IRP2019 EX 1.01C Appendix 1_Section2_Redacted



2

Transmission System – MiniGrid Analysis

A critical component of the formulation of the 2018 Integrated Resource Plan (IRP) is the identification of electrical islands or "MiniGrid" into which the system may be segregated after a major atmospheric event (e.g. hurricane). In other words, the MiniGrids are regions of the system that are interconnected with the rest of the electric power system via transmission lines that may take over a month to recover after a major event, and should be able to operate largely independently, with minimum disruption for the extended period of time that would take to recover full interconnection.

In this section an analysis of PREPA's transmission system is presented, first an overview of the PREPA's integrated system, second, the procedure for the initial definition of the MiniGrids, followed by the detailed analysis carried out for their design concept. For each MiniGrid we provide details regarding their supply and demand balance as well as the drivers for the capital transmission investment. In addition to the MiniGrids, there are also microgrids located within some of the MiniGrids that will be isolated from the MiniGrid after a major event. The microgrid supply and demand is also discussed in each MiniGrid section.

2.1 PREPA Transmission System

2.1.1 Overview

PREPA's transmission system has as one of its main objectives the efficient interconnection of generation sources to the load centers of power demand distributed throughout the island. The system connects generating plants, transmission centers and distribution substations through a complex and extensive network of transmission lines at the 230 kV and 115 kV voltage levels, as well as subtransmission lines at the 38 kV voltage level. The grid is designed based on steady-state, dynamic and transient system planning studies that require a thorough scientific evaluation of the transmission system, ensuring adequate system stability margins in the context of very high reliability levels and power quality standards.

In addition to NERC standards which are fundamental for planning the reliability of interconnected bulk electric systems in United States, PREPA's planning standards reflect the operational electric system characteristics, the geography, and the demography of an island which is electrical isolated. According to NERC Standards the bulk electric system must have the ability to meet the electrical demand at all times taking account scheduled or unscheduled outages of the system elements, which is adequacy. Also the bulk electric system must have the ability to withstand sudden disturbances such as electric short circuit or loss of system elements, which means security. Adequacy and Security define the interconnected bulk electric system reliability. Similarly, PREPA's planning standards are

developed to comply with the following critical reliability and system security objectives, standards and design criteria:

- a. Strategically prepared for the integration of new generation sources, including renewable and alternative energy sources.
- b. Adequate thermal capacity to handle active and reactive power transfer levels.
- c. Contingency planning analysis to ensure operational adequate levels of safety, stability and reliability.
- d. Compliance with the voltage and rotor angle stability safety margins of the electrical system.
- e. Minimization of thermal and reactive power transmission system losses.
- f. Optimization of the transmission network efficiency in the context of economic, physical and technical aspects and constraints.
- g. Structural transformation to an intelligent and smart electric transmission grid.

PREPA system is composed of 2,491 circuit miles of transmission lines, consisting of 413 circuit miles of 230 kV lines, 702 circuit miles of 115 kV lines and 1,376 circuit miles of 38 kV lines. The Authority has 37 miles of underground 115 kV cable, 63 miles of underground 38 kV cable and 22.59 miles of submarine 38 kV cable to the islands of Vieques and Culebra. PREPA system has 178 transmission centers and switchyards throughout the island and 30 transmission switchyards located at generating sites. The maximum transformation capacity connected to transmission centers and generating plants is 19,167,250 kilovolt amperes ("kVA"). For PREPA system maps, please see ITEM 46_Mapa_PR40_Grid_2.pdf and ITEM 46_Mapa Maestro_PR40_Grid_2.pdf in Appendix 1 work papers.

2.2 **PREPA MiniGrid Identification**

The first step in the process is identifying the boundaries of the future MiniGrids. Siemens PTI worked collaboratively with PREPA in defining these boundaries, which are discussed below.

Exhibit 2-1 shows, according to PREPA's experience and geography, the expected time to repair the 115 kV that could be affected after a major event. In this figure light green lines represent lines that due to geography, could take over a month to repair after a major event. Yellow (brown) represent lines that would take under 30 days to bring back in service, with a target of under 10 days, but require being hardened in accordance with new codes and standards. Red line should be recovered under 10 days with a target of few hours or ride through the storm for those connecting to critical loads, after being hardened in accordance with new codes and standards. Finally, blue lines are the 230 kV that could also be affected and out of service for longer periods of time, possibly well over a month. The length of time for outage recovery is a major factor but not the only input for determining the coverage area of each MiniGrid.

As will be discussed in this section the other key aspect in the definition of the MiniGrid is the transmission hardening projects, including the construction of a 115 kV and/or 38 kV backbone made of underground facilities, the location of critical loads that could become isolated due to the vulnerability of the 38 kV lines and the existing infrastructure hardening projects underway.

Exhibit 2-1: PREPA Transmission System Map with Proposed MiniGrids

Redacted

Siemens Industry, Inc. – Siemens Power Technologies International Error! Reference source not found. – Rev. Error! Reference source not found. – 2018 Integrated Resource Plan Appendix 1: Transmission and Distribution Based on this, eight (8) MiniGrids were identified, as shown in the Exhibit above; Arecibo, Caguas, Carolina, Cayey (Cayey MiniGrid is discussed in combination with Caguas MiniGrid), Mayaguez North, Mayaguez South, Ponce (East and West), and San Juan-Bayamon (single MiniGrid). Each of these MiniGrids will be presented in detail in the following sections.

Since PREPA operates the island on district basis, based on which the preliminary MiniGrid boundaries took into consideration; however, the main driver was the exposure of the overhead transmission lines to an extended outage. Keeping district boundaries, however, should facilitate the operation and repairs of the MiniGrids in the event of isolation.

2.3 MiniGrid Design

The Design of the MiniGrid as well as the potential microgrids consisted of two overarching activities; a) the generation resource selection to ensure that the MiniGrid will have local resources adequate to serve its load in isolation and b) a resilient electrical design so that the generation can be delivered to the load in a timely and reliable manner.

One fundamental aspect for the design of both the generation supply and the transmission and distribution system (T&D), is the relative importance of the load served, so that the design ensures that the most important loads to the restoration effort are recovered first, followed by those that will ensure appropriate management and timely recovery of an event. To account for this, the loads are classified into three categories:

Critical Loads: These loads include basic resources that should either ride through the storm or must be available shortly after. They are crucial for the restoration effort and include hospitals, airports, seaports, police, fire stations, storm water pumps, critical water supply/treatment AAA facilities, shelters /town centers and certain communication facilities.

Priority Loads: These loads are those necessary to restore normalcy to each of the localities and include loads like shopping centers and commercial establishments, gas stations, industries, higher density residential areas. These loads must be reconnected shortly after the Critical Loads. Some overhead lines may have to be inspected and repaired; the objective is to achieve full reconnection no more than 10 days after event.

Balance of the 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% restoration may exceed 10 days.

Exhibit 2-2 and Exhibit 2-3 below shows a conservative estimation of the critical, priority, and remaining balance of load for each MiniGrid for the year 2019.

It must be stressed that the "critical load" presented <u>must not be confused with the actual expected</u> <u>consumption of the customers that are considered critical.</u> This load represents the peak consumption of the <u>total load</u> connected to feeders that serve any critical customer¹ and that during

¹ The "Critical Loads" are also high due to the fact that based on hurricane recovery experience, PREPA recommended that the town centers to be considered critical and these feeders typically have significant load connected to them.

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the restoration effort may be taken together with these critical customers. Also, for the transmission connected load, it represents the entirety of the load connected to the substations, although some of it (perhaps the majority) may not be critical, but rather priority. This approach ensures that we will identify thermal resources adequate to serve these critical customers, without having to send crews to segregate them from the rest. Moreover, being conservative at this time is important as any available reliable thermal resources, after the critical load is supplied, will be allocated to the priority loads and minimize the need for load shedding during grid-isolated operations. Also, as was indicated in the main body of the IRP Report, just the elimination of load shedding was enough to justify the thermal generation assigned to the MiniGrids, just by considering a very small value of lost load².

On the other hand, for the determination of thermal generation needs, we reduced the critical load to 75% the value determined using the procedure above, to account for the fact that right after the event and before PV and BESS is available, it is likely to be reduced with respect of its peak. The 75% was determined considering the ratios we see between the high load months (e.g. August) to low load months (e.g. January).

2019 in the table below was selected for illustration as the percentage of load composition does not change significantly overtime in our projections and the estimation is based on the best available data in that year. However as shown later the analysis was carried out considering the load composition for all years.

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%		

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

Reference: IRP_19_Substation_LoadProcessing_Final.xlsx

* The "deemed" critical load includes other loads served together with it at feeder and substation level

² The Value of Lost Load for Puerto Rico as a whole was determined to by \$ 30,000/MWh when the entirety of the load composition is considered, but as the load shed will be managed, this value was reduced to \$ 2000/MWh (typical for residential loads).



Exhibit 2-3: 2019 Critical/Priority/Balance Load



Based on the above the following design criteria was identified:

2.3.1 Local Generation Resource Selection

The local generation resources are selected considering the following:

- The critical loads must be served by thermal resources only ensuring full coverage right after the event and before the renewable generation (PV) and battery storage (BESS) are back online.
- Priority loads can be served by a combination of thermal resources and PV + Storage.
- The installed capacity considering the storage and the thermal must be enough to cover the coincident peak load of critical and priority loads. In general, we assumed that during hurricane season, the MiniGrid generation unit will be in good operating condition, fully fueled and any maintenance will be planned/postponed for other times of the year.
 PREPA is also assumed to have mobile units in storage that could be deployed in case of emergencies. For this reason, generation outages are not considered during grid isolated mode. However, it would be worth pointing out that one of the key functions of the MiniGrid controller, as discussed in Section 2.11 is the automatic load shed in case of generation trips, and detailed studies will indicate the strategy and settings of the microgrid controller; which will always have underfrequency load shed as the backup.
- The energy production of thermal plus renewable must be able to meet the energy requirement of the critical and priority loads.
- Balance of loads are to be served by a combination of thermal resources and renewable + storage and under grid isolation mode some level of load shed is accepted. This however was tracked to identify differences between the LTCE portfolios.

2.3.2 MiniGrid Transmission / Distribution Design

The transmission and distribution system are designed considering the following:

- There will be a backbone for the MiniGrid created by the hardening of existing infrastructure and new underground facilities and GIS switchyards and substations. This backbone is for the connection of generation as well as for serving critical and priority loads.
- Ensuring reliable supply to critical loads via underground facilities for its interconnection to the backbone (see Section 4 for description of investments proposed at the distribution level to achieve this).
- Extension of the MiniGrid backbone to create high reliability and resiliency zones; most of these investments allow the interconnection of MiniGrids to form a larger MiniGrid allowing consolidation; but could be extensions to areas that otherwise would have to be a microgrid.
- Hardening of the existing infrastructure as complementary to the above.

2.3.3 MiniGrid Load Flow Assessment

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 look at the pre-contingency flows and bus voltages for MiniGrid operations. However, the contingency flows and bus voltages are available for reference as they can indicate the system vulnerability in case more damages occurred.

The general assumptions used in the assessment are as follows:

- 2025 S4S2B base case model was selected including all the generation derived from LTCE plan, and all the new transmission upgrades or existing infrastructure enhancements modeled based on the transmission investment project information from PREPA. It should be noted however that this plan does not deviates materially from the ESM plan and the conclusions regarding no overloads observed are applicable,
- 2. 2019 Night peak load was used to simulate higher total system load.
- 3. The system load and generation are balanced such that:
 - a. All available thermal generators are brought online
 - b. All PVs are turned off at night
 - c. BESS resources are assumed as generation at night, and they can be dispatched to achieve near zero imbalance between load and generation within each MiniGrid.
 - d. All Combined Heat and Power (CHP) units are online
- 4. Capacitor banks in the system adjusted to optimized voltages.
- 5. All 38 kV and above lines are monitored, and all transformers with high side voltage at and above 38 kV are monitored
- PREPA contingency set was considered, although this includes some N-2 common Right of Way contingencies

- Since the transmission system is already emergency conditions, all buses are monitored between 0.9 – 1.1 per unit under emergency.
- 8. We divide the analysis into two stage of system operations: MiniGrid with microgrids connected, as could be the situation a few weeks after the major event and MiniGrid with all microgrids disconnected simulating the system in further destructive scenario or few days / weeks after the event and before the microgrids are connected back to the MiniGrid.

All N-1 contingencies successfully met convergence tolerances. Based on the preliminary assessment, we found that, before contingency, no line overload is reported, and no bus voltage beyond the defined reliable planning criteria. The results observed from pre-contingency assessment are in line with the results discussed in the Integrated Steady State Analysis report, where under single contingency there is no line overload.

Additional observations are included in each MiniGrid discussion. Power flow results of the two scenarios under contingency for both thermal and voltage are available for reference.

2.3.4 Microgrid Considerations

It is recognized that there are areas where, given its location and geography, it would be impractical or excessively costly to try to maintain reliable supply with transmission after a major event. In this case the best option is to use microgrids; that is the local load will be served using local generation under "grid isolated mode" for a period after the major event and until the transmission infrastructure is recovered.

PREPA and Siemens PTI worked together to identify these microgrids and, approximately 50 potential zones for microgrid application were identified including the two islands Vieques and Culebra within the Carolina MiniGrid (see Exhibit 2-4 below).

Note that we identified the microgrid application zones based on the load information and transmission topology provided by PREPA. However, it must be stressed that the estimation is not a substitute for the detailed study that needs to be performed for each microgrid zone including the exact boundaries of the microgrids within the zones, load analysis, generation selection, available sites to install generation, T&D analysis, engineering design, environmental/permitting, and among others. In other words, in this analysis we only provide high level estimation of the required generation to serve the load in each of the microgrid and it is not a recommendation or proposal for the actual microgrid system. The detailed generation estimations will be discussed in each MiniGrid section in this report.

The section of microgrid analysis is subject to revision as more information becomes available.

MiniGrid	Microgrid Name	Critical	Priority	Balance	
	CAGUANA	2.0	0.0	0.7	
	CHARCO HONDO	3.6	0.0	0.0	
	CIALES	4.8	0.0	0.0	
	DOMINGUITO	3.2	0.0	4.8	
	DOS BOCAS	0.8	0.0	0.0	
Arecibo	FLORIDA	4.1	0.0	2.0	
	JAYUYA	7.1	2.1	0.0	
	GUAJATACA	0.4	0.0	2.3	
	ADJUNTAS	3.3	0.0	0.8	
	YAHUECAS	1.1	0.0	0.0	
	MOROVIS	8.8	0.0	0.0	
	UTUADO	6.6	0.6	3.7	
	AGUAS BUENAS	6.4	0.0	0.0	
	PUEBLITO RIO	4.5	0.0	0.0	
Caguas	SAN LORENZO	9.1	0.6	6.4	
Caguas	YABUCOA	4.2	0.0	3.9	
	NAGUABO	2.0	0.6	0.1	
	RIO BLANCO	2.9	0.0	0.0	
Carolina	CULEBRA	2.9	0.0	0.0	
Caronna	VIEQUES	5.7	0.0	0.0	
	ABANICO	4.5	0.0	0.0	
	AIBONITO	9.8	3.4	1.4	
Cayey	BARRANQUITAS	9.2	0.0	0.0	
	COMERIO	6.1	0.0	1.7	
	OROCOVIS	5.0	0.0	0.1	
Mayaguaz North	LARES	6.4	0.2	4.0	
wayaguez worth	SAN SEBASTIAN	12.1	0.0	9.5	
	BOQUERON	1.6	0.3	4.0	
	COMBATE	4.5	0.0	1.3	
	CROEM	0.8	0.0	1.7	
	LAS MARIAS	3.2	0.0	0.0	
Mayaguez South	LAS VEGAS	0.7	0.0	0.0	
	MARICAO	2.3	0.0	0.6	
	BARTOLO	0.6	0.0	0.0	
	INDIERA	0.4	0.0	0.2	
	MONTE DEL ESTADO	0.6	0.0	0.0	
	ARROYO	2.4	2.1	4.9	
	MAUNABO	2.8	0.0	0.7	
Ponce	PATILLAS	4.6	0.2	3.7	
	PENUELAS	2.3	0.0	4.5	

Exhibit 2-4: Microgrid Deemed Critical^{*} and Priority Loads in 2019 Night Peak Case, MW

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

Reference: IRP_19_Substation_LoadProcessing_Final.xlsx

* The "deemed" critical load includes other loads served together with it at feeder and substation level

Exhibit 2-5 and Exhibit 2-6 provides a detail of the separation of the loads in MiniGrid and microgrid for year 2019. The MiniGrid / microgrid separation was modeled in PSS®E.

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%				
Сауеу	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%				

Exhibit 2-5: 2019 MiniGrid/Microgrid Night Peak Load, MW

Reference: IRP_19_Substation_LoadProcessing_Final.xlsx



Exhibit 2-6: 2019 MiniGrid/Microgrid Night Peak Load, MW

Reference: IRP_19_Substation_LoadProcessing_Final.xlsx

It is important to note that from a supply point of view the microgrid should ideally be covered by reciprocating engines assigned by the LTCE base plan to the region using PV + Storage as a complement. In case of no or insufficient thermal peaker generation assigned in the LTCE base plan, additional thermal peaker generation amount is estimated for each microgrid zone to cover the critical load.

The general assumptions for estimating the microgrid generation supply are as follows:

- 1. The load forecast in 2019 Night peak case is selected for generation estimation.
- 2. The "deemed" critical loads that are connected in the microgrid zones should be covered by thermal peaker units, assumed at approximately 90% capacity factor.
- 3. The Priority loads should be covered by preferably PV and BESS resources plus any leftover thermal capacity after critical load. The PV and BESS was roughly estimated considering 3.2 MW of PV along with 1.6 MW 6 hour battery for every 1 MW of load that is to be covered 100% by these resources. These factors consider that the load will have a 76% load factor, PV a 20% capacity factor. For further details see Appendix 4, where we describe the requirements for a load to be supplied only from PV and Storage (grid defection unit).
- 4. Existing hydro generation located in the microgrid zones could be used for serving the load, but is assumed to be unavailable under microgrid mode operations. This will ensure sufficient amount of thermal peaker units to be estimated.
- 5. Additional PV and BESS resources planned in each MiniGrid can be installed within each microgrid to serve the remaining balance load.
- 6. S4S2B LTCE base plan is used as a representative example to estimate the additional generation resources required for the microgrid in combination of the planned resources in each of the MiniGrid that the microgrid zone is located.
- 7. The planned thermal peaker units in each MiniGrid could potentially be split into smaller units, e.g. 1 MW per unit, and installed in the microgrid zones as needed.

2.4 **115 kV Transmission Investments.**

In the balance of this MiniGrid Section, we first present below the investments at the 115 kV level as these projects are the main contributor to the MiniGrid backbone and allow creating interconnections between MiniGrids for faster integration. Following this sub-section, we will discuss the design of each MiniGrid including the generation-demand balance and the transmission investments at the 38 kV level, the investments in the MiniGrid controller and we conclude this section on the MiniGrid with a summary of the overall transmission level investments. Later in this Appendix 1 we will present the investments at the distribution level and its correlation with the transmission level investments.

Exhibit 2-7 provides an overview of the 115 kV transmission investments separated in backbone and grid integration. It can be observed that these investments are centered around those MiniGrids that have the least resilient 115 kV transmission system (see Carolina for example).

Also note that in San Juan the investments also leverage the existing underground 115 kV system.



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



As can be noted in the Exhibit below, there are approximately 156 distinct projects at 115 kV being the majority directed to address the need of creating a backbone for the MiniGrid followed by the hardening of existing infrastructure.

Technical Justification	Arecibo	Bayamón	Caguas	Carolina	Isla	Mayaguez	Ponce	San Juan	Total
Minigrid Main Backbone	8	10	13	13	3	11	7	10	75
Existing Infrastructure Hardening for Reliability	0	0	7	4	0	4	0	13	28
Interconnection of Critical Loads	0	1	0	1	0	0	4	0	6
Minigrid Backbone Extensions to Create High									
Reliability/Resiliency Zones	0	0	0	4	0	0	0	2	6
Interconnection of Minigrids	0	0	1	0	3	0	0	0	4
Aging Infrastructure Replacement	5	2	5	5	0	6	7	7	37
Total	13	13	26	27	6	21	18	32	156

Exhibit 2-8: 115 kV Projects by Technical Justification

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

The exhibit below provides detailed justification, line length, and cost on the 115 kV investments in new transmission lines (overhead) and underground cables. Note that some investments are identified as "existing infrastructure hardening" but in this case it is the replacement of the asset by a new facility, given its condition.

Exhibit 2-9: New 115 kV Transmission Line Facilities



Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

There is a total of 16 new 115 kV transmission line investment projects which account for approximately \$569 million on about 140 miles of new transmission lines. Also, the bulk of the investments (~77%, \$437 million) is directly related to the formation of the MiniGrid.

Complementing the new lines above there are 24 projects for approximately 198 miles of existing 115 kV lines that will need to be hardened to support the backbone of the MiniGrids or allow the interconnection of the MiniGrid with a total investment of \$277 million. This is detailed in the Exhibit 2-101 below.

Redacted

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

Finally, there are 44 substations/switchyards at 115 kV level with investments totaling \$1.44 billion, in most cases converted to GIS, which are detailed in the Exhibit 2-12 below. These investments are directly associated with the formation of MiniGrid main backbone.

As indicated earlier, Section 2.13 provides a summary of the total transmission investments by MiniGrid including the 38 kV investments discussed below. The generation investments were discussed under the IRP costs in the main report.



Exhibit 2-12: 115 kV Substation to be Hardened to Support MiniGrid

Redacted

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.5 Mayaguez North & Mayaguez South MiniGrids

2.5.1 Overview

Mayaguez North and Mayaguez South MiniGrids serve the critical loads of Rincón, Aguada, Moca, Aguadilla, Añasco, Mayaguez, Hormigueros, San Germán, Cabo Rojo, San Sebastián, Lares, Las Marías, Lajas, Sabana Grande and Maricao municipalities. These MiniGrids includes six transmission centers 115/38 kV: Victoria TC (Aguadilla), San Sebastián TC, Añasco TC, Mayaguez TC, Acacias TC (Hormigueros) and San Germán TC. The electric infrastructure of these MiniGrids serves principally industrial, commercial and tourism loads. Mayaguez North and Mayaguez South MiniGrids serve critical loads such as hospitals, airport, hotels, water infrastructure, communication infrastructure, government agencies, military base and commercial centers.

As was presented earlier, the Mayaguez area was divided into two MiniGrids due to mountain topography in the area hindering transmission recovery efforts. In particular, the 115 kV line from Añasco TC to Aguadilla (Victoria) TC can take over a month to recover and the underlying parallel 38 kV system (Añasco to Rincon) can take months to recover. Due to these reasons this area was split into two "MiniGrids" to make sure that north Mayaguez has acceptable load generation balance. If either of the lines above can be hardened so it can ride through the storm or be recovered under 10 days, then the MiniGrids can be consolidated. However even in this case thermal generation is recommended in the north.

Exhibit 2-13 shows the proposed area for these two MiniGrids in this figure the red points identify the critical loads and the yellow the priority loads with PSSE bus number. Potential generation injection points are also identified. Note that some of the injection points are from existing sites like Mayaguez and other injection point suggestions are new sites; Aguadilla TC (Victoria), San German TC and San Sebastian TC. As can be noted these points were selected with the dual purpose of providing distributed sources to the MiniGrids and potentially taking advantage of the 115 kV system, when available.

Exhibit 2-13: Mayaguez North & Mayaguez South MiniGrids



2.5.2 Supply – Demand Balance

As indicated earlier the MiniGrid supply is to be designed considering that the critical loads are to be covered with thermal resources and together with the priority loads, must be 100% served considering in addition to the thermal resources the PV and the Storage. The PV has the dual function of providing daytime load coverage and energy for the storage to be supplied at night. The balance of the load, beyond Critical and Priority, can have some level of curtailment.

The first step in assessing the generation demand balance is observing the results of the LTCE. These results were determined for each of the LTCE plans discussed in the main body of this IRP and can be reviewed in the individual spreadsheets for each case. However, as a reference of how these results are reviewed and processed, we discuss below the current results of the LTCE for S4S2B and Energy System Modernization (ESM), considering the base load forecast. Strategy 2 was selected as this strategy is producing the most consistent capacity expansion plans with respect of a balance between renewable generation and thermal generation.

The generation review assessed the capability to cover the peak demand considering the thermal generation capacity (MW) alone and the thermal plus Storage (MW). Energy coverage was also verified considering only the thermal energy generation (GWh) determined considering an 85% capacity factor and the thermal energy plus the energy from renewable resources.

As can be observed in Exhibit 2-14 and Exhibit 2-15 that illustrates Mayaguez North load-generation balance, the S4S2B LTCE plan will cover the critical load in the MiniGrid starting 2021. It shows the total energy is fully covered.





Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers

It should be noted that, as indicated earlier, for the assessment of the critical load that would have to be supplied from thermal resources, we took into consideration that following a major events load are reduced with respect of its peak consumption under normal conditions, and we assumed that 75% of the load would have to be covered; the 75% was determined considering the ratio between the months of minimum consumption (e.g. January) and the months of maximum consumption (August).



Exhibit 2-15: S4S2B Mayaguez North Load Generation Balance, GWh

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers

The exhibits below show the corresponding results for the ESM plan and we observe that the level of coverage for critical load is very similar to S4S2B and shows full coverage starting from 2021.



Exhibit 2-16: ESM Plan Mayaguez North Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers





Exhibit 2-17: ESM Mayaguez North Load Generation Balance, GWh

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

The Exhibits below show the corresponding generation coverage for the Mayaguez South load for S4S2B and ESM LTCE plans. As can be observed there is adequate coverage throughout the planning period.



Exhibit 2-18: S4S2B Mayaguez South Load Generation Balance, MW

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-19: S4S2B Mayaguez South Load Generation Balance, GWh

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-20: ESM Mayaguez South Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers





Exhibit 2-21: ESM Mayaguez South Load Generation Balance, GWh

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

2.5.3 Load Flow Assessment of the MiniGrid.

The analysis in grid isolated mode did not show any overloads or any voltage violations before contingency in Mayaguez North and Mayaguez South MiniGrids. Scheduled voltage was adjusted to control reactive output at the generators connected at the Mayaguez Plant bus to avoid high voltages pre contingency.

2.5.4 Investment to Consolidate the Mayaguez MiniGrids.

In this section we present the investments at the 38 kV level (46 kV insulated) necessary to consolidate the Mayaguez MiniGrids. The 115 kV investments were presented above.

Exhibit 2-22 shows geographically the proposed investments in the MiniGrids that make up Mayaguez. There are other investments associated to Mayaguez North, that are presented under the discussion of Arecibo as the investments were formulated by Area.

As can be observed in Exhibit 2-22, most of the investments are associated with interconnection of critical loads to the reliable generation injection points as presented earlier.

Exhibit 2-23 shows in tabular form the investments in 38 kV transmission line facilities in Mayaguez MiniGrids and the points of injection. It can be observed that most investments correspond to underground lines. The total investment of new 38 kV transmission lines is approximately \$240 million on approximately 72 miles of lines and cables. As mentioned earlier, the majority of investment is for the interconnection of critical loads, totaling about \$215 million.

Exhibit 2-22: Mayaguez North & Mayaguez South Investments and Generation Injection Points

Redacted



Mayaguez Region Investments Legend



Exhibit 2-23: New 38 kV (46 kV insulated) Transmission Lines and Cables in Mayaguez



Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

To supplement the investments above there are additional investments at the substation level and infrastructure hardening that are detailed below. In line with the investments above most of the substation level investment corresponds to GIS conversion. The total investment is approximately \$189.5 million with \$158 million at the substation level and \$31 million on infrastructure hardening applied to 24 miles of transmission lines, and \$176 million related to interconnection of critical loads.

Exhibit 2-24: New Substations/Switchyards and Infrastructure Hardening in Mayaguez

Redacted

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.5.5 Microgrids Zones in Mayaguez North and South

2.5.5.1 Mayaguez North Microgrid Zone 1 - LARES

We identify a potential microgrid zone located in the general area of the LARES substation and surroundings, consisting of 6.4 MW deemed critical load and 0.2 priority load. We estimated to install approximately 8 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.5.5.2 Mayaguez North Microgrid Zone 2 - SAN SEBASTIAN

We identify a potential microgrid zone located in Mayaguez North MiniGrid in the general area of the SAN SEBASTIAN substation and surroundings. Mayaguez North Microgrid Zone 2 consists of 12.1 MW deemed critical load. Based on the generation planned in S4S2B, we estimated to install approximately 14 MW thermal peaker unit from the total planned in Mayaguez North MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.5.5.3 Mayagüez South Microgrid Zone 1 - BOQUERON

We identify a potential microgrid zone located in Mayaguez South MiniGrid in the general area of BOQUERON substation in central zone of Cabo Rojo municipality and surroundings, consisting of 1.6 MW of deemed critical load and 0.3 MW priority load. Because there is no thermal peakers planned in Mayaguez South MiniGrid, we estimated to install new 2 MW thermal peaker units along with planned 3.2 MW PV and 1.6 MW BESS units in the microgrid, And the remaining balance load can be served preferably by combination of PV and BESS.

2.5.5.4 Mayaguez South Microgrid Zone 2 - COMBATE

We identify a potential microgrid zone located in Mayaguez North MiniGrid in the general southwest area of COMBATE substation in southern zone of Cabo Rojo municipality and surroundings, consisting of 4.5 MW of deemed critical load. Because there is no thermal peakers planned in Mayaguez South MiniGrid, we estimated to install new 6 MW thermal peaker units in the microgrid, And the remaining balance load can be served preferably by combination of PV and BESS.

2.5.5.5 Mayaguez South Microgrid Zone 3 - CROEM

We identify a potential microgrid zone located in Mayaguez North MiniGrid in the general area of CROEM substation in the limits of Mayaguez and San German municipalities and surroundings, consisting of 0.8 MW of deemed critical load. Because there is no thermal peakers planned in Mayaguez South MiniGrid, we estimated to install new 1 MW thermal peaker unit in the microgrid, And the remaining balance load can be served preferably by combination of PV and BESS.

2.5.5.6 Mayaguez South Microgrid Zone 4 - LAS MARIAS

We identify a potential microgrid zone located in Mayaguez North MiniGrid in the general area of LAS MARIAS substation and surroundings, consisting of 3.2 MW of deemed critical load. Because there is no thermal peakers planned in Mayaguez South MiniGrid, we estimated to install new 4 MW thermal peaker units in the microgrid, And the remaining balance load can be served preferably by combination of PV and BESS.

2.5.5.7 Mayaguez South Microgrid Zone 5 – LAS VEGAS

We identify a potential microgrid zone located in Mayaguez North MiniGrid in the general area of LAS VEGAS substation in the limits of Mayaguez and Maricao municipalities and surroundings, consisting of 0.7 MW of deemed critical load. Because there is no thermal peakers planned in Mayaguez South MiniGrid, we estimated to install new 1 MW thermal peaker unit in the microgrid, And the remaining balance load can be served preferably by combination of PV and BESS.

2.5.5.8 Mayaguez South Microgrid Zone 6 - MARICAO

We identify a potential microgrid zone located in Mayaguez North MiniGrid in the general area of MARICAO substation and surroundings, consisting of 2.3 MW of deemed critical load. Because there is no thermal peakers planned in Mayaguez South MiniGrid, we estimated to install new 3 MW thermal peaker units in the microgrid, And the remaining balance load can be served preferably by combination of PV and BESS.

2.5.5.9 Mayaguez South Microgrid Zone 7 - MONTE DEL ESTADO

We identify a potential microgrid zone located in Mayaguez North MiniGrid in the general area of MONTE DEL ESTADO substation in the limits of San German and Maricao municipalities and surroundings, consisting of 0.6 MW of balance load only. Since the load is not critical or priority in nature, they can be served preferably by combination of PV and BESS.

2.5.5.10 Mayaguez South Microgrid Zone 8 – BARTOLO

We identify a potential microgrid zone located in the general area of the BARTOLO substation in southern zone of Lares municipality and surroundings, consisting of 0.6 MW deemed critical load. Based on the planned generation in S4S2B, we estimated to install 1 MW of new thermal peaker unit in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.5.5.11 Mayaguez South Microgrid Zone 9 - INDIERA

We identify a potential microgrid zone located in the general area of the INDIERA substation in western zone of Maricao municipality and surroundings, consisting of 0.4 MW deemed critical load. Based on the planned generation in S4S2B, we estimated to install 1 MW of new thermal peaker unit in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.6 Caguas & Cayey MiniGrid

2.6.1 Overview

Caguas and Cayey MiniGrids serve the critical loads of Caguas, Orocovis, Barranquitas, Aibonito, Comerío, Aguas Buenas, Cidra, Cayey, San Lorenzo, Gurabo, Las Piedras, Naguabo, Humacao, Yabucoa and Juncos municipalities. Caguas and Cayey MiniGrids have nine transmission centers: Caguas TC, Bairoa TC (future), Barranquitas TC, Comerío TC, Juncos TC, Cayey TC, Aguas Buenas GIS, Humacao TC and Yabucoa TC. This municipality contains big load centers. The electric infrastructure of this area serves principally industrial loads in the Humacao, Las Piedras, Juncos and Gurabo municipalities. This minigrid will serve critical loads such as hospitals, water infrastructure, government agencies, radars, communication infrastructure, industries and commercial centers.

The Caguas region could not be maintained a single MiniGrid due to mountain topography between the east and west of this area that may result in long recovery times for the interconnecting transmission lines, for this reason we split Caguas into two; Caguas itself and Cayey MiniGrids so that local generation to supply critical loads in Cayey is developed and the long delays to bring the generation to the east are avoided.

Exhibit 2-25 shows an overview of the Caguas area where as before red dots are critical loads, yellow are priority loads and green are injection points with PSS®E bus number. These points include Comsat – Cayey (main injection point) and Comerio TC for Cayey as well as Juncos and Bairoa for Caguas. In Caguas we also have an injection point at Humacao TC, but in this case the generation is located at Yabucoa and it is delivered via reliable 115 kV overhead and future underground lines. Other injection points identified (Barranquitas) supply microgrids.

As can be noted these points were selected with the dual purpose of providing distributed sources to the MiniGrids and taking advantage of the 115 kV system and future reliable 38 kV system.

2.6.2 Supply – Demand Balance

As indicated earlier the MiniGrid supply is to be designed considering that the critical loads are to be covered with thermal resources and together with the priority loads must be 100% covered considering in addition to the thermal resources, the PV and Storage. The PV will provide daytime

coverage and energy for the storage to be supplied at night. The balance of the load can have some level of curtailment.

As was the case for the Mayaguez MiniGrid, the generation demand balance was determined for each of the LTCE formulated and can be reviewed in the individual spreadsheets for each case. However, as a reference of how these results are reviewed and processed, we discuss below the current results of the LTCE for S4S2B and ESM, considering the base load forecast.



Exhibit 2-25: Caguas & Cayey MiniGrids



As indicated earlier, the generation review assessed the capability to cover the peak demand considering the thermal generation capacity (MW) alone and the thermal plus Storage (MW). Energy coverage was also verified considering only the thermal energy generation (GWh) determined with 85% capacity factor and the thermal energy plus the energy from renewable resources.

As can be observed in Exhibits below that illustrate the Caguas load-generation balance, under the S4S2B LTCE plan the critical load will be almost covered (97%) by thermal capacity starting 2021, and the total load in the MiniGrid will be covered by thermal plus PV and storage starting 2021 as well. However, the energy coverage shows the Critical Load will be fully covered by thermal only and priority load will be covered by thermal plus PV and storage.



Exhibit 2-26: S4S2B Caguas Load Generation Balance, MW

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-27: S4S2B Caguas Load Generation Balance, GWh

The exhibits below show the corresponding results for the ESM plan and we observe that the capacity coverage adequate starting in 2021 while the energy is fully covered from 2021 (first year new generation assumed to be online).



Exhibit 2-28: ESM Caguas Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-29: ESM Caguas Load Generation Balance, GWh

The Cayey MiniGrid is separated from Caguas as explained in the earlier description. The Exhibits below show the corresponding generation coverage for the Cayey load for S4S2B, and ESM LTCE plans. As can be observed the level of capacity coverage is similar to the Caguas MiniGrid.

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-30: S4S2B Cayey Load Generation Balance, MW

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-31: S4S2B Cayey Load Generation Balance, GWh

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-32: ESM Cayey Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-33: ESM Cayey Load Generation Balance, GWh

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

Siemens Industry, Inc. – Siemens Power Technologies International This document may contain Critical Energy Infrastructure Information - Do Not Release.
2.6.3 Load Flow Assessment of the MiniGrid.

The analysis in grid isolated mode did not show any overloads or any voltage violations before contingency in Caguas and Cayey MiniGrids. Shunt capacity connected at CAYEY 115 bus was adjusted for pre-contingency high bus voltages.

2.6.4 Investment to Consolidate the Caguas/Cayey MiniGrid

In this section we present the investments at the 38 kV level (46 kV insulated) necessary to consolidate the Caguas and Cayey MiniGrid. The 115 kV investments were presented in Section 2.4 earlier. Exhibit 2-34 shows geographically the proposed investments in the MiniGrids that make up the Caguas region.

As can be observed in Exhibit 2-34 all investments are associated with interconnection of critical loads to the reliable generation injection points as presented earlier.

Exhibit 2-34: Caguas & Cayey MiniGrids Investments and Generation Injection Points

Redacted

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Caguas Region Investments Legend



Exhibit 2-35 shows the investments in 38 kV (46 kV insulated) transmission line facilities for the interconnection of critical loads. It can be observed that most investments correspond to underground lines. The total investment of new 38 kV transmission lines is approximately \$154 million on about 44 miles lines and cables.

Exhibit 2-35: New 38 kV (46 kV insulated) Transmission Lines and Cables in Caguas and Cayey



Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

To supplement the investments above there are additional investments at the substation level and infrastructure hardening that are detailed below. In line with the investments above most of the substation level investment corresponds to GIS conversion. The total investment is approximately \$228 million with \$151 million at the substation level and \$77 million on infrastructure hardening applied to 75 miles of transmission lines. And \$165 million investment is directly associated with the interconnection of critical loads.



Exhibit 2-36: New Substations/Switchyards and Infrastructure Hardening in Caguas and Cayey

Redacted

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.6.5 Microgrids in Caguas/Cayey MiniGrids

2.6.5.1 Caguas Microgrid Zone 1 - AGUAS BUENAS

We identify a potential microgrid zone located in the general area of the AGUAS BUENAS substation and surroundings, consisting of 6.4 MW deemed critical load. Based on the generation planned in S4S2B, we estimated to install approximately 8 MW thermal peaker unit from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.2 Caguas Microgrid Zone 2 – PUEBLITO DEL RIO

We identify a potential microgrid zone located in the general area of the PUEBLITO RIO substation in the limits of Las Piedras and Humacao municipalities and surroundings. This microgrid is also extended into Carolina MiniGrid, totally consisting of 4.5 MW deemed critical load. Based on the

generation planned in S4S2B, we estimated to install approximately 5 MW thermal peaker units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.3 Caguas Microgrid Zone 3 - SAN LORENZO

We identify a potential microgrid zone located in the general area of the SAN LORENZO substation and surroundings, consisting of 9.1 MW deemed critical load and 0.6 priority load. Based on the generation planned in S4S2B, we estimated to install approximately 11 MW thermal peaker units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.4Caguas Microgrid Zone 4 - YABUCOA

We identify a potential microgrid zone located in the general area of the YABUCOA substation and surroundings, consisting of 4.2 MW deemed critical load. Based on the generation planned in S4S2B, we estimated to install approximately 5 MW thermal peaker units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.5 Caguas Microgrid Zone 5 - NAGUABO

We identify a potential microgrid zone located in the general area of the NAGUABO substation and surroundings, consisting of 2.0 MW deemed critical load and 0.6 MW priority load. Based on the generation planned in S4S2B, we estimated to install approximately 3 MW thermal peaker units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.6 Caguas Microgrid Zone 6 - RIO BLANCO

We identify a potential microgrid zone located in the general area of the RIO BLANCO Hydro substation in Naguabo and surroundings, consisting of 2.9 MW deemed critical load. Based on the generation planned in S4S2B, we estimated to install approximately 4 MW thermal peaker units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.7

Cayey Microgrid Zone 1 - ABANICO

We identify a potential microgrid zone located in the general area of the ABANICO substation in the limits of Barranquitas and Naranjito municipalities and surroundings, consisting of 4.5 MW deemed critical load. Based on the generation planned in S4S2B, we estimated to install approximately 6 MW thermal peaker units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.8 Cayey Microgrid Zone 2 - AIBONITO

We identify a potential microgrid zone located in the general area of the AIBONITO substation and surroundings, consisting of 9.8 MW deemed critical load and 3.4 MW priority load. Based on the generation planned in S4S2B, we estimated to install approximately 11 MW thermal peaker units along with 12.8 MW planned PV and 6.4 MW BESS units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.9 Cayey Microgrid Zone 3 - BARRANQUITAS

We identify a potential microgrid zone located in the general area of the BARRANQUITAS substation and surroundings, consisting of 9.2 MW deemed critical load. Based on the generation planned in S4S2B, we estimated to install approximately 11 MW thermal peaker units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.10 Cayey Microgrid Zone 4 - COMERIO

We identify a potential microgrid zone located in the general area of the COMERIO substation and surroundings, consisting of 6.1 MW deemed critical load. Based on the generation planned in S4S2B, we estimated to install approximately 7 MW planned thermal peaker units in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.6.5.11 Cayey Microgrid Zone 5 - OROCOVIS

We identify a potential microgrid zone located in the general area of the OROCOVIS substation and surroundings, and this microgrid is also extended into Ponce MiniGrid, totally consisting of 5 MW deemed critical load. Based on the generation planned in S4S2B, we estimated to install approximately 6 MW thermal peaker units from the total planned in the MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.7 Carolina MiniGrid

2.7.1 Overview

Carolina Minigrid serve the critical loads of the municipalities of Carolina, Loiza, Canóvanas, Rio Grande, Luquillo, Fajardo, Ceiba, and the islands of Vieques and Culebra. Carolina MiniGrid has five transmission centers: Sabana Llana TC (Carolina), Canóvanas TC, Palmer TC, Fajardo TC and Daguao TC. This MiniGrid serves principally industrial and tourism loads. This MiniGrid will serve critical loads such as airport, hospitals, pharmaceutical, hotels, military base and water infrastructure.

Exhibit 2-37 shows the Carolina MiniGrid including the critical (red points) and the priority loads (yellow points) with PSS®E bus number, as well as the injection points.

In Exhibit 2-37 we note that there is a new candidate generation injection point at Sabana Llana, Fajardo TC, Canóvanas TC, and Palmer TC. At Daguao TC there is existing generation and is being upgraded to supply the MiniGrid. This MiniGrid will have in the same way as San Juan, an underground 115 kV backbone system as presented earlier.

2.7.2 Supply – Demand Balance

As indicated earlier the MiniGrid supply is to be designed considering that the critical loads are to be covered with thermal resources and together with the priority loads must be 100% covered considering in addition to the thermal resources, the PV and Storage. The PV will provide daytime coverage and energy for the storage to be supplied at night. The balance of the load can have some level of curtailment.

As was the case for the prior MiniGrid, the generation demand balance was determined for each of LTCE formulated and can be reviewed in the individual spreadsheets for each project. However, as a

reference of how these results are reviewed and processed, we discuss below the current results of the LTCE for S4S2B and ESM plan, considering the base load forecast.

As indicated earlier, the generation review assessed the capability to cover the peak demand considering the thermal generation capacity (MW) alone and the thermal plus Storage (MW). Energy coverage was also verified considering only the thermal energy generation (GWh) determined with 85% capacity factor and the thermal energy plus the energy from renewable resources.



Exhibit 2-37: Carolina MiniGrid





Exhibit 2-38: S4S2B Carolina Load Generation Balance MW

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-39: S4S2B Carolina Load Generation Balance, GWh

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers

As can be observed in Exhibit 2-38 that illustrates the Carolina load-generation balance under the S4S2B LTCE plan, the Critical and Priority load will be covered starting 2021. The energy coverage follows the same pattern.

The exhibits below show the corresponding results for the ESM Plan and we observe that the level of coverage is quite similar, showing energy for critical load is fully covered.



Exhibit 2-40: ESM Carolina Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-41: ESM Carolina Load Generation Balance, GWh

2.7.3 Load Flow Assessment of the MiniGrid.

The analysis in grid isolated mode did not show voltage violations before contingency in Carolina MiniGrids.

2.7.4 Investment to Consolidate the Carolina MiniGrid

In this section we present the minimum investments at the 38 kV level necessary to consolidate the Carolina MiniGrid. The 115 kV investments were presented earlier.

Exhibit 2-42 shows geographically the proposed investments in the MiniGrids that make up the Caguas region.

As can be observed in Exhibit 2-42 all investments are associated with interconnection of critical loads to the reliable generation injection points as presented earlier.

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-42: Carolina MiniGrid Investments and Generation Injection Points

Redacted

Carolina Region Investments Legend





Exhibit 2-43 shows the investments in 38 kV (46 kV insulated) transmission facilities for the Carolina MiniGrid. It can be observed that most investments correspond to underground lines. The total investment of new 38 kV transmission lines is approximately \$115 million on about 27 miles lines and cables, with \$98 million related to the interconnection of critical loads.

Exhibit 2-43: New 38 kV (46 kV insulated) Transmission Lines and Cables in Carolina



Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

To supplement the investments above there are additional investments at the substation level and infrastructure hardening that are detailed in Exhibit 2-44. In line with the investments above most of the substation level investment corresponds to GIS conversion. The total investment is approximately \$74 million with \$69 million at the substation level and \$4.5 million on infrastructure hardening applied to 4.5 miles of transmission lines. And \$61.5 million investment is directly associated with the interconnection of critical loads.

Exhibit 2-44: New Substations/Switchyards and Infrastructure Hardening in Carolina



Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.7.5 Microgrids in Carolina MiniGrid

2.7.5.1 Carolina Microgrid Zone 1 and Zone 2 - Vieques and Culebra Microgrid

Vieques and Culebra are the two smaller islands east side of the main Puerto Rico Island. We consider them as standalone microgrids because of the location and physical limitation. There is only one single 38 kV transmission submarine cable that connects the islands to the main island. There is 5.7 MW of critical load for Vieques and 2.9 MW critical load for Culebra. The two islands should be able to operate as two individual microgrids during and after a major event. An RFP was published in 2018 to meet the energy requirements of Vieques and Culebra accordingly.

2.8 Arecibo MiniGrid

2.8.1 Overview

Arecibo MiniGrid will serve the critical loads of the municipalities of Isabela, Quebradillas, Camuy, Hatillo, Utuado, Arecibo, Barceloneta, Florida, Manatí, Morovis, Ciales, Jayuya and Adjuntas. The Arecibo MiniGrid has six transmission centers: Mora TC, Hatillo TC, Cambalache TC, Barceloneta TC, Manatí TC and Dos Bocas. Arecibo MiniGrid serves principally industrial and commercial loads. This MiniGrid serve critical loads such as federal government installations, hospitals, communication infrastructure, PRASA principal infrastructure, commercial and industries centers.

The exhibit below shows the Arecibo MiniGrid including the critical (red points) and the priority loads (yellow points) with PSS®E bus numbers, as well as the injection points. In this case we have an existing injection point at Cambalache and two new injection points strategically located at Manati TC and Hatillo at the two eastern and western extremes of the MiniGrid. Also, this MiniGrid may receive support from the Mayaguez North MiniGrid to which Mora TC is assigned.

2.8.2 Supply – Demand Balance

As was the case for all MiniGrid, Arecibo supply was designed considering that the critical loads are to be covered with thermal resources and that critical and priority loads must be 100% covered considering in addition to the thermal resources, the PV and Storage.

As was the case for the prior MiniGrids, the generation demand balance was determined for each of the LTCE formulated and can be reviewed in the individual spreadsheets for each project. However, as a reference of how these results are reviewed and processed, we discuss below the current results of the LTCE for S4S2B and ESM Plan, considering the base load forecast.



Exhibit 2-45: Arecibo MiniGrid



As indicated earlier, the generation review assessed the capability to cover the peak demand considering the thermal generation capacity (MW) alone and the thermal plus Storage (MW). Energy coverage was also verified considering only the thermal energy generation (GWh) determined with 85% capacity factor and the thermal energy plus the energy from renewable resources.

As can be observed in the exhibits below that illustrates the Arecibo MiniGrid load-generation balance, under the S4S2B LTCE there is full coverage of the Critical load in the MiniGrid throughout the planning period with thermal resources. Note that one Cambalache unit cannot be retired and must stay on throughout the years.





Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-47: S4S2B Arecibo Load Generation Balance GWh

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers

The exhibits below show the corresponding results for the ESM Plan. It generally follows the same pattern as the S4S2B that only one Cambalache unit can be retired.







Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers





Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

2.8.3 Load Flow Assessment of the MiniGrid.

The analysis in grid isolated mode did not show any line overloads or voltage violations before contingency in Arecibo MiniGrid.

2.8.4 Investment to Consolidate the Arecibo MiniGrid

In this section we present the minimum investments at the 38 kV level necessary to consolidate the Arecibo MiniGrid. The 115 kV investments were presented earlier. Exhibit 2-50 shows geographically the proposed investments in the MiniGrid that make up the Arecibo region.

As can be observed in Exhibit 2-50 all investments are associated with interconnection of critical loads to the reliable generation injection points as presented earlier.

Exhibit 2-50: Arecibo MiniGrid Investments and Generation Injection Points





Arecibo Region Investments Legend

Redacted

Exhibit 2-51 shows the investments in 38 kV (46 kV insulated) transmission facilities for the Arecibo MiniGrid, all of which is related to the interconnection of critical loads. It can be observed that most investments correspond to underground lines. The total investment of new 38 kV transmission lines is approximately \$64 million on about 23 miles of lines and cables.

Exhibit 2-51: New 38 kV (46 kV insulated) Transmission Lines and Cables in Arecibo

Redacted

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

To supplement the investments above there are additional investments at the substation level and infrastructure hardening that are detailed below. In line with the investments above most of the substation level investment corresponds to GIS conversion. The total investment is approximately \$195 million with \$131 million at the substation level and \$64 million on infrastructure hardening applied to 64 miles of transmission lines. And \$176 million investment is directly associated with the interconnection of critical loads.



Exhibit 2-52: New Substations/Switchyards and Infrastructure Hardening in in Arecibo

Redacted

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.8.5 Microgrids in Arecibo MiniGrid

2.8.5.1 Arecibo Microgrid Zone 1 - CAGUANA

We identify a potential microgrid zone located in the general area of the CAGUANA substation in eastern zone of Utuado Municipality of and surroundings, consisting of 2 MW deemed critical load

and 0.6 MW priority load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 3 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.2 Arecibo Microgrid Zone 2 - CHARCO HONDO

We identify a potential microgrid zone located in the general area of the CHARCO HONDO substation in central zone of Arecibo and surroundings, consisting of 3.6 MW deemed critical load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 4 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.3 Arecibo Microgrid Zone 3 - CIALES

We identify a potential microgrid zone located in the general area of the CIALES substation and surroundings, consisting of 4.8 MW deemed critical load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 6 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.4 Arecibo Microgrid Zone 4 - DOMINGUITO

We identify a potential microgrid zone located in the general area of the DOMINGUITO substation in the limits of Hatillo and Arecibo municipalities and surroundings, consisting of 3.2 MW deemed critical load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 4 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.5 Arecibo Microgrid Zone 5 - DOS BOCAS

We identify a potential microgrid zone located in the general area of the DOS BOCAS Hydro substation in the limits of Arecibo and Utuado municipalities and surroundings, consisting of 0.8 MW deemed critical load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 1 MW thermal peaker unit for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.6 Arecibo Microgrid Zone 6 - FLORIDA

We identify a potential microgrid zone located in the general area of the FLORIDA substation and surroundings, consisting of 4.1 MW deemed critical load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 5 MW thermal peaker unit for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.7 Arecibo Microgrid Zone 7 - JAYUYA

We identify a potential microgrid zone located in the general area of the JAYUYA substation and surroundings, consisting of 7.1 MW deemed critical load and 2.1 MW priority load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 8 MW thermal peaker units along with 6.4 MW planned PV and 3.2 MW BESS units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.8 Arecibo Microgrid Zone 8 - MOROVIS

We identify a potential microgrid zone located in the general area of the MOROVIS substation and surroundings, consisting of 8.8 MW deemed critical load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 10 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.9 Arecibo Microgrid Zone 9 - UTUADO

We identify a potential microgrid zone located in the general area of the UTUADO and San Jose substations in central zone Utuado municipality and surroundings, consisting of deemed 6.6 MW critical load and 0.6 MW priority load. We estimated to install approximately 8 MW new thermal peaker units and 3.2 MW PV and 1.6 MW BESS units from the planned generation in S4S2B for the load to be served. No thermal peaker is required, and we estimate balance load can be served preferably by combination of PV and BESS.

2.8.5.10 Arecibo Microgrid Zone 10 - GUAJATACA

We identify a potential microgrid zone located in Arecibo MiniGrid in the general area of the GUAJATACA substation in the limits of Quebradillas and San Sebastian municipalities and surroundings. Arecibo Microgrid Zone 12 consists of 0.4 MW deemed critical load (recall that this value is conservative given the way it was determined). Based on the generation planned in S4S2B, we estimated to install approximately 1 MW thermal peaker unit from the total planned in Arecibo MiniGrid for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.8.5.11 Arecibo Microgrid Zone 11 - ADJUNTAS

We identify a potential microgrid zone in the general area of substation in Adjuntas municipality and surroundings, consisting of 3.3 MW deemed critical load. Based on the planned generation in S4S2B, we estimated to install 4 MW of new thermal peaker units in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.8.5.12 Arecibo Microgrid Zone 12 - YAHUECAS

We identify a potential microgrid zone in the general area of YAHUECAS substation in western zone of Adjuntas municipality and surroundings, consisting of 1.1 MW deemed critical load. Based on the planned generation in S4S2B, we estimated to install 2 MW of new thermal peaker units in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.9 San Juan–Bayamon MiniGrid – San Juan Area

2.9.1 Overview

San Juan and Bayamon MiniGrid serve the critical loads of the metropolitan area composed by the municipalities of San Juan, Trujillo Alto, Guaynabo, Corozal, Naranjito, Toa Alta, Vega Baja, Vega Alta, Dorado, Toa Baja, Bayamón and Cataño. San Juan and Bayamón Minigrid has eleven transmission centers: Isla Grande GIS, Martin Peña GIS, Hato Rey TC, Viaducto TC, Berwind TC, Monacillos TC, Vega Baja TC, Dorado TC, Hato Tejas TC and Bayamón TC. The San Juan MiniGrid is characterized by a high electricity demand concentration. The San Juan - Bayamón

MiniGrid is characterized by generation located in San Juan Steam Plant and Palo Seco Steam Plant. San Juan and Bayamon MiniGrid serve critical loads such as government installations, hospitals, water infrastructure, communication infrastructure, hotels, ports, fuel ports commercial centers and industries.

The San Juan Area together with Bayamon are expected to operate together as a single MiniGrid. However, given that these two regions are normally studied separately we present here the results for San Juan and when appropriate we refer to the Bayamon part of the MiniGrid.

Exhibit 2-53 and 2-54 below shows the San Juan Area divided in north and south zones for clarity. Also show the critical and priority loads with PSS®E bus numbers. In this figure we note that the only new generation injection point is Monacillos in San Juan south that given its central location in the system would benefit from a local supply. San Juan north includes San Juan Steam Plant as existing generation point.

2.9.2 Supply – Demand Balance

San Juan Steam Plant is a major generation center, so aside from the reserve requirement the LTCE process was let to define what additions and retirements were necessary. We discuss below the current results of the LTCE for S4S2B and ESM Plan, considering the base load forecast. Other scenarios are available in the corresponding spreadsheets delivered as part of the main report.



Exhibit 2-53: San Juan-Bayamon MiniGrid in San Juan Area (1)

Redacted

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The San Juan Minigrid is similar to the Arecibo MiniGrid in that the existing generation plays a significant role in covering both the load capacity and energy requirements. Exhibit 2-55 shows the combined thermal and storage capacity coverage as well as the just the thermal capacity coverage of the load.



Exhibit 2-55: S4S2B San Juan Load Generation Balance, MW

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-56: S4S2B San Juan Load Generation Balance, GWh

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers

The thermal generation the San Juan region is sufficient, even with retirements, to cover all critical load requirements throughout the years. And the total energy demand is following the same pattern. We also note that there is surplus load coverage in Bayamon, which is also a generation center, that can be used to provide support to the San Juan load.



Exhibit 2-57: ESM San Juan Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-58: ESM San Juan Load Generation Balance, GWh

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

The exhibits above show the corresponding results for the ESM Plan and we observe that the level of capacity coverage is similar to S4S2B except for the critical and priority load will be covered throughout the years.

2.9.3 Load Flow Assessment of the MiniGrid.

The analysis in grid isolated mode did not show any line overloads or voltage violations before contingency in San Juan-Bayamon MiniGrid.

2.9.4 Investment to Consolidate the San Juan Area of the San Juan - Bayamon MiniGrid

In this section we present the investments at the 38 kV level (46 kV insulated) necessary to consolidate the San Juan area of the San Juan - Bayamon MiniGrid. The 115 kV investments were presented earlier. Exhibit 68 shows geographically the proposed investments in the MiniGrid that make up the San Juan region.

Exhibit 2-59 shows the investments in 38 kV (46 kV insulated) transmission line facilities for the San Juan area. It can be observed that most investments correspond to underground lines. The total investment of new 38 kV transmission lines is approximately \$130 million on about 31 miles lines and cables.

As can be observed in Exhibit 2-61 the majority investments are associated with interconnection of critical loads to the reliable generation injection points as presented earlier.



Exhibit 2-59: San Juan MiniGrid and Generation Injection Points (1)

Redacted

Exhibit 2-60: San Juan MiniGrid and Generation Injection Points (2)





San Juan Region Investments Legend

Redacted

Exhibit 2-61: New 38 kV (46 kV insulated) Transmission Lines and Cables in San Juan Area



Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

To supplement the investments above there are additional investments at the substation level and infrastructure hardening that are detailed in Exhibit 2-62 below. In line with the investments above most of the substation level investment corresponds to GIS conversion. The total investment is approximately \$290 million with \$183 million at the substation level and \$107 million on infrastructure hardening applied to 58 miles of transmission lines. And \$224 million is directly associated with the interconnection of critical loads.



Exhibit 2-62: New Substations/Switchyards and Infrastructure Hardening in San Juan

Redacted

Reference: MiniGrids CapEx Summary _wPriority_Final.xlsx

2.9.5 Microgrids in San Juan-Bayamon MiniGrid

The microgrid analysis for San Juan area in San Juan-Bayamon MiniGrid is detailed as follows.

2.9.5.1 San Juan-Bayamon Microgrid Zone 1 - CARRAIZO

We identify a potential microgrid zone located in the general area of the CARRAIZO substation in the southern zone of Trujillo Alto Municipality and surroundings, consisting of 1.8 MW deemed critical load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 3 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.9.5.2 San Juan-Bayamon Microgrid Zone 2 - VILLA BETINA

We identify a potential microgrid zone located in the general area of the VILLA BETINA substation in southern zone of San Juan municipality and surroundings, consisting of 3.9 MW deemed critical load and 7 MW priority load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 5 MW thermal peaker units along with 22.4 MW planned PV and 11.2 MW BESS units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.9.5.3 San Juan-Bayamon Microgrid Zone 3 – QUEBRADA NEGRITO

We identify a potential microgrid zone located in the general area of the QUEBRADA NEGRITO substation in Trujillo Alto municipality and surroundings, consisting of 4.5 MW balance load. Since the load is not critical or priority, we estimate the load can be served by combination of PV and BESS.

2.10 San Juan–Bayamon MiniGrid – Bayamon Area

2.10.1 Overview

The San Juan Area together with Bayamon are expected to operate together in a single MiniGrid. However, given that these two regions are normally studied separately we present here the results for Bayamon and San Juan were presented earlier.

Exhibit 2-63 below shows the Bayamon Area critical and priority loads with PSSE bus numbers. In this figure we note that in addition to Palo Seco which will continue being a main supply point and Vega Baja where there is peaking generation, there are several injection points where new solar generation and storage could be located.


Exhibit 2-64: San Juan–Bayamon MiniGrid Bayamon Area



2.10.2 Supply – Demand Balance

Palo Seco Steam Plant is also a major generation center, so aside from the reserve requirement, the LTCE process was let to define what additions and retirements were necessary. We discuss below the current results of the LTCE for S4S2B and ESM Plan, considering the base load forecast. Other scenarios are available in the corresponding spreadsheets delivered as part of the main reports.

As can be observed in the exhibits below at the Bayamon Area there is enough coverage of the load throughout the planning period. We also note that there is surplus load coverage in Bayamon that can be used to provide support to the San Juan load, as discussed earlier.



Exhibit 2-65: S4S2B Bayamon Load Generation Balance, MW

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-66: S4S2B Bayamon Load Generation Balance, GWh

The exhibits below show the corresponding results for the ESM Plan and we observe that the level of load coverage at Bayamon is very similar and there would be surplus to cover the total energy shortage in San Juan area.



Exhibit 2-67: ESM Bayamon Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-68: ESM Bayamon Load Generation Balance, GWh

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

2.10.3 Load Flow Assessment of the MiniGrid.

The analysis in grid isolated mode did not show any line overloads or voltage violations before contingency in San Juan-Bayamon MiniGrid.

2.10.4 Investment to Consolidate the Bayamon Area of the San Juan – Bayamon MiniGrid

In this section we present the investments at the 38 kV level (46 kV insulated) necessary to consolidate the Bayamon area of the San Juan–Bayamon MiniGrid. The 115 kV investments were presented earlier. Exhibit 2-70 shows geographically the proposed investments in the MiniGrid that make up the Bayamon region.

As can be observed in Exhibit 2-70 all investments are associated with interconnection of critical loads to the reliable generation injection points as presented earlier.

Exhibit 2-69 shows the investments in 38 kV (46 kV insulated) transmission line facilities for the Bayamon area. It can be observed that most investments correspond to underground lines. The total investment of new 38 kV transmission lines is approximately \$122 million on about 28 miles lines and cables, of which \$111 million is related to the interconnection of critical loads.

Exhibit 2-69: New 38 kV (46 kV insulated) Transmission Lines and Cables in Bayamon Area

Redacted

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.10.5 Microgrids in San Juan-Bayamon MiniGrid

The microgrid analysis for Bayamon area in San Juan-Bayamon MiniGrid is detailed as follows.

2.10.5.1 San Juan-Bayamon Microgrid Zone 1 – COROZAL

We identify a potential microgrid zone located in the general area of the COROZAL (Monterrey) substation and surroundings, consisting of 6 MW deemed critical load and 2.7 MW priority load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 7 MW thermal peaker units and planned 9.6 MW PV and 4.8 MW BESS units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.10.5.2 San Juan-Bayamon Microgrid Zone 2 – NARANJITO

We identify a potential microgrid zone located in the general area of the NARANJITO substation and surroundings, consisting of 6.6 MW deemed critical load and 0.2 MW priority load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 8 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.10.5.3 San Juan-Bayamon Microgrid Zone 3 – BARRIO PIÑAS

We identify a potential microgrid zone located in the general area of the BARRIO PIÑAS substation in Toa Alta municipality and surroundings, consisting of 4.4 MW deemed critical load. Since there is no thermal peaker generation planned in S4S2B, we estimated to install approximately new 5 MW thermal peaker units for the load to be served. And the remaining balance load can be served preferably by combination of PV and BESS.

2.10.5.4 San Juan-Bayamon Microgrid Zone 4 - UNIBON

We identify a potential microgrid zone located in the general area of the UNIBON substation in the western zone of Corozal municipality and surroundings, consisting of 3.2 MW deemed priority load. Since the load is not critical, we estimate the load can be served by using planned 12.8 MW PV and 6.4 MW BESS units. And the remaining balance load can be served preferably by combination of PV and BESS.



Exhibit 2-70: Bayamon MiniGrid Investments and Generation Injection Points



Bayamon Region Investments Legend

Redacted

Siemens Industry, Inc. – Siemens Power Technologies International This document may contain Critical Energy Infrastructure Information - Do Not Release. To supplement the investments above there are additional investments at the substation level and infrastructure hardening that are detailed in Exhibit 2-71 below. In line with the investments above most of the substation level investment corresponds to GIS conversion. The total investment is approximately \$98 million with \$85 million at the substation level and \$13 million on infrastructure hardening applied to 13 miles of transmission lines, all of which are directly associated with the interconnection of critical loads.

Exhibit 2-71: New Substations/Switchyards and Infrastructure Hardening in Bayamon



Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.11 Ponce MiniGrid

2.11.1 Overview

Ponce MiniGrid will serve the critical loads of the municipalities of Coamo, Santa Isabel, Salinas, Guayama, Arroyo, Patillas, Maunabo, Yauco, Guanica, Guayanilla, Peñuelas, Ponce, Juana Díaz and Villalba. Ponce MiniGrid has seven transmission centers: Santa Isabel TC, Jobos TC, Maunabo TC, Guánica TC, Canas TC, Ponce TC and Juana Díaz TC. Ponce MiniGrid is characterized by high generation located in Costa Sur Steam Plant, Aguirre Steam Plant, and Cogeneration plants Ecoelectrica and AES. Ponce MiniGrid will serve critical loads such as hospitals, government agencies, industrial, commercial loads, fuel ports and water infrastructure.

Exhibit 2-72 and 2-73 shows the Ponce MiniGrid that is made of Ponce East and Ponce West due to the fact that the lines between these two areas are likely to be recovered in fairly short time. In these figures shows the critical and priority loads with the PSS®E bus numbers and we note that all generation injection points are existing plants and that there are a number of reliable injection points from the 115 kV system interconnecting to the Costa Sur, Aguirre, also Ecoelectrica and AES cogeneration plants. Jobos peaker at 38 kV in Guayama.

2.11.2 Supply – Demand Balance

Although on a first pass one would expect that given that Ponce is a generation center with the Costa Sur 5&6, the EcoEléctrica and AES Coal, there would be ample resources to cover the load, in reality

the load may not be enough to bring these units online. This may be the case even for EcoEléctrica, that may be limited to being able commit just one of the gas turbines.

So for the analysis we only considered the gas turbines available, the Aguirre Combine Cycles and when available in the future, the new CCGT to be installed at Costa Sur that should be designed to allow it to run with minimal load during emergencies.



Exhibit 2-72: Ponce MiniGrid (1)



Exhibit 2-73: Ponce MiniGrid (2)



The exhibits below show the load coverage for S4S2B and ESM plan for the east and west regions of Ponce. Also note that the surplus generation in Ponce East that will be used to support load in Ponce West, thus all critical load and energy are expected to be fully covered combining Ponce East and West.



Exhibit 2-74: S4S2B Ponce East Load Generation Balance, MW

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-75: S4S2B Ponce East Load Generation Balance, GWh

Siemens Industry, Inc. – Siemens Power Technologies International Error! Reference source not found. – Rev. Error! Reference source not found. – 2018 Integrated Resource Plan Appendix 1: Transmission and Distribution Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers

There is over 140 MW surplus thermal capacity available in Ponce West in the S4S2B plan that can be used to cover the load in Ponce East region. And energy capability in the Ponce West region follows the same pattern.



Exhibit 2-76: S4S2B Ponce West Load Generation Balance, MW

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-77: S4S2B Ponce West Load Generation Balance, GWh

Reference: S4S2B_Metrics_Base Case SII.xlsx LTCE&Nodal_Workpapers





Exhibit 2-78: ESM Ponce East Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-79: ESM Ponce East Load Generation Balance, GWh

It should be noted that the Exhibits below showing the effect when the Aguirre CC unit is assumed to be retired in 2033 in the ESM plan but can be extended beyond 2033. However, the more likely case is the EcoElectrica units can be modified to be available which will be adequate to serve the load in Ponce MiniGrid. Therefore all loads will be fully covered in Ponce.

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-80: ESM Ponce West Load Generation Balance, MW

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers



Exhibit 2-81: ESM Ponce West Load Generation Balance, GWh

Reference: ESM_Metrics_Base_SII.xlsx LTCE&Nodal_Workpapers

As was the case on the S4S4B case when Ponce is considered as an integrated MiniGrid, the are enough resources to cover the capacity and energy needs in the MiniGrid.

2.11.3 Load Flow Assessment of the MiniGrid.

The analysis in grid isolated mode did not show any line overloads or voltage violations before contingency in Ponce MiniGrid.

2.11.4 Investment to Consolidate the Ponce MiniGrid

In this section we present the investments at the 38 kV level necessary to consolidate the Ponce MiniGrid. The 115 kV investments were presented earlier. Exhibit 2-82 shows geographically the proposed investments in the MiniGrid that make up the Ponce region.

As can be observed in Exhibit 2-82 all investments are associated with interconnection of critical loads to the reliable generation injection points as presented earlier.





Redacted



Ponce Region Investments Legend



Exhibit 2-83 shows the investments in 38 kV (46 kV insulated) transmission line facilities for the interconnection of critical loads. It can be observed that most investments correspond to underground lines. The total investment of new 38 kV transmission lines is approximately \$413 million on about 95 miles lines and cables.



Exhibit 2-82: Ponce MiniGrid and Generation Injection Points

Redacted

Ponce Region Investments Legend





Redacted

Exhibit 2-83: New 38 kV (46 kV insulated) Transmission Lines and Cables in Ponce

Redacted

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

To supplement the investments above there are additional investments at the substation level and infrastructure hardening that are detailed in Exhibit 2-84 below. In line with the investments above most of the substation level investment corresponds to GIS conversion. The total investment is

approximately \$360 million with \$358 million at the substation level and \$2.5 million on infrastructure hardening applied to 2.5 miles of transmission lines. And \$347 million is directly associated with the interconnection of critical loads.

Exhibit 2-84: New Substations/Switchyards and Infrastructure Hardening in Ponce



Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.11.5 Microgrids in Ponce MiniGrid

2.11.5.1 **Ponce Microgrid Zone 1 - ARROYO**

We identify a potential microgrid zone in the general area of ARROYO substation and surroundings, consisting of 2.4 MW deemed critical load and 2.1 priority load. Based on the planned generation in S4S2B, we estimated to install 3 MW of new thermal peaker units and 6.4 MW planned PV and 3.2 MW BESS units in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.11.5.2 Ponce Microgrid Zone 2 - MAUNABO

We identify a potential microgrid zone in the general area of MAUNABO substation and surroundings, consisting of 2.8 MW deemed critical load. Based on the planned generation in S4S2B, we estimated to install 4 MW of new thermal peaker units in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.11.5.3 **Ponce Microgrid Zone 3 - PATILLAS**

We identify a potential microgrid zone located in the general area of the PATILLAS substation and surroundings, consisting of deemed 4.6 MW critical load and 0.2 MW priority load. Based on the planned generation in S4S2B, we estimated to install 6 MW of new thermal peaker units in the

microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.11.5.4 **Ponce Microgrid Zone 4 - PEÑUELAS**

We identify a potential microgrid zone located in the general area of the PEÑUELAS substation and surroundings, consisting of 2.3 MW deemed critical load. Based on the planned generation in S4S2B, we estimated to install 3 MW of new thermal peaker units in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.11.5.5 **Ponce Microgrid Zone 5 – VILLALBA (Toro Negro)**

We identify a potential microgrid zone in the general area of VILLALBA substation near to Toro Negro HP2 and surroundings, consisting of 7.2 MW deemed critical load and 1.9 priority load. Based on the planned generation in S4S2B, we estimated to install 8 MW of new thermal peaker units along with planned 6.4 MW PV and 3.2 MW BESS units in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.11.5.6 **Ponce Microgrid Zone 6 – PORTUGUES**

We identify a potential microgrid zone in the general area of PORTUGUES substation and surroundings, consisting of 0.4 MW deemed critical load and 0.3 balance load. Based on the planned generation in S4S2B, we estimated to install 1 MW of new thermal peaker units in the microgrid. And the remaining balance load can be served preferably by combination of additional PV and BESS.

2.12 MiniGrid Controls

For the MiniGrids and microgrids to isolate and operate effectively in autonomous mode for extended periods of time following a major event, a special type of Minigrid Controller is required. This control will work with an upper level monitoring and control system (i.e. SCADA) for this purpose and it will enhance grid resilience. The MiniGrid controller is only required in the grid islanded mode, but it could support day to day operations. The controller should have at minimum the following capabilities:

- 1. Be able to use the resources within each Minigrid/microgrid to control frequency and voltages within acceptable values.
- 2. Be able to shed load at preselected places according to a schedule to maintain minimum capacity reserves and/or in response to an incident, e.g. trip of a generator.
- 3. Be able to maintain an economic dispatch (fuel conservation) considering that the system will have a mix of thermal, renewable (PV and some Wind Turbine generation) and storage resources.
- 4. Be able to separate the MiniGrid/microgrid in preparation for an event and/or be able to deploy quickly after an event, assuming the SCADA system is already in place
- 5. Be able to inform operators on the status of the supervised grid (breaker positions) and perform remote control functions if desired.

Based on the required capabilities above, there are various vendors in the market and this includes the Siemens SICAM Mini Grid Controller (MGC) as a solution to meet the purpose. We provide next the characteristics of the SICAM Mini Grid Controller and a cost estimate to be included in the total capital investment.

2.12.1 Minigrid Controller

The minigrids / microgrid require a controller and for the description of its features we will use the SICAM MGC. This controller is an industry standard, robust, modular and flexible solution for

intelligent control of microgrid systems. As part of the continuation of the well-known Siemens RTU product family, the SICAM Microgrid Controller benefits from long-term experience and proven references worldwide. It provides flexible communication, seamless continuity, maximum security, and no limitation during the migration. The SICAM MGC allows a quick and easy integration, combining existing DG's, CHPs, CCHPs, additional renewable generation like photovoltaic and energy storage devices. This intelligently controlled energy mix allows a robust, safe and economical operation of the microgrid. The SICAM MGC is designed to operate hierarchically with the EMS overviewing the MiniGrids receiving instructions on dispatch and network operations inside the MiniGrid and supervise and provide instructions if required to the controllers of the microgrids included in the MiniGrid.

The functions of SICAM MGC include: User interface, Island detection, Blackout detection, Load frequency control (LFC), Automatic voltage control (AVC), Re-synchronization, Auto islanding, Multicontrol modes, Peak shaving, Reserve monitoring, Load shed and restore, Diesel generator control, Battery/PV/Storage control, Auto start/Sequencing, and more.

The controller is designed to work with the ESM to optimize the generation dispatch of the MiniGrid and can be instructed to operate is deferent modes ranging from fully economic (minimum operating costs) to fully defensive where the objective is the security of the MiniGrid, thermal generation is brought on line and the flows in/out are minimized. The controller will also have pre-defined operating conditions that when true (e.g. number of lines out of service or flows exceeded) the controller will safely separate and go to grid isolated mode, shedding load if necessary.

The estimated total cost for the Siemens SICAM MGC solution for the 8 PREPA MiniGrids and 20 microgrid areas identified will be \$120,000 to \$150,000, per MiniGrid/microgrid, depending on the final functions required and the number of interfaces with the upper control system SCADA. We will use \$135,000 per Minigrid/microgrid for total capital investment estimation.

2.13 Summary of Transmission Investments

In this section, we present the summary of the total capital investment on the PREPA transmission system centered around the formation of the aforementioned eight MiniGrids. It is important to gain an overall picture of the total MiniGrid related investments as part of the IRP.

2.13.1 115 kV MiniGrid Investment

Exhibit 2-85 and Exhibit 2-86 below summarized the total capital investment on MiniGrids transmission system enhancement. Note the slight difference between region and MiniGrids is due the proposed transmission projects that are organized by PREPA regions. As can be seen, the total capital investment on 115 kV transmission is approximately \$2.808 billion, led by San Juan-Bayamon MiniGrid of \$788 million. The investment on new 115 kV transmission line/cables and substation hardening accounts for 83% of total investment.

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

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

Siemens Industry, Inc. – Siemens Power Technologies International Error! Reference source not found. – Rev. Error! Reference source not found. – 2018 Integrated Resource Plan Appendix 1: Transmission and Distribution Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx





Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

Exhibit 2-87 and Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

Exhibit 2-88 show the total investment on 115 kV transmission investment related to MiniGrids by technical justification. As can be seen the majority (74%) of the investment is associated with the MiniGrid main backbone projects.

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

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





Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.13.2 38 kV MiniGrid Investment

Next we present the total capital investment on the MiniGrid transmission on the 38 kV level. We first summarized the 38 kV investment by project type and technical justification for all the MiniGrids and then detailed project and cost will be discussed in each of the MiniGrid sections.

Exhibit 2-89 and Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

Exhibit 2-90 below summarized the total capital investment on 38 kV Minigrids transmission system enhancement. As can be seen, the total capital investment on 38 kV transmission is approximately \$3.047 billion, led by Ponce Minigrid of \$773 million. The investment on new 38 kV transmission line/cables and substation hardening accounts for 79% of the total investment.

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

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



Exhibit 2-90: 38 kV MiniGrid Transmission Investment by Project Type, \$ million

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

Exhibit 2-91 and Exhibit 2-92 show the total investment on 38 kV transmission investment related to MiniGrids by technical justification. As can be seen the majority (79%) of the investment is associated with the projects for the interconnection of critical loads within the MiniGrids.

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

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





Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.13.3 Total MiniGrid Transmission Investment

Exhibit 2-93 and Exhibit 2-94 show the total capital investment on the transmission system related to the Minigrids. The estimated total investment is approximately \$5.86 billion, led by San Juan-Bayamon MiniGrid of \$1433 million followed by Ponce at \$1193 million.

	А	recibo	Ва	yamón	С	aguas	Ca	arolina	Isla	Ma	ayaguez	F	Ponce	Sa	n Juan		Total
115 kV	\$	295.3	\$	307.5	\$	481.2	\$	426.3	\$ 86.9	\$	311.2	\$	419.5	\$	480.1	\$2	2,808.1
38 kV	\$	252.7	\$	220.2	\$	526.5	\$	230.5	\$ 17.2	\$	602.6	\$	773.4	\$	423.8	\$3	8,046.9
MiniGrid Controller	\$	1.350	\$	0.405	\$	1.215	\$	0.270	\$ 1.215	\$	1.215	\$	0.540	\$	0.540	\$	6.750
Total	\$	549.4	\$	528.1	\$1	,008.9	\$	657.1	\$ 105.3	\$	915.0	\$1	,193.4	\$	904.5	\$5	,861.7

Exhibit 2-93: Total MiniGrid Transmission Investment, \$ million



Exhibit 2-94: Total MiniGrid Transmission Investment, \$ million

Reference: MiniGrids CapEx Summary wPriority Final 5.27.2019.xlsx

2.14 Other Transmission Investments

In this section, we present the summary of the total capital investments on the PREPA transmission system needed for Existing Infrastructure Hardening for Reliability and Aging Infrastructure Replacement in compliance with the new Codes and Standards as FEMA required due to the damages on PREPA's electric system caused by the path of Hurricane Maria in September 2017. These investments are aimed to strengthening all the components of the electric grid (lines, transformers, switchyards, etc.) at all levels: 230 kV, 115 kV and 38 kV for improved system reliability.

Exhibit 2-95 and 2-96 below summarized the total capital investment on Other Transmission Projects not directly related to the formation of the eight MiniGrids mentioned before. The first table presents transmission investment by Project Type. The second table presents the investments by voltage level. The total investment on Other Transmission Projects is approximately \$1,996.6 million.

Exhibit 2-97: Othe	r Transmission	Investment by	Project	Type, in	\$ million
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Technical Justification	Arecibo	Bayamón	Caguas	Isla	Mayaguez	Ponce	San Juan	Total
Aging Infrastructure Replacement	0.0	0.0	0.0	0.0	0.0	0.0	28.8	28.8
Existing Infrastructure Hardening for Reliability	327.3	196.8	83.2	777.1	70.8	303.5	209.2	1967.8
Potoronco: MiniGride CanEx Summ		iority Ei	nal vlev					

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

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

Reference: MiniGrids CapEx Summary_wPriority_Final.xlsx

2.15 Assessment of Value of Lost Load of the MiniGrids

2.15.1 Introduction

When considering the investments in transmission on the MiniGrids, the question of whether this design provides an optimal balance between ratepayer costs and improved reliability arises.

To address this question in this section we provide a determination for three representative MiniGrids (Caguas – Cayey, San Juan – Bayamon and Carolina) of the economic impact of not advancing the proposed investments and only carrying out those investments already identified for bringing the existing infrastructure up to code. Note that instead of identifying the impact and value of each investment, which would be a very time consuming exercise and that could be done at a later time before an actual investment is made, we identified how many weeks of load shedding of the "Critical Loads" would be enough to cover the entirety of the investments. As will be shown just one event that resulted in a duration of more than 2 to 4 weeks outage would have a Value of Lost Load (VoLL) to the critical loads enough to pay for the entirety of the required CapEx for the MiniGrid, not only the CapEx required to supply those critical loads, thus providing a clear view of the advantages of the MiniGrid design.

The VoLL analysis started considering that the system had separated into the MiniGrids following a major event according to the boundaries discussed earlier in this Appendix 1, and then estimated the Load Not Served (MW), Energy Not Served (MWh), and Cost of Energy Not Served (\$) under the condition that due to the lack of the MiniGrid investments, the transmission system was separated into individual load pockets following multiple line outages. The resulting cost was compared with the MiniGrid CapEx to determine the duration of outages necessary to justify this CapEx.

2.15.2 Assumptions

As will be recalled the MiniGrid CapEx was identified to address those the lines that given its location and construction type would be out for an extended period of time following a major event. Thus, for this analysis the transmission facilities were separated into two categories:

- Level 1: transmission lines that are assumed to be out immediately after a severe weather event, if the line was not upgraded or a parallel element built as part of the MiniGrid CapEx;
- Level 2: transmission lines that can be brought back in service one week after a severe weather event. These identified lines consist of those facilities that will be reinforced to bring them up to code and this investment will be carried out independently of the selection or not

of the MiniGrid design. It also includes lines that due to their current design are expected to be back within a week.

It is to be noted that during the first week (Level 1 outage) only those facilities that due to their current condition are expected to remain in service (e.g. existing underground cables), were considered.

Other assumptions and considerations are detailed below:

- 1. Siemens PTI PSS®E 33.11 is software tool used.
- 2. The PREPA power flow case with the topology including all MiniGrid investments was used. The identified transmission lines were taken out of service to represent as if the line is not included in the MiniGrid CapEx.
- 3. 2019 Night Peak load was selected as the highest peak load condition.
- 4. 2025 S4S2B generation plan from the latest LTCE runs was selected as most of the new resources are online.
- 5. All thermal units including peakers are at max output, all PV resources are offline, all battery resources are at max output.
- 6. All Combined Heat and Power (CHP) are available, however, they can only serve the loads where they are located.
- 7. The transmission system was first be separated into eight MiniGrids after a severe weather event. For demonstration purpose, Siemens PTI only analyzed the VoLL for Caguas & Cayey MiniGrid (combined), Caroline MiniGrid, and San Juan-Bayamon MiniGrid.
- 8. An average load factor of 75% was used to estimate the associated lost energy.
- 9. The loads were classified into three categories: Critical Load, Priority Load, and Balance Load, based on PREPA substation load information.
- 10. The cost of unserved Critical Load is assumed to be \$32,000 / MWh, the cost of unserved Priority Load is assumed to be \$10,000 / MWh, and the cost of unserved Balance Load is assumed to be \$2,000 / MWh. These values are lower than those reported in the VoLL section of the main report and thus conservative.
- 11. Level 1 lines include Level 2 lines as a sub-set. Level 2 lines are assumed back in service after 168 hours or the first week after weather event.

2.15.3 Methodology

The methodology to carry out the VoLL analysis is summarized following the procedures below:

- 1. Start from the 2019 Night Peak load power flow base case and include the Scenario 4 Strategy 2 (Base case) 2025 generation plan and dispatch all thermal/PV/battery resources according to the assumptions.
- Apply the necessary transmission line outages to convert the base case into a representation of the system segregated into MiniGrids, according to the boundaries in the previous sections.
- 3. Apply all Level 1 outages for the evaluated MiniGrids and identify the remaining individual load pockets to be out for the first week after the event.
- 4. Apply Level 2 changes (put lines back into service) and identify the new load pockets after level 2 changes; that is the load pockets likely to remain for an extended period after the event.
- 5. Analyze load to generation balance for each individual load pocket in the MiniGrid and calculate the Average Load Not Served in MW by taking the net difference between (peak load x load factor) and available generation, and calculate the Energy Not Served in MWh for the 1st week and each following week. The calculation is broken down for the Critical, Priority, and Balance load categories.
- 6. Calculate the Cost of Energy Not Served (\$) using the unit cost assumption for each category and calculate the total cost per week. For example, for a weather event causing three weeks outages, the total Cost of Energy Not Served will be the Cost of Energy Not Served for the 1st week (both L1 & L2 Out) plus twice of the weekly Cost of Energy Not Served following the 1st week (L1 out, L2 in).

2.15.4 Results

The results of MiniGrid VoLL analysis are presented in the Exhibit 2-99 below.

In this exhibit we observe for example that for that for the Carolina MiniGrid, the total MiniGrid peak load is 311 MW, when a weather event hit the island, 174 MW load is assumed to be unserved, and that translates into 21,977 MWh of energy not served and \$348 million of total Cost of Energy Not Served for the 1st week. After the 1st week when the Level 2 lines are brought back online, there would be still 158 MW peak load unserved, and equals to 19,877 MWh of energy not served, or \$320 million in cost per week for the total load, and \$238 million per week for the critical load. This is all under the assumption that there will be no specific MiniGrid CapEx (Level 2 only).

Siemens PTI also evaluate the case with the proposed MiniGrid CapEx fully implemented so that no Level 1 lines are assumed to be out of service after a severe weather event except for the lines that will isolate the transmission grid into MiniGrid mode. And the results show that no energy is unserved and thus \$0 cost for all three MiniGrids evaluated in this analysis.

Finally, we observe that it would take only 1.8 weeks of critical loads outages or 1.4 weeks of total load outage to pay for the entire CapEx of San Juan – Bayamon, 2.7 weeks of critical load outage or 2.3 weeks of total load outage to pay for the Carolina investments and 3.7 weeks of critical load outages or 3 weeks of total load to pay for the Caguas – Cayey investment. Based on the above it would likely take one major hurricane hitting the island to pay for the MiniGrid investments.

This can also be noted by comparing the cost of a 4-week outage with the required CapEx.

2.15.5 Conclusion

Based on the MiniGrid VoLL analysis assumptions and results, we can conclude that the total Value of Load Loss for any severe weather event that caused the transmission lines out for a few weeks would be more than enough to justify the total cost of the proposed MiniGrid CapEx and would possibly take one major event to justify all investments.

	Total MiniGrid Load (MW)				Load Not Served (MW)				Energy Not Served (MWh)					Cost of Energy Not Served (k\$)								Example: an event for 4
MiniGrid					Pre MiniGrid CapEx				Pre MiniGrid CapEx				Post MiniGrid CapEx	Post Pre MiniGrid CapEx MiniGrid CapEx			Total MiniGrid	# of Weeks to Justify the CapEx	# of Weeks to Justify the CapEx	Total Cost of Energy Not		
	Critical Priority Balance Subtotal			Critical	Priority	Balance	Subtotal	Critical	Priority	Balance	Subtotal	Subtotal	Critical	Priority	Balance	Subtotal	Subtotal	CapEx (k\$)	(Critical Only)	(All Loads)	Served (k\$)	
Caguas & Cayey	188	104	116	408	1st Week (Level 1+Level 2 out)																	
					110	35	87	233	13,905	4,397	10,994	29,296	0	\$444,948	\$43,967	\$21,988	\$510,904	\$0	¢1 008 017	37	2	\$1 274 296
						After 1st Week (Level 1 out, Level 2 in), Per Week												ş1,008,917	3.7	5	<i>Ş1,214,330</i>	
					53	26	31	110	6,688	3,275	3,871	13,834	0	\$214,001	\$32,755	\$7,741	\$254,497	\$0				
Carolina	133	34	144	311		1st Week (Level 1+Level 2 out)																
					76	16	83	174	9,598	1,979	10,400	21,977	0	\$307,132	\$19,789	\$20,801	\$347,721	\$0	\$762 367	27	22	<u>\$1 208 590</u>
						After 1st Week (Level 1 out, Level 2 in), Per Week													9702,307	2/	2.5	Ş1,308,350
					70	14	73	158	8,864	1,826	9,187	19,877	0	\$283,661	\$18,255	\$18,374	\$320,289	\$0				
San Juan- Bayamoon	399	185	467	1051	1st Week (Level 1+Level 2 out)																	
					224	121	284	629	28,276	15,193	35,759	79,228	0	\$904,826	\$151,932	\$71,518	\$1,128,276	\$0	\$1 432 630	18	14	\$2 810 788
					After 1st Week (Level 1 out, Level 2 in), Per Week													Ŷ1,732,030	1.0		<i>\$3,010,700</i>	
					177	94	244	515	22,323	11,844	30,701	64,868	0	\$714,330	\$118,439	\$61,402	\$894,171	\$0)	1		

Exhibit 2-100: MiniGrid VoLL Results

Reference: MiniGrid VOLL_final.xlsx workpaper.

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