February 1, 2018
Mayagüez, Puerto Rico

Written Testimony to the Financial Oversight and Management Board (FOMB) for Puerto Rico (submitted via email to comments@oversightboard.pr.gov)

Listening Session on the Future of Puerto Rico's Electric Utility
February 1, 2018
Alexander Hamilton U.S. Custom House
One Bowling Green in New York, NY

Members of the Board:

We are professors and researchers of electric power systems and power electronics[1] who have accepted "a personal obligation to our profession, its members and the communities we serve"[2]. Some of us have been teaching and studying electric energy matters in Puerto Rico since the late 1990s. We present our collective and personal vision to transform Puerto Rico's electric power infrastructure through sustainable energy technologies and strategies.

Key ideas that should guide our path to a more sustainable and resilient electric energy infrastructure are:

1. **No tax to the sun:** Taxes must not be imposed on using the sun to produce electric energy independent from the grid.
2. **No penalty to grid defection:** Penalties must not be imposed on those that abandon the grid to secure a safe return on investment at the expense of people's freedom to choose.
3. **Transition to distributed energy:** The distributed energy approach, in particular solar PV systems in rooftops, must be favored because of its consistent decreasing cost trend and the advantage to provide short term resiliency after disasters.
4. **No large rigid generation:** The number of large, fossil-based power plants must be reduced, and the remaining ones must have a new role of supporting an increased use of local energy resources (smaller, more flexible and providing ancillary services, not just selling kWh).
5. **Transition to citizen-owned generation:** Citizen owned generation must be favored to facilitate much needed private investment. Privatization of state-owned power plants cannot move us from a state owned monopoly to a private monopoly. If private generation exists it must be provided with an opportunity to make business and no

[1] See Attachment 1.

[2] *Code of Ethics of the IEEE* (Institute of Electrical and Electronics Engineers), http://www.ieee.org/about/corporate/governance/p7-8.html

warranties of profit. Private investors must be willing to take the risk associated with technological change and cannot oppose citizen-owned (i.e., private) generation.

6. **Fair regulatory framework:** We must have regulatory certainty in order to explore new ways to manage, operate and control the power grid that are better suited for a distributed energy infrastructure.
7. **Technological Opportunities:** Eolic generation in places where it is socially and environmentally acceptable. Electric vehicles deployment of charging stations around the island. Ocean waves generation has a real opportunity for commercialization in PR and must be supported.
8. **Socio-economic development opportunities:** Energy technologies can be manufactured in PR. In fact, in the past, inverters have been manufactured, and PV panels assembled locally. Market conditions at the time were not favorable, but we do have the capability to manufacture controllers and communication equipment as well as energy efficiency technologies. For example, hundreds of indoor LED luminaries where manufactured and installed in UPRM buildings (the product achieved UL certification). Financing options should be established to purchase high efficiency equipment (e.g., inverter-based air conditioners) as well as solar water heaters. The solar water heater industry must be supported so that it can grow and export their products. Another necessity as well as an economic development opportunity is the establishment of local recycling industry for batteries, PV panels, and electronic equipment. There are also opportunities to locally develop software for energy applications. Our construction codes should be reviewed to ensure energy use is minimized, and the building is ready for renewable or local generation use.
9. **Need new ways to discuss energy matters:** Processes matter. The importance of processes that are fair, open, with all information available to the public must be understood. Puerto Rico has many examples in energy matters where the selected process was not fair and open resulting in public rejection of proposals with technical merit as for example the failed effort to establish wheeling and the process of awarding purchase power agreements (PPAs) for utility-scale renewable generation.
10. **The social context:** "The transition toward sustainable energy is inherently social [3]". The challenge is not only technical or economic, there are vital social aspects that need to be addressed, e.g., public acceptance, public participation and engagement among others.

We expand on some of these ideas in the following sections.

[3] L. Jans, T. Bouman, K. Fielding, "A part of the energy crowd," *IEEE Power & Energy*, Jan-Feb 2018, p. 39.

The distributed energy approach

In a letter sent to the FOMB on July 30, 2017 we proposed distributed rooftop photovoltaic systems, solar communities, and microgrids, combined with effective demand response programs and energy storage, to transform the electric infrastructure in Puerto Rico. This section summarizes the key points from that letter.

Keeping the same type of electric system and simply transferring it from public to private hands will not resolve our electricity challenges. Until more affordable storage arrives, we will need traditional generation but these fossil fuel-based generators must prioritize enabling the maximum use of renewable energy. Replacement of fossil fuel-based generation must be made within existing power plants, in sites that are already environmentally impacted, and where Puerto Rico has leverage to negotiate better agreements with private investors.

We currently own a traditional power system; based on large generating plants connected to clients through transmission and distribution networks. This centralized generation model requires large financial investments. The replacement generation must be agile and smaller than the units to be replaced in order to maximize renewable energy use. Some proposals are already suggesting the use ofH-technology generation, which we consider a mistake. These units are typically too large for the needs of our system.

We contend that it is not enough to retain the same type of system and simply to transfer it from public to private hands. With declining energy demand, the construction of large, new gas power plants, even by private investors, would tie the Puerto Rico electric grid and economy to 40 years of continued fossil fuel dominance. Thus, we propose and are working to develop a citizen-owned, thus private, electric power system based on rooftop solar PV. This approach is the best and most forward-thinking electric power system: a reliable alternative that will take full advantage of local resources and innovative market-based opportunities. Our previous work (renewable energy, streamlined rooftop PV processes, maximizing the benefits from energy use), and our current work on microgrids and solar communities support our vision [4].

Puerto Rico requires a new electric power system that provides electric energy at reasonable cost, with greater efficiency, and with minimum impact on our environment. Renewable energy is economically competitive in Puerto Rico. Rooftop photovoltaic (PV) systems constitute a better alternative than utility scale solar installations, which require large amounts of land, and are not cheaper than rooftop PV since all our power purchase agreements (PPA) for utility scale solar have resulted in very expensive contracts[5] with escalating costs during the life of the project.

A rooftop solar-based electrical grid could leapfrog a centralized, hierarchical system to a distributed prosumer[6] transactive energy market in which public policy facilitates citizens' investments in the electric system mainly through rooftop solar, distributed energy storage and smart meter technology. We seek the integration of renewable energy, conservation strategies,

[4] See Attachments 2, 3 and 4 from the July 30, 2017 letter to the Board by the same authors

[5] The cost range used for actual utility scale solar in the IRP was $0.178/kWh to $0.197/kWh (Table 4-2, page 4-3, PREPA's IRP, vol. I)

[6] A *prosumer* is both a *pro*ducer of electricity and a con*sumer*.

and efficiency measures in solar communities to harness market forces through a transactive energy framework for the benefit of both consumers and investors[7]. Puerto Rico will benefit from a reduced dependence on fossil fuels, the emergence of new electricity markets within a transactive energy framework, an improved environmental health and local socio-economic development.

We cannot afford traditional power purchase agreements with guaranteed energy sales. With declining electricity demand and cheaper rooftop PV, investors considering large, private power plants would face a high-risk scenario: financing expensive facilities with no warranty of long-term sales to provide the payback and rates of returns they are used to from Puerto Rico. The business model of any organization that seeks to be part of the electric energy sector in Puerto Rico must go beyond merely selling electricity; it must provide competitive energy services in support of an increased use of local resources: conservation, efficiency and renewable energy.

Significance of "grid defection" – after María citizens realized it is possible to live without the electric grid. An increasing number of PREPA clients are privatizing their electric energy needs: individual families and businesses are buying their own PV systems or buying energy from private companies that install PV systems on the clients' rooftops. Through Act 133-2016, low-income communities will be able to develop their own private community solar systems.

Debunking excuses to limit renewable energy use in Puerto Rico

PREPA's management affirms a limit in the amount of renewable energy Puerto Rico's electric infrastructure (as it exists today) can integrate in a safe and reliable way. However, PREPA's management conveniently presents only part of the picture. Electric power networks in Puerto Rico and around the World were indeed designed to operate with hydro, fossil fuel fired and nuclear plants. The new electric power network for Puerto Rico must be re-designed to operate with abundant rooftop solar PV, wind and ocean wave energy combined with robust energy efficiency and flexible electricity rates. We know how to re-design the electric power network to incorporate these. Europe is investing in a better, smarter grid that allows more renewables and we must do the same. Furthermore, the higher prices of fossil fired electricity in islands and the advent of affordable energy storage provide new, cost effective, storage solutions.

Since the technical limitations of traditional power grids are presented in isolation, or conveniently, in order to support the dominance of the centralized, fossil-based model and resist a renewable-based transformation, it is important to clearly explain where the infamous 580 MW limit to renewable energy comes from and why it is NOT correct. The 580 MW limit to renewables comes from Siemens' integration study is wrong. It is based on conservative and convenient assumptions and a ridiculously low curtailment level. Curtailment is a strategy whereby electric utilities do not use available power from a generator, even if it is available, usually because of system security concerns. The utility-scale power purchase agreements signed

[7] Through projects funded by the U.S. National Science Foundation and the U.S. Department of Energy.

by PREPA between 2009 and 2012 have generous clauses for developers regarding times when the power system needs to curtail the generation from private projects. The Siemens study (ordered by PREPA but paid with funds from the customers) had a 2% curtailment limit (Siemens, 2014), resulting in an increase in the cost of utility-scale projects of $3.5 per MWh at the 580 MW limit (section 7.3.1.2 "Energy Curtailment" of the study). The study argues that the 2% limit is acceptable, as compared to other places in the continental USA (none of the places are islands). **A 2% limit is not acceptable**. Hawaii is a better comparison to Puerto Rico in many respects, including curtailment levels. For example, Maui would have not had the success regarding renewable energy use without renewable energy curtailment, which frequently goes over 5%. Without curtailment the 100% renewable goal by 2045 could not be achieved: "…curtailment is essential to the functioning of Maui's grid today and its hopes of reaching 100% renewables by 2045" … "Without storage or curtailment, fossil resources would have to make up that demand, which won't work for a state with a 100% renewables mandate," (Bade, 2016). Table 7-22 of the Siemens study shows that if the accepted curtailment level was 4%, 770 MW of renewable energy could be used; an increase of curtailment to 5.4% yields a renewable energy integration of 884 MW, which is close to the 800 MW limit established in a UPRM study (Figueroa, 2013). That limit is for integration to the grid as it exists today, without any improvement or new generators. Thus, to achieve the maximum level of renewable energy use in isolated electric systems such as Puerto Rico, flexibility from the generators (of any kind) is needed as well as operating actions to benefit the overall goal of increasing renewable energy, not maximizing individual project benefits or profit. Those PPAs are currently in court. However, regardless of the outcome, Puerto Rico needs to re-evaluate curtailment penalties in those contracts signed by PREPA.

Fortunately, there are already various options to address even an 800 MW limit in the short term. For example, if a community, or customers in hybrid commercial-residential area agree to cooperatively manage their electric energy needs, they could be able to manage any renewable energy variations *within* their area, so that the utility substation only receives a typical load variation profile. We have proven at UPRM that PV systems, combined with storage, demand response strategies and appropriate control and communications equipment could achieve such operation. The cost to do this is very close to what PREPA was charging customers before Hurricane María hit Puerto Rico. There are no technical impediments to do this. The missing steps are regulatory (Appropriate and fair regulations and grid service rate need to be established.), financial (Initial cost need to be financed.) and social, since new social agreements need to be reached.

In the long term, as previously stated, we must design and build an electric infrastructure based mainly on renewable energy with a minimal role for any fossil-based technology. Puerto Rico cannot afford to continue wasting money on made-to-order studies that follow a conservative and outdated vision of an electric power system. Instead of making convenient assumptions to steer a study towards one's preferences, a study should cover a wide spectrum of energy options that might be used in a future power infrastructure. The principles of

infrastructure integrity are suggested to guide the planning and creation of a new electric infrastructure. Infrastructure integrity includes: the ability of infrastructure to be reliable (maintain service availability), flexible (respond quickly to changes in demand), resilient (use operational measures to minimize service cost impact for recovery from extreme events), and adaptable (invest to adapt infrastructure to changing futures to provide continuous low-cost services). Five visions for enhancement of infrastructure integrity of the local power grid are being studied using tools that have been validated in previous, larger-scale studies. The visions go from just reconstructing the previous infrastructure to the study of an infrastructure where distributed resources are the main energy suppliers. A broad set of stakeholders will be included during different phases of the study: NGOs, community groups, research professors, utilities from all sectors, and consulting engineers.
https://www.nsf.gov/awardsearch/showAward?AWD_ID=1810800&HistoricalAwards=false

Issues that need further discussion

The following are examples of important issues that deserve further attention to achieve an effective transition of Puerto Rico's energy industry. These issues are meant to illustrate the complexity of the challenge, and the need for further dialogue. Our group is willing to participate in such an important effort to ensure the electric infrastructure transformation is not only technically strong but first and foremost socially-beneficial.

- Energy is mostly a public business now (69%), while communications are 100% private. There are two regulatory entities in place, The Energy Commission and the Telecommunications Regulatory Board. The public electric utility organization is a centralized system, not only technologically but also administratively; decisions are made by a board. Communications exist under private ownership also administratively centralized; their decisions are also made by a board. With those similarities and dissimilarities Hurricanes Irma and María devastated both the electrical as well as the communications systems. The recovery of both systems was less than acceptable, more than four months after the hurricanes hit there are approximately 30% of the people with no electricity and communications are at best unreliable. Thus, there must be clear and certain rules such that both energy and communications systems are more robust, sustainable, reliable and resilient for normal operation and future emergencies. This is especially important if the electrical system is updated to technology intensive smart grids which require robust communications as well as a diversified portfolio of energy sources.
- PREPA has outstanding debt of approximately $8,000 million. This debt was guaranteed by energy sales. A technological transition is currently occurring that will allow citizens to produce their own electricity. This is a free market transition thus the risk to bond holders must remain within the bond holders and cannot be transferred to rate-payers.

- Subsidies, as well as other transfers, should not be part of the electricity bill. Funding for energy public policy must be collected elsewhere, not in the electricity bill.
- Smart grid requires a new rate structure such that the energy consumer and producer can take advantage of the variance of prices over the day. Those rates must be fair and debated in an objective, stable, regulatory forum.

Conclusions

The new reality of Puerto Rico's electric sector is one of diminished electricity demand, increased emphasis in efficiency and a strong interest in using renewable energy. The existing model, based on large, fossil fuel power plants and passive users is insufficient to address our current challenges. Building new, large, private power plants is only an option if the private developers are willing to take the complete risk of technological change plus a strong public policy toward distributed, renewable generation. Large, centralized, private projects take money out of Puerto Rico's economy and will do almost nothing to generate local capacities and abilities that enable people to create new, local and permanent socio-economic activity. The model of capital attraction is also insufficient.

We need a new electric system with the flexibility to use renewable energy as our first energy option, combined with aggressive conservation and efficiency initiatives, and an active participation from users (e.g., through demand response programs). Thus, the business model of any organization that wants to get involved in electric energy must be expanded from merely selling electricity to *providing energy services* in support of an increased use of renewable energy.

We contend that it is not enough to retain the same type of system and simply to transfer it from public to private hands. With declining energy demand, the construction of large, new gas power plants, even by private investors, would tie the Puerto Rico electric grid and economy to 40 years of continued fossil fuel dominance. Thus, we propose and are working to develop a citizen-owned, thus private, electric power system based on rooftop solar PV. This approach is the best and most forward-thinking electric power system: a reliable alternative that will take full advantage of local resources and innovative market-based opportunities. There are many examples in Puerto Rico showing how community-led efforts yielded better results to deal with local problems than any top-down approach. There are many well-organized communities in Puerto Rico that share a common albeit local vision of their future, and use that vision to inspire actions by many local volunteers willing to work for their own. They put their community first, over other considerations, including political party bickering. Distributed Rooftop PV systems, solar communities and microgrids, combined with aggressive demand response programs constitute key opportunities to transform the electric infrastructure of Puerto Rico. The local nature of these distributed energy resources, combined with the work of well-organized communities can yield local socio-economic development initiatives. A sustainable energy market at the distribution level could be the tool through which this could be executed.

Sincerely,

[redacted]
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Dr. Eduardo I. Ortiz-Rivera

Attachments

ATTACHMENT 1: BRIEF BACKGROUND OF SIGNATORIES

Name	Degree/University	Research & Teaching Areas
Erick E. Aponte	DEng (2006) Rensselaer Polytechnic Institute	Power system analysis, power electronics.
Marcel Castro Sitiriche	PhD (2007) Howard University	Appropriate technology, native dc power, responsible wellbeing, rural electrification.
Agustín A. Irizarry-Rivera	PhD (1996) Iowa State University	Power systems dynamics and operation, renewable energy sources.
Efraín O'Neill-Carrillo	PhD (1999) Arizona State University	Sustainable energy, distributed generation, energy policy, power quality, power distribution systems, engineering education, social and ethical implications of engineering and technology.
Lionel R. Orama-Exclusa	DEng (1997) Rensselaer Polytechnic Institute	Power system transients and protection, switching devices, switchgear technology, arc discharges in vacuum and gases, EMTP modeling of power devices.
Eduardo I. Ortiz-Rivera	PhD (2006) Michigan State University	Photovoltaic systems, power electronics, mathematical modeling of renewable energy systems, aerospace & unmanned systems, nonlinear control, engineering education.
Alberto Ramírez-Orquín	PhD (2002) University of Texas, Arlington.	Power system operation and control, power systems dynamics and stability, power system transients and protection, deregulation, power markets, congestion management.