print.php?sid=HI. (2) U.S. EIA. 2018. Puerto Rico Territory Energy Profile. EIA. Available at: https://www.eia.gov/state/print.php?sid=RQ. (3) U.S. Census Bureau. QuickFacts: Puerto Rico, Hawaii and United States. Available at: https://www.census.gov/quickfacts/fact/table/PR/PST045218, https://www.census.gov/quickfacts/fact/table/HI/IPE120218#IPE120218, and https://www.census.gov/quickfacts/fact/table/US/SEX255218. (4) U.S. EIA. 2018 Form EIA-860 Data - Schedule 3, 'Generator Data' (Operable Units Only. Available at: https://www.eia.gov/electricity/data/eia860/. (5) U.S. EIA. EIA-923 Monthly Generation and Fuel Consumption Time Series File, 2018 Data Early Release. Available at: https://www.eia.gov/electricity/data/eia923/. (6) PREPA. June 7, 2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. Exhibit 4-1.

There are also important differences between the two jurisdictions: Puerto Rico is much more dependent on fossil fuels for electric generation than Hawaii, particularly on gas; Hawaii is more dependent on oil for electric generation than Puerto Rico; Hawaiians pay higher electric rates than Puerto Ricans; and Puerto Rico serves a population that has a much higher incidence of poverty and is more than twice as large as that of Hawaii.

In 2014, the Hawaiian utilities—The Hawaiian Electric Company, Inc., Hawaii Electric Light Company, Inc. and Maui Electric Company, Ltd.—released their Power Supply Improvement Plans (PSIPs). The Hawaiian Public Utilities Commission (HPUC) and other stakeholders then worked with the Hawaiian utilities to further develop these PSIPs to accelerate the achievement of Hawaii's 100 percent Renewable Portfolio Standard (RPS), required by 2045.[3] The Hawaiian utilities released a final joint PSIP in 2016 that includes an

[3] The Hawaiian Electric Companies. 2016. *The Hawaiian Electric Companies' 2016 Power Supply Improvement Plan (PSIP) Update*. Executive Summary. p. ES-1. Available at: https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/power-supply-improvement-plan.

action plan for the 2017 to 2021 period. The development of the Hawaiian utilities' final PSIP included feedback from multiple stakeholders, including the Hawaiian utility commission. The 2016 Hawaiian PSIP is widely considered to be among the leading integrated resource plans in the nation in developing local, renewable energy and resilient, technologically advanced electric grids.[4]

The recent history of Puerto Rico's electric utility, the Puerto Rican Electric Power Authority (PREPA), has been troubled: the island suffered massive damage from Hurricanes Irma and Maria in September 2017, leaving nearly the entire territory without power and creating the need for extensive re-building of the electric grid.[5] Even before the hurricanes, PREPA was in dire financial straits, and had filed for bankruptcy in July 2017.[6] Following Irma and Maria, Puerto Rico has embarked on a process to both privatize PREPA and rebuild the electric grid to "create a consumer focused, efficient, resilient, and environmentally friendly grid system that delivers affordable electricity to the people of Puerto Rico," according to José F. Ortiz Vázquez, the Executive Director and Chief Executive Officer of PREPA.[7] The rebuilding of the island's electric system has been fraught, however, as large numbers of Puerto Ricans have dealt with extensive hurricane damage and long-term electric outages and PREPA has found itself embroiled in multiple scandals—accusations of taking kickbacks, making corrupt deals[8] and questionable oil payments.[9] There has also been internal upheaval at PREPA: the company has cycled through multiple Chief Executive Officers since the hurricane.[10]

In February 2019, PREPA released its latest IRP. In March 2019, Puerto Rico's Energy Bureau rejected PREPA's filing, and instructed the utility to address various deficiencies identified by the Bureau, such as inadequate renewable buildout, a deficient consideration of distributed generation, and an overreliance on

---

[4] See, for example: Center for the New Energy Economy. 2018. *State Brief: Hawaii*. Available at: http://cnee.colostate.edu/wp-content/uploads/2018/09/State-Brief_HI.pdf and Magill, B. February 19, 2019. Hawaii 'Postcard From the Future' for Renewables. *Bloomberg Environment*. Available at: https://news.bloombergenvironment.com/environment-and-energy/hawaii-postcard-from-the-future-for-renewables.
[5] Becker, R. September 25, 2017. "After Hurricane Maria, what will it take to turn Puerto Rico's power back on?" *The Verge*. Available at: https://www.theverge.com/2017/9/25/16362410/hurricane-maria-puerto-rico-power-outages-electrical-grid-destroyed.
[6] Volpe, M. April 15, 2019. "The Complicated Evolution of PREPA." *Al Día News*. Available at: https://aldianews.com/articles/culture/complicated-evolution-prepa/55417.
[7] Ibid.
[8] Alarcón, D. August 23, 2018. "What Happened in the Dark: Puerto Rico's Year of Fighting for Power". *Wired*. Available at: https://www.wired.com/story/puerto-rico-hurricane-maria-recovery/.
[9] Sanzillo, T. and Kunkel, C. July 2018. *Multibillion-Dollar Oil Scandal Goes Unaddressed in PREPA Contract Reform and Privatization*. Institute for Energy Economics and Financial Analysis. Available at: http://ieefa.org/wp-content/uploads/2018/07/Multibillion-Dollar-Oil-Scandal-Goes-Unaddressed-in-PREPA-Contract-Reform-and-Privatization-_July-2018.pdf.
[10] Sullivan, E. August 15, 2018. "Nearly A Year After Maria, Puerto Rico Officials Claim Power Is Totally Restored." *NPR*. Available at: https://www.npr.org/2018/08/15/638739819/nearly-a-year-after-maria-puerto-rico-officials-claim-power-totally-restored.

gas resources—critiques very reminiscent of the Hawaiian commission's response to its utilities' 2014 PSIPs.[11] In April 2019, former Puerto Rico Governor Ricardo Rosselló signed the Public Energy Policy Law, which mandates 100 percent renewable energy by 2050.[12] The law specifically directs PREPA to obtain 40 percent of its energy from renewable sources by 2025 and to eliminate coal from its energy mix by 2028. In June 2019, PREPA released an updated IRP filing, which this report assesses by way of comparison to Hawaii's current resource plan. While Puerto Rico undoubtedly faces an array of challenges that were not shared in the development of Hawaii's 2016 PSIP, Hawaii's experience illuminates several best practices that seem particularly relevant to Puerto Rico's current planning process.

This Applied Economics Clinic report presents the results of our assessment of best practices and lessons learned from the Hawaiian utilities' joint 2016 PSIP filing as they apply to PREPA's June 2019 IRP filing.[13] Sections of this report address each of the three major areas of critique made by Puerto Rico's Energy Bureau regarding how well PREPA's initial February 2019 IRP filings contribute to grid reliability and climate resiliency:

- Local renewable generation (Section 2),
- Distributed energy resources (Section 3), and
- Oil to gas conversion and degree of reliance on imported liquefied natural gas (LNG) (Section 4).

2. Renewable Generation

Best practices learned in the Hawaiian planning process can serve as valuable input for Puerto Rico's resource planners as the island continues to recover from the devastation wrought by Hurricanes Irma and Maria and to rebuild its electric grid to maximize grid reliability and climate resiliency while providing the lowest possible cost to its ratepayers.

Section 2 presents the current state of renewable energy development in Hawaii, details best practices gleaned from our review of Hawaii's most recent IRP, review the state of renewable energy in Puerto Rico, and assesses Puerto Rico's IRP in the context of Hawaiian best practices:

- Develop low-cost renewable resources and battery storage,

[11] Kunkel, C. March 29, 2019. "IEEFA Puerto Rico: Regulator rejects PREPA's 20-year plan." *Institute for Energy Economics and Financial Analysis*. Available at: http://ieefa.org/ieefa-puerto-rico-regulator-rejects-prepas-20-year-plan/.
[12] Bade, G. April 12, 2019. "Puerto Rico governor signs 100% renewable energy mandate." *Utility Dive*. Available at: https://www.utilitydive.com/news/puerto-rico-governor-signs-100-renewable-energy-mandate/552614/.
[13] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. *Puerto Rico Integrated Resource Plan 2018-2019*. Submitted by Siemens Industry. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf.

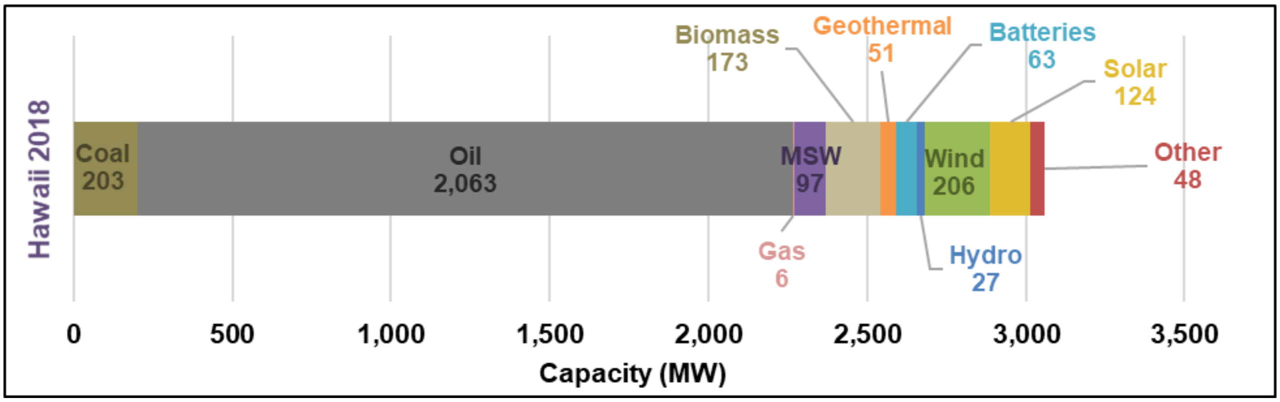
- Pursue renewables with the highest certainty of deployment early in the planning period, and
- Ensure lowest costs for ratepayers by considering renewables on equal footing with fossil fuels.

The subsequent section of this report (Section 3) discusses the closely related topic of distributed energy resources.

Renewables in Hawaii

In 2018, Hawaii had a total of 3,061 megawatts (MW) of installed electric generating capacity (see Figure 1). Oil-fired generation accounted for nearly 70 percent of the islands' total capacity, while renewable geothermal, wind, solar, hydro and battery storage accounted for 15 percent (the remainder is composed of coal, gas and energy from municipal solid waste (MSW)).[14] Hawaii's peak electric demand in 2017 was 1,184 MW.

Figure 1. Hawaiian installed electric generating capacity as of June 2019 (MW)



Note: MSW = Municipal Solid Waste. Also note that the scale in Figure 3 is not the same as the scale in Figure 4 below. Source: EIA. 2018 Form EIA-860 Data - Schedule 3, 'Generator Data' (Operable Units Only. Available at: https://www.eia.gov/electricity/data/eia860/.

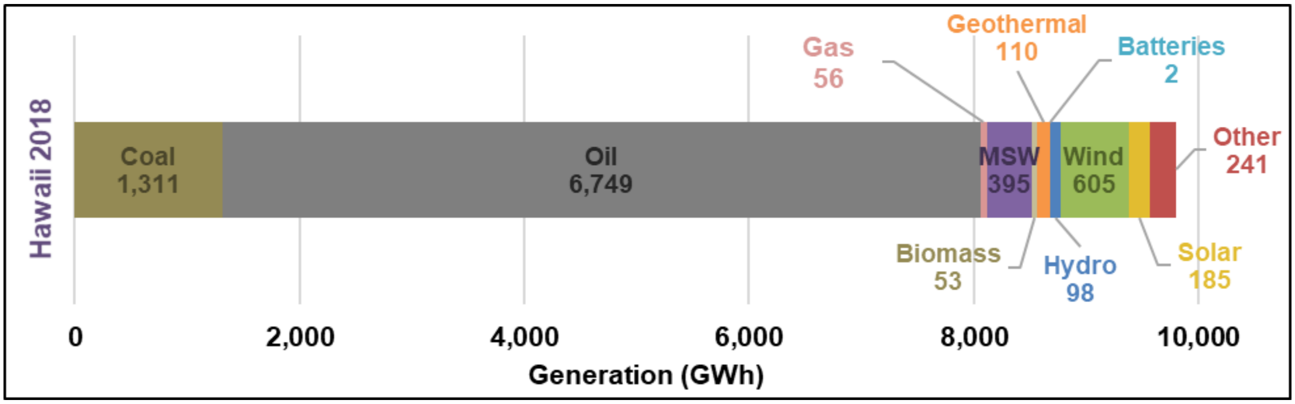
In 2018, 11 percent of Hawaii's total utility-scale electric generation[15] (1,050 gigawatt-hours (GWh)) came from renewable energy sources (solar, wind, biomass, battery storage, geothermal and hydro in Figure 2 below). According to state law, all electric utilities must acquire renewable generation equal to 30 percent

[14] In Hawaii, utility-scale solar resources are assumed to have a 24 percent capacity factor, while utility-scale wind resources are assumed to have a 35 to 45 percent capacity factor. (A capacity factor represents the amount of expected electrical output, given as a percentage of that resource's maximum total output). See: Hawaii State Energy Office. 2016. "Hawaii Energy Facts & Figures." Available at: http://energy.hawaii.gov/wp-content/uploads/2011/08/FF_Nov2016.pdf. p. 3.

[15] When behind-the-meter resources are included, the share of renewable generation increases to 23 percent of total generation (as of July 2019). See: Hawaii State Energy Office. 2019. "Hawaii Energy Facts and Figures." Available at: https://energy.hawaii.gov/wp-content/uploads/2019/07/2019-FF_Final.pdf. Figure 1, p. 2.

of retail sales by the end of 2020—a share that increases to 70 percent in 2040.[16] By the end of 2045, Hawaii's fossil fuel-powered generation must be completely replaced by renewable sources.

Figure 2. Hawaii electricity generation by source, 2018 (GWh)



Note: Generation for battery storage constitutes negative generation. We have changed its sign to positive for illustrative purposes. Source: U.S. EIA. EIA-923 Monthly Generation and Fuel Consumption Time Series File, 2018 Data Early Release. Available at https://www.eia.gov/electricity/data/eia923/.

Lessons Learned from Hawaii

The process of developing and finalizing the Hawaiian utilities' final PSIPs included substantial changes to the treatment of renewable generation. In their original 2014 PSIPs, the Hawaiian utilities planned only for just under 300 MW of renewable capacity expansion by 2022. The Hawaiian utility commission found that this proposed plan:

- **Picked winners:** Placed "inappropriate" limitations or constraints on the amounts and types of renewable resources considered, which ultimately served to unduly restrict the resources eligible for selection during model analysis;[17]
- **Left money on the table:** Planned to build renewable energy resources too late in the planning period given the state's climate goals and the disappearing opportunity for tax credits; and
- **Spent more than necessary:** Selected renewable resources with higher costs (or greater uncertainty) than other renewable opportunities available.

[16] Bill No. HB623. 2015. State of Hawaii House of Representatives. *House of Representatives Twenty-Eighth Legislature, Renewable Portfolio Standards.* Available at: https://www.capitol.hawaii.gov/session2015/bills/HB623_CD1_.htm.

[17] The Public Utilities Commission of the State of Hawaii. November 2015. Docket No. 2014-0183. Order No. 33320. *Instituting a Proceeding to Review to Power Supply Improvement Plans for Hawaiian Electric Company, Inc., Hawaii Electric Light Company, Inc. and Maui Electric Company Limited*. Available at: https://cca.hawaii.gov/dca/files/2015/11/2014-0183-Order-No.-33320-2015-11-4.pdf. p. 73-89.

In their 2016 final PSIPs Hawaiian utilities plan to build over 950 MW of new, utility-scale renewable resources and demand response by 2022 (see Table 2), equivalent to 31 percent of the island's current total installed capacity and the largest amount of new generation ever undertaken in the state, according to the Hawaiian utility commission.[18] This represents a large increase from the amount of planned utility-scale renewable resources and demand response in the original 2014 PSIPs (a 660 MW, or 31 percent, increase). Pursuing this amount of renewable capacity early in the planning period enables the Hawaiian utilities to take advantage of federal tax credits and low interest rates.[19]

Table 2. Hawaiian renewable energy additions installed by the end of 2021 (MW)

Planned Renewable Energy and Demand Response (MW)		
	Original PSIPs	Final PSIPs
Demand Response	34	115
Rooftop Solar	234	326
Utility Solar	0	360
Wind	30	157
TOTAL	298	958

Source: Original PSIPs—(1) HI PUC. Docket No. 2011-0206. August 26, 2014. Hawaiian Electric Power Supply Improvement Plan. Table 5-4; (2) HI PUC. Docket No. 2011-0092. August 26, 2014. Maui Electric Power Supply Improvement Plan. Table 5-1; (3) HI PUC. Docket No. 2011-0212. August 26, 2014. Hawai'i Electric Power Supply Improvement Plan. Table 5-3. Final PSIPs—HI PUC. Docket No. 2014-0183. December 23, 2016. Hawaiian Electric Companies'' PSIPs Update Report; Book 1 of 4. p. ES-3. All documents available at: https://dms.puc.hawaii.gov/dms/dockets?action=search&docketNumber=2014-0183.

The Hawaiian commission also noted that the original PSIPs' reliance on fossil fuel generation (switching all oil generators to imported LNG) for grid-stabilization did not appear to support further renewable integration because only small amounts of renewable generation were added after LNG investments, despite the cost-effectiveness of wind and solar.[20]

To address these shortcomings, the commission called on the Hawaiian utilities to more fully assess the risks and uncertainties presented by their plans—such as the impacts of LNG imports, improvements in renewable resource technology and availability, and the potential for stranded assets[21]—to ensure that the proposed renewable energy plan is the most reasonable and cost-effective way to ensure reliability,

[18] The Public Utilities Commission of the State of Hawaii. July 2017. Docket No. 2014-0183. Order No. 34696. *Instituting a Proceeding to Review to Power Supply Improvement Plans for Hawaiian Electric Company, Inc., Hawaii Electric Light Company, Inc. and Maui Electric Company Limited*. Available at: https://cca.hawaii.gov/dca/files/2017/07/C-DOCUME-1ADMINI-1.PUCLOCALS-1TempE0EE20B8BF764C829EFE43659308E00200007802.pdf. p. 27.
[19] Ibid. p. 14-15.
[20] Ibid. p. 66-69.
[21] Ibid. p. 6-7.

affordability and the enhanced integration of renewable energy sources.[22] The final 2016 PSIPs reflect these changes: more renewable energy capacity additions, a greater share of distributed energy resources, and an elimination of planned LNG imports.

Hawaiian Best Practices

Hawaii's electric-sector planning experience demonstrates that for renewable resources to provide maximum benefit for electric customers utilities must prioritize these goals:

a) **Develop low-cost renewable resources and battery storage:** Low-cost renewable energy resources, and pair some of these resources with battery storage to provide the greatest grid reliability and resiliency;

b) **Pursue renewables with the highest certainty of deployment early in the planning period**: Building renewable energy sources with a high certainty of successful deployment early in the planning period in order to take advantage of declining federal tax credits and as a buffer against fossil fuel price volatility; and

c) **Ensure lowest costs for ratepayers by considering renewables on equal footing with fossil fuels:** Obtaining the lowest costs for electric consumers by considering all types of supply-side resources on a level playing field.

Renewables in Puerto Rico

In 2018, Puerto Rico had a total of 6,129 MW of installed electric capacity (see Figure 3 below)—more than double that of Hawaii. Like Hawaii, oil-fired resources accounted for the majority of the island's total electric capacity (65 percent in Puerto Rico). However, hydro, wind and solar [23] only make up 5 percent of Puerto Rico's electric capacity, compared to Hawaii's 12 percent. Puerto Rico's electric system also differs from that of Hawaii in its use of gas: 22 percent of Puerto Rico's installed electric capacity is gas-fired; Hawaii has no gas generation. Puerto Rico's peak electric demand in 2017 was 3,685 MW.[24]

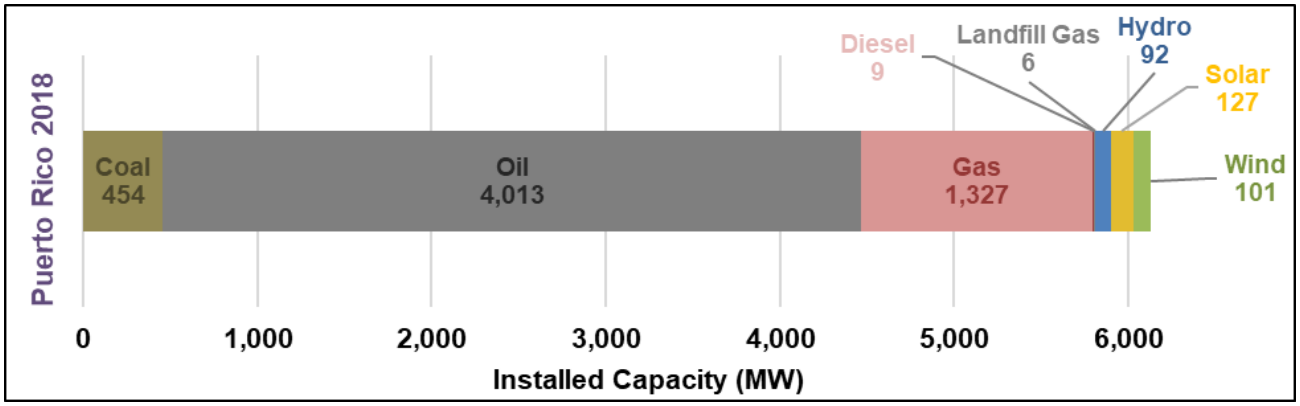
---

[22] The Public Utilities Commission of the State of Hawaii. November 2015. Docket No. 2014-0183. Order No. 33320. p. 6.

[23] Note that Puerto Rico does not have any installed biomass or geothermal capacity. PREPA does not report battery storage as a separate category. However, U.S. EIA data from June 2019 suggests that Puerto Rico has 30.5 MW of battery storage installed.

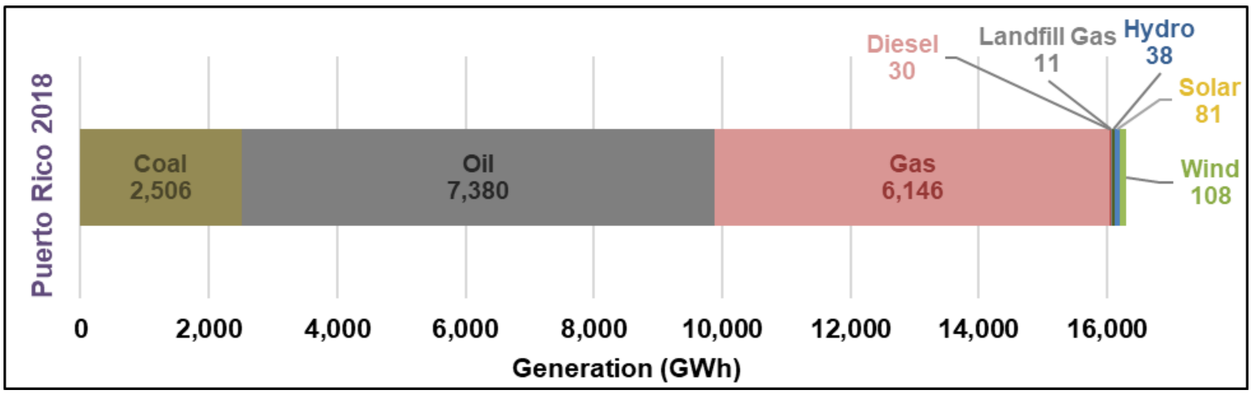
[24] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. Exhibit 7-17.

Figure 3. 2018 Puerto Rican installed electric generating capacity (MW)



Note: Horizontal scale differs from that of Figure 1 (2018 Hawaiian installed electric generation capacity) above. In the data source listed below, PREPA classified Costa Sur 5 and 6 as oil-fired units. We reclassified them as gas units in accordance with PREPA's June IRP (Exhibit 4-5) and in U.S. Energy Information Administration (EIA) data (see: EIA. June 2019. "Monthly Electric Generator Inventory". Available at: https://www.eia.gov/electricity/data/eia860m/).
Source: PREPA. June 7, 2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. Exhibit 4-1.

Figure 4. 2018 Puerto Rican electric generation (GWh)



Note: Horizontal scale differs from that of Figure 3 above.
Source: PREPA. June 7, 2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. Exhibit 4-1.

In 2018, just 1.4 percent of Puerto Rico's total electric generation came from renewable energy sources (hydro, solar and wind in Figure 4). According to Puerto Rico law,[25] 40 percent of total retail sales must come from renewable sources by 2025. By the end of 2050, Puerto Rico's fossil fuel-powered generation

[25] Legislative Assembly of Puerto Rico. April 11, 2019. Act No. 17-2019 (S. B. 1121). Puerto Rico Energy Public Policy Act. 5th Regular Session of the 18th Legislative Assembly of Puerto Rico. Available at: https://aeepr.com/es-pr/QuienesSomos/Ley17/A-17-2019%20PS%201121%20Politica%20Publica%20Energetica.pdf.

must be completely replaced by renewable sources. Using the expected rates of generation[26] used by PREPA in its IRP modeling, the preferred portfolio (ESM scenario) in the June 2016 plan would result in 38 percent of retail sales in 2025[27]—assuming that 400 MW of existing and 235 MW of new customer-owned distributed generation could be certified and tracked with renewable energy certificates. Without distributed generation, Puerto Rico's renewables would amount to only 30 percent of retail sales in 2025, far below the 40 percent requirement.[28] PREPA's June 2016 IRP preferred plan does not appear to comply with Puerto Rico's April 2019 Energy Public Policy Act.[29]

The Hawaiian best practices—pursue low-cost renewable resources and battery storage; prioritize renewables with the highest certainty of deployment and pursue them early in the planning period; and choose the amounts and types of renewables that will lower customer costs—may serve as lessons for Puerto Rico as it endeavors to more aggressively develop its own renewable resources in such a way as will provide maximum benefits to its electric grid and ratepayers.

a) Develop low-cost renewable resources and battery storage

Puerto Rico aims to transition to 100 percent renewables by 2050, with a milestone of 40 percent renewable energy generation by 2025.[30] Although PREPA's June preferred plan goes further to shift the island towards that goal than that proposed in February, nearly two-fifths of planned capacity expansions in the June plan are fossil fuel resources. PREPA plans to add 1,622 MW of new greenhouse gas emitting gas-fired capacity, convert 600 MW of oil capacity to become gas-fired, and build three new LNG terminals. By law, no gas or other non-renewable generation may run in Puerto Rico after 2050[31]; according to PREPA's reported lifetimes of these facilities (see Table 3 below), the two 302 MW gas combined cycle plants (Palo Seco and Yabucoa) will have 3 years of remaining useful life in 2050 but cannot operate after that year. Based on PREPA's estimates of the cost of the proposed new gas plants, approximately $84

[26] In Puerto Rico, utility-scale solar resources are assumed to have a 22 percent capacity factor, while utility-scale wind resources are assumed to have a 25 percent capacity factor. See: Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. *Puerto Rico Integrated Resource Plan 2018-2019*. Submitted by Siemens Industry. Available at: https://drive.google.com/drive/folders/1ot4u-aV2U6gZNdzEru42WqQeKljjfdC0. Exhibit 6-32.
[27] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. Exhibits 3-18, 3-16, and 3-11.
[28] Ibid. Exhibits 3-34 and 3-32.
[29] Legislative Assembly of Puerto Rico. April 11, 2019. Act No. 17-2019 (S. B. 1121). *Puerto Rico Energy Public Policy Act*. 5th Regular Session of the 18th Legislative Assembly of Puerto Rico. Available at: https://aeepr.com/es-pr/QuienesSomos/Ley17/A-17-2019%20PS%201121%20Politica%20Publica%20Energetica.pdf.
[30] Puerto Rico Federal Affairs Administration. May 23, 2019. "Governor Ricardo Rossello Signs Historic Climate Change Bill." Available at: http://prfaa.pr.gov/governor-ricardo-rossello-signs-historic-climate-change-bill/.
[31] Legislative Assembly of Puerto Rico. April 11, 2019. Act No. 17-2019 (S. B. 1121). *Puerto Rico Energy Public Policy Act*. 5th Regular Session of the 18th Legislative Assembly of Puerto Rico. Available at: https://aeepr.com/es-pr/QuienesSomos/Ley17/A-17-2019%20PS%201121%20Politica%20Publica%20Energetica.pdf.

million would still be owed to pay the full cost of these plants in 2050.[32]

Table 3. PREPA June 2019 IRP Exhibit 6-2 Capital Cost Recovery Factor by Asset Class

Asset Class	Capital Recovery Period (Years)	CCR
Combined Cycle Plant	28	9.5%
Small Combined Cycle	20	10.6%
Existing Unit Fuel Conversion / Switching (San Juan)	21	10.4%
Solar PV /Wind	25	9.8%
Battery Storage	20	10.6%
LNG Terminal	22	9.8%

Source: Reproduced from PREPA June 2019 IRP Exhibit 6-2.

PREPA's June IRP includes more low-cost renewable resources than the utility's February plan, putting Puerto Rico on relatively equal footing with Hawaii in terms of solar buildout and demand response measures but falling short in terms of renewable buildout as a share of electric peak in the near-term—Hawaii is planning for 958 MW of utility-scale solar and wind, rooftop solar, and demand response by the end of 2021 (see Table 2 above), equal to 31 percent of its 2018 total installed capacity, while PREPA is planning for 810 MW of solar and demand response (no wind) by the end of 2021, equal to 13 percent of its 2018 total installed capacity. PREPA's June 2019 IRP includes a preferred plan that more aggressively develops low-cost renewable energy capacity, in order to respond to "the need for a reliable and resilient electric grid".[33] In its June IRP, solar additions total 1,800 MW and battery storage additions total 800 MW by the end of 2023 (see Table 4 below).

PREPA's plans for battery storage are ambitious, with its June IRP describing batteries' role in increased grid resilience due to their ability to produce or absorb power throughout the day as needed and to continue to supply electricity even during short-duration outages. Battery storage also provides an important grid stabilization benefit to utilities managing supply to meet load. In its June IRP preferred plan, PREPA aims to install 800 MW of battery storage throughout the planning period, 480 MW of which will be built by 2022[34] (for reference, Puerto Rico had 31 MW of battery storage installed in 2018).[35] By comparison, Hawaii plans to install 512 MW of battery storage by the end of 2045, 192 MW of which will be built by 2022 (see Table 2 above) (for reference, Hawaii had 63 MW of battery storage installed in

[32] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. Exhibits 6-14, 6-15 and 8-44.
[33] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 2-6.
[34] Note that PREPA's June IRP (in Exhibit 10-2 and elsewhere) indicates that the cumulative battery storage additions total 920 MW when in fact, they only total 800 MW.
[35] U.S. EIA. June 2019. "Monthly Electric Generator Inventory". Available at: https://www.eia.gov/electricity/data/eia860m/.

2018).[36] Puerto Rico is currently planning to deploy considerable amounts of battery storage that go beyond the storage planned in Hawaii and will help the island most efficiently and cost-effectively utilize its renewable resources. Rapid, large-scale deployment of battery storage technology in PREPA's system will depend on success in several sequential steps in engineering, design, and planning, including issuing one or more requests for proposals (RFPs) for battery storage or renewable capacity plus battery storage, studies to identify optimal siting locations, and interconnection analysis under both connected and "islanded" scenarios.

Table 4. Renewable energy in PREPA's February and June IRP preferred plans

		2019	2020	2021	2022	2023	TOTAL
Solar PV (MW)	February IRP	0	0	240	480	180	900
	June IRP	0	300	480	600	420	1,800
	Change	0	+300	+240	+120	+240	+900
Battery Energy Storage (MW)	February IRP	20	100	160	160	160	600
	June IRP	40	200	480	80	0	800
	Change	20	100	320	-80	-160	+200

Note: PREPA's June IRP (in Exhibit 10-2 and elsewhere) indicates that the cumulative battery storage additions total 920 MW when in fact, they only total 800 MW. The numbers listed here for PREPA's June IRP are for their ESM scenario, however, PREPA also presents numbers for its S4S2 plan of 1,280 MW of battery storage additions and 1,740 MW of solar additions through 2023. It is unclear which of these data points applies to PREPA's preferred plan.
Data sources: (1) PREPA. June 7,2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. (2) PREPA. February 12, 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens PTI Report Number: RPT-015-19.

Although PREPA's June IRP considered onshore wind resources, none were chosen in its preferred plan (or any of its candidate portfolios). PREPA considered, but did not include in modeling, offshore wind resources because "it is expected to have cost higher than the equivalent Solar PV project".[37] In addition, PREPA assumes wind costs starting at $103 to $105 in 2018 and declining to $53 to $99 in 2038.[38] These costs are much higher than those assumed by the Hawaiian utilities ($34 to $65 in 2016 and $52 to $100 in 2040)[39] and those provided by Lazard—a global leader in financial advisory and asset management firm—which estimates onshore wind costs of $29 to $56 on an unsubsidized basis.[40]

[36] U.S. EIA. 2018. Form EIA-860 Data - Schedule 3, 'Generator Data'. Available at: https://www.eia.gov/electricity/data/eia860/.
[37] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. Exhibit 6-32.
[38] Ibid. Exhibit 6-42.
[39]The Hawaiian Electric Companies. 2016. *The Hawaiian Electric Companies' 2016 Power Supply Improvement Plan (PSIP) Update.* Book 2 of 4. Table F-14. Available at: https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/power-supply-improvement-plan p. F-65.
[40] Lazard. 2018. *Lazard's Levelized Cost of Energy Analysis—Version 12.0*. Available at: https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf. p. 2

b) Pursue renewables with the highest certainty of deployment early in the planning period

PREPA's June IRP falls short of the Hawaii best practice regarding renewable deployment and taking measures to reduce demand. First, the amount of planned demand response is lower in the June IRP than in the February IRP; and second, the renewable buildout as a percentage of total generating capacity is less than that planned in Hawaii in the near-term (before 2022). Puerto Rico—with a population and electric peak demand about double that of Hawaii's—is planning for less renewable and demand response capacity additions than Hawaii (958 MW of solar, wind and battery storage compared to 810 MW) over the same four-year period (2018-2021, see Table 5). In addition, Puerto Rico's RPS targets of 40 percent renewable energy by 2025 and 100 percent renewable energy by 2050 will be more difficult to achieve without including wind resources over the 20-year planning period. Failing to pursue wind resources in the short-term also means that Puerto Rico will not benefit from federal tax credits, which are in the process of being phased out.

Table 5. Hawaii and Puerto Rico planned demand response, solar and wind total capacity additions by the end of 2021

Planned Renewable Energy and Demand Response (MW) by 2022			
	Hawaii	Puerto Rico	
		February IRP	June IRP
Demand Response	115	57	30
Solar	686	240	780
Wind	157	0	0
TOTAL	958	297	810

Note: The numbers listed here for PREPA's June IRP are for their ESM scenario, however, PREPA also presents numbers for its S4S2 plan of 1,280 MW of battery storage additions and 1,740 MW of solar additions through 2023. It is unclear which of these data points applies to PREPA's preferred plan.

Sources: 1) Final PSIPs—HI PUC. Docket No. 2014-0183. December 23, 2016. Hawaiian Electric Companies'' PSIPs Update Report; Book 1 of 4. p. ES-3. All documents available at: https://dms.puc.hawaii.gov/dms/dockets?action=search&docketNumber=2014-0183. 2) PREPA. June 7,2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. 3) PREPA. February 12, 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens PTI Report Number: RPT-015-19.

According to PREPA, given the massive destruction from hurricanes Irma and Maria, for resources to be successful in the Puerto Rican context it must "increase the resiliency and survivability of its systems".[41] To achieve those needs, PREPA's June IRP notes that it must harden its system against severe weather, add distributed generation, decrease the island's dependence on imported oil, and increase their reliance on renewable energy sources.[42] To this end, PREPA's preferred plan includes considerable renewable energy buildout paired with battery storage as well as "system hardening" techniques like anchoring solar

[41] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 1-1
[42] Ibid.

installations deeper in the ground to enable them to better withstand hurricane conditions.[43] The other key prong in PREPA's plan aimed at enhancing the resiliency and survivability of the grid is distributed energy, addressed in Section 2 below.

c) Ensure lowest costs for ratepayers by considering renewables on equal footing with fossil fuels

Unlike Hawaii, Puerto Rico is not treating renewable resources on an equal footing with fossil fuel alternatives in its design of a least-cost electric-sector plan. PREPA's February and June IRPs both place annual capacity expansion constraints on solar and battery storage, without limiting fossil fuel resources (see Table 6). For example, in 2022, the model used to determine PREPA's preferred resource plan allows the addition of a maximum of 300 MW of solar resources; the permitted addition of gas resources was unlimited.

Table 6. PREPA February and June IRP annual installation constraints (MW) for solar and battery storage in its base case, low cost of renewables sensitivity scenario (LCR), and ESM scenario

		Solar	Battery
2019	*Base Case*	0	60-180
	LCR	0	60-180
	ESM	-	20
2020	*Base Case*	300	300
	LCR	300	300
	ESM	-	100
2021	*Base Case*	300	300
	LCR	1,200	1,200
	ESM	240	160
2022-2038	*Base Case*	600	600
	LCR	1,200	1,200
2022	*ESM*	480	160
2023		480	160
2024		300	150

Source: 1) Siemens Industry. February 12, 2019. Puerto Rico Integrated Resource Plan 2018-2019: Draft for the Review of the Puerto Rico Energy Bureau. Prepared for Puerto Rico Electric Power Authority. Siemens PTI Report Number: RPT-015-19. Exhibit 6-27, Exhibit 6-28, Exhibit 6-29, Exhibit 6-30.

Constraining renewable resources in this way may lead to a more expensive resource plan. Compared to its February IRP, PREPA's June IRP has a higher share of renewable energy, battery storage and energy efficiency, and therefore a lower share of imported gas and its associated infrastructure costs and potential

[43] Ibid. p. 2-6.

price volatility.[44] PREPA's June IRP also notes that more renewable generation "[achieves] a reduction of cost of supply".[45] It is unclear why PREPA's June preferred plan incorporates more solar and battery storage resources than its February IRP, given that the limitations on solar and battery resources were identical in both iterations.

By arbitrarily constraining the amounts and types of renewables considered and leaving fossil fuel alternatives unconstrained, Puerto Rico is falling short of the treatment of renewable energy for future capacity expansion needs that would ensure the most cost-effective resource plan. An optimized, least-cost resource plan requires renewable energy capacity of all types (including wind resources) to be modelled without discretionary installation constraints.

3. Distributed Energy Resources

Distributed energy resources refer to technologies that generate electricity in geographic proximity to where that electricity will be consumed. Most commonly, a distributed energy refers to single energy systems, like solar panels on residential homes, but distributed energy may also take the form of microgrids or community-based energy districts where energy is pooled into a small grid, which is connected to the larger utility grid.[46] According to the Hawaiian utility commission, distributed energy resources include: demand response, energy efficiency, electric vehicles, distributed generation (including solar, wind, hydro, biomass, natural gas fuel cells, gasoline or diesel generators, combined heat and power systems and municipal solid waste incineration) and distributed energy storage.[47]

Section 3 presents the current state of distributed generation in Hawaii and Puerto Rico and details the best practices that resulted from our review of Hawaii's most recent IRP and assesses Puerto Rico's IRP in the context of Hawaiian best practices:

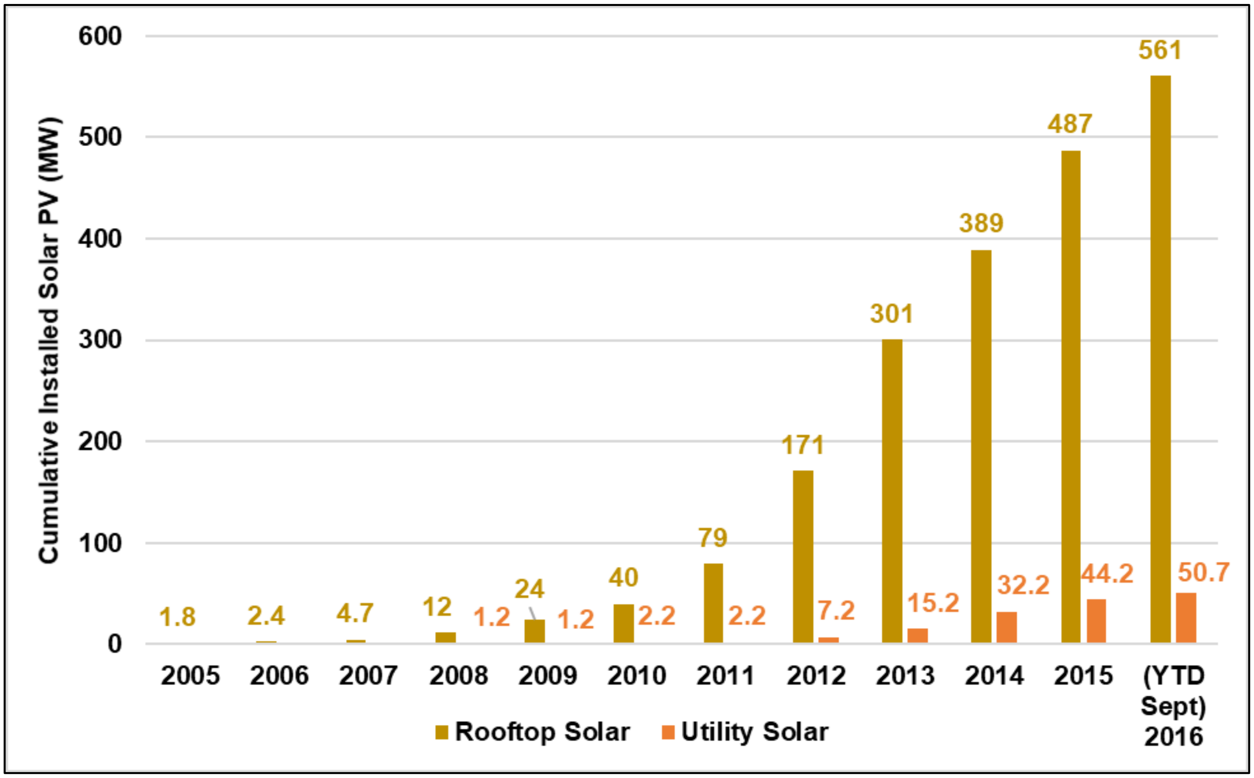
- Shift from centralized to distributed energy resources,
- Assess all types of distributed energy resources on equal footing with other capacity expansion opportunities, and
- Consider the grid services and risk reduction from distributed energy resources relative to other capacity expansion opportunities.

[44] Ibid. p. 2-6.
[45] Ibid. p. 5-1.
[46] United States Environmental Protection Agency. n.d. "Distributed Generation of Electricity and its Environmental Impacts.: *Energy and the Environment.* Available at: https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts.
[47] The Public Utilities Commission of the State of Hawaii. November 2015. Docket No. 2014-0183. Order No. 33320. p. 5.

Distributed Energy Resources in Hawaii

Between 2005 and 2016, distributed solar generation in Hawaii increased from 1.8 MW to over 560 MW (see Figure 5), while utility-scale solar grew from 1.2 MW in 2008 to 125 MW in 2018. Since 2011, Hawaii's distributed solar has grown by a minimum of 88 MW each year. About two-thirds of Hawaii's installed distributed generation capacity is from residential rooftop solar, while the remaining one-third comes from combined generation of commercial installations and independent power producers.[48]

Figure 5. Annual growth of Hawaiian rooftop solar



Sources: (1) Hawaiian Electric Companies. 2016. PSIPs Update Report. Before the Public Utilities Commission of the State of Hawai'i. Docket No. 2014-0183. Figure D-3: PV Generation Growth (2005-2016). p. D-33. (2) Source: EIA. 2006 to 2018 Form EIA-860 Data - Schedule 3, 'Generator Data' (Operable Units Only). Available at: https://www.eia.gov/electricity/data/eia860/.

Lessons learned in the Hawaiian context

Developing and finalizing the Hawaiian utilities' PSIPs led to a substantial increase in planned distributed generation resources. In their original 2014 PSIPs, the Hawaiian utilities planned to build 234 MW of

[48] The Hawaiian Electric Companies. 2016. *The Hawaiian Electric Companies' 2016 Power Supply Improvement Plan (PSIP) Update*. Book 1 of 4. Available at: https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/power-supply-improvement-plan p. D-33.

rooftop solar and 34 MW of demand response by 2022 (see **Error! Reference source not found.** below), and was found by the commission to have used overly conservative estimates of benefits paired with a more complete accounting of costs regarding updating the electric system to accommodate distributed energy resources.[49] The Hawaiian utility commission found that utilities' original plan:

- **Left distributed generation opportunities on the table:** Did not sufficiently discuss the use and integration of distributed energy resources,[50] incorporated too little diversity in the types of renewable distributed generation considered, and did not sufficiently utilize distributed resources to the maximum benefit of the system and the customer;[51]
- **Short-changed some types of distributed generation:** Did not adequately consider all types of distributed energy resources, including demand response, energy efficiency, electric vehicles, distributed generation, and distributed energy storage resources[52]; and
- **Failed to include valuable grid services and risk reduction:** Inadequately considered the ability of distributed generation to provide important benefits like offsetting future transmission and distribution upgrades and providing valuable grid services like enhanced reliability.[53]

In their 2016 final PSIPs, the Hawaiian utilities: anticipate 326 MW of rooftop solar by 2022—an increase of 39 percent above the amount of rooftop solar in their 2014 original PSIPs (see Table 7 below); procure diverse community-based renewable energy sites including solar, wind, demand response and distributed energy storage resources, develop additional distributed energy initiatives; and undertake improvements to facilitate distributed energy integration in the grid.

The Hawaiian utilities are taking a planned, step-by-step approach to distributed energy resource development—including phased transmission enhancements; plans to monitor the reporting, performance and integration of distributed energy resources; and plans to continue research into innovative and emerging distributed energy technologies.[54] The Hawaiian commission noted that the utilities' distributed energy plans will "promote the reliable and economic operation of the electrical grid" and "assist with the integration of additional renewable energy resources".[55] It is also important to note, however, that the Hawaiian utilities' final PSIPs did not consider distributed energy resources on equal footing with other supply-side resources—the modeling approach treated distributed energy resources exogenously and

[49] The Public Utilities Commission of the State of Hawaii. November 2015. Docket No. 2014-0183. Order No. 33320. p. 25-26.
[50] The Public Utilities Commission of the State of Hawaii. November 2015. Docket No. 2014-0183. Order No. 33320. p. 44.
[51] Ibid. p. 90-91.
[52] Ibid. p.5.
[53] The Public Utilities Commission of the State of Hawaii. July 2017. Docket No. 2014-0183. Order No. 34696. p. 30.
[54] The Hawaiian Electric Companies. 2016. *The Hawaiian Electric Companies' 2016 Power Supply Improvement Plan (PSIP) Update*. Book 1 of 4. Pages 7-4 to 7-16.
[55] The Public Utilities Commission of the State of Hawaii. July 2017. Docket No. 2014-0183. Order No. 34696. p. 30.

failed to consider distributed resources together with battery storage, a combination that can enhance the grid benefits by way of stabilization and resiliency.

Table 7. Hawaii distributed solar and demand response additions installed by the end of 2021 (MW)

	Original PSIPs	Final PSIPs
Demand Response	34	115
Rooftop Solar	234	326
TOTAL	298	441

Source: Original PSIPs—(1) HI PUC. Docket No. 2011-0206. August 26, 2014. Hawaiian Electric Power Supply Improvement Plan. Table 5-4; (2) HI PUC. Docket No. 2011-0092. August 26, 2014. Maui Electric Power Supply Improvement Plan. Table 5-1; (3) HI PUC. Docket No. 2011-0212. August 26, 2014. Hawai'i Electric Power Supply Improvement Plan. Table 5-3. Final PSIPs—HI PUC. Docket No. 2014-0183. December 23, 2016. Hawaiian Electric Companies'' PSIPs Update Report; Book 1 of 4. p. ES-3. All documents available at: https://dms.puc.hawaii.gov/dms/dockets?action=search&docketNumber=2014-0183.

Hawaiian Best Practices

Hawaii's electric-sector planning experience illuminates best practices that help enable distributed energy resources to provide maximum benefit for electric customers utilities must prioritize:

a) **Shift from centralized to distributed energy resources:** Distributed energy resources provide a more resilient, reliable and economic grid where customers provide a multitude of valuable services;

b) **Assess all types of distributed energy resources on an equal footing with other capacity expansion opportunities**: Building diverse distributed energy resources and considering opportunities to build these resources in community-based sites like micro grids and local energy districts[56] is the best way to most fully capture the range of potential benefits offered by distributed generation opportunities; and

c) **Consider grid services and risk reduction from distributed energy resources relative to other capacity expansion opportunities:** Distributed energy resources provide valuable direct and indirect grid services, such as providing system security benefits or offsetting future transmission-and-distribution infrastructure upgrades, which are important benefits to be considered relative to other capacity expansion options.

[56] The Public Utilities Commission of the State of Hawaii. November 2015. Docket No. 2014-0183. Order No. 33320. p. 26.

Distributed Energy Resources in Puerto Rico

According to PREPA's June IRP, Puerto Rico has 173 MW of installed distributed generation resources across the island, composed primarily of rooftop solar (see Table 8).

Table 8. Puerto Rico distributed generation in service as of June 2019

Distributed Generation (MW)			
Region	Distribution	Transmission	Total
Arecibo	12	4	16
Bayamon	23	7	31
Caguas	22	9	31
Carolina	12	4	16
Mayaguez	20	2	22
Ponce ES	8	4	11
Ponce OE	13	4	17
S. Juan	20	9	30
Total	130	42.75	173

Source: PREPA. 2019. Puerto Rico Integrated Resource Plan 2018-2019 Appendix 4: Demand Side Resources. Submitted by Siemens Industry. Draft for the Review of the Puerto Rico Energy Bureau. Report No. PRT-001-19. Exhibit 3-1.

Investment in distributed energy resources has increased across the United States due to the growing affordability of solar panels for many homeowners and businesses, state policy incentives, and grid operators utilizing distributed generation to maintain reliable service during times of peak electric use.[57] In Puerto Rico, transmission towers and lines must cross the center of the island—mountainous terrain that is particularly vulnerable to extreme weather conditions—to get electricity to customers.[58] The island also has a high poverty rate (45 percent of individuals fall below the poverty level[59]) and is particularly vulnerable to extreme weather like hurricanes, making the need to shift from centralized generation to distributed energy resources particularly acute in Puerto Rico.

a) Shift from centralized to distributed energy resources

PREPA's June 2019 IRP includes more distributed energy resources than were proposed in February as well

[57] United States Environmental Protection Agency. n.d. "Distributed Generation of Electricity and its Environmental Impacts.: *Energy and the Environment.* Available at: https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts.
[58] Ellsmoor, J. February 12, 2019. Puerto Rico's Utility PREPA Plans To Divide Island Into Renewable Energy Microgrids. *Forbes*. Available at: https://www.forbes.com/sites/jamesellsmoor/2019/02/12/puerto-ricos-utility-prepa-plans-to-divide-island-into-renewable-energy-microgrids/#25a3fac355fc
[59] United States Census Bureau. 2017. "Community Facts." *American Fact Finder.* Available at: https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml?src=bkmk.

as very ambitious plans to shift the grid from centralized generation to distributed, flexible, energy resources that are closer to the customer, eliminate the need for extensive transmission and distribution planning, and create a more flexible, reliable and resilient electric grid. To accomplish this goal, PREPA proposes to develop distributed energy resources in the form of eight connected regional "minigrids" across the island that are all connected to each other. Each minigrid would be capable of operating in "island" mode (that is, it can operate self-sufficiently) and each minigrid is further broken down into smaller microgrids, which would be able to function autonomously. PREPA's proposal for advancing distributed generation goes further than that of the Hawaiian utilities.

In PREPA's June preferred portfolio, the role of distributed energy resources is to create eight largely self-sufficient electric "islands" in the form of minigrids.[60] In order to develop this mini- and microgrid system, PREPA plans for large-scale transmission upgrades based on defined priorities and a strict timetable (see Table 9). PREPA's June IRP does not provide the associated capacity amounts (in MW) of its planned mini- and microgrid projects.

Table 9. PREPA minigrid transmission plan (2018$ million)

	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5
Technical Justification	2020-2022	2023-2024	2025-2026	2027	2028
Interconnection of Critical Loads	88	32	36	0	0
Interconnection of Minigrids	67	0	7	0	0
Minigrid Backbone Extensions	70	0	0	0	0
Minigrid Main Backbone	1,616	220	59	102	70
Existing Infrastructure Hardening for Reliability	81	32	100	21	11
Aging Infrastructure Replacement - MG	126	39	11	16	5
Total	2,048	322	214	138	86

Source: PREPA. June 7, 2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. Exhibit 4-1.

While PREPA's plan to advance distributed energy resources in the form of minigrids goes further than Hawaii's, Hawaii has more developed rooftop solar resources at present. Indeed, while Hawaii had 561 MW of total rooftop solar installed in 2016,[61] Puerto Rico currently has 173 MW of distributed generation resources (comprised mostly of solar).[62] PREPA's June IRP is short on detail about the imagined role of rooftop solar resources in Puerto Rico—the only time it references rooftop solar is to note that "the levelized cost of customer owned generation is…significantly lower than the total rate" and that "the [distributed generation] forecast [assumes] that the continuance of 'net-metering' rates will occur, and the

[60] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 1-5.
[61] The Hawaiian Electric Companies. 2016. *The Hawaiian Electric Companies' 2016 Power Supply Improvement Plan (PSIP) Update*. Before the Public Utilities Commission of the State of Hawai'i. Docket No. 2014-0183. Available at: https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/power-supply-improvement-plan. p. D-33.
[62] Puerto Rico Electric Power Authority. June 2019. Report No. PRT-001-19. Exhibit 3-1.

customer side roof top PV adoptions will continue to be in line with the high adoption rates observed to date."[63] In contrast, Hawaii's 2016 PSIP stated its intention "maximize distributed energy resources"[64] but did not present a detailed step-by-step plan like PREPA's June IRP.

b) Assess all types of distributed energy resources on equal footing with other capacity expansion opportunities

PREPA's June 2019 preferred portfolio would establish a microgrid electric system to enhance grid reliability and resiliency. Although PREPA presents specific forecasts for energy efficiency savings and demand response measures—which are not presented in the Hawaiian IRP—it does not consider these resources on equal footing with other capacity expansion resources. (Neither did the Hawaiian IRP, despite the urging of the Hawaiian utility commission). Energy efficiency and demand response projections were not offered as resources in PREPA's capacity expansion model—they were introduced exogenously[65] and their projections were estimated based PREPA's qualitative review and resultant prioritization of demand-side measures.[66] The impact of the programs on this list was then estimated based on participation rates, energy savings and program costs.[67] In addition, neither the Hawaiian nor the Puerto Rican IRPs offer a clear presentation of the current status of, or future plans for, electric vehicles.

Compared to the February version, PREPA's June preferred plan includes more aggressive energy efficiency savings but less aggressive demand response measures (see Table 10 below). Between the February and June versions of its IRP, PREPA decreased planned demand response by 30 percent and increased planned energy efficiency by 87 percent, all by the end of 2023. PREPA states its aim to reach 2 percent annual incremental energy efficiency savings by 2025[68] as the result of an order from Puerto Rican Energy Bureau.[69] The Hawaiian utilities did not publish demand response or energy efficiency forecasts in their final PSIPs, making comparisons between Puerto Rico and Hawaii impossible.

[63] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 8-59.
[64] The Hawaiian Electric Companies. 2016. Executive Summary. p. ES-2.
[65] In resource modeling, an exogenous change is one that comes from outside the model and is unexplained by the model.
[66] Puerto Rico Electric Power Authority. June 2019. Report No. PRT-001-19. Exhibit 3-1.
[67] Ibid.
[68] Ibid.
[69] "Subsequently, the Puerto Rican Energy Bureau (PREB) ordered PREPA to "model EE with gains of two percent (2%) per year, based on the energy sales of that year… for 18 years." Source: Puerto Rico Electric Power Authority. June 2019. Report No. PRT-001-19. Appendix 4: Demand Side Resources. p. 2-1.

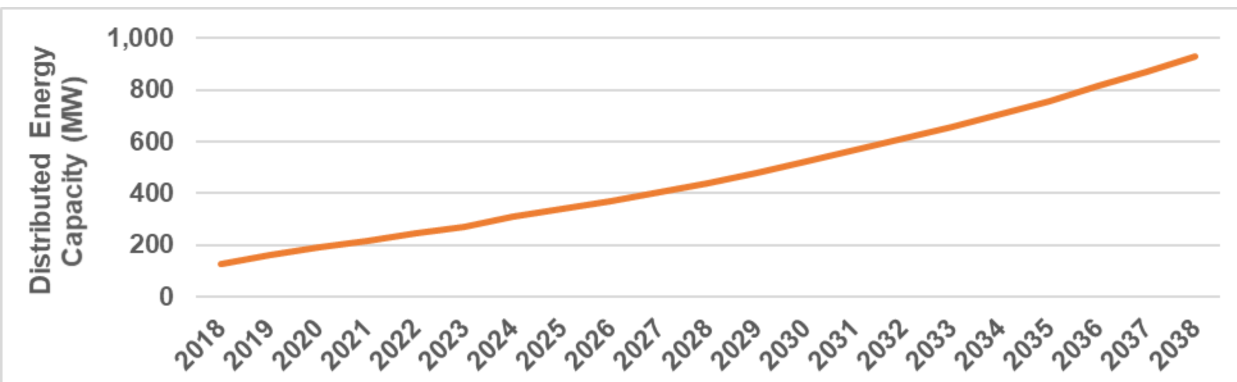
Table 10. Demand response and energy efficiency in PREPA's February and June IRP preferred plans

		2019	2020	2021	2022	2023	TOTAL
Demand Response (MW)	February IRP	17	13	27	22	35	114
	June IRP	-	17	13	28	22	80
	Change	0	+4	-14	+5	-12	-34
Energy Efficiency (GWh/yr)	February IRP	192	128	283	204	358	1,166
	June IRP	-	483	304	788	609	2,184
	Change	0	+355	+21	+584	+250	+1,018

Data sources: (1) PREPA. June 7,2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. (2) PREPA. February 12, 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens PTI Report Number: RPT-015-19.

In the appendices to its June IRP, PREPA forecasts that installed distributed capacity (primarily rooftop solar) will grow from 127 MW in 2018 to 929 MW by the end of the planning period (2038) (see Figure 6). (In the main IRP report, PREPA also reports 1,176 MW of customer-owned generation in 2038.)[70]

Figure 6. PREPA June IRP distributed energy capacity projection (MW)



Source: PREPA. 2019. Puerto Rico Integrated Resource Plan 2018-2019 Appendix 4: Demand Side Resources. Submitted by Siemens Industry. Draft for the Review of the Puerto Rico Energy Bureau. Report No. PRT-001-19. Exhibit 3-3.

PREPA's assessment of distributed energy resources in its June IRP resulted in plans for mini- and microgrids that are presented in great detail along with clear targets energy efficiency and demand response savings. However, while Puerto Rico is meeting the first half of the Hawaiian best practice—"assess all types of distributed energy resources" (with the exception of electric vehicles)—it is not meeting the second half—"on equal footing with other capacity expansion opportunities." PREPA does not consider energy efficiency and demand response alongside other supply-side resources in its capacity expansion modeling. Although Puerto Rico includes a clear target for distributed energy capacity (929 MW by the end of 2038, up from 173 MW currently installed), it is important to keep in mind that Hawaii already had 561 MW of distributed solar installed to serve less than half the population and electric peak. Puerto Rico is

[70] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 8-4.

falling short of the Hawaii best practice in terms of the amount of planned capacity as a share of total electric capacity. Puerto Rico would need to develop distributed solar more rapidly to reach the standard set by Hawaii.

c) Consider grid services and risk reduction from distributed energy resources relative to other capacity expansion opportunities

Although the large, centralized resources presented in PREPA's February IRP preferred plan resulted in lower overall costs than the June preferred plan—which has more renewable energy and distributed energy resources—PREPA, in consultation with its stakeholders, concluded that "the larger centralized resources…depend on the reliability of the transmission system during a major event like a hurricane. Considering the experience with the 2017 hurricanes in Puerto Rico, a distributed resources strategy was selected for providing resiliency to the electric service, even though it could result in higher costs."[71] PREPA's June preferred plan itself makes the case that distributed energy resources—in the form of an extensive microgrid system—provide a valuable benefits in the form of storm risk reduction, especially relative to centralized generation resources. The IRP's main cost comparison is only relevant to a future in which no major storm damages occur. In a future with great storm impact, the portfolio built with more resiliency measures would very likely result in lower total costs over time. For example, PREPA June IPR states that it did not consider its Scenario 3 to be "the preferred portfolio due to its assumed deep reduction in renewable prices and the risk of managing the implied amount of renewable generation and storage."[72] Scenario 3, however, had a $42 to $61 million lower cost of energy not served by minigrids than Scenario 4 or the ESM scenario (the preferred scenarios).[73]

The prioritization of distributed energy resources in PREPA's June IRP means that a share of Puerto Rico's load will be supplied by local resources and can be isolated from the rest of the grid during a major event like a hurricane. This design will allow for greater grid flexibility because the microgrids will be able to easily switch from interconnection to "island" mode.[74] PREPA's June IRP also notes that developing new distributed energy resources in Puerto Rico will bring employment opportunities in building the necessary infrastructure and a reduction in costs to electric customers who take advantage of opportunities to participate in distributed energy production.[75]

[71] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 9-2.
[72] Ibid. p. 8-10.
[73] Ibid. Exhibits 8-52 and 8-83.
[74] Ibid. p. 1-3.
[75] Ibid. p. 1-2.

4. Oil to Gas Conversion and LNG

Across the United States, coal and oil have become more costly fuel sources relative to gas while at the same time, aging coal and oil-fired power plants have become less efficient relative to newer gas-fired plants. U.S. utilities have been investing in new gas generation and converting their coal and oil-fired plants to run on gas and choosing gas-fired technologies for capacity expansion.[76] Nationwide, installed coal capacity has fallen from 322 GW in 2002 to 243 GW in 2018. U.S. gas capacity, on the other hand, has grown from 120 GW in 2002 to 264 MW in 2018.[77] Liquification of gas makes it possible to transport gas to places, like Puerto Rico, that pipelines cannot reach, where it is then re-gasified for distribution, sale and combustion.[78]

Section 4 presents the status of gas generation in Hawaii and Puerto Rico, details best practices taken from our review of Hawaii's most recent IRP, and evaluates Puerto Rico's June 2019 IRP based on these Hawaiian best practices:

- Reduce generation costs by retiring aging fossil fuel plants,
- Place renewable energy, energy efficiency, demand response and battery storage on equal footing with fossil fuel generation for capacity expansion, and
- Assess the risks of stranded costs, uncertainties, and rate impacts of imported LNG fuels and new fossil generation.

Gas in Hawaii

Hawaii does not use gas for electric generation. Hawaii's electric generation is dominated by oil-fired (67 percent) and coal-fired resources (13 percent, see Figure 2 above). The Hawaiian utilities' original 2014 PSIPs proposed oil to gas conversion but gas investments were ultimately rejected in their final plan. This was a large shift, given that the 2014 PSIPs preferred plan aimed to convert a total of 1,744 MW of oil-fired generating capacity to gas (see Table 11 below)—57 percent of Hawaiian generating capacity in 2018.

---

[76] Manussawee, S. March 8, 2019. "New U.S. power plants expected to be mostly natural gas combined-cycle and solar PV." *EIA.* Available at: https://www.eia.gov/todayinenergy/detail.php?id=38612.
[77] Dubin, Kenneth. April 10, 2019. "U.S. natural gas-fired combined-cycle capacity surpasses coal-fired capacity." *EIA.* Available at: https://www.eia.gov/todayinenergy/detail.php?id=39012.
[78] EIA. June 4, 2019. "Natural gas explained: Liquefied natural gas." Available at: https://www.eia.gov/energyexplained/natural-gas/liquefied-natural-gas.php.

Table 11. Oil to gas conversions from Hawaii original 2014 PSIP preferred plan

Plant/Generator Name	Conversion Date	Size (MW)
Kahe 1-6	2017	650
Waiau 5-10	2017	500
Kalaeloa (IPP)	2017	208
Ma'alea 14-17, 19	2017	212
Puna CT3	2017	37
Keahole CT4,CT5	2017	78
Hamakua Energy Partners	2018	60

Sources: 1) Hawaiian Electric Companies. 2014. Hawaiian Electric Supply Improvement Plan. Docket No. 2011-0206. 2) Hawaiian Electric Companies. 2014. Maui Electric Supply Improvement Plan. Docket No. 2011-0092. 3) Hawaiian Electric Companies. 2014. Hawai'i Electric Light Supply Improvement Plan. Docket No. 2012-0212.

Lessons learned in the Hawaiian context

The Hawaiian utility commission's critiques of the original 2014 PSIPs resulted in a dramatic reassessment of the role of gas in Hawaii's energy future. The Hawaiian utility commission found that the 2014 proposed plan:

- **Was too cost-optimistic regarding gas:** Strategies to convert existing fossil fuel-generation to LNG did not adequately consider the "substantial uncertainties"[79] regarding the cost-effectiveness of LNG fuels, and failed to assess the impact of alternative projections of fossil fuel prices[80] or the impact of delays in planned LNG infrastructure, such as the Hawaiian utilities announcement of a two-year delay of LNG imports[81];
- **Failed to adequately consider low-cost renewable energy alternatives to fossil fuel generation:** Did not "utilize [renewable] lower cost resources earlier and to a greater extent in order to deliver additional customer savings"[82] and did not provide adequate information about cost-benefit comparisons; and
- **Inadequately assessed risks including stranded costs and rate impacts of imported LNG fuels and new gas generation:** Did not "provide adequate consideration or analysis of substantial risks and uncertainties for customers including the impacts of the timing, availability, and pricing of LNG imports" nor the "potential risks of stranded costs and rate impacts in light of the extensive

[79] The Public Utilities Commission of the State of Hawaii. November 2015. Docket No. 2014-0183. Order No. 33320. p. 5.
[80] Ibid. p. 109.
[81] Ibid. p. 106.
[82] Ibid. p. 79.

proposed capital expenditure plans"[83].

The Hawaiian utilities' final 2016 PSIPs do not include plans to build any new gas-fired electric generation capacity or LNG terminals as part of the near-term resource plan (2017-2021), although the Hawaiian utilities note that gas resources "will continue to be evaluated as alternatives in the transition to 100% renewable energy."[84] The final 2016 PSIPs emphasize that gas resources were no longer included and focus on the "near-term actions that allow us to make strong progress on achieving our clean energy goals,"[85] by eliminating reliance on imported fossil fuels (and their associated cost risks) and aggressively developing renewable energy resources.[86]

Hawaiian Best Practices

Hawaii's electric-sector planning experience illuminates best practices for fossil fuel resource planning that help provide the maximum potential benefit for electric customers:

a) **Reduce generation costs by retiring aging fossil fuel plants:** Retiring old and inefficient fossil fuel plants reduces the cost of operating the generation fleet by replacing those resources with lower-cost and/or more efficient generating resources;

b) **Place renewable energy, energy efficiency, demand response and battery storage on equal footing with fossil fuel generation for capacity expansion**: Assessing all supply and demand-side resources on equal footing is the most effective way to ensure that a truly optimized and least-cost resource plan; and

c) **Assess the risks of stranded costs, uncertainties, and rate impacts of imported LNG fuels and new fossil generation:** Gas resources entail a number of risks unique to that resource, including volatile price projections and unknown future developments of environmental regulations—these are important risks to consider when assessing gas resources for capacity expansion needs.

[83] The Public Utilities Commission of the State of Hawaii. November 2015. Docket No. 2014-0183. Order No. 33320. p. 7.

[84] The Hawaiian Electric Companies. 2016. Book 2 of 4. p. 7-1.

[85] The Hawaiian Electric Companies. 2016. Executive Summary. p. ES-2.

[86] On June 22, the Hawaii Public Utilities Commission (HPUC) approved a risk sharing mechanism that splits fuel price volatility risk 98% and 2% between ratepayers and HECO. See: 1) Hawaiian Public Utilities Commission. June 22, 2018. PUC Approves Rate Decrease for Hawaiian Electric Company, Inc. Available at: https://puc.hawaii.gov/wp-content/uploads/2018/06/2016-0328.Press-Release.mk_.06-22-2018.Final_.pdf and 2) Trabish, H.K. August 6, 2018. Hawaii's new fuel price performance incentive gives HECO 'skin in the game'. *UtilityDive*. Available at: https://www.utilitydive.com/news/hawaiis-new-fuel-price-performance-incentive-gives-heco-skin-in-the-game/528329/.

Gas in Puerto Rico

Puerto Rico depends heavily on imported fuels for its power generation—65 percent of its electric generation is oil-fired, 7 percent is coal-fired and 22 percent is gas-fired (see Figure 4 above). In 2018, Puerto Rico imported 60 billion cubic feet (bcf) of LNG[87] (equivalent to approximately 35,000 bcf of gas) for a total cost of $433 billion,[88] all of which was used for electric generation[89] at two power plants—EcoEléctrica (574 MW) and Costa Sur 5 and 6 (820 MW). Between 2013 and 2016, Puerto Rico had an average of two LNG shipments per month, equivalent to 159 million cubic feet per day.[90] Peñuelas in Ponce is the sole LNG terminal currently in operation in Puerto Rico, and has been in operation since 2005. In August 2017, the U.S. Federal Energy Regulatory Commission approved a 75 percent expansion of the Peñuelas LNG facility to 279 million cubic feet per day—186 million cubic feet per day for the Costa Sur plant and 93 million cubic feet per day for the EcoEléctrica plant.[91]

In addition to Puerto Rico's dependency on imported gas resources with potentially volatile prices, PREPA itself notes that "load growth is a very real concern to PREPA, and growth at this moment is highly uncertain and could go from negative to positive should federal monies stimulate the economy, outmigration reverse, or industrial and tourism industries increase".[92] Shrinking demand makes building new gas-fired resources riskier, because the power they produce may not be needed before the end of their lifetime and the ability to recover the cost of building the plant may be impacted—in other words, the plant may become a stranded asset.

Puerto Rico's new RPS legislation also greatly increases the likelihood that some portion of new gas plants costs will be stranded: Only 40 percent of the island's generation can come from non-renewables sources like gas in 2025 and none in 2050. This context creates greater reason to look to Hawaiian best practices that treat gas as one of many alternative resources to meet demand.

[87] The volume of natural gas in its liquid state is about 600 times smaller than its volume in its gaseous state. Liquified natural gas, therefore, makes it possible to transport natural gas to places that pipelines cannot reach. For this reason, we use the terms gas and LNG interchangeably in this section. EIA. June 4, 2019. "Natural gas explained: Liquefied natural gas." Available at: https://www.eia.gov/energyexplained/natural-gas/liquefied-natural-gas.php.
[88] Office of Fossil Energy. 2018. *LNG Annual Report.* Available at: https://www.energy.gov/fe/downloads/lng-annual-report-2018.
[89] Tsai, Kristen. April 8, 2019. "Puerto Rico's LNG imports returned to pre-Hurricane Maria levels in late 2018." *EIA.* Available at: https://www.eia.gov/todayinenergy/detail.php?id=38972.
[90] Ibid.
[91] Gas Processing & LNG. Federal Energy Regulatory Commission approves LNG import terminal expansion in Puerto Rico. Available at: http://www.gasprocessingnews.com/news/ferc-approves-lng-import-terminal-expansion-in-puerto-rico.aspx.
[92] Puerto Rico Electric Power Authority. June 2019. p. 1-3.

Table 12. Summary of PREPA June IRP preferred plan

	2019	2020	2021	2022	2023	2024	2025
Renewable energy, energy efficiency and demand response (MW and GWh)							
Energy Efficiency (GWh)	-	483	304	788	609	1,094	873
Battery Energy Storage (MW)	40	200	480	80	0	-	-
Demand Response (MW)	-	17	13	28	22	33	27
Solar PV (MW)	0	300	480	600	420	-	-
Cumulative Total (MW only)	**40**	**557**	**1,530**	**2,238**	**2,680**	**2,713**	**2,740**
Gas Installations (MW)							
Costa Sur CCGT**	-	-	-	-	-	-	302
Mayagüez CCGT*	-	-	-	-	-	-	302
Mobile GT	-	-	414	-	-	-	-
Palo Seco CCGT	-	-	-	-	-	-	302
Yabucoa CCGT*	-	-	-	-	-	-	302
Cumulative Total	**0**	**0**	**414**	**414**	**414**	**414**	**1,622**
Gas Conversions (MW)							
Mayagüez 1-4 to gas	-	-	-	200	-	-	-
San Juan 5&6 to gas	400	-	-	-	-	-	-
Cumulative Total	**400**	**400**	**400**	**600**	**600**	**600**	**600**
Retirements (MW)							
Aguirre CCGT 2 (Diesel)	-	-	-	-	-	-	260
Aguirre ST 1&2 (Oil)	900	-	-	-	-	-	-
Costa Sur 5&6 (NG, Oil)	-	820	-	-	-	-	-
Frame 5 Peaker	-	378	-	-	-	-	-
Palo Seco ST 3&4 (Oil)	-	-	-	-	-	-	432
San Juan 6 CCGT (Diesel)	-	-	-	-	-	-	200
San Juan 7 (Oil)	-	-	-	-	100	-	-
San Juan 8 (Oil)	-	-	100	-	-	-	-
Cumulative Total	**900**	**2,098**	**2,198**	**2,198**	**2,298**	**2,298**	**3,190**
LNG Terminals (MMCf/d)							
Mayagüez (Ship-Based) LNG*	-	-	-	-	-	-	43.2
San Juan (Land-Based) LNG	-	-	-	-	-	-	43.2
Yabucoa (Ship-Based) LNG*	-	-	-	-	-	-	43.2
Cumulative Total	**0**	**0**	**0**	**0**	**0**	**0**	**129.6**

*Notes: *Need for this unit will be re-evaluated based on load growth and progress of other projects. **The ESM scenario would need to add the 302 MW CCGT plant at Costa Sur should PREPA not be able to negotiate and acceptable agreement with EcoEléctrica. However, should an acceptable agreement be negotiated, Siemens would recommend that PREPA cease all activities associated with developing the new CCGT at Cost Sur.*

Source: PREPA. June 7, 2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. Pages 10-2 to 10-8.

a) Reduce generation costs by retiring aging fossil fuel plants

While PREPA's June IRP retires slightly more fossil fuel-fired capacity than its February IRP (3,190 MW in June versus 2,990 MW in February, both by the end of 2025), [93] PREPA's June plan still installs up to 1,622 MW of new gas-fired capacity[94], converts 600 MW of capacity to gas generation, and builds three new LNG terminals, all by the end of 2025 (see Table 12 above).[95] For comparison, Hawaii's final preferred plan retires 1,224 MW of oil-fired capacity and builds no new gas generation.[96]

PREPA's preferred plan falls short of Hawaiian best practices to retire aging plants. PREPA plans to retire 55 percent (3,190 MW) of its total installed fossil fuel capacity by the end of 2025. This would bring Puerto Rico closer to the Hawaiian best practice were it not for PREPA's plans to increase its total installed gas capacity from 1,327 MW in 2018 to as much as 3,549 MW in 2025 through planned installations and conversions.

b) Place renewable energy, energy efficiency, demand response and battery storage on equal footing with fossil fuel generation for capacity expansion

PREPA's June IRP fails to consider renewable energy, energy efficiency, demand response and battery storage on equal footing with gas-fired generation for its capacity expansion needs. While PREPA modeled solar and battery storage resource options in the same way that it modeled fossil fuel resources, the amounts of solar and battery that the model was able to select were restricted (see the discussion on choosing renewables to lower customer costs above). PREPA's energy efficiency and demand response projections, on the other hand, were not modeled together with other capacity expansion resources (see the discussion on evaluating all resources on an equal footing above); they were included exogenously[97] and their projections were estimated based PREPA's qualitative review and resultant prioritization of demand-side measures.[98]

As a result of these inconsistencies in the way both supply- and demand-side resources are modeled and selected, PREPA's June IRP preferred plan includes as much as 2,222 MW of new gas-fired generation, and as many as three new LNG terminals by the end of 2025 (see Table 12 above).

PREPA's June IRP did model one scenario (Scenario 1, out of 6 total) in which no new gas-fired generation

---

[93] Puerto Rico Electric Power Authority. June 2019. p. 10-4 to 10-8.
[94] Some capacity expansions proposed by PREPA are contingent on load growth or contract agreements. See the notes below Table 9 for additional details.
[95] Puerto Rico Electric Power Authority. June 2019. p. 10-5 to 10-8.
[96] The Hawaiian Electric Companies. 2016. Book 1 of 4. p. 4-6, 4-7, 4-14, 4-19, 4-22.
[97] In resource modeling, an exogenous change is one that comes from outside the model and is, therefore, unexplained by the model.
[98] Puerto Rico Electric Power Authority. June 2019. Report No. PRT-001-19. Appendix 4: Demand Side Resources. Exhibit 3-1.

is installed (with the exception of the San Juan 5 and 6 conversion which is taken as a given in all scenarios since the work is nearing completion). A scenario is what utilities use in their resource planning analyses to account for potential risks or uncertainties—such as a future with low or high coal prices, or a future with more stringent environmental regulations. Scenario 1 (PREPA's "no new gas" scenario) was found to be more expensive than the preferred plan because the lack of new gas resulted in increased use of peaking generation and battery storage, and greater fuel consumption of the existing fossil fuel-fired generation capacity (see Table 13).[99]

Table 13. Costs of PREPA's no gas scenario versus its preferred plan

Model run	NPV k$ (2019-2038)	Difference from preferred plan
Scenario 1 S2B	$14,773,629	$423,434
Scenario 1 S2H	$16,134,592	$1,784,397
Scenario 1 S2L	$13,535,576	-$814,619
Scenario 1 S3B	$14,687,535	$337,340
Scenario 1 S2S1B	$14,449,784	$99,589
Scenario 1 S2S5B	$15,378,227	$1,028,032
Scenario 1 S2S6B	$16,018,738	$1,668,543
Scenario 1 S2S7B	$15,696,705	$1,346,510
Scenario 1 S1B	$14,366,811	$16,616
Average of all Scenario 1 runs	*$15,004,622*	*$654,427*
S4S2B (Preferred Plan)	**$14,350,195**	**N/A**

Note: NPV calculations assume a 9 percent discount rate.
Source: PREPA. June 7,2019. Puerto Rico IRP 2018-2019. Siemens PTI Report Number: RPT-015-19. Exhibit 8-63.

PREPA's model, however, does not allow for non-gas resources to compete on a level playing field with gas resources: that is, Scenario 1 did not relax the constraints on annual additions of renewable capacity. As a result, Scenario 1 may have selected more peaking generation and with it more fuel consumption for existing plants because it was unable to select a greater amount of renewables than permitted by the renewable capacity constraints.

Even so, the Scenario 1 base case was found to be just 3 percent ($423,434) more expensive than the preferred plan. In the Hawaiian case, the final preferred plan, which does not include any LNG, was found to be 6 percent ($2.2 billion) more expensive than the least cost plan ($34.7 billion) that did rely on LNG.[100] Unlike the 2014 PSIPs, the final 2016 PSIP did not identify a single preferred plan for each island, but it still noted that despite the plan's renewable additions "the price of oil, the disuse of coal and the cost of

[99] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 8-63.
[100] The Hawaiian Electric Companies. 2016. Book 1 of 4. Pages 5-4, 5-11, 5-25.

modernizing the grid to accept more renewables will move customer bills higher in the near term."[101] The plan was chosen anyway, because "in the longer term the aggressive pursuit of low-cost renewables will cause customer bills to be flat or slightly declining on a real-dollar basis. The renewable investments in the near-term action plans were selected to minimize the potential for making dead-end decisions and stranding assets."[102]

c) *Assess the risks of stranded costs, uncertainties, and rate impacts of imported LNG fuels and new fossil generation*

The development of Hawaii's resource plan demonstrated that building extensive renewable energy resources and no new gas-fired generation works to achieve grid reliability and resiliency, in addition to achieving the state's ambitious climate goals.[103] Hawaii's PSIPs demonstrate that aggressive build-out of renewable energy, if cost-effective, poses very little risk of stranded costs because renewable fuels (i.e. the wind, the sun, running water) are, and will remain, free—unlike fossil fuel price projections that become more uncertain over longer time periods.[104] PREPA's 2016 IRP offers no assessment of the risk of creating stranded assets by investing in new gas-fired generation capacity—a particularly important shortcoming given PREPA's troubled financial situation.

Table 14. Gas investments in PREPA's June IRP

IRP Option	Generator Name	Capacity (MW)	Investment ($ millions)
Modifiy Existing	San Juan 5&6	400	$20
New Resources	Palo Seco CCGT	302	$293
	Costa Sur CCGT	302	$293
	18 Mobile Gas Turbines	414	$433
Land Infrastructure	San Juan Land Based LNG Terminal	-	$472
Hedge Options	Yabucoa Ship Based LNG Terminal	-	$285
	Yabucoa CCGT	302	$293
	Mayaguez Ship Based LNG Terminal	-	$215
	Mayaguez CCGT	302	$293
	Mayaguez Peaker	-	$5
Totals		2,022	$2,602

Source: Reproduced from presentation by Ingrid M. Vila-Biaggi, President and Co-Founder of Cambio Puerto Rico at the Institute for Energy Economics and Financial Analysis (IEEFA) Conference. June 18, 2019.

101 The Hawaiian Electric Companies. 2016. Executive Summary. p. ES-5.
102 Ibid.
103 Ibid.
104 Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 6-6.

PREPA's June IRP plans for extensive new gas-fired capacity and supporting infrastructure, which represents a total investment of $2.6 billion over the planning period (see Table 14 above). If this capital expenditure were to become stranded for any reason, PREPA's financial situation would be negatively impacted. In addition, PREPA did not consider the risk of failing to attain reasonable interest rates on loans for gas investments.[105]

In its analysis of gas prices to supply plants without existing fuel supply contracts (Aguirre, San Juan, Mayagüez and Yabucoa), PREPA utilizes 115 percent of Henry Hub gas price forecasts with a cost adder of $4.35/MMBtu to reflect additional costs like liquefaction and transport.[106] Henry Hub on its own would be an inappropriate gas price forecast for Puerto Rico because the island's gas is not purchased from the United States; there are no U.S.-built and operated (Jones Act compliant) LNG carriers that are legally allowed to transport gas to Puerto Rico, which is why nearly all of Puerto Rico's gas imports come from Trinidad & Tobago.[107] While it is reasonable to assume that gas delivered to Puerto Rico will be more expensive than Henry Hub prices, PREPA's June IRP fails to explain how it accounts for the Jones Act in its modeling—the Jones Act was temporarily lifted during Hurricane Maria and discussions about a permanent exemption are ongoing.[108]

5. Best practices and lessons learned

The Hawaiian utilities' development of their 2016 resource plan resulted in nine best practices for other utilities seeking to balance strong renewable energy policy requirements with grid resiliency (see Table 15 below).

These important lessons have the potential to improve Puerto Rico's planning process, ensure that PREPA is in compliance with Puerto Rico's climate laws, and provide the lowest possible rates to consumers. A repeated theme in IRP best practices is the need to allow resources to compete on their own merits, taking into consideration risks and uncertainties possible in wide set of future scenarios. PREPA's IRP does not comply with new renewables requirements and does not allow renewables to compete with other resources to bring low-cost energy to consumers. The result is a significant increase in investment in gas-fired generation and related infrastructure that is likely to become stranded financial assets by 2050.

[105] Ibid. p. 8-28.
[106] Puerto Rico Electric Power Authority. June 2019. Report No. RPT-015-19. p. 7-21.
[107] U.S. Department of Energy. 2019. *Natural Gas Imports and Exports, First Quarter Report 2019.* Report No. DOE/FE-0614. Available at: https://www.energy.gov/sites/prod/files/2019/08/f65/1Q2019.pdf. p. 52.
[108] Gallagher, J. February 7, 2019. "Lawmakers oppose Puerto Rico's Jones Act waiver request." *FreightWaves*. Available at: https://www.freightwaves.com/news/regulations/lawmakers-oppose-puerto-rico-jones-act-waiver-request.

Table 15. PREPA June IRP performance vis-à-vis Hawaii best practices

1(a). Develop low-cost renewable resources and battery storage
PREPA's IRP plans for 2,222 MW of new and converted gas generating capacity but only 2,740 MW of renewable solar, battery capacity and demand response by 2024. PREPA solar capacity additions appear to be insufficient to achieve 2025 compliance with the new RPS requirement of 40 percent.
1(b). Pursue renewables with the highest certainty of deployment early in the planning period
PREPA's IRP falls short of the Hawaii best practice in terms of the total amount of planned renewable capacity (relative to population and peak demand) and in terms of the failure to pursue wind resources.
1(c). Ensure lowest costs for ratepayers by considering renewables on equal footing with fossil fuels
PREPA's IRP gives fossil fuel generation an advantage over renewables in its modeling: the IRP analysis places annual capacity expansion constraints solely on solar and battery storage.
2(a). Shift from centralized to distributed energy resources
PREPA's IRP includes ambitious plans to develop distributed energy resources with the aim of creating a more reliable and resilient electric grid. These plans go further than those of the Hawaiian utilities.
2(b). Assess all types of distributed energy resources on equal footing with other capacity expansion opportunities
PREPA's IRP tips the scale in favor of gas-fired resources by limiting installation of renewable distributed generation resources.
2(c). Consider grid services and risk reduction from distributed energy resources relative to other capacity expansion opportunities
PREPA's IRP notes that large, centralized resources (from the February 2019 version of its IRP) resulted in lower overall costs than the June 2019 IRP preferred plan but that the utility concluded that distributed energy resources provide greater resiliency, which is worth a slightly higher cost.
3(a). Reduce generation costs by retiring aging fossil fuel plants
PREPA's IRP plans to retire 55 percent (3,190 MW) of its 2018 fossil fuel capacity by the end of 2025, but also plans to install and convert another 2,222 MW of gas capacity.
3(b). Place renewable energy, energy efficiency, demand response and battery storage on equal footing with fossil fuel generation for capacity expansion
PREPA's IRP does not allow renewable energy, energy efficiency, demand response and battery storage to complete on equal terms with gas-fired generation.
3(c). Assess the risks of stranded costs, uncertainties, and rate impacts of imported LNG fuels and new fossil generation
PREPA's IRP offers no assessment of the risk of creating stranded assets by investing in new gas-fired generation capacity—a particularly important shortcoming given PREPA's troubled financial situation.

EXHIBIT C

DIRECT TESTIMONY OF

ELIZABETH A. STANTON, PHD
ON BEHALF OF ENVIRONMENTAL DEFENSE FUND

PREPA Least Cost IRP Testimony Workbook

Applied Economics Clinic
www.aeclinic.org

Primary Contact: Elizabeth A Stanton
liz.stanton@aeclinic.org

Table of Contents

Summary Tables + Figures	Library	Data Tabs

559764

	Base Load	Base Load	Base Load	Base Load	Base Load	Base Load	Base Load	Base Load	Base Load	Base Load	Base Load	Base Load	Base Load
Fiscal Year	**Gross Energy Sales (GWh)**	**Losses (calculation)**	**Total Energy Demand (GWh)**	**EE (GWh)**	**EE (% gross sales cumulative)**	**EE (% gross sales annual incremental)**	**Total Energy Demand After EE (GWh)**	**Customer owned DG (GWh)**	**Total Energy Demand After EE, DG (GWh)**	**CHP (GWh)**	**Total Energy Demand After EE, DG, CHP (GWh)**	**All Reductions from Total Energy Demand (GWh)**	**All Reductions from Total Energy Demand (%)**
2019	15,301	19.9%	18,351	27	0%	0.2%	18,324	62	18,262	66	18,196	155	1%
2020	15,357	19.9%	18,415	586	4%	3.6%	17,829	183	17,646	236	17,410	1,005	5%
2021	15,403	19.9%	18,469	940	6%	2.3%	17,529	249	17,280	404	16,876	1,593	9%
2022	15,470	19.9%	18,545	1,294	8%	2.3%	17,251	300	16,951	922	16,029	2,516	14%
2023	15,530	19.9%	18,613	1,649	11%	2.3%	16,964	350	16,614	922	15,692	2,921	16%
2024	15,574	19.8%	18,665	2,006	13%	2.3%	16,659	404	16,255	922	15,333	3,332	18%
2025	15,595	19.8%	18,689	2,314	15%	2.0%	16,375	456	15,919	922	14,997	3,692	20%
2026	15,596	19.8%	18,690	2,624	17%	2.0%	16,066	514	15,552	922	14,630	4,060	22%
2027	15,554	19.9%	18,642	2,934	19%	2.0%	15,708	575	15,133	922	14,211	4,431	24%
2028	15,487	19.9%	18,565	3,245	21%	2.0%	15,320	642	14,678	922	13,756	4,809	26%
2029	15,341	19.9%	18,397	3,558	23%	2.0%	14,839	708	14,131	922	13,209	5,188	28%
2030	15,223	20.0%	18,261	3,871	25%	2.1%	14,390	781	13,609	922	12,687	5,574	31%
2031	15,120	20.0%	18,144	4,186	28%	2.1%	13,958	857	13,101	922	12,179	5,965	33%
2032	15,025	20.0%	18,034	4,501	30%	2.1%	13,533	941	12,592	922	11,670	6,364	35%
2033	14,939	20.1%	17,935	4,817	32%	2.1%	13,118	1,022	12,096	922	11,174	6,761	38%
2034	14,862	20.1%	17,848	5,135	35%	2.1%	12,713	1,109	11,604	922	10,682	7,166	40%
2035	14,796	20.1%	17,772	5,395	36%	1.8%	12,377	1,200	11,177	922	10,255	7,517	42%
2036	14,741	20.1%	17,708	5,656	38%	1.8%	12,052	1,298	10,754	922	9,832	7,876	44%
2037	14,694	20.1%	17,654	5,917	40%	1.8%	11,737	1,392	10,345	922	9,423	8,231	47%
2038	14,654	20.2%	17,608	6,179	42%	1.8%	11,429	1,494	9,935	922	9,013	8,595	49%
2039				35.1%				8.5%		5.2%	9,013		
2040											9,013		
2041											9,013		
2042											9,013		
2043											9,013		
2044											9,013		
2045											9,013		
2046											9,013		
2047											9,013		
2048											9,013		
2049											9,013		
2050											9,013		

		Base Load
	RPS Requirement (%)	**RPS Requirement (GWh)**
2019	20%	3,639
2020	20%	3,482
2021	20%	3,375
2022	20%	3,206
2023	20%	3,138
2024	20%	
2025	40%	5,999
2026	40%	5,852
2027	40%	5,684
2028	40%	5,502
2029	40%	5,284
2030	40%	5,075
2031	40%	4,872
2032	40%	4,668
2033	40%	4,470
2034	40%	4,273
2035	40%	4,102
2036	40%	3,933
2037	40%	3,769
2038	40%	3,605
2039	40%	
2040	60%	5,408
2041	60%	5,408
2042	60%	5,408
2043	60%	5,408
2044	60%	5,408
2045	60%	5,408
2046	60%	5,408
2047	60%	5,408
2048	60%	5,408
2049	60%	
2050	100%	9,013

	Base Load	Base Load	Base Load	Base Load	
	Small Reductions to Gross Demand (GWh)	**All Reductions from Total Energy Demand (%)**	**Net Energy Demand at 30% reductions (GWh)**	**RPS Requirement (GWh)**	
2019	124	1%	18,227	3,645	
2020	795	4%	17,620	3,524	
2021	1,219	7%	17,250	3,450	
2022	1,643	9%	16,902	3,380	
2023	2,068	11%	16,545	3,309	
2024	2,496	13%	16,169		
2025	2,865	15%	15,824	6,330	
2026	3,236	17%	15,454	6,181	
2027	3,608	19%	15,034	6,013	
2028	3,982	21%	14,583	5,833	
2029	4,359	24%	14,038	5,615	
2030	4,735	26%	13,526	5,410	
2031	5,115	28%	13,029	5,212	
2032	5,495	30%	12,539	5,016	
2033	5,472	31%	12,463	4,985	
2034	5,446	31%	12,402	4,961	
2035	5,424	31%	12,348	4,939	
2036	5,405	31%	12,303	4,921	
2037	5,388	31%	12,266	4,906	
2038	5,374	31%	12,234	4,893	1,288
2039	5,374		12,234		0.263263
2040	5,374		12,234	7,340	
2041	5,374		12,234	7,340	
2042	5,374		12,234	7,340	
2043	5,374		12,234	7,340	
2044	5,374		12,234	7,340	
2045	5,374		12,234	7,340	
2046	5,374		12,234	7,340	
2047	5,374		12,234	7,340	
2048	5,374		12,234	7,340	
2049	5,374		12,234		
2050	5,374		12,234	12,234	

	High Load	Base Load	High Load	High Load	High Load	High Load	High Load	High Load	High Load	Base Load	High Load	High Load	High Load
Fiscal Year	**Gross Energy Sales (GWh)**	**Losses (calculation)**	**Total Energy Demand (GWh)**	**EE (GWh)**	**EE (% gross sales cumulative)**	**EE (% gross sales annual incremental)**	**Total Energy Demand After EE (GWh)**	**Customer owned DG (GWh)**	**Total Energy Demand After EE, DG (GWh)**	**CHP (GWh)**	**Total Energy Demand After EE, DG, CHP (GWh)**	**All Reductions from Total Energy Demand (GWh)**	**All Reductions from Total Energy Demand (%)**
2019	15,670	19.9%	18,794	1	0%	0.0%	18,793	128	18,665	66	18,599	195	1%
2020	16,001	19.9%	19,187	505	3%	3.1%	18,682	419	18,263	236	18,027	1,160	6%
2021	16,166	19.9%	19,384	827	5%	2.0%	18,557	653	17,904	404	17,500	1,884	10%
2022	16,358	19.9%	19,610	1,156	7%	2.0%	18,454	1,222	17,232	922	16,310	3,300	17%
2023	16,730	19.9%	20,051	1,507	9%	2.1%	18,544	1,272	17,272	922	16,350	3,701	18%
2024	16,642	19.8%	19,945	1,821	11%	1.9%	18,124	1,326	16,798	922	15,876	4,069	20%
2025	16,755	19.8%	20,079	2,115	13%	1.8%	17,964	1,379	16,585	922	15,663	4,416	22%
2026	17,024	19.8%	20,401	2,439	14%	1.9%	17,962	1,436	16,526	922	15,604	4,797	24%
2027	17,136	19.9%	20,538	2,754	16%	1.8%	17,784	1,497	16,287	922	15,365	5,173	25%
2028	17,114	19.9%	20,515	3,056	18%	1.8%	17,459	1,564	15,895	922	14,973	5,542	27%
2029	16,998	19.9%	20,384	3,360	20%	1.8%	17,024	1,630	15,394	922	14,472	5,912	29%
2030	16,939	20.0%	20,319	3,671	22%	1.8%	16,648	1,703	14,945	922	14,023	6,296	31%
2031	16,932	20.0%	20,318	3,994	24%	1.9%	16,324	1,780	14,544	922	13,622	6,696	33%
2032	17,078	20.0%	20,498	4,359	26%	2.1%	16,139	1,864	14,275	922	13,353	7,145	35%
2033	17,235	20.1%	20,691	4,735	27%	2.2%	15,956	1,944	14,012	922	13,090	7,601	37%
2034	16,923	20.1%	20,323	4,979	29%	1.4%	15,344	2,032	13,312	922	12,390	7,933	39%
2035	17,113	20.1%	20,555	5,312	31%	1.9%	15,243	2,122	13,121	922	12,199	8,356	41%
2036	16,976	20.1%	20,393	5,542	33%	1.4%	14,851	2,221	12,630	922	11,708	8,685	43%
2037	17,270	20.1%	20,749	5,915	34%	2.2%	14,834	2,314	12,520	922	11,598	9,151	44%
2038	16,719	20.2%	20,089	5,991	36%	0.5%	14,098	2,417	11,681	922	10,759	9,330	46%
2039											10,759		
2040											10,759		
2041											10,759		
2042											10,759		
2043											10,759		
2044											10,759		
2045											10,759		
2046											10,759		
2047											10,759		
2048											10,759		
2049											10,759		
2050											10,759		

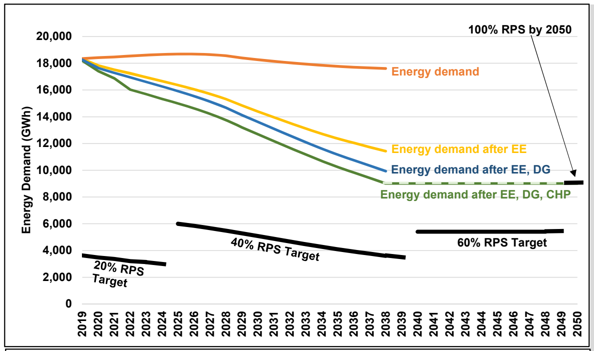
		High Load
	RPS Requirement (%)	**RPS Requirement (GWh)**
2019	20%	3,720
2020	20%	3,605
2021	20%	3,500
2022	20%	3,262
2023	20%	3,270
2024	20%	
2025	40%	6,265
2026	40%	6,242
2027	40%	6,146
2028	40%	5,989
2029	40%	5,789
2030	40%	5,609
2031	40%	5,449
2032	40%	5,341
2033	40%	5,236
2034	40%	4,956
2035	40%	4,880
2036	40%	4,683
2037	40%	4,639
2038	40%	4,304
2039	40%	
2040	60%	6,456
2041	60%	6,456
2042	60%	6,456
2043	60%	6,456
2044	60%	6,456
2045	60%	6,456
2046	60%	6,456
2047	60%	6,456
2048	60%	6,456
2049	60%	
2050	100%	10,759

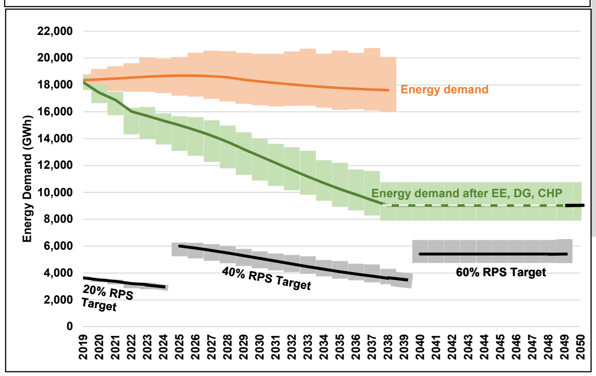
	High Load	High Load	High Load	High Load
	Small Reductions to Gross Demand (GWh)	**All Reductions from Total Energy Demand (%)**	**Net Energy Demand at 30% reductions (GWh)**	**RPS Requirement (GWh)**
2019	93	0%	18,700	3,740
2020	698	4%	18,489	3,698
2021	1,084	6%	18,300	3,660
2022	1,478	8%	18,132	3,626
2023	1,898	9%	18,153	3,631
2024	2,275	11%	17,670	
2025	2,627	13%	17,453	6,981
2026	3,015	15%	17,387	6,955
2027	3,393	17%	17,145	6,858
2028	3,756	18%	16,760	6,704
2029	4,121	20%	16,263	6,505
2030	4,496	22%	15,824	6,330
2031	4,885	24%	15,434	6,173
2032	5,324	26%	15,174	6,070
2033	6,299	30%	14,392	5,757
2034	6,189	30%	14,134	5,654
2035	6,258	30%	14,297	5,719
2036	6,210	30%	14,183	5,673
2037	6,317	30%	14,432	5,773
2038	6,119	30%	13,971	5,588
2039	6,119		13,971	
2040	6,119		13,971	8,382
2041	6,119		13,971	8,382
2042	6,119		13,971	8,382
2043	6,119		13,971	8,382
2044	6,119		13,971	8,382
2045	6,119		13,971	8,382
2046	6,119		13,971	8,382
2047	6,119		13,971	8,382
2048	6,119		13,971	8,382
2049	6,119		13,971	
2050	6,119		13,971	13,971

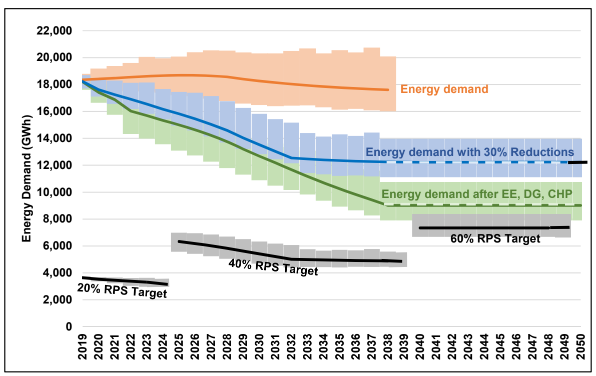
	Low Load	Base Load	Low Load	Low Load	Low Load	Low Load	Low Load	Low Load	Low Load	Base Load	Low Load	Low Load	Low Load
Fiscal Year	Gross Energy Sales (GWh)	Losses (calculation)	Total Energy Demand (GWh)	EE (GWh)	EE (% gross sales cumulative)	EE (% gross sales annual incremental)	Total Energy Demand After EE (GWh)	Customer owned DG (GWh)	Total Energy Demand After EE, DG (GWh)	CHP (GWh)	Total Energy Demand After EE, DG, CHP (GWh)	All Reductions from Total Energy Demand (GWh)	All Reductions from Total Energy Demand (%)
2019	14,844	19.9%	17,803	-1	0%	0.0%	17,804	128	17,676	66	17,610	193	1%
2020	14,811	19.9%	17,760	465	3%	3.1%	17,295	419	16,876	236	16,640	1,120	6%
2021	14,636	19.9%	17,549	746	5%	1.9%	16,803	653	16,150	404	15,746	1,803	10%
2022	14,596	19.9%	17,497	1,028	7%	1.9%	16,469	1,223	15,246	922	14,324	3,173	18%
2023	14,588	19.9%	17,484	1,310	9%	1.9%	16,174	1,273	14,901	922	13,979	3,505	20%
2024	14,514	19.8%	17,395	1,585	11%	1.9%	15,810	1,326	14,484	922	13,562	3,833	22%
2025	14,352	19.8%	17,199	1,808	13%	1.6%	15,391	1,379	14,012	922	13,090	4,109	24%
2026	14,292	19.8%	17,127	2,043	14%	1.6%	15,084	1,436	13,648	922	12,726	4,401	26%
2027	14,148	19.9%	16,957	2,269	16%	1.6%	14,688	1,497	13,191	922	12,269	4,688	28%
2028	13,989	19.9%	16,769	2,493	18%	1.6%	14,276	1,565	12,711	922	11,789	4,980	30%
2029	13,831	19.9%	16,586	2,728	20%	1.7%	13,858	1,631	12,227	922	11,305	5,281	32%
2030	13,740	20.0%	16,482	2,973	22%	1.8%	13,509	1,703	11,806	922	10,884	5,598	34%
2031	13,664	20.0%	16,397	3,218	24%	1.8%	13,179	1,780	11,399	922	10,477	5,920	36%
2032	13,690	20.0%	16,432	3,489	25%	2.0%	12,943	1,864	11,079	922	10,157	6,275	38%
2033	13,702	20.1%	16,450	3,760	27%	2.0%	12,690	1,943	10,747	922	9,825	6,625	40%
2034	13,582	20.1%	16,311	3,992	29%	1.7%	12,319	2,031	10,288	922	9,366	6,945	43%
2035	13,435	20.1%	16,137	4,165	31%	1.3%	11,972	2,122	9,850	922	8,928	7,209	45%
2036	13,476	20.1%	16,188	4,394	33%	1.7%	11,794	2,221	9,573	922	8,651	7,537	47%
2037	13,390	20.1%	16,087	4,580	34%	1.4%	11,507	2,315	9,192	922	8,270	7,817	49%
2038	13,323	20.2%	16,009	4,769	36%	1.4%	11,240	2,417	8,823	922	7,901	8,108	51%
2039											7,901		
2040											7,901		
2041											7,901		
2042											7,901		
2043											7,901		
2044											7,901		
2045											7,901		
2046											7,901		
2047											7,901		
2048											7,901		
2049											7,901		
2050											7,901		

		Low Load
	RPS Requirement (%)	RPS Requirement (GWh)
2019	20%	3,522
2020	20%	3,328
2021	20%	3,149
2022	20%	2,865
2023	20%	2,796
2024	20%	
2025	40%	5,236
2026	40%	5,091
2027	40%	4,908
2028	40%	4,716
2029	40%	4,522
2030	40%	4,354
2031	40%	4,191
2032	40%	4,063
2033	40%	3,930
2034	40%	3,746
2035	40%	3,571
2036	40%	3,461
2037	40%	3,308
2038	40%	3,160
2039	40%	
2040	60%	4,740
2041	60%	4,740
2042	60%	4,740
2043	60%	4,740
2044	60%	4,740
2045	60%	4,740
2046	60%	4,740
2047	60%	4,740
2048	60%	4,740
2049	60%	
2050	100%	7,901

	Low Load	Low Load	Low Load	Low Load
	Small Reductions to Gross Demand (GWh)	All Reductions from Total Energy Demand (%)	Net Energy Demand at 30% reductions (GWh)	RPS Requirement (GWh)
2019	91	1%	17,712	3,542
2020	650	4%	17,111	3,422
2021	986	6%	16,563	3,313
2022	1,324	8%	16,173	3,235
2023	1,662	10%	15,822	3,164
2024	1,992	11%	15,403	
2025	2,259	13%	14,941	5,976
2026	2,540	15%	14,587	5,835
2027	2,811	17%	14,145	5,658
2028	3,081	18%	13,689	5,475
2029	3,363	20%	13,223	5,289
2030	3,658	22%	12,824	5,130
2031	3,954	24%	12,443	4,977
2032	4,280	26%	12,152	4,861
2033	5,027	31%	11,423	4,569
2034	4,985	31%	11,326	4,530
2035	4,933	31%	11,204	4,482
2036	4,949	31%	11,240	4,496
2037	4,918	31%	11,169	4,468
2038	4,895	31%	11,114	4,446
2039	4,895		11,114	
2040	4,895		11,114	6,668
2041	4,895		11,114	6,668
2042	4,895		11,114	6,668
2043	4,895		11,114	6,668
2044	4,895		11,114	6,668
2045	4,895		11,114	6,668
2046	4,895		11,114	6,668
2047	4,895		11,114	6,668
2048	4,895		11,114	6,668
2049	4,895		11,114	
2050	4,895		11,114	11,114





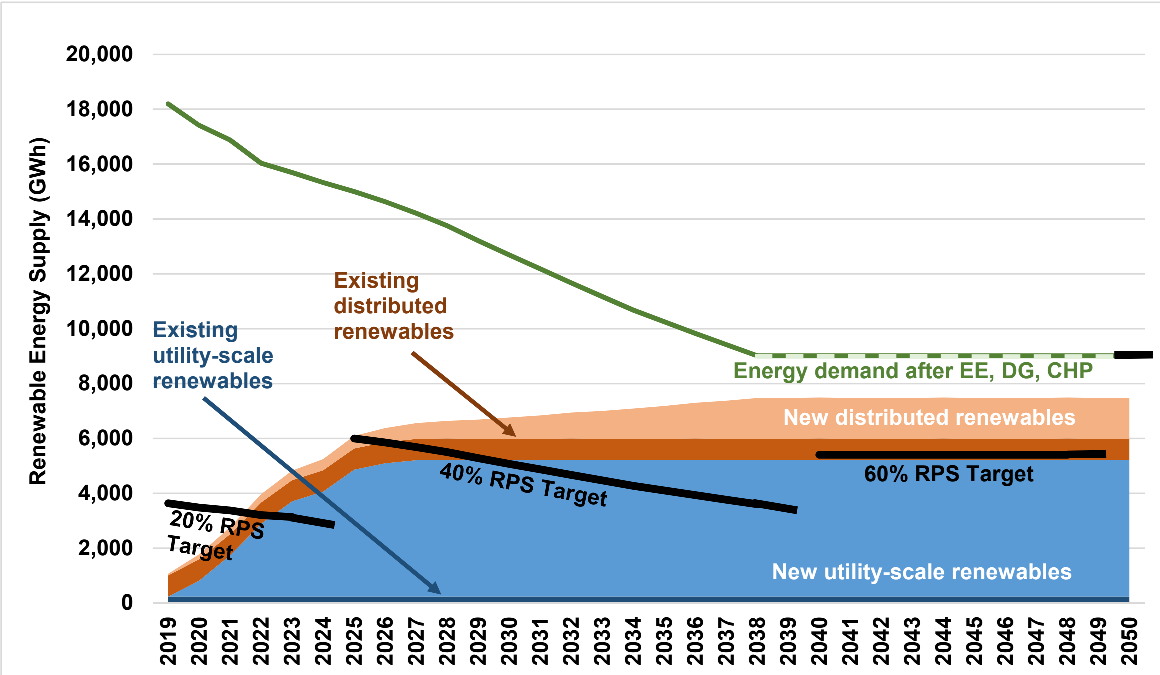


	Energy Demand		Net Energy		Net Energy with 30% F		RPS Requirement		RPS Reqwith 30% Reductions	
	Error Up	Error Down	Error Up	Error Down	Error Up	Error Down	Error Up	Error Down	Error Up	Error Down
2019	443	548	403	586	474	515	81	117	95	103
2020	772	655	617	770	869	510	123	154	174	102
2021	915	920	624	1,130	1,050	687	125	226	210	137
2022	1,065	1,048	281	1,705	1,230	729	56	341	246	146
2023	1,438	1,129	658	1,713	1,608	723	132	343	322	145
2024	1,280	1,270	543	1,771	1,502	766	0	0	0	0
2025	1,390	1,490	666	1,907	1,629	883	266	763	651	353
2026	1,711	1,563	974	1,904	1,933	866	390	761	773	347
2027	1,896	1,685	1,154	1,942	2,112	888	462	777	845	355
2028	1,950	1,796	1,217	1,967	2,177	894	487	787	871	358
2029	1,987	1,811	1,263	1,904	2,225	815	505	762	890	326
2030	2,058	1,779	1,336	1,803	2,298	702	535	721	919	281
2031	2,174	1,747	1,443	1,702	2,405	586	577	681	962	234
2032	2,464	1,602	1,683	1,513	2,635	388	673	605	1,054	155
2033	2,756	1,485	1,916	1,349	1,930	1,040	767	540	772	416
2034	2,475	1,537	1,708	1,316	1,733	1,076	683	526	693	430
2035	2,783	1,635	1,944	1,327	1,948	1,144	778	531	779	458
2036	2,685	1,520	1,876	1,181	1,879	1,064	750	472	752	425
2037	3,095	1,567	2,175	1,153	2,166	1,097	870	461	867	439
2038	2,481	1,599	1,746	1,112	1,737	1,120	699	445	695	448
2039	0	0	1,746	1,112	1,737	1,120	0	0	0	0
2040	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2041	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2042	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2043	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2044	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2045	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2046	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2047	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2048	0	0	1,746	1,112	1,737	1,120	1,048	667	1,042	672
2049	0	0	1,746	1,112	1,737	1,120	0	0	0	0
2050	0	0	1,746	1,112	1,737	1,120	1,746	1,112	1,737	1,120

ESM Case

										Base Load	Base Load		
Fiscal Year	**New Utility-Scale Solar (MW)**	**Existing Customer DG (MW)**		**Existing Utility-Scale RE in 2018 (GWh)**	**New Utility-Scale Solar (GWh)**	**Existing Customer DG (GWh)**	**New Customer DG (GWh)**	**Total RE (GWh)**		**RPS Requirement (GWh)**	**Total Energy Demand After EE, DG, CHP (GWh)**	**Renewables (%)**	**Net Energy Demand with 30% reduction**
2019	0	401		237	0	772	62	1,072		3,639	18,196	6%	18,227
2020	300	403		237	580	779	183	1,779		3,482	17,410	10%	17,620
2021	780	401		237	1,503	772	249	2,762		3,375	16,876	16%	17,250
2022	1,380	401		237	2,660	772	300	3,969		3,206	16,029	25%	16,902
2023	1,800	401		237	3,469	772	350	4,829		3,138	15,692	31%	16,545
2024	1,980	403		237	3,826	779	404	5,246			15,333	34%	16,169
2025	2,400	401		237	4,625	772	456	6,091		5,999	14,997	41%	15,824
2026	2,520	401		237	4,857	772	514	6,380		5,852	14,630	44%	15,454
2027	2,580	401		237	4,972	772	575	6,557		5,684	14,211	46%	15,034
2028	2,580	403		237	4,986	779	642	6,644		5,502	13,756	48%	14,583
2029	2,580	401		237	4,972	772	708	6,690		5,284	13,209	51%	14,038
2030	2,580	401		237	4,972	772	781	6,763		5,075	12,687	53%	13,526
2031	2,580	401		237	4,972	772	857	6,839		4,872	12,179	56%	13,029
2032	2,580	403		237	4,986	779	941	6,943		4,668	11,670	59%	12,539
2033	2,580	401		237	4,972	772	1,022	7,004		4,470	11,174	63%	12,463
2034	2,580	401		237	4,972	772	1,109	7,091		4,273	10,682	66%	12,402
2035	2,580	401		237	4,972	772	1,200	7,182		4,102	10,255	70%	12,348
2036	2,580	403		237	4,986	779	1,298	7,300		3,933	9,832	74%	12,303
2037	2,580	401		237	4,972	772	1,392	7,374		3,769	9,423	78%	12,266
2038	2,580	401		237	4,972	772	1,494	7,476		3,605	9,013	83%	12,234
2039	2,580	401		237	4,972	772	1,494	7,476			9,013	83%	12,234
2040	2,580	403		237	4,986	779	1,494	7,496		5,408	9,013	83%	12,234
2041	2,580	401		237	4,972	772	1,494	7,476		5,408	9,013	83%	12,234
2042	2,580	401		237	4,972	772	1,494	7,476		5,408	9,013	83%	12,234
2043	2,580	401		237	4,972	772	1,494	7,476		5,408	9,013	83%	12,234
2044	2,580	403		237	4,986	779	1,494	7,496		5,408	9,013	83%	12,234
2045	2,580	401		237	4,972	772	1,494	7,476		5,408	9,013	83%	12,234
2046	2,580	401		237	4,972	772	1,494	7,476		5,408	9,013	83%	12,234
2047	2,580	401		237	4,972	772	1,494	7,476		5,408	9,013	83%	12,234
2048	2,580	403		237	4,986	779	1,494	7,496		5,408	9,013	83%	12,234
2049	2,580	401		237	4,972	772	1,494	7,476			9,013	83%	12,234
2050	2,580	401		237	4,972	772	1,494	7,476		9,013	9,013	83%	12,234

0.3031596



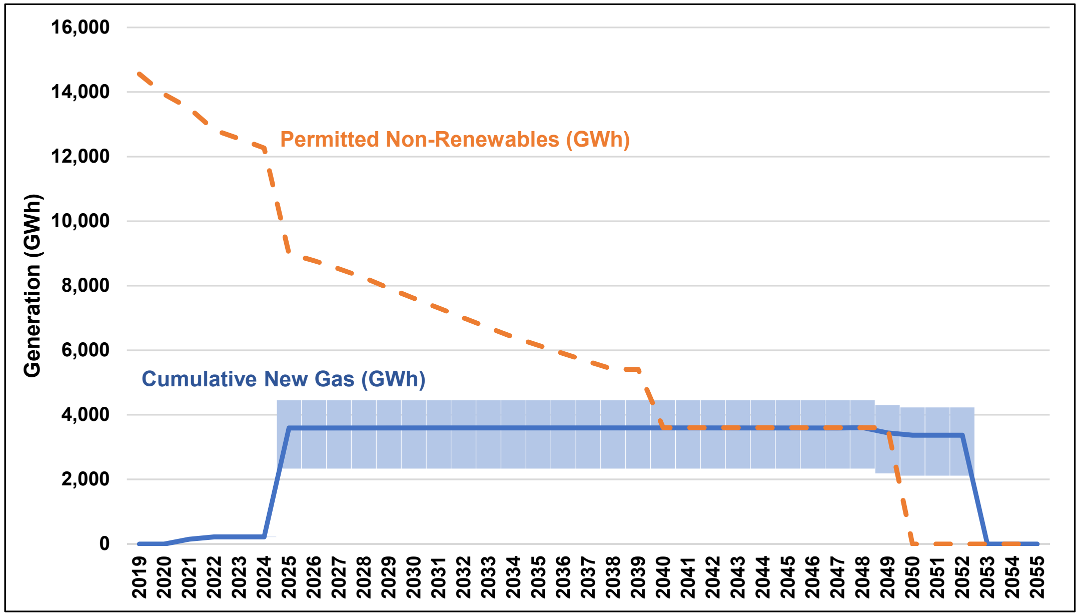
	2022	2025	2040	2022	2025	2040
RPS target (share of energy demand)	20%	40%	60%			
49% reduction in energy demand (GWh)	16,029	14,997	9,013			
30% reduction in energy demand (GWh)	16,902	15,824	12,234			
Renewable supply with customer-owned generation (GWh)	3,969	6,091	7,496	25%	41%	83%
(share of total energy demand)	(23% to 25%)	(38% to 41%)	(61% to 83%)	23%	38%	61%
Renewable supply without customer-owned generation (GWh)	2,897	4,863	5,223	18%	32%	58%
(share of total energy demand)	(17% to 18%)	(31% to 32%)	(43% to 58%)	17%	31%	43%

2025	Existing Utility-Scale RE in 2018 (GWh)	New Utility-Scale Solar (GWh)	Existing Customer DG (GWh)	New Customer DG (GWh)	Total RE (GWh)	Total Energy Demand After EE, DG, CHP (GWh)	Renewables (%)
S1S2B	237	4,972	772	456	6,438	14,997	43%
S1S2H	237	5,435	772	456	6,900	15,663	44%
S1S2L	237	4,510	772	456	5,975	13,090	46%
S1S3B	237	4,972	772	456	6,438	14,997	43%
S1S2S1B	237	4,972	772	456	6,438	14,997	43%
S1S2S5B	237	4,972	772	456	6,438	14,997	43%
S1S2S6B	237	4,972	772	456	6,438	14,997	43%
S1S2S7B	237	5,550	772	456	7,016	14,997	47%
S1S1B	237	4,857	772	456	6,322	14,997	42%
S3S2B	237	5,435	772	456	6,900	14,997	46%
S3S2H	237	6,360	772	456	7,825	15,663	50%
S3S2L	237	5,782	772	456	7,247	13,090	55%
S3S3B	237	5,435	772	456	6,900	14,997	46%
S3S2S5B	237	5,435	772	456	6,900	14,997	46%
S3S2S8B	237	5,435	772	456	6,900	14,997	46%
S4S2B	237	4,278	772	456	5,744	14,997	38%
S4S2H	237	4,741	772	456	6,207	15,663	40%
S4S2L	237	4,047	772	456	5,513	13,090	42%
S4S2S9B	237	4,278	772	456	5,744	14,997	38%
S4S3B	237	4,972	772	456	6,438	14,997	43%
S4S2S1B	237	4,278	772	456	5,744	14,997	38%
S4S2S4B	237	4,972	772	456	6,438	14,997	43%
S4S2S5B	237	4,278	772	456	5,744	14,997	38%
S4S2S6B	237	4,278	772	456	5,744	14,997	38%
S4S1B	237	5,203	772	456	6,669	14,997	44%
S5S1B	237	4,972	772	456	6,438	14,997	43%
S5S1S5B	237	4,972	772	456	6,438	14,997	43%
S5S1S1B	237	4,972	772	456	6,438	14,997	43%
S5S1S6B	237	4,972	772	456	6,438	14,997	43%
ESM	237	4,625	772	456	6,091	14,997	41%
ESM High	237	4,510	772	456	5,975	15,663	38%
ESM Low	237	3,700	772	456	5,166	13,090	39%
ESMS1B	237	4,625	772	456	6,091	14,997	41%
ESMS6B	237	4,625	772	456	6,091	14,997	41%
ESMS5B	237	4,625	772	456	6,091	14,997	41%

2038	Existing Utility-Scale RE in 2018 (GWh)	New Utility-Scale Solar (GWh)	Existing Customer DG (GWh)	New Customer DG (GWh)	Total RE (GWh)	Total Energy Demand After EE, DG, CHP (GWh)	Renewables (%)
S1S2B	237	5,203	772	1,494	7,707	9,013	86%
S1S2H	237	6,128	772	1,494	8,632	10,759	80%
S1S2L	237	4,510	772	1,494	7,013	7,901	89%
S1S3B	237	4,972	772	1,494	7,476	9,013	83%
S1S2S1B	237	5,203	772	1,494	7,707	9,013	86%
S1S2S5B	237	5,203	772	1,494	7,707	9,013	86%
S1S2S6B	237	5,203	772	1,494	7,707	9,013	86%
S1S2S7B	237	6,244	772	1,494	8,748	9,013	97%
S1S1B	237	4,857	772	1,494	7,360	9,013	82%
S3S2B	237	7,979	772	1,494	10,482	9,013	116%
S3S2H	237	8,788	772	1,494	11,292	10,759	105%
S3S2L	237	7,863	772	1,494	10,367	7,901	131%
S3S3B	237	7,979	772	1,494	10,482	9,013	116%
S3S2S5B	237	7,979	772	1,494	10,482	9,013	116%
S3S2S8B	237	7,979	772	1,494	10,482	9,013	116%
S4S2B	237	5,435	772	1,494	7,938	9,013	88%
S4S2H	237	4,857	772	1,494	7,360	10,759	68%
S4S2L	237	4,857	772	1,494	7,360	7,901	93%
S4S2S9B	237	5,435	772	1,494	7,938	9,013	88%
S4S3B	237	5,435	772	1,494	7,938	9,013	88%
S4S2S1B	237	5,435	772	1,494	7,938	9,013	88%
S4S2S4B	237	5,897	772	1,494	8,401	9,013	93%
S4S2S5B	237	5,435	772	1,494	7,938	9,013	88%
S4S2S6B	237	5,435	772	1,494	7,938	9,013	88%
S4S1B	237	5,203	772	1,494	7,707	9,013	86%
S5S1B	237	4,972	772	1,494	7,476	9,013	83%
S5S1S5B	237	4,972	772	1,494	7,476	9,013	83%
S5S1S1B	237	4,972	772	1,494	7,476	9,013	83%
S5S1S6B	237	4,972	772	1,494	7,476	9,013	83%
ESM	237	4,972	772	1,494	7,476	9,013	83%
ESM High	237	4,741	772	1,494	7,245	10,759	67%
ESM Low	237	3,816	772	1,494	6,320	7,901	80%
ESMS1B	237	4,972	772	1,494	7,476	9,013	83%
ESMS6B	237	4,972	772	1,494	7,476	9,013	83%
ESMS5B	237	4,972	772	1,494	7,476	9,013	83%

CT CF	64%	CC CF	0.04083333

Fiscal Year	Cumulative New Gas CC (MW)	Cumulative New Gas CT (MW)	Cumulative New Gas (GWh)	Non-RE Permitted (GWh)	Cumulative New Gas 40%CF (GWh)	Cumulative New Gas 80% CF (GWh)
2019	0	0	0	14,557	0	0
2020	0	0	0	13,928	0	0
2021	0	418	150	13,501	150	150
2022	0	618	221	12,823	221	221
2023	0	618	221	12,554	221	221
2024	0	618	222	12,266	221	221
2025	604	618	3,594	8,998	2,337	4,454
2026	604	618	3,594	8,778	2,337	4,454
2027	604	618	3,594	8,527	2,337	4,454
2028	604	618	3,604	8,254	2,337	4,454
2029	604	618	3,594	7,925	2,337	4,454
2030	604	618	3,594	7,612	2,337	4,454
2031	604	618	3,594	7,307	2,337	4,454
2032	604	618	3,604	7,002	2,337	4,454
2033	604	618	3,594	6,704	2,337	4,454
2034	604	618	3,594	6,409	2,337	4,454
2035	604	618	3,594	6,153	2,337	4,454
2036	604	618	3,604	5,899	2,337	4,454
2037	604	618	3,594	5,654	2,337	4,454
2038	604	618	3,594	5,408	2,337	4,454
2039	604	618	3,594	5,408	2,337	4,454
2040	604	618	3,604	3,605	2,337	4,454
2041	604	618	3,594	3,605	2,337	4,454
2042	604	618	3,594	3,605	2,337	4,454
2043	604	618	3,594	3,605	2,337	4,454
2044	604	618	3,604	3,605	2,337	4,454
2045	604	618	3,594	3,605	2,337	4,454
2046	604	618	3,594	3,605	2,337	4,454
2047	604	618	3,594	3,605	2,337	4,454
2048	604	618	3,604	3,605	2,337	4,454
2049	604	200	3,445	3,605	2,188	4,304
2050	604	0	3,373	0	2,116	4,233
2051	604	0	3,373	0	2,116	4,233
2052	604	0	3,373	0	2,116	4,233
2053	0	0	0	0	0	0
2054	0	0	0	0	0	0
2055	0	0	0	0	0	0



Energy Demand

	Error Up	Error Down
2019	0	0
2020	0	0
2021	0	0
2022	0	0
2023	0	0
2024	-1	1
2025	860	1,257
2026	860	1,257
2027	860	1,257
2028	850	1,266
2029	860	1,257
2030	860	1,257
2031	860	1,257
2032	850	1,266
2033	860	1,257
2034	860	1,257
2035	860	1,257
2036	850	1,266
2037	860	1,257
2038	860	1,257
2039	860	1,257
2040	850	1,266
2041	860	1,257
2042	860	1,257
2043	860	1,257
2044	850	1,266
2045	860	1,257
2046	860	1,257
2047	860	1,257
2048	850	1,266
2049	860	1,257
2050	860	1,257
2051	860	1,257
2052	860	1,257
2053	0	0
2054	0	0
2055	0	0

Puerto Rico's definition of renewable energy

Alternative Renewable Energy	Distributed Renewable Energy	Sustainable Renewable Energy
Landfill Gas	Community Solar	Solar energy
Anaerobic digestion		Wind energy
Fuel cells		Geothermal energy
		Renewable Biomass Combustion
		Renewable Biomass Gas Combustion
		Combustion of biofuel derived solely from renewable biomass
		Hydropower
		Marine and hydrokinetic renewable energy
		Ocean thermal energy

Source: Act 17-2019. 2019. Puerto Rico Integrated Resource Plan. Section 4.1 parts 13-15. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Puerto Rico Renewable Energy Standard (Act 17-2019)

Year	Minimum Renewables Requirement
2019-2025	20%
2025	40%
2040	60%
2050	100%

Puerto Rico Energy Efficiency Goal (Act 17-2019)

Year	Minimum Efficiency Requirement
2040	30%

Source: PS 1121. Approved April 11, 2019. *Puerto Rico Energy Public Policy Act.* No. 17-2019. *Section 1.6. Available at: https://aeepr.com/es-pr/QuienesSomos/Ley17/A-17-2019%20PS%201121%20Politica%20Publica%20Energetica.pdf. p. 23*

Exhibit 3-5. CHP Projects by Stages (as of May 2018)

Certified Electric Plans	Value
Total (MW)	11.66

Source: Puerto Rico Electric Power Authority. 2019. *Puerto Rico Integrated Resource Plan 2018-2019, Appendix 4: Demand Side Resources*. Siemens Industry. Report No. RPT-015-19. Exhibit 3-5.

Exhibit 6-24. LCOE for CHP and RICE Units

Capacity Factor
90%

Source: Puerto Rico Electric Power Authority. 2019. *Puerto Rico Integrated Resource Plan 2018-2019*. Siemens Industry. Report No. RPT-015-19. Exhibit 6-24. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Number of Hours in a Year (2019-2050)

2019	8760
2020	8784
2021	8760
2022	8760
2023	8760
2024	8784
2025	8760
2026	8760
2027	8760
2028	8784
2029	8760
2030	8760
2031	8760
2032	8784
2033	8760
2034	8760
2035	8760
2036	8784
2037	8760
2038	8760
2039	8760
2040	8784
2041	8760
2042	8760
2043	8760
2044	8784
2045	8760
2046	8760
2047	8760
2048	8784
2049	8760
2050	8760

Exhibit 6-32. Levelized Cost of Energy (LCOE) Assumptions

Capacity Factor (%)
22%

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019, Exhibit 6-32

Exhibit 6-21. LCOE for Large and Medium Combined Cycle Units: Range of CC Capacity Factors

Range	Capacity Factor (%)
Low End	40%
High End	80%

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019, Appendix 4: Demand Side Resources. Siemens Industry. Report No. RPT-015-19. Exhibit 6-21

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 1-3. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Exhibit 1-3: Summary of Results by Scenario, Strategy and Load Growth

	Central Metrics							
Case ID	NPV @ 9% 2019-2038 (k$)	Average 2019-2028 (2018$/MWh)	RPS 2038	NPV Deemed Energy Not Served (k$) 1	NPV + ENS (k$)	Lowest Reserve Margin (%)	Emissions Reductions (%)	Capital Investement Costs ($ Millions)
S1S2B	14,773,629	102.2	54%	214,355	14,941,402	38%	96%	5,840
S1S2H	16,134,592	101.4	68%	392,504	16,527,096	36%	94%	5,857
S1S2L	13,535,576	101.3	68%	263,997	13,799,572	37%	99%	4,684
S1S3B	14,687,535	101.8	54%	485,666	15,173,201	33%	97%	5,560
S1S2S1B	14,449,784	100.1	54%	214,355	14,617,557	38%	96%	5,293
S1S2S5B	15,378,227	106	54%	214,355	15,546,000	38%	96%	5,840
S1S2S6B	16,018,738	110.2	54%	214,355	16,186,511	38%	96%	7,898
S1S2S7B	15,696,705	106.8	68%	422,543	16,119,248	44%	96%	6,606
S1S1B	14,366,811	98.4	68%	1,150,508	15,517,319	35%	96%	5,546
S3S2B	13,843,500	96.4	87%	205,871	14,049,371	48%	97%	8,474
S3S2H	15,191,427	97.3	68%	475,629	15,667,056	36%	92%	8,716
S3S2L	13,242,760	99.6	68%	303,185	13,545,945	47%	96%	7,851
S3S3B	14,627,724	99.8	68%	202,994	14,830,718	30%	92%	8,396
S3S2S5B	14,811,928	102	87%	205,871	15,017,799	48%	97%	8,474
S3S2S8B	14,357,561	99.2	87%	205,871	14,563,432	48%	97%	9,467
S4S2B	14,350,195	99.3	68%	247,445	14,597,640	42%	86%	6,595
S4S2H	15,254,859	97	53%	391,816	16,087,374	60%	91%	5,585
S4S2L	12,865,937	96.5	77%	198,037	12,866,033	33%	89%	5,321
S4S2S9B	14,480,364	99.6	68%	267,841	14,748,205	51%	94%	6,265
S4S3B	14,416,274	99.9	54%	279,349	14,695,623	37%	82%	6,188
S4S2S1B	14,012,096	97.4	68%	247,445	14,259,541	42%	86%	5,961
S4S2S4B	14,466,325	100.9	65%	345,809	14,812,134	34%	84%	6,552
S4S2S5B	15,255,494	104.8	68%	247,445	15,502,939	42%	86%	6,595
S4S2S6B	15,565,108	106.7	68%	247,445	15,812,553	42%	86%	8,756
S4S1B	14,039,431	97.9	68%	1,108,890	15,148,321	47%	88%	6,674
S5S1B	14,122,690	98.4	67%	593,173	14,715,863	32%	87%	6,201
S5S1S5B	15,660,368	110	67%	593,173	16,253,541	32%	87%	6,201
S5S1S1B	13,813,169	96.4	67%	593,173	14,406,342	32%	87%	5,697
S5S1S6B	15,335,600	106.4	67%	593,173	15,928,773	32%	87%	8,165
ESM	14,431,214	99	67%	266,947	14,698,161	53%	88%	5,556
ESM High	15,695,558	99.2	53%	391,816	16,087,374	60%	91%	5,763
ESM Low	13,952,366	105	54%	202,453	14,154,819	58%	91%	4,779
ESMS1B	14,121,243	97.1	67%	266,947	14,121,340	53%	88%	5,556
ESMS6B	15,592,035	106.3	67%	266,947	15,592,141	53%	88%	5,556
ESMS5B	15,612,073	106.9	67%	266,947	15,612,180	53%	88%	5,556

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 3-11. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Exhibit 3-11. Gross Energy Demand for Generation

Fiscal Year	Gross Energy Sales (GWh)	Technical Losses (GWh)	Non-Technical Losses (GWh)	Auxiliary (GWh)	PREPA Own Use (GWh)	Total Energy Demand (GWh)
2019	15,301	1,438	827	751	34	18,351
2020	15,357	1,444	830	751	34	18,415
2021	15,403	1,448	832	751	34	18,469
2022	15,470	1,454	836	751	34	18,545
2023	15,530	1,460	839	751	34	18,613
2024	15,574	1,464	841	751	34	18,665
2025	15,595	1,466	842	751	34	18,689
2026	15,596	1,466	843	751	34	18,690
2027	15,554	1,462	840	751	34	18,642
2028	15,487	1,456	837	751	34	18,565
2029	15,341	1,442	829	751	34	18,397
2030	15,223	1,431	822	751	34	18,261
2031	15,120	1,421	817	751	34	18,144
2032	15,025	1,412	812	751	34	18,034
2033	14,939	1,404	807	751	34	17,935
2034	14,862	1,397	803	751	34	17,848
2035	14,796	1,391	799	751	34	17,772
2036	14,741	1,386	796	751	34	17,708
2037	14,694	1,381	794	751	34	17,654
2038	14,654	1,377	792	751	34	17,608
CAGR	**-0.23%**	**-0.23%**	**-0.23%**	**0.00%**	**0.00%**	**-0.22%**

	Losses				
	9.4%	5.4%	4.9%	0.2%	19.9%
	9.4%	5.4%	4.9%	0.2%	19.9%
	9.4%	5.4%	4.9%	0.2%	19.9%
	9.4%	5.4%	4.9%	0.2%	19.9%
	9.4%	5.4%	4.8%	0.2%	19.9%
	9.4%	5.4%	4.8%	0.2%	19.8%
	9.4%	5.4%	4.8%	0.2%	19.8%
	9.4%	5.4%	4.8%	0.2%	19.8%
	9.4%	5.4%	4.8%	0.2%	19.8%
	9.4%	5.4%	4.8%	0.2%	19.9%
	9.4%	5.4%	4.9%	0.2%	19.9%
	9.4%	5.4%	4.9%	0.2%	20.0%
	9.4%	5.4%	5.0%	0.2%	20.0%
	9.4%	5.4%	5.0%	0.2%	20.0%
	9.4%	5.4%	5.0%	0.2%	20.1%
	9.4%	5.4%	5.1%	0.2%	20.1%
	9.4%	5.4%	5.1%	0.2%	20.1%
	9.4%	5.4%	5.1%	0.2%	20.1%
	9.4%	5.4%	5.1%	0.2%	20.1%
4%	9.4%	5.4%	5.1%	0.2%	20.2%

Source Workpaper: Load Forecast by Region PREPA 2018 IRP Base Case Revised 35 pct EE 050319.xlsm

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 3-16. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Exhibit 3-16. Energy Demand for Generation after EE

Fiscal Year	Gross Energy Sales (GWh)	Technical Losses (GWh)	Non-Technical Losses (GWh)	Auxiliary (GWh)	PREPA Own Use (Gwh)	Total Energy Demand (Gwh)
2019	15,301	1,412	827	751	34	18,324
2020	14,874	1,367	803	751	34	17,829
2021	14,617	1,338	790	751	34	17,529
2022	14,379	1,310	777	751	34	17,251
2023	14,133	1,283	763	751	34	16,964
2024	13,872	1,253	749	751	34	16,659
2025	13,628	1,225	736	751	34	16,375
2026	13,364	1,195	722	751	34	16,066
2027	13,057	1,160	705	751	34	15,708
2028	12,725	1,123	687	751	34	15,320
2029	12,311	1,078	665	751	34	14,839
2030	11,926	1,035	644	751	34	14,390
2031	11,556	993	624	751	34	13,958
2032	11,193	951	605	751	34	13,533
2033	10,838	910	585	751	34	13,118
2034	10,492	869	567	751	34	12,713
2035	10,207	834	551	751	34	12,377
2036	9,932	799	537	751	34	12,052
2037	9,665	765	522	751	34	11,737
2038	9,405	731	508	751	34	11,429
CAGR	**-2.53%**	**-3.41%**	**-2.53%**	**0.00%**	**0.00%**	**-2.45%**

Source Workpaper: Load Forecast by Region PREPA 2018 IRP Base Case Revised 35 pct EE 050319.xlsm

Losses

9.2%	5.4%	4.9%	0.2%	19.8%
9.2%	5.4%	5.0%	0.2%	19.9%
9.2%	5.4%	5.1%	0.2%	19.9%
9.1%	5.4%	5.2%	0.2%	20.0%
9.1%	5.4%	5.3%	0.2%	20.0%
9.0%	5.4%	5.4%	0.2%	20.1%
9.0%	5.4%	5.5%	0.2%	20.1%
8.9%	5.4%	5.6%	0.3%	20.2%
8.9%	5.4%	5.8%	0.3%	20.3%
8.8%	5.4%	5.9%	0.3%	20.4%
8.8%	5.4%	6.1%	0.3%	20.5%
8.7%	5.4%	6.3%	0.3%	20.7%
8.6%	5.4%	6.5%	0.3%	20.8%
8.5%	5.4%	6.7%	0.3%	20.9%
8.4%	5.4%	6.9%	0.3%	21.0%
8.3%	5.4%	7.2%	0.3%	21.2%
8.2%	5.4%	7.4%	0.3%	21.3%
8.0%	5.4%	7.6%	0.3%	21.4%
7.9%	5.4%	7.8%	0.4%	21.4%
7.8%	5.4%	8.0%	0.4%	21.5%

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 3-18. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Exhibit 3-18. Impact of Customer Owned Generation on the Energy Demand for Generation after EE

Fiscal Year	Total Energy Demand (GWh)	New Customer Owned Distributed Generation (GWh)	New CHP (GWh)	Total Energy Demand after DG & CHP (GWh)
2019	18,324	62	66	18,196
2020	17,829	183	236	17,410
2021	17,529	249	404	16,876
2022	17,251	300	922	16,028
2023	16,964	350	922	15,692
2024	16,659	404	922	15,333
2025	16,375	456	922	14,996
2026	16,066	514	922	14,630
2027	15,708	575	922	14,211
2028	15,320	642	922	13,755
2029	14,839	708	922	13,209
2030	14,390	781	922	12,687
2031	13,958	857	922	12,179
2032	13,533	941	922	11,670
2033	13,118	1,022	922	11,174
2034	12,713	1,109	922	10,682
2035	12,377	1,200	922	10,255
2036	12,052	1,298	922	9,831
2037	11,737	1,392	922	9,422
2038	11,429	1,494	922	9,012
CAGR	**-2.45%**	**18.25%**	**14.86%**	**-3.63%**

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 3-32. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Exhibit 3-32. Gross Sales Forecast Scenarios - High and Low Cases

Fiscal Year	Gross Energy Sales (GWh)				
	Reference	Very Optimistic	Very Pessimistic	High Case	Low Case
2019	15,301	16,043	14,703	15,670	14,844
2020	15,357	17,400	14,470	16,001	14,811
2021	15,403	17,869	14,257	16,166	14,636
2022	15,470	17,976	14,015	16,358	14,596
2023	15,530	18,102	13,776	16,730	14,588
2024	15,574	18,239	13,545	16,642	14,514
2025	15,595	18,385	13,325	16,755	14,352
2026	15,596	18,540	13,112	17,024	14,292
2027	15,554	18,699	12,901	17,136	14,148
2028	15,487	18,863	12,695	17,114	13,989
2029	15,341	19,030	12,498	16,998	13,831
2030	15,223	19,200	12,304	16,939	13,740
2031	15,120	19,372	12,118	16,932	13,664
2032	15,025	19,547	11,939	17,078	13,690
2033	14,939	19,725	11,765	17,235	13,702
2034	14,862	19,906	11,597	16,923	13,582
2035	14,796	20,091	11,439	17,113	13,435
2036	14,741	20,280	11,295	16,976	13,476
2037	14,694	20,474	11,160	17,270	13,390
2038	14,654	20,672	11,033	16,719	13,323
CAGR	**-0.23%**	**1.34%**	**-1.50%**	**0.34%**	**-0.57%**

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 3-33. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Exhibit 3-33. Sales Forecast Scenarios after EE - High and Low Cases

Fiscal Year	Gross Energy Sales (GWh)				
	Reference	Very Optimistic	Very Pessimistic	High Case	Low Case
2019	15,301	16,043	14,703	15,669	14,845
2020	14,874	16,852	14,015	15,496	14,346
2021	14,617	16,956	13,529	15,339	13,890
2022	14,379	16,708	13,026	15,202	13,568
2023	14,133	16,474	12,537	15,223	13,278
2024	13,872	16,245	12,064	14,821	12,929
2025	13,628	16,066	11,645	14,640	12,544
2026	13,364	15,887	11,236	14,585	12,249
2027	13,057	15,697	10,830	14,382	11,879
2028	12,725	15,497	10,431	14,058	11,496
2029	12,311	15,271	10,030	13,638	11,103
2030	11,926	15,041	9,640	13,268	10,767
2031	11,556	14,805	9,262	12,938	10,446
2032	11,193	14,560	8,894	12,719	10,201
2033	10,838	14,309	8,536	12,500	9,942
2034	10,492	14,052	8,188	11,944	9,590
2035	10,207	13,858	7,892	11,801	9,270
2036	9,932	13,662	7,611	11,434	9,082
2037	9,665	13,465	7,341	11,355	8,810
2038	9,405	13,267	7,082	10,728	8,554
CAGR	**-2.53%**	**-1.00%**	**-3.77%**	**-1.97%**	**-2.86%**

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 3-34. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Exhibit 3-34. Sales Forecast Scenarios after EE and Customer Generation - High and Low Cases

Fiscal Year	Gross Energy Sales (GWh)				
	Reference	Very Optimistic	Very Pessimistic	High Case	Low Case
2019	15,173	15,915	14,575	15,541	14,717
2020	14,455	16,433	13,596	15,077	13,927
2021	13,963	16,303	12,876	14,686	13,237
2022	13,156	15,485	11,804	13,980	12,345
2023	12,861	15,201	11,265	13,951	12,005
2024	12,546	14,919	10,738	13,495	11,603
2025	12,250	14,687	10,266	13,261	11,165
2026	11,928	14,451	9,800	13,149	10,813
2027	11,560	14,199	9,333	12,885	10,382
2028	11,160	13,933	8,866	12,494	9,931
2029	10,681	13,641	8,400	12,008	9,472
2030	10,223	13,338	7,937	11,565	9,064
2031	9,776	13,025	7,482	11,158	8,666
2032	9,329	12,697	7,031	10,855	8,337
2033	8,894	12,365	6,592	10,556	7,999
2034	8,461	12,020	6,156	9,912	7,559
2035	8,085	11,736	5,770	9,679	7,148
2036	7,711	11,441	5,390	9,213	6,861
2037	7,350	11,151	5,027	9,041	6,495
2038	6,989	10,850	4,665	8,311	6,137
CAGR	**-4.00%**	**-2.00%**	**-5.82%**	**-3.24%**	**-4.50%**

Sales Forecast Scenarios after EE, DG, and Losses - High and Low Cases

	Reference	Very Optimistic	Very Pessimistic	High Case	Low Case
2019	18,172	19,060	17,456	18,612	17,626
2020	17,327	19,698	16,297	18,072	16,694
2021	16,746	19,552	15,442	17,613	15,875
2022	15,784	18,578	14,162	16,772	14,811
2023	15,437	18,246	13,522	16,746	14,410
2024	15,067	17,916	12,895	16,206	13,934
2025	14,718	17,646	12,335	15,933	13,415
2026	14,340	17,373	11,781	15,808	12,999
2027	13,906	17,081	11,227	15,500	12,489
2028	13,436	16,774	10,674	15,042	11,956
2029	12,874	16,442	10,125	14,474	11,417
2030	12,335	16,094	9,577	13,954	10,937
2031	11,808	15,732	9,037	13,477	10,467
2032	11,280	15,353	8,502	13,125	10,081
2033	10,765	14,966	7,979	12,777	9,682
2034	10,252	14,564	7,459	12,010	9,159
2035	9,804	14,231	6,997	11,737	8,668
2036	9,358	13,884	6,541	11,180	8,326
2037	8,926	13,542	6,105	10,979	7,887
2038	8,493	13,185	5,669	10,100	7,458

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 4-1. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Plant Name	Estimated Generation 2013	Estimated Generation 2014	Estimated Generation 2015	Estimated Generation 2016	Estimated Generation 2017	Estimated Generation 2018		
Aguirre Steam 1&2	3,863,160	3,468,960	3,626,640	2,290,014	2,601,720	2,917,080		40%
Aguirre CCGT 1&2	266,742	640,181	640,181	641,204	480,136	213,394		9%
Aguirre GT	0	0	11,826	3,948	3,942	0	GT	1%
San Juan Steam 7, 8, 9 & 10	1,436,640	1,611,840	1,506,720	1,263,456	805,920	560,640		34%
San Juan CCGT 5 & 6	1,852,740	1,029,300	1,523,364	2,433,030	2,346,804	2,470,320		47%
Costa Sur Steam 3 & 4	14,454	0	86,724	28,954	0	0		2%
Costa Sur Steam 5 & 6	3,735,264	4,381,752	4,740,912	4,532,648	3,088,776	3,304,272	NG	55%
Costa Sur GT	3,942	3,942	15,768	7,897	3,942	0	GT	2%
Culebra	175	0	0	0	701	9,286		10%
Daguao	0	3,942	11,826	7,897	43,362	55,188		5%
Jobos	0	3,942	11,826	3,948	11,826	0		1%
Mayaguez Plant 1,2 ,3 & 4	134,904	173,448	115,632	57,908	134,904	115,632		6%
Palo Seco Steam 1,2, 3 & 4	2,091,888	1,098,241	1,045,944	1,466,662	470,675	941,350		23%
Palo Seco GT	11,738	82,169	93,907	82,300	187,814	129,122	GT	8%
Vega Baja	0	3,942	0	3,948	11,826	3,942		1%
Vieques	0	0	0	0	0	22,075		6%
Yabucoa	0	0	23,652	19,742	15,768	15,768		3%
Cambalache GT 1, 2 & 3	65,174	108,624	173,798	108,798	195,523	86,899	GT	6%
Toro Negro 1	10,249	1,577	788	3,948	3,942	2,365		5%
Toro Negro 2	1,577	1,051	1,226	0	526	0		4%
Garzas 1	613	0	0	0	0	1,226		1%
Garzas 2	438	0	0	0	0	0		0%
Yauco 1	19,272	14,016	0	0	0	0		3%
Yauco 2	9,110	6,307	6,307	7,019	6,307	6,307		10%
Dos Bocas	42,574	34,690	29,959	47,380	36,266	33,113		24%
Caonillas 1	9,461	23,652	22,075	20,531	9,461	0		9%
Río Blanco	4	0	4	0	0	0		0%
EcoEléctrica	3,553,056	3,686,296	2,931,271	3,336,314	2,753,618	3,020,098	NG	72%
AES	3,420,254	3,658,877	3,261,173	3,465,555	2,306,683	2,505,535		78%
Windmar Renewable	3,679	4,555	4,906	4,387	3,854	4,205		24%
San Fermín Solar	0	1,752	31,536	35,096	26,280	8,760		12%
Horizon Energy Inc.	0	0	14,892	23,690	18,396	5,256		18%
AES Ilumina	36,792	40,296	40,296	38,606	29,784	24,528		20%
Oriana Energy Solar	0	0	0	11,845	67,014	19,710		8%
Humacao Solar (Fonroche)	0	0	0	0	5,256	5,256		2%
Windamr Solar (Cotto Laurel)	0	0	0	877	5,256	10,512		6%
Punta Lima Wind	56,940	54,662	59,218	50,187	38,719	0		19%
Pattern Energy	118,260	164,250	177,390	144,771	111,690	105,120		21%
Landfill Gas Technologies	0	0	350	7,019	6,307	2,453		12%
Landfill Gas Technologies	0	0	0	0	4,030	6,833		31%

Exhibit 4-1. Summary of Existing Plant Characteristics and performance

Plant Name	2018 Data						Capacity Factor						Nameplate Capacity (MW)	Resource Type	Fuel Type	Ownership	Location	Commercial Operation Date
	Available Capacity (MW)	Net Generation (MWh)	Average Rate Heat (Btu/ kWh)	Fuel Cost $Mmbtu	$/O&M per kWh	Total $O&M plus fuel	2013	2014	2015	2016	2017	2018						
Aguirre Steam 1&2	900	2,945,857	10,693	12.52	0.01	0.14	49%	44%	46%	29%	33%	37%	900	Oil	Fuel#6	PREPA	Salinas	1975
Aguirre CCGT 1&2	592	218,653	13,882	17.1	0.04	0.27	5%	12%	12%	12%	9%	4%	609	Oil	Fuel#2	PREPA	Salinas	1977
Aguirre GT	42	1,642	13,688	11.73	0.2	0.4	0%	0%	3%	1%	1%	0%	45	Oil	Fuel#2	PREPA	Salinas	1972
San Juan Steam 7, 8, 9 & 10	400	557,340	8,957	11.41	0.01	0.14	41%	46%	43%	36%	23%	16%	400	Oil	Fuel#6	PREPA	San Juan	1965to1969
San Juan CCGT 5 & 6	440	2,323,272	13,688	16.73	0.01	0.14	45%	25%	37%	59%	57%	60%	470	Oil	Fuel#2	PREPA	SanJuan	2008
Costa Sur Steam 3 & 4	170	0	11,898	10.12	0	0	1%	0%	6%	2%	0%	0%	165	Oil	Fuel#6	PREPA	Guayanilla	1962&1963
Costa Sur Steam 5 & 6	782	3,145,699	11,898	9.01	0.01	0.11	52%	61%	66%	63%	43%	46%	820	Oil	NG&Fuel#6	PREPA	Guayanilla	1972&1973
Costa Sur GT	42	0	13,688	0	0	0	1%	1%	4%	2%	1%	0%	45	Oil	Fuel#2	PREPA	Guayanilla	1972
Culebra	2	9,344	0	0	0	0	1%	0%	0%	0%	4%	53%	2	Diesel	Diesel	PREPA	Culebra	1972
Daguao	42	50,938	13,688	16.19	0.31	0.61	0%	1%	3%	2%	11%	14%	45	Oil	Fuel#2	PREPA	Ceiba	1972
Jobos	42	703	13,688	12.2	0.09	0.19	0%	1%	3%	1%	3%	0%	45	Oil	Fuel#2	PREPA	Guayama	1973
Mayaguez Plant 1,2 ,3 & 4	220	124,872	13,688	17.2	0.18	0.37	7%	9%	6%	3%	7%	6%	220	Oil	Fuel#2	PREPA	Mayagüez	2009
Palo Seco Steam 1,2, 3 & 4	602	932,865	11,174	11.74	0.02	0.15	40%	21%	20%	28%	9%	18%	597	Oil	Fuel#6	PREPA	Toa Baja	1960,1961&1970
Palo Seco GT	126	121,137	13,688	16.03	0.24	0.48	1%	7%	8%	7%	16%	11%	134	Oil	Fuel#2	PREPA	Toa Baja	1972&1973
Vega Baja	42	5,013	13,688	15.78	0.23	0.47	0%	1%	0%	1%	3%	1%	45	Oil	Fuel#2	PREPA	Vega Baja	1971
Vieques	7	20,774	0	22.73	0	0	0%	0%	0%	0%	0%	36%	7	Diesel	Diesel	PREPA	Vieques	2004
Yabucoa	42	16,020	13,688	14.94	0.29	0.59	0%	0%	6%	5%	4%	4%	45	Oil	Fuel#2	PREPA	Yabucoa	1971
Cambalache GT 1, 2 & 3	248	81,788	13,143	16.4	0.05	0.27	3%	5%	8%	5%	9%	4%	248	Oil	Fuel#3	PREPA	Arecibo	1977
Toro Negro 1	9	1,899	-	-	-	-	13%	2%	1%	5%	5%	3%	9	Hydroelectric	Water	PREPA	Villalba	1937
Toro Negro 2	2	0	-	-	-	-	9%	6%	7%	0%	3%	0%	2	Hydroelectric	Water	PREPA	Orocovis	1937
Garzas 1	7	1,501	-	-	-	-	1%	0%	0%	0%	0%	2%	7	Hydroelectric	Water	PREPA	Peñuelas	1941
Garzas 2	5	0	-	-	-	-	1%	0%	0%	0%	0%	0%	5	Hydroelectric	Water	PREPA	Peñuelas	1941
Yauco 1	25	0	-	-	-	-	11%	8%	0%	0%	0%	0%	20	Hydroelectric	Water	PREPA	Yauco	1956
Yauco 2	9	7,235	-	-	-	-	13%	9%	9%	10%	9%	9%	8	Hydroelectric	Water	PREPA	Yauco	1954
Dos Bocas	15	27,203	-	-	-	-	27%	22%	19%	30%	23%	21%	18	Hydroelectric	Water	PREPA	Utuado	1942-1945
Caonillas 1	18	0	-	-	-	-	6%	15%	14%	13%	6%	0%	18	Hydroelectric	Water	PREPA	Arecibo	1952
Río Blanco	5	0					0%	-	0%	-	-	-	5	Hydroelectric	Water	PREPA	Naguabo	1930
EcoEléctrica	507	2,999,834	-	-	-	-	80%	83%	66%	75%	62%	68%	507	Natural Gas	Natural Gas	Purchase	Peñuelas	1999
AES	454	2,505,636	-	-	-	-	86%	92%	82%	87%	58%	63%	454	Coal	Coal	Purchase	Guayama	2002
Windmar Renewable	2	4,424	-	-	-	-	21%	26%	28%	25%	22%	24%	2	Photovoltaic	Sun	Purchase	Ponce	9/1/2011
San Fermín Solar	21	10,063	-	-	-	-	-	1%	18%	20%	15%	5%	20	Photovoltaic	Sun	Purchase	Loíza	12/1/2015
Horizon Energy Inc.	10	5,295	-	-	-	-	-	-	17%	27%	21%	6%	10	Photovoltaic	Sun	Purchase	Salinas	11/1/2016
AES Ilumina	20	23,923	-	-	-	-	21%	23%	23%	22%	17%	14%	20	Photovoltaic	Sun	Purchase	Guayama	11/1/2012
Oriana Energy Solar	45	21,018	-	-	-	-	-	-	-	3%	17%	5%	45	Photovoltaic	Sun	Purchase	Isabela	9/1/2016
Humacao Solar (Fonroche)	20	5,703	-	-	-	-	-	-	-	0%	3%	3%	20	Photovoltaic	Sun	Purchase	Humacao	12/1/2016
Windamr Solar (Cotto Laurel)	10	10,417	-	-	-	-	-	-	-	1%	6%	12%	10	Photovoltaic	Sun	Purchase	Ponce	11/1/2016
Punta Lima Wind	26	0	-	-	-	-	25%	24%	26%	22%	17%	0%	26	Wind	Wind	Purchase	Naguabo	12/1/2012
Pattern Energy	75	108,072	-	-	-	-	18%	25%	27%	22%	17%	16%	75	Wind	Wind	Purchase	Santa Isabel	12/1/2012
Landfill Gas Technologies	4	2,401	-	-	-	-	-	-	1%	20%	18%	7%	4	Landfill Gas	Methane Gas	Purchase	Fajardo	10/1/2016
Landfill Gas Technologies	2	8,171	-	-	-	-	-	-	-	-	23%	39%	2	Landfill Gas	Methane Gas	Purchase	Toa Baja	10/1/2016
		16,298,716																

Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019. Siemens Industry. Report No. RPT-015-19. Exhibit 8-1. Available at: http://energia.pr.gov/wp-content/uploads/2019/02/PREPA-Ex.-1.0-IRP-2019-PREPA-IRP-Report.pdf

Exhibit 8-1: Summary of Investment Decisions by Scenario, Strategy and Load Growth

Case ID	F-Class Palo Seco 2025	F-Class Costa Sur 2025	San Juan 5&6 Conversion	F-Class Yabucoa 2025	Mayaguez Peaker Conversion	Other	Peakers 2025 (MW)	New Solar 2025 (MW)	BESS 2025 (MW)	New Solar 2038 (MW)	BESS 2038 (MW)	Customer Owned Gen 2038 (MW)
S1S2B	-	EcoElectrica Instead	Yes	-	-	-	504	2,580	1,280	2,700	1,720	1,176
S1S2H	-	EcoElectrica Instead	Yes	-	-	Costa Sur 5 to 2034	325	2,820	1,360	3,180	1,840	1,176
S1S2L	-	EcoElectrica Instead	Yes	-	-	-	325	2,340	1,240	2,340	1,800	1,176
S1S3B	-	EcoElectrica Instead	Yes	-	-	-	513	2,580	1,280	2,580	1,840	1,176
S1S2S1B	-	EcoElectrica Instead	Yes	-	-	-	504	2,580	1,280	2,700	1,720	1,176
S1S2S5B	-	EcoElectrica Instead	Yes	-	-	-	504	2,580	1,280	2,700	1,720	1,176
S1S2S6B	-	EcoElectrica Instead	Yes	-	-	-	504	2,580	1,280	2,700	1,720	1,176
S1S2S7B	-	EcoElectrica Instead	-	-	-	Costa Sur 5 to 2034	507	2,880	1,280	3,240	1,760	1,176
S1S1B	-	EcoElectrica Instead	Yes	-	-	Costa Sur 5&6 to 2037 & 2031	302	2,520	1,240	2,520	2,080	1,176
S3S2B	-	Yes	Yes	-	-	-	348	2,820	1,320	4,140	3,000	1,176
S3S2H	-	Yes	Yes	-	-	-	364	3,300	1,680	4,560	2,600	1,176
S3S2L	-	-	Yes	-	-	-	389	3,000	1,600	4,080	2,520	1,176
S3S3B	-	Yes	Yes	-	-	-	371	2,820	1,280	4,140	2,280	1,176
S3S2S5B	-	Yes	Yes	-	-	-	348	2,820	1,280	4,140	2,280	1,176
S3S2S8B	-	Yes	Yes	-	-	-	348	2,820	1,280	4,140	2,280	1,176
S4S2B	Yes	Yes	Yes	-	-	-	371	2,220	1,320	2,820	1,640	1,176
S4S2H	Yes	Yes	Yes	-	-	-	394	2,460	940	2,520	980	1,176
S4S2L	-	Yes	Yes	-	-	-	434	2,100	960	2,520	1,020	1,176
S4S2S9B	Yes	EcoElectrica Instead	Yes	-	-	-	3,488	2,220	1,320	2,820	1,640	1,176
S4S3B	2027	Yes	Yes	-	-	-	394	2,580	1,320	2,820	1,320	1,176
S4S2S1B	Yes	Yes	Yes	-	-	-	371	2,220	1,320	2,820	1,640	1,176
S4S2S4B	-	Yes	Yes	-	-	-	371	2,580	1,320	3,060	1,640	1,176
S4S2S5B	Yes	Yes	Yes	-	-	-	371	2,220	1,320	2,820	1,640	1,176
S4S2S6B	Yes	Yes	Yes	-	-	-	371	2,220	1,320	2,820	1,640	1,176
S4S1B	-	-	Yes	2028	-	F-Class at Mayaguez 2025	348	2,700	1,240	2,700	1,640	1,176
S5S1B	-	369 MW (2025&2028)	Yes	-	-	-	371	2,580	1,200	2,580	1,480	1,176

Case ID	F-Class Palo Seco 2025	F-Class Costa Sur 2025	San Juan 5&6 Conversion	F-Class Yabucoa 2025	Mayaguez Peaker Conversion	Other	Peakers 2025 (MW)	New Solar 2025 (MW)	BESS 2025 (MW)	New Solar 2038 (MW)	BESS 2038 (MW)	Customer Owned Gen 2038 (MW)
S5S1S5B	-	369 MW (2025&2028)	Yes	-	-	-	371	2,580	1,200	2,580	1,480	1,176
S5S1S1B	-	369 MW (2025&2028)	Yes	-	-	-	371	2,580	1,200	2,580	1,480	1,176
S5S1S6B	-	369 MW (2025&2028)	Yes	-	-	-	371	2,580	1,200	2,580	1,480	1,176
ESM	Yes	EcoElectrica Instead	Yes	Yes	Yes	-	421	2,400	920	2,580	1,640	1,176
ESM High	Yes	EcoElectrica Instead	Yes	Yes	Yes	-	421	2,340	1,040	2,460	1,040	1,176
ESM Low	Yes	EcoElectrica Instead	Yes	Yes	Yes	-	421	1,920	1,040	1,980	1,040	1,176
ESMS1B	Yes	EcoElectrica Instead	Yes	Yes	Yes	-	421	2,400	920	2,580	1,640	1,176
ESMS6B	Yes	EcoElectrica Instead	Yes	Yes	Yes	-	421	2,400	920	2,580	1,640	1,176
ESMS5B	Yes	EcoElectrica Instead	Yes	Yes	Yes	-	421	2,400	920	2,580	1,640	1,176

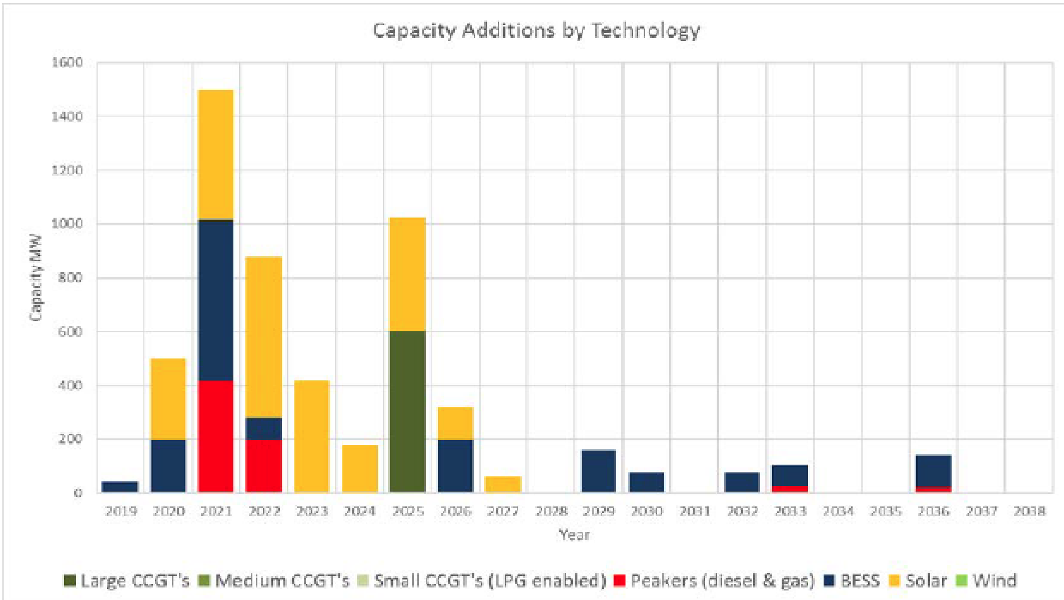
Source: Puerto Rico Electric Power Authority. 2019. Puerto Rico Integrated Resource Plan 2018-2019, Appendix 4: Demand Side Resources. Siemens Industry. Report No. RPT-015-19. Exhibit 8-44.

MW	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Solar	0	300	480	600	420	180	420	120	60	0
Large CCGT	0	0	0	0	0	0	604	0	0	0
Peakers	0	0	418	200	0	0	0	0	0	0

Exhibit 8-44. ESM Plan Capacity Additions

MW	Solar		Large CCGT		Peakers	
	annual	cumulative	annual	cumulative	annual	cumulative
2019	0	0	0	0	0	0
2020	300	300	0	0	0	0
2021	480	780	0	0	418	418
2022	600	1380	0	0	200	618
2023	420	1800	0	0	0	618
2024	180	1980	0	0	0	618
2025	420	2400	604	604	0	618
2026	120	2520	0	604	0	618
2027	60	2580	0	604	0	618
2028	0	2580	0	604	0	618
2029	0	2580	0	604	0	618
2030	0	2580	0	604	0	618
2031	0	2580	0	604	0	618
2032	0	2580	0	604	0	618
2033	0	2580	0	604	0	618
2034	0	2580	0	604	0	618
2035	0	2580	0	604	0	618
2036	0	2580	0	604	0	618
2037	0	2580	0	604	0	618
2038	0	2580	0	604	0	618
2039	0	2580	0	604	0	618
2040	0	2580	0	604	0	618
2041	0	2580	0	604	0	618
2042	0	2580	0	604	0	618
2043	0	2580	0	604	0	618
2044	0	2580	0	604	0	618
2045	0	2580	0	604	0	618
2046	0	2580	0	604	0	618
2047	0	2580	0	604	0	618
2048	0	2580	0	604	0	618
2049	0	2580	0	604	-418	200
2050	0	2580	0	604	-200	0
2051	0	2580	0	604	0	0
2052	0	2580	0	604	0	0
2053	0	2580	-604	0	0	0
2054	0	2580	0	0	0	0

Exhibit 8-44: ESM Plan Capacity Additions



Capacity by Technology MW	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Large CCGT's	0	0	0	0	0	0	604	0	0	0
Medium CCGT's	0	0	0	0	0	0	0	0	0	0
Small CCGT's (LPG enabled)	0	0	0	0	0	0	0	0	0	0
Peakers (diesel & gas)	0	0	418	200	0	0	0	0	0	0
BESS	40	200	600	80	0	0	0	200	0	0
Wind	0	0	0	0	0	0	0	0	0	0
Total Distchable Additions	40	200	1018	280	0	0	604	200	0	0
Solar	0	300	480	600	420	180	420	120	60	0
Total Additions	40	500	1,498	880	420	180	1,024	320	60	0

Capacity b	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Large CCG	0	0	0	0	0	0	604	0	0	0
Medium C	0	0	0	0	0	0	0	0	0	0
Small CCG	0	0	0	0	0	0	0	0	0	0
Peakers (d	0	0	418	200	0	0	0	0	0	0
BESS	40	200	600	80	0	0	0	200	0	0
Wind	0	0	0	0	0	0	0	0	0	0
Total Dispa	40	200	1,018	280	0	0	604	200	0	0
Solar	0	300	480	600	420	180	420	120	60	0
Total Additio	**40**	**500**	**1,498**	**880**	**420**	**180**	**1,024**	**320**	**60**	**0**