Resilience Optimization Proceeding

January 21-22, 2021

Optimization - Workshop #1

Agenda – Day 1

- Introduction
- Presentation – Overview of Analytical Approach
- Discussion
- Presentation – Load Segmentation
- Discussion
- Break
- Presentation –MG Transmission Elements and DER Options / Solutions
- Discussion
- Wrap-up Day 1

Agenda – Day 2

- Recap – Day 1
- Discussion – Observations Day 1
- Presentation – Guiding Principles for Optimization / Cost Effectiveness Metrics
- Discussion
- Break
- Presentation – DER Resiliency Placeholder Value
- Discussion
- Wrap-up Day 2 / Workshop #1

Introduction

Resiliency of PREPA's Grid

The goal is for the electric power system to exhibit a degree of resilience such that for severe transmission system disruptions, likely coupled with extensive distribution system disruption, load service (especially for critical load at essential facilities, but also for other load) is minimally interrupted or not interrupted at all.

- *"…this proceeding will be the forum to further explore the costs, benefits, and alternative configurations of combinations of wires (i.e., hardened T&D assets) and local distributed resources that best serve Puerto Ricans in safeguarding against the effects of short-term and extended electric system outages that can occur as a result of severe weather events." [IRP Order ¶117]*

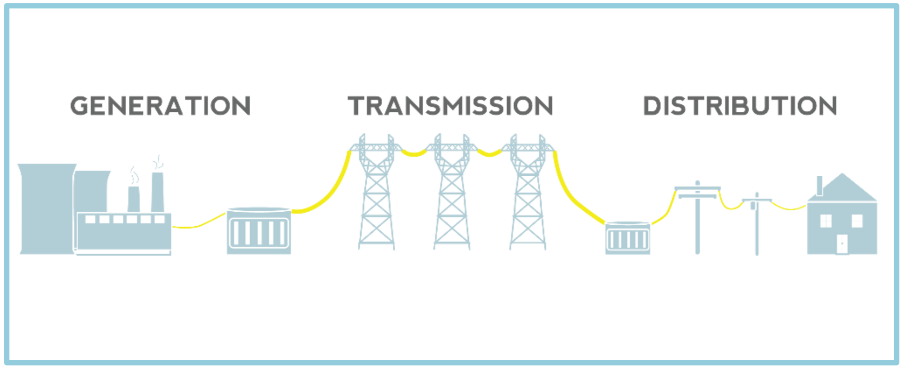
Optimization Proceeding Objective

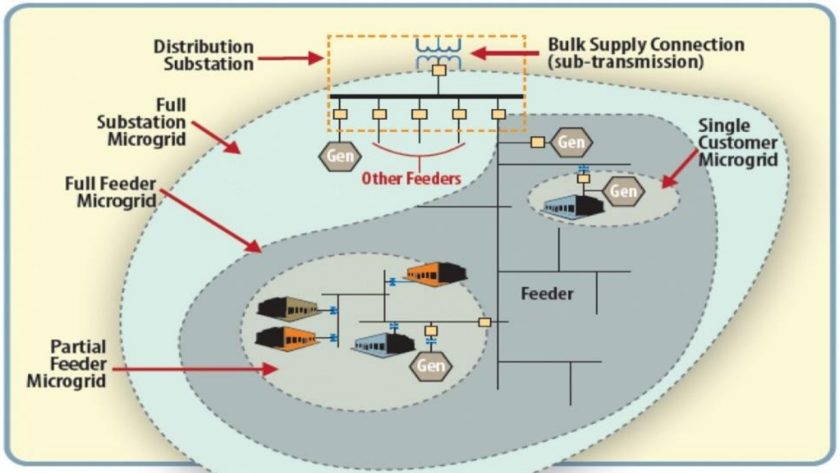
- Determine a reasonable, near-optimal mix of:
  - additional transmission investment for the PREPA identified MiniGrid regions; and
  - local distributed resource deployment.
- Determine the way resiliency investments would be made:
  - Direct customer installation
    - energy or energy/capacity resources behind the meter,
    - with or without PREPA tariff-based or procurement-based support;
  - PREPA resource procurement (direct RFPs/PPOA, DR tariffs, other forms of feed-in tariffs);
  - PREPA installation of transmission or distribution equipment (traditional); or,
  - A combination of these mechanisms.

Two Types of Resiliency Solutions

Not Mutually Exclusive

T&D System Hardening Approach VS. **Distributed Resource Approach**





Source: Sandia report.

MiniGrid Approach

- Undergrounding of existing/new transmission infrastructure
- Selective substation hardening
- \$5.9B in MG Tx expenditures, + additional distribution \$
- Ensure sufficient capacity to meet critical/other load

DER Deployment

- Site-specific DG or microgrids serving critical (& other?) load during grid outage
- Distributed resiliency
- Avoids some level of T&D expenditure

Workshop Objectives

Workshop 1

- **<u>Engagement and discussion</u>** – stakeholders/PREPA – **<u>informal</u>**
- Define resiliency or need
  - Electrical service to critical / essential facilities, and other load (to what extent?)
  - MW, MWh? Load Factor (how much is critical)? Time horizons (duration)?
- Specify forms of resiliency solutions and how they overlap with "blue sky" needs
  - Distributed resources at load (capacity, energy) - including microgrids, and single site DER
  - Transmission & distribution upgrades delivering capacity, energy – blue sky & storms
- How will resiliency solutions be procured and paid for, and how does that affect optimization?
  - Practicalities: time horizons? who pays/what services? costs allocated? what's fair?
  - Methods to rapidly deploy DER as resiliency solution
  - Funding sources – any impact?
- Define/discuss/refine analytical approach
  - Load segmentation to determine need – at what granularity? Why?
  - Determine/estimate costs of alternatives – in aggregate - T, D, GIS, microgrids, stand-alone DER
  - Means to determine which resiliency solution will be used for which loads, and where
- End result: Guiding principles for optimization – practicality, not perfection
  - determine which transmission to proceed with
  - determine DER deployments

Issues Summary and Remaining Workshops

- Next slide

Issues and Remaining Workshops

- Issues – How does optimization address:
  - "Blue sky" and resiliency needs – all DER resources service both normal and weather event circumstances
  - Consideration of the avoided costs of T, D for DER solutions
  - Uncertainty of costs for both forms of solutions
  - Transmission grid is integrated – MiniGrid and "Non-MiniGrid" infrastructure
    - How does optimization address "other" transmission?
- Remaining Workshops
  - Review transmission projects/categories; determine which are reasonable to proceed
  - San Juan / Bayamon projects first
  - Distributed resources for balance of resiliency need

Workshop Day 1 Topics

- Analytical Approach
- Load Segmentation
- MiniGrid (MG) Transmission Elements
- Distributed Resource Options

Questions & Discussion

- Objectives
- Agenda Items
- Process

Overview of Analytical Approach

Analytical Objective

- Determine reasonably lowest cost mix of MiniGrid transmission assets and DERs to enhance grid resiliency
- Identify "no regrets" solutions for:
  - Transmission infrastructure hardening
  - Microgrid or stand-alone distributed generation
- Refine analysis for more difficult transmission vs DG cases

- Recognize that DER resources for grid resiliency are also available for "blue sky" days; conversely, DERs that support capacity and energy needs can be doubly-purposed to also provide resiliency.
- Transmission reinforcement needed for "blue sky" operation in addition to serving as "MiniGrid" resource in severe weather/islanded mode.

Analytical Framework for Resilient Grid

1. Identify and define classes of customers regarding the criticality of electricity service and associated expected levels of resiliency.
2. Identify and describe the customers' roles in providing capacity and energy supply for resiliency.
3. Provide microgrid and related single-site (individually, or in the aggregate as VPPs) local capacity and energy solutions for both resiliency and normal energy/capacity needs.
4. Determine transmission costs, avoided transmission costs.
5. Optimize transmission and distribution (T&D) system expenditures for resiliency, including aspects of PREPA's MiniGrid concept.

Detailed Analytical Approach

- Segment the load
- Determine the resiliency need by segment
  - Define what is critical – type of load (e.g., essential facilities) – and the importance of “other”load (e.g., refrigeration and water pumps)
  - Quantitative metrics to define capacity/energy need (e.g., MW, MWh, load coverage to provide resiliency)
- Assess cost of DER solutions
- Assess cost of transmission system to serve dense critical load clusters, other?
- Split resiliency approach into two groups:
  - MiniGrid approach (T&D system hardening)
  - DER approach (microgrid and stand-alone, single site DER)
- What works quickly? What’s best for long-term?
- Test cost-effectiveness
- Determine transmission builds
- Determine DER builds

Data Inputs to Analytical Approach

- Load inputs – for segmentation – capacity, energy, by segment
- Requirements – resiliency need for essential facilities, other load (% ?)
- Cost, and coverage (kW, kWh), for DER solutions (data source: Sandia? NREL? Actual installations?)
  - PV/BESS standalone / Other generation?
  - Microgrid
- Cost, and coverage for transmission & distribution solutions under MiniGrid approach, from IRP Order, Appendix 1
  - Tx costs by component and type (minigrid vs non-minigrid)
  - Tx costs by technical justification
  - Distribution
  - Address what data is confidential; what is needed for optimization
- Estimate of avoided transmission, distribution costs with DER approaches for resiliency

Resiliency Approach Matrix

Illustrative

San Juan / Bayamon									Comparison Metrics and Outcomes – MiniGrid (MG) and microgrid/DER Solutions	
Essential Facility Category	**Customer Type**	**Example: Peak Load of Essential Facility Category**	**Example: Energy % of normal for resiliency**	**Comment**	**Default form of service for resilience**	**Total load served by solution**	**Cost – MiniGrid**	**Cost – Microgrid/DER**	**Cost of Resiliency ($/MWh) MiniGrid**	**Cost of Resiliency ($/MWh) DER**
1 – Very Large/ Critical Loads	Airports, Large Hospitals, Major PRASA (water/sewer)	5-10 MW	Actual load factor (100% of all load)	Site specific, customized solution, highly critical infrastructure	MiniGrid connected					
2 – Large	Hospitals, nursing homes, large pumping stations, arenas, military installations, government buildings serving essential services	1-5 MW	50-100%	Site specific, customized solution, highly critical infrastructure but not optimally located for MiniGrid	Minigrid connected or Microgrid					
3 –Medium/ Large	Fire, police, water/sewer pumping, large town centers	250-1000 kW	50-100%	Opportunistic connection to Minigrid if <1 mile away	Microgrid or stand-alone					
4 – Medium/ Small	Small town centers/dense residential areas	50-250 kW	25-50%	Opportunistic connection to Minigrid/microgrid if < ½ mile away	Stand-alone					
5 – Small	Grocery store/gas stations	5-50 kW	25-50%	PV/BESS/IC units	Stand-alone PPOA/FIT/DR					
6 – Very Small	Telecommunications towers	<5 kW	100%	PV/BESS/Integrated Circuit (IC) units	Stand-alone PPOA/FIT/DR					
7 - Other	Residences, other single sites	<10 kW	25-50%	PV/BESS	NEM/DR					

Questions & Discussion

- Resiliency Approach Matrix?
- How quickly can specific, "least regrets" transmission projects be identified to allow "fast track" for construction? [E.g., which San Juan projects?]
- How can we discern "least regrets" transmission from more marginal projects?
- How do we determine the value of avoided transmission costs?
  - Simple $/kW? Which $? Which kW?
- Distribution hardening is key to allow critical load service for any project associated with transmission.
  - How to align D with T projects? Wasted T if D not addressed?
- How does DER payment / control / accounting work for blue sky vs. resiliency needs?
- Who pays for battery capacity (customer or PREPA) – how much, through what mechanism? How to measure quantity? Does PREPA control via VPP/DR aggregator? How is control instituted?
- Who pays for solar PV panels – how much and through what mechanism?
- Who pays for transmission / distribution? Spread across all load? Does all load benefit?

Load Segmentation

Purpose of Load Segmentation

- …"primary purpose of a determination on load segmentation approaches at the very outset of the proceeding is to appropriately define baseline criteria for which load constitutes truly "critical" or "priority" load for purpose of examining the cost-effectiveness of alternative resiliency solutions."

  Optimization Proceeding Order, page 8

Objective of Load Segmentation

- To optimize expenditures between wires and DERs, must first identify and define the "critical" or other load service across customer classes with respect to both the size and location of that load.
- Capacity and energy needs are required, in part to test ability of PV alone to meet needs for DER solutions for some load segments.
  - Some critical service needs come with a high load factor requirement (with respect to normal peak), and energy need may drive the requirements more than peak load.
  - Other critical service needs may be minimal with respect to normal peak (e.g., household needs).
- After identifying the loads, the costs of potential solutions will be determined, as applicable.

Approach to Load Segmentation

- Customer segmentation:
  - By essential facility classification or customer class (see Resiliency Matrix)
  - By time – Energy and peak demands by day, day-type (weekend vs. weekday), season
  - By size (kW or MW peak demand, and kWh consumption patterns)
  - By type of load (resiliency need): e.g., PREPA defines need as critical, priority, and balance
    - But other definitions considered for purpose of optimization (e.g., portion of “balance” load that is critical; and portion of “critical” load that is not critical).
  - By location – Minigrid region, substation, feeder, transmission line, other?
- Presumption of headroom on feeders for “resiliency” load needs, though “blue sky” needs may be more restrictive
  - Eventually: incorporate hosting capacity analysis results to identify “headroom” on feeders for maximizing integration of distributed generation

Resiliency Approach Matrix

Illustrative

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6 – Very Small	Telecommunications towers	<5 kW	100%	PV/BESS/Integrated Circuit (IC) units	Stand-alone PPOA/FIT/DR						
7 - Other	Residences, other single sites	<10 kW	25-50%	PV/BESS	NEM/DR						

Load segmentation granularity - IRP

➢ Is this sufficient granularity for DER considerations? [No?]

Exhibit 2-2: 2019 Deemed Critical/Priority/Balance Load*

2019 Critical/Priority/Balance Night Peak Load , MW							
MiniGrid	Total Load	Critical	Priority	Balance	% Critical	% Priority	% Balance
Arecibo	234.2	117.2	60.6	56.4	50%	26%	24%
Caguas	306.7	128.2	74.4	104.1	42%	24%	34%
Carolina	310.8	132.9	33.7	144.2	43%	11%	46%
Cayey	101.1	59.7	29.9	11.5	59%	30%	11%
Mayaguez North	163.5	85.1	7.5	70.9	52%	5%	43%
Mayaguez South	161.7	110.4	9.7	41.6	68%	6%	26%
Ponce	332.3	144.2	79.2	108.9	43%	24%	33%
San Juan	1050.7	399.0	185.0	466.7	38%	18%	44%
Total	**2660.9**	**1176.7**	**480.0**	**1004.2**	**44%**	**18%**	**38%**

Reference: IRP_19_Substation_LoadProcessing_Final.xlsx

Critical / Priority / Balance Load

- What is the amount of critical load requiring resiliency solution?
  - PREPA IRP: *Critical load represents the peak consumption of the total load connected to feeders that serve any critical customer*
  - PREPA noted that up to 1,177 MW of critical load could exist.
  - *Is this the right # for DER optimization that targets individual facilities, and not entire feeders?* ***No***.

- How does this impact the optimization?
  - Need to consider actual critical and other customer load served under each of the respective solutions.

Open Discussion / Questions

- Feedback on load segmentation approach
- What load is critical?
- What are best sources for load data – PREPA only?
- How to fill in Matrix
- Is data on the loads of critical customers readily available?
- Other considerations?

Break

MiniGrid Transmission Elements

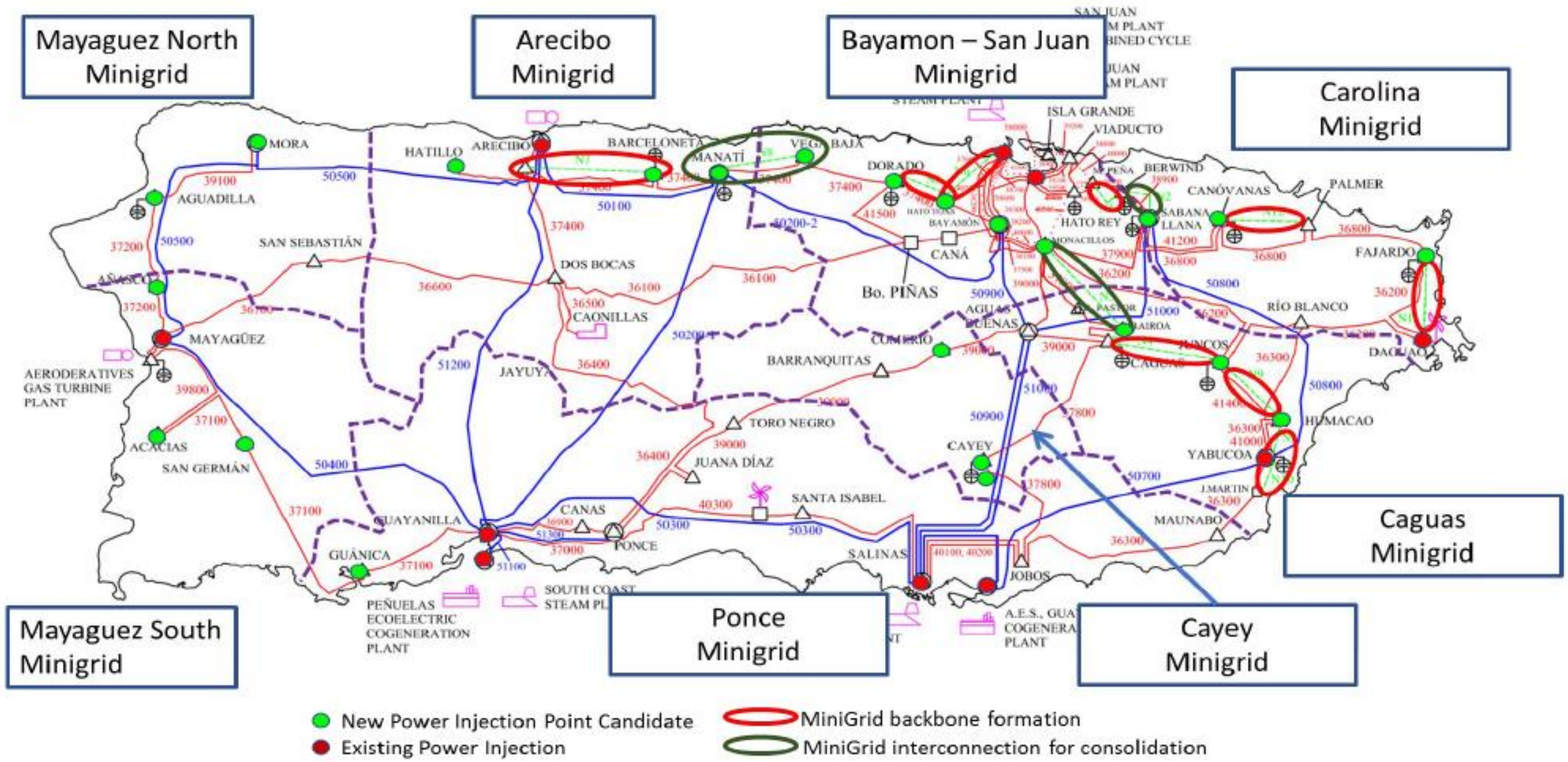
Bureau Order – MiniGrid/DER Approach

- The Bureau intends at each workshop to start with an identification of the most critical, and reasonably obvious, transmission grid needs for infrastructure upgrades, dependent in significant part on identification of the location and size of the most critical larger loads, their proximity to the transmission system, and the relative density of all such critical loads in proximity to the transmission system in each region (i.e., a "top down" approach to identifying transmission resiliency solutions).

- Simultaneously, each workshop will identify those locations where a DER approach to providing resiliency is likely more reasonable than a transmission investment, by examining, for example, smaller size critical loads in lightly loaded areas furthest from the transmission grid or critical loads regardless of size or geographical location, but electrically distant from a transmission connection point (i.e., a "bottom up" approach to identifying DER resiliency solutions).

PREPA Transmission System

Exhibit 2-7: PREPA Transmission System Map with Proposed 115 kV Investments



Source: IRP Appendix 1, Redacted Exhibit

Transmission MiniGrid Elements

- “MiniGrid” elements are a proposed subset of infrastructure –hardened, new & existing – intended to promote resilient system operation.
- MiniGrid infrastructure includes transmission, substation, and distribution system elements.
  - PREPA MiniGrid approach included thermal and BESS capacity within regions.
  - Hardened system allows critical load service to be retained in event of severe disruption.
- IRP
  - Bureau approved $2 billion for essentially “other” non-MiniGrid transmission
  - Remaining proposed $5.8 billion is for review in this proceeding.
- Optimization proceeding review:
  - Focuses on determining which wires components of MG approach are optimal to provide resiliency, and where DER is a better alternative.
- Next slides: summary of MiniGrid costs and type of infrastructure

115 kV MiniGrid Elements

Exhibit 2-85: 115 kV MiniGrid Transmission Investment by Project Type, $ million

Project Type	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
Line Hardening/Reconstruction	9.3	41.5	82.1	63.0	86.9	102.5	54.5	39.1	**478.9**
New Transmission Line	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	**2.2**
New Underground Construction	80.8	57.7	145.2	181.6	0.0	0.0	0.0	120.1	**585.4**
Switchyard Hardening/Reconstruction	205.2	208.4	251.8	181.7	0.0	208.7	364.9	320.9	**1741.6**
Grand Total	**295.3**	**307.5**	**481.2**	**426.3**	**86.9**	**311.2**	**419.5**	**480.1**	**2808.1**

Exhibit 2-87: 115 kV MiniGrid Transmission Investment by Technical Justification, $ million

Technical Justification	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
Interconnection of Minigrids	0.0	0.0	17.2	0.0	56.4	0.0	0.0	0.0	**73.6**
Minigrid Backbone Extensions to Create High Reliability/Resiliency Zones	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.4	**70.4**
Minigrid Main Backbone	271.4	254.8	372.0	294.7	30.5	215.4	306.5	322.1	**2067.2**
Interconnection of Critical Loads	0.0	36.0	0.0	52.0	0.0	0.0	67.7	0.0	**155.6**
Existing Infrastructure Hardening for Reliability	0.0	4.5	65.0	58.8	0.0	66.2	0.0	50.2	**244.6**
Aging Infrastructure Replacement	23.9	12.3	27.1	20.9	0.0	29.7	45.3	37.4	**196.6**
Grand Total	**295.3**	**307.5**	**481.2**	**426.3**	**86.9**	**311.2**	**419.5**	**480.1**	**2808.1**

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

38 kV MiniGrid Elements

Exhibit 2-89: 38 kV MiniGrid Transmission Investment by Project Type, $ million

Project Type	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
Line Hardening/Reconstruction	57.0	13.6	188.5	46.0	17.2	203.7	2.4	108.7	**637.2**
New Transmission Line	0.0	0.0	23.2	0.0	0.0	25.5	0.0	0.0	**48.7**
New Underground Construction	64.4	121.9	153.2	115.3	0.0	215.1	412.8	145.4	**1228.1**
Switchyard Hardening/Reconstruction	131.3	84.7	147.8	57.0	0.0	158.2	358.2	169.8	**1107.1**
New Substation/Switchyard	0.0	0.0	13.6	12.2	0.0	0.0	0.0	0.0	**25.8**
Grand Total	**252.7**	**220.2**	**526.5**	**230.5**	**17.2**	**602.6**	**773.4**	**423.8**	**3046.9**

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

Exhibit 2-91: 38 kV MiniGrid Transmission Investment by Technical Justification, $ million

Technical Justification	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
Existing Infrastructure Hardening for Reliability	0.0	0.0	154.7	41.5	0.0	198.0	0.0	0.0	**394.2**
Interconnection of Critical Loads	240.5	209.3	298.7	159.4	10.4	390.9	759.8	343.8	**2412.9**
Interconnection of Minigrids	0.0	0.0	55.3	0.0	0.0	0.0	13.6	0.0	**69.0**
Minigrid Backbone Extensions to Create High Reliability/Resiliency Zones	5.3	10.9	2.6	29.6	6.8	0.0	0.0	80.0	**135.2**
Minigrid Main Backbone	6.9	0.0	15.1	0.0	0.0	13.6	0.0	0.0	**35.6**
Grand Total	252.7	220.2	526.5	230.5	17.2	602.6	773.4	423.8	**3046.9**

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

MiniGrid Elements Cost By Project/Infrastructure Type

$ Millions	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Grand Total
115 kV Switchyard		17	7						24
115 kV Transmission Line	9	42	84	63	87	102	55	49	491
115 kV Underground Line	81	58	145	182				120	585
115/38 kV Transmission Center	24	8	36	36		28	44	37	213
230/115 kV Transmission Center		9	26			21	23		78
38 kV Switchyard		9		10		13	14	58	104
38 kV Transmission Line	57	11	212	46	17	229	2	44	618
38 kV Underground Line	64	125	153	115	-	215	413	212	1,297
Gas Insulated Substation	313	250	350	205		305	643	393	2,459
Grand Total	548	528	1,013	657	104	914	1,193	913	5,870

Source: IRP (Redacted Transmission Appendix)

MiniGrid and Non-MiniGrid Cost Components by Technical Justification

$ Millions	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Grand Total
Existing Transmission / Non-MiniGrid									
Aging Infrastructure Replacement								29	29
Existing Infrastructure Hardening for Reliability	327	197	83	-	701	71	276	209	1,864
Existing Infrastructure Hardening for Reliability					38				38
SubTotal Non-MiniGrid	327	197	83	-	738	71	276	238	1,930
MiniGrid Transmission									
Interconnection of Critical Loads	240	245	299	211	10	391	827	344	2,569
Interconnection of Minigrids			72		56		14		143
Minigrid Backbone Extensions to Create High Reliability/Resiliency Zones	5	11	3	30	7			150	206
Minigrid Main Backbone	278	255	387	295	30	229	306	322	2,103
Existing Infrastructure Hardening for Reliability - MG		5	220	100		264		60	648
Aging Infrastructure Replacement-MG	24	12	33	21		30	45	37	202
Subtotal MinGrid	548	528	1,013	657	104	914	1,193	913	5,870
Grand Total	875	724	1,097	657	842	985	1,469	1,151	7,800

Other Transmission Costs

Exhibit 2-97: Other Transmission Investment by Project Type, in $ million

Technical Justification	Arecibo	Bayamón	Caguas	Isla	Mayaguez	Ponce	San Juan	Total
Aging Infrastructure Replacement	0.0	0.0	0.0	0.0	0.0	0.0	28.8	**28.8**
Existing Infrastructure Hardening for Reliability	327.3	196.8	83.2	777.1	70.8	303.5	209.2	**1967.8**

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

Exhibit 2-98: Other Transmission Investment by Voltage, $ million

Voltage	Arecibo	Bayamón	Caguas	Isla	Mayaguez	Ponce	San Juan	Total
115 kV	178.8	71.8	0.0	211.3	0.0	50.7	70.5	**583.2**
115/38 kV	0.0	0.0	0.0	0.0	0.0	0.0	28.8	**28.8**
230 kV	28.1	0.0	0.0	543.7	0.0	0.0	0.0	**571.8**
230/115 kV	3.5	14.4	0.0	0.0	0.0	0.0	0.0	**17.9**
38 kV	116.9	110.6	83.2	22.1	70.8	252.8	138.6	**795.0**
Grand Total	**327.3**	**196.8**	**83.2**	**777.1**	**70.8**	**303.5**	**238.0**	**1996.6**

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

10-Year Plan “Near Term” transmission and distribution

- 115kV / 230kV transmission Lines
  - “near-term objective is to provide hardening/resiliency and/or rebuild 12 transmission lines (237 circuit miles).” P34, 10-year plan
- Distribution
  - “…95 feeders were identified as critical with an immediate need to repair. These feeders have been included in the near-term and classified in the first tier of projects to be completed.”
- How do these proposed infrastructure projects align with MiniGrid, or non-MiniGrid, transmission?

Questions and Discussion

- What are the categories of transmission, or specific projects, that are readily seen as reasonable for installation? Any?
- Can this be easily discerned?
- Where are the most dense urban clusters in the San Juan region? Other regions?
- Should MiniGrid hardening needs be separate from other transmission / distribution hardening needs?

DER Options and Distributed Resiliency Approach

DER Resiliency Solution Options and Approach - General

- Options: Provide capacity and energy at specific facility locations, to serve critical – and other? - load
  - Microgrids
  - Standalone DER
  - Virtual Power Plants (VPP) – aggregate of standalone DER, possibly microgrid resource
  - Demand Response – battery offerings through DR regulation
- Approach: Determine locations across Puerto Rico best suited to DER (distant from hardened grid; less densely loaded areas)
  - Identify microgrid options
  - Identify stand-alone options
  - Determine deployment methods

DER Options and Approach - Specific

- Hi Level Costs, Attributes of DERs
  - Capacity
  - Energy
  - Ancillary Services (AS)
  - Controllability
- Considerations: Who pays? How? Capacity and energy? AS?
- Determine/estimate which loads best served by DER approach
  - How to address small-scale, kW size needs – residential, small commercial – mass market.
- Determine/estimate which load best served by MiniGrid approach
- Parameters to roughly bound solution sets:
  - Broadly: rural vs. urban / dense vs. less dense load
  - Distance from potential MiniGrid / distance from existing transmission
  - Feeder load locational analysis
  - Transmission/sub-transmission system connected load
  - Existing data from PREPA – critical load levels by feeder, other?

PREPA Distributed Resiliency Approach

- DER approach minimal, limited to microgrids; 50 zones identified
- Identified critical, balance and balance load within each optional microgrid. No detailed analysis, cost, or deployment options assessed.
- Portion of Exhibit 2.4 (Appendix 1, IRP):

MiniGrid	Microgrid Name	Critical	Priority	Balance
	VILLALBA (Toro Negro)	7.4	1.9	1.9
	PORTUGUES	0.4	0.0	0.3
San Juan	CARRAIZO	1.8	0.0	10.7
	NARANJITO	6.6	0.2	6.1
	PINAS	4.4	0.0	11.6
	UNIBON	0.0	3.2	5.3
	VILLA BETINA	3.9	7.0	15.2
	QUEBRADA NEGRITO	0.0	0.0	4.5
	COROZAL	6.0	2.7	0.0

Reference: IRP_19_Substation_LoadProcessing_Final.xlsx

Sandia Distributed Resiliency Approach

- Sandia identified 159 candidate microgrids, supplemented with backup generation to critical assets in locations that may not warrant a microgrid.
- System costs \$1.2B if only critical loads served by microgrids and \$2B to serve both critical and non-critical load.
- A large cluster of portfolios achieves performance benefits close to the do-everything scenario at cost on the order of \$300-\$400M.
  - Estimate total microgrid cost on the order of \$1.3-\$2M per MW of peak load required for the microgrid
  - Appendix A: Microgrid Cost Methodology pgs. 55-60
  - Latitudes and longitudes of buildings suggested under each of the 159 candidate microgrids

Snapshot from Sandia Report

Table 7. Microgrid Cost Estimates for each Microgrid Area

Microgrid #	Microgrid Name	Critical Demand (kW)	Non-Critical Demand (kW)	Option A1 ($M)	Option A2 ($M)	Option B1 ($M)	Option B2 ($M)
1	San Juan City Hall	1079	4630	15.42	20.90	4.56	5.60
2	Hospital Complex	70049	9323	203.99	280.19	181.13	248.37
3	International Airport	122315	12805	346.71	476.42	314.93	432.35
4	Muelle De Viejo Ferry and Cruise Terminals	4202	4069	21.97	29.91	12.56	16.59
5	Calle Cuervillas	1201	4250	14.75	19.99	4.87	6.03
6	Doctors Hospital Center	2164	2097	11.71	15.80	7.34	9.42
7	Centro Comunal El Gandel	456	1100	4.78	6.28	2.97	3.41
8	Conservatoria de Musica de Puerto Rico	2655	886	9.86	13.26	8.60	11.15
9	Pavia Hospital Complex	2032	14882	44.10	60.34	7.00	8.95
10	Avenida Wilson	1579	10464	31.63	43.19	5.84	7.36
11	Avenida Doctor Ashford	2902	14966	46.54	63.70	9.23	12.02
12	University Sacred Heart	1332	3019	11.94	16.12	5.21	6.49
13	FRD Airport and Convention Center	7774	21268	75.15	103.03	21.70	29.16
14	Sagrado Corazon	1377	3848	14.18	19.19	5.33	6.65

Source: Sandia report, page 56.

- "There is a great range in size with the microgrids, so the costs for given microgrids vary widely. It may be possible to further reduce the size of larger microgrids like microgrid 2, the Hospital Complex, or microgrid 3, the International Airport, by splitting them into smaller microgrids or serve a smaller subset of critical loads. In any case the results presented show load and cost comparative information which can be further analyzed to determine which ones are the most important and critical for service to Puerto Rico during major events." (Sandia report, page 55)

RMI Distributed Resiliency Approach

- RMI urged a DER-focused solution
  - Not a detailed, comprehensive presentation of DER solution
- 20,000 critical facilities
- Solar PV and storage
- 650-700 MW PV capacity
- 900-1,000 MWH battery storage

Microgrid Boundary Delineation

- Determine boundaries for the potential distributed microgrid solutions
  - Note: Identify independent microgrids (e.g. some resilience nodes may overlap)
    - Can eventually look at a networked microgrid approach, where practical

  Data Inputs:
  - Sandia 2018 Microgrid Locations Report (159 microgrid locations)
  - Electrical distribution system layout (e.g. critical loads, feeders, switches, physical equipment, etc.)
- Assess data on relative reliability and resiliency of individual feeders
- Identify existing grid resiliency solutions (e.g. batteries, generators, etc.)

Microgrid Design Considerations

- **Responsibility**
  - What is PREPA's role? Customer role? Third-party role?
- **Backup Duration**
  - Duration of time microgrid required to be functional
    - *Minimal time needed for microgrid operation*
- **Size**
  - Size each microgrid system based on critical load demands
- **Generation Resources**
  - Types and composition of distributed generation considered
    - *Maximum allowable renewable resource coverage for microgrid*
    - *Incorporation of available existing generation resources*
    - *Need for any new small fossil generation given PV/BESS economics?*
- **Grid-Tied**
  - Island-mode versus grid-connected

Microgrid Cost, Size, Design

- Use standard sources (NREL, Lazard) to estimate costs for microgrid system, in aggregate, at high level, for purposes of this proceeding?
- Estimate total cost of microgrids
  - Note: Sandia estimates total microgrid cost ~$1.3M-$2M per MW of peak load
- Sizing and designing microgrids:
  - Optimize resource mix to deliver least-cost microgrid solution for each location using techno-economic modeling tool (HOMER, DER-CAM, etc.)
  - Estimate other microgrid-related construction costs (e.g. overhead/underground lines, switches, points of common coupling, etc.)
  - Add safety factor to estimate other auxiliary costs (e.g. EPC, controls, etc.)

How much resiliency can avoided transmission buy?

- $5.9 billion – MG elements (transmission only) – distribution needs add more
- Microgrid costs (Sandia): ~$2 million/MW
  - @$6 billion: 3,000 MW worth of microgrid.
- So why do any MiniGrid approach at all?
  - Densely clustered load
  - Availability of existing resources on grid, blue sky / partial outage conditions – supports resiliency, especially in near/medium term – economies of scale for utility PV, BESS
  - MiniGrid – a form of a very large microgrid

Questions and Discussion

- Stand alone DER
  - At what scale?
  - How to procure?
  - Who pays?
  - Capacity only, or capacity + energy?
  - Timeframe of deployment
- Microgrid resources
  - Fully customer/third party, or role for PREPA / Other agencies?
  - How to design, size, integrate into PREPA grid
  - Feedback on Sandia distributed resiliency approach?
  - Timeframe of deployment
  - Other considerations?

Wrap Up – Day 1

- Open Questions / Discussion
- Return to:
  - Analytical Approach
  - Load Segmentation
  - MiniGrid Elements
  - DER Options
- Process – Submitting information, responding to questions
- Plans for Day 2

Para más información:

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Backup Slides – Day 1

10-Year Plan Near Term Transmission

Transmission – Near-Term (2021-2023)

Table 4.5 – Near-Term Transmission Projects

Transmission Project Name	Brief Description	Est. COR3 /FEMA Submission	Est. Cost (M USD)	IRP Reference
21-Transmission Existing (38 kV)	The objective of this project is to harden existing 38kV transmission lines to consensus-based codes and standards, improve reliability and resiliency of the infrastructure to critical loads, and accelerate future restoration efforts by strengthening and/or replacing transmission structures and components. This project includes work on 21 transmission lines for an estimated total of 442 miles.	2021 Q4	$419.65	Section III C
12-Transmission Existing (115 & 230 kV)	The objective of this project is to harden existing 115kV and 230kV transmission lines to consensus-based codes and standards, improve reliability and resiliency of the infrastructure to critical loads, and accelerate future restoration efforts by strengthening and/or replacing transmission structures and components. This project includes work on 12 transmission lines for an estimated total of 237 miles.	2021 Q4	$262.30	Section III C
14-Transmission New Lines (38kV, 115 & 230 kV)	The objective of this project is to build new underground or overhead transmission lines across all three voltage levels (38 kV, 115 kV, and 230 kV) to consensus-based codes and standards and increase the transmission grid reliability and resiliency by providing redundancy to existing disaster damaged lines. This project includes work on 14 transmission lines for an estimated total of 53 miles.	2022 Q2	$215.00	Section III E

10- Year Plan Mid-Term Transmission Projects

Transmission – Mid-Term (2024-2027)

Table 4.15 – Mid-Term Transmission Projects

Transmission Project Name	Brief Description	Est. COR3 /FEMA Submission	Est. Cost (M USD)	IRP Reference
37- Transmission Existing (115 & 230 kV)	The objective of this project is to harden existing 115kV and 230kV transmission lines to consensus-based codes and standards, improve reliability and resiliency of the infrastructure to critical loads, and accelerate future restoration efforts by strengthening and/or replacing transmission structures and components. This project includes work on 37 transmission lines for an estimated total of 496 miles.	2025	$548.60	Section III C
40- Transmission Existing (38 kV)	The objective of this project is to harden existing 38kV transmission lines to consensus-based codes and standards, improve reliability and resiliency of the infrastructure to critical loads, and accelerate future restoration efforts by strengthening and/or replacing transmission structures and components. This project includes work on 40 transmission lines for an estimated total of 511 miles.	2025	$537.70	Section III C
16- Transmission New Lines (38kV, 115 & 230 kV)	The objective of this project is to build new underground or overhead transmission lines across all three voltage levels (38 kV, 115 kV, and 230 kV) to consensus-based codes and standards and increase the transmission grid reliability and resiliency by providing redundancy to existing disaster damaged lines. This project includes work on 16 transmission lines for an estimated total of 125 miles.	2026	$294.00	Section III E

Optimization Proceeding Workshop #1 Day 2

Agenda – Day 2

- Recap – Day 1
- Discussion – Observations Day 1
- Presentation – Guiding Principles for Optimization / Cost Effectiveness Metrics
- Discussion
  - Including impact of funding sources on optimization
- Break
- Presentation – DER Resiliency Placeholder Value
- Discussion
- Wrap-up Day 2 / Workshop #1

Recap Day 1; Discussions / Observations – Day 1

- Overall analytical approach
- Load Segmentation and overall determination of resiliency need / critical load service.
- Practical means of procuring or obtaining DER solutions

- Process
- Data needs
- Submission of additional comments
- Petitioners' request – 90 days to answer questions from Appendix C of Order.

Cost Effectiveness Metrics

Data Needs for Cost Effectiveness Comparison

- Total (and Incremental?) cost to provide comparable level of resiliency under different approaches.
- Need to measure or define resiliency in order to compare
  - Aggregate resiliency by region.
  - Is estimated level of "energy not served" a useful metric that can be considered when examining DER solutions? The only metric?
- MiniGrid approach:
  - Change in value of energy not served , to compare different scenarios.
  - Absolute assessment of value of energy not served, to compare to solution cost (MG capex)
  - No assessment of solution cost for DER
  - Based on estimates of how much load would be lost, for how long
- What are the key metrics that require computation?
- Note: IRP solution already lays out core resource paths for blue sky days.

Can these be determined? Can they be compared?

- Cost of Resiliency – DER solution – Microgrid
- Cost of Resiliency – DER solution – Standalone
- Cost of Resiliency – MG solution

- Installed cost, Microgrid DER solution, $/kW
- Installed cost, Standalone DER solution, $/kW
- Installed cost, MG solution, $/kW

- Operating cost, Microgrid DER solution, $/kW or $/kWh
- Operating cost, Standalone DER solution, $/kW or $/kWh
- Operating cost, MG solution, $/kW or $/kWh

- Value of Resiliency Provision – all solutions - $/kWh – backstop cost?
  - The cost that is incremental to provision of services used for blue sky days?

VOLL Exhibit from IRP

MiniGrid	Total MiniGrid Load (MW)				Load Not Served (MW)				Energy Not Served (MWh)					Cost of Energy Not Served (k$)					Total MiniGrid CapEx (k$)	# of Weeks to Justify the CapEx (Critical Loads Only)	# of Weeks to Justify the CapEx (All Loads)	Example: an event for 4 Total Cost of Energy Not Served (k$)
					Pre MiniGrid CapEx				Pre MiniGrid CapEx				Post MiniGrid CapEx	Pre MiniGrid CapEx				Post MiniGrid CapEx				
	Critica	Priorit	Balanc	Subto	Critical	Priority	Balance	ubtota	Critical	Priority	Balance	Subtotal	ubtota	Critical	Priority	Balance	Subtotal	Subtotal				
Caguas & Cayey	188	104	116	408	1st Week (Level 1+Level 2 out)														$1,008,917	3.7	3	*$1,274,396*
					110	35	87	**233**	13,905	4,397	10,994	**29,296**	0	$444,948	$43,967	$21,988	**$510,904**	$0				
					After 1st Week (Level 1 out, Level 2 in), Per Week																	
					53	26	31	**110**	6,688	3,275	3,871	**13,834**	0	$214,001	$32,755	$7,741	**$254,497**	$0				
Carolina	133	34	144	311	1st Week (Level 1+Level 2 out)														$762,367	2.7	2.3	*$1,308,590*
					76	16	83	**174**	9,598	1,979	10,400	**21,977**	0	$307,132	$19,789	$20,801	**$347,721**	$0				
					After 1st Week (Level 1 out, Level 2 in), Per Week																	
					70	14	73	**158**	8,864	1,826	9,187	**19,877**	0	$283,661	$18,255	$18,374	**$320,289**	$0				
San Juan-Bayamon	399	185	467	1051	1st Week (Level 1+Level 2 out)														$1,432,630	1.8	1.4	*$3,810,788*
					224	121	284	**629**	28,276	15,193	35,759	**79,228**	0	$904,826	$151,932	$71,518	**$1,128,276**	$0				
					After 1st Week (Level 1 out, Level 2 in), Per Week																	
					177	94	244	**515**	22,323	11,844	30,701	**64,868**	0	$714,330	$118,439	$61,402	**$894,171**	$0				

Closer View – VOLL Slide

- Estimate for value of transmission system providing resiliency assumes a % level of lost load

MiniGrid	Total MiniGrid Load (MW)				Load Not Served (MW) Pre MiniGrid CapEx (as % of Total Load)			
	Critica	Priorit	Balanc	Subto	Critical	Priorit	Balance	Subtotal
San Juan-Bayamon	399	185	467	**1051**	224	121	284	**629**
					56%	65%	61%	60%
					177	94	244	**515**
					44%	51%	52%	49%

Cost to Mitigate Lost Load with DER Solution - 1

- Considering how MG VOLL Assessment was done
- \$3.8 billion cost of "energy not served" was much greater than \$1.4 billion cost of MiniGrid expenditures for San Juan / Bayamon

San Juan / Bayamon Only	Critical	Priority	Balance	
MWh from outage (1 week Level 2, 3 weeks Level 1)	95,244	50,725	127,861	273,830
VOLL per unit: $/MWh	32,000	10,000	2,000	
Total costs ENS by load type	3,047,815,247	507,250,458	255,722,354	**3,810,788,060**
ave load factor 1st week	0.75	0.75	0.75	
ave load factor after 1st week	0.75	0.75	0.75	

Cost to Mitigate Lost Load with DER Solution - 2

- However: depending on how DER costs are allocated, costs can be lower than MG solution
- This illustration - NOT CORRECT? - You cannot <u>target</u> load that might be lost?

SEE Analysis San Juan / Bayamon Only		Critical	Priority	Balance	
MWh from outage (1 week Level 2, 3 weeks Level 1)		95,244	50,725	127,861	273,830
VOLL per unit: $/MWh		32,000	10,000	2,000	
Total costs ENS by load type		3,047,815,247	507,250,458	255,722,354	**3,810,788,060**
ave load factor 1st week		0.75	0.75	0.75	
ave load factor after 1st week		0.75	0.75	0.75	
DER Incremental and Total Cost Illustrations					
Bookend: Full DER PV/BESS, but costed on energy basis (rest of costs allocated to all other non-storm uses of resources).					
Idealized PV output/BESS storage patterns.					
Serving ALL of this outaged load with on-site DER solar/BESS					
150	PV cost per MWh	14,286,634	7,608,757	19,179,177	
500	BESS cost per MWh	47,622,113	25,362,523	63,930,589	
	Total	61,908,747	32,971,280	83,109,765	177,989,792

Cost to Mitigate Lost Load with DER Solution - 3

- However – you must consider allocating a smaller portion (than values shown) when considering that DERs serve blue sky needs also.
- Rough per unit costs used here – fuller analysis required.

DER Incremental and Total Cost Illustrations					
Bookend: Full DER PV/BESS, but costed on energy basis (rest of costs allocated to all other non-storm uses of resources).					
Idealized PV output/BESS storage patterns.					
Serving ALL of this outaged load with on-site DER solar/BESS					
150	PV cost per MWh	14,286,634	7,608,757	19,179,177	41,074,567
500	BESS cost per MWh	47,622,113	25,362,523	63,930,589	136,915,225
	Total	61,908,747	32,971,280	83,109,765	$ 177,989,792
Bookend: Full DER PV/BESS					
Serving ALL of this outaged load with on-site DER solar/BESS, costed on full capacity basis (initial cost).					
Idealized PV output/BESS storage patterns.					
3,700,000	PV cost per MW	830,321,623	446,150,019	1,050,058,924	2,326,530,565
1,500,000	BESS cost per MW	336,616,874	180,871,629	425,699,564	943,188,067
	Total	1,166,938,497	627,021,648	1,475,758,487	$ 3,269,718,632
Bookend: Full DER PV/BESS					
Serving ALL of regional load with on-site DER solar/BESS, costed on full capacity basis (initial cost).					
Idealized PV output/BESS storage patterns.					
3,700,000	PV cost per MW	1,476,300,000	684,500,000	1,727,900,000	3,888,700,000
1,500,000	BESS cost per MW	598,500,000	277,500,000	700,500,000	1,576,500,000
	Total	2,074,800,000	962,000,000	2,428,400,000	$ 5,465,200,000

Cost to Mitigate Lost Load with DER Solution - 4

- Closer Look – last one – in comparison to MiniGrid cost for SJ/Bayamon of $1.4 billion
- But – cost provides both resiliency and blue sky services
- How to untangle? Capacity portion alone: much less than cost of ENS

DER Incremental and Total Cost Illustrations					
Bookend: Full DER PV/BESS					
Serving ALL of regional load with on-site DER solar/BESS, costed on full capacity basis (initial cost).					
Idealized PV output/BESS storage patterns.					
3,700,000	PV cost per MW	1,476,300,000	684,500,000	1,727,900,000	3,888,700,000
1,500,000	BESS cost per MW	598,500,000	277,500,000	700,500,000	1,576,500,000
	Total	2,074,800,000	962,000,000	2,428,400,000	$ 5,465,200,000

MG Transmission Costs per Peak Load Service

➢ Based on IRP Aggregate $, MiniGrid transmission

MiniGrid Transmission Cost	**Arecibo**	**Bayamón**	**Caguas**	**Carolina**	**Isla**	**Mayaguez**	**Ponce**	**San Juan**	**Total**	**SJ/Baya**
Total MG $ Millions, All Types/Justifications	548	528	1,008	657	104	914	1,193	904	5,855	1,432
Share by region	9.4%	9.0%	17.2%	11.2%	1.8%	15.6%	20.4%	15.4%	100.0%	24.5%

	Arecibo	**Bayamon**	**Caguas**	**Carolina**	**Cayey**	**MayaG N+S**	**Ponce**	**San Juan**	**Total**	**SJ/Baya**
2019 Peak Load, MW (at generator)	234	390	307	311	101	325	332	661	2,661	1,051
Share by region	8.8%	14.6%	11.5%	11.7%	3.8%	12.2%	12.5%	24.8%	100.0%	39.5%
MG Cost per Peak Load by Region, Mill. $/MW	2.34	1.35	3.62	2.11	-	2.81	3.59	1.37	2.20	1.36

Note: "Isla" costs assumed to be in Caguas region.

MiniGrid Costs per average energy consumption

➢ Average energy basis to cover MG transmission costs

Annual Basis - cost of transmission, $ millions										
	Arecibo	**Bayamon**	**Caguas**	**Carolina**	**Cayey**	**MayaG N+S**	**Ponce**	**San Juan**	**Total**	**SJ/Baya**
Assume Fixed Charge Rate (10%)	54.80	52.77	100.77	65.68	10.40	91.38	119.29	90.40	585.50	143.17
Assume Fixed Charge Rate (15%)	82.21	79.16	151.16	98.53	15.61	137.07	178.93	135.59	878.25	214.75
Assume Fixed Charge Rate (20%)	109.61	105.54	201.54	131.37	20.81	182.76	238.58	180.79	1,171.00	286.34
Energy at 75% Load Factor, GWh	1,539	2,561	2,015	2,042	665	2,136	2,183	4,342	17,482	6,903
Annual Basis - cost of MG transmission, average $ per kWh										
	Arecibo	**Bayamon**	**Caguas**	**Carolina**	**Cayey**	**MayaG N+S**	**Ponce**	**San Juan**	**Total**	**SJ/Baya**
Assume Fixed Charge Rate (10%)	0.036	0.021	0.050	0.032	0.016	0.043	0.055	0.021	0.033	0.021
Assume Fixed Charge Rate (15%)	0.053	0.031	0.075	0.048	0.023	0.064	0.082	0.031	0.050	0.031
Assume Fixed Charge Rate (20%)	0.071	0.041	0.100	0.064	0.031	0.086	0.109	0.042	0.067	0.041

Adding it all up? Resiliency Value of DER and How it Affects Overall Costs

- Illustrative: Credit for DER for Avoided MG transmission:

Total annual load, SJ/Bayamon, GWh	2,621	1,215	3,068	6,905
credit: MG Tx only, $/kWh	0.03	0.03	0.03	0.03
Credit avoided Tx, $millions/year	79	36	92	207

- Considered with prior assessment: credit *lowers* capacity cost?

DER Incremental and Total Cost Illustrations					
Bookend: Full DER PV/BESS					
Serving ALL of regional load with on-site DER solar/BESS, costed on full capacity basis (initial cost).					
Idealized PV output/BESS storage patterns.					
3,700,000	PV cost per MW	1,476,300,000	684,500,000	1,727,900,000	3,888,700,000
1,500,000	BESS cost per MW	598,500,000	277,500,000	700,500,000	1,576,500,000
	Total	2,074,800,000	962,000,000	2,428,400,000	$ 5,465,200,000

Placeholder – Funding Sources Discussion - DERs

- PREPA provision of DERs to support resiliency:
  - Via PPOA (e.g., via VPP contracts which include batteries)
  - Via NEM (e.g., PV + batteries)
  - Via DR vehicle (e.g., batteries)
- Agencies (FEMA, HUD, CDBG)
  - Alternatives funding: support the capacity? portion of DER as a form of resiliency value in lieu of of increased hardening.
- Customers
  - Energy - self supply? Energy – via PPOA?
  - Capacity – sell to PREPA for blue sky days

Questions and Discussion – Cost Effectiveness Metrics

- Is the value of mitigating against lost load the key, or only, form of assessing resilience value?
- How do you measure the cost and value of resiliency provision, incremental to the value provided by solutions on blue sky days?

Guiding Principles

Guiding Principles – Straw Proposal Adaptation Needed

- Careful approach to examining each form of solution needed
  - Analytical complexities make head-to-head comparisons subject to error.
  - Substitution of capacity and energy resources to avoid transmission expenditures must consider the extent of customers affected/benefitting, and how costs of the different approaches are allocated across customer groups.
- A means to properly account for blue sky benefits must be directly included in any comparative approach – for both solutions.
  - Each solution provides resiliency benefits incremental to their normal day operational value.
- PREPA must be able to better describe different levels of transmission investment required if large-scale, or larger-scale (than baseline) DER solutions were to be in place.
  - There are different transmission needs to support resilience under different scenarios of DER deployment where DER provides a resiliency solution for (some) load. Determining, or estimating what these differences are must be given immediate focus.
  - What is the minimum standard for transmission buildout? Building up to "codes and standards" as required does not imply full-scale hardening / GIS installation. Is an estimate of the value of resiliency the only way to support building beyond "codes and standards" levels?
- Microgrids potentially covering a sizable percentage of actual Puerto Rico critical load must be considered as a valuable part of any solution – and thus the overall level of remaining load requiring assurances of resiliency may be considerably lower than currently assumed by PREPA, even in dense load regions.
  - The greater the extent of microgrid penetration, the lesser the extent of remaining load for resiliency provision.

DER Placeholder Value for Resiliency

Resiliency Value of DERs

- "The purpose of an early signaling of the value of DER resource deployment is to allow, as best as possible, for the commencement of a "rapid deployment" of such resources. As this proceeding continues, refinement of this value would be expected based on analysis of DER resource deployment cost effectiveness".

  IRP Order, paragraph 736, page 227.

- Is resiliency value for DERs as simple as a measure of the avoided transmission investments?
- How should the Bureau untangle MiniGrid from non-MiniGrid transmission when considering comparative resiliency solutions?
- What analytical lessons can be considered for DER, based on PREPA's VOLL approach when valuing a MiniGrid solution?

Day 2 Wrap Up

- Submissions
- Posting of Slides and Backup – Energy Bureau
- Other?
- Next Steps / next workshop: tentative – February 23 (Tuesday)

Para más información:

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