GOVERNMENT OF PUERTO RICO
PUBLIC SERVICE REGULATORY BOARD

PUERTO RICO ENERGY BUREAU

IN RE: OPTIMIZATION PROCEEDING OF MINIGRI TRANSMISSION AND DISTRIBUTION INVESTMENTS	**CASE NO.** NEPR-MI-2020-0016 **SUBJECT:** QUESTIONS FOR STAKEHOLDERS

CAMBIO And IEEFA Answers to Questions for Stakeholders

To the Puerto Rico Energy Bureau:

On behalf of CAMBIO and the Institute for Energy Economics and Financial Analysis (IEEFA), we provide the following answers to the Bureau's March 24, 2021 questions to stakeholders:

Questions 1-3

Regarding Questions 1-3, we urge the Bureau to also ask PREPA what loading criteria were used in the design of these projects, e.g., the wind speed they are designed to withstand. This information would help determine whether these projects include the cost to increase the resiliency of these lines.

As discussed in the attached Affidavit of Ray Harold, the engineer who conducted the Puerto Rico Distribution Modeling study filed by CAMBIO and IEEFA in this proceeding on March 11, 2021, undergrounded lines are threatened by flooding and liquefaction. It would be useful to know what, if any, mitigations are included to address these factors. Indeed, amongst Puerto Rican municipalities San Juan is ranked #1 in liquefaction hazard susceptibility according to the Hazard Risk Assessment Report prepared as part of the CDBG-MIT process[1] which raises significant questions about why undergrounding in that area would make sense.

[1] Christopher Emrich and Yao Zhou, Puerto Rico Hazard Risk Assessment Report, July 2020, p. 221.

We would strongly encourage the Bureau to supplement its request to PREPA with additional questions covering these topics.

Question 5

CAMBIO and IEEFA urge the Bureau to consider widespread deployment of residential DERs (rooftop solar and storage) as a "no regrets" solution that provides the surest way to avoid loss of life in the event of another major hurricane. Resiliency at the level of individual homes provides critical services including: refrigeration of medication, operation of life-saving medical equipment, ability to refrigerate and prepare food, and the avoidance of crowding in shelters (particularly important if there were another pandemic). We note that Act 17-2019 gives the Bureau the power to define homes as "essential service facilities."[2] Furthermore, rooftop solar and storage systems that provide a basic level of household resiliency[3] can be considered "no regrets" because they enable the following:

- The ability to continue providing service to critical loads at homes so as to avoid loss of human life amidst various possible grid interruptions, including: natural disasters, fuel supply or other supply chain disruptions (given PREPA's fiscal crisis or worldwide issues that affect supply or markets), closing of borders due to future pandemics or other worldwide disruptions, a terrorist attack on major assets, etc.
- Maximization of local renewable energy resources, in compliance with Puerto Rico's approved renewable portfolio standard
- Minimization of system losses by placing generation near load
- Reduced dependency on transmission / distribution lines to address critical loads

Widespread residential DER deployment could be achieved using available FEMA funds. The grid modeling studies recently published by CAMBIO and filed in this docket indicate that equipping 1 million homes in Puerto Rico (roughly 100%) with solar and storage systems would require 2,700 MW of PV and 11.4 GWh of storage. This would cost approximately $9.2 billion ($8.1 billion in 2020 dollars) to deploy between now and 2030.[4] A recent letter from FEMA to Senator Schumer indicates

[2] Act 17-2019, Section 1.9(3)(K).

[3] A 2.7 kW system with battery storage, as proposed in the CAMBIO studies, can meet basic household needs including refrigeration, lighting, laundry and small appliances.

[4] We arrived at this estimate by using the same annual trajectory of residential PV and storage costs used in the CAMBIO studies but accelerating the deployment of residential solar and storage systems to complete deployment by 2030.

that federal funds could be used for this purpose.[5] PREPA could procure systems using FEMA funds and enter into legal arrangements to provide them to participating households. The rollout of this program could prioritize the communities that waited the longest to have service restored after Hurricane Maria (see figure below), keeping in mind that, as the CAMBIO studies demonstrated, stress on distribution lines is mitigated most thoroughly when an entire feeder is "treated" with DER solutions.

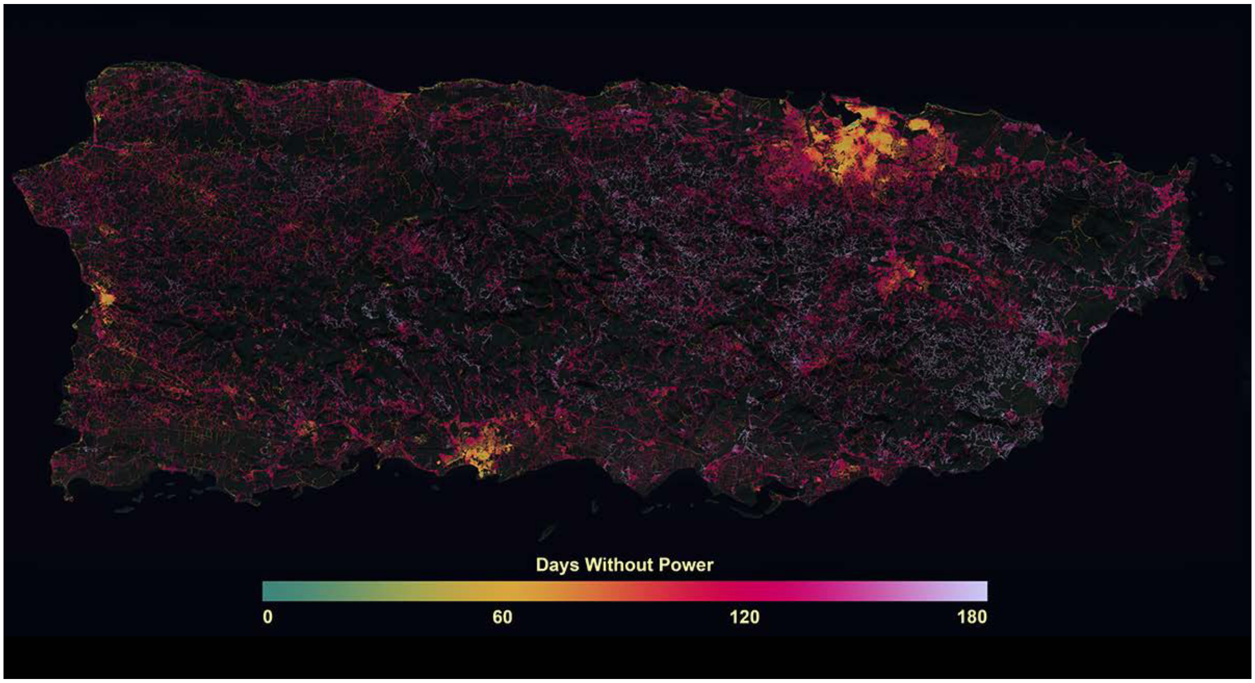

Figure 1. Days without power after Hurricane Maria. (Source: Universities Space Research Association, 2019)

Question 6

We believe that the resiliency value of any particular solution should be gauged by its ability to avoid loss of life during a major storm, earthquake or other grid disruption, as opposed to trying to put a dollar value on resiliency. If avoiding loss of life is, in fact, the overarching goal, we believe that DERs are more suited to meet this goal than transmission and distribution system hardening, which do not eliminate the risk of extended outages, as described in more detail in the attached affidavit of Ray Harold.

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[5] In a February 8, 2021 letter to Senator Chuck Schumer, the Regional Administrator for FEMA Region 2 wrote, "There are no governing statutes, regulations, or guidance that prohibit Puerto Rico or PREPA from pursuing and proposing power grid projects that support renewable generation and storage in their recovery solutions."

As such, cost-benefit analysis, which would require putting an arbitrary monetary value on human life, is not a meaningful exercise. We also note a recent IEEE report that points out:

> There is no widely accepted or standardized method or publicly available solution that can be used to perform benefit-cost analyses involving improvements to system resilience. Current approaches in the resilience valuation have limitations as they do not appropriately capture the potentially devastating consequences of not having adequate resilience. For example, prolonged outages lasting weeks is no longer just a mere inconvenience but results in significant pain and suffering or even deaths that are not straight forward to assign a monetary valuation.[6]

The Bureau has suggested deployment of DER resources if the cost of such resources is less than their resiliency value plus avoided T&D costs.[7] LUMA has suggested a more elaborate cost-benefit framework that may include deferred capacity, renewables integration capacity, emissions reduction, energy savings, ancillary services and the value of resiliency.[8] These metrics seem to imply a valuation of human life in order to adequately value resiliency. We anticipate that these cost-benefit assessments will ultimately delay deployment as parties argue over how to make that quantification and what weight to assign to other potential benefits or costs of DER.

We further note that some of the typical costs and benefits of DER may not be applicable in the Puerto Rican context. For example, LUMA has stated that DERs may be less reliable than grid-level resources in their ability to operate over an extended duration, and that "particularly remote DERs may take longer to repair and restore."[9] While these statements may be true in a typical U.S. or Canadian context, they were clearly not true after hurricane Maria, relative to the time required to restore centralized grid service to many parts of the island. Properly installed rooftop PV systems, on the other hand, were able to withstand hurricane conditions. Further, attempts to value DERs may require a higher level of data and functionality of the electrical system than currently exists. For example, LUMA has asserted in the Performance Metrics docket that "PREPA does not currently allocate [line] losses to the components of the system," which would appear to make it difficult to accurately value avoided T&D losses from specific DER projects.[10]

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[6] IEEE Power & Energy Society, Resilience Framework, Methods, and Metrics for the Electricity Sector, October 2020.

[7] Puerto Rico Energy Bureau, Optimization Workshop #3, Case No. NEPR-MI-2020-0016, March 23, 2021, slide 36.

[8] LUMA Energy, Resilience Optimization Technical Workshop – LUMA's response, Case No. NEPR-MI-2020-0016, March 23, 2021, p. 15.

[9] Ibid., pp. 15-16.

[10] LUMA's Performance Metrics Targets, Case No. NEPR-AP-2020-0025, February 24, 2021, p. 7.

For these reasons, we believe it is more appropriate to adopt resiliency solutions that prioritize DERs for their ability to meet critical needs (including critical household loads) through a Category 4-5 storm.

Question 7

The most rapid deployment of DER solutions could be achieved by directing PREPA to use FEMA funds to procure rooftop PV and storage systems. PREPA could install these systems and enter into contractual arrangements with customers such that PREPA retains ownership over the assets. The use of federal funds would ensure that low-income households would also be able to participate in resiliency solutions, creating a more equitable outcome in line with Law 17-2019. And PREPA's ability to prioritize deployment of DERs would ensure that (a) areas that have historically waited the longest to have service restored could be high priority; and (b) DER installations along a feeder could be coordinated with any necessary distribution system upgrades.

Question 8

(a) We caution that we don't think that microgrids should be a primary focus of PREPA or the Bureau if the goal is the "most rapid deployment of distributed energy solutions" (as stated by the Bureau in Question 7). In our experience, the design, engineering and deployment of microgrids is very time-consuming (multiple years), while a similar capacity of rooftop solar and storage solutions can be deployed within months. Puerto Rico does not have time to waste.

(b) We believe deployment would be facilitated more effectively and rapidly through PREPA's use of federal funds, as described previously.

(c) Yes, we believe that PREPA and its workforce should be directly involved in the installation and maintenance of rooftop solar and storage systems. This would not only accelerate adoption of rooftop solar and storage, which is in accordance with Act 17's support for "prosumers", but would ensure that such expansion of "prosumers" is equitable by allowing low-income communities to also participate and share in the benefits of renewable energy. Additionally, this arrangement would align with Act 17's principles that underscore every customer's right to reliable service (Section 1.5(10)(a)) and that seek to "accelerate" distributed generation (Section 1.6(9)).

Question 9

As above, we believe that individual solar/storage solutions can be deployed more rapidly than microgrids and should be prioritized for this reason. Also, to our knowledge, there is no public version of IRP Appendix 1.

Question 10

(a) DER solutions should be paid for with federal funds, as described previously. We note that the March 2021 update to PREPA's 10-Year Infrastructure Plan now includes over $14 billion in FEMA 428, 404 and 406 funds. As stated previously, procuring PV and storage systems for 1 million homes in Puerto Rico would require an outlay of only $9.2 billion, plus a modest amount for distribution system upgrades. (The CAMBIO studies identified $650 million in distribution system upgrades required to accommodate the scenario of 75% distributed renewable energy by 2035, including 1 million resilient homes).

(b) As indicated before, resiliency should be gauged by its ability to avoid loss of life and within this context, discussion should focus on critical loads, not on whether their purpose is public or private. DER solutions to address critical loads can and should be procured and deployed by PREPA using federal funds, whether those loads are public or private. There should be a preference to ensure DER deployment by PREPA to address critical loads in low-income communities, as these communities are less likely to have other procurement/financing options.

Question 11

We reiterate our disagreement with the premise of using cost-benefit analysis to "optimize" between DERs and hardening approaches because we do not believe that these approaches provide the same level of service in response to a major (category 4-5) storm. PREPA and LUMA have thus far not indicated what their anticipated service restoration time would be if the transmission and distribution hardening solutions they propose were implemented. Based on the attached affidavit, these solutions could result in significant delays in service restoration, whereas DER solutions could serve critical loads, including critical residential loads, minimizing interruption.

CERTIFICATE OF SERVICE

We hereby certify that on April 14, 2021, we have filed this Response via to: comentarios@energia.pr.gov, secretaria@energia.pr.gov, kbolanos@diazvaz.law, astrid.rodriguez@prepa.com, jorge.ruiz@prepa.com, n-vazquez@aeepr.com, c-aquino@prepa.com; fabiola.rosa@prepa.com, marisol.pomales@prepa.com, vilmarie.fontanet@prepa.com; jmarrero@diazvaz.law; mario.hurtado@lumamc.com; wayne.stensby@lumamc.com; Ashley.engbloom@lumamc.com; Legal@lumamc.com; margarita.mercado@us.dlapiper.com; Elias.sostre@aes.com; jesus.bolinaga@aes.com; cfl@mcvpr.com; ivc@mcvpr.com; notices@sonnedix.com; leslie@sonnedix.com; victorluisgonzalez@yahoo.com; jcmendez@reichardescalera.com; r.martinez@fonroche.fr; gonzalo.rodriguez@gestampren.com; kevin.devlin@patternenergy.com; fortiz@reichardescalera.com; jeff.lewis@terraform.com; mperez@prrenewables.com; cotero@landfillpr.com; geoff.biddick@radiangen.com; hjcruz@urielrenewables.com; carlos.reyes@ecoelectrica.com; brent.miller@longroadenergy.com; tracy.deguise@everstreamcapital.com; agraitfe@agraitlawpr.com; h.bobea@fonrochepr.com; ramonluisnieves@rlnlegal.com; hrivera@oipc.pr.gov; info@sesapr.org; yan.oquendo@ddec.pr.gov; acarbo@edf.org; pjcleanenergy@gmail.com; Jmadej@veic.org; nicolas@dexgrid.io; javrua@gmail.com; JavRua@sesapr.org; lmartinez@nrdc.org; thomas.quasius@aptim.com; rtorbert@rmi.org; tjtorres@amscm.com; lionel.orama@upr.edu; noloseus@gmail.com; aconer.pr@gmail.com; dortiz@elpuente.us; wilma.lopez@ddec.pr.gov; gary.holtzer@weil.com; ingridmvila@gmail.com; rstgo2@gmail.com; agc@agcpr.com; presidente@ciapr.org; cpsmith@unidosporutuado.org; jmenen6666@gmail.com; cpares@maximosolar.com; CESA@cleanegroup.org; acasepr@gmail.com; secretario@ddec.pr.gov; julia.mignuccisanchez@gmail.com; professoraviles@gmail.com; gmch24@gmail.com; ausubopr88@gmail.com; carlos.rodriguez@valairlines.com; amaneser2020@gmail.com; acasellas@amgprlaw.com; presidente@camarapr.net;

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IN RE: OPTIMIZATION PROCEEDING OFMINIGRID TRANSMISSION AND DISTRIBUTION INVESTMENTS	**CASE NO.: NEPR-MI-2020-0016** **SUBJECT:** Responses to Questions to Stakeholders

AFFIDAVIT OF RAY HAROLD

I, Ray Harold, under penalty of perjury, declare as follows:

1. I am a magna cum laude graduate of Kansas State University, with a degree in electrical engineering. I am a licensed professional engineer in the State of Kansas.

2. I have worked as a transmission and distribution engineer and consulting engineer since January 1984. I have worked directly for multiple electric utilities, as well as several transmission and distribution consulting firms during my tenure. I have written papers for CEATI on storm hardening of distribution assets, as well as the analytical techniques to be applied to the analysis of photovoltaic systems to electrical distribution systems. I have testified as an expert witness before several US courts as well as the Federal Energy Regulatory Commission.

3. I performed extensive analysis of the cost and relative efficiency of undergrounding distribution lines for both Kansas City Power & Light and Midwest Energy in coordination with applications for storm damage relief from applicable Federal and State Agencies.

4. I have worked extensively throughout the Caribbean, on a variety of projects. This has included a presentation to the Carilec CEO and Carilec Engineering and Procurement conferences on resiliency and storm hardening. I have provided services for St. Vincent, St. Lucia, the Bahamas, Barbados, the Turks and Caicos, Jamaica, Grenada, and Puerto Rico. I believe my direct experience with the structure of island utilities, allows me to make relevant commentary on the applicable subject.

5. I am aware that wholesale replacement of overhead distribution lines with comparable underground lines is a very common response for regions subject to various weather-related hazards such as ice stormer, tornados and hurricanes. It appears to laymen observers and regulators to be a “permanent” solution to the issue of weather-related outages and the attendant repair costs. For

utility personnel, this is not necessarily the case. The inherent flaws with this approach include:

- Long term replacement costs, often within a relatively short period;
- Non-weather-related cable failures and attendant replacement times;
- Exposure to alternate, development-related hazards (i.e. dig-ins);
- Longer repair and replacement times when failure eventually occurs.

The factors listed above are significantly impacted by the strategies employed during the replacement process, such as direct burial versus installation in conduit, use of the most inexpensive cable insulation available to minimize the initial capital investment, and the relatively high cost of upgrading underground facilities subsequent to initial installation.

6. There are two issues associated with the long-term replacement costs of wholesale undergrounding efforts: infant mortality and long-term degradation of insulation. Infant mortality refers to cables and accessories that fail immediately or shortly after initial installation. In the early 1980's (circa 1983) the Missouri Public Service Commission issued a rule that all electrical power distribution lines installed by independently owned utilities (IOUs) within residential subdivisions would be installed underground as a reaction to multiple storm-related, extended outage events primarily in Kansas City and St. Louis. As this rule was implemented the infant mortality of underground cable systems, particularly Underground Residential Utility (URD) increased significantly, partially due to equipment defects but for the most part due to the substantive increase in installations and the associated time constraints. These infant mortality instances exacerbated the already increased costs associated with undergrounding the utility lines, along with the public perception of the reliability of the electrical grid. Infant mortality rates of various types of underground equipment, as analyzed by KEMA, include:

- Direct cable failures – 14%
- Termination failures – 52%
- Joint / Splice failures – 42%

Analogously, wholesale replacement programs performed in the mid-seventies throughout the Kansas City metropolitan area resulted in an unusually high failure rate in the mid-eighties, as the manufacturing flaws associated with both the cable and accessories began to surface. Of import was the high failure rate of cross-linked polyethylene cable (XLPE) due to water incursion into the insulation. Because a significant amount of this cable was installed "direct buried" (i.e. not in conduit), the replacement process was both expensive and time consuming. While the failure rate of XLPE cables has declined with improved manufacturing techniques and insulation design (particularly tree-resistant XLPE), when contemplating a replacement program of the magnitude suggested for Puerto Rico, there is an obvious risk of long-term manufacturing defects that could appear well after the initial installation effort, representing a significant financial and reliability risk to the Puerto Rico grid.

7. The replacement costs of underground versus overhead distribution lines is highly dependent upon the approach employed. If a least-cost approach is used, the relative premium for underground lines versus overhead lines may only be 30 – 40 %. If an apples-to-apples comparison, relative to reliability, is performed (i.e. using closely spaced steel or oversized poles versus using EPR cable, sized to accommodate growth, in conduit) the initial capital investment cost may be as high as a factor of 1.8 to 2.5, contingent on local wage rates. The initial installation timeframe is even more dramatically different, particularly in an island environment, where the road right of way and geospatial challenges for undergrounding may be dramatically increased. This may result in an implementation period 1.5 to 2 times greater than overhead replacement. The Mean Time To Repair (MTTR) for underground lines is as much as 10 times longer than for overhead lines, per NEI Engineering analyses. Thus, undergrounding represents both an initial and long-term risk to the Puerto Rico grid in terms of cost and reliability.

8. There is substantive risk on Puerto Rico for non-weather related failures associated with human and geologic events. In urban areas of high development (i.e. the San Juan region) the likelihood of dig-ins without a robust 1-Call utility locating system is quite high. Historical statistics from the Kansas City metropolitan area indicated that dig-ins accounted for nearly 20% of the cable related outages, while rural areas were in the 3 – 5% range. Additionally, Puerto Rico is a relatively unstable seismic zone, exposing underground utilities to ground liquification hazards that may wipe out large swaths of underground distribution systems in a matter of minutes, leading to very extended outages as replacements (either overhead or underground) are contemplated. The attendant threat of flooding washouts associated with hurricanes or other major weather events also exist for underground lines, necessitating both expensive and long-duration replacements.

9. The alternative of building overhead lines to withstand a Category 5 hurricane exposure has been widely discussed within the Caribbean utility community. Some utilities claim to have achieved this, though the extent to which it has actually been achieved has yet to be fully tested. The principle is to install either steel or significantly oversized wood poles, spanned at short lengths accompanied by storm breaks to mitigate cascading failures. This technique is substantially more expensive than normal overhead construction, obviously, but is more robust in terms of the ability of the structural system to support much higher wind profiles. What is problematic, however, is the

inability of this approach to mitigate vegetation related risk. Most island environments are replete with heavy vegetation due to the climate and agricultural activities. It is essentially impossible to protect the intervening phase conductors from damage, even if the support structures remain intact. This approach obviously represents an improvement over the current conditions, but is not necessarily a panacea, and has associated risk. Replacing poles and attendant support infrastructure, when necessary, following a major hurricane will have a much longer lead time than replacing standard distribution equipment. Getting the wire back in the air will likely be quicker than if both the poles and wire are on the ground, but there almost certainly be extended outages, particularly in areas with heavy vegetation.

10. In summary, both undergrounding and overhead hardening have substantive costs and risks associated with them. In either case, they represent an improvement to the status quo, but do not provide the same level of household resiliency as alternate resource decentralization proposals. A realistic, rigorous comparison of these alternatives – and a recognition that transmission and distribution hardening proposals do not eliminate the risk of extended outages following a hurricane or seismic event - is warranted given the magnitude of the proposed investments.

I declare under penalty of perjury that the foregoing is true and correct to the best of my information, knowledge, and belief.

Ray C. Harold

Digitally signed by Ray C. Harold
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Ray Harold, PE

April 14, 2021