PREPA IRP 2019
MiniGrids & Transmission Assessment

August 13, 2019

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MiniGrids

Introduction

- In parallel with the generation expansion plan Siemens PTI evaluated PREPA's transmission system and determined the convenience of its separation into 8 electrical islands called MiniGrids for short, considering the geography of the system and the expected time to repair for the various overhead lines.
- The concept is that following (or even in preparation for) a major event the system can be segregated into autonomous electrical islands that can operate separately from each other for extended periods of time including months.
- As presented earlier, the expansion plan is being designed so that there will be local resources to the MiniGrids and next we will present how this resources achieve balance with Critical, Priority and the total load. Also we will provide the identified investments necessary to consolidate the MiniGrids.
- Supplementary to the MiniGrids, microgrids as proposed for areas where there is difficulty of access and it would be impractical to harden the system to integrate them to the MiniGrid.

Eight MiniGrids – Ten Areas

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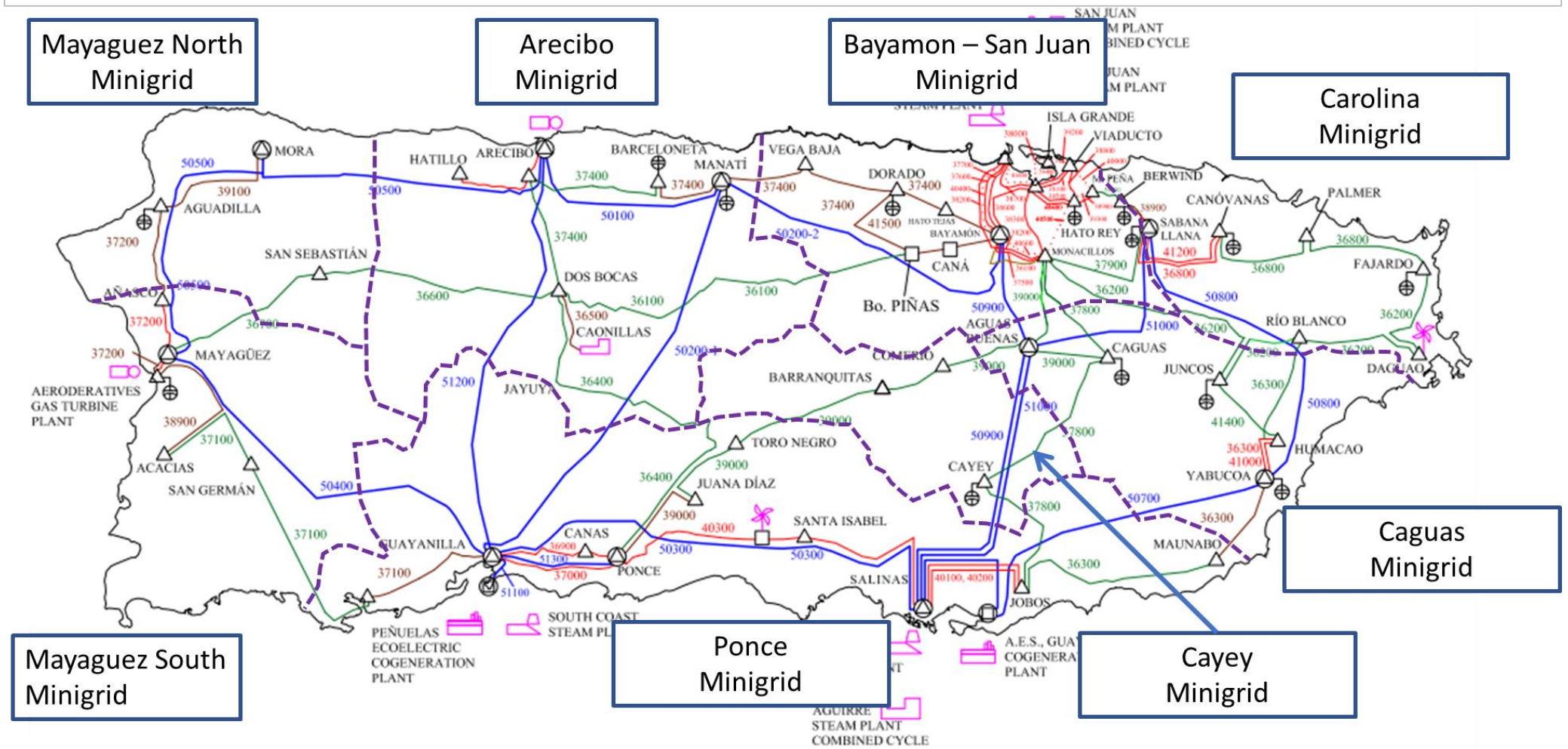
Red lines - Under 10 days with a target of few hours or ride through the storm

Yellow - Under 30 days after being hardened in accordance with new codes and standards, with a target of under 10 days

Green - Due to geography, could take over a month to repair after a major event.

Blue - 230 kV Long lines, Long recovery time, Not used for determining Minigrid boundaries due to inter-Minigrid in natural

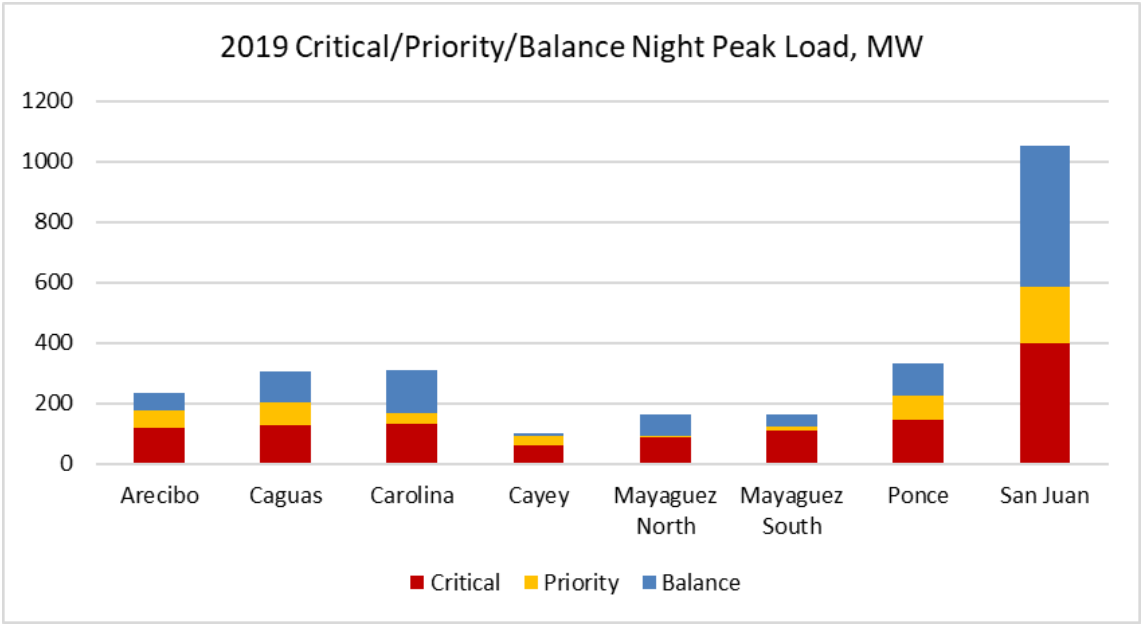


Ten Areas considering that Ponce Minigrid is consist of Ponce East and Ponce West, and Bayamon and San Juan are one MiniGrid

MiniGrids – Loads Category

- **Critical Loads:** these loads should either ride through the storm or must be available shortly after. They are crucial for the restauration effort, Including hospitals, airports, shelters and town center, police/fire stations, storm water pumps, critical water supply/treatment AAA facilities and certain communication facilities.
- **Priority Loads:** these loads are necessary to restore normalcy to localities and include shopping centers and commercial establishments, gas stations, industries, higher density residential areas. These loads must be reconnected shortly after the Critical Loads. Overhead lines may be inspected and repaired; no more than 10 days for the full connection.
- **Balance Loads:** these are the rest of the loads within the minigrid and the objective is to restore them also within 10 days of the event, but more overhead lines may be involved and 100% restauration may exceed 10 days.

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%**

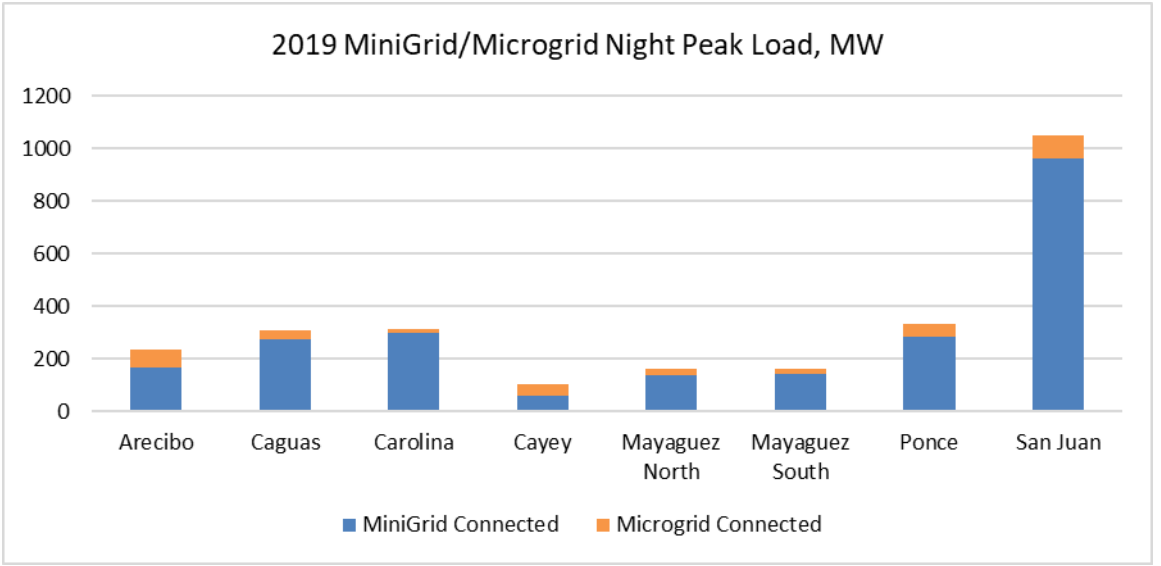


MiniGrids – Microgrids Loads

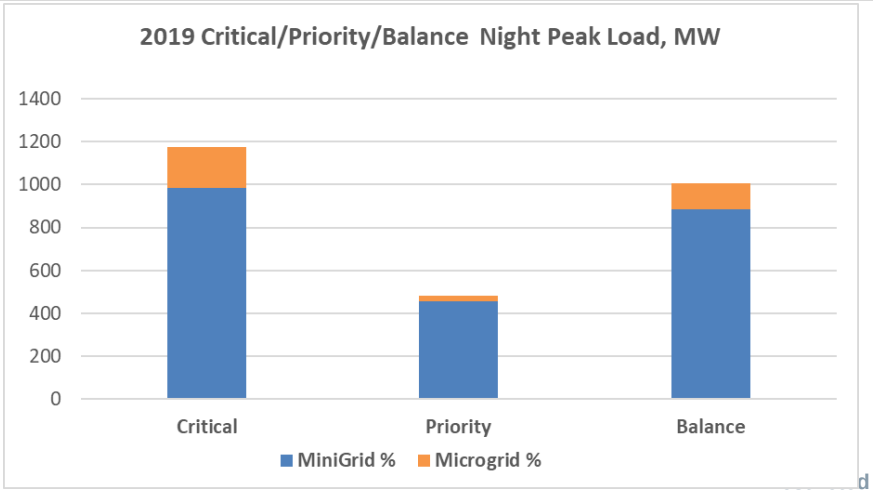
The load can be located in the MiniGrid or Microgrid:

- 16 % of the critical loads and 5% of the priority loads are located in the microgrids that require similar restoration time

2019 MiniGrid/Microgrid Night Peak Load, MW					
MiniGrid	Total	MiniGrid Connected	Microgrid Connected	% MiniGrid	% Microgrid
Arecibo	234.2	168.7	65.5	72%	28%
Caguas	306.7	271.7	35.1	89%	11%
Carolina	310.8	296.6	14.1	95%	5%
Cayey	101.1	59.9	41.2	59%	41%
Mayaguez North	163.5	139.2	24.3	85%	15%
Mayaguez South	161.7	140.2	21.5	87%	13%
Ponce	332.3	285.7	46.5	86%	14%
San Juan	1050.7	961.6	89.1	92%	8%
Total	**2660.9**	**2323.6**	**337.3**	**87%**	**13%**



2019 Critical/Priority/Balance Night Peak Load, MW							
	Total	Critical	Priority	Balance	Critical %	Priority %	Balance %
MiniGrid	2323.6	983.9	455.1	884.6	42%	20%	38%
Microgrid	337.3	192.8	24.9	119.6	57%	7%	35%
Total	**2660.9**	**1176.7**	**480.0**	**1004.2**	**44%**	**18%**	**38%**
MiniGrid %	87%	84%	95%	88%			
Microgrid %	13%	16%	5%	12%			



MiniGrids Design

The Design of the MiniGrids (and microgrids) consist of two overarching activities:

Local Generation Resource Selection:

- The critical loads must be able to be served by thermal resources only; full coverage right after the event.
- Priority loads to be served by a combination of thermal resources and PV + Storage.
- Balance of loads to be served by a combination of thermal resources and PV + Storage, and on grid isolated mode some level of load shed is accepted.
- Microgrid loads ideally should be covered by reciprocating engines assigned by the LTCE to the region. PV + Storage can complement.

Transmission / Distribution Design:

- Hardening / new underground facilities to create a MiniGrid backbone to which the generation is connected and loads are served from.
- Building underground facilities for interconnection of critical loads.
- New underground reliable facilities for the Interconnection of MiniGrids and faster consolidation.
- Extension of the MiniGrid backbone to areas of high reliability and resiliency.
- Hardening of the existing infrastructure or replacing aging infrastructure for MiniGrid as complementary to the above.

MiniGrids Design: 115 kV Transmission

- 147 projects at 115 kV level analyzed for MiniGrids in the IRP context under the different categories and encompasses activities ranging from reconstruction to new lines as highlighted below.

Technical Justification	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
Aging Infrastructure Replacement-MG	5	2	5	5	0	6	7	7	**37**
Existing Infrastructure Hardening for Reliability - MG	0	0	7	4	0	4	0	13	**28**
Interconnection of Critical Loads	0	1	0	1	0	0	4	0	**6**
Interconnection of Minigrids	0	0	1	0	3	0	0	0	**4**
Minigrid Backbone Extensions to Create High Reliability/Resiliency Zones	0	0	0	0	0	0	0	2	**2**
Minigrid Main Backbone	8	10	13	9	3	11	7	9	**70**
Total	**13**	**13**	**26**	**19**	**6**	**21**	**18**	**31**	**147**

Arecibo	**13**
Line Hardening/Reconstruction	1
New Underground Construction	2
Switchyard Hardening/Reconstruction	10
Bayamón	**13**
Line Hardening/Reconstruction	4
New Underground Construction	1
Switchyard Hardening/Reconstruction	8
Caguas	**26**
Line Hardening/Reconstruction	8
New Transmission Line	1
New Underground Construction	4
Switchyard Hardening/Reconstruction	13

Carolina	**19**
Line Hardening/Reconstruction	5
New Underground Construction	4
Switchyard Hardening/Reconstruction	10
Isla	**6**
Line Hardening/Reconstruction	6

115 kV projects by Project Type

Mayaguez	**21**
Line Hardening/Reconstruction	8
Switchyard Hardening/Reconstruction	13
Ponce	**18**
Line Hardening/Reconstruction	3
Switchyard Hardening/Reconstruction	15
San Juan	**31**
Line Hardening/Reconstruction	12
New Underground Construction	5
Switchyard Hardening/Reconstruction	14

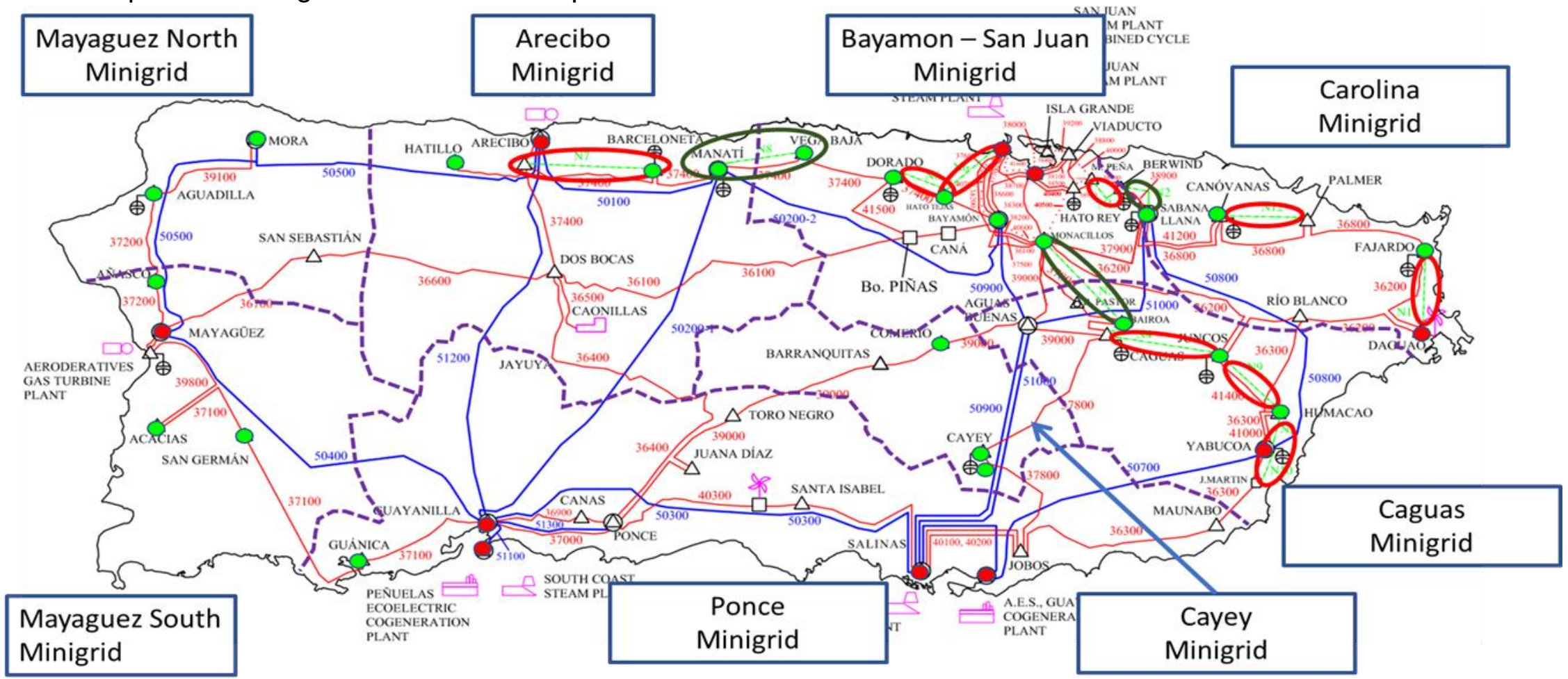
MiniGrids Design: 115 kV Transmission

Project Description		Technical Justification
Arecibo		
	PE	Minigrid Main Backbone
		Minigrid Main Backbone
	2750	Minigrid Main Backbone
		Minigrid Main Backbone
		Minigrid Main Backbone
	PE	Minigrid Main Backbone
		Minigrid Main Backbone
		Minigrid Main Backbone
		Minigrid Main Backbone
		Minigrid Main Backbone
		Minigrid Main Backbone
	XLPE	Minigrid Backbone Extensions
		Minigrid Main Backbone
		Minigrid Backbone Extensions

- 70 out of the 147 projects are associated with MiniGrid Main Backbone
- One of the most important investments are those associated with new transmission lines / underground cables, which are presented here by area and technical justification.
- Most of them are associated with forming the MiniGrid main backbone

MiniGrids Design: Transmission 115 kV

- Overview of the key 115 kV projects designed to support the backbone of the MiniGrids or create interconnections between MiniGrid for fasted integration.
- Also provides a high level view of the spatial distribution of resources



MiniGrids Design: 38 kV Transmission

- 330 projects at 38 kV level analyzed for MiniGrids in the IRP context under different categories and encompasses activities ranging from reconstruction to new lines as highlighted below.

Technical Justification	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
Existing Infrastructure Hardening for Reliability - MG	0	0	30	7	0	25	0	0	**62**
Interconnection of Critical Loads	31	24	24	15	1	34	58	53	**240**
Interconnection of Minigrids	0	0	7	0	0	0	1	0	**8**
Minigrid Backbone Extensions to Create High Reliability/Resiliency Zones	1	1	1	2	1	0	0	10	**16**
Minigrid Main Backbone	1	0	1	0	1	1	0	0	**4**
Total	**33**	**25**	**63**	**24**	**3**	**60**	**59**	**63**	**330**

Arecibo	**33**
Line Hardening/Reconstruction	14
New Underground Construction	8
Switchyard Hardening/Reconstruction	11
Bayamón	**25**
Line Hardening/Reconstruction	5
New Underground Construction	14
Switchyard Hardening/Reconstruction	6
Caguas	**63**
Line Hardening/Reconstruction	34
New Transmission Line	4
New Underground Construction	12
Switchyard Hardening/Reconstruction	12
New Substation/Switchyard	1

Carolina	**24**
Line Hardening/Reconstruction	8
New Underground Construction	10
Switchyard Hardening/Reconstruction	5
New Substation/Switchyard	1
Isla	**3**
Line Hardening/Reconstruction	3

38 kV projects by Project Type

Mayaguez	**60**
Line Hardening/Reconstruction	29
New Transmission Line	2
New Underground Construction	17
Switchyard Hardening/Reconstruction	12
Ponce	**59**
Line Hardening/Reconstruction	1
New Underground Construction	31
Switchyard Hardening/Reconstruction	27
San Juan	**63**
Line Hardening/Reconstruction	26
New Underground Construction	20
Switchyard Hardening/Reconstruction	17

MiniGrids Design: 38 kV Transmission

- 240 out of the 330 projects are associated with the Interconnection of Critical Loads
- Important investments are those associated with new transmission lines / underground cables, more than 120 new projects
- 107 of them are associated with the Interconnection of Critical Loads
- The rest are associated with Minigrid Backbone Extensions, Interconnection of MiniGrids, or Existing Infrastructure Hardening for Reliability – MG
- New projects will be presented in the following MiniGrids section

MiniGrids Design: 115 kV Transmission Investment

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- **115 kV MiniGrid Transmission Investment By Project Type**

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	48.5	**488.4**
New Submarine Cable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
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	201.7	125.9	248.4	181.7	0.0	201.7	243.1	320.9	**1523.4**
New Substation/Switchyard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Grand Total	**291.8**	**225.1**	**477.8**	**426.3**	**86.9**	**304.2**	**297.6**	**489.6**	**2599.4**

- **115 kV MiniGrid Transmission Investment By Technical Justification**

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	181.3	372.0	294.7	30.5	215.4	207.1	322.1	**1894.5**
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 - MG	0.0	0.0	65.0	58.8	0.0	66.2	0.0	59.7	**249.6**
Aging Infrastructure Replacement - MG	20.4	7.8	23.7	20.9	0.0	22.7	22.8	37.4	**155.7**
Grand Total	**291.8**	**225.1**	**477.8**	**426.3**	**86.9**	**304.2**	**297.6**	**489.6**	**2599.4**

MiniGrids Design: 38 kV Transmission Investment

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- **38 kV MiniGrid Transmission Investment By Project Type**

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**

- **38 kV MiniGrid Transmission Investment By Technical Justification**

Technical Justification	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
Existing Infrastructure Hardening for Reliability - MG	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**

MiniGrids Design: 115 and 38 kV Transmission Investment

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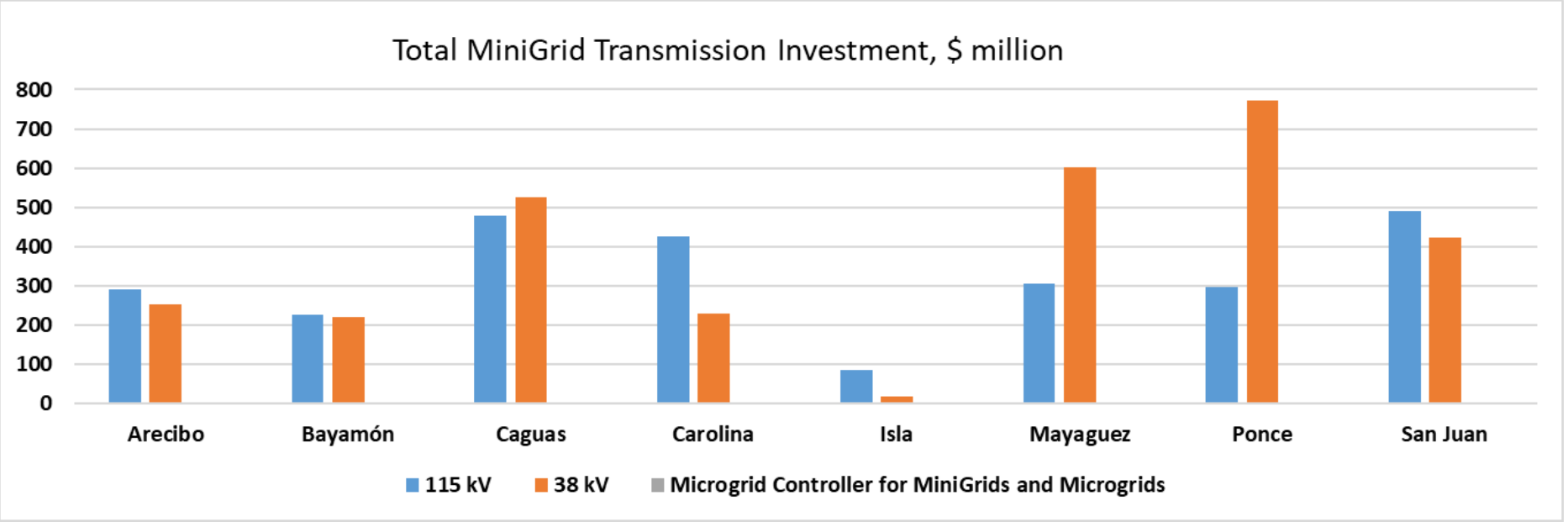
- **Total MiniGrid Transmission Investment**

	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
115 kV	291.8	225.1	477.8	426.3	86.9	304.2	297.6	489.6	**2599.4**
38 kV	252.7	220.2	526.5	230.5	17.2	602.6	773.4	423.8	**3046.9**
Microgrid Controller for MiniGrids and Microgrids	1.4	0.4	1.2	0.3	1.2	1.2	0.5	0.5	**6.8**
Grand Total	**545.9**	**445.7**	**1005.5**	**657.1**	**105.3**	**908.0**	**1071.6**	**914.0**	**5653.0**



MiniGrids: Load Flow Analysis

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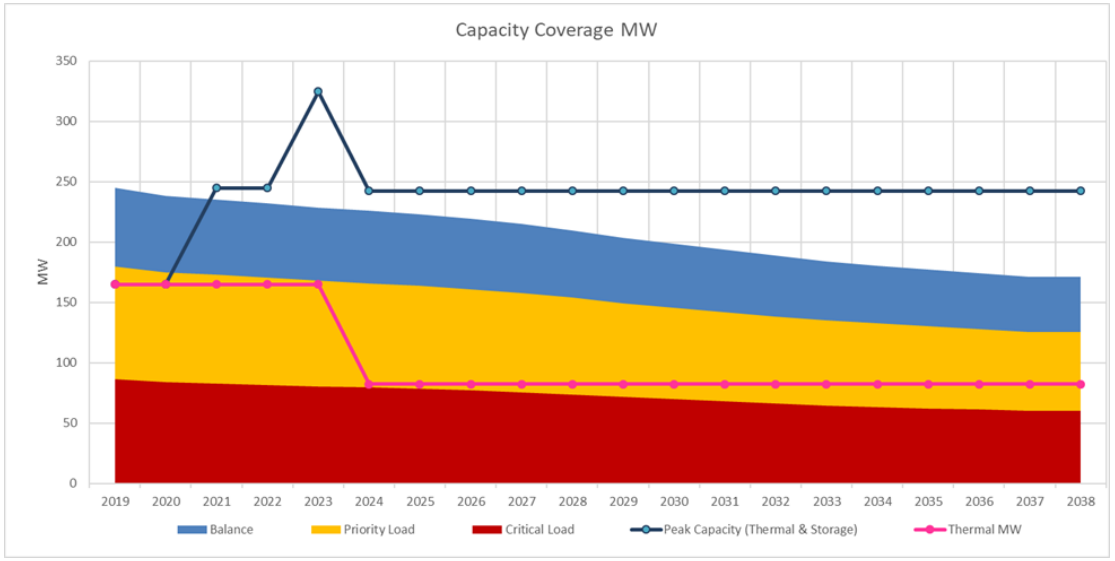
Summary

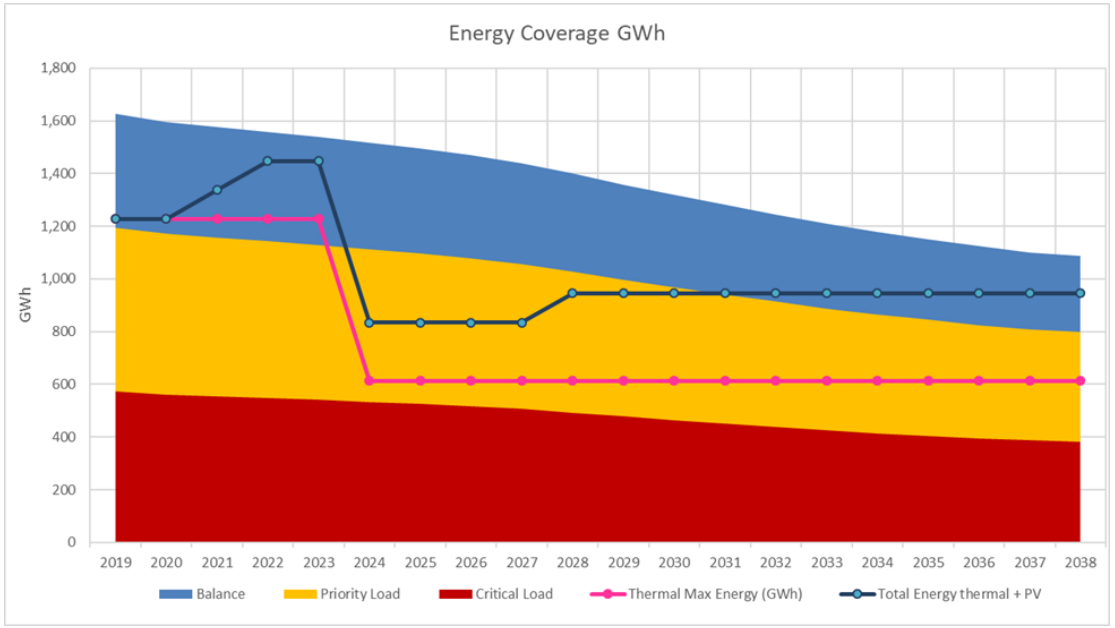
- The purpose of MiniGrid load flow analysis is to assess the reliability of the PREPA's transmission system operated under MiniGrid (isolated) mode following a major event.
- Since the destruction of transmission facilities already causing grid separations, we mainly focus on the pre-contingency flows and bus voltages.
- S4S2B with 2019 Night Peak load condition was analyzed.
- Two stages of system operations:
  - MiniGrid with microgrids connected, as could be the situation a few weeks after the major event
  - MiniGrid with all microgrids disconnected simulating the system in further destructive scenario or few days / weeks after the event

Observation

- No thermal or voltage violations were reported before contingency based on planning criteria under emergency
- In line with the results discussed in the Integrated Steady State Analysis
- The discussion on Integrated system, Weakened system, and Existing system will be presented in the Transmission Steady State Analysis section.

Supply – Demand Balance: *Arecibo MiniGrid*





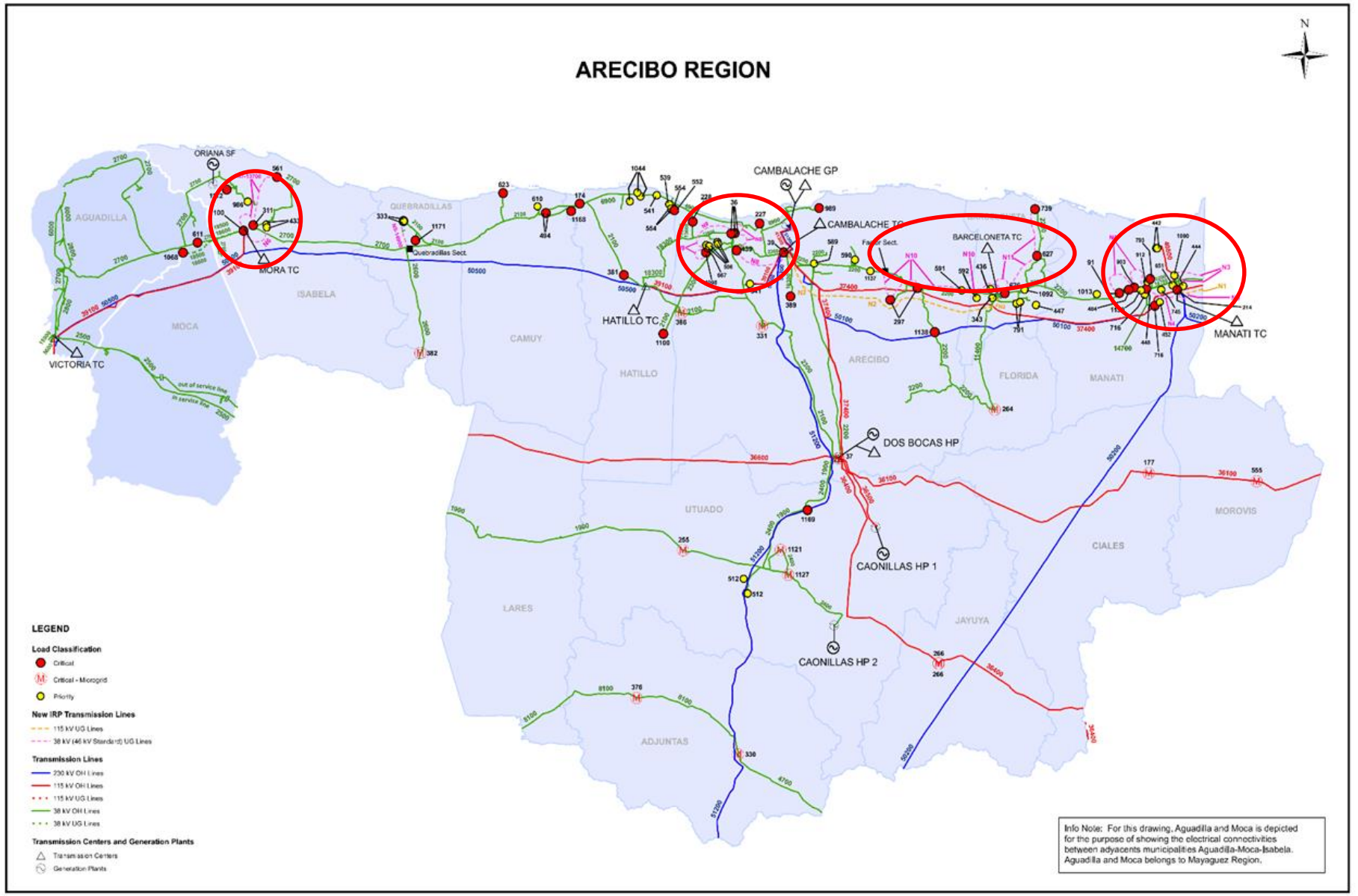
Resources

- The Arecibo MiniGrid under S4S2B is projected by 2023 to have 82 MW of thermal, 160 MW of Storage and 120 MW of PV (utility & customer owned)
- Note one Cambalache unit to retire in 2023 and the other unit must stay on throughout the planning period

Observations

- The local thermal resources cover the critical load (red band) for all years
- From 2021, capacity from all available resources cover the entire local load (red, yellow, and blue)
- Energy is not fully covered, indicating some level of load shedding could occur

Transmission Investment – *Arecibo MiniGrid*



Project Number	Project Description
N1	New 115 kV Underground Circuit Vega Baja TC – M
N2	Ne TC
N3	Ne Ho Ma
N4	Ne AC Ce 14
N5	Un Qu
N6	Ne 27
N7	Un 75 75
N8	Ne - A Are
N9	Ne Se Inc tap
N10	Ne Me Su 80
N11	Ne Ba 85

Transmission Investment – *Arecibo MiniGrid*

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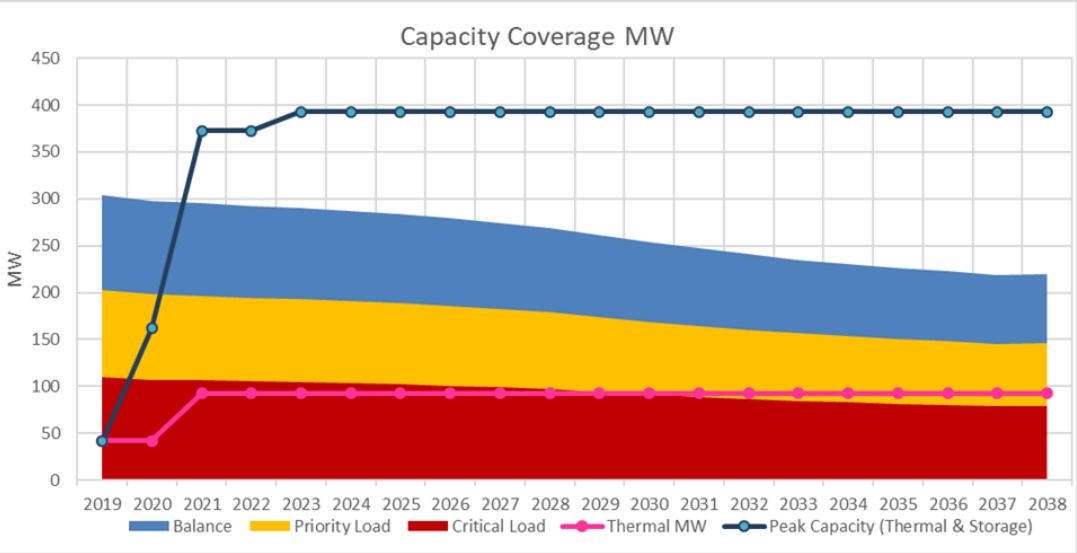
115 kV Transmission	Arecibo	
Technical Justification	**# of Projects**	**Million $**
Aging Infrastructure Replacement-MG	5	20
Existing Infrastructure Hardening for Reliability - MG	0	0
Interconnection of Critical Loads	0	0
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	0	0
Minigrid Main Backbone	8	271
Grand Total	**13**	**292**

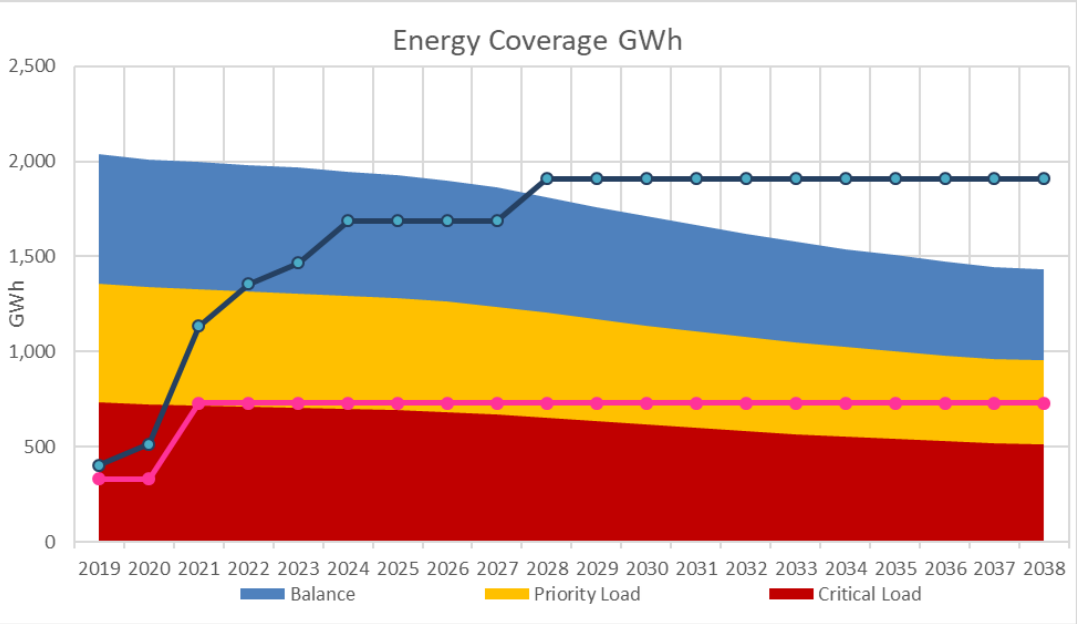
38 kV Transmission	Arecibo	
Technical Justification	**# of Projects**	**Million $**
Existing Infrastructure Hardening for Reliability - MG	0	0
Interconnection of Critical Loads	31	240
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	1	5
Minigrid Main Backbone	1	7
Grand Total	**33**	**253**

115 kV Transmission	Arecibo	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	1	9
New Submarine Cable	0	0
New Substation/Switchyard	0	0
New Transmission Line	0	0
New Underground Construction	2	81
Switchyard Hardening/Reconstruction	10	202
Grand Total	**13**	**292**

38 kV Transmission	Arecibo	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	14	57
New Substation/Switchyard	0	0
New Transmission Line	0	0
New Underground Construction	8	64
Switchyard Hardening/Reconstruction	11	131
Grand Total	**33**	**253**

Supply – Demand Balance: *Caguas MiniGrid*





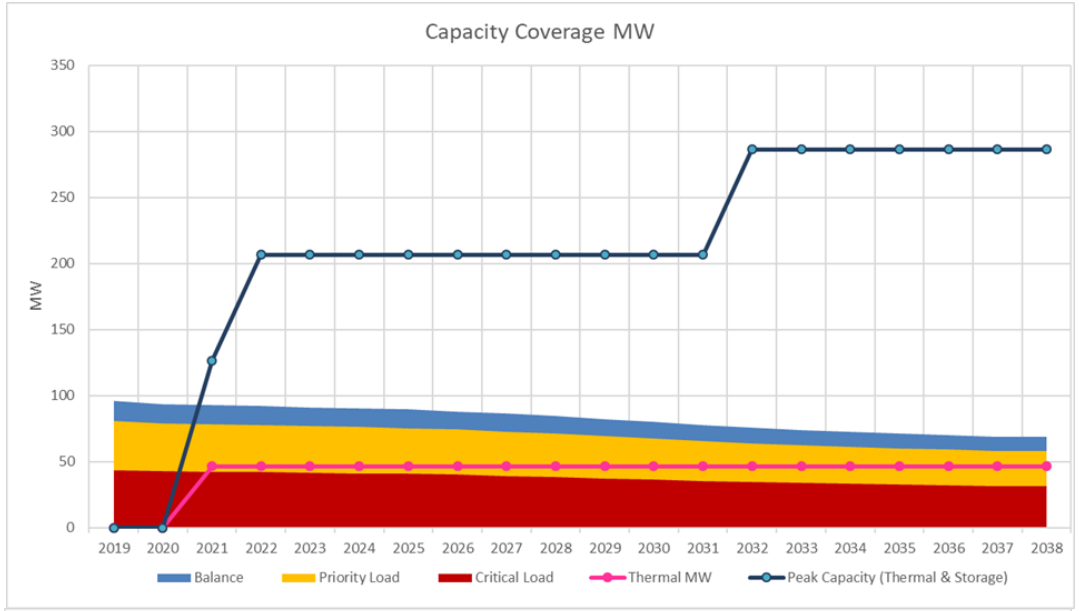
Resources

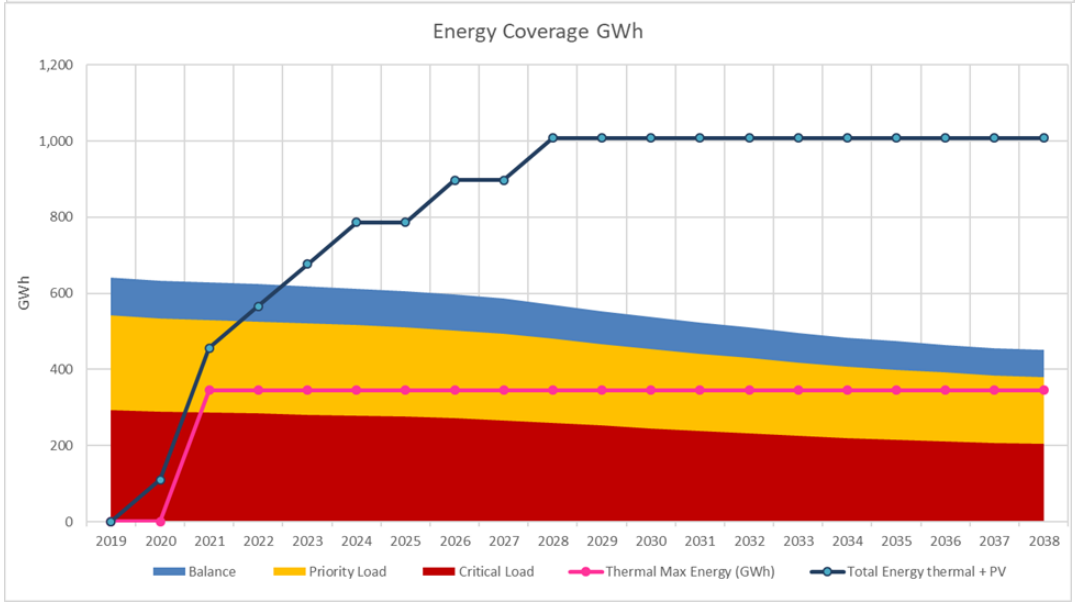
- The Caguas area under S4S2B is projected by 2024 to have 92.8 MW of thermal (4 new peakers), 300 MW of Storage and 520 MW of PV (utility & customer owned)

Observations

- By 2021 the local thermal resources cover the critical load
- From 2021, capacity from all available resources cover the entire local load
- Energy is not fully covered until 2028, indicating some level of load shedding could occur

Supply – Demand Balance: *Cayey MiniGrid*





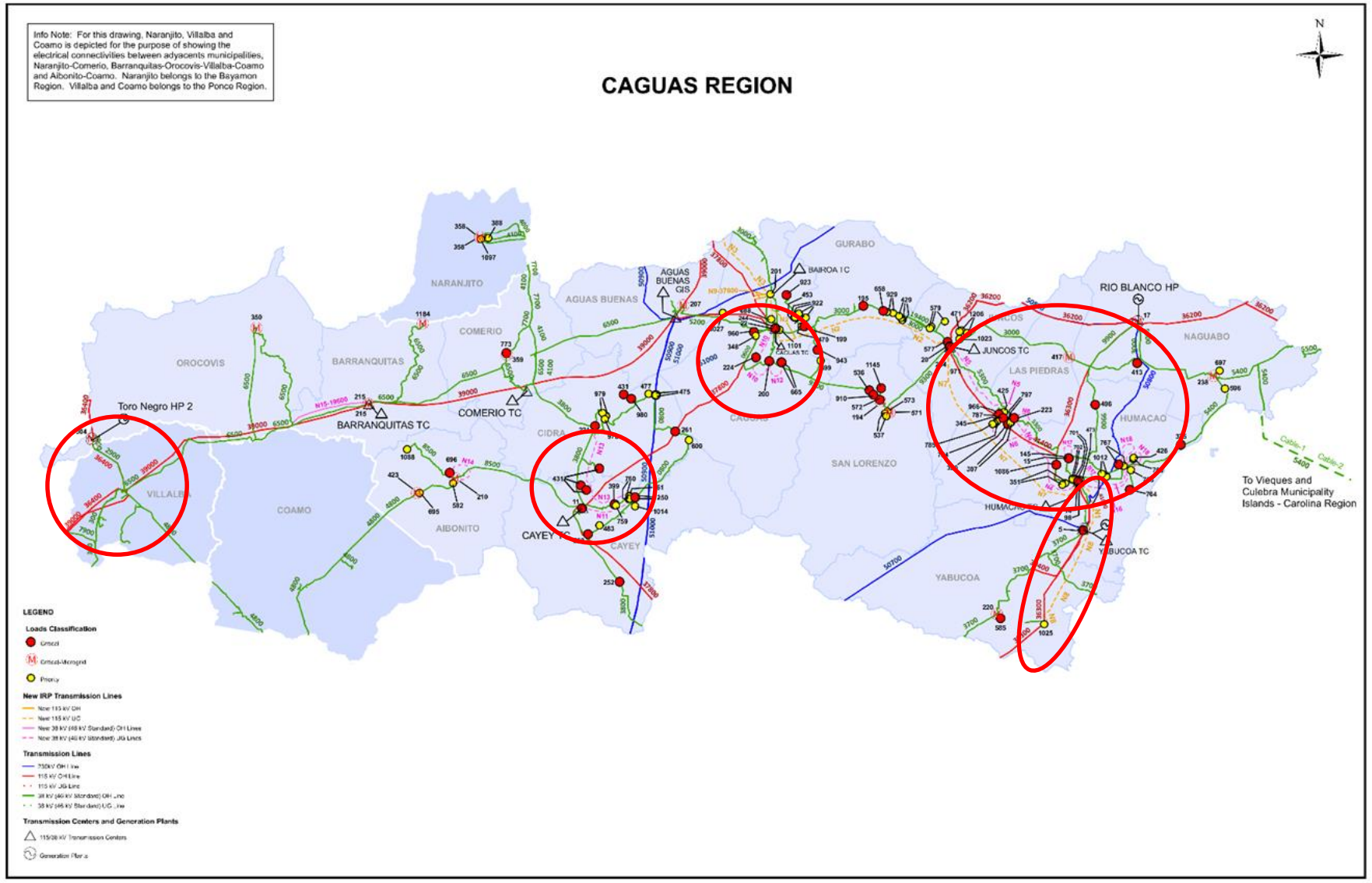
Resources

- The Cayey area under S4S2B is projected by 2022 to have 46.4 MW of thermal (2 new peakers), 160 MW of Storage and 120 MW of PV (utility & customer owned)

Observations

- By 2021 the local thermal resources cover the critical load (red band)
- From 2021, capacity from all available resources cover the entire local load
- Energy is not fully covered until 2023, indicating some level of load shedding could occur during the first couple years

Transmission Investment – *Caguas and Cayey MiniGrids*



Project Number	Project Description
N1	New Underground Line 115 kV Yabucoa TC- Humacao TC @
N2	
N3	
N4	
N5	
N6	
N7	
N8	
N9	
N10	
N11	
N12	
N13	
N14	
N15	
N16	
N17	
N18	Myers Squibb, etc...) @ 2-800 kcmil Cu

Transmission Investment – *Caguas and Cayey MiniGrids*

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115 kV Transmission	Caguas	
Technical Justification	**# of Projects**	**Million $**
Aging Infrastructure Replacement-MG	5	24
Existing Infrastructure Hardening for Reliability - MG	7	65
Interconnection of Critical Loads	0	0
Interconnection of Minigrids	1	17
Minigrid Backbone Extensions to Create High Reliability/Resiliency	0	0
Minigrid Main Backbone	13	372
Grand Total	**26**	**478**

38 kV Transmission	Caguas	
Technical Justification	**# of Projects**	**Million $**
Existing Infrastructure Hardening for Reliability - MG	30	155
Interconnection of Critical Loads	24	299
Interconnection of Minigrids	7	55
Minigrid Backbone Extensions to Create High Reliability/Resiliency	1	3
Minigrid Main Backbone	1	15
Grand Total	**63**	**526**

115 kV Transmission	Caguas	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	8	82
New Submarine Cable	0	0
New Substation/Switchyard	0	0
New Transmission Line	1	2
New Underground Construction	4	145
Switchyard Hardening/Reconstruction	13	248
Grand Total	**26**	**478**

38 kV Transmission	Caguas	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	34	189
New Substation/Switchyard	1	14
New Transmission Line	4	23
New Underground Construction	12	153
Switchyard Hardening/Reconstruction	12	148
Grand Total	**63**	**526**

MiniGrid VoLL Analysis

Introduction

- Assess the economic impact of not advancing the proposed transmission investments
- Value of Lost Load (VoLL) was calculated under MiniGrid operations following a major event
- MiniGrids were separated into individual load pockets after multiple line outages assuming no MiniGrids transmission investment

Assumptions

- Level 1: transmission lines that are assumed to be out immediately after a major event
- Level 2: transmission lines that can be brought back in service one week after the event
- 2019 Night Peak load and 2025 S4S2B generation plan from LTCE
- Average load factor: 75% of the peak load
- Cost of unserved load: Critical Load $32,000/MWh, Priority Load $10,000/MWh, Balance Load $2,000/MWh

Methodology

- Apply transmission outages to convert the Base Case to MiniGrids
- Apply Level 1 outages for the MiniGrid and identify the individual load pockets
- Apply Level 2 changes (put lines back into service) and identify the new load pockets after Level 2 changes
- Analyze load to generation balance for each individual load pocket and calculate the Load Not Served, the Energy Not Served, the Cost of Energy Not Served, broken down by the Critical, Priority, and Balance load

Conclusion

- The total VoLL for any severe event that caused transmission lines out for a few weeks would be more than enough to justify the total cost of the proposed MiniGrid transmission investment

VoLL – *Caguas and Cayey MiniGrids*

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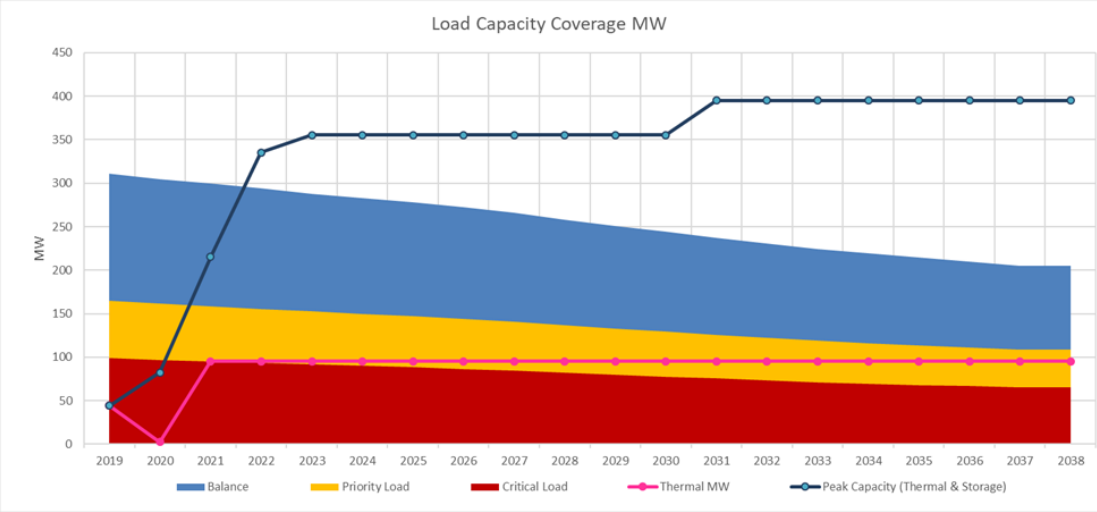
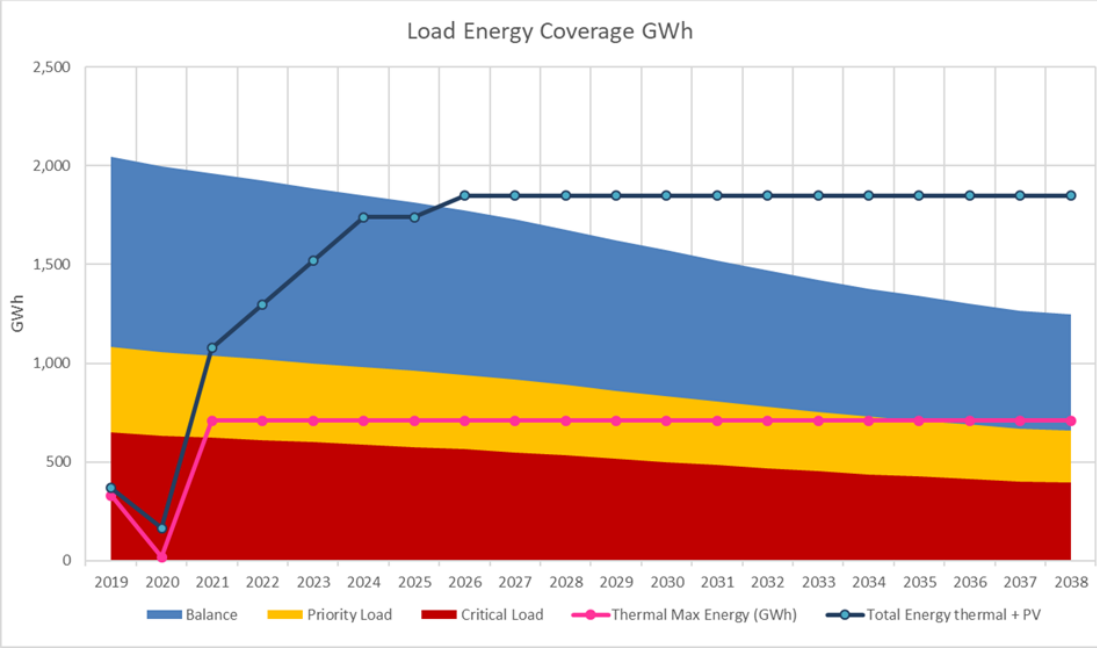
MiniGrid	Total MiniGrid Load (MW)				Load Not Served (MW)				Energy Not Served (MWh)					Cost of Energy Not Served (k$)				
					Pre MiniGrid CapEx				Pre MiniGrid CapEx				Post MiniGrid CapEx	Pre MiniGrid CapEx				Post MiniGrid CapEx
	Critical	Priority	Balance	Subtotal	Critical	Priority	Balance	Subtotal	Critical	Priority	Balance	Subtotal	Subtotal	Critical	Priority	Balance	Subtotal	Subtotal
					1st Week (Level 1+Level 2 out)													
Caguas & Cayey	188	104	116	**408**	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**

			Example: an event for 4 weeks
Total MiniGrid CapEx (k$)	**# of Weeks to Justify the CapEx (Critical Loads Only)**	**# of Weeks to Justify the CapEx (All Loads)**	**Total Cost of Energy Not Served (k$)**
$1,008,917	**3.7**	**3**	***$1,274,396***

Supply – Demand Balance: *Carolina MiniGrid*





Resources

- The Carolina Area under S4S2B by 2023 is projected to have 92.8 MW of thermal (4 new peakers), 260 MW of Storage and 440 MW of PV (utility & customer owned)

Observations

- By 2021 the local thermal resources cover the critical load
- From 2022, capacity from all available resources cover the entire local load
- Energy is not fully covered until 2026, indicating some level of load shedding could occur

Transmission Investment – *Carolina MiniGrid*

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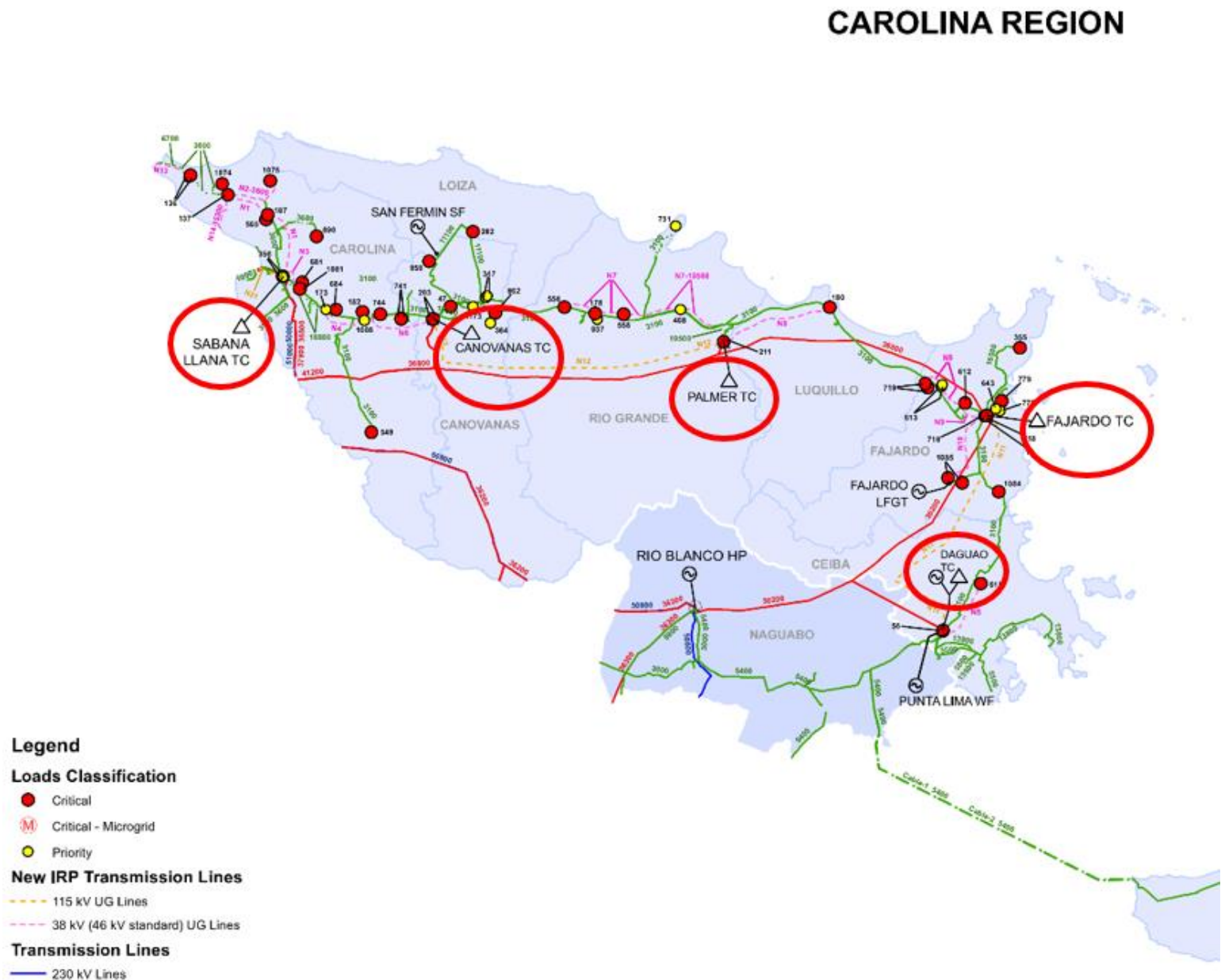

Project Number	Project Description
N1	Ne … @ … ct.
N2	Ur … Su … n. 2
N3	Ne … Ca …
N4	Ur … Ne … to
N5	Ne … kc … 0
N6	Ne … @ …
N7	Ex … Es … Su …
N8	Ur … kc … 300
N9	Ne … 20 … .
N10	Ne … Ac …
N11	Ne … Cu … Se … mil … V
N12	Ne … kc …
N13	Ne … Cu … mil
N14	Ur … kc … 300
N21	Ne … kcmil Cu XLPE

Transmission Investment – *Carolina MiniGrids*

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115 kV Transmission	Carolina	
Technical Justification	**# of Projects**	**Million $**
Aging Infrastructure Replacement-MG	5	21
Existing Infrastructure Hardening for Reliability - MG	4	59
Interconnection of Critical Loads	1	52
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	4	0
Minigrid Main Backbone	13	295
Grand Total	**27**	**426**

38 kV Transmission	Carolina	
Technical Justification	**# of Projects**	**Million $**
Existing Infrastructure Hardening for Reliability - MG	7	42
Interconnection of Critical Loads	15	159
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	2	30
Minigrid Main Backbone	0	0
Grand Total	**24**	**231**

115 kV Transmission	Carolina	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	5	63
New Submarine Cable	4	0
New Substation/Switchyard	2	0
New Transmission Line	0	0
New Underground Construction	5	182
Switchyard Hardening/Reconstruction	11	182
Grand Total	**27**	**426**

38 kV Transmission	Carolina	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	8	46
New Substation/Switchyard	1	12
New Transmission Line	0	0
New Underground Construction	10	115
Switchyard Hardening/Reconstruction	5	57
Grand Total	**24**	**231**

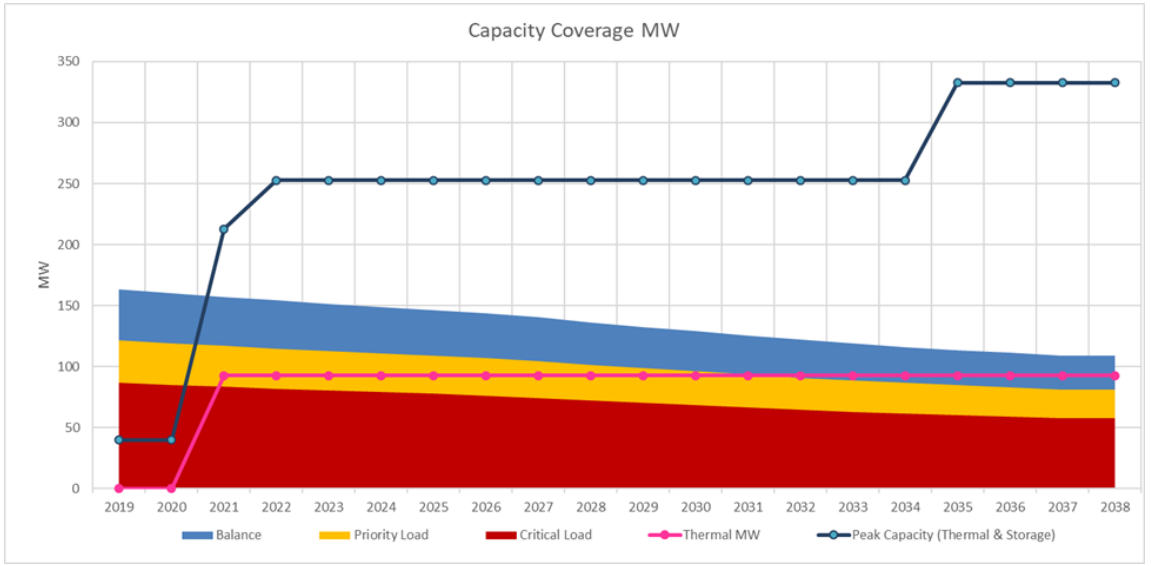
VoLL – *Carolina MiniGrid*

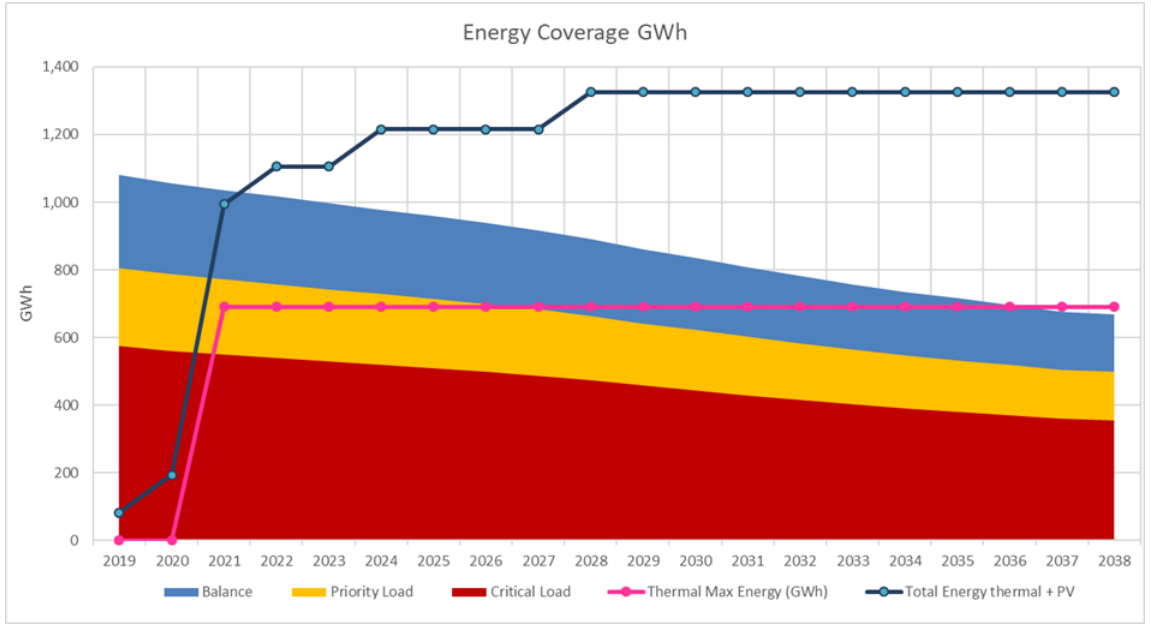
SIEMENS
Ingenuity for life

MiniGrid	Total MiniGrid Load (MW)				Load Not Served (MW)				Energy Not Served (MWh)					Cost of Energy Not Served (k$)				
					Pre MiniGrid CapEx				Pre MiniGrid CapEx				Post MiniGrid CapEx	Pre MiniGrid CapEx				Post MiniGrid CapEx
	Critical	Priority	Balance	Subtotal	Critical	Priority	Balance	Subtotal	Critical	Priority	Balance	Subtotal	Subtotal	Critical	Priority	Balance	Subtotal	Subtotal
					1st Week (Level 1+Level 2 out)													
Carolina	133	34	144	**311**	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**

			Example: an event for 4 weeks
Total MiniGrid CapEx (k$)	**# of Weeks to Justify the CapEx (Critical Loads Only)**	**# of Weeks to Justify the CapEx (All Loads)**	**Total Cost of Energy Not Served (k$)**
$762,367	**2.7**	**2.3**	***$1,308,590***

Supply – Demand Balance: *Mayaguez North MG*





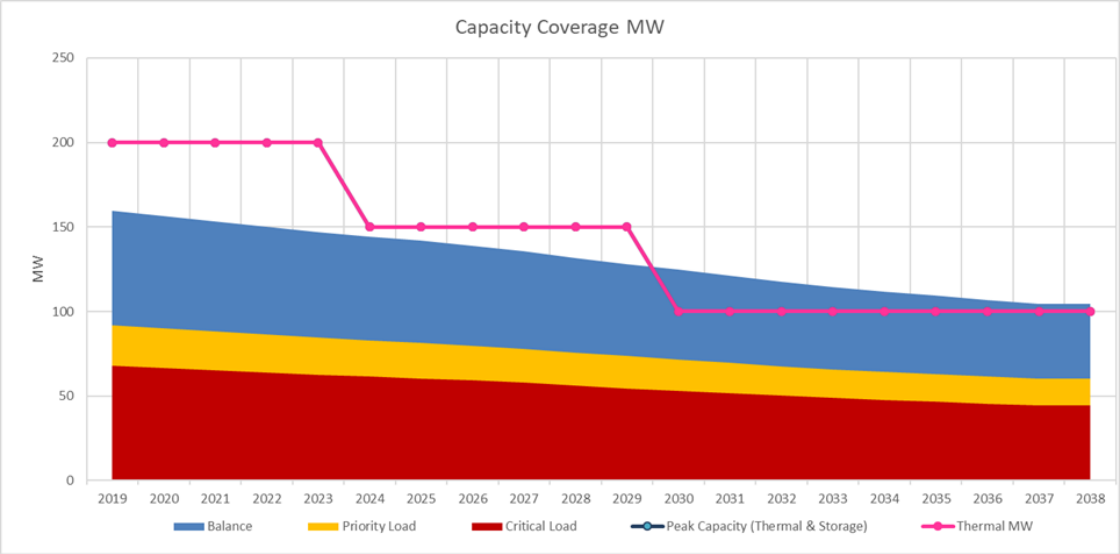
Resources

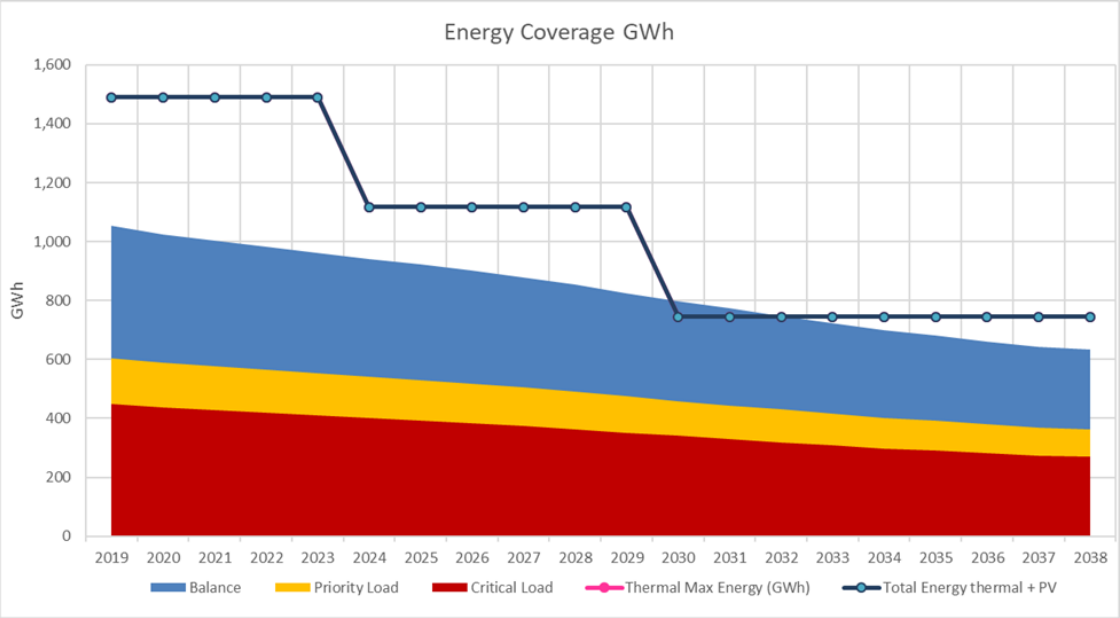
- The Mayaguez North Area under S4S2B by 2022 is projected to have 92.8 MW of thermal (4 new peakers), 160 MW of Storage and 225 MW of PV (utility & customer owned)

Observations

- By 2021 the local thermal resources cover the critical load (red band)
- From 2021, capacity from all available resources cover the entire local load
- Energy is not fully covered until 2022, indicating some level of load shedding could occur during the first couple years

Supply – Demand Balance: *Mayaguez South MG*





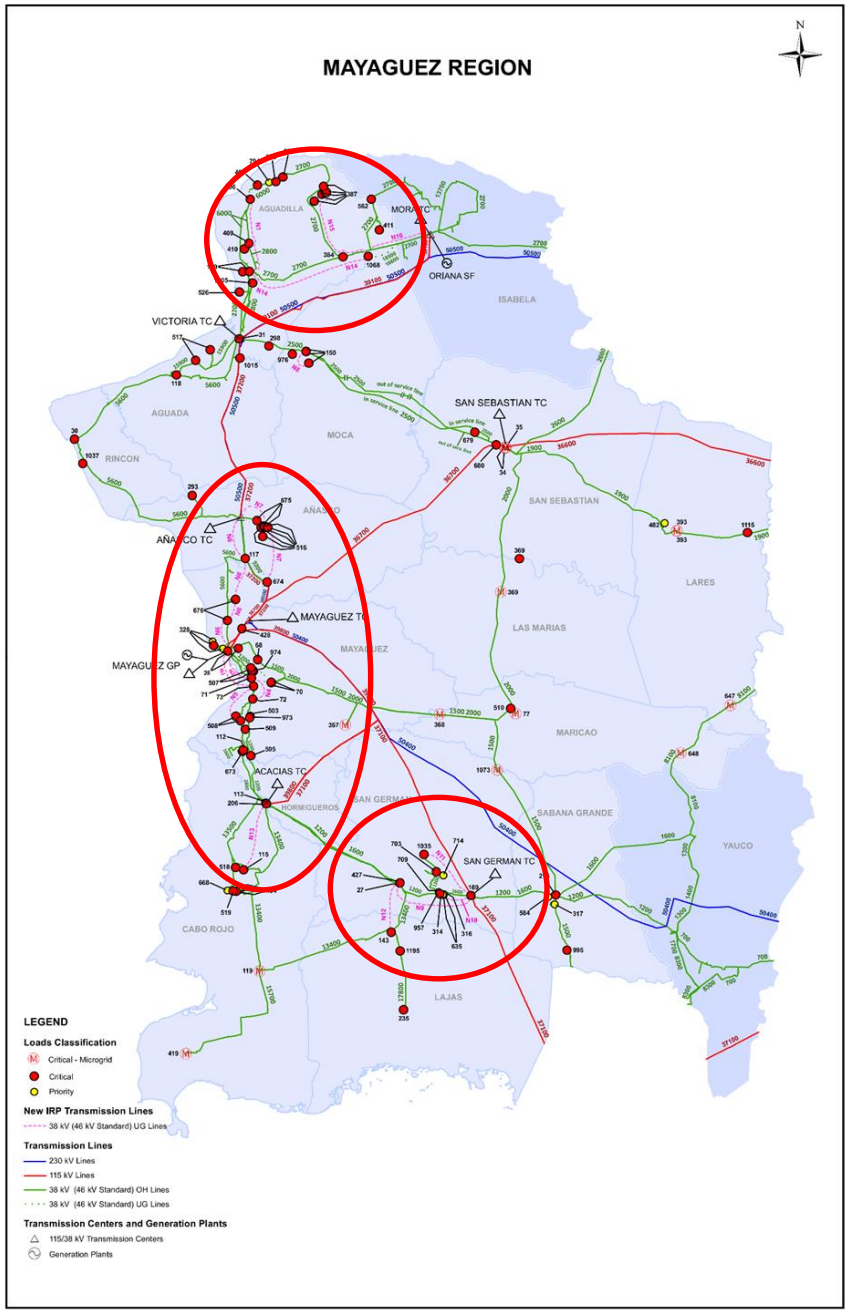
Resources

- The Mayaguez South Area under S4S2B is projected to have resource from thermal GT, 200 MW until 2023, then reduce to 100 starting 2030

Observations

- Local thermal resources cover the critical load (red band) for all years
- Energy is fully covered throughout, except for a slight shortage in 2030 to 2031

Transmission Investment – *Mayaguez North and South MG*



Project Number	Project Description
N1	New Fie ey
N2	New @ 2 IS
N3	New @ 2 GIS
N4	New Sec
N5	New Me kcm 00
N6	New (Ve TC (
N7	New Ind sec
N8	New Hos
N9	New Sec n
N10	New San
N11	New Cor
N12	New 134 0
N13	New Urb
N14	Unc Sec H.
N15	Unc 800 2-
N16	Unc Gue l

Transmission Investment – *Mayaguez North and South MG*

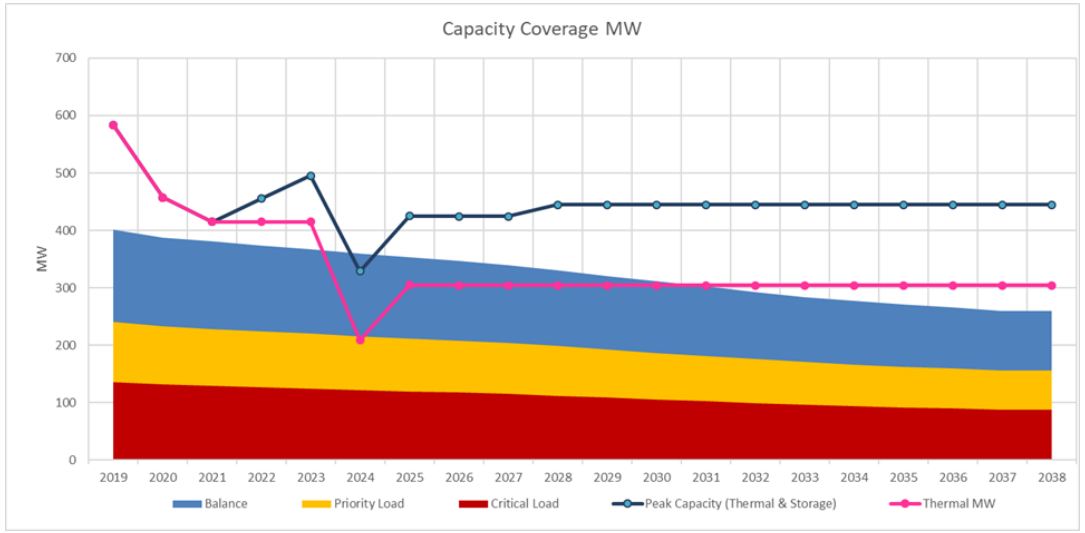
115 kV Transmission	Mayaguez	
Technical Justification	**# of Projects**	**Million $**
Aging Infrastructure Replacement-MG	6	23
Existing Infrastructure Hardening for Reliability - MG	4	66
Interconnection of Critical Loads	0	0
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	0	0
Minigrid Main Backbone	11	215
Grand Total	**21**	**304**

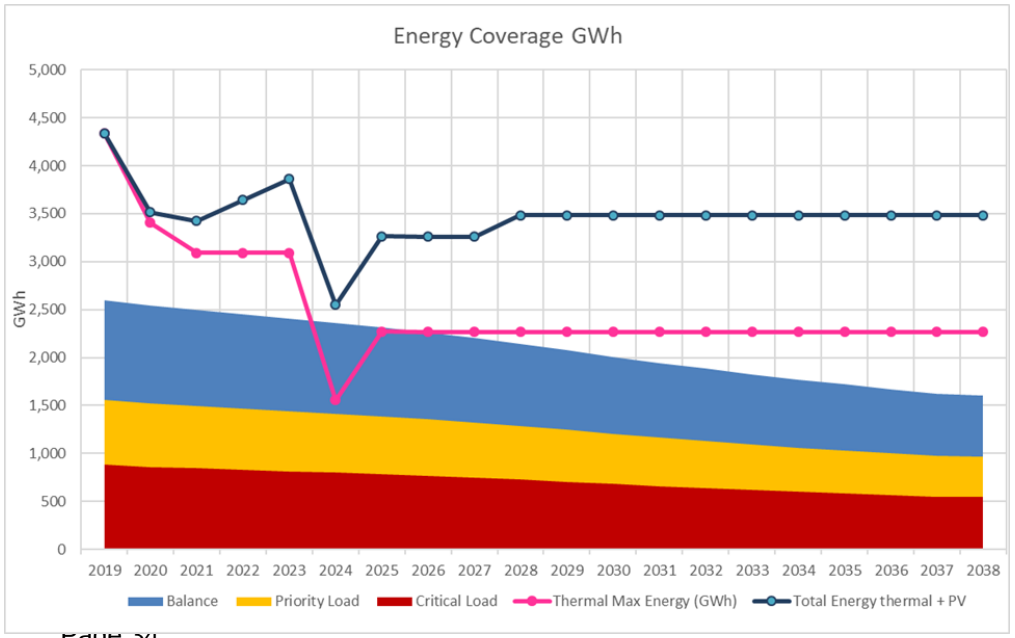
115 kV Transmission	Mayaguez	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	8	102
New Submarine Cable	0	0
New Substation/Switchyard	0	0
New Transmission Line	0	0
New Underground Construction	0	0
Switchyard Hardening/Reconstruction	13	202
Grand Total	**21**	**304**

38 kV Transmission	Mayaguez	
Technical Justification	**# of Projects**	**Million $**
Existing Infrastructure Hardening for Reliability - MG	25	198
Interconnection of Critical Loads	34	391
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	0	0
Minigrid Main Backbone	1	14
Grand Total	**60**	**603**

38 kV Transmission	Mayaguez	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	29	204
New Substation/Switchyard	0	0
New Transmission Line	2	26
New Underground Construction	17	215
Switchyard Hardening/Reconstruction	12	158
Grand Total	**60**	**603**

Supply – Demand Balance: *San Juan MG-Bayamon*





Resources

- Bayamon area under S4S2B by 2025 is projected to have a new 305 MW of thermal (no new peaker and including a new CCGT at Palo Seco), 120 MW of Storage and 540 MW of PV (utility scale and customer owned)

Observations

- Local thermal resources cover the critical load for all years
- The load, by energy, is expected to be fully covered throughout, even considering the retirements

Transmission Investment – *San Juan MG-Bayamon*

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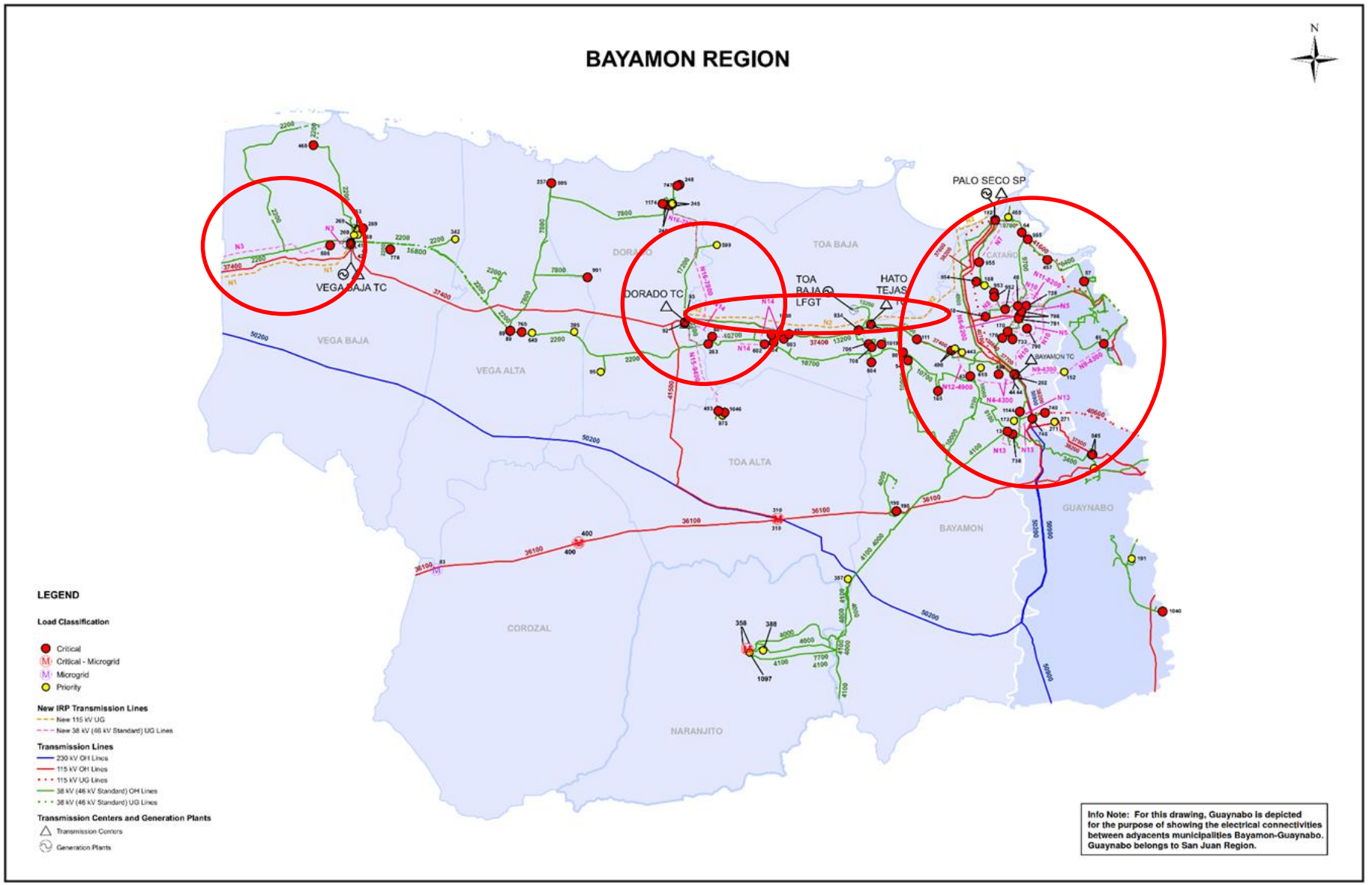
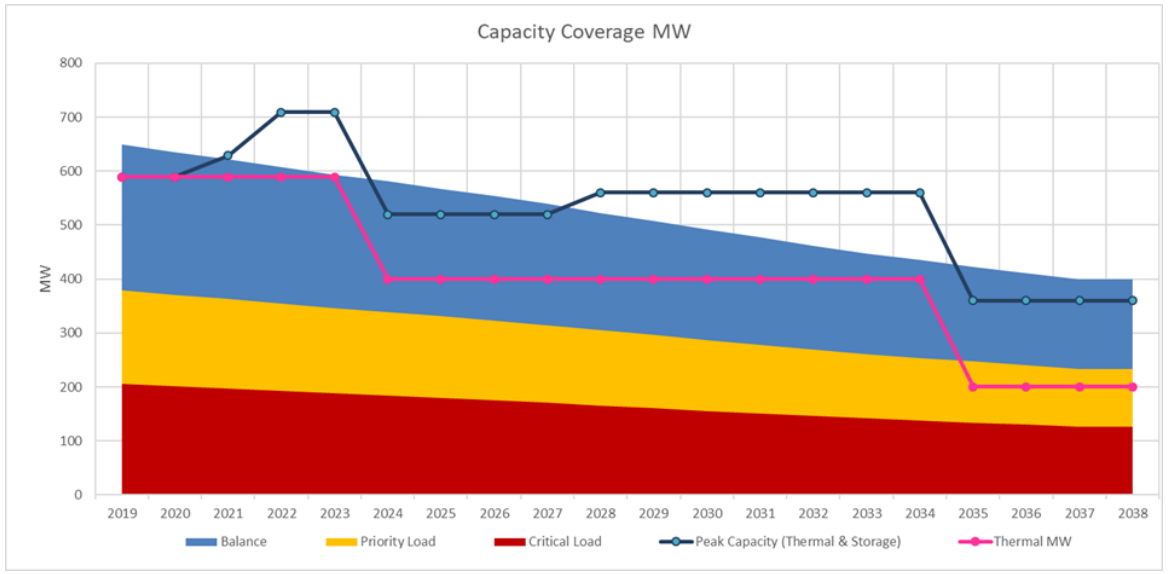
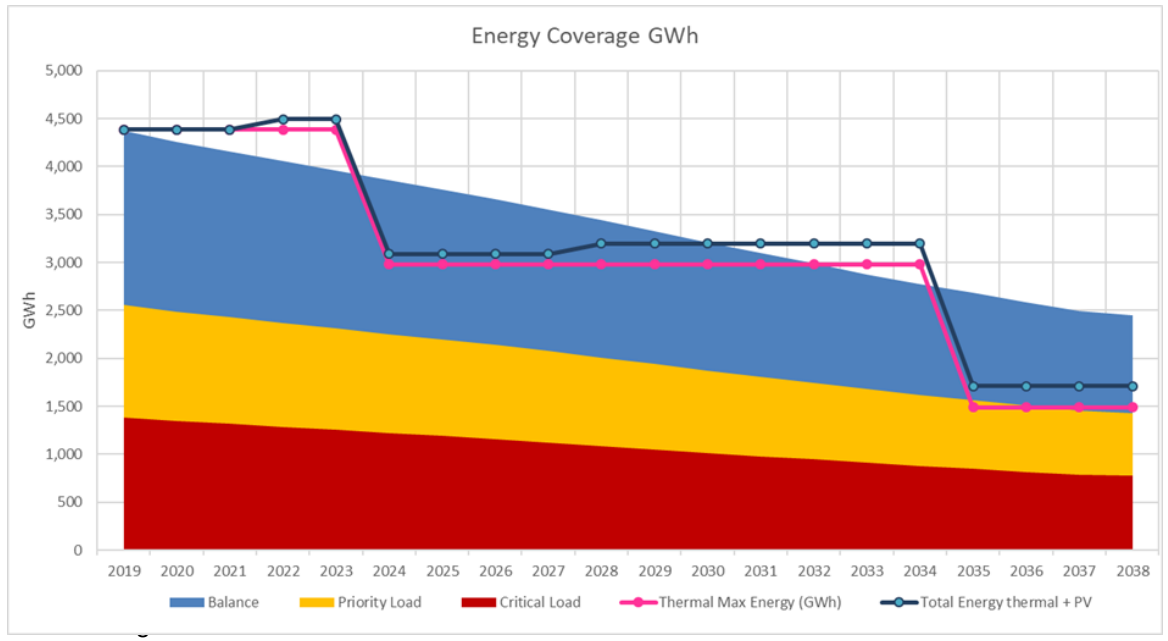


Project Number	Project Description
N1	N… @
N2	N… T…
N3	N… V…
N4	U… P…
N5	N… G… 8…
N6	U… 1…
N7	N… b…
N8	N… C… @…
N9	U… S…
N10	N… @…
N11	U… 1…
N12	C… S… k…
N13	N… A…
N14	N… (V… 8…
N15	U… @… fr…
N16	U… Pueblo Sect. @ 2-800 kcmil Cu

Supply – Demand Balance: *San Juan MG-San Juan*





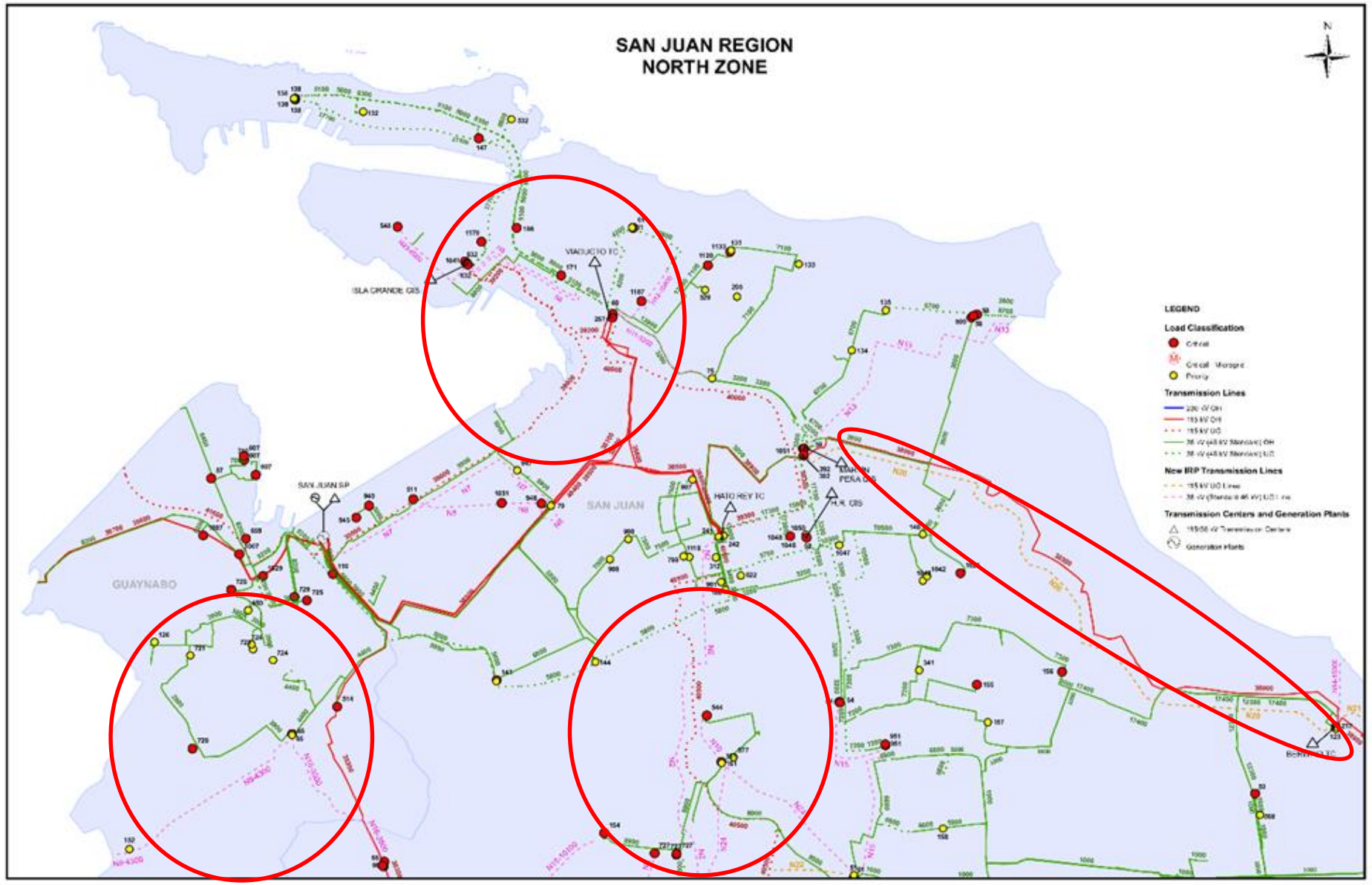
Resources

- San Juan area under S4S2B by 2024 is projected to have 400 MW of thermal (no new peaker), 120 MW of Storage and 60 MW of PV (utility scale)

Observations

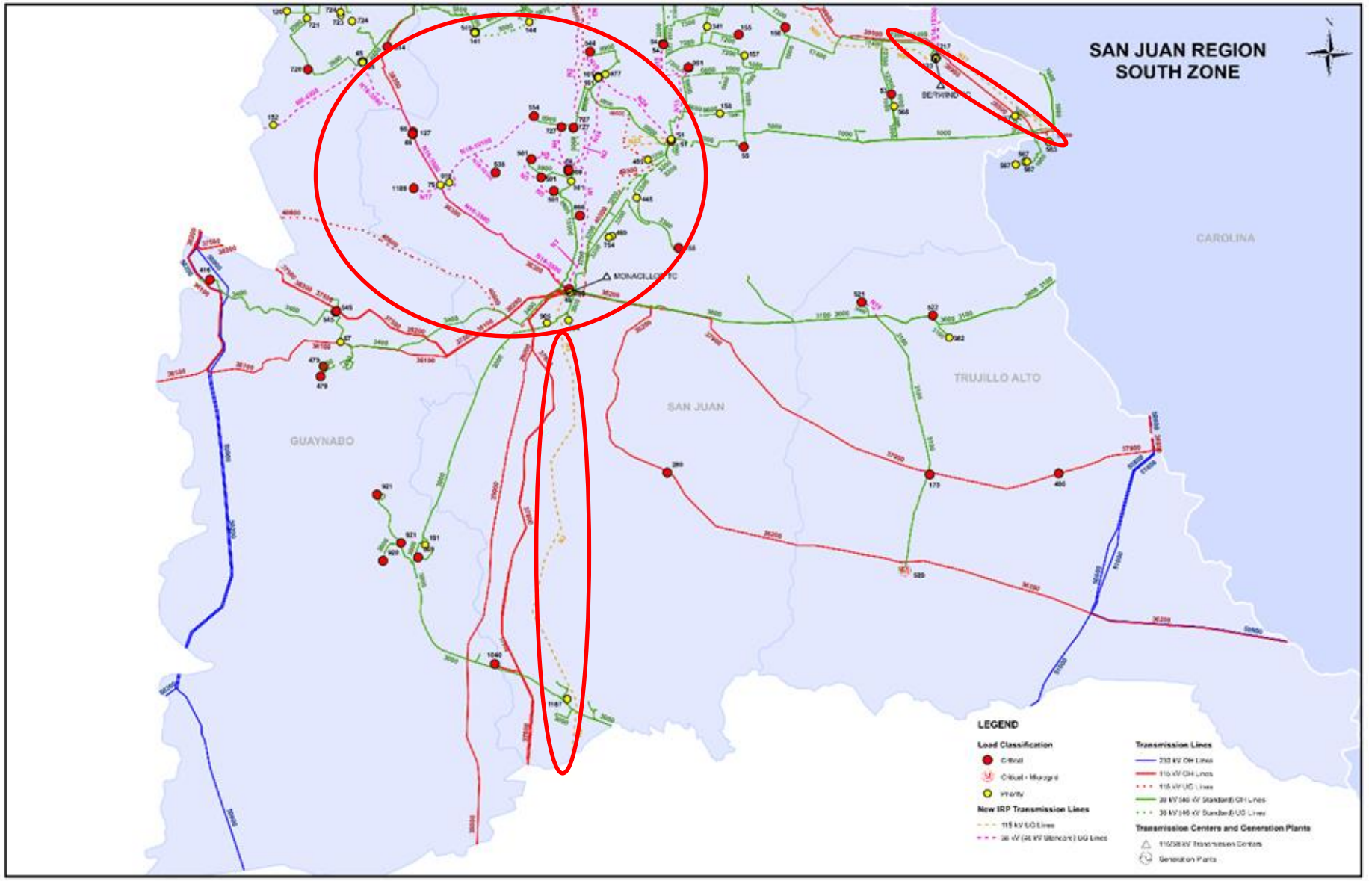
- The LTCE retired all the steam generation in SJ and SJ 6 in 2024, and install the new CCGT starting 2020, and retire one unit in 2035
- Local thermal resources cover the critical load for all years
- Capacity from all available local resources cover most of the load
- Energy is calculated to be almost fully covered, considering resources from Bayamon area in the same MiniGrid can be used

Transmission Investment – *San Juan MG-San Juan (1)*



Project Number	Project Description
N1	New Juan
N2	New San
N3	New TC –
N4	New Cent kcm new
N5	Und for i 800 new
N6	Inte Line
N7	New Cren expr
N8	New Sect (sub
N9	Und Dom
N10	New Hosp
N11	Und @ 2-
N12	Und @ 2-800 kcmil Cu

Transmission Investment – *San Juan MG-San Juan (2)*



Project Number	Project Description
N13	Ne... Sec...
N14	Un... Ang...
N15	Ne... Mu...
N16	Un... Ca... 2-8...
N17	Un... Ho... Cu...
N18	Un... AC... Me... un... Cu...
N19	Ne... Sec...
N20	Ne... Be...
N21	Ne... Be...
N22	Lin... GIS...
N23	Ha... Cr... @...
N24	Ne... For... kcr...

Transmission Investment – *San Juan MiniGrid*

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115 kV Transmission	San Juan	
Technical Justification	**# of Projects**	**Million $**
Aging Infrastructure Replacement-MG	7	37
Existing Infrastructure Hardening for Reliability - MG	13	60
Interconnection of Critical Loads	0	0
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	2	70
Minigrid Main Backbone	10	322
Grand Total	**32**	**490**

115 kV Transmission	San Juan	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	13	49
New Submarine Cable	0	0
New Substation/Switchyard	0	0
New Transmission Line	0	0
New Underground Construction	5	120
Switchyard Hardening/Reconstruction	14	321
Grand Total	**32**	**490**

38 kV Transmission	San Juan	
Technical Justification	**# of Projects**	**Million $**
Existing Infrastructure Hardening for Reliability - MG	0	0
Interconnection of Critical Loads	53	344
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	10	80
Minigrid Main Backbone	0	0
Grand Total	**63**	**424**

38 kV Transmission	San Juan	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	26	109
New Substation/Switchyard	0	0
New Transmission Line	0	0
New Underground Construction	20	145
Switchyard Hardening/Reconstruction	17	170
Grand Total	**63**	**424**

VoLL – *San Juan MiniGrid*

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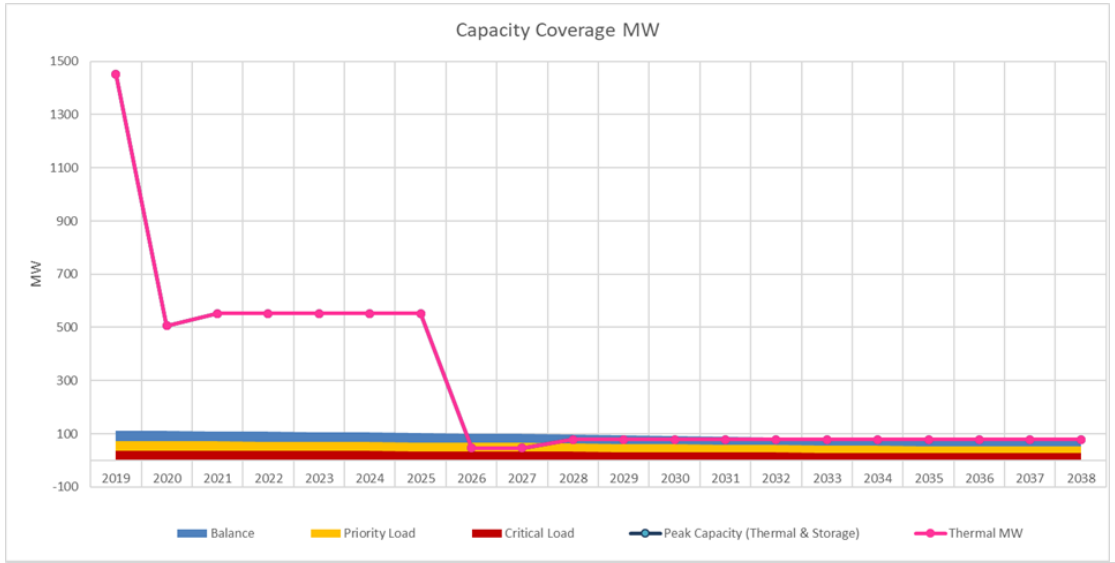
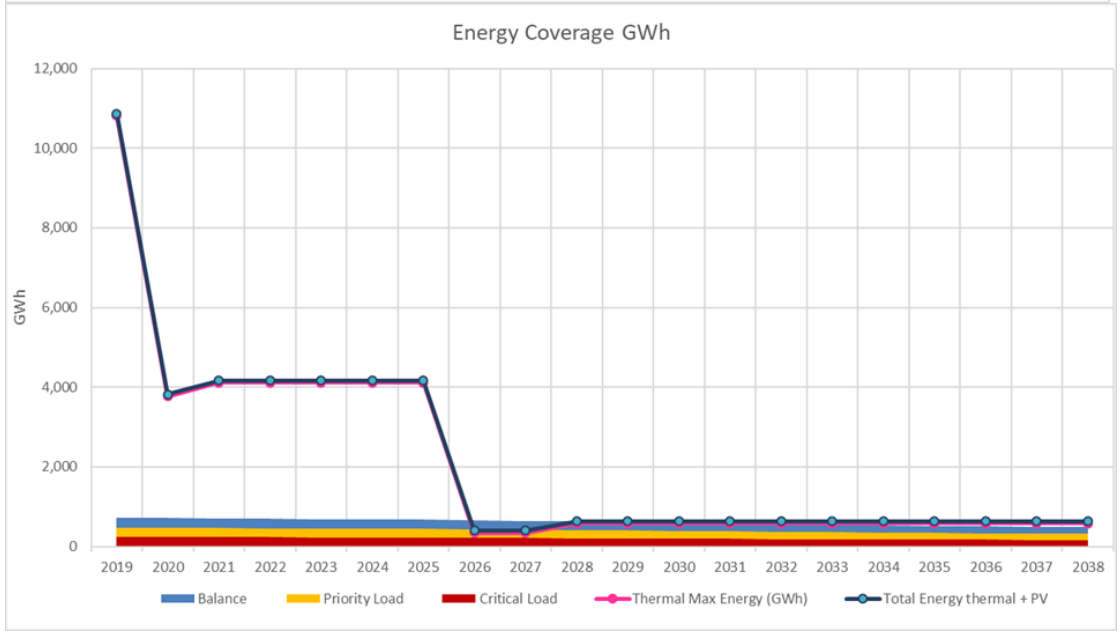
MiniGrid	Total MiniGrid Load (MW)				Load Not Served (MW)				Energy Not Served (MWh)					Cost of Energy Not Served (k$)				
					Pre MiniGrid CapEx				Pre MiniGrid CapEx				Post MiniGrid CapEx	Pre MiniGrid CapEx				Post MiniGrid CapEx
	Critical	Priority	Balance	Subtotal	Critical	Priority	Balance	Subtotal	Critical	Priority	Balance	Subtotal	Subtotal	Critical	Priority	Balance	Subtotal	Subtotal
					1st Week (Level 1+Level 2 out)													
San Juan-Bayamon	399	185	467	**1051**	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**

			Example: an event for 4 weeks
Total MiniGrid CapEx (k$)	**# of Weeks to Justify the CapEx (Critical Loads Only)**	**# of Weeks to Justify the CapEx (All Loads)**	**Total Cost of Energy Not Served (k$)**
$1,432,630	**1.8**	**1.4**	***$3,810,788***

Supply – Demand Balance: *Ponce MiniGrid-East*





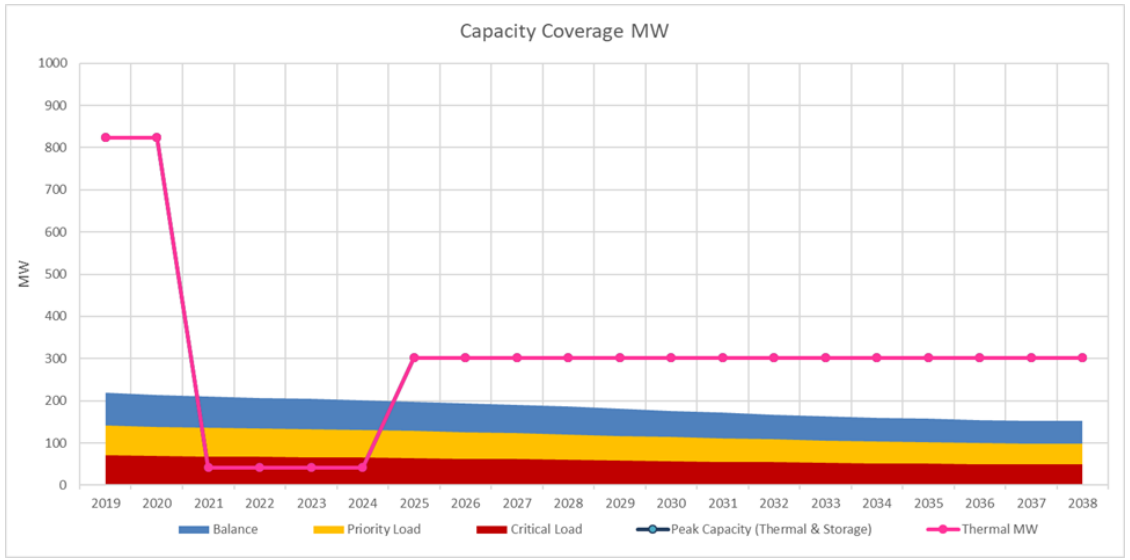
Resources

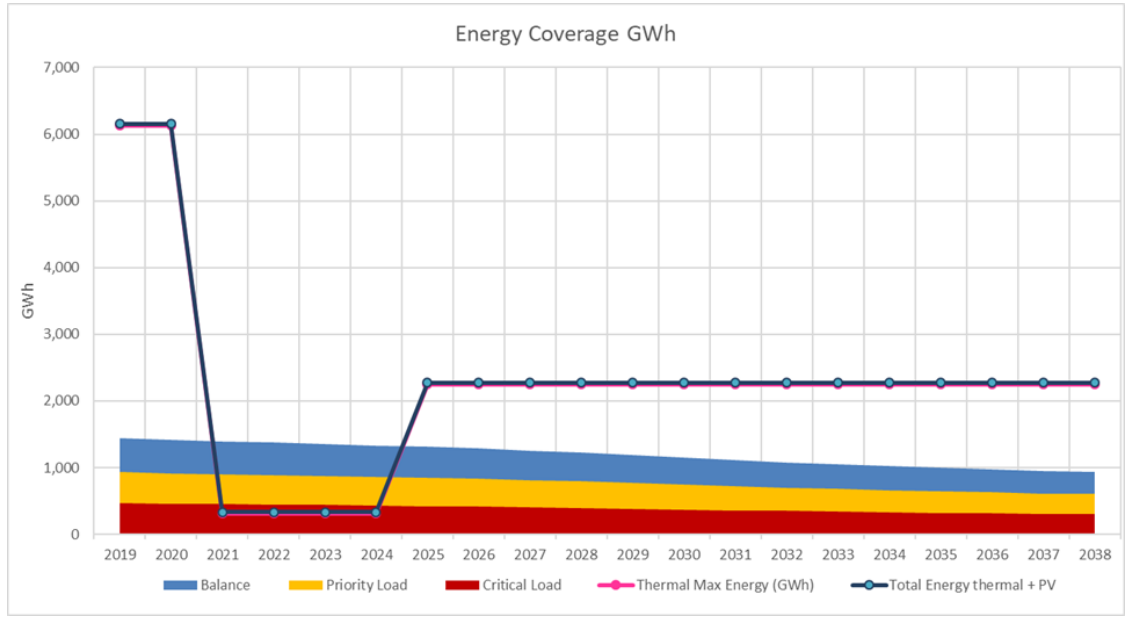
- Ponce East area under S4S2B by 2026 is projected to have 46.4 MW of thermal (2 new peakers) after the retirement of Aguirre CC in 2025, 0 MW of Storage and 30 MW of PV (customer owned)

Observations

- The LTCE retired all the thermal generation in Ponce East and install only new peaker units in 2026 and 2028
- Local thermal resources cover the critical load for all years
- Energy is calculated to be fully covered, considering resources from Ponce West area in the same MiniGrid can be used

Supply – Demand Balance: *Ponce MiniGrid-West*





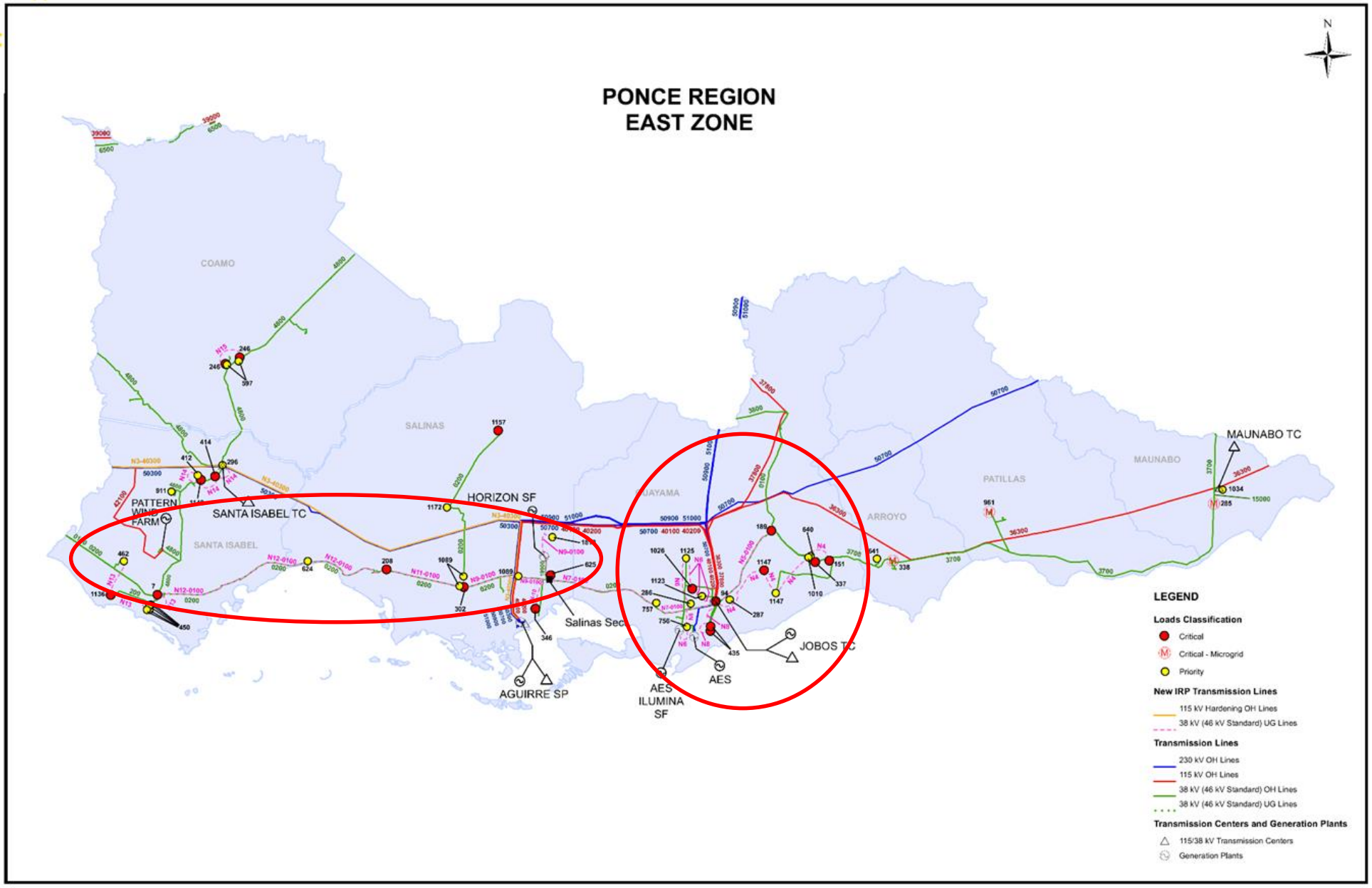
Resources

- Ponce West area under S4S2B by 2025 is projected to have 302 MW of Costa Sur CC thermal generation (no new peaker), 0 MW of Storage and 12 MW of PV (customer owned)

Observations

- The LTCE retired all the thermal generation in Ponce West by 2024 and install a new CC unit in 2025
- Considering resources from Ponce East area in the same MiniGrid:
  - All critical loads in Ponce MiniGrid are fully covered by thermal resources
  - Energy is fully covered in Ponce MiniGrid

Transmission Investment – *Ponce MiniGrid*



Transmission Investment – *Ponce MiniGrid*

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Project Number	Project Description
N1	
N2	
N3	
N4	
N5	
N6	
N7	
N8	
N9	
N10	
N11	
N12	
N13	
N14	
N15	
N16	
N17	

Project Number	Project Description
N18	
N19	
N20	
N21	
N22	
N23	
N24	
N25	
N26	
N27	
N28	
N29	
N30	
N31	
N32	
N33	
N34	

Transmission Investment – *Ponce MiniGrid*

SIEMENS
Ingenuity for life

115 kV Transmission	Ponce	
Technical Justification	**# of Projects**	**Million $**
Aging Infrastructure Replacement-MG	7	23
Existing Infrastructure Hardening for Reliability - MG	0	0
Interconnection of Critical Loads	4	68
Interconnection of Minigrids	0	0
Minigrid Backbone Extensions to Create High Reliability/Resiliency	0	0
Minigrid Main Backbone	7	207
Grand Total	**18**	**298**

38 kV Transmission	Ponce	
Technical Justification	**# of Projects**	**Million $**
Existing Infrastructure Hardening for Reliability - MG	0	0
Interconnection of Critical Loads	58	760
Interconnection of Minigrids	1	14
Minigrid Backbone Extensions to Create High Reliability/Resiliency	0	0
Minigrid Main Backbone	0	0
Grand Total	**59**	**773**

115 kV Transmission	Ponce	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	3	55
New Submarine Cable	0	0
New Substation/Switchyard	0	0
New Transmission Line	0	0
New Underground Construction	0	0
Switchyard Hardening/Reconstruction	15	243
Grand Total	**18**	**298**

38 kV Transmission	Ponce	
Project Type	**# of Projects**	**Million $**
Line Hardening/Reconstruction	1	2
New Substation/Switchyard	0	0
New Transmission Line	0	0
New Underground Construction	31	413
Switchyard Hardening/Reconstruction	27	358
Grand Total	**59**	**773**

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Transmission Steady State Analysis

Transmission Steady State Analysis

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Introduction

- Identify constraints, reliability issues, and critical contingencies based on an integrated system
- Considering higher likelihood of implementation, a total of 10 power flow cases were assessed
- Generation portfolios from the LTCE plans
- Additional cases were analyzed based on similarity of resources
- Considered both Day and Night Peak, 2025 and 2028

	S1S2B	S4S2B	ESM	S3S2B	S5S1B
2025	Night	Day & Night	Day & Night	Analyzed	Analyzed
2028	Night	Day & Night	Day & Night	Analyzed	Analyzed

- Present fully Integrated System, followed by Weakened System (assuming selected lines out) and Existing System (current system as is).

Transmission Steady State Analysis – *Integrated System*

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Assumptions

- Base case assumes all generation resources from LTCE plan and mapped to buses
- Include all transmission investment projects: new and upgrades
- System loads and generation are balanced: large thermal, small peaker, PV and storage, DG, CHP
- Capacitor banks adjusted to provide necessary reactive power support

Methodology

- Monitor all 38 kV and above facilities, for thermal and voltage violations
- N-0, system intact
- N-1 contingencies (NERC P1)
- N-2 Right-of-Way contingencies (NERC P7): Selected double circuit lines
- 100% of Rate A and B for normal and emergency (contingency) violations
- Bus voltage at 38 kV and above, 0.95 – 1.05 per unit for system intact and 0.9 – 1.1 per unit following a contingency

Transmission Steady State Analysis – *Integrated System*

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Generation Dispatch – S4S2B

S4S2B Scenario	2025			2028		
	Capacity	Day	Night	Capacity	Day	Night
Bayamon F Class	**302**	0	284	**302**	0	285
Costa Sur F Class	**302**	0	302	**302**	0	302
San Juan Rep 1&2	**400**	0	400	**400**	0	400
AES	**454**	322	454	**0**	0	0
New Solar	**2220**	2220	0	**2820**	2643	0
Existing Renewable	**252.2**	252.2	0	**252.2**	252.2	0
DG	**428**	428	0	**533**	533	0
CHP	**162**	162	162	**162**	162	162
Daguao Gas	**0**	0	0	**93**	0	29
Total Generation		**3384.2**	**1602**		**3590.2**	**1178**
Load		2295	2377		2161	2247
Losses		32	24		29	21
Load + Losses		**2327**	**2401**		**2190**	**2268**
Storage	**1320**	1058	797	**1400**	1400	1090
Gen - Load		0	0		0	0
Reserve			541			391

- Reserve is calculated to accommodate a continuous supply in case of the biggest single unit is tripped out of service.
- For example: In night cases, the biggest unit is the new 302 MW CC F Class, therefore, at least 302 MW is assured from other resources
- Storage is charging (load) during the day and discharging (generation) at night

Transmission Steady State Analysis – *Integrated System*

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Generation Dispatch – ESM

ESM Scenario	2025			2028		
	Capacity	Day	Night	Capacity	Day	Night
Bayamon F Class	**302**	0	284	**302**	0	285
Yabucoa F Class	**302**	0	302	**302**	0	302
San Juan Rep 1&2	**400**	0	400	**200**	0	200
EcoEléctrica	**507**	0	507	**507**	0	507
AES	**454**	322	454	**0**	0	0
New Solar	**2400**	2079	0	**2580**	2362	0
Existing Renewable	**252.2**	252.2	0	**252.2**	252.2	0
DG	**428**	428	0	**533**	533	0
CHP	**162**	162	162	**162**	162	162
Daguao Gas	**0**	0	0	**116**	0	29
Total Generation		**3243.2**	**2109**		**3309.3**	**1485**
Load		2295	2377		2161	2247
Losses		30	28		28	23
Load + Losses		**2325**	**2405**		**2189**	**2270**
Storage	**920**	920	295	**1120**	1120	782
Gen - Load		0	0		0	0
Reserve			643			442

Transmission Steady State Analysis – *Integrated System*

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Thermal and BESS Resource Comparison

	Large & Medium CCGTs and Peakers				Storage	
CASE ID	F - Class Palo Seco 2025	F - Class Costa Sur 2025	San Juan 5&6 Conversion	Peakers 2025 (MW)	BESS 2025 (MW)	BESS 2028 (MW)
S1S2B	–	Eco instead	✓	504	1,280	1,280
S3S2B	–	✓	✓	348	1,400	1,920
S4S2B	✓	✓	✓	371	1,320	1,400
S5S1B	–	369 MW (2025&2028)	✓	371	1,200	1,200
ESM	✓	✓	✓	421	920	1,120

- S1S2B is similar to S4S2B as the only major difference is the absence of the large CC F Class in Palo Seco and F Class unit in Costa Sur replaced by EcoEléctrica, supplemented by additional peakers
- S3S2B and S5S1B are also similar to S4S2B or S1S2B where the F class in Palo Seco is not in the mix and complimented by thermal peakers and additional BESS resources

Transmission Steady State Analysis – *Integrated System*

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Observations

- The loss of a 38 kV line line resulted in a radial feed to a 20.33 MVA of load causing a slight overload on the other 38 kV line. This is a local issue not really related to the IRP.
  - Recommend to upgrade the affected line to higher rating based on preliminary observation
- No other thermal violations above 38kV were reported for all 10 power flow cases
- Low voltage violations at 38kV were reported in Arecibo near Dos Bocas area due to the loss of one of the 115 kV lines. This is also local in nature.

Transmission Steady State Analysis – *Weakened System*

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Summary

- As a complement of the MiniGrid analysis which evaluate the system conditions under 8 separated MiniGrids, Weakened system analysis evaluates the conditions in which the system may be lesser in strength, but still integrated
- The certain critical lines assumed to be out of service for an extended period of time after a major event, mostly in east and south
- AES is disconnected as a result
- S4S2B and ESM Night Peak cases assessed for both 2025 and 2028
- No thermal or voltage violations were reported under this assessment.

Transmission Steady State Analysis – *Existing System*

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Summary

- In addition to the fully Integrated System, Weakened System and MiniGrid System analysis, the Existing System representing the PREPA transmission network currently as is also assessed
- Assuming system unreinforced and no proposed transmission investment
- The purpose is to mainly identify any constraints and reinforcements required to relieve constraints as a result of two major resources: 302 MW each at Yabucoa and Mayaguez
- Benchmark (without the units) and Study (with the units) cases were assessed
- In Study case the new units were dispatched to full capacity, and the generation in the rest of PREPA system was adjusted to maintain the same level
- Adding a CCGT at Mayaguez did not result in any violations.
- The unit in Yabucoa would result in overloads under certain contingencies.
- This overload will not occur under the ranforced system for Resiliency. Also PREPA has plan in place in the area that could address this issue.

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Thank you