Final Slide Deck

Resilience Optimization Proceeding

JRSP JUNTA REGLAMENTADORA DE SERVICIO PÚBLICO

NEGOCIADO DE ENERGÍA DE PUERTO RICO

June 23, 2021

Optimization - Workshop #4

Agenda

AM

- Introduction
  - Recap of Workshop #3 – Wires, DER Solutions – and Overall Objectives
  - Summarize relevant Infrastructure Plan elements – Bureau approvals and relationship to “no regrets” resiliency solutions
  - National Labs resiliency analyses, support / scope and timing
- Discussion of responses to the March 24, 2021 Energy Bureau questions on resiliency alternatives.

PM

- Benefit/cost analysis high-level screening results and comparison across DER and wires-based resiliency solutions.
- Proposed initial “no regrets” or “limited regrets” actions for DER and wires alternatives reflecting the results of the B/C screening and a need for rapid deployment of resiliency solutions.
  - No Regrets wires for resiliency
  - No Regrets DER procurement for resiliency

Introduction / Recap Workshop #3

- Can we draw preliminary conclusions / no regrets?
- Transmission solutions – 115 kV – especially new underground
  - If needed for blue sky – do it. But don't overbuild – net load on grid declining (EE, DERs). If not needed:
    - Is it needed to serve clusters of critical load after storm event? (what is analytical basis?)
    - Or: is it needed for overall resilience of densely-loaded region?
  - Metrics
    - Costs per MW or MWh of total load (duration?) on feeders with critical load, or total load?
    - Clusters: MW feeder critical load per substation?
    - Other?
  - Then: iterate for 38 kV? Coupled to 115 kV solutions?

- DER solutions
  - All PREPA identified microgrid areas (337 MW)? All Sandia microgrid areas(742 MW)?
    - Who designs? Who implements? How? Tariff/DR/VPP support for battery component?
  - Current procurement plan: 150 MW carve out VPP/DER for batteries.
    - In July: insight into possible locations, types of facilities?
  - Other: stand-alone DER at essential facilities, and at other locations (residences, small commercial)
  - Metrics:
    - Costs per MW or MWh of critical, priority, other load served (duration?)?
    - Actual critical load MW
    - Distance from likely hardened wires sections (T, sub-T, D)?
    - Avoided or deferred T costs, $. Avoided, deferred or reduced D costs, $.
  - If incremental cost of DER < resiliency value + avoided costs, do it.

Revised Infrastructure Plan Summary – Near Term

- Near term is 2021-2023
- Approvals underway pending final documentation submissions by PREPA for:
  - Near Term 230 kV and 115 kV transmission projects
    - 2 projects (32 miles): 230 kV, existing lines: Cambalache to Manati; Ponce to Costa Sur
    - 14 projects: 115 kV, existing lines (various, ~278 miles) including San Juan underground loop repairs
    - Total costs ~$627 million
  - Near Term 38 kV transmission projects (same process underway)
    - 27 projects
    - ~506 miles, ~$996 million
- Bureau 6/8 /21 Order: subset of these projects approved
- Generally aligned with IRP designation allowing for up to $2 Billion for existing transmission asset repair/hardening
- Excludes all new 115 or 38 kV underground "MiniGrid" projects, for near-term

Infrastructure Plan – Discussion

- Resiliency context:
  - Existing asset hardening – wires, substations, other
  - Vegetation management – how does this affect consideration of MG, DER solutions?
  - Timing of installations – phasing per Infrastructure Plan, per IRP
  - How fast can resiliency solutions be deployed for each of options?
    - What are realistic timeframes for new UG wires solutions? Existing asset hardening is given priority.
    - What are realistic timeframes for deployment of different forms of DER solutions? Not in Infrastructure Plan at any level of detail at this point.

US DOE, National Labs: Role / Timeline

- Longer-term analytical support for examining resiliency issues
- Integrated analysis of transmission, distribution and microgrids
- Pacific Northwest National Lab, Sandia National Lab, US DOE
- Using US DOE / National Labs tools:
  - ReNCAT (microgrids) Resilient Node Cluster Analysis Tool
  - DCAT (transmission) Dynamic Contingency Analysis Tool
  - EGRASS (distribution) Electrical Grid Resilience and Assessment System
- Tools will work with each other, obtain integrated analysis of resiliency benefits from proposed investments
  - Focus: SJ/Bayamon region, and El Cano Martin Pena
  - Data needs – considerable – e.g., transmission, distribution, GIS, other infrastructure / parameters
- Timing: Methodology and tools: Spring 2022

Responses to March 24, 2021 Energy Bureau Questions

- Questions: 1-4 (wires), 5-11 (DERs)
- Respondents:
  - LEOs
  - OIPC
  - Cambio/IEEFA
  - ICSE
  - PREPA (with attachments)
  - LUMA

- Synapse note: Apologies for any mischaracterizations in this slide deck, of filed stakeholder information – intention for workshop is high level summary of main points.

Q. 1- Transmission

1. See the reference to Exhibit 2-9 (PREPA response to Appendix B questions). There are 13, 115 kV new underground projects listed. Five are within the San Juan / Bayamon region.
   a. State specifically which projects make up what is referred to as the "San Juan underground loop" in the FEMA infrastructure filing/report.
   b. Describe the San Juan underground loop project and why it is needed.
   c. Of these 13 projects, which are most critical for overall transmission reliability in the San Juan / Bayamon and adjoining regions under extreme weather event conditions?
   d. As best as able, provide a priority order ranking of importance for these projects.
   e. Provide further additional explanation as warranted to support the priority ranking.
   f. Are any of these 13 projects required to support operations under "blue sky" conditions? If so, explain why for each project.
   g. Explain the relative importance of the last three projects, #14-16, in comparison to the new underground proposed projects.

Q. 1- Transmission Responses - PREPA

- a) and b) San Juan underground loop – existing segments, repairs planned - $10 million

- c) through f) remaining 13 new UG projects
  - Parallel path to existing 115 kV OH lines – intent is "minigrid backbone"
  - Also support transfers under 230 kV contingencies
  - 5 are in or connect adjacent regions to the SJ/Bayamon region
  - #3 "extend reach of Palo Seco generation"

  - No analysis for how existing line repair / hardening might affect need for these lines / no specific ranking of importance provided

- g) 3 new OH projects
  - New source in parallel to existing 230 kV
  - "additional 115 kV source" "back up and additional reliability"
  - "for the event of contingency of existing OH 230 kV line 50500"
  - "backup for the 51200 line" [230 kV]

  - No analysis for any of these three OH lines addresses potential lower peak loads, effect of future BESS on transmission grid loading at peak

Q2, Q3 – 38 kV new UG, critical load clusters associated with 115 and 38 kV new UG proposals

2. There are more than 100, 38 kV undergrounding projects, for roughly 318 miles, listed in IRP Exhibits 23, 35, 43, 51, 61, 69, 83 (and ~35 in the SJ/Bayamon region).
   a. For the San Juan and Bayamon region projects listed, provide a rough ranking of the projects, or groups of projects, that would be required to serve what PREPA understands to be the densest clusters of feeder or 38kV-connected critical loads.
   b. Provide additional explanation or support for prioritized 38 kV new underground work.
   c. Are any of the 35 projects in the San Juan / Bayamon region required to support operations under "blue sky" conditions? If so, explain why for each project.
   d. What is PREPA's best estimate of the total costs of additional distribution system hardening work required to enable delivery of power to critical loads attached to the hardened network or lines resulting from 38 kV undergrounding?

3. For the 115 kV and 38 kV new underground projects listed in the above questions (SJ/Bayamon):
   a. Are there clearly identifiable clusters of critical load that in total represent the most densely loaded areas of the San Juan / Bayamon region, that could benefit from increased reliability through specific undergrounding projects? If so, please identify those clusters with as much specificity as possible.
   b. For those clusters, identify which projects are necessary, in combination, in order to serve the critical load.
   c. Specify the critical loads in question, and the magnitude (confidential response).

PREPA Response to Q2

- Attachment 3 lists 38 kV-fed critical load as priority; and 24 projects with same “ranking”
  - Cost as listed in Attachment 3 ~ $273 million ($4.5 M/Mi) for these 35 projects (60 miles)
  - Cost in Response to original for ~same projects ~885 million (class 5 estimate) was ~$15 M/mile.

ID	Region	Miles (total)		Cost Estimate: 10 YR PLAN (M$)	NOTES
		OH	UG		
7	San Juan	31.11		$ 468.21	IRP Exhibit 2-61
		0	31.11		
	Bayamon	27.7		$ 416.89	IRP Exhibit 2-69
		0	27.7		

  - Which is correct/best estimate at this time?
  - Part c) of Q2 asked “needed for blue sky”? Response “will add reliability to existing connections” but no indication of actual need
- Remaining 11 projects (to stations with feeders) ranked lower than 38 kV-fed projects

PREPA Response to Q3 – Clearly Identifiable Clusters? 115 kV, 38 kV Projects

- Response references Q2
- No further detail on linkage across 115, 38 kV UG projects to serve clusters of critical load
- Outstanding question: how to prioritize / sequence 38 kV projects to densest critical load clusters?

Q4 – Substation Hardening

4. Of the 43 substation hardening projects listed in response to Appendix B questions (see table below):
   a. For each project, state with specificity the underlying rationale for the proposed hardening.
   b. Which projects are recommended for hardening separate from any consideration of a MiniGrid configuration across the Island? Why?

Per Exhibit 2-12: 115 kV Stations to Harden- 43 Projects

Item No.	Project Description	Cost Estimate (Class 5- $M)	Item No.	Project Description	Cost Estimate (Class 5- $M)
1	Manati TC - 115 kV and 46 kV Switchyards	20	23	Switchyards (in addition to hardening should at least include protection and control systems modernization + remote	93.3
2	Cambalache - TC 115 kV and 46 kV Switchyards	23.5	24	Aguirre 230 kV, 115 kV and 46 kV Switchyards	42.2
3	Dos Bocas HP - 115 kV and 46 kV Switchyards	19.1	25	Maunabo TC Hardening/Reconstruction 115 kV and 46 kV Switchyards	4.5
4	Barceloneta TC - 115 kV and 46 kV Switchyards	20	26	Jobos TC 115 kV and 46 kV Gas Insulated Substation (includes new 230/115 kV Transformer conneceted to 230 kV line to AES)	27.6
5	Mora TC Gas Insulated Substation 115 kV and 46 kV Switchyards	11.5	27	Ponce TC 115 kV and 46 kV Switchyards GIS	17.1
6	Bayamon TC - 230 kV, 115 kV and 46 kV Switchyards	65.7	28	San Juan GIS 115 kV Switchyard	3.5
7	Vega Baja TC - 115 kV and 46 kV Switchyards	20.5	29	Isla Grande TC - Hardening GIS 115 kV and 46 kV Switchgear	3.5
8	Dorado TC - 115 kV and 46 kV Switchyards	27.1	30	Monacillo TC - 115 kV, 46 kV and 13.2 kV Switchyards	49
9	Juncos TC - 115 kV and 46 kV Switchyards	25.5	31	Hato Rey TC - 115 kV, 46 kV and 13.2 kV Switchyards	29.2
10	Caguas TC -115 kV and 46 kV Switchyards	29.4	32	Viaducto TC - 115 kV and 46 kV Swichyards	36.3
11	Rio Blanco HP - 115 kV and 46 kV Switchyards	35.8	33	Berwind TC - 115 kV, 46 kV and 13.2 kV Switchyards	14.8
12	Cayey TC - 115 kV and 46 kV Switchyards	16.2	34	New Venezuela TC Gas Insulated Substation for 115 kV, 46 kV and	4.4
13	Humacao TC - Hardening and Expansion 115 kV and 46 kV	23.9	35	Yabucoa TC - 115 kV extension includes provision for 115 kV underground circuits and future generation)	21.5
14	Canóvanas TC - 115 kV and 46 kV Switchyards (includes 46 kV bus	9.8	36	Mayaguez TC - Hardening/Reconstruction 230 kV and 115 kV Switchyards	14.2
15	Sabana Llana TC - 115 kV and 46 kV Switchyards	34.7	37	Comerio TC - Hardening/Extension 115 kV and 46 kV Switchyards (includes extension to interconnect new 46 kV line to new	12.4
16	Fajardo TC - 115 kV and 46 kV. Extension of 46 kV Bus for New UG to Fajardo	19.4	38	Palmer TC - Hardening/Reconstruction 115 kV and 46 kV Switchyards	15.5
17	Daguao TC - 115 kV and 46 kV Switchyards	18.4	39	Añasco TC - Hardening/Reconstruction 115 kV Switchyard	3
18	Victoria TC - 115 kV and 38 kV Switchyards	31.1	40	Rio Bayamon Sect - 115kv Hardening/Reconstruction	8.3
19	San Sebastián TC - 115 kV and 38 kV Switchyards	17.8	41	Crea (Hogar Crea) 115 kV Sect.	3.6
20	Mayaguez GP - 115 kV and 38 kV Switchyards	23.9	42	Candelaria Arenas 115 kV Sect.	2.8
21	Acacias TC - 115 kV and 38 kV Switchyards (includes extension for new	40	43	Juan Martin 115 kV Sect.	1.4
22	San Germán TC - 115 kV and 46 kV Switchyard Costa Sur Gas Insulated	12.7			$ 954.1 million ($1.4 B in IRP)

Q4 PREPA Response / Discussion

- Q4: substation hardening
- All station hardening required (43 projects). Useful life, degradation, repair needed.
- $954 million

- Discussion:
  - Extent of repair / cost required –
    - Is $954 million “maximum” level of repair?
    - What is the level of repair / cost required to meet codes and standards?
- Other questions?

Q1-4 Other Party Responses

- OIPC:
  - Undergrounding could be problematic if flooding concerns / also, undergrounding where load is densest is most relevant.
  - Accessibility and ROW conditions important
  - Sabana Llana and Berwind 115 kV undergrounding, and Palo Seco to Hato Tejas TC to Dorado TC
- LUMA
  - No new undergrounding in its System Remediation or Initial Budgets filings/plans.
  - Rebuild, repair, harden existing 115 and 38 kV. General agreement with San Juan underground loop repair need.
  - Rationale for undergrounding in specific circumstances, but better if initial focus is on overhead T&D.
  - Cost savings from not undergrounding allows for more overhead remediation work. Longer-term concern – cable failures w/ undergrounding.
  - Enhance understanding – system GIS, for example.
  - But also acknowledges that undergrounding of distribution could be more cost effective per customer than rooftop + storage (Q11 response)
- Cambio/IEEFA
  - Flooding a concern for new undergrounding.
  - Disagree w/ C/B premise - cannot optimize DER / wires – different levels of service in response to event (Q11) – Syn. note: Exh. 2-100 contains estimates of lost load MWh/MW, after outages for 3 areas
- LEOs
  - Undergrounding flooding concerns, and need to compare wires solutions with DER solutions
- ICSE
  - Overall context for analysis, 1-4 related to 5-11.
  - Importance of DER solutions / customer-specific DER packages

Q1-4 - Discussion Prompts

- Are any of the new 115 kV underground projects needed at this time?
  - Why or why not?
  - No ranking provided
  - Parallel transmisson paths already exist
  - Hardening of existing (other) assets is planned
- Are any of the 38 kV projects needed at this time?
  - Why or why not? Parallel 38 kV paths exist…
  - No relative ranking for top 24 projects (of total of 35)
    - What would staged implementation look like, for (say) top 5 projects?
    - What specific combination of 38 kV circuits, and distribution system work, is top priority for near term?
- How would installation of DERs (at low/med/high levels) affect need for any of these projects, for either blue sky or resiliency reasons?
  - Blue sky conditions: lower loading w/ distributed BESS
  - Black sky conditions: DERs provide customer-level resiliency – cumulative DR installation timing, and timing of overall wires solutions affects comparisons

Q5-7 DERs No Regrets, Resiliency Value, Rapid Deployment

- PREPA
  - Utility and DER resources for resiliency / consider locational aspects – local generation important
  - Microgrid DERs – other DERs higher cost because of economies of scale
    - But no direct accounting for resiliency benefits in response
    - Acknowledgement that avoiding costs of transmission help DER economics - no quantitative analysis
- Cambio/IEEFA/LEOs – Cambio study / We Want Sun and We Want More
  - Widespread deployment of rooftop solar and battery storage – household level resiliency
  - Funding through FEMA; PREPA procure [and own? "enter into legal arrangements and provide to participating households"]
  - Act 17 – "gives the Bureau the power to define homes as 'essential facilities' ".
  - DERs more suited to avoid loss of life than T&D hardening
- LUMA
  - PV, BESS, DSM. Supports both utility scale and rooftop scale.
  - Interconnection requirements.
  - Resiliency: grid restoration, vulnerabilities, energy limitation considerations.
- OIPC:
  - BESS (dist. substations and on feeders) and solar PV, small scale and FEMA/CDBG financed. VPP, procurement tariffs also.
- ICSE: Customer specific DER packages

Q8 and Q9 – Role of PREPA/LUMA in DER and Microgrids – Analysis, Procurement Tariffs, Installation

- PREPA
  - PREPA/LUMA does microgrid analysis; private microgrid: self-financed
  - Some public purpose microgrids possibly eligible for FEMA 404 or 428 / Stafford Act funding.
  - Net metering - sufficient for DERs – no other procurement incentive
    - But "capacity product", fully dispatchable, could be compensated in areas with need
  - No role for PREPA/LUMA in installations. Third-parties/private sector role.
- LUMA
  - LUMA does analysis; is developing "optimal microgrid deployment …framework"
  - Room for community, feeder-based microgrids, and individual customer DERs. LUMA does not install.
  - Competitive RFPs (VPPs), DR, tariff, combination: mechanisms to procure DERs.
  - Notes support for direction of Cambio study, but technical and other considerations, and further refinement needed
- Cambio/IEEFA
  - Microgrids less important than rooftop PV/BESS for resiliency
  - Household level resiliency w/ rooftop PV/BESS
  - Yes, PREPA should be involved in installation – LI communities, less likely to have procurement/financing options
  - Note: IRP Append. 1 – Public Version is available on Energy Bureau website with rest of IRP documents (6/19/'18)
    - https://energia.pr.gov/wp-content/uploads/sites/7/2019/06/5-IRP2019-EX-1.01C-Appendix-1_Section2_Redacted.pdf
- LEOs:
  - PREPA (not LUMA) should procure and install (and own) rooftop systems, FEMA funded. Low and moderate income consumers – upfront costs are major obstacles – need PREPA to fund/install.
  - No comment on microgrids.
- OIPC:
  - PREPA/LUMA analyze microgrids, and some public microgrids could be supported by PREPA.
- ICSE:
  - No microgrid analysis or involvement (except monitoring) by PREPA/LUMA. No PREPA/LUMA role in DER installations.
  - Best-fit packages of DERs, procured via 3rd parties, funded through FEMA. Beyond FEMA funding: "Revolving Energy Trust"

Q10 How to Pay for DERs

- PREPA
  - Privately financed for most DERs
  - Some public purpose could be eligible through FEMA hazard mitigation mechanism (COR3 administration process)
- LUMA
  - Competitive procurement, demand-side programs, tariff incentive, combinations
- Cambio/IEEFA/LEOs/OIPC/ICSE
  - FEMA / Stafford Act / CDBG
  - ICSE: "Revolving Energy Trust" after FEMA funding

DER Discussion Question Prompts (1)

- For customers not served by hardened wires / MiniGrid – e.g., all the load PREPA already indicates can't be economically reached with hardened system, plus any other load better served w/ DERs for resiliency:
  - Rural Puerto Rico, essential facilities and households
  - Across sectors, facility types; varying levels/requirements to meet actual critical load
- Energy Bureau is considering means for resiliency procurement for these customers, to attain "rapid deployment". Complements wires solutions.
  - Detailed mechanisms needed. Must move beyond just "FEMA pays", or "third-party".
- What does this DER procurement look like, in detail, across the customer populations that need resiliency? How would you do it? Ensure access?
  - Not all of this population can self-supply.
  - Not all of this population will be served by VPP options.
  - Low/Moderate income / how to overcome obstacles to first costs?
  - Public spaces / small town centers / police, fire / small health centers/hospitals?
  - Community solar, microgrid options – framework? [Per Act 17-2019]
  - What does VPP response to 1st tranche say about this procurement vehicle for this load?

DER Discussion Question Prompts (2)

- Procurement mechanism factors:
  - Ownership of DER elements
  - Building/facility type – not microgrid? Eventual microgrid beyond one site?
  - Rate type – net metered for energy?
  - Product sold/purchased/installed – capacity, energy, or combination.
  - Visibility / control: owner/operator, or PREPA/LUMA. DERs: not necessarily for grid restoration.
- Procurement options – illustrative - mechanisms to provide resiliency to end use load – rural load
  - Self provide (net meter, self-resilient)
  - Via VPP contract
    - Conventional – rooftop rental, VPP owns? Other: BESS only, customer owns, VPPs controls?
  - DR program participant
    - Need DR tariff structure.
    - Sell battery capacity for blue sky days – PREPA controls, evening discharge contract amount?
    - Keep for resiliency when grid is down.
    - Net metered for energy? Other metering/rate arrangements?
  - PREPA/other agency, non-profit, ?, provides financing, owns systems / LMI participants
    - Promotion of community solar and microgrid? [Act 17-2019, section 6.3, (tt)]
    - For those not part of VPP portfolio / obstacles to finance, capital
    - Rooftop rental? Other examples/modes?
    - Customer pays regular bills on gross demand. Is resilient when grid is down.

DER Discussion Question Prompts (3)

- Are VPP contracts / PPOAs, and DR programs sufficient to support DERs for resiliency? At what MW level, for what timing needs? (IRP: 6 tranches of procurement)
  - If so: what further actions are needed now, to ensure "rapid deployment"?
  - Or are additional procurement vehicles needed?
  - In what way do net metering issues figure into DER procurements for resiliency?
- How best to address low/moderate income obstacles to funding, self-provision?
  - Do VPP procurement vehicles suffice, or is other form of access to financing necessary?
  - Who owns DERs on rooftops? How to structure procurement/ownership/rates? Up to VPP provider?
  - Puerto Rico public agencies as vehicle? PREPA? Municipalities? Other?
- What portion of PV/BESS DERs for different procurement vehicles?
  - Energy: currently, net metering – high incentive, but limited access for low/moderate income customers
  - Capacity: more closely aligned as "substitute" for conventional transmission/distribution hardening to support resilience at customer level
  - PV/BESS work together – best to keep them coupled from financing/procurement perspective?
  - Or can/should PREPA procure just batteries, and let consumers/third-party financers pay for PV?

PM Session

Resiliency Screening Summary – Benefit/Cost Analysis

- MiniGrid resiliency
  - MG Transmission costs, by region and total, updated (PREPA, Jan. 2021)
  - Excludes other non-MG transmission hardening (e.g., existing Infrastructure Plan near-term)
  - Includes additional local peaker capacity costs (371 MW, ~$543 million). IRP metrics file.
  - Includes estimate of distribution hardening costs, based on IRP 10-year priorities. Exhibit 10-19, IRP.
    - Portion incurred regardless of MG; but other costs expected for full MG/trunkline hardening are not in IRP.
- DER sourced resiliency
  - Resiliency at end user sites – not necessarily tied to resources for restoration of grid
  - Based on January 2021 NREL benchmarking report
  - 7 kW solar PV and 13 kWh, 4-hour battery as basis for costs for DER solutions.
- Value of load not lost is the 'benefit" for both MG and DER solutions. Taken directly from PREPA VOLL case. To attain that value:
  - MG solutions - all MG transmission costs (~$7.7 billion) plus Dist. & local capacity.
  - DER solutions: <u>ALL</u> load with PV and BESS, at incremental costs relative to utility-scale PV / BESS resources.
    - This is key consideration in screening – to allow for head-to-head comparison, assuming "perfect" MG functionality, must assume deployment of DER solution for ALL load within each MG region.
    - Actual DER, distribution costs, timing for MG/DER solutions is unclear. Actual levels of lost load prevented with either solution difficult to render.
- <u>Screening exercise only, attempt at comparability of options.</u>

Data and Sources for Resiliency Screening

- Transmission costs – PREPA responses and updates
- Distribution costs – IRP, Exhibit 10-19, and App. 1, Exh 5-22, 23, 24
- Local capacity costs – MG solution – IRP metrics files (371 MW new)
- Distributed Resource Costs – NREL benchmark report, Jan ’21
  - Differential between utility scale and distributed/small scale PV/BESS
- Load, peak and energy – PREPA IRP load forecast, metric files
- Critical load portion – PREPA, IRP
- Estimate of lost load, and value of lost load (VOLL) – PREPA, IRP – Exh. 2-100

B/C Analysis – Resiliency Screening – Transmission Costs

- MiniGrid transmission costs.

Total Cost Estimate: 10 YR PLAN (M$)								
Region	115 kV exist OH	115 kV new UG	115 kV new OH	Subst/ Switchyd	38 kV exist OH	38 kV new UG/OH mix	38 kV new UG	Grand Total
Arecibo	14	222	48	83	126		347	840
Bayamon	69	159		122	25		417	792
Caguas/Cayey	52	362	4	129	149	532		1,228
Carolina	30	309		134	9		400	881
Isla	110		74	101				285
Mayaguez	56			154	47	800		1,058
Ponce	101			91	5		1,425	1,623
San Juan	15	283		141	116		468	1,023
Grand Total	**447**	**1,336**	**126**	**954**	**477**	**1,332**	**3,057**	**7,729**

- From PREPA response to Appendix B questions (January)

B/C Analysis – Resiliency Screening – Distribution and Local Capacity Costs

- MiniGrid effectiveness at providing resiliency – reducing lost load – depends on distribution system work.
  - "for these [Minigrid] investments to be effective, a parallel effort must be conducted at the distribution level" (IRP Appendix 1, Section 5-4, p. 5-2.]
  - IRP Exhibit 10-19

	Priority 1	Priority 2	Priority 3	Priority 4	
	2020 -2022	2023-2024	2025	2026	Total
Substations GIS	81.17	52.40	21.94	21.67	177.17
Feeder	367.89	214.59	118.93	32.90	734.31
Total	449.06	266.99	140.86	54.57	911.48

  - Capacity costs ("metrics detail" tab of metric file) – 371 MW at ~$1,541/kW

CapEx $000 2018	2019	2020	2021
New Solar	-	399,420	765,242
Peaker_diesel	-	-	-
Peaker_gas	-	-	543,570
BESS_6hr	-	61,830	57,872
BESS_4hr	48,741	177,597	582,880
	-	-	-
Grand Total	**48,741**	**638,848**	**1,949,564**
Cumulative	48,741	687,589	2,637,153

B/C Analysis – Resiliency Screening – MG Solution Costs - Annual Basis, and per kWh of Puerto Rico load

- Underlying cost of full MiniGrid transmission solution for resiliency
- Average annual costs: 9.2 c/kWh, 0.15 "fixed charge rate" basis
- Higher in rural areas, lower in SJ/Bayamon (range 5.0 c/kWh – 14.8 c/kWh)

	Arecibo	Bayamon	Caguas/ Cayey/Isla	Carolina	Mayaguez N+S	Ponce E+W	San Juan	SJ/Baya	Total
Full MG Solution Costs from PREPA (Tx, Dst wires, Pkr Cap)									
Transmission Costs MG Only	840	792	1,513	881	1,058	1,623	1,023	1,815	7,729
Other costs - peaker capacity, MG			215	143	143	72			572
Other costs - Distribution 10 Yrs	165	131	166	99	174	118	59	189	911
Total Costs MG Solution ($ Mill.)	**1,005**	**923**	**1,894**	**1,123**	**1,375**	**1,812**	**1,081**	**2,004**	**9,213**
FCR (fixed charge rate / capital recovery factor)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Annual Costs ($ Mill.)	**151**	**138**	**284**	**168**	**206**	**272**	**162**	**301**	**1,382**
Annual sales (GWh) (IRP Load Fcst, 2019)	1,501	2,189	2,424	1,675	1,678	1,837	3,780	5,970	15,084
Annual cost cents per kWh	**10.0**	**6.3**	**11.7**	**10.1**	**12.3**	**14.8**	**4.3**	**5.0**	**9.2**
Sensitivity to carrying charges for Tx:									
at higher FCR (.20)	**13.4**	**8.4**	**15.6**	**13.4**	**16.4**	**19.7**	**5.7**	**6.7**	**12.2**
at lower FCR (.08)	**5.4**	**3.4**	**6.3**	**5.4**	**6.6**	**7.9**	**2.3**	**2.7**	**4.9**
Note: "Isla" reflect MiniGrid Tx costs w/o specific MG region - allocated to Caguas/Cayey for this contruct									
Distribution costs based on IRP Appendix 1 Exh. 5-22, 5-24, and 5-25. Did not inflate. Peaker capacity costs from metrics file, inflated to 2021.									

MiniGrid Solution - Resiliency Cost Screening (1)

- PREPA MiniGrid VOLL (Exh. 2-100) is the basis. A single event / 4 weeks duration.
- Expanded to estimate effect for Arecibo, Mayaguez, Ponce – screening purpose only
- Crit/Priority/Bal load VOLL = $32,000/$10,000/$2,000
- Same criterion / level of lost load avoided and VOLL to be used for DER valuation

One Event / 4 weeks (L1+L2 out 1st; L1 out, L2 in next 3 weeks)	Arecibo	Caguas/ Cayey/Isla	Carolina	Mayaguez N+S	Ponce E+W	SJ/Baya	Total
MWh Critical	*20,261*	33,967	36,191	*33,976*	*37,207*	95,244	256,846
MWh Priority	*4,503*	14,223	7,455	*7,550*	*8,268*	50,725	92,724
MWH Balance	*20,261*	22,606	37,961	*33,976*	*37,207*	127,861	279,872
MWh resiliency provided (avoided Lost Loa	*45,025*	70,797	81,607	*75,502*	*82,682*	273,830	629,443
Relative Index of avoided lost load (MWh not lost per GWh annual sales)	*30*	*29*	*49*	*45*	*45*	*46*	*42*
Relative Index - actual or estimated	*Estimated*	*Actual*	*Actual*	*Estimated*	*Estimated*	*Actual*	*Act. + Est.*
VO resiliency provided ($) Critical	$648,365,530	$1,086,951,758	$1,158,114,165	$1,087,223,784	$1,190,617,495	$3,047,815,247	$8,219,087,980
VO resiliency provided ($) Priority	$45,025,384	$142,231,885	$74,553,758	$75,501,652	$82,681,771	$507,250,458	$927,244,907
VO resiliency provided ($) Balance	$40,522,846	$45,212,463	$75,922,064	$67,951,487	$74,413,593	$255,722,354	$559,744,807
VO resiliency provided ($) total	$733,913,759	$1,274,396,105	$1,308,589,987	$1,230,676,923	$1,347,712,859	$3,810,788,060	$9,706,077,694

Cost of Resiliency and B/C ratios for MG Resiliency Solution

	Arecibo	Caguas/ Cayey/Isla	Carolina	Mayaguez N+S	Ponce E+W	SJ/Baya	Total
MiniGrid Proposal Preliminary Estimated Resiliency Cost and Benefit / Cost ratio ($/$)							
MG Costs $ / MWh - single storm event resiliency based on annual carrying costs of MG costs	3,347	4,013	2,065	2,732	3,288	1,098	2,195
MiniGrid B/C $/$, Based on total MG costs	0.73	0.67	1.16	0.90	0.74	1.90	1.05

MiniGrid Solution - Resiliency Costs Screening (2)

- Overall Benefit / Cost ratio of 1.05 island-wide
- San Juan / Bayamon exhibits highest B/C ratio, more rural regions (Ponce, Caguas/Cayey, Arecibo) exhibit lowest B/C ratios
- To be compared against analogous metrics for DER solution

Cost of Resiliency and B/C ratios for MG Resiliency Solution							
	Arecibo	Caguas/ Cayey/Isla	Carolina	Mayaguez N+S	Ponce E+W	SJ/Baya	Total
MiniGrid Proposal Preliminary Estimated Resiliency Cost and Benefit / Cost ratio ($/$)							
MG Costs $ / MWh - single storm event resiliency based on annual carrying costs of MG costs	3,347	4,013	2,065	2,732	3,288	1,098	2,195
MiniGrid B/C $/$, Based on total MG costs	0.73	0.67	1.16	0.90	0.74	1.90	1.05

B/C Analysis – Resiliency Screening – MiniGrid Discussion

- Extended (Arecibo, Mayaguez, Ponce) to see overall value across Puerto Rico of this construct. IRP VOLL exhibit only addressed other regions.
- To be compared to DER valuation.
  - DER valuation will assume ALL load needs DER solution to achieve the level of resiliency / avoided lost load as in MG proposal
- Purpose is not to determine absolute representations of resiliency, or DER costs, or how DERs will operate blue sky vs. dark sky.
- Purpose is to allow comparison with rough degree of quantitative comparability to gauge relative resiliency solution efficacy.
  - Same lost load saved
  - Respects need to implement more DER to get broad coverage
  - Some parameters uncertain, or ignored – potentially critical – for example:
    - Assume all MiniGrid resiliency benefits are achieved, even though full distribution hardening required to ensure attainment of estimated value. Estimate may not capture full extent of distribution cost needs for MG solution.
    - Assume equivalent resiliency with DER even with just 4-hour BESS solutions – no additional fossil backup/on-site generation in screening.
    - No temporal sensitivity – compare solutions without implementation trajectory effects.

B/C Analysis – DER Resiliency Screening

- For purpose of computing costs for DER to use in resiliency screening:
  - Differential costs to provide same BESS peak output, BESS duration, and similar PV/BESS ratio at DER scale, vs. utility scale – NREL benchmark costs
  - To the extent that economics of scale affect purchasing (e.g., VPPs), these values directly affect comparative B/C ratios, next slide.

NREL PV/BESS Costs	Per Peak Period BESS output		Basis - 2020 NREL Benchmark (Jan 2021)
Benchmark Costs - utility scale systems	2,883	$/KW	100 MW PV, 60 MW, 4-hour BESS
Benchmark Costs - equiv. cost utility scale systems w/ 10% losses for T/D vs. DER	3,204	$/KW	100 MW PV, 60 MW, 4-hour BESS
Benchmark Costs - small scale systems	8,285	$/KW	7 kW PV, 4 kW, 4-hour BESS
Incremental Cost for small scale systems	5,081	$/KW	7 kW PV, 4 kW, 4-hour BESS

B/C Analysis – DER Resiliency Screening Key Result

- B/C ratio across Island: 0.92. Varies by region. Only for comparison to MG solution.

Incremental Cost from Utility Scale, at Peak, mid-range system, based on 10% loss savings							
	ARECIBO	CAGUAS/ CAYEY	CAROLINA	MAYAGUEZ N+S	PONCE ES+OE	SJ/Baya Combined	TOTAL
Peak Load total at facilities, MW	207	332	230	235	253	809	2,066
Inc. Cost of PV/BESS Systems - **all load** - millions	$1,050	$1,688	$1,170	$1,194	$1,285	$4,111	$10,498
Annualized inc. cost of PV/BESS, millions	$158	$253	$176	$179	$193	$617	$1,575
Incremental Cost of DER, cents/ per kWh	**10.5**	**10.4**	**10.5**	**10.7**	**10.5**	**10.3**	**10.4**
Cost of Resiliency (Annualized) and B/C ratios for DER Resiliency Solution - Assume ALL load is served with DERs.							
DER Costs $ / MWh - single storm event resiliency - based on annualized DER costs	3,499	3,576	2,151	2,372	2,331	2,252	2,502
DER B/C $/$ based on incremental cost of DER resource	0.70	0.76	1.12	1.03	1.05	0.93	0.92

B/C Analysis – MiniGrid vs. DER Resiliency Screening

- MiniGrid B/C all regions = 1.05, DER B/C all regions = 0.92

Cost of Resiliency and B/C ratios for MG Resiliency Solution							
	Arecibo	Caguas/ Cayey/Isla	Carolina	Mayaguez N+S	Ponce E+W	SJ/Baya	Total
MiniGrid Proposal Preliminary Estimated Resiliency Cost and Benefit / Cost ratio ($/$)							
MG Costs $ / MWh - single storm event resiliency based on annual carrying costs of MG costs	3,347	4,013	2,065	2,732	3,288	1,098	2,195
MiniGrid B/C $/$, Based on total MG costs	0.73	0.67	1.16	0.90	0.74	1.90	1.05

	ARECIBO	CAGUAS/ CAYEY	CAROLINA	MAYAGUEZ N+S	PONCE ES+OE	SJ/Baya Combined	TOTAL
Cost of Resiliency (Annualized) and B/C ratios for DER Resiliency Solution - Assume ALL load is served with DERs.							
DER Costs $ / MWh - single storm event resiliency - based on annualized DER costs	3,499	3,576	2,151	2,372	2,331	2,252	2,502
DER B/C $/$ based on incremental cost of DER resource	0.70	0.76	1.12	1.03	1.05	0.93	0.92

Discussion Points – Head-to-Head Comparison, DER vs. MiniGrid solutions

- Overall: MG better for more densely loaded regions, DER better for more lightly loaded regions.
  - Overall resiliency costs between the two solutions are notably similar. False precision generally, given sensitivity to assumptions.
  - Regional differences useful – logical result given load density differences. But regional differences would also be sensitive to cost allocation methods used (for wires and capacity).
  - DER incremental costs / potential economies of scale vs. using NREL benchmarking – not captured.
  - Distribution costs exclude some additional MG requirements but include some costs that would be incurred anyway.
  - Transmission costs themselves also sensitive – based on class five estimates (+100%/-50%)
- Screening does not help to better differentiate solutions within the San Juan / Bayamon region itself.
- It is a rough screening – numerous factors to consider include/not limited to:
  - Especially for 115 kV, costs associated with a given MG region provide resiliency benefit to adjacent regions also – allocating for screening purposes only.
  - DER solution set assumes roughly 7 kW PV and 4 kW / 13 kWh BESS. Assumes this is similar level of resiliency provision, on average considering all factors, as the MG solution which in theory has unlimited ability to provide kWh.
  - Ability to equitably cover resiliency needs across Island leads to using both solutions. Screening does not help to assess how the approach to resiliency is likely to ensure broad access to resiliency.
  - Other: timing, practicality of implementation – important, but not directly included in screening for either solution set.

Proposed "No Regrets/Limited Regrets" Actions

- DER solutions for self-resiliency at end user load is economic or likely economic in significant part across much of the Island, based on economic screening. MG solutions are economic in densely loaded areas.
- No initial evidence that any new 115 kV undergrounding should be part of "no or limited regrets" actions. The SJ UG loop is included. All other new 115 kV underground region-to-region interconnection paths are redundant to existing asset paths, which when hardened will make this aspect of SJ/Bayamon more resilient (without the new underground assets).
- PREPA did not fully rank the 38 kV new UG projects. It seems reasonable to think that some limited 38 kV hardening may be warranted – but PREPA information did not help to ascertain which ones are most important. A staged approach with initial sets of 38 kV and coupled feeder projects is recommended.

<u>Actions – Screening Indications</u>

1. Wires:
    - 115 kV: Existing transmission wires, substation asset hardening only, at this time. 38 kV: Staged project hardening, select 1-5 circuits/projects in San Juan area, in densest critical load area.
    - Distribution undergrounding: couple initial preferential, directed feeder hardening to 38 kV projects (feeders from 38 kV substations to which 38 kV supply lines have been hardened). Priority 1 from IRP Appendix 1 as guide. LUMA/PREPA to file specific set of projects.
2. Structured DER procurement needed:
    - To cover load unreachable through MG approach.
    - VPPs – through procurement 2nd tranche mechanism –focus fully on DER options
    - DR tariff details – complementary means to allow for smaller-scale DER installations outside of VPP mechanism
    - Energy Bureau to further determine means to address low-medium income financing/procurement obstacles, and public purpose critical load solutions to ensure broad access to PV, BESS through VPP, DR, or other mechanism.

Wrap-Up and Next Steps

- Wrap-Up
  - Comments post-workshop – respond to Proposed Actions, Slide 36 (previous slide) – submit by July 14, 2021.
    - Provide specific suggestions for DER procurement vehicles, per workshop discussions.
    - Provide specific comment on best candidate for staged approach for 38 kV plus feeder hardening project(s) in the San Juan region.
    - Provide further general or specific comments on any issue discussed during this workshop.

Para más información:

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Backup Slides Including Relevant Slides from Earlier Workshops

Update to MiniGrid Transmission Costs

- PREPA response to Appendix B, Q2. Note cost magnitude vs. Sandia microgrid cost estimate.
- Significant increase in costs over MG components from IRP filing ($5.9 Billion)

Revised Cost Estimates per 10 Yer Plan (Class 5 Estimates): Assets listed in IRP Exhibits 2-85 to 2-93

Minigrid Transmission System Required Investment

Item	Description	Cost ($M)	Notes
1	**Controllers & SCADA: 8 Minigrids**	**$ 6.75**	***No change in estimate from IRP***
2	**115 kV Transmission system investment**	**$ 2,863.71**	**Class 5 Cost Estimates: Please refer to corresponding tab**
	2a. Existing Lines to Harden:	$ 447.44	List of 24 Projects ~198 miles from IRP Ex 2-11
	2b. New Lines (OH & UG):	$ 1,462.17	List of 16 Projects ~141 miles from IRP Ex 2-09
	2c. Existing Stations to Harden: 43 Projects	$ 954.10	List of Stations per IRP Ex 2-12
3	**38 kV Transmission system investment**	**$ 4,865.61**	**Class 5 Cost Estimates: Please refer to corresponding tab**
	3a. Existing Lines to Harden:	$ 476.97	List of ~241 miles per IRP Ex 24, 36 ,44 ,52, 62, 71, 84
	3b. New Lines (OH & UG):	$ 4,388.65	List of ~318 miles per IRP Ex 23, 35, 43, 51, 61, 69, 83
	3c. New Stations & Harden to Existing Stations:		List of Stations per IRP Ex 24, 36 ,44 ,52, 62, 71, 84
		$ 7,736.07	
	Total Peak Load at End User	~2,400 MW	(critical plus priority load = ~1,600 MW)
	Cost per MW Peak Load ($ Mill.)	$ 3.22	Sandia: $2 Million/MW for Microgrid
	Cost per MW critical + priority	$ 4.84	

Notes

1 A class 5 cost estimate is one that is prepared at an early stage in the project development process and is expected, based on industry standards, to range from 50% below to 100% above the actual final project cost. Leading industry practice is to revise estimates, so they become more accurate as engineering design progresses and project requirements are solidified.

2 PREPA will begin in Q1 2021 performing field assessment and A&E design on T&D assets. Once completed, PREPA can provide more accurate estimates

Recap: Optimization Proceeding Objective

- Identify "no regrets" resiliency solutions
- 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.

Revised Infrastructure Plan Summary –PREPA April Filing – 230, 115 kV Projects

Short Term Priorities: HV Lines per PREPA LUMA alignment process

Item	Line #	Voltage	START	END	Length (Miles)	Class 5 Estimate ($M)	Notes
1	50100	230	CAMBALACHE	MANATI	20.2	$ 43.47	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Requires update to new Codes and Standards
2	51300	230	PONCE	COSTA SUR	12.0	$ 26.08	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Requires update to new Codes and Standards
3	36100	115	DOS BOCAS	MONACILLOS	48.8	$ 115.49	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Listed in IRP Exhibit 2-11 / Requires update to new Codes and Standards. Priority: Segment Monacillos-Quebrada Negrito (8 MI). Selected due to importance of powering Pharma Sector in Juncos
4	36400	115	DOS BOCAS	PONCE	36	$ 87.44	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Requires update to new Codes and Standards. Priority: Segment Dos Bocas Jayuya (12 MI). Selected due to importance of powering Jayuya substation which serves pharma in the area
5	37100	115	COSTA SUR	ACACIAS	37.6	$ 91.99	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Listed in IRP Exhibit 2-11 / Requires update to new Codes and Standards
6	36200	115	MONACILLOS	JUNCOS	22.0	$ 42.74	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Listed in IRP Exhibit 2-11 / Requires update to new Codes and Standards
7	37800	115	CAGUAS	BUEN PASTOR	10.3	$ 22.37	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Requires update to new Codes and Standards
8	37800	115	BUEN PASTOR	MONACILLOS	5.0	$ 11.03	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Listed in IRP Exhibit 2-11 / Requires update to new Codes and Standards
9	37800	115	JOBOS	CAYEY	15.3	$ 26.87	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Listed in IRP Exhibit 2-11 / Requires update to new Codes and Standards
10	37800	115	CAYEY	CAGUAS	12.3	$ 25.13	PREPA Operations Priorities considering system limitations and feasible operational line outages / Disaster Damaged Tline with temporary repairs / Listed in IRP Exhibit 2-11 / Requires update to new Codes and Standards
11	38000	115	SAN JUAN SP	ISLA GRANDE	4.0	$ 10.00	Existing UG loop provides a highly reliable power path and ties together the most significant TCs around San Juan that PREPA relies on to supply power to the metropolitan area. One segment is currently Out of service and upgrades are neded at other terminal to optimize operation.
12	36200	115	FAJARDO	DAGUAO	10.2	$ 23.87	Line rebuild to address end-of-life issues, post-Maria temporary repairs and resiliency improvements.
13	36200	115	DAGUAO	RIO BLANCO	8.3	$ 20.44	Line rebuild to address end-of-life issues, post-Maria temporary repairs and resiliency improvements.
14	39000	115	AGUAS BUENAS	CAGUAS	5.0	$ 9.70	Line rebuild to address end-of-life issues, post-Maria temporary repairs and resiliency improvements.
15	36800	115	CANOVANAS	SABANA LLANA	7.8	$ 15.05	Line rebuild to address end-of-life issues, post-Maria temporary repairs and resiliency improvements.
16	36800	115	CANOVANAS	PALMER FAJARDO	23.0	$ 55.26	Line rebuild to address end-of-life issues, post-Maria temporary repairs and resiliency improvements.
16					278	**$ 626.92**	

Revised Infrastructure Plan Summary –PREPA April Filing – 38 kV Projects – 1 of 2

Short Term Priorities: 38 kV Lines per PREPA LUMA alignment process

LINE	VOLTAGE (kV)	FROM	TO	LENGTH (MI)	Region	Class 5 Estimate ($M)	
100	38	Ponce TC	Jobos TC	43.5	Ponce	$ 85.86	P n
200	38	Ponce TC	Jobos TC	35.8	Ponce	$ 70.69	P n
500	38	Ponce TC	Costa Sur SP	18.0	Ponce	$ 36.59	Li
600	38	Caguas TC	Gautier Benitez Sect	4.8	Caguas	$ 10.11	Li
1100	38	Garzas 1 HP	Garzas 2 HP	1.7	Ponce	$ 3.58	P S
1200	38	Mayaguez GP	Yauco 2 HP	28.0	Mayaguez	$ 55.37	n 2
1500	38	Mayaguez GP	GOAB 1515	29.7	Mayaguez	$ 58.61	Li
1900	38	Dos Bocas HP	San Sebastian TC	25.0	Arecibo/Mayaguez	$ 51.20	Li
2200	38	Dos Bocas HP	Dorado TC	52.6	Arecibo/Bayamon	$ 103.81	P n
2400	38	Dos Bocas HP	America Apparel	12.8	Arecibo	$ 26.86	Li
2700	38	Victoria TC	Quebradillas Sect	20.3	Arecibo/Mayaguez	$ 41.27	Li
2800	38	guadilla Hospital Distrito Se	T-Bone TO	10.9	Mayaguez	$ 22.21	Li
3000	38	Monacillos TC	Juncos TC	44.4	SJ/Caguas	$ 90.44	Li
3100	38	Monacillos TC	Daguao TC	57.4	SJ/CAGUAS/CAROLINA	$ 113.34	P /

Revised Infrastructure Plan Summary –PREPA April Filing – 38 kV Projects – 2 of 2

					SJ/CAGUAS/CAROLINA			/
3600	38	Monacillos TC	Martin Peña	19.6	SJ/Carolina	$	39.98	Li
4000	38	Comerio HP	Escuela Francisco Morales	10.6	Caguas	$	22.33	Li
4100	38	Guaraguao TC	Comerio TC	12.8	Caguas	$	25.28	P n
5400	38	Rio Blanco HP	Daguao TC	37.0	Caguas	$	73.06	P /
6700	38	Martin Pena TC	Villamar Sect	3.0	San Juan	$	6.01	Li
8200	38	San Juan SP	Catano Sect	4.1	San Juan	$	8.07	P /
8900	38	Monacillos TC	Adm. Tribunal Apelaciones	5.8	San Juan	$	11.51	P /
9100	38	Guaraguao TC	Bayamon Pueblo Sect	2.4	Bayamon	$	5.05	Li
9500	38	Palo Seco SP	Catano Sect	3.4	Bayamon	$	6.71	P /
9700	38	Palo Seco SP	Bay View Sect	3.4	Bayamon	$	7.14	Li
11100	38	Canovanas TC	GOAB 11115	10.4	Carolina	$	1.26	Li
11400	38	Barceloneta TC	Florida TO	6.6	Arecibo	$	13.81	Li
13300	38	Bayamon TC	Plaza del Sol	2.7	Bayamon	$	5.39	Li
27				506		$	995.53	

Q. 1- 115 kV New Transmission Projects

Per Exhibit 2-9: New Lines (OH & UG): 16 Projects ~ 141 miles					Region
ID	Project	Miles	Cost Estimate: 10 YR PLAN	M$/mi	
1	New 115 kV Underground Circuit Vega Baja TC – Manati TC @2750 kcmil Cu XLPE	6.78	$ 98.95	$ 14.59	Arecibo
2	New 115 kV Underground Circuit Cambalache TC – Barceloneta TC @2750 kcmil Cu XLPE	8.46	$ 123.46	$ 14.59	Arecibo
3	New 115 kV Underground Circuit Palo Seco Steam Plant –Hato Tejas TC - Dorado TC @2750	10.88	$ 158.78	$ 14.59	Bayamon
4	New Underground Line 115 kV Yabucoa TC- Humacao TC @ 2750 kcmil Cu XLPE	2.50	$ 32.29	$ 12.92	Caguas
5	Underground 115 kV Line Yabucoa TC - Sun Oil - Juan Martin Sect @ 2750 kcmil Cu	5.12	$ 74.72	$ 14.59	Caguas
6	New 115 kV Underground Circuit Juncos TC – Caguas TC- Bairoa TC @2750 kcmil Cu XLPE	9.17	$ 118.43	$ 12.92	Caguas
7	New 115 kV Underground Circuit Humacao TC - Juncos TC @ 2750 kcmil Cu XLPE	10.60	$ 136.90	$ 12.92	Caguas
8	New 115 kV Underground Circuit Daguao TC – Fajardo TC@ 2750 kcmil Cu XLPE (manhole to	10.16	$ 148.32	$ 14.60	Carolina
9	New 115 kV Underground Circuit Canóvanas TC – Palmer TC@2750 kcmilCu XLPE	11.00	$ 160.53	$ 14.59	Carolina
10	Line 40500 extension to Interconnect Venezuela TC GIS @2750 kcmil Cu XLPE	0.68	$ 8.79	$ 12.92	San Juan
11	New Underground 115 kV Line Martin Peña GIS - Berwind TC @ 2750 kcmil Cu XLPE	6.60	$ 85.24	$ 12.92	San Juan
12	New Underground 115 kV Line Sabana Llana TC- Berwind TC @ 2750 kcmil Cu XLPE	2.70	$ 34.87	$ 12.92	San Juan
13	New 115 kV Underground Circuit Caguas TC/Bairoa TC – Monacillo TC @2750 kcmil Cu XLPE	10.59	$ 154.55	$ 14.59	San Juan
14	Construction of 115 kV Line 37800 for Bairoa TC @ 1192.5 kcmil ACSR	1.55	$ 4.29	$ 2.77	Caguas
15	New 115 kV Line Hatillo TC - Mora TC @1192.5 kcmil ACSR Bunting	17.33	$ 47.93	$ 2.77	Arecibo
16	New 115 kV Line Costa Sur - Dos Bocas HP @1192.5 kcmil ACSR Bunting @ 230 kV	26.80	$ 74.11	$ 2.77	Isla
		140.92	**$ 1,462.17**		
		13 UG:	**$ 1,335.84**		

Q1 PREPA Response 115 kV Projects - #s 1-7

H or U	IRP Exhibit 2-9: New Lines (OH & UG): 16 Projects ~ 141 m			Information		
	ID	Project	Miles		Existing Parallel OH Tline	Cost
UG	1	New 115 kV Underground Circuit Vega Baja TC – Manati TC @2750 kcmil Cu XLPE	6.78	The existing line has been observed to overload for the trip of the single Bayamon 230/115 kV for the outage of the two 230 kV lines conencted to Bayamon that follow the same ROW. This underground line is an interconnection between the SJ-B and the Arecibo MiniGrid Backbone extending the reach of the generation from Palo Seco to this area.	TL37400 Vega Baja TC - Manati TC	$ 98.95
UG	2	New 115 kV Underground Circuit Cambalache TC – Barceloneta TC @2750 kcmil Cu XLPE	8.46	Minigrid backbone extending the realible reach of the generation at Cambalache.	TL37400 Cambalache TC - Barceloneta TC	$ 123.46
UG	3	New 115 kV Underground Circuit Palo Seco Steam Plant –Hato Tejas TC - Dorado TC @2750 kcmil Cu XLPE	10.88	The segment Palo Seco to Hato Tejas is a new line extending the reach of the Palo Seco Generation and initiating the backbone of the MiniGrid. The segment Hato Tejas - Dorado parallels the exting line and its role it create the backbone.	TL37400 Hato Tejas TC - Dorado TC	$ 158.78
UG	4	New Underground Line 115 kV Yabucoa TC-Humacao TC @ 2750 kcmil Cu XLPE	2.50	The corridor Yabucoa to Humacao has been historicaly subject to high loadings whith heavy sout to north transfers (i.e. lower generation levels in the north). There are currently two 115 kV lines 36300 & 41000 between Yabucoa and Humacao and under various studies we have observed that the trip of one line overloaded the other. In the IRP this underground line would become part of the MiniGrid backbone delivering the energy from Yabucoa to the loads in Cagua.	TLs 36300 & 41000	$ 32.29
UG	5	Underground 115 kV Line Yabucoa TC - Sun Oil - Juan Martin Sect @ 2750 kcmil Cu	5.12	Minigrid backbone	TL36300 Yabucoa-SunOil-Juan Martin	$ 74.72
UG	6	New 115 kV Underground Circuit Juncos TC – Caguas TC- Bairoa TC @2750 kcmil Cu XLPE	9.17	This circuit provides a parellel path to the line Jobos - Cayey (37800) and it continuation Cayey - Caguas (37800) that under heavy flows under severe contingencies as the loss of both parallel lines Aguire - Aguas Buenas. It is a continuation of the Caguas MiniGrid backbone.	TL37800	$ 118.43
UG	7	New 115 kV Underground Circuit Humacao TC - Juncos TC @ 2750 kcmil Cu XLPE	10.60	This is a continuation of the project with ID 4 above. The trip of the 115 kV line 36300 Humacao Rio Blanco produces heavy loadings on Humacao to Juncos (41400) and this additional circuit would address these loadings in addtion to providing a backbone to the minigrid (continuation of the transfer of generation from Yabucoa to the loads in the MiniGrid)	TL41400 Humacao TC - Juncos TC	$ 136.90

Q1 PREPA Response 115 kV Projects - #s 8-16

UG	8	New 115 kV Underground Circuit Daguao TC – Fajardo TC@ 2750 kcmil Cu XLPE (manhole to be provided in front of Playa Los Machos 115 kV Sect. GIS)	10.16	Minigrid backbone to provide a resilient outlet for the generation at Daguao and benefits Vieques and Culebra Islands.	TL36200 Daguao TC - Fajardo TC	$ 148.32
UG	9	New 115 kV Underground Circuit Canóvanas TC – Palmer TC@2750 kcmilCu XLPE	11.00	Minigrid backbone to provide a resilient interconnection with new generation at Sabana Llana and Canovanas.	TL36800 Canovanas TC - Palmer TC	$ 160.53
UG	10	Line 40500 extension to Interconnect Venezuela TC GIS @2750 kcmil Cu XLPE	0.68	This is a new UG segment (extension) to interconnect a Station (Venezuela) that will be expanded to have a 115 kV SWYD	TL40500 exists (Monacillos-Hato Rey)	$ 8.79
UG	11	New Underground 115 kV Line Martin Peña GIS - Berwind TC @ 2750 kcmil Cu XLPE	6.60	Under heavy transfers south - north the outage of the 230 kV line 50900 Bayamón - Aguas Buenas the 115 kV line 38900 Berwind - Martín Peña presents heavy loadings beyond its current limit. This circuit would provide support and is a continuation of the project 12 below extending the MiniGrid backbone.	TL38900 Martin Peña GIS - Berwind TC	$ 85.24
UG	12	New Underground 115 kV Line Sabana Llana TC-Berwind TC @ 2750 kcmil Cu XLPE	2.70	Under heavy transfers south - north the outage of line 50900 Bayamon - Aguas Buenas results in heavy loadings on the lines Sabana Llana - Escorial -Berwind. Additonally these lines can overload for the loss of the single Bayamon transformer under this transfers. The proposed project addresses this situation and extends the Carolina MiniGrid Backbone to the Bayamon - San Juan MiniGrod to Create High Reliability/Resiliency Zones	TL38900 Sabana Llana TC-Berwind TC	$ 34.87
UG	13	New 115 kV Underground Circuit Caguas TC/Bairoa TC – Monacillo TC @2750 kcmil Cu XLPE	10.59	This is a continuation of the MiniGrid backbone that starts at Yabucoa (ID 4,6, 7). Creates a resileint interconnection that can be supplied from the north (Palo Seco / San Juan) or the south. There is a parallell overhead Caguas - Monacillos 37800.		$ 154.55
OH	14	Construction of 115 kV Line 37800 for Bairoa TC @ 1192.5 kcmil ACSR	1.55	See question 1 (g)		$ 4.29
OH	15	New 115 kV Line Hatillo TC - Mora TC @1192.5 kcmil ACSR Bunting	17.33	The technical justification was the interconnection of critical loads to Minigrid Main BackBone. See also question 1 (g)		$ 47.93
OH	16	New 115 kV Line Costa Sur - Dos Bocas HP @1192.5 kcmil ACSR Bunting	26.80	See question 1 (g)		$ 74.11
			140.92			$ 1,462.17

PREPA Response to Q2 - Attachment 3 – 38 kV / 24 Critical Load Cluster Projects @38 kV

Project Description	Load @ 38 Kv	Region	Technical Justification	Miles	Total Cost in Millions ($)
Baldrich Sect. 46 kV GIS (including interconnection to new underground to Auxilio Mutuo)	HOSPITAL	San Juan	Interconnection of Critical Loads		15.1
New Underground Line Segment 46 kV Hato Rey TC - San Juan Medical Center Sect. @ 2000 kcmil Cu	HOSPITAL	San Juan	Interconnection of Critical Loads	3.2	12.6
New Underground Line 46 kV Venezuela TC - Fonalledas - San Juan Medical Center Sect. @ 2000 kcmil Cu	HOSPITAL	San Juan	Interconnection of Critical Loads	2.5	9.9
New Underground Line 46 kV Monacillo TC - San Juan Medical Center Sect. @ 2000 kcmil Cu	HOSPITAL	San Juan	Interconnection of Critical Loads	1.9	7.2
New Underground 46 kV Line New Crematorio 46 kV Sect. - AAA (subs 1572) - SAM's (sub 1581) - Puertos (sub 1571) @ 2-800 kcmil Cu	WATER PUMP, PORTS, COMMERCIAL	San Juan	Interconnection of Critical Loads	1.5	6.6
Underground subtransmission system and circuits for internal facilities at San Juan Medical Center @ 2-800 kcmil Cu (includes integration of critical loads to new loop)	HOSPITAL	San Juan	Interconnection of Critical Loads	1.2	5.3
New Underground 46 kV Line Venezuela TC – Auxilio Mutuo – Baldrich Sect. @ 2-800 kcmil Cu	HOSPITAL	San Juan	Interconnection of Critical Loads	1.1	4.8
New Underground 46 kV Line Fonalledas Sect. GIS - Hosp. El Maestro 2-800 kcmil (ACB 8929B)	HOSPITAL	San Juan	Interconnection of Critical Loads	0.7	3.1
New Underground 46 kV Line San Juan Medical Center Sect. - 8900 Tap Americo Miranda @ 2-800 kcmil Cu (includes integration of critical loads to new loop)	HOSPITAL	San Juan	Interconnection of Critical Loads	0.7	2.9
Underground 46 kV Circuit Las Lomas Sect. GIS – Hospital Metropolitano (ACB 10101) @ 2-800 kcmil Cu	HOSPITAL	San Juan	Interconnection of Critical Loads	0.3	1.5
New Underground 46 kV Line New Trujillo Alto 46 kV Sect. - Sergio Cuevas Substations @ 1-800 kcmil Cu	WATER PUMP	San Juan	Interconnection of Critical Loads	0.3	1.0
New Underground 46 kV Line Vega Baja TC - Hospital Wilma Vazquez - Walmart - Ortho - Manati TC @ 2-800 kcmil Cu	HOSPITAL	Bayamón	Interconnection of Critical Loads	4.7	20.7
New Underground 46 kV Line Dorado TC - ACB 10729 (Walmart) - Holsum - AAA Sub. 9384 - Sub. 9368 (Pepsi) @ 2-800 kcmil Cu	WATER PUMP, COMMERCIAL	Bayamón	Interconnection of Critical Loads	3.1	13.6

PREPA Response to Q2 (cont'd.) – 38 kV load

Project Description	Load @ 38 Kv	Region	Technical Justification	Miles	Total Cost in Millions ($)	Distribution Substations with Critical Loads
New Underground 46 kV Circuit P. Seco - AAA (New ACB between 9501C and Sub. 1883)@ 2-800 kcmil Cu	WATER PUMP	Bayamón	Interconnection of Critical Loads	1.8	8.1	
New Underground 46 kV Line Guaraguao Sect. - Pan Pepin - AAA Superacueductos - COSTCO @ 2-800 kcmil Cu	WATER PUMP	Bayamón	Interconnection of Critical Loads	1.6	6.8	
New Underground 46 kV Circuit Cataño Sect. - Centro Medico Carcel/Carcel Regional (New ACB between 9503C and 9503D) @ 2-800 kcmil Cu	PRISION, HOSPITAL	Bayamón	Interconnection of Critical Loads	1.4	6.0	
Underground of 46 kV Line 4300 Bayamón TC – Hosp. San Pablo (ACB 4301) – Bayamón Pueblo Sect. @ 2-800 kcmil Cu	HOSPITAL	Bayamón	Interconnection of Critical Loads	1.4	6.0	
New Underground 46 kV Circuit Cataño Sect. - Zona Industrial Goya (New 3 Way GOABs between 9623A and 9607B) @ 2-800 kcmil Cu	INDUSTRIAL	Bayamón	Interconnection of Critical Loads	1.4	5.9	
New Underground 46 kV Short Line New Caná TC - New Rexville Zone (Big Kmart, Home Depot) with backup from aerial 4000 tap to avoid unnecessary outages from remote lines @2-800 kcmil Cu	COMMERCIAL	Bayamón	Existing Infrastructure Hardening for Reliability	1.4	5.6	
Complete Underground 46 kV Line 4900 Bayamón Pueblo Sect. – ACB 4905B (Plaza del Sol, H. Depot, Walmart) @ 2-800 kcmil Cu (extender el soterrado existente)	COMMERCIAL TOWN CENTER	Bayamón	Interconnection of Critical Loads	1.0	4.3	
Underground Line 6200 Cataño Sect - Puma Energy (Sub. 1771) @ 2-800 kcmil Cu	INDUSTRIAL	Bayamón	Interconnection of Critical Loads	0.8	3.3	
Underground 46 kV Line 8200 Cataño Sect - ACB 8215A (Sub. 1882, Claro) @ 2-800 kcmil Cu	INDUSTRIAL	Bayamón	Interconnection of Critical Loads	0.2	0.7	
New Underground 46 kV Line Planta San Juan - New Crematorio 46 kV Sect. @ 2-800 kcmil Cu (línea expreso)	INDUSTRIAL	San Juan	Interconnection of Critical Loads	1.9	8.2	No Critical Loads Found
Interconnection/Sectionalizing Underground 46 kV Line 6300 to Isla Grande TC GIS @ 1-800 kcmil Cu		San Juan	Minigrid Backbone Extensions to Create High Reliability/Resiliency Zones	0.7	2.6	No Critical Loads Found

PREPA Response to Q2 - Attachment 3 – 38 kV projects serving distribution feeders

- 4 feeders, 3 distribution substations – short-term priority list
- 9 substations, 15-20 feeders- medium/long term priority

Project Description	Region	Technical Justification	Miles	Total Cost in Millions ($)	Distribution Substations with Critical Loads	Feeders with Critical Loads in Short Term List	Feeders with Critical Loads in Intermediate Term List	Feeders with Critical Loads in Long Term List
New Underground 46 kV Circuit Bayamón TC – Cataño Sect. @ 2-800 kcmil Cu	Bayamón	Interconnection of Critical Loads	2.1	9.3	1801, 1716	1801-02 (3.2 MVA), 1801-03(3.5 MVA), 1716-03 (6.6 MVA)		1716-01 (2.0 MVA), 1716-02 (4.2 MVA)
Underground 46 kV Line 4300 Bayamón TC - Juan Domingo Sect. - Caparra Sect. @ 2-800 kcmil Cu	Bayamón	Minigrid Backbone Extensions to Create High Reliability/Resiliency Zones	2.5	10.9	1716, 1911	1716-03 (6.6 MVA)		1911-06 (4.9 MVA), 1716-01 (2.0 MVA), 1716-02 (4.2 MVA)
Underground 46 kV Line 9400 Dorado TC - Toa Alta Sub. 9401 @ 2-800 kcmil Cu (backup shall be provided by hardened tap from hardened line 2200 Dorado TC - Vega Alta)	Bayamón	Interconnection of Critical Loads	2.5	11.1	9401, 9203	9401-01 (2.4 MVA)		9401-02 (2.4 MVA), 9203-02 (2.1 MVA)
Underground 46 kV Line 7800 Dorado TC - New Dorado Pueblo Sect. @ 2-800 kcmil Cu	Bayamón	Interconnection of Critical Loads	3.4	15.1	9206, 9203, 9202		9202-01 (1.6 MVA), 9202-02 (1.9)	9203-02 (2.1 MVA), 9206-08 (0.8 MVA)
Underground 46 kV Line 4300 Caparra Sect - Juan Domingo Sect. - Bayamón TC @ 2-800 kcmil Cu	San Juan	Minigrid Backbone Extensions to Create High Reliability/Resiliency Zones	2.5	10.9	1911			1911-06 (4.9 MVA)
Underground Line 3500 46 kV Circuit Caparra Sect. – Cachete Sect. – Las Lomas Sect. – Monacillo TC @ 2-800 kcmil Cu	San Juan	Interconnection of Critical Loads	4.2	18.3	1911			1911-06 (4.9 MVA)
New Underground Line 46 kV M. Peña GIS - Villamar Sect. @ 2000 kcmil Cu	San Juan	Interconnection of Critical Loads	3.7	14.4	1113			1113-01 (2.5 MVA)
Underground Line 10100 Las Lomas Sect - ACB10133/10131 (Suiza Dairy) - Reparto Metropolitano TO @ 2-800 kcmil Cu (includes underground of line tap to Suiza Dairy @ 1-800 kcmil Cu)	San Juan	Interconnection of Critical Loads	1.7	7.6	1531		1531-02 (2.29 MVA)	
Underground 46 kV Line 15300 Berwind TC – Los Angeles Sect. @ 2-800 kcmil Cu	San Juan	Interconnection of Critical Loads	1.7	7.6	1301			1301-03 (1.3 MVA)
Underground Line 3300 Viaducto TC - Egozcue Sect. @ 2-800 kcmil Cu	San Juan	Interconnection of Critical Loads	0.8	3.6	1100			1100-03 (0.3 MVA)
Underground Line 10600 Viaducto TC - Villamil Sub. @ 2-800 kcmil Cu	San Juan	Interconnection of Critical Loads	0.5	2.2	1100			1100-03 (0.3 MVA)

PREPA Response to Q2 - Attachment 3 – 38 kV projects serving distribution feeders

- Various critical load types on proposed projects serving dist. feeders:

Project Description	Critical Loads Connected	Ranking (Based on Critical Load Circuits)
New Underground 46 kV Circuit Bayamón TC – Cataño Sect. @ 2-800 kcmil Cu	1801-02 (Prisión (3), Comandancia), 1801-03 (CDT, Manejo de Emergencias, Bombas Pluviales, Policía, Bomberos, Refugio (Escuela Francisco Oller)), 1716-01 (Bayamón Medical Center, Torres Médicas, Hospital San Pablo), 1716-02 (Centro Gubernamental), 1716-03 (Manejo de Emergencias, Hospital Regional)	19.5
Underground 46 kV Line 4300 Bayamón TC - Juan Domingo Sect. - Caparra Sect. @ 2-800 kcmil Cu	1911-06 (FEMA, Oficinas de Agencias Federales, Facilidades de Telecomunicaciones), 1716-01 (Bayamón Medical Center, Torres Médicas, Hospital San Pablo), 1716-02 (Centro Gubernamental), 1716-03 (Manejo de Emergencias, Hospital Regional)	17.7
Underground 46 kV Line 9400 Dorado TC - Toa Alta Sub. 9401 @ 2-800 kcmil Cu (backup shall be provided by hardened tap from hardened line 2200 Dorado TC - Vega Alta)	9401-01 (Bomberos), 9203-02 (Policía, Alcaldía), 9401-02 (Hospital Municipal)	6.9
Underground 46 kV Line 7800 Dorado TC - New Dorado Pueblo Sect. @ 2-800 kcmil Cu	9206-08 (Policía, Manejo de Emergencias), 9203-02 (Policía, Alcaldía), 9202-01 (Alcaldía, Bombas de Aguas Usadas), 9202-02 (CDT Mameyal)	6.4
Underground 46 kV Line 4300 Caparra Sect - Juan Domingo Sect. - Bayamón TC @ 2-800 kcmil Cu	1911-06 (FEMA, Oficinas de Agencias Federales, Facilidades de Telecomunicaciones)	4.96
Underground Line 3500 46 kV Circuit Caparra Sect. – Cachete Sect. – Las Lomas Sect. – Monacillo TC @ 2-800 kcmil Cu	1911-06 (FEMA, Oficinas de Agencias Federales, Facilidades de Telecomunicaciones)	4.9
New Underground Line 46 kV M. Peña GIS - Villamar Sect. @ 2000 kcmil Cu	1113-01 (CDT El Belavar en la calle Borinquen de Barrio Obrero)	2.5
Underground Line 10100 Las Lomas Sect - ACB10133/10131 (Suiza Dairy) - Reparto Metropolitano TO @ 2-800 kcmil Cu (includes underground of line tap to Suiza Dairy @ 1-800 kcmil Cu)	1531-02 (Clínica Ciencias Médicas)	2.29
Underground 46 kV Line 15300 Berwind TC – Los Angeles Sect. @ 2-800 kcmil Cu	1301-01 (Planta Filtración calle Neblin)	1.3
Underground Line 3300 Viaducto TC - Egozcue Sect. @ 2-800 kcmil Cu	1100-03 (Bombas colectoras de agua en la Ave. Fernández Juncos)	0.3
Underground Line 10600 Viaducto TC - Villamil Sub. @ 2-800 kcmil Cu	1100-03 (Bombas colectoras de agua en la Ave. Fernández Juncos)	0.3

B/C Analysis – Resiliency Screening – Utility Scale PV/BESS Costs

➢ Utility Scale Basis

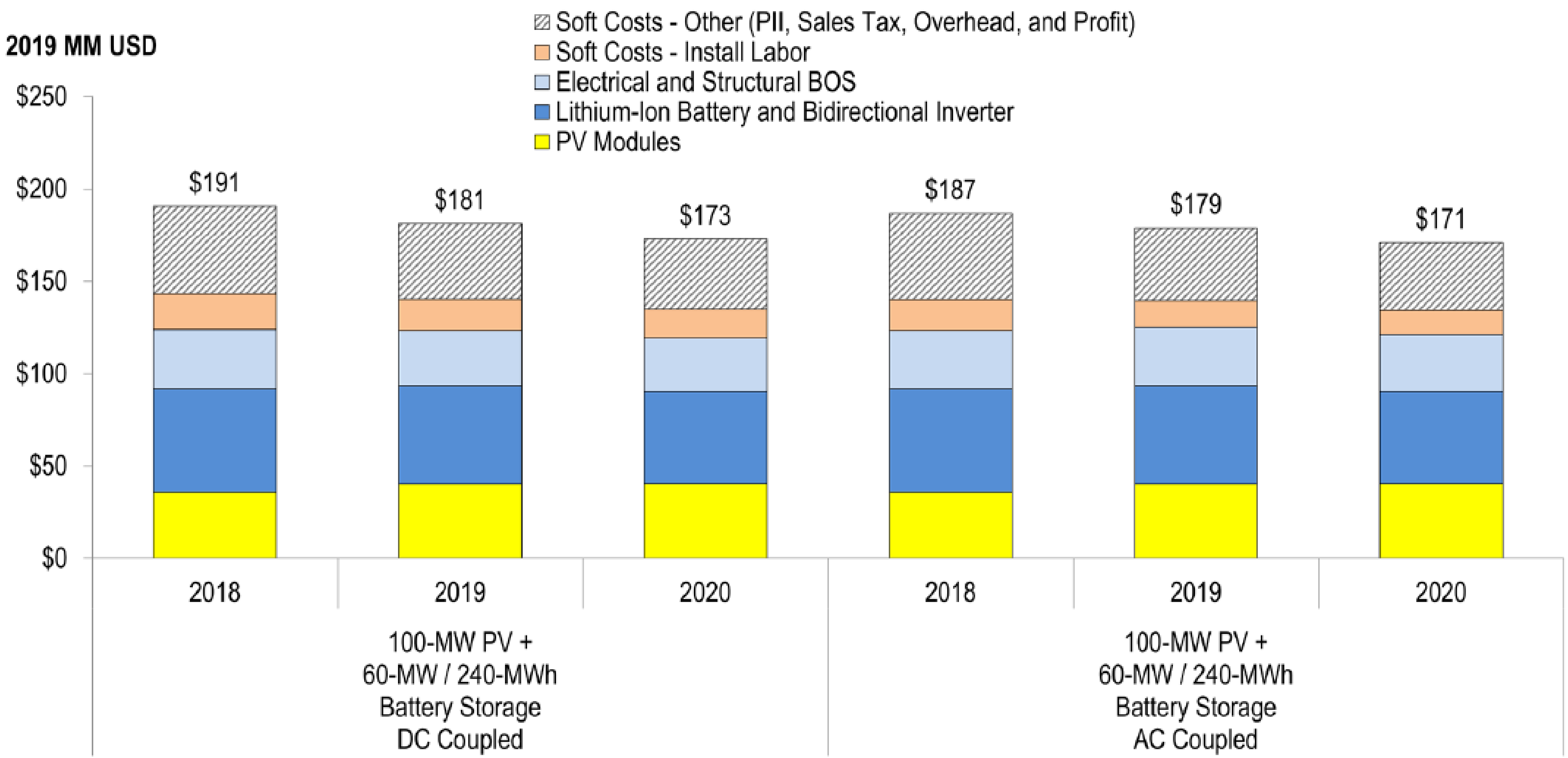

Figure ES-4. Utility-scale PV-plus-storage system cost benchmark summary (inflation-adjusted), 2018–2020, DC-coupled and AC-coupled

B/C Analysis – Resiliency Screening – Residential Scale PV/BESS Costs

- Residential Scale Basis:

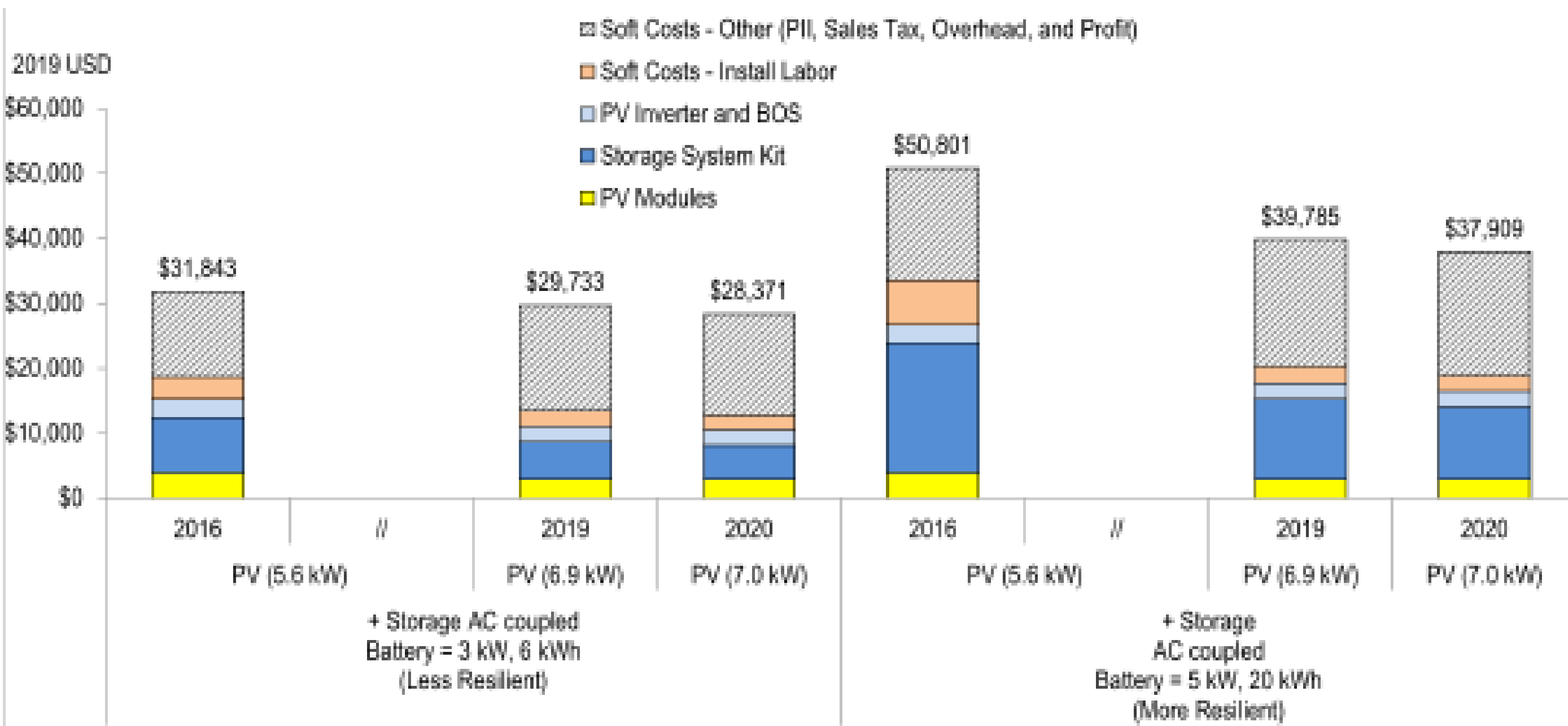

Figure ES-5. Residential PV-plus-storage system cost benchmark summary (inflation-adjusted), 2016, 2019, and 2020