COMMONWEALTH OF PUERTO RICO
PUERTO RICO ENERGY COMMISSION

IN RE: ENERGY COMMISSION INVESTIGATION REGARDING THE STATE OF PUERTO RICO'S ELECTRIC SYSTEM AFTER HURRICANE MARIA CASE NO.: CEPR-IN-2017-0002	) Subject: Request for Public Comments.) Issue: Implementation of regulatory) actions to facilitate the tasks of) restoring electric service and) encourage the deployment of new technologies.

COMMENTS OF THE AES COMPANIES

AES Puerto Rico L.P., AES Ilumina LLC and AES Energy Storage LLC, (collectively, the "AES Companies") respectfully submit these comments in response to the Puerto Rico Energy Commission ("Commission" or "CEPR") on the subject of implementation of regulatory actions to facilitate the tasks of restoring electric service and encourage the deployment of new technologies.[1]

I. DESCRIPTION OF THE AES COMPANIES

All of the AES Companies are subsidiaries of The AES Corporation (NYSE: AES), which is a Fortune 200 global power company. Through its subsidiaries, AES owns and operates generation facilities and distribution businesses throughout the world and is present in 17 countries across 4 continents. AES's United States-based generation facilities serve customers in California, Hawaii, Indiana, Maryland, Ohio, Oklahoma, Texas, West Virginia and Puerto Rico.

AES Puerto Rico, L.P. ("AESPR") has been a partner to PREPA for over 20 years. AESPR provides 17 percent of all power consumed in Puerto Rico via a 510 MW power plant considered one of the top 10 cleanest coal power plants in the US. AESPR's power plant is the

[1] *Case No; CEPR-IN-2017-002, Request for Public Comments Puerto Rico Energy Commission, November 10, 2017.*

least cost, most reliable power resource on the entire island, which set the standard for emissions when it came online in 2002. AESPR was incorporated in 1994 and is based in Guayama, Puerto Rico.

AES Ilumina, LLC is a 24 MW solar plant located in Guayama, Puerto Rico. It was the first grid scale solar facility on the island and the biggest solar facility in the Caribbean when it began commercial operations in 2012.

AES Energy Storage, LLC ("AESES") is a pioneer in the commercialization of battery based energy storage on the grid, placing the first lithium ion grid battery in service in 2008. Today, AESES is a global leader in commercial energy storage solutions. Its solutions unlock value from existing power infrastructure, improve flexibility and reliability of the power system, and provide customers with a complete alternative to traditional peaking power plants.

II. COMMUNICATIONS

The AES Companies request that service be made upon and communications directed to the following:

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III. GENERAL

The AES Companies believe that electricity is fundamental to everything we do and has the power to change people's lives. We have an opportunity with new technologies to make the power system in Puerto Rico an active, resilient infrastructure that enables energy to become abundant and reshape the way we work and live. The power grid remains at the center of the strategy.

With power assets on all the islands in the Caribbean, the AES Companies understand how to build to the specifications of island grids. AES Illumina's Puerto Rico solar plant, the first of its kind on the island, is currently over 90% physical intact with over 75% of capacity available. Despite a direct hit from Hurricane Maria, AESPR's thermal plant was able to declare availability within 16 days. The plant is now 100 % available to generate power as soon as transmission line 50700 is repaired. In Dominican Republic our generation plants and battery-based energy storage project kept the gird operational in extreme conditions.

The AES Companies' proven expertise in power systems and solutions around the world combined with local market intimacy in Puerto Rico allow us to align acute problems with the best solutions to maintain a low-cost, reliable power system. As the global market leader in battery-based energy storage, AESES has been quickly assessing and offering feasible, effective solutions for Puerto Rico's short-term recovery, which can provide emergency power to critical facilities such as hospitals or help key commercial and industrial facilities get back online. Additionally, we bring extensive knowledge and know how to what we do – our people's proven experience in and dedication to advancing the power sector is unmatched.

A Vision for Puerto Rico's Grid

Transmission and Distribution

Prior to Hurricane Maria, Puerto Rico's grid, similar to many other island grids, had transmission system that primarily went around the circumference of the island, with the main transmission lines delivering power to San Juan (50900 and 51000) running through the mountains in the center of the island.

The circumferential design was a cost-effective way to ensure that power could be delivered from generators to coastal load centers. However, this design left the island at the risk of large scale outages if parts of the transmission system were disrupted, as happened after Hurricane Maria. This highlights a fundamental challenge—the fragile nature of the transmission system during extreme conditions. In large scale transmission system outages, load shedding often occurs exponentially. i.e., 10% of physical outage on transmission might result in 80% load shedding due to dependency on few transmission lines for power flows and system stability.

In general, island markets have some unique characteristics that set them apart from how we would traditionally plan and operate the mainland electric system as described in Table 1.

Table 1

Attribute	Island Grids	Mainland
Fuel prices	Tends to be high (imported fuel in many cases)	Tends to be low due to lower transportation costs and available supply
Power supply stack	Fewer generation units leading to significant gradation in cost	Wide variation of units and interconnected nature brings diversity in supply stack
Transmission	Usually sparse and not very networked	Highly networked with several redundancies available to meet contingencies
Loss of generation or transmission failure	High system impact due to generation loss or transmission failure	Generally options may be available due to highly networked transmission grid
System Restoration	Typically tends to be slow and expensive due to supply and labor scarcity	Tends to be faster due to assistance from neighboring regions and accessibility
System size, Improvement and Redesign Effort	Small, larger value for local system with any redesign	Large, consequently lower impact for any system redesign

It is important to factor these unique challenges that occur in island electric grids while thinking about a redesign of the electric system in Puerto Rico. In our view, there are several different ways that the electricity system could be redesigned to reduce large scale outages. These redesign ideas broadly fall into three categories:

1. **Meshed Transmission System:** A meshed transmission system has many pathways to deliver power from one location to another. These systems are designed to ensure that power can still be delivered from large generating stations to load centers even if other transmission lines are inoperable. Building a meshed system requires substantial investment in transmission infrastructure and potentially long lead times towards completion given the challenges associated with terrain and access issues. In addition, the

risk of transmission contingencies, particularly structural damage on towers, may still exist in extreme weather events.

2. **Fully Distributed System**: A fully distributed system does not require any central transmission infrastructure connecting load centers with large scale generation resources, and focuses on distributed generation at customer locations as the primary source of power during normal and emergency conditions. In this scenario, a majority or all of the customers are self-sufficient with respect to their electricity needs. The importance associated with a central T&D system becomes extremely minimal in this case, but with an associated increase in cost and potentially time to recover as discussed below.

3. **Mini-Grids with Hardened Critical Tie Lines**: We define a Mini-Grid as a small partially self-sufficient system that has the capability to serve a substantial portion of critical loads during emergency conditions and provide low cost power during normal operations. We generally define tie-lines in two categories – (1) Connect low cost generation to critical loads in Northern Puerto Rico (2) Connect certain neighboring mini-grids to take advantage of load and supply diversity and reduce restoration time. A system with mini-grids and Hardened[2] Critical Tie Lines would have the capability to serve load with lowest cost possible and under all type of conditions.

We envision these mini-grids could range in size from a few MW's to one serving all of San Juan. This is the solution we recommend for Puerto Rico. Mini-grids have many of the same properties as microgrids. They both have interconnected loads and generating resources

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[2] In the context of this discussion, weatherization means potential storm/hurricane hardening measures such as additional reinforcement on the footing of large transmission towers, elevating specific substations and similar measures to enhance resiliency.

able to operate either by themselves or while interconnected to a larger gird. The main distinguishing feature between a mini-grid and a micro-grid is **size, and in the case under consideration, the use of existing distribution systems of a utility**. A microgrid is generally a single site/building or small grouping of sites/buildings that share a common owner, whereas a mini-grid could be much larger, possibly the size of San Juan, and include many sites/buildings that do not share common ownership. A microgrid containing a single building can be a standalone mini-grid. It could also be part of a larger mini-grid that contains additional microgrids serving critical loads and other loads that may not all be fully self-sufficient without power from a larger island-wide grid.

Given the low cost of serving distribution connected load during normal operations, and low probability of significant load curtailment during natural disasters, the mini-grid with hardened critical tie-line design is the most effective and economical design framework for both normal system operations and during natural disasters. This system would help Puerto Rico take advantage of substantial cost declines in renewable energy generation and battery-based energy storage while taking advantage of existing low-cost, reliable generation on the island.

There are several reasons mini-grids with Hardened critical tie-lines are the most effective solution:

1. The operation of a mini-grid primarily relies on the distribution system, which tends to have a radial nature and proportional relationship between system outage and load shedding capability.[3] This is a direct advantage over a meshed transmission system where a transmission system outage can lead to an exponential increase in load shedding.

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[3] "*One of the primary differences between transmission and distribution systems is that problems on transmissions systems can cause large-scale blackouts over many states, while problems on distribution systems are usually more localized in nature, impacting generally fewer people*", Page 14, National Electricity Emergency Response Capabilities, U.S. Department of Energy, Office of Energy Policy and Systems Analysis, August 1, 2016

Continued on next page

2. Hardened critical tie-lines also provide the capability to loosely connect separate distribution systems to leverage the effects of reliability, economy and diversity by pooling distribution connected generation, storage and load.
3. Critical tie-lines also help connect large and low cost supply to distribution connected load during normal operations.

As highlighted in Figure 1, the mini-grid approach is advantaged both from the perspective of lowering cost to consumers and increasing reliability vs. the meshed transmission system or the fully distributed systems. A meshed transmission system would be more expensive and less reliable because it requires large and expensive upfront investment in transmission infrastructure while still having substantial exposure to weather-related risks with respect to load serving capability.[4] It also suffers from long restoration times due to labor, terrain and access issues – as experienced in Post-Maria restoration efforts right now.

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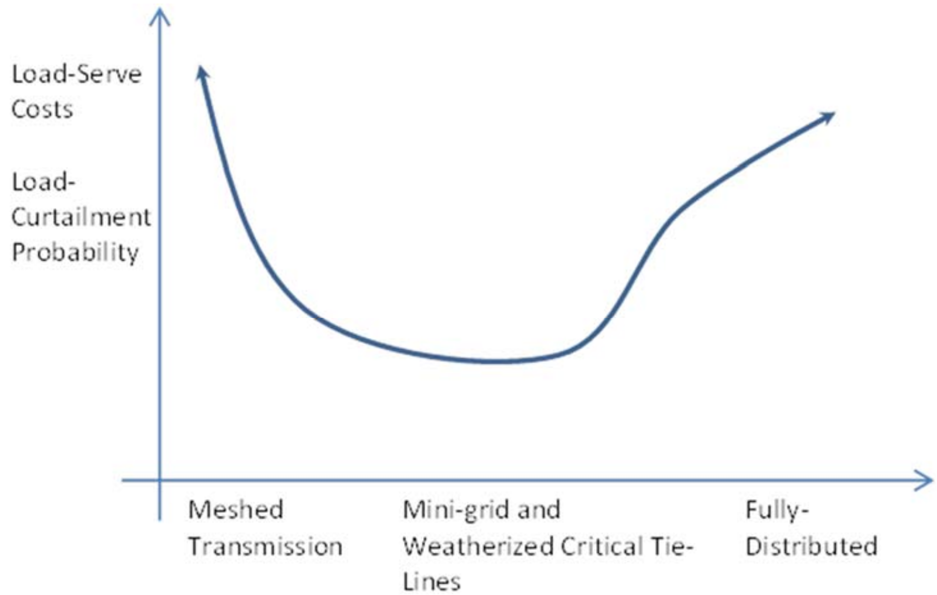
https://energy.gov/sites/prod/files/2017/01/f34/National%20Electricity%20Emergency%20Response%20Capabilities.pdf

[4] See Economic Benefits of Increasing Electric Grid Resilience to Weather Outages (2013), Executive Office of the President, August 2013 available at https://www.energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf

Figure 1



The fully distributed redesign may have higher reliability than the meshed transmission case during emergency operations, but will be significantly more expensive during normal operation.[5] Moreover, this design does not provide the best reliability/resiliency nor the lowest cost option. It also does not fully take advantage of the naturally occurring supply and load diversity in the system which is a hallmark of the mini-grid setup. If large portions of the fully distributed system were out of service due to damage, it could be slow and expensive to restore distributed generation back online on an individual customer basis. These costs may need to be borne by customers who may already be stretched in their capability to handle other storm damage. The individual customer level generation cannot be as well hardened as those facilities in a mini-grid setup. Therefore, it also increases the probability of significant derates or outages during hurricane type events. Of course, properly hardened backup systems for critical loads exist

[5] See Fox-Penner, Peter. "Why Solar 'Microgrids' Are Not a Cure-All for Puerto Rico's Power Woes." The Conversation, 8 Nov. 2017, https://theconversation.com/why-solar-microgrids-are-not-a-cure-all-for-puerto-ricos-power-woes-86437

today, are necessary, and should be expanded for improved resiliency going forward, but such system have a higher cost and are not practical for every point load.

The Future Generation Fleet

The current generation supply stack in Puerto Rico is primarily made up of fossil fuel power plants as shown in Figure 2. In particular, the two least expensive generators, AESPR and EcoElectrica, have long term contracts with PREPA. Additional generators include PREPA owned and managed gas generator Costa Sur and oil generators Aguirre, Palo Seco, San Juan, Mayaguez and Cambalache. The oil plants have significantly higher operating costs—many of which are above $150/MWh and a few exceeding $200/MWh.[6] They provided nearly 9,000 GWh of electricity in 2016, about 45% of total generation, and accounted for over 55% of the island's emissions and operating costs, as shown in Figure 2.[7] These units are primarily located on the southern and eastern coast so require access to transmission to serve the load centers which are predominantly on the northern and western coast. The generation units located near load centers, such as San Juan and Palo Seco are expensive in terms of $/MWh cost of electricity production and are also the oldest units in the generation fleet that serves Puerto Rico[8].

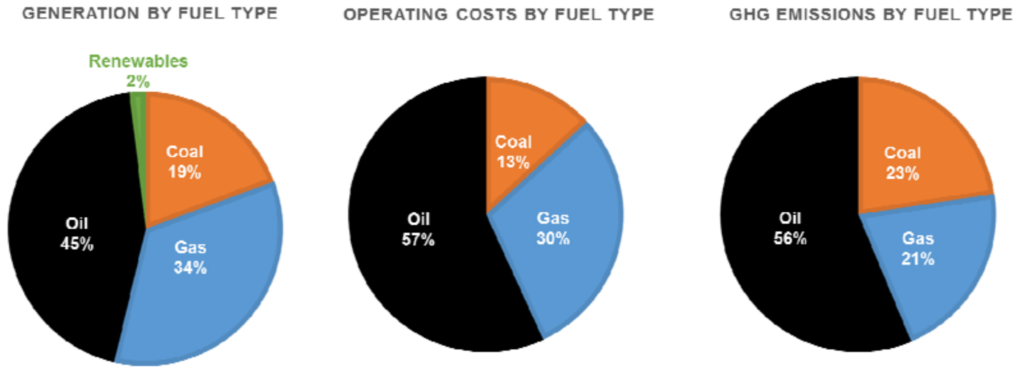
[6] Based on review of publicly available information from PREPA and Integrated Resource Plan (IRP) documents

[7] AES and RMI analysis of EPA, PREPA, and other publically available data.

[8] With the exception of units 5, 6 of San Juan which were repowered recently.

Figure 2: 2016 Energy Generation (MWh) and Operating Costs by Fuel Type

Fossil Generation accounts for majority of the energy supply



Notes: AES and RMI analysis of EPA and other publically available data.

The cost of solar PV generation has decreased precipitously over the past decade, and continues to decline globally. These cost declines have made solar cheaper than the fuel costs of existing generation plants, particularly in places with very high fuel prices.[9] As an example, AES is building a 20 MW, 5-hour energy storage project with a 28 MW solar project in the island of Kauai. This facility will ensure the renewable output from solar can be used during the peak load hours.[10] This would help the island offset the need to burn expensive fuel during evening peak loads.

In general, we believe solar PV generation in Puerto Rico would cost around $40/MWh-$50/MWh for **large (>50 MW), utility-scale energy** installations.[11] At these low costs, solar PV can economically provide a significant portion, if not the majority, of the electric energy need on the island—displacing the need to run the more expensive fossil units. Moreover, these solar

[9] Samans, Richard, and Michael Drexler. "Renewable Infrastructure Investment Handbook: A Guide for Institutional Investors ." www3.weforum.org/docs/WEF_Renewable_Infrastructure_Investment_Handbook.pdf

[10] Spector, Julian. "AES' New Kauai Solar-Storage 'Peaker' Shows How Fast Battery Costs Are Falling." Greentech Media, 16 Jan. 2017, www.greentechmedia.com/articles/read/aes-puts-energy-heavy-battery-behind-new-kauai-solar-peaker.

[11] These costs are consistent with the 2017 Lazard Levelized Cost of Energy. See: "Lazard's Levelized Cost of Energy Analysis — Version 11.0." Lazard, Nov. 2017, www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf

installations can be located closer to load centers aggregated at the mini-grid level to reduce reliance on transmission.

Based on a preliminary analysis of Puerto Rico's electricity system, we estimate a solar PV system producing up to 15,000 GWh of AC solar energy annually would be able to replace up to 12,000 GWh of expensive fossil generation. This over generation accounts for solar's production volatility during daily operation. This translates to about 10,000 MWdc/6,000 MWac of solar PV nameplate capacity. We understand that this number might sound large, considering that the peak load of Puerto Rico is less than 3,000 MW. However, it's important to note that the solar PV generation is used primarily to provide energy required for the system, and hence the seemingly excess solar capacity number is not relevant to our discussion here. In terms of land requirements, it requires approximately 2% of the landmass of the island to install this level of solar, based on Puerto Rico's solar insolation.[12] In such situations where unused land is constrained, solar PV generation can be added to already impacted terrain such as parking lots, rooftops, and closed landfills.

As the annual solar power resource exceeds the annual displaced fossil fueled energy, and peak solar power production during a day can exceed the load, energy storage is a natural and cost effective method of spreading the solar energy across other daily hours where load exceeds solar generation. For a long-duration battery-based energy storage system (BESS), e.g., 10-hour duration, the cost of using a battery storage each day system could potentially be between

[12] We assume 7.5 acres/MWac based on Table ES-1 from National Renewable Energy Laboratory Based on this assumption, the proposed 6,000 MWac would require approximately 2 billion square feet. This is approximately 2% of Puerto Rico's 96 billion square feet (8,959 square kilometers) of land area according to the Central Intelligence Agency's World Factbook. See Ong, Sean, et al. "Land-Use Requirements for Solar Power Plants in the United States." June 2013, www.nrel.gov/docs/fy13osti/56290.pdf and "The World Factbook: PUERTO RICO." Central Intelligence Agency, 14 Nov. 2017, www.cia.gov/library/publications/the-world-factbook/geos/rq.html.

$55/MWh to $65/MWh, provided that the BESS has a high energy utilization rate per day.[13] In this type of BESS usage, the integrated solar + storage system primarily shifts energy where costs should be measured in MWh, rather than in capacity services, where costs are measured in MW. This high battery utilization lowers cost per MWh of energy storage in the battery. Moreover, there are additional cost savings in pairing solar and BESS, related to their technical design. For example, the AESES PPA with Kauai Island Utility Cooperative was $110/MWh for a combined solar and BESS project.[14]

As described earlier, our analysis found that up to 15,000 GWh of annual solar energy (representing 10,000 MWdc of solar PV capacity) coupled with up to 25 GWh of BESS projects located all through the island distributed within the mini-grids would provide substantial value to customers. **The upfront capital cost of adding these new resources would be lesser than the present value of ten-year fuel costs of operating the existing high cost generation resources in the island while substantially increasing the reliability of the grid and reducing overall emissions**.[15]

For simplicity, our initial analysis was focused on solar resources, but other types of resource could also be cost-effective. For example, addition of a new LNG facility and combined cycle gas generation to support the San Juan region could be considered. In contrast to solar and storage, such a system would require extensive planning and permitting which could take several years by which time solar and storage would be less expensive than today.

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[13] With proper adjustments for size and duration these estimates are consistent with the Lazard's 2017 Levelized Cost of Storage Capital Cost Outlook for lithium ion based storage systems in 2022. See Lazard's Levelized Cost of Storage Analysis — Version 3.0." Lazard, Nov. 2017, https://www.lazard.com/media/450338/lazard-levelized-cost-of-storage-version-30.pdf

[14] Spector, Julian. "AES' New Kauai Solar-Storage 'Peaker' Shows How Fast Battery Costs Are Falling." Greentech Media, 16 Jan. 2017, www.greentechmedia.com/articles/read/aes-puts-energy-heavy-battery-behind-new-kauai-solar-peaker.

[15] The AES Companies' and RMI's high level, preliminary estimate of net present value of 10 years of generation cost for Puerto Rico is $16 billion with the existing fleet.

Wind generation would be a good fit if wind with solar is more correlated with load than just solar. The additional wind generation could reduce the need for storage by producing a flatter net load. Engines could also be a useful addition to the mini-grid, with their low fixed costs, ease of maintenance, and ability to run intermittently to support the mini-grids in the case of transmission outages caused by extreme conditions. This could serve as an effective insurance to prevent load shed during high load and low renewable periods or outages of other resources.

Improving Flexibility of Low Cost Generators on the Island

In addition to firming solar with BESS, low cost fossil generations can be incentivized to increase their operational flexibility through an increase in ramp capability, a decrease in minimum generation, and an improvement in heat rate. Base-load flexibility and efficiency provides (1) baseload power when needed, (2) load following capability when there is significant solar generation on the grid. The ability for fossil based base load capacity to reduce minimum generation is to allow more energy from least-cost solar PV, and to reduce the installation of BESS as there will be less solar production in excess of load. Moreover, flexible and least-cost fossil plants are a robust resource to support grid restoration, such as black start service and voltage stability service where frequent adjustments to operational set points are required.

IV. <u>RESPONSE TO QUESTIONS</u>

Appendix I – Microgrids in Unserved Areas

2. <u>**Placement and Availability**</u>

2.1. What are the advantages and disadvantages of focusing microgrid development on specific types of customer loads (e.g., large industrial loads, urban loads, rural loads, residential neighborhood loads)? Are some types of load profiles, or some geographic areas, better suited than others? What data exist to support your answer?

Mini-grids are most effective when they are able to meet the 4 characteristics outlined below:

- **Existence of Aggregated Loads**: When all of the loads are closely interconnected, the mini-grid can effectively and efficiently balance the load on the system.
- **Correlated Demand and Supply:** Highly correlated demand and supply enable the system to meet all of the real power needs on the system. This correlation can either occur due to their profiles or by utilizing dispatchable load and generation resources. This will also ensure the reactive power needs of the system are met in the most efficient way.
- **Ability to dispatch load flexibly**: Flexible load that can be dispatched to match mini-grid generation or changes in grid conditions makes the system more efficient.
- **Ability to serve Critical Loads during catastrophic conditions**: Critical loads (such as hospitals, public shelters, water treatment, law enforcement, etc.) should continuously have access to electricity. Effective mini-grids are able to prioritize these critical loads and ensure supply continuity at all times.

We do not think that mini-grid development should be focused on particular types of customer loads. Instead, mini-grid development should be focused on places with supply and demand that meets or is potentially able to meet the characteristics outlined above.

In the discussion below, we outline some of the characteristics of specific types of loads that need to be satisfied within a mini-grid. To this end, all the loads approach these “ideal load” conditions from differing dimensions.

Type of Load	Characteristics
Large Industrial	Very aggregated, high cost of energy disruptions, may have a flexible demand profile, and typically needs high power quality
Urban	Aggregated, balanced power quality, reasonably correlated with renewable generation, numerous possibilities to increase flexibility on load profile at low cost. This aspect should be studied and encouraged.
Residential Neighborhood	Somewhat aggregated, balanced power quality, numerous possibilities to increase flexibility.
Rural	Sparse, issues related to reactive power and voltage have to be considered, can encourage flexibility.

2.2. Regardless of the possible priorities to place on different types of loads, what are the most cost-effective paths to getting microgrid service universally available to all customers regardless of their locations?

The most effective design to ensure affordable, reliable, and resilient power is through mini-grids with hardened critical tie-lines.[16] Here are key design principles for such systems:

i. Normal operation should match generation and load to increase reliability at all times at the lowest cost.
ii. Operation during emergencies can serve >70% of critical load and >50% of all loads averaged on a bi-weekly rolling average basis.
iii. Power quality of the mini-grid should be sufficient to support operation during disaster conditions.
iv. Least cost existing generation facilities are kept with hardened critical tie-lines to serve local loads and optimize system wide costs operating costs and capital costs.
v. Loads should be aggregated to encourage correlation with low-cost generation, including fossil, and renewable, and storage capability.
vi. Distribution systems within each mini-grid design should be hardened at low cost to maintain reliability and decreased restoration time.
vii. Neighboring mini-grids should be connected via tie-line if economical to

[16] See the General section for a more detailed description of these systems.

a. Achieve generation and demand correlation during normal operations
b. Serve not more than 30% of critical loads and 50% of all loads averaged on a rolling average basis (if lines are out of service or derated, then local load should be adequately served)
c. Achieve decreased restoration time of critical loads in neighboring mini-grids by supplying power through restoring tie-lines.

viii. Encourage demand to correlate with renewable supply, and balanced power factors at load locations.

ix. Establish central locations where people can access electricity during emergencies.

2.3. What level of financial assurance will microgrid developers reasonably require before investing their own funds in Puerto Rico microgrids?

With any type of investment decision, investors need assurance that they would receive a rate of return commensurate with the level of risk associated with the investment. There are various commercial structures that can be adopted to provide mini-grid investors a reasonable return. Examples of these are Power Purchase Agreements (PPA) and cost-based rate of return.

In addition to long-term power purchase agreements, mini-grid developers could be incentivized through Build Own Transfer (BOT), turn-key Engineering Procurement Construction (EPC) contracts or any other commercial structure. The AES Companies recommends all commercial contracts be backed by financially credit-worthy counterparties as the most cost-effective way of incentivizing rapid deployments of mini-grids in Puerto Rico.

2.4. What can the Commission do to facilitate universal service in the restoration?

The AES Companies appreciate all of the hard work done by their employees in Puerto Rico, PREPA, the Federal Emergency Management Agency, non-profit groups, and all other people and organizations working to restore power and other essential services on the island. We encourage the commission to continue to conduct stakeholder processes such as these to actively consider innovative solutions should be continued and necessary steps be taken to implement any results out of these proceedings in the immediate future. This will ensure that the entire system can be designed, implemented and put into service clusters of mini-grids throughout Puerto Rico which will ensure quality universal electric service to all customers during normal and emergency conditions.

4. <u>**Generation Technology**</u>

4.1. Information provided to the Commission by Pattern Santa Isabel, LLC suggests that the Santa Isabel wind farm is operable, but lacks load and a source of energizing power. This condition could affect other renewable independent power producers, whose installations are operable but require power from PREPA to get back online.

4.1.1. Is there a technical solution to add a small solar or diesel generator to restart the wind farm, and storage to firm up the supply?

4.1.2. Is there load close to the wind farm that could be served from a microgrid based on the wind farm?

Like the Santa Isabel wind farm, there are other renewable generating facilities that are operable but lack either the energizing power or load to connect to the grid. Battery based energy storage presents a technology that can both serve to energize generation facilities, as well as provide grid balancing services to these generators such that they can provide high quality energy to the grid, during emergency and normal operating conditions. There are several advantages to using battery based energy storage for these applications:

- <u>Twice the resource</u>: source and dispatchable load, which is very valuable for frequency control when starting the grid up from zero.
- Instantaneous response to support critical loads (e.g., other plants in the region like Pattern Santa Isabel)
- Ability to provide real and reactive power in order to serve loads and stabilize the grid.
- Digital or synthetic inertia capability to instantaneously provide grid frequency control - Recent research in Northern Ireland found that "360 MW of batteries could have provided

the same amount of power after 0.1 seconds as the inertial response of 3000 MW of synchronous generators"[17].

- Reduced technology and fuel risk (resource diversity)
- Overrate capability: fewer MW delivers same capability
- Easier siting and Scalable

Energy Storage Storm Resilience in the Dominican Republic

Recent examples of how energy storage is providing grid balancing services to keep critical generation online are AES' two Advancion energy storage arrays deployed at their generation facilities, Andres and Los Mina Dominican Power Partner (DPP) in the Dominican Republic. The two Advancion arrays are each 10 MW, 30-minute duration energy storage arrays providing frequency response to the grid.

On September 7th, 2017, the Dominican Republic was in the path of Hurricane Irma, a Category 4 storm originating in the Atlantic Ocean with torrential rain and wind speeds of 155 mph. More than 5,500 people were evacuated from the Dominican Republic in anticipation of the hurricane that resulted in storm surges, flooding, and destruction across the island. In anticipation of Hurricane Irma's arrival, the grid operator requested that both the Andres and Los Mina DPP energy storage arrays be kept online and operational during the storm. The two energy storage arrays are unmanned facilities co-located within or next to thermal operating plants. They are operated by the thermal plant control room and are remotely monitored by the AESES Services Team to ensure proper operation and to provide the local operators with remote assistance if required. As the storm struck, almost 40% of the generation assets on the island were forced to shut down and several transmission and distribution circuits were cut off, putting additional stress

[17] Reynolds, Paul, et al. "Batteries: Beyond the Spin." Everoze, Commissioned by AES, Oct. 2017, info.aesenergystorage.com/hubfs/Collateral/Everoze%20-%20Batteries%20Beyond%20the%20Spin.pdf?t=1510890229557

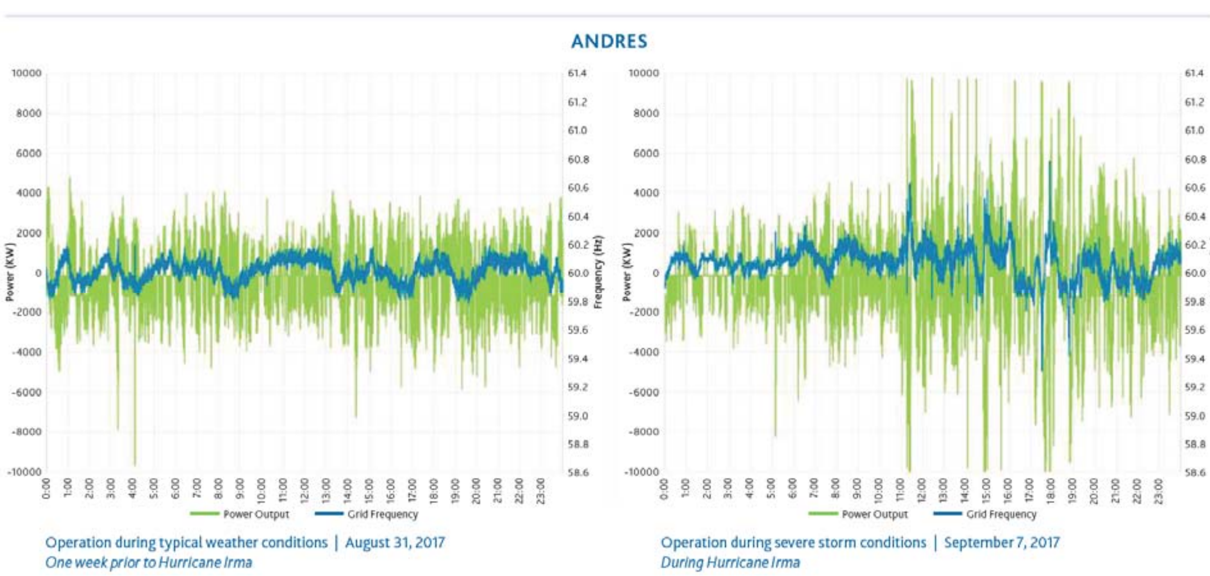
on the system. There were some periods during the storm that only a few power plants and the Advancion energy storage systems were online.

During the storm, power lines were damaged, distribution lines were disconnected in zones that had risk of flood or high winds, and some power plants had to go offline. These events resulted in volatile fluctuations in grid frequency during the hurricane, and both energy storage arrays performed significantly more work than usual in order to stabilize the frequency.

The Andres array, housed in a building enclosure, is a 10 MW, 30-minute duration energy storage system installed in June 2017 in Santo Domingo. The graph below on the left shows the measured frequency and corresponding power output of the Andres energy storage array under typical operating conditions. The grid frequency in the Dominican Republic is maintained within their standard operating frequency band of approximately 59.8 to 60.2 Hz with the MW output of the energy storage unit ranging from +4.8 MW to -9.7 MW to counterbalance the changes in frequency.

Figure 3: Frequency Control Provided by AES Energy Storage Arrays During Hurricane Irma

Energy storage continuously provided frequency control during hurricane conditions.



The graph above on the right shows that the measured frequency range increased significantly during the storm, moving from 59.3 to 60.8 Hz, and the energy storage system charged and discharged at maximum capacity (10 MW) on a number of occasions to quickly rebalance the system. The period of increased frequency disturbances lasted for more than 10 hours and the Andres energy storage array delivered 56.5% greater energy throughput than under typical operating conditions.

Severe storm conditions created significant deviations in grid frequency and the energy storage systems provided rapid response to counteract these deviations, maintain the target frequency, and support grid resiliency and stability. No energy storage outages were experienced at either site and the arrays maintained a total combined capacity of over 20 MW for the entire duration of the storm, demonstrating the technology's capability to perform continuously without issues and provide responsiveness under times of grid duress. During the storm the arrays went from a typical operating range of approximately +5 MW to -9.8 MW each, to a wider range of +9.8 MW to -10 MW each, effectively requiring an additional +/-5 MW each, or 10 MW total to maintain a balanced frequency.

4.2. Are there any existing solar facilities that could be firmed up with storage and connected to load?

Yes, all of the existing solar generation in the island including AES Illumina can be firmed up using energy storage resources. At least one-third the MW capacity of solar generation should be added in the form of energy storage with several hours of duration to make the resource dispatchable.[18] This is different from existing Minimum Technical Requirements (MTR) which only manage rate of change of solar PV output requirements over a short amount of time (minutes).

[18] Denholm, Paul, et al. "Evaluating the Technical and Economic Performance of PV Plus Storage Power Plants." National Renewable Energy Laboratory, www.nrel.gov/docs/fy17osti/68737.pdf.

As described earlier, AESES is currently building a 20 MW, 5-hour energy storage project with a 28 MW solar project on the island of Kauai to make sure that the renewable output from solar is aligned with the peak load conditions.[19] This would help the island offset the need to burn expensive fuel to serve evening peak loads.

Earlier this year, in just 6 months, AESES built the largest lithium-ion battery-based energy storage project in the world with SDG&E; the 30 MW/4-hour Advancion project deployed at Escondido, as well as an additional 7.5MW/4-hour project in El Cajon. These two projects are currently providing 37.5 MW of flexible capacity to communities in the San Diego region, reinforcing the utility's commitment to ensuring the highest level of reliability and delivering more clean energy for its customers. Delivering both systems at the same time has drawn global attention to storage's ability to serve as flexible capacity, and is a testament to storage's ability to respond to critical grid needs. California's accelerated integration of storage illustrates the ability of suppliers like AESES to meet demand in a matter of months, not years.

4.3. For generation facilities under contract with PREPA, how would use of those facilities to serve a microgrid affect PREPA's contract?

4.3.1. Can a party other than PREPA develop a microgrid from such a facility?

We suggest that the physical dispatch of the generation facilities under contract with PREPA be separate from the financial settlement of contract with the supplier. We propose a construct similar to long term power purchase agreements in RTO's (California has such a system). Under this process, the system operator is responsible for dispatching the least cost plants to serve the system needs. These generators are later compensated consistent with the terms of the power purchase agreement by their counterparty. There may also be several

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[19] Spector, Julian. "AES' New Kauai Solar-Storage 'Peaker' Shows How Fast Battery Costs Are Falling." Greentech Media, 16 Jan. 2017, www.greentechmedia.com/articles/read/aes-puts-energy-heavy-battery-behind-new-kauai-solar-peaker.

technical issues to be resolved like the point of interconnection of existing generation facilities and voltage levels of proposed new mini-grids.

If the mini-grid or similar case were pursued, we propose the consideration of such a construct for PREPA's contracts. Facilities can be dispatched to serve the mini-grids if they are the most cost-effective resource, but the financial settlement is still done by PREPA consistent with the existing power purchase agreements. We suggest the Commission take steps in the settlement process to ensure the benefits of PREPA's low price contracts, such as the one with AES Puerto Rico, are shared with all customers, not just the ones being physically served by the plant.

4.4. Can any of PREPA's hydro-electric facilities be firmed up with storage and connected to load?

Yes, PREPA's hydro-electric facilities can be firmed up with storage. This application of battery based energy storage is currently being done in Virginia.[20]

4.4.1. Can other parties use those facilities to serve local load?

Other parties should be able to use existing generation to serve local load.

4.4.2. What arrangements would be needed with PREPA to implement this option?

We suggest a construct similar to the one proposed in 2.3.

4.5. Is it legal, practical, and necessary for solar-storage or wind-storage microgrids to have some fossil fuel back-up capacity?

In certain circumstances it may be beneficial to have fossil generation capacity available as backup, as mentioned above in section III. We suggest mini-grid developers be allowed to choose the best resources to fit their system needs.

[20] Maloney, Peter. "AEP, Greensmith Team up for Storage+Hydro Project in Virginia." Utility Dive, 20 Oct. 2017, www.utilitydive.com/news/aep-greensmith-team-up-for-storagehydro-project-in-virginia/507726/.

V. **CONCLUSION**

The AES Companies respectfully submit these comments to the Commission for consideration. The Commission should take these comments into account in formulating future decisions related to grid redesign.

Respectfully Submitted:

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