Toward Electric System Sustainability in Puerto Rico

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Tomás J. Torres, Executive Director,
The Puerto Rico Institute of Competitiveness and Sustainable Economy (tjtorres@amscm.com) &

Cathy Kunkel, Energy Analyst, IEEFA
(ckunkel@ieefa.org)

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By Tomás J. Torres, Executive Director,
The Puerto Rico Institute of Competitiveness and Sustainable Economy
and Cathy Kunkel, Energy Analyst,
Institute for Energy Economics and Financial Analysis

Abstract

This paper presents a detailed conceptualization of energy transformation for Puerto Rico—one that prioritizes the growth of renewables and distributed energy, complemented by highly-efficient generation. Such a mix results is a balanced portfolio that achieves 40% of the island's generation based on indigenous renewable energy by 2028 and puts the island on a path toward 100% reliance on renewables by 2050. Our research emphasizes the importance of having strong regulatory guidance from the Puerto Rico Energy Commission as the island strives to overcome devastation by Hurricanes Irma and Maria and its history of poor utility system governance. This analysis also considers the role of the Congressionally-appointed Financial Oversight and Management Board in overseeing operational focus and debt relief while, in coordination with the Energy Commission, restoring customer confidence in the electricity system and restoring market confidence in the island as a desirable place to invest.

Both the Institute for Competitiveness and Sustainable Economy (ICSE-PR) and the Institute for Energy Economics and Financial Analysis (IEEFA) have conducted extensive analyses of the Puerto Rico electricity system over the past several years[1] and have been actively involved in proceedings before the Puerto Rico Energy Commission. This paper draws on those previous analyses and includes new projections for the future generation mix.

Introduction: Importance of an Independent Regulator

Hurricane Maria's devastation of Puerto Rico in September 2017 reinforced a general understanding that the Puerto Rico Electric Power Authority (PREPA) cannot stand on its own. Unnecessary delays, lack of coordination with national utilities and dubious contracts resulted in intermittent service restoration to just 50% of customers three months after the hurricane. PREPA needs fundamental reform alongside strong supervision from the Puerto Rico Energy Commission (PREC) and the Fiscal Oversight and Management Board (FOMB). The purpose of this document is to propose basic strategies that can transform the current electrical system into one that is strongly regulated in line with U.S. mainland standards and that is resilient, environmentally compliant, competitive and compatible with robust development of distributed energy resources, and built around diverse sources of energy and prominently indigenous renewables.

[1] See, for example, Report: Opportunity for a New Direction for Puerto Rico's Electric System, IEEFA, September, 2015 (Versión en Español); Electricity in Puerto Rico Key to Economic Crisis, ICSE, Public Utilities Fortnightly, May 2017.

Puerto Rico has an opportunity now to design a resilient system based on a diverse and competitive energy portfolio with much greater use of renewables than is currently the case. It is clear that the present generation system is unsustainable. PREPA pays over $1 billion a year for fossil-fuels, non-indigenous energy sources that include oil, coal and gas.[2] Current policy supports off-island fuel providers and outdated power stations (many of which are out of compliance with federal air quality regulations). In fiscal year 2017, 48%[3] of Puerto Rico's electricity was generated from oil, and an additional 50% from coal and gas.

The island's grid is poorly configured, with approximately 65% of electricity generation facilities located in southern Puerto Rico while the majority of consumption is in the north. This reliance on long-distance south-to-north transmission has been a major barrier to PREPA's ability to restore power after Hurricane Maria.

PREPA has also suffered from highly-politicized management and, in recent years, the retirement of a large number of skilled workers as a result of the Puerto Rican government's fiscal crisis. While PREPA workers are in favor of having the utility become 100% reliant on renewables[4], management has consistently prioritized politically-driven investments and contracts. A long-term practice of putting unqualified political appointees into high-level positions that require technical and professional competence has not served PREPA or the people of Puerto Rico.

Puerto Rico needs a strong energy regulator to implement a new vision for an electrical system built around resiliency, indigenous renewable energy and competition. In fiscal year 2017, PREPA generated less than 2% of its electricity from renewable energy, putting it out of compliance with the legal mandate of 12% by 2015. In 2015, PREPA filed its first-ever Integrated Resource Plan with the PREC, proposing continued heavy reliance on centralized fossil fuel generation. That plan would have had PREPA get only 15% of its electricity from renewables and 322 MW[5] from distributed energy by 2035. It included the construction of a second liquid natural gas (LNG) import terminal on the south of the island (a floating storage and regasification unit instead of a land-based one) and the retrofit and gas-conversion of the majority of units at the existing Aguirre site. Questioning many of the plan's underlying assumptions, the PREC rejected it and approved one that called for greater reliance on energy efficiency and renewable energy. It also required further economic analysis before continuing the proposed LNG terminal at Aguirre.

Until recently, PREPA has had no independent regulator. Legislation in 2014 and 2016 expanded regulatory oversight to two entities: the Puerto Rico Energy Commission (PREC) and the Financial Oversight and Management Board (FOMB). Each has regulatory jurisdiction over different aspects of PREPA and the electrical system. The PREC (under Act 57 of 2014) has the authority to develop a long-term vision for the electricity system and to create applicable rules and regulations. In the short term, the PREC's regulatory oversight forced

[2] Information form FY 2017 Rate Case. Prior to the global oil price collapse in late 2014, PREPA was paying more than $2 billion a year. This expense contributed to PREPA's current insolvency, as the authority chose to borrow money to cover operating expenses rather than further raise rates.

[3] Information from PREPA Statistics "Distribución Porcentual de la Generación Neta de Energia por Tipo por Año Fiscal."

[4] Comments submitted at the Financial Oversight and Management Board hearing in December 4, 2017 by PREPA workers union UTIER.

[5] Table 4.2, PREPA Supplemental Integrated Resource Plan, April 1, 2016.

PREPA to exit from or renegotiate out-of-market contracts for renewable energy that had been entered into without regulatory oversight.[6] It also initiated a proceeding to develop regulations that can facilitate private capital investment in distributed energy and microgrids, as a way to assist in restoring power and modernize the system.

The FOMB, established by Congress, has focused on developing 10-year fiscal plans for PREPA and other insolvent Puerto Rican government agencies. But in the absence of a long-term vision for the energy system, these fiscal plans alone will not provide PREPA financial stability. Decisions about energy resource planning made over the next 10 years should be made in the context of a long-term Integrated Resource Plan designed to avoid wasting capital or encouraging PREPA to continue to rely on centralized fossil-fuel-based generation located far from demand. It is of upmost importance that the FOMB and the PREC establish a protocol for cooperation and avoidance of conflict in their oversight responsibilities.

The PREC is the entity with clear, independent authority to regulate Puerto Rico's energy system as a whole— a system that includes more than just PREPA. The island's future energy system should include community-owned and privately-owned distributed energy and microgrid facilities. The PREC has the expertise and legal authority to develop rules to facilitate competitive development of these resilient renewable resources. They also have the know-how to ensure that deployment of these technologies fits into a long-term vision for both the energy system as a whole and for PREPA.

The near-term future of Puerto Rico's power system— in terms of rebuilding and investment— will involve significant reliance on fossil fuels, but we believe that it is imperative to re-think investment priorities and encourage private solar and microgrid developers who have recently expressed interest in Puerto Rico.[7]

Electrical-system modernization has been hampered by years of mismanagement by PREPA, resulting in a severely deteriorated and outmoded generation and transmission system. This lack of effective governance has hindered competitive private sector participation. That said, two areas in which PREPA retains significant value are its ability to charge customers and the knowledge and skill base of its remaining and retired employees. Any plan that does not consider both factors will likely fail.

Recently, the governor of Puerto Rico announced his intentions of selling PREPA's generation assets and leasing its transmission and distribution system. Whatever form of ownership results from this transaction (e.g., investor-owned, state-owned, municipal utilities, customer-owned utility cooperatives or some combination of these) the key to successful electric system redevelopment is strong regulation and a related legal framework that harmonizes the

[6] PREPA entered into 68 renewable energy contracts between 2008 and 2012 (before the establishment of the Puerto Rico Energy Commission), of which 58 are still in effect. Only 11 have resulted in projects that are under development or currently operational. In its order on PREPA's Integrated Resource Plan, the Energy Commission noted that PREPA's renewable energy contracts set prices that include excessive profits to developers.

[7] Although there have been very public discussions of the importance of microgrids and solar in rebuilding Puerto Rico's electricity system, the bulk of the resources for rebuilding the system have so far gone towards rebuilding infrastructure that previously existed. Some microgrid demonstration projects have been constructed, and the heightened interest from private solar developers in investing in Puerto Rico will be critical to the successful long-term transformation of the electrical system. However, in the short term, Puerto Rico's electricity system will still include significant levels of fossil fuels.

interests of all players for the benefit of the public. Importantly, whatever form new ownership takes should not worsen the exodus of employees who (as explained above) serve as the system's institutional memory. We see new forms of partnership as essential, and believe that any viable financial plan will require investment in a stable, professional, growing sector of well-managed employees.

In summary, if true modernization of Puerto Rico's electrical system is to be achieved, regulation in line with U.S. standards— bringing transparency for the benefit of both investors and customers— is a must. Although the importance of regulation is well understood on the U.S. mainland, the concept is still new in Puerto Rico. As long as the PREC is able to proceed with its urgent work regulating the modernization of Puerto Rico's electricity system, we see no reason why Puerto Rico cannot rebuild its electricity system with widespread public benefit, by adopting a far more ambitious long-term vision than the one articulated by PREPA thus far. In the short to medium term, the energy sector as a whole (including PREPA) is likely Puerto Rico's largest economic development opportunity, with the potential of attracting billions of dollars in capital investment, resulting in billions of dollars in avoided fuel and energy costs.

2028 Transformation Proposal

This document is a first attempt to define the redesign of Puerto Rico's energy system in a post-Maria scenario, based on specific assumptions that require further study and that need to be validated as part of a regulatory proceeding. The proposed plan is based on seven main elements:

1) **The Integrated Resource Plan (IRP) approved by the Puerto Rico Energy Commission on Sept. 23, 2016, should be the basis for the redesign of Puerto Rico's electricity system.**
2) **System redesign should be based on a long-term vision.**
3) **Existing outdated steam and combined cycle units should either be retired as expeditiously as possible or designated limited use, and existing purchased power contracts should be reevaluated in light of their expiration dates.**
4) **Demand Response and Energy Efficiency Programs should be implemented immediately, aimed at reducing existing peak demand values**
5) **The generation mix should be comprised of utility-scale generation, including renewables, highly-efficient fossil generation and distributed energy, including combined heat and power (CHP) and microgrids with energy storage.**
6) **New and efficient utility-scale dual fuel diesel/natural gas generation, should be installed on a transitional basis in San Juan, Palo Seco, and in the south, with the objective of propelling the deployment of renewable energy resources.**
7) **Utility-scale demand will unavoidably decline as ratepayers shift toward distributed energy (private, behind-the-meter generation).**[8]

In addition, five fundamentals should be further developed:

1) **Differentiation between overall generation requirements and utility-scale generation.**

[8] For analysis purposes, a linear relation between energy sales and load reduction (MW) was assumed.

2) **Definition of a minimum reserve margin.**
3) **The importance of achieving sustainable debt levels for PREPA.**
4) **Significance of battery storage developments for achieving higher penetration of renewable energy.**
5) **The implementation of new governance structures to ensure cost-effective integration of new resources.**

On the following page, Figures 1 and 2 show the 2028 generation mix envisioned under our scenarios. Figure 1 shows total electrical generation in the island, including distributed energy resources; Figure 2 shows utility-scale generation.

Figure 1:

Puerto Rico Electrical System Transformation Plan

Electric System Generation (GWH)

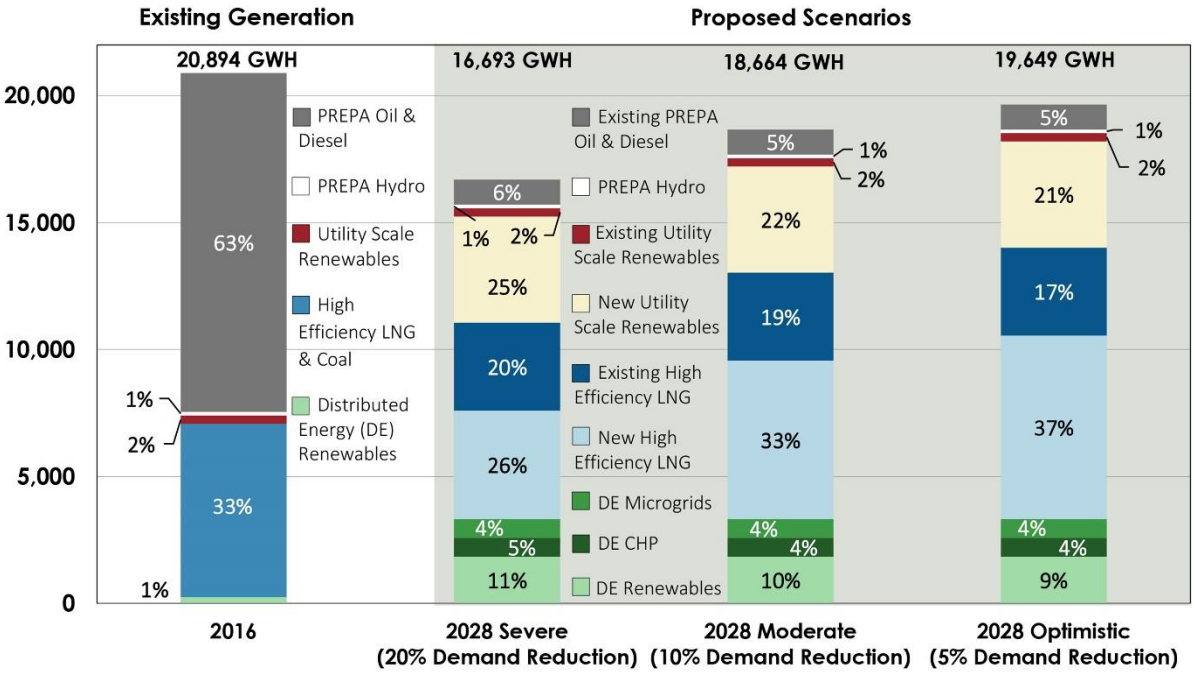
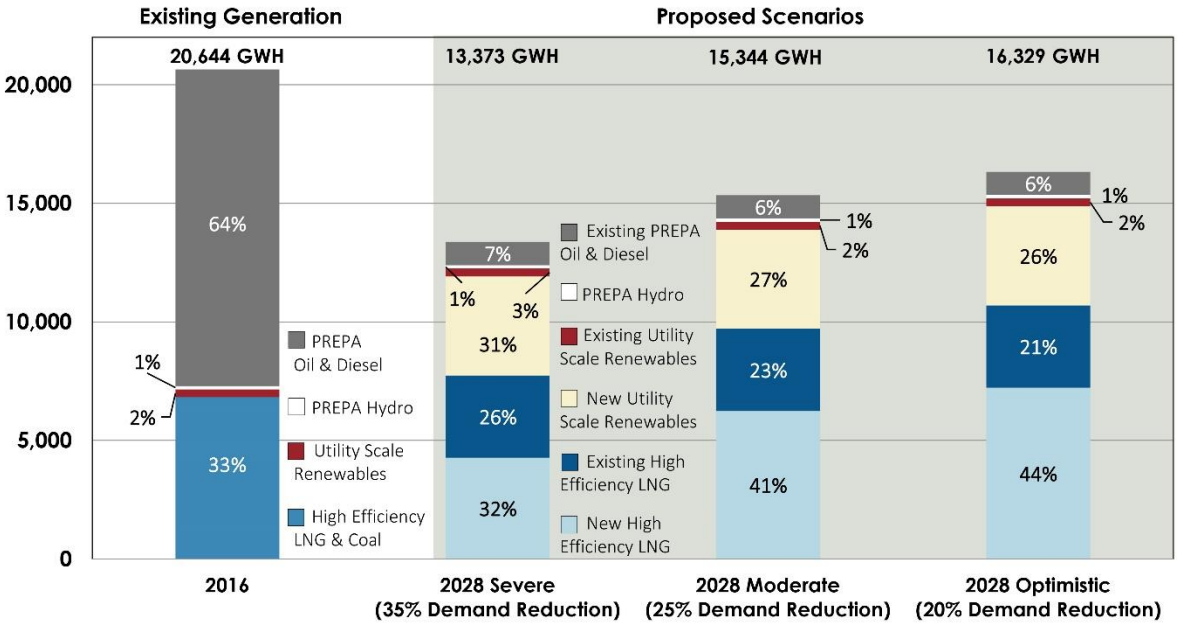


Figure 2:

Puerto Rico Electrical System Transformation Plan

Utility Scale Generation (GWH)



The 2016 Approved IRP

The redesign of Puerto Rico's energy system need not start from scratch. The Integrated Resource Plan (IRP) approved by the Puerto Rico Energy Commission on September 23, 2016, should be the basis of any redesign initiative. The approved IRP would, for the first time, have PREPA's operation guided by plans that meet uniform, professional standards required of every public and private utility in the U.S. These standards require adherence to practices of sound energy planning, responsible management, prudent budgeting and borrowing, affordable rates, professional workforce development and responsive customer service.

Failure to meet such standards in the past was primarily what caused PREPA's current dismal physical condition, bankruptcy and outmoded electricity system. Adherence to new planning and financial discipline will provide a sustainable path forward. The approved IRP articulated the need for PREPA to retire oil-fired units that are out of compliance with the Mercury and Air Toxics Standard (MATS); to prioritize new renewable energy and energy efficiency projects; and not to proceed with constructing a second LNG import terminal until such time that such a project could meet professional standards for grid inclusion.

Post-Hurricane Maria, the PREC must modify its existing five-year IRP Action Plan to address basic elements of small-to-medium scale microgrids (in homes, hospitals, commercial locations and industry) as well as development of larger-scale municipal and regional microgrids. A revised 20-year Integrated Resource Plan aimed at providing a total redesign of the system in a resilient and modern way should also be developed, maximizing microgrids and other advanced technologies.

The PREC has already started this process: in October 2017, it launched an investigation into the "vulnerabilities in the electrical system that contributed to its collapse and to identify short-, medium- and long-term strategies and regulatory actions [that] result in an electric system that is modern, flexible, resilient and capable of supplying electric service effectively and at just and reasonable prices."[9] The inquiry includes a plan to identify regulatory actions needed to provide a more certain investment climate for new technologies (including distributed generation and microgrids) that can help support the restoration of electric service in the short term. On January 3, 2018, the PREC issued a draft microgrid regulation for Puerto Rico. Over the longer term, the PREC will be identifying regulatory actions needed to transition towards a more sustainable model of electric service delivery. This will feed into the next round of revisions of PREPA's Integrated Resource Plan.

Redesign Vision

From a technical standpoint, there is no reason why Puerto Rico cannot rebuild its grid to support the goal of 100% renewable energy by 2050.[10] This would require modification of the current 20% by 2035 renewable energy target currently articulated in the Commonwealth law.

[9] Puerto Rico Energy Commission case number CEPR-2017-IN-0002, "Resolution Initiating Investigation," October 27, 2017.

[10] By "renewable energy," we refer specifically to "sustainable renewable energy" comprising wind, solar, geothermal, renewable biomass, hydroelectric, marine and ocean thermal energy as defined in Act 82-2010.

Other island electricity systems have articulated long-term visions for moving to renewable energy-based systems. Hawaii, for example, has a goal of 100% renewable energy by 2045, and the Hawaii Public Utilities Commission has ensured that Hawaii's main utility has a plan for achieving that target five years ahead of schedule.[11] The U.S. Virgin Islands has a target of 30% renewable energy by 2025 and has been moving aggressively to reduce its dependence on imported oil.[12]

As part of the IRP process in Puerto Rico, we believe it is reasonable to bring forward the target for a minimum of 20% renewable energy to 2023 and to set a 50% renewable target by 2035 and 100% by 2050. The rate of growth and ultimate amount of renewable energy is not a function of the technical and engineering capability of renewable technologies. Rather, it is a question of the governance of the utility (PREPA), the electrical system as a whole and the strength of regulatory oversight.[13]

One of the largest uncertainties over the next few years will be how quickly Puerto Rico's electricity demand will drop, a key element in terms of compliance with renewable energy goals. As stated in Act 82, 2010[14] "[t]he mandatory amount of sustainable renewable energy or alternative renewable energy applicable to a retail electricity supplier in a specific year shall be obtained by multiplying the percentage corresponding to said year[...] by the total amount of electric power, expressed in megawatt-hours (MWh), sold by the retail electricity supplier during the same calendar year."

When PREPA produced its first IRP to the PREC in 2015, it assumed an 11% decline in energy generation from 2017 through 2026.[15] In its 2017 Fiscal Plan[16]— released prior to Hurricane Maria— PREPA projected a 23% decline in sales through 2026, though it never updated its IRP to reflect this. This projected decline in sales reflected "continued and accelerated deployment of distributed generation" plus a "[p]ipeline of co-generation units planned by large industrial/commercial clients."[17]

We see the decrease in PREPA electricity demand likely exceeding the 23% projected pre-Maria. However, as explained below, we distinguish between electricity demand from the central utility (PREPA) and overall demand, comprised of utility-scale and distributed energy generation. We consider three scenarios: significant demand loss (20% of overall demand loss and a 35% demand loss for PREPA by 2028); moderate demand loss (10% overall demand loss and 25% for PREPA); and an optimistic scenario (5% overall demand loss and 20% for PREPA). These reductions are on top of the 16% reduction that has already occurred over the past 10 years. As a result of the significant (though uncertain) projected drop in sales, we believe

[11] https://www.greentechmedia.com/articles/read/hawaiian-electric-100-renewable-energy-plan-green-light#gs.JAqjeU8

[12] https://energy.gov/savings/us-virgin-islands-renewables-portfolio-targets; https://energy.gov/eere/articles/us-virgin-islands-ramping-clean-energy-efforts-eye-toward-sustainable-future

[13] The organic law of the first-ever energy independent regulator (PR Energy Commission) was enacted in May 2014.

[14] Public Policy on Energy Diversification by Means of Sustainable and Alternative Renewable Energy in Puerto Rico Act.

[15] April 19, 2016 IRP, p. 27.

[16] Puerto Rico Electric Power Authority Fiscal Plan, submitted to the Fiscal Oversight and Management Board (FOMB) during it Seventh Meeting in April 28, 2017.

[17] Ibid., page 25.

that incrementally building out smaller-scale generation aimed at propelling renewable energy resources while retiring older oil-fired units is more appropriate, and more capital-efficient, than building large centralized generating plants.

Under a declining load scenario, PREPA must avoid major investments in new fuel infrastructure like the proposed second LNG import terminal at Aguirre and related generation retrofits, and it must retire its old oil-fired units that are out of compliance with MATS. It should prioritize investments in smaller-scale, highly efficient generation alongside renewable and distributed energy close to population centers in order to reduce Puerto Rico's dependence on unreliable south-to-north transmission. These objectives are broadly consistent with the existing Integrated Resource Plan, which needs to be modified to take into account post-hurricane realities.

Another important requirement of long-term planning involves addressing environmental concerns that could affect the system's future development. The expiration of EcoEléctrica and AES contracts in 2022 and 2027, respectively, presents an enormous opportunity to rethink the electrical system toward eliminating non-indigenous fossil energy source. This can start with a shift toward cleaner fossil energy while promoting flexible, smaller, highly efficient units that supplement load variation and that mitigate the intermittency caused by renewable energy when there is no battery storage support.

Retirement of Existing Units

The September 2016 approved IRP modified by the PREC discussed the retirement of existing PREPA oil-fired steam units. Although the schedule for retirement of the existing steam fleet will be revised post-Maria, retirements of these units should occur within the next five years. Our proposal considers the retirement of all oil-fired units (with the exception of the units mentioned below, which were designated as limited use). As indicated in Table 1, Aguirre 1 & 2 and Costa Sur 6 are the newest oil units. These units were placed in operation in 1971 and 1972. Due to high maintenance costs and unreliable service, the oil-fired steam units are a burden for PREPA and its ratepayers. Additionally, none of the oil-fired steam units, with the exception of Costa Sur 5 & 6 (which co-fire natural gas and oil), are in compliance with the federal Mercury and Air Toxics Standard unless they are retired or designated limited use (meaning a capacity factor of less than 8%). Because maintaining generation in the north side of the island is so important, we assume that the recently retrofitted Palo Seco Units 3 & 4 can be designated as limited use and that the remainder of the steam units can be retired.

This plan also considers the Aguirre and San Juan combined cycle units. The Aguirre combined cycle was placed in operation in 1976. The average energy output of this unit compared with its generation capacity (its capacity factor) based on data provided by PREPA[18] for FY 2012 to 2016 was 8.76%. The San Juan 5 & 6 combined cycle was placed in operation in 2008 and has a capacity factor of 35% for the same period. Based on our estimates of declining energy demand, the Aguirre combined cycle can be retired and the San Juan 5 & 6 placed under limited use.

The capacity factor for the peaking units (including Cambalache, Mayaguez and other units) averaged 5% for fiscal years 2012 to 2016.[19] The proposed capacity factors included in

[18] PREPA Response ROI DRR CEPR-AH-03-07 Attach 01.
[19] PREPA Response ROI DRR CEPR-AH-03-07 Attach 01.

Table 1 for those units were based on those historic values.

As needed, retired units under our proposal would be replaced by a combination of:

- Demand response and energy-efficiency programs.
- New utility-scale renewable generation.
- New distributed generation comprised of renewables and combined heat and power (CHP).
- New high-efficiency dual-fuel natural gas/diesel generation.

Immediate Implementation of Demand Response and Energy Efficiency Programs

As indicated in Table 1, Puerto Rico's average demand in 2016 was 1976 (MW)[20] and peak demand was 3,087 MW. Peak demand is 56% higher than average demand. Puerto Rico could avoid building peak generation capacity if it were to develop ways to decrease peak demand. Typically, on the U.S. mainland and abroad, this is achieved though demand response and energy efficiency programs, and (more recently) energy storage facilities. Puerto Rico's demand peak occurs in the afternoon, evening, and night until 11 p.m. followed by a well-defined "demand valley" from 12 to 6:00 a.m. This suggests a need for programs to help reduce and shift the highest demand to the demand valley and/or to the renewables generation peak between 10:00 a.m. and 3:00 p.m.

By reducing peak demand to 2,570 MW or so (1.3 times the base demand), approximately 500 megawatts of generation capacity could be saved and/or avoided. This would reduce generation-fleet costs and related financial and environmental costs.

We propose that by 2028, Puerto Rico implement demand response and energy efficiency programs, with the goal of reducing peak demand to 130% of average demand. This will be challenging, representing an approximate 17% reduction in the 2016 peak.

Generation Mix of Distributed Energy and Utility-Scale Generation

According to the 2017 PREPA fiscal plan, the amount of distributed energy in 2016 was 136 MW. Our proposal includes an additional 1,500 MW of distributed energy by 2028. In all scenarios, this is comprised of 1000 MW of distributed solar, 400 MW of microgrids and 100 MW of CHP. In terms of utility-scale generation, 650 MW of new high efficiency dual fuel generation is included in the significant (35%) demand loss scenario; 950 MW in the moderate (25%) demand loss scenario and 1,100 in the optimistic scenario, plus 2,555 MW of utility-scale renewables (including hydroelectric) in all demand loss scenarios.

Utility-scale generation, including renewables, amounts to 5,430 MW in the significant (35%) demand loss scenario, 5,730 MW in the moderate 25% scenario and 5,880 MW in the optimistic (20%) demand loss scenario. For the complete energy mix, please refer to Table 1.

This proposed energy portfolio not only improves the electrical system's reliability and

[20] Based on a demand of 17,311 GWH.

exceeds the legislatively-mandated renewable energy target, it also promotes local investment in distributed energy generation. This is essential under prevailing economic conditions post-Maria.

New High Efficiency Small-Scale Dual Fuel Units

All scenarios consider new transitional high efficiency dual fuel diesel-natural gas generation. By 2028, the 35% demand decrease scenario considers 650 MW, the 25% reduction scenario 950 MW and the optimistic 20% decrease scenario 1,100 MW, to be split among small generating units mainly between the San Juan and Palo Seco plants, located in the north side of the island, with a few units in the south. While our scenarios assume new dual fuel combined cycle generation, it is possible that a more detailed economic analysis of fossil fuel options would reveal that repowering existing combined cycle units is a more cost-effective approach to ensuring baseload power generation. Either way, new investment to improve the efficiency and flexibility of fossil fuel generation is clearly required.[21]

In addition to new generation at the San Juan and Palo Seco plants, and considering EcoEléctrica's contract expiration by 2022 and AES's by 2027, this proposal assumes: (1) the renegotiation of EcoElectrica's contract to the end of the IRP period in 2035 and (2) the termination of AES's contract by 2027.

This plan assumes the utilization of new small dual fuel units at the San Juan and Palo Seco plants, and for the replacement of generation from the AES plant; and the continued operation of EcoEléctrica until 2035, with the LNG terminal at EcoElectrica remaining as the only LNG terminal in operation in Puerto Rico. New small dual fuel combined cycles should explore the possibility of using the existing (now largely amortized) infrastructure of the LNG import terminal, which may require transmission line improvements.

Depending on the relative cost of replacement technologies and anticipated energy demand at the time new generation proposals are being evaluated, the new generation from high efficiency dual fuel (diesel/natural gas) units assumed in this plan could be partially or entirely replaced by solar and battery storage plants. Because of the uncertainty around declining demand in Puerto Rico, we emphasize the importance of a plan that includes build-out of new generation in relatively small increments, so that the plan can be adjusted if demand is larger or smaller than anticipated.

The regulation and governance of new high efficiency generation should emphasize competitive pricing, incentivize low operating costs and utilize existing infrastructure. This plan assumes a maximum useful life of 25 years for new natural gas generation equipment.

[21] Our scenario of new dual fuel generation in the north would require natural gas to be delivered to the north coast of Puerto Rico. The question of how to bring additional natural gas to Puerto Rico has been intensely debated for the past decade. PREPA is aggressively pursuing the Aguirre Offshore Gas Port, a proposed LNG import terminal on the south coast of Puerto Rico, despite a lack of either financing for the project or regulatory approval from the Energy Commission. A "Fuel Delivery Option Assessment" prepared for PREPA in March 2017 recommended that PREPA "evaluate the feasibility of bulk LNG delivery and onsite tank storage to improve the cost competitiveness of LNG to San Juan and Palo Seco." This evaluation has not been conducted, to our knowledge. Regardless of whether repowering existing oil-fired combined cycle units (at San Juan and Palo Seco) proves to be a more cost-effective approach, it is clear that some level of investment in fossil fuel generation will be required to improve the reliability of the system and to support the transition to a renewable energy-based system.

Existing fossil generation, as well as the new proposed dual fuel generation under 25-year contract, is assumed to be replaced with a combination of utility-scale and distributed energy renewables with battery storage, in order to achieve 100% renewable energy by 2055.

Unavoidable Reduction in Utility-Scale Demand

Before Hurricane Maria, PREPA projected that it would experience a decrease in electricity demand of 39% between 2006 to 2026. From 2006 to 2016, PREPA's energy sales decreased 16%,[10] and an additional 23% sales decrease by 2026 was projected in PREPA's 2017 Fiscal Plan.[7] A reduction in population could lead to an additional demand decrease. A population loss of approximately 470,000 residents between 2017 and 2019 is expected after Hurricane Maria.[22]

Additional reduction in projected demand and generation from the utility are related to:

- The implementation of demand response and energy efficiency programs.
- The switch from a traditional centralized generation model to distributed generation.
- The installation of co-generation and CHP units at industrial plants.

For FY 2016, PREPA's energy generation was 20,644 GWh[23] and distributed solar resources (136 MW) provided an addition of approximately 250 GWh, for a total of 20,894 GWh. This proposal considers a 20-35% reduction in demand from the centralized utility and a 5-20% decrease in overall electric system demand by 2028.

Differentiation Between Overall Generation Requirements and Utility-Scale Generation

As microgrids, wheeling and other means of producing and distributing energy are implemented, a sharp reduction in utility-scale demand can be expected over a few years. It is critical, then, to differentiate between utility-scale demand reduction and the island's total demand for electricity in a revision of the IRP. Projections for demand reduction in most regulatory documents do not make this differentiation. It is imperative to assess and periodically publish a record of distributed energy, since it comprises an important and growing part of energy demand.

Definition of a Minimum Reserve Margin

As previously mentioned, this document is a first effort to propose a redesign of Puerto Rico's electrical system and desirable 2028 generation mix, which should be validated as part of a regulatory proceeding.

How to best define the island's minimum reserve margin requires further analysis. Historically, PREPA has operated with a very high reserve margin of approximately 80%, which is a result of very high forced outage rates and the unreliability of many of PREPA's fossil fuel units. As

[22] Population projections from: https://centropr.hunter.cuny.edu/sites/default/files/RB2017-01-POST-MARIA%20EXODUS_V3.pdf

[23] PREPA Response ROI DRR CEPR-AH-03-07 Attach 01.

these units are retired, and as Puerto Rico develops more renewable energy capacity, a more detailed modelling analysis must be made to determine an appropriate reserve margin for system reliability.

In our scenarios, the 2028 reserve margin is estimated at between 61-69%. Compared to other island systems (Hawaii has a target reserve margin of 30%[24]), this reserve margin is high but reflects the high forced outage rates at some of PREPA's existing fossil fuel units and the need for more analysis of the appropriate reserve margin to ensure reliability of an independent island system. It also anticipates the retirement of additional fossil fuel units after 2028 as Puerto Rico continues to transition to renewable energy.

Sustainable Debt Level for the State-Owned Utility (PREPA)

Since 1941, electricity in Puerto Rico has been generated for and provided to customers by PREPA, a public corporation and vertically-integrated utility with three major functions: generation, transmission and distribution. In July of 2017, PREPA filed bankruptcy under Title III of PROMESA, Public Law 114–187 (the Puerto Rico Oversight, Management and Economic Stability Act).

Prior to Hurricane Maria, in accordance with the latest audited financial statements for FY 2014, PREPA's total liabilities amounted to $11.74 billion.[25] This total includes $8.2 billion in outstanding bond indebtedness[26] and additional current and long-term liabilities. There were other liabilities listed in the audit,[27] bringing the total long-term liabilities to an estimated $13-15 billion.

Hurricane Maria resulted in the collapse of 80% of Puerto Rico's transmission and distribution system, and estimates for the cost of restoration exceed $17 billion.[28] Although part of that cost is expected to be covered by federal aid, including from the Federal Emergency Management Agency (FEMA) and from other programs and grants, not all of the cost is likely to be covered through federal relief or assistance funds. This places PREPA in fiscal crisis and prioritizes resolving the bankruptcy filing in a way that allows the utility to attain a level of debt sustainability.
Court proceedings currently involve debt mediation, and if a sustainable debt level for PREPA is not reached, the Commonwealth's already deeply weakened economy will be dealt another blow.

Previous attempts to reconcile bondholder interests and ratepayer interests produced a plan that would have paid bondholders at a recovery rate of 85%. This plan was rejected by the FOMB because it would have pushed electricity rates to economically uncompetitive levels.

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[24] Hawaiian Electric Companies' Power Supply Improvement Plans Update Report, Hawaii Public Utilities Commission Docket No. 2014-0183, December 23, 2016, page J-2.
[25] http://www.gdb-pur.com/investors_resources/documents/PREPA-FS-6.30.2014.pdf, p. 28.
[26] http://www.gdb-pur.com/investors_resources/documents/PREPA-FS-6.30.2014.pdf, p. 28 and p. 137. We use here the figure for revenue bond liabilities outstanding as presented in the Audit. Subsequent presentations of indebtedness made during various regulatory proceedings appear to be the subject of negotiations. Since the authority has not produced an audit since the 2014 audit through June 30, 2014, any subsequent indebtedness representations are unaudited.
[27] http://www.gdb-pur.com/investors_resources/documents/PREPA-FS-6.30.2014.pdf, p. 128.
[28] Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico, December 2017, New York Power Authority, et al.

Any debt resolution plan aimed at restoring investment confidence in Puerto Rico cannot saddle ratepayers and taxpayers with exorbitant debt.

There is no shortage of debt-management strategies that can support PREPA ratepayers while ensuring bondholders are treated equitably[29] Such strategies can also grow Puerto Rico's economy. An appropriate debt-management model would resolve legacy debt problems and create an investment climate whereby PREPA can secure access to capital markets that can honestly rate bond offerings as investment grade.

After more than a decade of decline, Puerto Rico's storm-wrecked economy is in no position to absorb increased energy costs beyond the current average price of 20 cents per kilowatt-hour. Urgently needed modernization of the electric system will require that every effort be aimed at achieving a sustainable debt load and lowering electricity rates.

Significance of Battery Storage Development

The deployment of utility-scale and distributed renewable energy within this proposal assumes that solar operates during the daytime without considering energy storage (except in microgrids). As photovoltaic, wind generation, other renewables and energy storage costs decrease, the implementation of energy storage will allow renewable energy to be dispatched at any time of day. PREPA was once a pioneer in energy storage for hydroelectric generation applications. It should revisit this precedent.

For example, if the proposed installed capacity of utility-scale and distributed renewable energy is increased by 55% by 2035 and complemented by the use of battery storage at competitive dispatchable energy prices, assuming no change in demand after 2028, 57-67% of energy generation by 2035 could be achieved through renewables.

Implementation of New Governance Structures

In 2016, the PREC began an investigation into opportunities for improving PREPA's performance.[30] The PREC emphasized the need for both improving PREPA's operational and managerial performance and for greater reliance on independent third-party providers when such help improves performance. In its current investigation into modernizing the electrical system post-Maria, the PREC has also acknowledged the need to rethink Puerto Rico's energy model, specifically to "identify the correct combination of products and services, as well as the adequate market structures to deliver them."

As Puerto Rico's electrical system evolves over the next decade, new sources of electricity and new forms of ownership will emerge. More and more energy consumers will become producers and take a more active role in the grid.

A modern electricity system will be required to develop new dispatch models (similar to wholesale energy markets) alongside new protocols for integrating new generating sources and structures into a coherent and cost-effective whole. Regulation will be needed to ensure that investors and the public interest are protected. This process should be managed so as to

[29] http://ieefa.org/trump-says-eliminate-puerto-ricos-debt-agree/
[30] Puerto Rico Energy Commission Case No. CEPR-IN-2016-0002.

avoid discrimination against new generators, to ensure that large- and small-scale generators are treated equitably and to ensure that all sectors of Puerto Rican society have equitable participation in the new system, promoting energy democracy.

It is of paramount importance that capital needs and operating costs are transparemt to system stakeholders and that all parties can participate with equal opportunity. The current lack of competitive price formation (marginal pricing), uniform tax framework (public vs. private), market access and independent grid operations creates dubious management incentives that do not align with the public interest.

Conclusion

Any strategy for energy sustainability requires independent local regulators who operate under the highest standards of integrity and who understand conditions specific to Puerto Rico. Under those terms, the 2016 Approved Integrated Resource Plan should be the base document for redesigning the system in accordance with a long-term vision.

Demand uncertainty must be addressed more comprehensively in the redesign plan. This proposal attempts to do that by bounding future demand reduction and by planning a supply portfolio that places greater reliance on distributed energy resources, which can be developed with shorter lead times and with smaller capital increments than typical fossil fuel assets. Distributed energy resources could be financed through local, private capital, which would have the important side effect of expanding the local economy. This should be done in a way that ensures low-income communities have equitable access to private capital and to new, modern energy technologies.

Our proposal includes investment in a limited number of reliable, high-efficiency combined cycle gas generators which would increase system efficiency (i.e., reduced heat rate), reduce fuel consumption and lower fuel costs for ratepayers. By retiring existing oil and coal plants, this proposal reduces fuel requirements and shrinks the system's carbon footprint.

This proposal would also increase system reliability and resiliency by developing microgrids and by concentrating proposed new generation in the north near the densest demand.

The transformation of the Puerto Rico energy system requires not only physical changes to generation, transmission and distribution but strong regulation to ensure successful implementation. How changes are made will significantly affect their effectiveness. A strong, independent regulator is needed to implement a comprehensive planning process and provide certainty to consumers and investors as the energy system is modernized.

About the Authors

Tomás J. Torres, tjtorres@amscm.com

Tomás Torres is the executive director of the Institute for Competitiveness and Sustainable Economy of Puerto Rico (ICSE-PR). Torres was a member of the Puerto Rico Planning Board; has lectured in Puerto Rico and abroad, highlighting energy and planning issues; and for the past two years, has chaired the Energy Committee at the Puerto Rico Manufacturers Association. He is an active member of the Institute of Engineers and Surveyors of Puerto Rico and of the Puerto Rican Planning Society.

Torres is an experienced licensed engineer and licensed professional planner. During his career he has worked in the Puerto Rico Electric Power Authority; in the pharmaceutical and high-tech industry; in construction and housing development and as a consultant. He graduated with honors from engineering at the University of Puerto Rico, Mayaguez Campus and has a Master's Degree in Planning from the University of Puerto Rico, Rio Piedras Campus.

Cathy Kunkel, ckunkel@ieefa.org

IEEFA energy analyst Cathy Kunkel has co-authored numerous reports for the Institute for Energy Economics and Financial Analysis related to utility regulation, electricity markets, mergers and acquisitions and coal plant finances. Previously, she was a Senior Research Associate in the Electricity Markets and Policy group at Lawrence Berkeley National Laboratory. She has been an expert witness in eight West Virginia Public Service Commission proceedings regarding resource planning and energy efficiency.

Kunkel has also participated in hearings before the Puerto Rico Energy Commission in its Integrated Resource Plan proceeding and 2016 rate case proceeding. Kunkel graduated from Princeton University with a B.A. in physics and from Cambridge University with a Certificate of Advanced Study from the Department of Applied Mathematics and Theoretical Physics.

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Table 1:
2028 Puerto Rico Electrical System Transformational Plan
Generation Proposal

		Current Capacity 2016 (MW)	Current Generation 2016 (GWh)	Year of Initial Operation	Generation Capacity (MW) Significant (35/20%) Demand Loss	Generation Capacity (MW) Moderate (25/10%) Demand Loss	Generation Capacity (MW) Optimistic (20/5%) Demand Loss	Capacity Factor (CF) for All Demand Loss Scenarios	2028 Generation (GWh) Significant (35/20%) Dem. Loss	2028 Generation (GWh) Moderate (25/10%) Dem. Loss	2028 Generation (GWh) Optimistic (20/5%) Dem. Loss	Possible 2035 Capacity Factor (CF) for All Scenarios	Posible 2035/45 Generation (GWh) Significant (45/20%) Dem. Loss (11)	Posible 2035/45 Generation (GWh) Moderate (35/12%) Dem. Loss (11)	Possible 2035/45 Generation (GWh) Optimistic (23/7%) Dem. Loss (11)
PREPA Legacy Plants	Oil Fired Steam Units - Aguirre Steam 1 & 2 (1)	900		1971	0	0	0	0%	0	0	0	0%	0	0	0
	Oil Fired Steam Units - Costa Sur 3 & 4 (1)	170		1960 / 1962	0	0	0	0%	0	0	0	0%	0	0	0
	Oil and Gas Fired Steam Units - Costa Sur 5 &6 (1)	820		1969 / 1972	0	0	0	0%	0	0	0	0%	0	0	0
	Oil Fired Steam Units - Palo Seco 1 & 2(1)	170		1959	0	0	0	0%	0	0	0	0%	0	0	0
	Oil Fired Steam Units - Palo Seco 3 & 4 (2)	432		1967 / 1968	432	432	432	8%	303	303	303	0%	0	0	0
	Oil Fired Steam Units - San Juan 7, 8, 9 & 10 (1)	400	13,418	1964/64/65/66	0	0	0	0%	0	0	0	0%	0	0	0
	Aguirre Combined Cycle (1)	592		1976	0	0	0	0%	0	0	0	0%	0	0	0
	San Juan 5 & 6 Combined Cycle (2)	440		2008	440	440	440	8%	308	308	308	0%	0	0	0
	Mayaguez Tuirbines (2)	220		2009	220	220	220	5%	96	96	96	0%	0	0	0
	Cambalache Turbines (2)	248		1997/97/98	248	248	248	5%	109	109	109	0%	0	0	0
	Peak Units (9 Bolcks) (2)	378		1971 to 1973	378	378	378	5%	166	166	166	0%	0	0	0
	Existing Hydroelectric Plants (3)	100	70	1929-1984	100	100	100	16%	140	140	140	0%	0	0	0
	Subtotal PREPA Legacy Plants	4,870	13,488		1,818	1,818	1,818		1,122	1,122	1,122		0	0	0
Existing Purchased Power Contracts	Ecoelectrica 22 Year PPOA (3)	507	3,346	2000	507	507	507	78%	3,464	3,464	3,464	0%	0	0	0
	AES 25 Year PPOA (3)	454	3,477	2002	0	0	0	0%	0	0	0	0%	0	0	0
	Existing utility-scale renewables	181	333	2010-2013	181	181	181	21%	333	333	333	21%	516	516	516
	Subtotal Existing Power Purchase Contracts	1,142	7,156		688	688	688		3,797	3,797	3,797		516	516	516
New Utility-scale Generation	New Dual Fuel Natural Gas - Diesel Generation - San Juan	0	0	2023	250	350	400	75%	1,643	2,300	2,628	75%	1,643	2,300	2,628
	New Dual Fuel Natural Gas - Diesel Generation - Palo Seco	0	0	2023	250	350	400	75%	1,643	2,300	2,628	75%	1,643	2,300	2,628
	New Dual Fuel Natural Gas Generation (AES Succesor) (4)	0	0	2028	150	250	300	75%	986	1,643	1,971	75%	986	1,643	1,971
	New Utility-Scale Renewables	0	0	Present-2028	2,274	2,274	2,274	21%	4,183	4,183	4,183	21%	6,484	6,484	6,484
	Subtotal New Utility-Scale Generation	0	0		2,924	3,224	3,374		8,454	10,425	11,410		10,755	12,726	13,711
	Subtotal - Centralized Generation	**6,012**	**20,644**		**5,430**	**5,730**	**5,880**		**13,373**	**15,344**	**16,329**		**11,271**	**13,242**	**14,227**
Distributed Generation	Distributed Solar (5)	136	250	Present -2028	1,000	1,000	1,000	21%	1,840	1,840	1,840	21%	2,851	2,851	2,851
	Combined Heat and Power (CHP) (6)	0	0	Present-2028	100	100	100	85%	745	745	745	85%	1,154	1,154	1,154
	Microgrids (7)	0	0	Present-2028	400	400	400	21%	736	736	736	21%	1,141	1,141	1,141
	Subtotal - Dist. Energy and Microgrids	**136**	**250**		**1,500**	**1,500**	**1,500**		**3,320**	**3,320**	**3,320**		**5,146**	**5,146**	**5,146**
	Total Capacity(MW)	**6,148**			**6,930**	**7,230**	**7,380**								
	Total Generation (GWh) (8)		**20,894**						**16,693**	**18,664**	**19,649**		**16,417**	**18,388**	**19,373**
	Peak Demand (MW) (9)	**3,087**													
	Annual Demand (GWh) (9)		**17,311**												
	Annual Demand Plus DG (GWh) (9)		**17,561**												
	"Firm Capacity" (MW) (10)	**5,831**			**3,475**	**3,775**	**3,925**								

(1) Retired Units by 2023.

(2) Limited Use Units.

(3) Fortieth Consulting Engineering Report of PREPA and PREPA Historical Data.

(4) Depending on the relative cost of replacement technologies when this project is being evaluated, some or all of this energy might instead come from renewable energy plus storage.

(5) As indicated in the April 2017 PRPEA's Fiscal Plan, Puerto Rico had 136 MW of distributed solar in 2016. We assume that this will grow to at least 500 MW total by 2023, an increase of 364 MW. (Hawaii, which has smaller population than Puerto Rico, forecasts growth of 385 MW from 2015-2020. Source: Hawaiian Electric Companies' PSIPs Update Report, Filed with the Hawaii Public Utilities Commission December 23, 2016 page H-5). Another 500 MW are assumed from 2023-2028.

(6) 100 MW would include CHP at all 68 hospitals and some large industrial and commercial sites (average size of hospital CHP installation in U.S. is 1.2 MW).
https://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf

(7) We assume 21% for microgrid capacity factor, assuming that microgrids are based on solar with battery storage

(8) Gross energy generation for 2016 was 20,644 GWh, based in PREPA "Historical Series", June 2017.

(9) Energy sales during 2016 were 17,311 GWH, equivalent to a demand load of 1976 (MW). Peak Demand for 2016 was 3,087 MW. Values based in PREPA "Historical Series", June 2017. A linear relation is assumed between energy sales and generation reduction.

(10) Nominal generation capacity for units that can contribute to meeting peak demand. We conservatively assume that solar (without storage) does not contribute to peak. It is assumed microgrids and CHP can be centrally dispatched.

(11) Possible 2035 scenarios assume 55% increase in distributed energy resources and utility-scale renewable energy

Table 2:
2028 Projected Generation and Peak Demand

Generation Reduction	Electricity Generation	Significant Utility Sales Loss (35/20%)	Moderate Utility Sales Loss (25/10%)	Optimistic Utility Sales Loss (20/5%)
Total Utility Generation, 2016 (GWh)	20,644			
Utility Scale Generation Based in Proposed Plan		13,373	15,344	16,329
Utility Scale Genration Reduction		7,271	5,300	4,315
Percentage of Reduction - Utility Scale		**35.22%**	**25.67%**	**20.90%**
Total Overall Generation including DG (GWh)	20,894			
Total Generation		16,693	18,664	19,649
Total Genration Reduction		4,201	2,230	1,245
Percentage of Reduction - Total Generation		**20.11%**	**10.67%**	**5.96%**
Reserve Margin	**Electricity Demand**	**Significant Utility Sales Loss (20%)**	**Moderate Utility Sales Loss (10%)**	**Optimistic Utility Sales Loss (5%)**
2016 System Peak Demand (MW)	3,087	2,007	2,315	2,470
Average System Total Demand (MW)	1,976	1,581	1,779	1,877
Peak Demand After Demand Response Program (MW)	1,976	2,055	2,312	2,441
Firm capacity (Incl. CHP Distributed Energy)		3,475	3,775	3,925
Reserve Margin		**69%**	**63%**	**61%**

2035 Projected Generation

Generation Reduction	Electricity Generation	Significant Utility Sales Loss (45/20%)	Moderate Utility Sales Loss (35/12%)	Optimistic Utility Sales Loss (30/7%)
Total Utility Generation, 2016 (GWh)	20,644			
Utility Scale Generation Based in Proposed Plan		11,271	13,242	14,227
Utility Scale Generation Reduction		9,373	7,402	6,417
Percentage of Reduction - Utility Scale		**45.40%**	**35.86%**	**31.08%**
Total Overall Generation including DG (GWh)	20,894			
Total Generation		16,417	18,388	19,373
Total Generation Reduction		4,477	2,506	1,521
Percentage of Reduction - Total Generation		**21.43%**	**12.00%**	**7.28%**