2010 Phase 1 CTPG 2020 Study Report

Final

February 17th, 2010

This document is the final report for Phase 1 of the CTPG State-wide transmission plan. Additional phases will be conducted during the first part of 2010 that include refinements to this plan as well as additional study scenarios.

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1 Executive Summary

1.1 Background

The California Transmission Planning Group (CTPG) is a forum for conducting joint transmission planning studies consistent with FERC Order 890 principles, and for coordinating CTPG members' transmission planning activities. CTPG members include transmission owners or transmission operators and are subject to WECC transmission planning regulations. The purpose of the CTPG study work is to develop a state-wide transmission plan providing transmission infrastructure that reliably and efficiently meets, by year 2020, the state's 33% renewable portfolio standard (RPS) goal. This will be achieved by utilizing a diverse portfolio of renewable energy generation technologies including wind, geothermal, small hydro, biomass and solar available to supply projected electricity demand in California. In this effort, the CTPG is using elements of California's Renewable Energy Transmission Initiative (RETI) conceptual transmission plan that was developed to facilitate access to RETI-identified Competitive Renewable Energy Zones (CREZs).

1.2 Study Cases and Methodology

In this initial phase of CTPG studies the CTPG developed the following cases starting with the WECC 2019 Heavy Summer seed case:

- Case A: 2020 Northern California adverse weather (90/10)
- Case B: 2020 Southern California adverse weather (90/10)
- Case C: 2020 Normal Weather (50-50)

Additionally, CTPG developed the following case starting with the WECC 2019 Heavy Winter seed case:

- Case L: 2020 Light Spring Weather (off-peak)

Cases A and B include those transmission additions included in the WECC 2019 Heavy Summer seed case as well as certain elements of the RETI Phase 2A conceptual transmission plan. Case C is intended to lay a foundation for identifying the first set of transmission elements that mitigate reliability criteria violations that arise with increasing amounts of renewable resources. This is accomplished by connecting a controlled set of renewable resources under expected summer peak conditions and identifying the amount and location of renewable resource additions at which reliability criteria violations are first observed. Case L includes the transmission additions included in Cases A and B and was intended to assess California's additional transmission needs under light loads, such as spring mornings. The heavy and light load scenarios will capture a fairly broad range of renewable generation output patterns. This range includes high solar output coupled with low wind output and vice versa.

Using the 2020 energy forecast from the CEC's 2009 Integrated Energy Policy Report (IEPR), an estimated 289,697 GWh of retail load in the state of California would be subject to the state's renewable goals. To meet a 33% goal in year 2020, entities with responsibility for supplying retail loads in the state would be required to obtain a total of 95,600 GWh of renewable energy. California is already making significant progress toward this goal and it is estimated that existing renewable generation projects, plus renewable generation projects under construction during calendar year 2009, will supply 39,324 GWh of renewable energy in year 2020. CTPG's purpose in Phase 1 is to develop a transmission plan that will support the additional renewable resource development necessary to reach the 95,600 GWh goal.

Participating load serving entities that are members of CTPG provided planned renewable resource addition/purchase scenarios that support their respective RPS and environmental goals for year 2020. Table 1 compares CTPG's estimates of renewable energy requirements and renewable energy production with corresponding estimates from the RETI Phase 2A process. The CTPG estimates slightly exceed the 33% target while RETI intentionally planned for renewable resource additions significantly greater than the 33% target. RETI accounted for the uncertainty in renewable resource development patterns by assembling a Phase 2A conceptual transmission plan intended to provide transmission sufficient to supply 45% of the state's retail energy requirements with renewable energy.

Table 1: CTPG 2020 Planning Target (Net Short)

	CTPG (GWh)	**RETI Phase 2A (GWh)**
Forecast Retail Load subject to California's renewable goals:	289,697	301,974
Renewable Portfolio Standard (RPS) Goal:	33%	33%
Renewable Portfolio Standard (RPS) Energy Requirement:	**95,600**	**99,651**
Existing and New Renewables expected to be on line by end of 2009:	39,324	36,807
Miscellaneous renewable resource additions:	2,670	3,134
	41,995	**39,941**
Net Short:	**53,605**	**59,710**
Identified Renewable Resource Additions:	55,535	95,536
Total Renewable Energy Production:	**97,529**	**135,477**
Identified Renewable Energy as a Fraction of Retail Sales:	**33.70%**	**44.9%**

The renewable procurement scenarios provided by CTPG members reflect installed capacity and in some cases the expected renewable dispatch at time of peak. In other cases, CTPG used generic factors to relate nameplate capacity to expected renewable dispatch for the hour of study (e.g., peak hour, off-peak hour). These generic factors were obtained from RETI's CREZ- and technology-specific hourly generation patterns. These hourly generation patterns were also used to estimate the annual energy output for specific renewable technologies in specific CREZs. Rooftop PV and other distribution-level generation were considered as a reduction to load. Figure 1 shows the resulting installed renewable capacity by area.

Figure 1: CTPG Renewable Generation

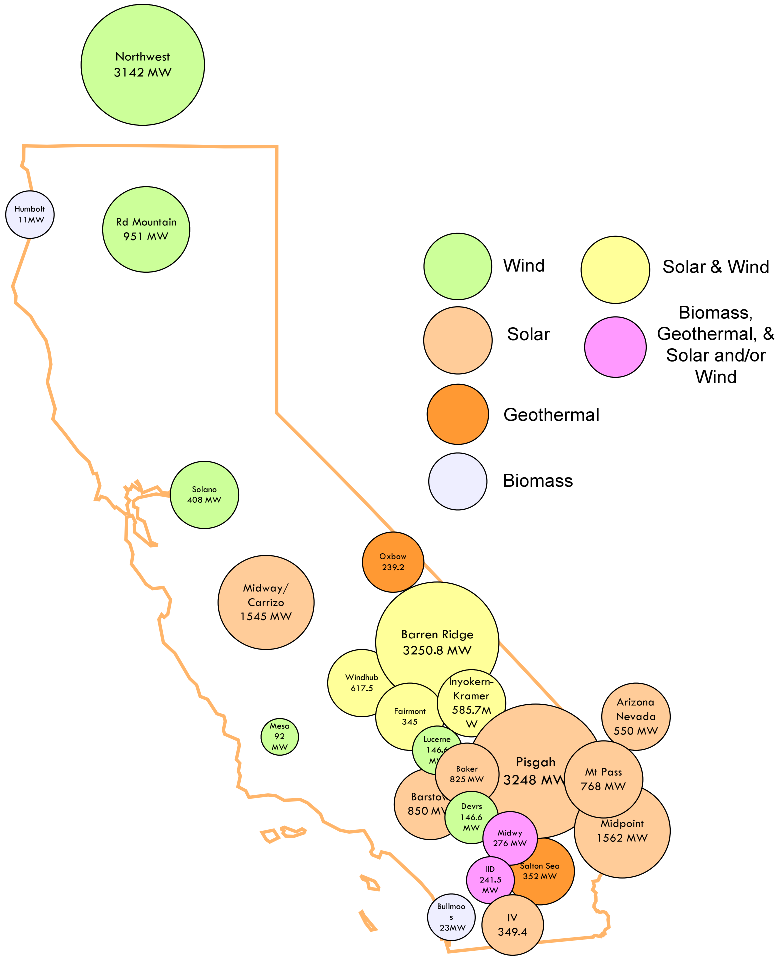
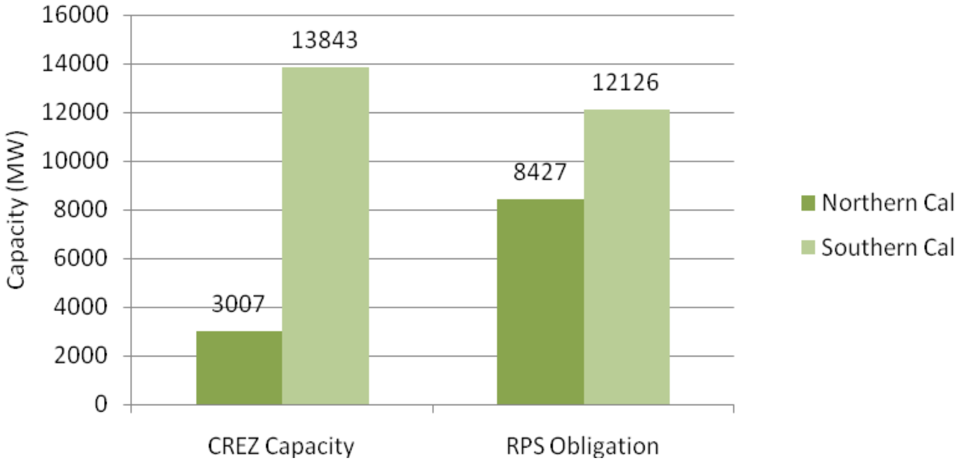


Figure 1 provides a visual indication that the location of potential new renewable resources has significant implications for transmission expansion planning. As can be seen in the figure, the great majority of renewable resource development potential based on the renewable scenario chosen for these cases is located in southern California. At the same time, a significant amount of the fossil generation that will be displaced by the assumed renewable resources located in southern California is located in northern California. Figure 2 compares the resource location versus the RPS obligation between northern and southern California load for the renewable resource portfolio assumed in these studies.

Figure 2: Renewable Location vs. RPS Obligation



To accommodate the output of new renewable generators dispatched in the 2020 power flow cases, it is necessary to reduce the output of fossil-fired generators by corresponding amounts. To accomplish this, fossil-fired generation was reduced in blocks, equal to the increments of renewable generation. A 70/30 split between California fossil generation and other WECC fossil generation was used. Fossil generation was decremented in a merit-order fashion (least economic reduced first). Nuclear and hydro units are not decremented in the summer peak cases. Approximately 13,000 MW of fossil-fired generation is backed down to accommodate the renewable generation dispatch with approximately 9,300 MW in-state and 3,700 MW out-of-state.

1.3 Study Results

The study results summarized below are based on the limited scenarios considered in the initial studies conducted by the CTPG study team. Most of the scenarios analyzed do not consider the full output of all renewable generation since, at any given point in time, it is a virtual certainty that all renewable generators will not be operating at full output.

It is possible, however, that all renewable generators within a given area could, from time to time, be operating at something approximating full output and it is important to understand the potential impacts on the grid were this to occur. These impacts are identified through “deliverability” analyses and these analyses represent a different set of renewable and fossil-fired dispatch scenarios, each with its own likelihood of occurrence. Deliverability studies are a subject for future consideration by CTPG and it is likely that they will identify additional transmission upgrades that could provide capacity-, congestion- and loss–related benefits that exceed the costs of the upgrade.

Based on the initial studies performed to date, the following conclusions were reached:

1. Provided identified Category C reliability criteria violations can be mitigated through controlled load drop and/or generation-tripping schemes, and provided other localized criteria violations can be addressed through relatively simple mitigation measures, California can make substantial progress towards its renewable resource goals with those transmission upgrades listed on Table 11 and Table 30.

2. Significant upgrades of both Path 26 and Path 15 will mitigate the adverse consequences of contingencies that could occur with north-bound flows near 4500 MW and 8500 MW, respectively.

3. Assuming high north to south flows with corresponding reductions in fossil-fired generation, the Sacramento and San Diego areas exhibit potential reliability concerns, primarily due to increased imports into the respective areas. Further study is required to address these potential concerns.

4. Additional transmission enhancements or other mitigation measures are needed to address reliability criteria violations associated with increased renewable generation in the following CREZ locations: (a) Tehachapi area assuming significant amounts of generation in this area are connected to the Barren Ridge substation, (b) Kramer, (c) Pisgah, (d) Central Nevada/Inyokern, and (e) East Riverside County.

5. Under heavy summer conditions, the assumed location of new renewable generation and the corresponding location of displaced fossil-fired generation will cause the historical direction of flows on Path 26 and Path 15 to change from North-to-South to South-to-North. In turn, there will be contingency-based overloads on certain 230 kV facilities along the path connecting the southern and northern California load centers and effective mitigation for these overloads will need to be identified.

6. Several local overloads in the load centers would have to be mitigated by local transmission reinforcements or by new operational measures.

7. Further studies are needed to assess the effectiveness, practicality, cost and benefits of other mitigation measures and alternatives that could be useful in reliably and efficiently meeting the 33% RPS goal. These include:

    a. Reactive energy sources (voltage support), particularly in the SDG&E and SCE areas.
    b. Controlled load drop for certain contingency conditions as a potentially quick and cost-effective way to facilitate the connection of new renewable generation to the existing grid.
    c. Development of generation Special Protection Schemes (SPS) and/or related operating procedures, including generation tripping to allow full dispatch of renewable generation within CREZs, and the cross-tripping of load and/or generation for certain contingency conditions, as a potentially quick and cost-

effective way to facilitate the connection of new renewable generation to the existing grid.

1.4 Proposed New Transmission Additions

The following transmission segments have been identified in these initial studies as network infrastructure candidates that mitigate reliability criteria violations identified in the CTPG studies conducted to date assuming renewable resource dispatch at levels that meet California's 33% RPS goal. These transmission upgrades are in addition to the network transmission lines and new substations assumed to be in place to connect the CREZs to the grid as outlined in the report (Table 11 and Table 30). It should be stressed that these are a preliminary set of infrastructure additions that address the identified reliability criteria violations. As CTPG defines and analyzes other resource development scenarios in the next phases of its work, other potentially valuable transmission and non-transmission additions and alternatives will be identified. Some of these alternatives may prove better-suited to address the reliability criteria violations identified to date, and not all of the network infrastructure additions listed below may be included in subsequent updates of CTPG's conceptual transmission plan.

Transmission infrastructure additions identified on the basis of CTPG's initial studies are::

1. New Midway – Gregg 500 kV line with 50% series compensation.
2. Gregg-Bay Area-Sacramento Lines: Two 500 kV lines north of Gregg to the Bay Area via Warnerville with 50% series compensation.
3. Re-conductor Los Banos – Westley 230 kV line and station equipment.
4. New Barren Ridge – Vincent 500kV or Barren Ridge – Whirlwind 500kV Line. It should be noted that the need for this line may be due to the assumed renewable resource split between the Barren Ridge and Whirlwind (or Windhub) stations. Future studies will adjust this split in order to evaluate the need for this upgrade under more probable renewable resource connection patterns in the Tehachapi area.
5. New Midway – Kramer 500 kV line
6. New Kramer – Lugo 500kV Line
7. Existing Eldorado – Lugo 500kV line looping in at the new Pisgah 500kV Substation
8. New Pisgah-Barstow-Kramer, new Pisgah – Barstow, or new Pisgah – Kramer 500 kV Line
9. New Devers-Mira Loma 500 kV Line
10. In the absence of the Green Path North Project (GPNP), additional reinforcements would be required along the Devers-Mira Loma 230 kV lines.
11. Additional Control-Inyokern 230kV Line

12. Completion of a 230 kV double-circuit loop in the IID control area (Highline-El Centro-Imperial Valley)

1.5 Next Steps

CTPG emphasizes that the study work conducted to date reflects Phase 1 of CTPG's work. Only a limited number of scenarios have been considered. The following studies and scenario assessments are recommended as next-steps to be completed before a comprehensive conceptual transmission plan is developed:

1. Input from stakeholders: Develop cases and scenarios as may be requested by stakeholders and determined to be potentially helpful in improving the efficacy of CTPG's conceptual transmission plan.

2. Test a range of renewable net-short estimates: A reasonable range of renewable net short estimates may be defined by RETI.

3. Generation Redispatch Alternatives: Test other fossil-fired generation dispatch patterns that would accommodate the increase in renewable generation.

4. Procurement Scenarios: Test other renewable resource development scenarios (location, type and quantity of renewable resource additions). For instance: out of state scenarios and Owens Lake development.

5. Tehachapi -Barren Ridge Renewable Split: Adjust the renewable split to reflect a more likely pattern of renewable generator connection configurations in the Tehachapi area.

6. Once-through Cooling (OTC) Study: Continue the OTC studies and update the CTPG's conceptual transmission plan as appropriate.

7. Deliverability: Develop cases to test the deliverability of renewable resources considering that renewable resources at given locations and at given points in time, may be dispatched at or near peak capacity.

2 Background and Overview of the 2010 Initial CTPG 2020 Study Report

2.1 CTPG Background

The California Transmission Planning Group (CTPG) is a forum for conducting joint transmission planning studies and for coordinating members' transmission planning activities. CTPG's transmission planning work is structured to meet the transmission needs of California and is intended to be consistent with FERC Order 890. The purpose of CTPG's transmission planning studies is to provide planning information useful to project sponsors (inside or outside of CTPG), decision makers, and regulatory entities in order to reach decisions on which elements of the conceptual transmission plan should be pursued.

The CTPG was formed in early 2009 as a result of discussions facilitated by FERC to address California's transmission needs in a coordinated manner that would respect various business models and Balancing Authority Areas. CTPG's members include transmission owners with an obligation to serve and transmission operators with responsibility for reliable operations. All of CTPG's members and membership organizations (i.e., TANC) are subject to WECC transmission planning regulations. The CTPG members are:

- California Independent System Operator (ISO)
- Imperial Irrigation District (IID)
- Los Angeles Department of Water and Power (LADWP)
- Pacific Gas and Electric (PG&E)
- Southern California Edison (SCE)
- Southern California Public Power Authority (SCPPA)
- San Diego Gas and Electric (SDG&E)
- Sacramento Municipal Utility District (SMUD)
- Transmission Agency of Northern California (TANC)
- Turlock Irrigation District (TID)
- Western Area Power Administration (Western)

2.2 Initial CTPG Study Report Overview

The CTPG is committed to developing a California state-wide transmission plan to meet, by year 2020, the state's 33% renewable portfolio standard (RPS) goal. This transmission plan will seek to leverage a diverse portfolio of renewable energy generation technologies including wind, geothermal, small hydro, biomass and solar thermal and solar photovoltaic available to supply projected electricity demand in California from now to beyond 2020. In this effort, the CTPG is using elements of the Renewable Energy Transmission Initiative (RETI) conceptual transmission plan.

The objective of the initial phase of CTPG's studies is to identify potential transmission upgrades associated with certain resource expansion scenarios that support the state's 33% RPS goals. It is likely that other resource expansion scenarios would result in the identification of transmission upgrades that are not presented in this initial report. Further, the identified upgrades will be coordinated with existing utility plans, and, in future CTPG work will be evaluated against other alternatives that mitigate identified reliability criteria violations. The resulting statewide transmission plan will allow the state to meet its renewable and environmental objectives in a manner that provides the greatest value to consumers and that is sensitive to the environmental consequences of new transmission infrastructure.

Maximizing the use of the existing grid should be a starting point for any evaluation of new transmission needed to meet California's 33% RPS goal. This reduces the risk that additional transfer capability provided by new transmission will become stranded. This report represents a starting point for the eventual state-wide transmission plan.

For the initial set of scenarios, the CTPG developed the following cases that represent forecast adverse and normal conditions:

- Case A: 2020 Northern California adverse weather (90/10) case where imports from the Pacific Northwest are modeled near their existing operating limits.
- Case B: 2020 Southern California adverse weather (90/10) case
- Case C: 2020 Normal Weather (50-50) case
- Case L: 2020 Light Spring Weather (off-peak) case

Cases A and B include those transmission additions included in the WECC 2019 Heavy Summer seed case as well as certain elements of the RETI Phase 2A conceptual transmission plan. Case C is intended to lay a foundation for identifying the first set of transmission elements that mitigate reliability criteria violations that arise with increasing amounts of renewable resources. This is accomplished by connecting a controlled set of renewable resources under expected summer peak conditions and identifying the amount and location of renewable resource additions at which reliability criteria violations are first observed. Case L includes the transmission additions included in Cases A and B and was intended to assess California's additional transmission needs under light loads, such as spring mornings. The heavy and light load scenarios will capture a fairly broad range of renewable generation output patterns. This range includes high solar output coupled with low wind output and vice versa.

Case A incorporates forecast Northern California adverse summer weather peak loads (90/10) for year 2020. Case A1 assumes that major RETI upgrades are built including GPN, Midpoint-Devers-Valley, Tehachapi Segments 1-11, the Haskell Canyon upgrades, upgrades in the Owens Valley, and new substations and six network transmission lines in the southern Nevada-Los Angeles area corridor. Case A2 assesses how much additional transmission is needed during a northern California 1-in-10 year peak to mitigate identified reliability criteria violations assuming 33% RPS goals are met while stressing imports from the Pacific Northwest.

Case B incorporates forecast Southern California adverse summer weather peak loads (90/10) for year 2020. Case B1 assumes that major RETI upgrades are built including GPN, Midpoint-Devers-Valley, Tehachapi Segments 1-11, the Haskell Canyon upgrades, upgrades in the Owens Valley, and new substations and six network transmission lines in the southern Nevada-Los Angeles area corridor. Case B2 assesses how much additional transmission is needed during a southern California 1-in-10 year peak to mitigate identified reliability criteria violations assuming 33% RPS goals are met but without predetermining or stressing path flows.

Case C incorporates forecast expected summer weather peak loads (50/50) for year 2020. Case C1 assumes that major RETI upgrades are built including GPN, Midpoint-Devers-Valley, Tehachapi Segments 1-11, the Haskell Canyon upgrades, upgrades in the Owens Valley, and new substations in the southern Nevada-Los Angeles corridor looped into existing transmission lines owned by LADWP and SCE. Case C2 is designed to assess the capability of the existing grid (including the upgrades included in Case C1) and to lay a foundation for identifying the first set of transmission elements that mitigate reliability criteria violations that arise with increasing amounts of renewable resources. This is accomplished by determining the amount and location of renewable resources that can be connected without violating Category A and B reliability criteria under an expected summer peak case. Case C2 identified certain Category C reliability criteria violations and further study is required to identify suitable mitigation, such as controlled load drop and/or generator tripping, for these conditions.

The identification of grid upgrades starts with snapshot analysis of grid performance under system conditions which, based on experience, can result in reliability criteria violations. Peak load contingency analysis is one such condition and is studied in the A, B and C cases. Other system conditions need to be studied and some of these are already in progress (e.g., light load conditions). The initial phase of the CTPG's analysis is focusing on *transmission upgrades* that mitigate identified reliability criteria violations with increased renewable resource development. Future phases of the CTPG's work will consider *other alternatives* for mitigating identified reliability criteria violations. These may include different transmission upgrades, remedial action schemes that trip generation and/or load, generation redispatch, higher levels of distributed generation, and larger impacts from demand side programs.

NERC Standards TPL-001 through -003 requires that the transmission system be "planned such that the Network can be operated to supply projected customer demands and projected Firm (non-recallable reserved) Transmission Services, at all demand levels over the range of forecast system demands". For the initial phase of the CTPG work, on- and off-peak studies were conducted to help frame system needs while accommodating increased renewable resource development. In evaluating the performance of the transmission system with increased levels of renewable resources, it is important to understand and prepare for what happens under adverse system conditions, as well as during expected system conditions. Adverse conditions include high load hours when solar output will be at high levels. Adverse conditions may also occur during lower load hours when wind generation is high but the amount of on-line dispatchable generation is relatively low.

An analysis of different scenarios beyond those already in progress would be useful in examining the range of potential transmission additions and other mitigation measures that would support attainment of California's various environmental objectives (33% RPS, greenhouse gas emission reduction, elimination of coastal fossil-fired once-through cooling units). Scenarios involving higher levels and different locations of new renewable resources will likely result in the identification of a different set of transmission additions than are presented in this report. For this reason the CTPG will work with stakeholders to gather input to define the next study iterations.

3 General Guidelines and Criteria

CTPG conducted contingency-based power flow analysis for the cases described in the previous section. The General Electric Positive Sequence Load Flow program (GE-PSLF) was used in conjunction with in-house Engineer Programming Control Language (EPCL) routines to help analyze the study results.

3.1 Reliability Criteria

The criteria provides a framework from which computer simulation studies were performed to model future system conditions and evaluate the system performance. With the exception of the

Reactive Margin Adequacy test, the following standards were used for reliability assessments and standards compliance. The CTPG study team did not apply the Reactive Margin Adequacy test since this is intended for purposes of establishing path ratings and is therefore outside the scope of CTPG's current work. Table 2 provides a summary of the contingency analysis and criteria that were applied for purposes of the initial phase of CTPG's work.

1. NERC Reliability Standards
    - TPL-001: System Performance Under Normal Conditions
    - TPL-002: System Performance Following Loss of a Single BES Element
    - TPL-003: System Performance Following Loss of Two or More BES Elements
        - Due to the nature of this study, TPL-003 was not fully applied in some instances. The violations are noted and these violations will be further evaluated and mitigated either by transmission additions or non-wire solutions.
2. WECC
    - Reliability Criteria For Transmission System Planning
    - Voltage Stability Criteria, Under voltage Load Shedding Strategy, and Reactive Power Reserve Monitoring Methodology
3. Each member's Specific Local Planning Criteria

Table 2: Contingency Analysis and Criteria

Contingency Analysis	Criteria
Power Flow Contingency Analysis	• For Cases A and B all transmission lines in California • For Case C, transmission lines in California operated at 500 and 230 kV • Selected external major transmission lines/paths • N-2 contingencies
Transient Stability Analysis (Three-phase Fault at / Outage)	• N-1 and N-2 contingencies • WECC criteria
Voltage Stability Analysis	• For Cases A and B, all transmission buses in California were studied, monitored and reported • For Case C, all 500 kV and 230 kV buses in California were studied, monitored and reported • WECC voltage stability criteria (5% for N-1, 10% for N-2) • 7% N-1 voltage drop permitted for SCE buses

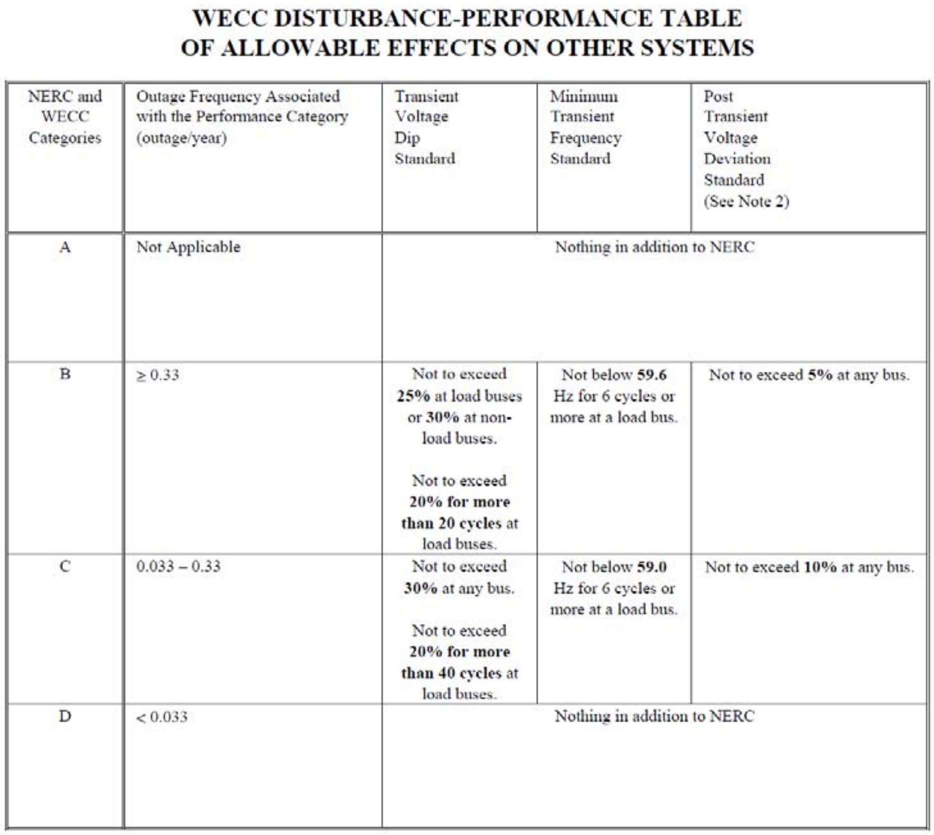
3.2 Power Flow Contingency Analysis Guidelines

Power flow contingency analysis was performed for each scenario consistent with the standards referenced in the previous section to identify thermal overload conditions. Section 11: Appendix 1 Contingencies, provides the list of contingencies included in the analysis. Note that additional contingencies may have been added based upon engineering judgment for particular runs.

3.3 Transient Stability Analysis Guidelines

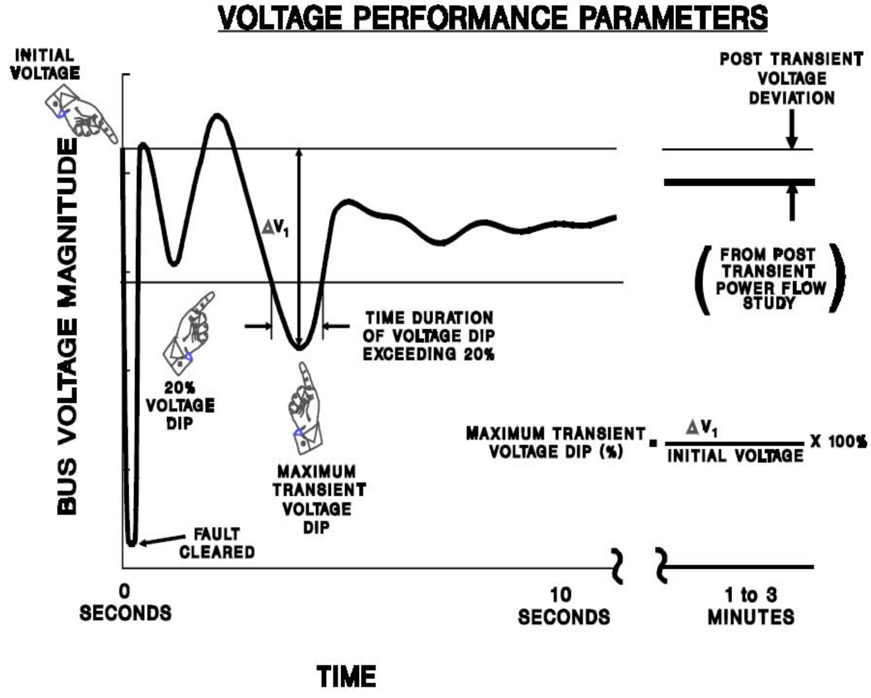
Stability studies were performed to establish stability transfer limits and ensure system stability following a critical fault on the system and to facilitate the development of the dynamic voltage support requirements, if required.

- Machine Representation
    - For the stability analysis, resources consistent with the time period studied were dispatched to meet the load requirements in the base cases. Representation of turbine generators was consistent with available turbine generator data. The base case power system stabilizers that are normally in-service within the WECC system were modeled for the Heavy Summer operating period studied. For new generator technologies that do not yet have specific representations, the study group made reasonable assumptions and chose the closest existing generator representation.
- Load Representation
    - Studies were conducted with at least 20% of the total load represented in the WECC system as induction motor load.
- System Disturbances
    - All N-1 and credible N-2 system disturbances were simulated.
- Fault Clearing Time
    - Faults on the transmission lines being evaluated were cleared in accordance with guidelines provided by the facility owners.
- Under frequency Load-Shedding Simulated
    - The frequency was monitored at key buses. If any stability run causes the frequency to drop sufficiently such that relays will “pick up”, the under frequency load-shedding data was reviewed and updated as necessary.
- Series Capacitors
    - Series capacitor modeling during transient conditions is indicated by the attached switching sequences.
- Unit Tripping
    - Unit tripping of other utility generation and pumping loads on under-frequency were modeled in accordance with WECC guidelines or those provided by the appropriate facility owner.
- Generator Voltage Ride Through
    - Generator voltage ride through as per the WECC regional standard.
- Evidence of System Stability: The following WECC Disturbance-Performance criteria were used:



WECC DISTURBANCE-PERFORMANCE TABLE OF ALLOWABLE EFFECTS ON OTHER SYSTEMS

NERC and WECC Categories	Outage Frequency Associated with the Performance Category (outage/year)	Transient Voltage Dip Standard	Minimum Transient Frequency Standard	Post Transient Voltage Deviation Standard (See Note 2)
A	Not Applicable	Nothing in addition to NERC		
B	≥ 0.33	Not to exceed **25%** at load buses or **30%** at non-load buses. Not to exceed **20% for more than 20 cycles** at load buses.	Not below **59.6** Hz for 6 cycles or more at a load bus.	Not to exceed **5%** at any bus.
C	0.033 – 0.33	Not to exceed **30%** at any bus. Not to exceed **20% for more than 40 cycles** at load buses.	Not below **59.0** Hz for 6 cycles or more at a load bus.	Not to exceed **10%** at any bus.
D	< 0.033	Nothing in addition to NERC		



3.4 Voltage Stability Analysis Guidelines

Post-transient studies were performed to ensure the WECC Voltage Stability Criteria was met following credible outages within the system. Certain contingencies may activate Remedial Action Schemes (RAS)/Special Protection Schemes (SPS) which will be included in the switching sequences as appropriate. See section 11: Appendix 1 Contingencies, for a list of the contingencies analyzed. The post-transient voltage deviations shall meet the WECC/NERC Planning Standards except for SCE area which allows 7% voltage drop for N-1 contingencies.

The following assumptions apply to post-transient voltage stability studies:

- All loads were modeled as constant MVA during the first few minutes following an outage or disturbance.
- Remedial actions such as generator dropping, load shedding and blocking of automatic generation control (AGC) were considered as appropriate.
- Shunt capacitors (132 MVAR) at Adelanto and Marketplace were used if the post-transient voltage deviation exceeds 5% at those buses. Although modeled as shunt capacitors the actual devices are automatically controlled SVCs.
- Shunt capacitors in the SCE service area were modeled according to the SCE Centralized Grid Capacitor Control to be provided by SCE.
- All automatic switching was allowed if the switching action could be completed within the post-transient study time frame.

4 Input Assumptions

This section describes the input assumptions to this transmission plan including CTPG's renewable energy planning target (net short), peak demands, renewable generation portfolios, baseline grid configuration, and selected elements of the RETI Phase 2A conceptual transmission plan.

4.1 CTPG's 2020 Renewable Energy Planning Target (Net Short)

Using the 2020 energy forecast of the CEC's 2009 Integrated Energy Policy Report (IEPR), an estimated 289,697 GWh of retail load in the state of California would be subject to the state's renewable goal. Assuming a 33% goal in year 2020, load serving entities would be required to obtain a total of 95,600 GWh of renewable energy in order to meet the target.

Members of CTPG that are responsible for supplying most of California's retail loads provided the CTPG study team with a planned renewable resource addition scenario or scenarios. These scenarios included additions and purchases that support the entities' respective plans for meeting renewable energy goals and/or greenhouse gas emission reduction targets by the year 2020. Table 3 lists the load serving entities that provided the requested information, those load serving entities for which no information on planned renewable resource additions/purchases was modeled, and the respective year 2020 forecast retail sales for all of these entities.

Table 3: California Load Serving Entities (LSEs) Renewable Resource Additions and Year 2020 Retail Sales

California LSEs Providing Planned Renewable Resource Additions		California LSEs for which Planned Renewable Resource Additions were either not known by CTPG or could not be Modeled *	
Name	Forecast Year 2020 Retail Sales** (GWh)	Name	Forecast Year 2020 Retail Sales** (GWh)
PG&E on behalf of bundled customers	91,010	Calaveras Public Power Agency	30
SMUD	12,079	City of Alameda	483
Turlock Irrigation District	2,302	City of Biggs	20
SCE on behalf of bundled customers	90,126	City of Gridley	42
LADWP	26,365	City of Healdsburg	76
Glendale	1,149	City of Lodi	527
Burbank	1,213	City of Lompoc	151
SDG&E on behalf of bundled customers	19,927	City of Palo Alto	1,072
Imperial Irrigation District	4,280	City of Redding***	1,012
		City of Roseville	1,487
		City of San Francisco	941
		City of Shasta Lake	193
		City of Ukiah	133
		Lassen Municipal Utility District	153
		Merced Irrigation District	473
		Modesto Irrigation District***	2,897
		Suppliers for direct access customers in the PG&E service territory	5,603
		Plumas-Sierra Rural Electric Cooperative	172
		Port of Oakland	54
		Port of Stockton	14
		Power and Water Resource Purchasing Authority	370
		Silicon Valley Power***	3,082
		Tuolumne County Public Power Agency	29
		Anza Electric Cooperative, Inc.	62
		Bear Valley Electric Service	176
		Boulder City/Parker Davis	137
		City of Anaheim	2,819
		City of Azusa	267
		City of Banning	184
		City of Cerritos	48
		City of Colton	413
		City of Rancho Cucamonga	67
		City of Riverside	2,531
		City of Vernon	1,249
		Moreno Valley Utilities	65
		Suppliers for direct access customers in the SCE service territory	7,869

California LSEs Providing Planned Renewable Resource Additions		**California LSEs for which Planned Renewable Resource Additions were either not known by CTPG or could not be Modeled ***	
Name	Forecast Year 2020 Retail Sales** (GWh)	Name	Forecast Year 2020 Retail Sales** (GWh)
		Valley Electric Association, Inc.	7
		Victorville Municipal	32
		City of Pasadena	1,266
		Suppliers for direct access customers in the SDG&E service territory	3,175
		City of Needles	58
		Mountain Utilities	4
		PacifiCorp	916
		Sierra Pacific Power Company	536
		Surprise Valley Electrical Corporation	92
		Trinity Public Utility District	99
		Truckee-Donner Public Utility District	163
Total	**248,450**	**Total**	**41,247**
Grand Total			**289,697**

[*] It is assumed that the Central Valley Project (3,320 GWh of forecast load in year 2020), Metropolitan Water District (1,507 GWh of forecast load in year 2020) and California Department of Water Resources (8,729 GWh of forecast load in year 2020) are exempt from California's renewable resource goals.

[**] From the California Energy Commission's 2009 Integrated Energy Policy Report (IEPR) adopted on December 2, 2009. See Form 1.1c, "California Energy Demand 2009-2020 Staff Revised Forecast, Electricity Deliveries to End Users by Agency."

***These load serving entities provided renewable resource addition information, in aggregate, to TANC. TANC is a member of the CTPG.

Based on forecast retail sales for year 2020 (see Table 3 above), the CTPG modeled data concerning planned renewable resource additions/purchases for load serving entities representing approximately 86% of the load served by entities subject to California's renewable resource goals. The load serving entities providing renewable data to CTPG that could be modeled have identified a total of 55,535 GWh of additional renewable resources/purchases by year 2020. Including existing renewable resources and RETI's miscellaneous renewable resource additions, the CTPG is planning for a minimum of 97,529 GWh of renewable energy production in year 2020.

If the load serving entities for which CTPG does not currently have planned renewable resource additions/purchases, or for which CTPG was unable to model the provided renewable resource additions (representing 14% of California's retail load), do in fact intend to add renewable resources not already reflected in CTPG's modeling, it will be necessary to plan for a larger amount of renewable generation in year 2020.

Table 4 compares CTPG's estimated renewable energy production to support California's 33% goal with the RETI Phase 2A calculation. Renewable generation reported in the CEC's 2008 Net System Power Report, together with estimated renewable generation from renewable generators added and expected to be added by the end of 2009, totals 39,324 GWh. An interim estimate developed by RETI indicated that there will be 2,670 GWh of miscellaneous renewable resource additions added by year 2020 that is unlikely to require any new transmission facilities (e.g. digester and landfill gas, small hydro).[1]

The CTPG assumes that California's 33% RPS goals apply to all load serving entities supplying retail loads in the state of California. Loads in California served by CDWR, MWD and WAPA are excluded. In contrast, it appears RETI excludes "OTHER" California retail loads in calculating California's "net short." The California retail loads excluded by RETI are those served by the City of Needles, Mountain Utilities, PacifiCorp, Sierra Pacific Power Company, Surprise Valley Electrical Corporation, Trinity Public Utility District and the Truckee-Donner Public Utility District. The CEC forecasts that these retail loads will total 1,869 GWh in year 2020.

In calculating California's renewable net short, CTPG used the CEC's forecast of rooftop solar photovoltaic penetration for year 2020 (3,218 GWh). RETI adopted a considerably higher estimate for rooftop solar (7,358 GWh).

Also, in calculating California's renewable net short, CTPG uses an interim RETI estimate for miscellaneous renewable resource additions (digester, landfill gas and small hydro) (2,670 GWh). RETI has recently determined that this interim estimate contains an error and is now recommending that the RETI stakeholder steering committee adopt a miscellaneous renewable resource addition forecast for year 2020 totaling 1,862 GWh. RETI may also be recommending that the RETI stakeholder steering committee adopt other changes to California's net short calculation, namely updates to the amount of renewable generation that existing and under construction renewables will provide in year 2020. CTPG will consult with RETI for changes to the net short calculation for future studies.

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[1] As noted below, CTPG understands RETI is reevaluating this estimate and CTPG plans to update this number to match what RETI adopts.

Table 4: CTPG 2020 Planning Target (Net Short)

	CTPG (GWh)	RETI Phase 2A (GWh)
Forecast Retail Load subject to California's renewable goals:	289,697	301,974
Renewable Portfolio Standard (RPS) Goal:	33%	33%
Renewable Portfolio Standard (RPS) Energy Requirement:	**95,600**	**99,651**
Existing and New Renewables expected to be on line by end of 2009:	39,324	36,807
Miscellaneous renewable resource additions:	2,670	3,134
	41,995	**39,941**
Net Short:	**53,605**	**59,710**
Identified Renewable Resource Additions:	55,535	95,536*
Total Renewable Energy Production:	**97,529**	**135,477***
Identified Renewable Energy as a Fraction of Retail Sales:	**33.70%**	**44.9%***

*For purposes of developing a conceptual transmission plan that addresses uncertainties in the location of renewable resource development, RETI planned for renewable resource additions equal to approximately 1.6 times the RETI net short.

4.2 Peak Demand

Load serving entities listed on Table 5 provided peak demand forecasts for their respective service territories to be used in the simulations. Table 5 provides for each area the 1-in-2 and 1-in-10 year peak demand forecasts for year 2020.

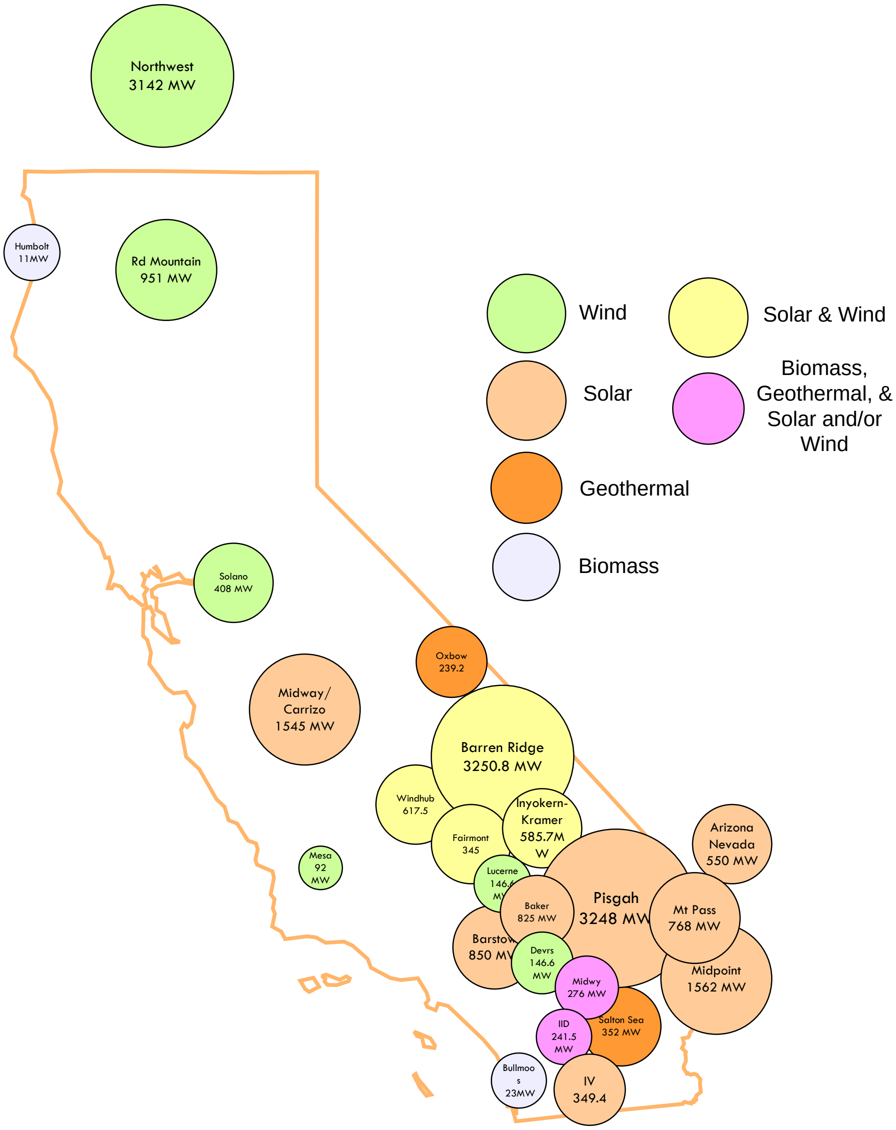
Table 5: Year 2020 Peak Demand

Area	PEAK DEMAND (MW)	
	1-in-2-year	1-in-10-year
SDG&E	4,913	5,374
LADWP*	6,293	6,816
IID	1,246	1,280
SCE**	25,573	27,540
PG&E**	26,168	27,221
SMUD	3,182	3,634
TID	683	700
Total	**68,058**	**72,565**

4.3 Renewable Generation Portfolios

As discussed above, load serving entities supplying the majority of California retail loads provided renewable procurement scenarios reflecting anticipated plans, installed capacity, and in some cases the expected renewable dispatch at time of peak. In other cases CTPG used generic factors to relate nameplate capacity to expected renewable dispatch for the hour of study (e.g., peak hour, off-peak hour). These generic factors were from RETI's CREZ- and technology-specific hourly/monthly renewable energy output profiles. These hourly/monthly output profiles were also employed to determine the annual capacity factors used to estimate CREZ- and technology-specific renewable energy generation in year 2020. Rooftop PV and other distribution-level generation were considered as a reduction to load. Figure 3 shows the resulting installed renewable capacity by area.

Figure 3: CTPG Renewable Generation



The renewable procurement scenarios upon which CTPG's initial study work is based reflect a quantity and pattern of renewable resource development that is not the same as that used by RETI to develop RETI's Phase 2A conceptual transmission plan (see Table 6). These procurement plans -- which to a significant degree are based on signed Power Purchase Agreements (PPAs) -- suggest that the actual quantities, mix and location of renewable resource additions may be significantly different than what was developed by RETI.[2]

Table 6: CTPG Renewable Generation Comparison to RETI

	CTPG		RETI*	
Location (Region/CREZ)	**Installed Capacity (MW)**	**Identified Annual Renewable Energy Production (GWh)**	**Maximum Potential Installed Capacity adjusted for success rate (MW)**	**Identified Potential Annual Renewable Energy Production adjusted for success rate (GWh)**
British Columbia	0	0	340	1849
Washington	963	2594	0	0
Montana	413	1111	N/A	N/A
Idaho	130	350	N/A	N/A
Oregon	1637	4408	392	3062
Round Mountain-A	0	0	101	710
Round Mountain-B	78	319	49	196
Lassen North	873	2262	387	999
Lassen South	0	0	108	292
Nevada N	0	0	115	822
Nevada C	239	1886	352	2624
Nevada S	217	502	N/A	N/A
Owens Valley	0	0	370	954
Inyokern	242	467	642	1669
Kramer	344	988	1693	4370
Mountain Pass	768	1777	438	1145
San Bernardino – Baker	825	1870	969	2299
Barstow	850	1985	617	1546
Pisgah	3248	7763	673	1658
San Bernardino – Lucerne	174	560	800	2150
Twenty-nine Palms	0	0	477	1219
Victorville	0	0	432	1128
Tehachapi	3868	10189	5514	15716
Fairmont	345	862	929	2734
Needles	0	0	122	313
Iron Mountain	0	0	1297	3065
Arizona	333	740	0	0

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[2] Not all entities serving retail loads in California that are subject to California's renewable resource goals supplied renewable procurement plans to CTPG. Table 3 lists those load serving entities that supplied renewable procurement plans to CTPG, and those that did not.

	CTPG		**RETI***	
Location (Region/CREZ)	**Installed Capacity (MW)**	**Identified Annual Renewable Energy Production (GWh)**	**Maximum Potential Installed Capacity adjusted for success rate (MW)**	**Identified Potential Annual Renewable Energy Production adjusted for success rate (GWh)**
Riverside East	1562	3471	2785	6725
Palm Springs	147	500	203	685
Imperial North-A	352	2775	1370	10626
Imperial North-B	*386*	*1843*	483	1190
Imperial South	*466*	*1091*	981	2420
Imperial East	15	43	429	1045
Baja-B (Santa Catarina)	0	0	2632	8931
Baja-A (La Rumorosa)	0	0	2368	8035
San Diego South	0	0	179	508
San Diego North Central	0	0	74	195
San Diego	23	171	N/A	N/A
Humboldt	11	82	N/A	N/A
Solano	408	1248	236	756
Cuyama	0	0	211	471
Carrizo North	0	0	422	896
Carrizo South	1545	3429	1024	2197
Santa Barbara	92	249	114	312
Total	**20553**	**55535**	**30327**	***95536***

* For purposes of developing a conceptual transmission plan that addresses uncertainties in the location of renewable resource development, RETI planned for renewable resource additions equal to approximately 1.6 times the RETI net short.

The RETI data was developed at the direction of the RETI Stakeholder Steering Committee and reflects: (1) RETI's Phase 2A identified renewable "net short," (2) the desire of utilizing, on a comparable basis, all of the identified CREZs to meet the "net short", and (3) the RETI Stakeholder Steering Committee's decision to adjust the RETI-identified economically feasible renewable resource development potential to approximate a 1.6 times the RETI "net short" quantity of renewable energy. According to RETI, this adjustment is a "success factor" adjustment. CTPG did not adjust or modify any of the reported RETI data. As described above, the CTPG renewable resource data was supplied by load serving members of the CTPG.

CTPG assumed that load serving entities' renewable procurement plans are a better indicator of the amount, type and location of renewable resource additions that will actually get built than are RETI's estimates. Note that RETI developed its estimates based on economically feasible renewable development potential, not on actual commercial interest in that potential. In addition RETI arbitrarily limited its consideration of out-of-state renewable resource development potential to British Columbia, Washington, Oregon, Nevada, Arizona and Baja. As is evident from the data collected by the CTPG, California load serving entities' plans to add renewable resources also include the states of Idaho and Montana.

4.4 Grid configuration

The studies were performed using the latest available data for the WECC interconnected system for the 2020 time frame being studied which at this time is WECC's 2019 Heavy Summer case. A WECC full-loop representation was used; and includes the Western United States, Western Canada and the system of Comisión Federal de Electricidad (CFE) of Baja California, Mexico.

Table 7 lists the major transmission upgrades in the 2019 WECC Base Case that were assumed in-service for all CTPG cases in this study.

Table 7: Transmission Upgrades included in the 2019 "Heavy Summer" Seed Case

Transmission Upgrades with Key Regulatory Approvals and Environmental Permits	Transmission Upgrades without Key Regulatory Approvals and Environmental Permits
Tehachapi Segments 1-3	New Colorado River ("Midpoint") 500 kV substation looping in existing 500 kV Palo Verde-Devers #1 line.
	500 kV Colorado River-Devers #2 line
	500 kV Devers-Valley #2 line
Sunrise Powerlink project	500 kV Green Path North project. Includes new Indian Hills 500/230 kV substation, new 500 kV Indian Hills-Devers #1 line, and new 230 kV Coachella Valley-Indian Hills #1, #2 lines (each line rated at 800 MVA normal).
Tehachapi Segments 4-11	Expand Barren Ridge 230 kV substation. Upgrade existing 230 kV Owens Gorge-Rinaldi line from Barren Ridge to Haskell Canyon with double circuit 230 kV towers. Add Barren Ridge-Haskell Canyon #2 line on open side of towers
	Upgrade existing 230 kV Owens Gorge-Rinaldi line from Haskell Canyon to Rinaldi
	Add 230 kV Castaic-Haskell Canyon #2 line on open side of towers
	Loop existing 230 kV Coachella Valley-Devers line into Mirage substation creating 230 kV Mirage-Devers #2 line.
	Reconductor 230 kV Mirage-Devers #2 line from 393 MVA to 494 MVA.

5 Methodology

5.1 General Methodology

The studies that form the basis for this report were performed using the same general methodology as follows:

Step 0: Develop Benchmark Base Case:

- Reflect the 2020 transmission system configuration for each scenario
- WECC 2019 Heavy Summer case as seed case
- Update California peak demand according to the scenario
- A0 case: Maximize North-to-South power transfers on COI and Path 26
- Perform detailed contingency analysis to meet reliability criteria

Step 1: Add Renewable Projects, at 0 MW Output

- Modify grid to provide CREZ connections
- A1 and B1 cases: add major projects from RETI conceptual transmission plan (e.g. GPN, Midpoint-Devers-Valley, Tehachapi Segments 1-11, the Haskell Canyon upgrades, upgrades in the Owens Valley, and new substations and six network transmission lines in the southern Nevada-Los Angeles area corridor)
- Case C1: add selected RETI upgrades (e.g. GPN, Midpoint-Devers-Valley, Tehachapi Segments 1-11, the Haskell Canyon upgrades, upgrades in the Owens Valley, and new substations in the southern Nevada-Los Angeles corridor looped into existing transmission lines owned by LADWP and SCE)
- Perform detailed contingency analysis to meet reliability criteria

Step 3: Dispatch renewable generation in increments offset by equal decrements of fossil generation

- Perform detailed contingency analysis to meet reliability criteria
- Identify and review limiting constraints or violations
- Identify transmission upgrades that mitigate reliability criteria violations

5.2 Contingency analysis

CTPG is conducting contingency-based power flow analysis for potentially adverse system conditions. Transformers and transmission lines within California were monitored for thermal violations and buses within California were monitored for voltage violations (steady-state and delta-V) with WECC Category B and C contingencies applied.

Where contingencies reveal reliability criteria violations, potential mitigation alternatives need to be identified. These mitigation alternatives can include different CREZ connection schemes, different transmission upgrades, remedial action schemes that trip generation and/or load for given contingency conditions[3], pre-contingency generation redispatch, increased levels of distributed generation, greater reliance on demand side programs, different locations and patterns of renewable resource additions, and possibly new generation at strategic locations. The choice of which option best addresses the identified reliability criteria violation is dependent on many factors including but not limited to: alternative cost, technical feasibility and operational flexibility. Phase 1 of CTPG's work focused on identifying transmission infrastructure additions that would mitigate the identified Category B, and in some cases Category C, reliability criteria violations found in cases A, B, C and L. Future phases of CTPG's work will identify mitigation for all identified Category C reliability criteria violations and will evaluate the technical feasibility and economic competitiveness of other mitigation alternatives.

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[3] For more detail on the option of tripping generation, see CTPG's response to comments submitted to CTPG by the Bay Area Municipal Transmission Group following the CTPG's December 17, 2009 stakeholder meeting.

5.3 Generation Dispatch

To accommodate the output of new renewable generators dispatched in the 2020 power flow cases, it is necessary to reduce the output of fossil-fired generators by corresponding amounts. To accomplish this, fossil-fired generation was reduced in blocks, equal to the increments of renewable generation. A 70/30 split between California fossil generation and other WECC fossil generation was used. Fossil generation was decremented in a merit-order fashion (least economic reduced first). This merit order was established through the use of heat rate data obtained from the WECC Transmission Expansion Planning & Policy Committee's (TEPPC's) 2017 economic database.

Table 8 shows an example of the fossil generation decremented for the first block of renewable generation. Units in the next block are decremented equally until all units in the block are turned off. Decrements below minimum output level are not allowed; i.e., the unit is turned off. The units in the next block are then reduced in the same fashion. Nuclear and hydro units are not decremented in the summer peak cases.

Table 8: Fossil Generation Decrement Example - First Block

Internal (California)			
Name	**Unit**	**Nameplate (MW)**	**FL H.R. (mmBtu/MWh)**
Mandalay	3	130	16.065
Ellwood	1	54	15.125
Olive	1	44	13.953
Long Beach	1	65	13.106
Long Beach	2	65	13.106
Long Beach	3	65	13.106
Long Beach	4	65	13.106
RAMCO OY	1	42	13.009
Grayson	8b	70	13.009
Goose	2	48	13.009
Lambie	1	48	13.009
	Total	**695 MW**	

External			
Name	**Unit**	**Nameplate (MW)**	**FL H.R. (mmBtu/MWh)**
Ocotillo GT1	1	56	14
Ocotillo GT2	1	56	14
Yucca CT1	1	19	14
Yucca CT2	1	19	14
WPhx GT1	1	56	14
WPhx GT2	1	56	14
Reeves	1	40	13.613
	Total	**302 MW**	

CTPG understands that this is just one of many possible redispatch alternatives. CTPG also expects to perform additional analyses in this area based on stakeholder input.

6 Results

6.1 Case A

The purpose of Case A was to identify transmission alternatives under 1 in 1o peak load conditions in northern California that will mitigate reliability criteria violations that may appear for one potential scenario in which enough new renewable generation is added to meet California's RPS goals. As discussed elsewhere in this report, other resource procurement scenarios could result in a different set of criteria violations that could result in the identification of additional transmission facilities in northern California that would mitigate those violations. Also, sensitivities to major WECC path flows, in both magnitude and direction, were examined to determine potential transmission additions that will mitigate reliability criteria violations that may appear with the addition of enough new renewable generation to meet California's RPS goals and with assumed fossil-fired dispatch patterns that would give rise to such path flows.

Two north to south (N-S) sensitivities were developed. Initially, both N-S cases stressed COI and Path 26 to their respective limits, 4800 and 3700 MW prior to the CREZ energy dispatch. However, the fossil-fired redispatch differed in each case. In one case, (Case AI[4]) both COI and Path 26 flows were held constant at their maximum ratings. In the other case, the intertie flows were allowed to change based on the redispatch methodology described in Section 5.3.

Additionally, a south to north (S-N) Case A was developed to investigate grid impacts due to renewable energy delivery during S-N flows on Path 15 and Path 26. Due to the significant overloads on Path 15, a further sensitivity was performed assuming the addition of a new 500 kV transmission facility from the Bay Area to Gregg.

Table 9: Comparison of Major Inter-tie and Intra-tie Flows for A0, A1, A2, and A2-PGE Cases

Path Name	Current Rating (MW)	A0 Case (MW)	A1 Case (MW)	A2I Case (MW)	A2- Case (MW)
COI	4800	4800	4800	4,800	4,028
Path 15	3265 (N-S) 5400 (S-N)	-860(S-N)	-860(S-N)	110 (S-N)	2,054 (S-N)
Path 26	4000 (N-S) 3000 (S-N)	3,700(N-S)	3,700(N-S)	3,700 (N-S)	1,684 (N-S)
EOR	9300	5,845	5,845	4,533	3,308
WOR	10623	7,837	7,837	7,763	6,249
PDCI	3100	3,100	3,100	3,100	3,100
IPP DC	2400	1,850	1,850	1,850	1,850

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[4] "I" designates constant interchange

Table 10: Comparison of Major Inter-tie and Intra-tie Flows for A0SN, A1SN, A2SN, and A2SN-TEWA Cases

Path Name	Current Rating (MW)	A0SN Case (MW)	A1SN Case (MW)	A2SN Case (MW)	A2SN-TEWA Case (MW)
COI	4800	1,000	1,000	345	345
Path 15	3265 (N-S) 5400 (S-N)	5,400(S-N)	5,400(S-N)	8,480 (S-N)	8,500 (S-N)
Path 26	4000 (N-S) 3000 (S-N)	-2,458(N-S)	-2,458(N-S)	-4,350 (N-S)	-4,370 (N-S)
EOR	9300	4,750	4,750	3,411	3,423
WOR	10623	4,880	4,880	3,810	3,815
PDCI	3100	-600	-600	-600	-600
IPP DC	2400	1,850	1,850	1,850	1,850

6.1.1 Grid Configuration

In setting up Cases A1 and B1, changes to the grid configuration included in the 2019 WECC "Heavy Summer" seed case described in Section 4.4 were made to connect the RETI-identified Competitive Renewable Energy Zones (CREZs) to the network. These CREZ connections are described on Table 11.

The renewable resource connection schemes described in Table 11 (Cases A1 and B1) and in Table 30 (Case C) differ only in the way renewable resources in the Mountain Pass, Baker, Barstow and Pisgah CREZs are connected to the grid. Table 11 and Table 30 both reflect the construction of new 500 kV substations, including the Mountain Pass, Baker, Barstow and Pisgah 500 kV substations. And both Table 11 and Table 30 reflect the loop-in of SCE's existing 500 kV Mohave-Lugo line into the new Pisgah substation.

Table 11 connects renewable resources in these CREZs by assuming the addition of the following network upgrades: 500 kV Mountain Pass-El Dorado #1 line, 500 kV Mountain Pass-Baker #1 line, construction of a Mountain Pass2 287 kV substation looping in the existing 287 kV Mead-Victorville #1 line, 500 kV Baker-Barstow #1 line, 500 kV Barstow-Kramer #1 line, 500 kV Pisgah-Barstow #1 line and 500 kV Barstow-Lugo #1 line. Table 30, on the other hand connects renewables in these CREZs by looping the Mountain Pass, Baker and Barstow substations into LADWP's existing LA 500 kV Marketplace-Adelanto line, and by looping the new Pisgah substation into both SCE's existing 500 kV Mohave-Lugo line and SCE's existing 500 kV El Dorado-Lugo line.

Note that the Case C2 analysis suggests that the addition of a new 500 kV Pisgah-Mira Loma #1 line or, alternatively, the addition of a new 500 kV Pisgah-Barstow-Kramer line, would mitigate reliability criteria violations that arise with increasing levels of renewable resource development in the Pisgah CREZ.

Table 11: Case A1 and B1 - Grid Configuration Changes to enable CREZ Network Connection

CREZ/Renewable Development Area		
Location	**CTPG-Identified Renewable Resource Additions: Installed Capacity (MW)**	**Grid Configuration Change**
Washington	963	Connect renewables to existing McNary 500 kV bus
Montana	103.5	Connect renewables to existing South Cutbank 115 kV bus
	309	Connect renewables to existing Great Falls 230 kV bus
Idaho	130	Connect renewables to existing Goshen 345 kV bus
Oregon	573.6	Connect renewables to existing Malin 500 kV bus
	1063	Connect renewables to existing Grizzly 500 kV bus
Round Mountain-B	78	Connect renewables to existing Round Mountain 500 kV bus
Round Mountain-A	0	N/A
Lassen South	0	N/A
Lassen North	873	Build new Raven 500 kV substation Build 500 kV Raven-Round Mountain #1 line Connect renewables to new Raven 500 kV substation
Humboldt	11	Connect renewables to existing Humboldt 115 kV bus
Solano	408	Build new Solano 500 kV substation Build 500 kV Solano-Vaca Dixon #1 line Connect renewables to new Solano 500 kV bus
Cuyama	0	N/A
Carrizo North	0	N/A
Carrizo South	1545	Build new 230 kV Carrizo substation looping in existing 230 kV Morro Bay-Midway #1 and #2 lines Reconductor 230 kV Morro Bay-Midway #1 and #2 lines Reconductor 230 kV Morro Bay-Gates #1 line Connect renewables to new Carrizo 230 kV bus
Nevada N	0	N/A
Nevada C	120	Remove existing 115 kV Control-Inyokern #1 and #2 lines Build 230 kV Control-Inyokern #1 line Connect renewables to existing Control 230 kV bus via new radial 230 kV line

CREZ/Renewable Development Area		
Location	**CTPG-Identified Renewable Resource Additions: Installed Capacity (MW)**	**Grid Configuration Change**
	69.2	Connect renewables to existing Dixie Valley 230 kV bus ("Oxbow A")
	50	Connect renewables to existing Oxbow 230 kV bus ("Oxbow B") with radial 230 kV line
Nevada S	217	Connect renewables to existing Marketplace 500 kV bus
Owens Valley	0	N/A
Inyokern	242	Remove existing 115 kV Inyokern-Kramer #1 and #2 lines Add 230 kV capability at existing Inyokern substation Add 230 kV Inyokern-Kramer #1 and #2 lines on double-circuit towers
		Connect renewables to new Inyokern 230 kV bus
Kramer	343.7	Expand Kramer substation by adding 500 kV capability
		Connect renewables to existing Kramer 230 kV bus
Mountain Pass	358	Build new Mountain Pass 500 kV substation Build 500 kV Mountain Pass-El Dorado #1 line Build 500 kV Mountain Pass-Baker #1 line
		Connect renewables to new Mountain Pass 500 kV bus
	410	Build new Mountain Pass2 287 kV substation looping in existing 287 kV Mead-Victorville #1 line
		Connect renewables to new Mountain Pass2 287 kV substation
San Bernardino - Baker	825	Build new 500 kV Baker substation Build 500 kV Baker-Barstow #1 line
		Connect renewables to new Baker 500 kV bus
Barstow	850	Build new Barstow 500 kV substation Build 500 kV Barstow-Kramer #1 line Build 500 kV Barstow-Lugo #1 line
		Connect renewables to new Barstow 500 kV bus
Pisgah	3248	Build new Pisgah 500 kV substation looping in existing 500 kV Lugo-Mohave #1 line Build 500 kV Pisgah-Barstow #1 line Connect renewables to new Pisgah 500 kV bus
Victorville	0	N/A
San Bernardino - Lucerne	174	Build new Lucerne 500 kV substation Build 500 kV Lucerne-Lugo #1 line Connect renewables to new Lucerne 500 kV bus

CREZ/Renewable Development Area		
Location	**CTPG-Identified Renewable Resource Additions: Installed Capacity (MW)**	**Grid Configuration Change**
Twenty-nine Palms	0	N/A
Tehachapi	3250.8	Connect renewables to existing Barren Ridge 230 kV bus
	617.5	Connect renewables to new Windhub 230 kV bus added as part of Tehachapi Segments 4-11
Fairmont	345	Build new Fairmont 500 kV substation looping in existing 500 kV Adelanto-Rinaldi and 500 kV Victorville-Rinaldi lines Connect renewables to new Fairmont 500 kV bus
Arizona	333	Connect renewables to existing Westwing 500 kV bus
Riverside East	1562	Connect renewables to new Colorado River 500 kV bus
Needles	0	N/A
Iron Mountain	0	N/A
Palm Springs	146.6	Connect renewables to existing Devers 230 kV bus
Imperial North-A	352	Build new SS6 230 kV substation Build new 230 kV SS6-Midway #1 and #2 lines on double circuit towers Connect renewables to new SS6 230 kV bus
Imperial North-B	386	Connect renewables to existing Midway 230 kV bus
Imperial South	16.5	Connect renewables to existing Rockwood 92 kV bus
	100	Connect renewables to existing Dixieland 230 kV bus
	349.4	Connect renewables to existing Imperial Valley 230 kV bus
Imperial East	15	Connect renewables to existing Pilot Knob 92 kV bus
Baja-A (La Rumorosa)	0	N/A
Baja-B (Santa Catarina)	0	N/A
San Diego South	0	N/A
San Diego	23	Build new Bullmoose 13.8 kV substation connected radially to existing Border 69kV bus Connect renewables to new Bullmoose 13.8 kV bus
San Diego North Central	0	N/A
Santa Barbara	92	Connect renewables to PG&E's existing Mesa 230 kV bus
TOTAL	**20552.8**	

6.1.2 Power Flow Analysis

Power flows runs for case A0 and A1 revealed some overloaded transformers, located in SCE area, and some overloaded 70kV-115kV lines within the PG&E control area, as listed in Table 12: Normal overloads for Case A1, A2, and A2I.

6.1.2.1 (N-0) Normal Conditions

Table 12: Normal overloads for Case A1, A2, and A2I

								A1			A2I			A2		
FROM	KV	TO	KV	CK	RATE	UNIT	AR	MVA	AMPS	PCT	MVA	AMPS	PCT	MVA	AMPS	PCT
ARCO	70	TWISSLMN	70	#1	437	Amps	30	72.77	577.67	132%	72.9	581	133%	73.1	587	135%
ARCO	230	ARCO	70	#2	134	MVA	30	169.17	432.28	126%	169.2	434	126%	169.7	438	127%
TESLA	115	AEC_TP1	115	#1	631	Amps	30							154.7	761	121%
TX_LOSHL	70	NTPTRL	70	#1	437	Amps	30	58.88	506.21	116%	59.0	510	117%	59.1	516	118%
TWISSLMN	70	TX_LOSHL	70	#1	437	Amps	30	62.07	505.36	116%	62.2	509	117%	62.4	515	118%
CORCORAN	115	CORCORAN	70	#2	19	MVA	30	20.47	103.69	110%	20.4	103	109%	20.4	107	109%
SFWY_TP1	115	AEC_TP1	115	#1	743	Amps	30							152.2	762	103%
VIEJOSC	230	VIEJO66	66	#1	280	MVA	24				331.9	854	120%	317.6	811	115%
VIEJOSC	230	VIEJO66	66	#2	280	MVA	24				331.9	854	120%	317.6	811	115%
BARRE	230	LEWIS	230	#1	3000	Amps	24				1204.3	3172	106%			
LUGO	500	BARSTOW	500	#1	1899	Amps	24				1724.4	1916	101%			
MIRALOMA	500	PISGAH	500	#1	1899	Amps	24				1695.2	1900	100%			
VINCENT	230	VINCENT	500	#4	1120	MVA	24				1106.1	2816	100%			
JOHANNA	230.0	JOHANNA	66	#4	302	MVA	24	309.27	798.16	104%						
JOHANNA	230.0	JOHANNA	66	#3	302	MVA	24	306.17	790.18	103%						
ETIWANDA	66.0	ETIWANDA	230	#8	280	MVA	24	290.71	2445.34	102%						
CHINO	66.0	CHINO	230	#1	285	MVA	24	284.63	2459.17	102%						
CHINO	66.0	CHINO	230	#2	286	MVA	24	288.03	2422.80	101%						
NAVAJO	500.0	CRYSTAL	500	#1	1630	Amps	26	1557.70	1645.69	102%						

Table 13: Normal overloads for Case A1SN, A2SN, and A2SN-TEWA

FROM	KV	TO	KV	CK	AR	RATE	UNIT	A1SN			A2SN			A2SN-TEWA		
								AMPS	MVA	PCT	AMPS	MVA	PCT	MVA	AMPS	PCT
WARNERVL	230	COTTLE B	230	#1	30	675	Amps	No Overload			1104	444	164%	No Overload		
BELLOTA	230	COTTLE B	230	#1	30	675	Amps	No Overload			1044	420	155%	No Overload		
ARCO	70	TWISSLMN	70	#1	30	437	Amps	540.4	71	124%	540	71	124%	540	70	124%
ARCO	230	ARCO	70	#2	30	134	MVA	426.4	164	123%	432	165	123%	432	165	123%
BORDEN	230	GREGG	230	#1	30	675	Amps	No Overload			805	321	119%	794	315	118%
TEMPLETN	230	MORROBAY	230	#1	30	825	Amps	No Overload			932	372	113%	930	371	113%
WESTLEY	230	LOSBANOS	230	#1	30	1484	Amps	No Overload			1654	661	112%	1631	653	110%
TX_LOSHL	70	NTPTRL	70	#1	30	437	Amps	479.9	58	110%	480	58	110%	479	58	110%
TWISSLMN	70	TX_LOSHL	70	#1	30	437	Amps	479.0	61	110%	479	61	110%	478	61	110%
TESLA	115	AEC_TP1	115	#1	30	631	Amps	No Overload			670	136	106%	689	140	109%
HURLEY S	230	PROCTER	230	#1	30	801	Amps	No Overload			849	341	106%	No Overload		
CORCORAN	115	CORCORAN	70	#2	30	19	MVA	100.4	20	106%	102	20	106%	102	20	106%
GATES	500	MIDWAY	500	#1	30	2230	Amps	2222.2	2031	100%	2273	2029	103%	No Overload		
PANOCHEJ	115	HAMMONDS	115	#1	30	487	Amps	510.2	107	105%	No Overload			No Overload		
SCATERGD	230	OLYMPC	230	#2	26	876	Amps	1008	418	115%	No Overload			No Overload		
VIEJOSC	230	VIEJO66	66	#1	24	280	MVA	726	288	105%	731	286	104%	731	286	104%
VIEJOSC	230	VIEJO66	66	#2	24	280	MVA	726	288	105%	731	286	104%	731	286	104%
MIRAGE	230	JHINDSCE	230	#1	24	600	MVA	712	289	121%	No Overload			No Overload		
EISENHOW	115	TAMARISK	115	#1	24	592	MVA	601	123	102%	No Overload			No Overload		

6.1.3 Single Contingency Conditions

6.1.3.1 A0, A1 Cases

Table 14: N-1 Emergency Thermal Overload in A1 Case

Base case A1											
Contingency:	Overload Equipment										
	FROM BUS	KV	TO BUS	KV	ID	AREA	AMPS	MVA	RATING	UNIT	PERCENT
IV-N.Gila	BRANDOW	230	KYRENE	230	#1	14	1644.1	668.8	1600.0	Amps	102.76%

6.1.3.2 A2, A2-I, A2SN, and A2SN-TEWA Cases

Table 15: N-1 Emergency Thermal Overloads in A2 and A2-I Cases

Contingency:	Overload equipment							A2				A2I			
	FROM BUS	KV	TO BUS	KV	ID	Unit	AR	AMPS	MVA	RATE	PCT	AMPS	MVA	RATE	PCT
IV-N.Gila_CREZ	BARRE	230	ELLIS	230	#1	Amps	24	3236	1236	2480	130.46%	2945	1087	2480	118.76%
IV-Miguel 23050 SLO	BARRE	230	ELLIS	230	#1	Amps	24	3154	1205	2480	127.16%	2825	1043	2480	113.90%
IV-Miguel 23040 SLO	BARRE	230	ELLIS	230	#1	Amps	24	3141	1200	2480	126.64%	2835	1047	2480	114.32%
SONG 1G	BARRE	230	ELLIS	230	#1	Amps	24	2962	1140	2480	119.42%	2662	986	2480	107.33%
RM-TM #1 SLO	ROUND MT	500	TABLE MT	500	#2	Amps	30	No thermal overload				3336	3071	3281	101.70%

Table 16: N-1 Emergency Thermal Overload in A2SN and A2SN-TEWA Cases

Contingency:	Overload equipment								A2SN			A2SN + Tesla - Warn		
	FROM BUS	KV	TO BUS	KV	ID	Unit	AREA	RATING	AMPS	MVA	PCT	AMPS	MVA	PCT
SONGS 1G	BARRE	230	ELLIS	230	#1	Amps	24	2480	2559	983	103.17%	2558	983	103.16%
O'Banion - Sutter	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	1699	676	100.32%	No Overload		
	HURLEY S	230	PROCTER	230	#1	Amps	30	925	1103	439	119.37%	983	391	106.30%
PDCI SN Bipole	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	1702	694	100.63%	No Overload		
Moss Landing - Metcalf	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	1886	748	111.29%	1849	736	109.11%
Moss landing - Los Banos	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	1897	751	112.00%	1859	739	109.74%
Los Banos - Midway slo	GATES	500	MIDWAY	500	#1	Amps	30	3556	3569	3101	100.83%	No Overload		
	TEMPLETN	230	MORROBAY	230	#1	Amps	30	975	1015	400	104.12%	1008	398	103.39%
	HURLEY S	230	PROCTER	230	#1	Amps	30	925	963	384	104.23%	No Overload		
Los Banos - Gates #1	HURLEY S	230	PROCTER	230	#1	Amps	30	925	934	373	101.03%	No Overload		
IV-N.Gila	BARRE	230	ELLIS	230	#1	Amps	24	2480	2627	1007	105.93%	2628	1007	105.95%
Gregg - Rancho Seco slo	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	1927	760	113.82%	1925	760	113.66%
Gregg - Midway	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	1732	687	102.33%	1729	688	102.19%
	TEMPLETN	230	MORROBAY	230	#1	Amps	30	975	982	389	100.77%	983	389	100.80%
Gates - Midway slo	TEMPLETN	230	MORROBAY	230	#1	Amps	30	975	1073	423	110.01%	1064	420	109.11%
	HURLEY S	230	PROCTER	230	#1	Amps	30	925	925	370	100.08%	No Overload		
O'Banion -- Elverta	FOLSOM	230	ROSEVILL	230	#1	Amps	30	801	862	346	107.81%	839	337	104.97%
IV - Miguel 23050 slo	BARRE	230	ELLIS	230	#1	Amps	24	2480	2724	1043	109.82%	2724	1043	109.82%
IV - Miguel 23040 slo	BARRE	230	ELLIS	230	#1	Amps	24	2480	2658	1019	107.18%	2658	1019	107.18%

6.1.4 Double Contingency Conditions

6.1.4.1 A0 and A1 Cases

Table 17: N-2 Emergency Thermal Overload in A0 Case

Base case A0											
Contingency:	Overload Equipment										
	FROM BUS	KV	TO BUS	KV	ID	AREA	AMPS	MVA	RATING	UNIT	PERCENT
Table Mt. South DLO	TABLE MT	500	TB MT 1M	500	#1	30	1230.0	1144.2	1122.0	MVA	101.97%
SONGS-Santiago DLO	BARRE	230	ELLIS	230	#1	24	3336.7	1239.2	2480.1	Amps	134.54%
R.Seco-Bellota-DLO	HEDGE	230	PROCTER	230	#1	30	931.6	344.9	925.0	Amps	100.76%
	HURLEY S	230	TRCY PMP	230	#2	30	1083.6	398.7	1080.0	Amps	100.33%
PV-W.Wing-DLO	BRANDOW	230	KYRENE	230	#1	14	1725.3	703.4	1600.0	Amps	107.83%
MoutainView G2	SANBRDNO	230	DEVERS	230	#1	24	816.7	303.2	795.7	Amps	102.63%
	DEVERS	230	EL CASCO	230	#1	24	1287.4	502.1	1149.7	Amps	112.19%
Moss Landing G2	GRIZZLY	500	CAPTJACK	500	#1	40	2422.8	2273.1	2400.1	Amps	100.95%
Lugo-El Lugo-Moh DLO	LUGO	500	VICTORVL	500	#1	24	3273.2	2850.7	2999.9	Amps	109.13%

Table 18: N-2 Emergency Thermal Overload in A1 Case

Base case A1											
Contingency:	Overload Equipment										
	FROM BUS	KV	TO BUS	KV	ID	AREA	AMPS	MVA	RATING	UNIT	PERCENT
Table MT. South DLO	TABLE MT	500	TB MT 1M	500	#1	30	1225.7	1175.7	1122.0	MVA	104.78%
	TB MT 1M	500	TBL MTX1	230	#1	30	1286.5	1141.1	1122.0	MVA	102.03%
SONGS-Santiago DLO	BARRE	230	ELLIS	230	#1	24	3271.5	1239.5	2480.1	Amps	131.91%
Mountain View G2	DEVERS	230	EL CASCO	230	#1	24	1254.5	496.4	1149.7	Amps	109.29%
Lugo-El Lugo-Moh DLO	LUGO	500	VICTORVL	500	#1	24	3264.9	2890.3	2999.9	Amps	108.91%
Elverta_bkr1182_sb	HURLEY S	230	ELVERTAW	230	#2	30	1227.3	481.3	1080.0	Amps	113.74%
Devers-Valley DLO	LUGO	500	VICTORVL	500	#1	24	3173.4	2767.1	2999.9	Amps	105.78%
	SANBRDNO	230	DEVERS	230	#1	24	887.0	334.0	795.7	Amps	111.47%
	DEVERS	230	EL CASCO	230	#1	24	1356.5	533.8	1149.7	Amps	118.17%

6.1.4.2 A2, A2-I, A2SN, and A2SN-TEWA Cases

Table 19: N-2 Emergency Thermal Overloads in A2 and A2-I Cases

Contingency:	Overload equipment							A2				A2I			
	FROM BUS	KV	TO BUS	KV	ID	Unit	AR	AMPS	MVA	RATE	PCT	AMPS	MVA	RATE	PCT
Elverta_bkr1182_sb	HURLEY S	230	ELVERTAW	230	#2	Amps	30	1218	476	1080	112.87%	1230	483	1080	114.00%
Devers - Valley DLO	SANBRDNO	230	DEVERS	230	#1	Amps	24	No thermal overload				912	354	796	114.79%
	DEVERS	230	EL CASCO	230	#1	Amps	24	No thermal overload				1225	492	1150	106.68%
Table Mt. South DLO	TABLE MT	500	TB MT 1M	500	#1	MVA	30	1227	1132	1122	100.85%	1277	1175	1122	104.69%
	TB MT 1M	500	TBL MTX1	230	#1	MVA	30	1696	675	1700	100.07%	1340	1151	1122	102.66%
Palo Verde - W.Wing DLO	BRANDOW	230	KYRENE	230	#1	Amps	14	1704	686	1600	106.50%	1754	705	1600	109.59%
Lugo South DLO	MIRALOMA	500	PISGAH	500	#1	Amps	24	2779	2489	2565	108.36%	3019	2643	2565	117.72%
Lugo -MiraRvst DLO	MIRALOMA	500	PISGAH	500	#1	Amps	24	2654	2367	2565	103.49%	2922	2541	2565	113.95%
Lugo - Miraloma DLO	MIRALOMA	500	PISGAH	500	#1	Amps	24	2776	2489	2565	108.26%	3016	2643	2565	117.59%

Table 20: N-2 Emergency Thermal Overload in A2SN and A2SN-TEWA Cases

Contingency:	Overload equipment								A2SN			A2SN + Tesla - Warn		
	FROM BUS	KV	TO BUS	KV	ID	Unit	AREA	RATING	AMPS	MVA	PCT	AMPS	MVA	PCT
Tracy - Hurley 230 DLO	HURLEY S	230	PROCTER	230	#1	Amps	30	925	1159	463	125.41%	1094	437	118.30%
SONGS-Santiago-DLO	BARRE	230	ELLIS	230	#1	Amps	24	2480	3939	1477	158.85%	3940	1478	158.89%
Palo Verde - W. Wing DLO	BRANDOW	230	KYRENE	230	#1	Amps	14	1600	1753	709	109.57%	1753	709	109.57%
Midway - sb	TEMPLETN	230	MORROBAY	230	#1	Amps	30	975	1062	419	108.96%	1053	416	108.04%
Midway - Gregg DLO	PANOCHE	230	MCMULLN1	230	#1	Amps	30	975	1097	435	112.52%	No Overload		
	MCMULLN1	230	KEARNEY	230	#1	Amps	30	975	1044	414	107.12%	No Overload		
	MC CALL	230	HENTAP2	230	#1	Amps	30	975	1008	382	103.86%	No Overload		
	HENTAP1	230	GATES	230	#1	Amps	30	1837	1963	735	106.83%	No Overload		
Metcalf Xformer sb	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	1883	747	111.11%	1846	735	108.95%
Los Banos sb	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	2060	810	121.74%	1987	785	117.42%
	HURLEY S	230	PROCTER	230	#1	Amps	30	925	1016	404	109.97%	No Overload		
Los Banos North DLO	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	2174	882	128.29%	2049	835	120.93%
Elverta bkr1182	CARMICAL	230	HURLEY S	230	#1	Amps	30	900	957	384	108.65%	983	395	111.54%
	FOLSOM	230	ROSEVILL	230	#1	Amps	30	801	875	351	109.44%	852	342	106.54%
Tracy South DLO	WESTLEY	230	LOSBANOS	230	#1	Amps	30	1700	2187	869	129.16%	2146	855	126.77%
	HURLEY S	230	PROCTER	230	#1	Amps	30	925	981	393	106.18%	No Overload		
Midway North DLO	TEMPLETN	230	MORROBAY	230	#1	Amps	30	975	1024	407	105.00%	1007	401	103.33%

6.1.5 Conclusions

1. Significant upgrades to both Path 26 and Path 15 will mitigate identified reliability criteria violations with south to north flows near 4500 MW and 8500 MW, respectively.

2. During N-S operating conditions, no degradation to the existing WECC paths, COI and Path 26, was found under this particular resource procurement scenario. It is critical to understand that other procurement scenarios involving resources in northeastern California, northern Nevada, and/or the Pacific Northwest would likely require additional transmission facilities within northern California and from northern California to Nevada and/or the Pacific Northwest.

3. Under the N-S studies, two areas demonstrated reliability concerns; SMUD and SDG&E, primarily due to increased imports into their respective areas resulting from generation back down.

6.1.6 Proposed New Transmission Enhancements

The projects listed below help to alleviate power flow solution issues which arise when contingencies are taken with South to North flows on Path 26 and Path 15 operating at or near their existing limits and the output of southern California renewables ramped-up. Power flow solution issues are an indication of possible voltage collapse conditions.

1 New Gregg – Midway 500 kV line with 50% series compensation .

2. Gregg-Bay Area-Sacramento Lines: Two 500 kV lines north of Gregg to the Bay Area via Warnerville with 50% series compensation. Gregg – Warnerville – Rancho Seco - Tesla, and Gregg – Warnerville – Tesla. The new 500 kV Warnerville – Tesla line significantly alleviates both normal and emergency thermal overloads in Sacramento and Fresno areas. Re-conductor of the Warnerville - Cottle B – Bellota 230 kV line sections may also be an option.

3. Midway – Kramer 500 kV line. Absent this line, it will be necessary to trip as much as 1500 MW of generation south of Vincent and 1500 MW of load north of Vincent in order to mitigate overloads resulting from the N-2 outage of the 500 kV Midway-Vincent #1 and #2 lines.

4.Reconductor Los Banos–Westley 230 kV line and upgrade of associated station equipment. These upgrades may include the addition of circuit breakers with 1,800 Amp normal/2,200 Amp emergency capability.

6.2 Case B

The purpose of case B was to identify transmission alternatives under 1-in-10 peak load conditions in southern California that will mitigate reliability criteria violations that may appear with the addition of enough new renewable generation to meet California's RPS goals.

There was one additional sensitivity run for case B where the Green Path North Project (GPNP) was excluded. This sensitivity was performed to assess system capability in the event of possible postponement of the GPNP beyond 2020. The results for this sensitivity are included as Case B2 minus GPNP.

The case was built up following three steps described above in Section 5.1. These steps are:

Step 0: Develop Benchmark Base Case

Step 1: Add Renewable Projects, status off

Step 3: Dispatch renewable generation in increments offset by equal decrements of fossil generation

Table 21Table 21 provides a comparison of major inter-tie and intra-tie flows for the different steps in the B case.

Table 21: Comparison of Major Inter-tie and Intra-tie Flows for B0, B1 and B2 Cases

Path Name	Current Rating (MW)	B0 Case (MW)	B1 Case (MW)	B2 Case (MW)	Difference B2 - B0 Case (MW)
COI	4800	3775	3783	3292	(483)
Path 15	3265 (N-S) 5400 (S-N)	495(S-N)	491(S-N)	4372(S-N)	3877
Path26	4000 (N-S) 3000 (S-N)	1959(N-S)	1968(N-S)	1171 (S-N)	3130
EOR	9300	5078	5071	3436	(1642)
WOR	10623	6217	6211	5297	(920)
PDCI	3100	2996	2996	2996	0
IPP DC	2400	1789	1789	1789	0

6.2.1 Grid Configuration

The grid configuration is the same as for case A. Please refer to Section 6.1.1.

6.2.2 Power Flow Analysis

6.2.2.1 (N-0) Normal Conditions

Power flow runs for case B0 and B1 revealed some overloaded load banks, located in SCE area, and some overloaded 70kV-115kV lines within the PG&E control area, as listed in Table 22. These overloads alleviated and disappeared in the B2 case due to the implementation of photovoltaic rooftop program which were modeled as load reductions.

Table 22: Overloaded Load Banks and 70-115kV Lines in B0 and B1 Cases

Overloaded Components	Case B0 % Overload	Case B1 % Overload	Case B2 % Overload	Area
CHINO 66/230kV xfmr 1	103%	103%	N/A	SCE
CHINO 66/230kV xfmr 2	102%	102%	N/A	SCE

Overloaded Components	Case B0 % Overload	Case B1 % Overload	Case B2 % Overload	Area
CHINO 66/230kV xfmr 3	101%	101%	N/A	SCE
EAGLROCK 66/230kV xfmr 3	104%	104%	N/A	SCE
EAGLROCK 66/230kV xfmr 4	107%	107%	103%	SCE
JOHANNA 66/230kV xfmr 3	107%	107%	103%	SCE
JOHANNA 66/230kV xfmr 4	108%	108%	104%	SCE
VIEJO66 - VIEJOSC 66/230kV xfmr 1	130%	130%	125%	SCE
VIEJO66 - VIEJOSC 66/230kV xfmr 2	130%	130%	125%	SCE
ARCO 230/70kV xfmr 2	122%	122%	122%	PG&E
ARCO - TWISSLMN 70kV line 1	124%	123%	122%	PG&E
CORCORAN 115/70 xfmr 2	117%	117%	115%	PG&E
GLEAF TP - RIO OSO 115kV Line 1	101%	100%	N/A	PG&E
TWISSLMN - TX LOSHL 70kV Line 1	109%	109%	109%	PG&E
TX LOSHL - NTPTRL 70kV Line 1	110%	109%	109%	PG&E
WEBER 1 - WEBER 2 60kV Line 1	105%	111%	110%	PG&E

In addition, both the Kramer-Lugo 230 kV Lines and the Borden-Gregg 230 kV Line were overloaded in the benchmark cases B0 and B1 as shown in Table 23. These overloads disappeared in case B2, due to the addition of the Kramer-Lugo 500 kV line as well as the re-dispatching generation scheme utilized under the post-CREZ conditions.

Table 23: Overloaded 230 kV Lines in B0 and B1 Cases

Overloaded Component	Case B0 % Overload	Case B1 % Overload	Case B2 Overload?	Area
KRAMER - LUGO 230kV Line 1	102%	103%	No	SCE
KRAMER - LUGO 230kV Line 2	102%	103%	No	SCE
BORDEN - GREGG 230kV Line 1	101%	101%	No	PG&E

Finally, power flow of B2 case also revealed four overloads shown in Table 24. These overloads were deemed not critical and can be mitigated by simple enhancements.

Table 24: Overloads in B2 Case

Overloaded Components	Case B2 % Overload	Area
JHINDMWD - JHINDSCE 230kV	108%	SCE
OXBOW B 230/115kV xfmr 1	230%	SCE
PALERMO - HONC JT1 115kV Line 1	102%	PG&E
TESLA - AEC TP1 115kV Line 1	112%	PG&E

6.2.3 Single Contingency Conditions

6.2.3.1 B0 and B1 Cases

Full analyses of all N-1 outages listed in Section 11, revealed the existing and planned system should be able to sustain every studied contingency except for the two contingencies listed in Table 25 below.

Table 25: (N-1) Overloads in B0 and B1 Cases

Contingency				Impacted Element	Case B0 % Overload	Case B1 % Overload	Area
SILVERGT	SY230	230	1	SWEETWTR - MONTGYTP 69kV	113%	114%	SDG&E
KRAMER	LUGO	230	1	**KRAMER-LUGO 230KV**	144%	145%	SCE

6.2.3.2 B2 Case:

Besides, the JHINDMWD-JHINDSCE sectionalizing breaker which was overloaded for all studied contingencies, only two overloads were found as a result of the contingencies shown on Table 26.

Table 26: (N-1) Overloads in B2 Case

Contingency				Impacted Elements	Case B2 % Overload	Area
NGILA	WGILA	500	1	IMPRLVLY –ELCENTRO 230kV	119%	SDG&E-IID
WGILA	IMPRLVLY	500	1	IMPRLVLY –ELCENTRO 230kV	118%	SDG&E-IID

The overloaded JHINDMWD – JHINDSCE sectionalizing breaker will be mitigated by an SPS currently under development.

The overloaded IMPRLVLY – ELCENTRO 230kV line could be mitigated by implementing a Special Protection Scheme (SPS).

Among the most severe single contingencies in the B2 case is the outage of the newly added CONTROL-INYOKERN 230 kV Line. The loss of this line would result in voltage collapse. This could be avoided by the addition of the second CONTROL-INYOKERN 230 kV line.

6.2.4 Double Contingency Conditions

6.2.4.1 B0 and B1 Cases

Simulation of all credible (N-2) contingencies revealed only a few “local” overloads in the SDG&E and SMUD areas, as listed in Table 27.

Table 27: (N-2) Overloads in B0 and B1 Cases

Contingency				Impacted Element	Case B0 % Overload	Case B1 % Overload	Area
S.ONOFRE	TALEGA	230	1	OCNSDETP – STUARTTP 69kV	110%	110%	SDG&E
S.ONOFRE	TALEGA	230	2	JAPANESE MESA – TALEGATP 69kV	108%	108%	SDG&E
				STUARTTP – LASPULGS 69kV	105%	105%	SDG&E
PEN	ESCNDIDO	230	1	NORTHCTY-PENSQTOS 69kV	107%	106%	SDG&E
PEN	ESCNDIDO	230	2	MELRSTP – SANLUSRY 69kV	104%	105%	SDG&E
RNCHSECO	BELLOTA	230	1	PROCTER – HEDGE 230kV	113%	114%	SMUD
RNCHSECO	BELLOTA	230	2	WEBER 1 – WEBER 2 60kV	104%		SMUD

6.2.4.2 B2 Case

Full analysis of all credible (N-2) contingencies revealed the same local overloads seen in B0 and B1 cases and two bulk-system overloads along the Westley-Los Banos 230kV line in the PG&E area and the Barre-Ellis 230 kV line in the SCE area. Table 28 lists the N-2 Overloads in B2 Case.

Table 28: (N-2) Overloads in B2 Case

Contingency				Impacted Element	Case B2 % Overload	Area
MALIN	ROUND MT	500	1	WESTLEY – LOS BANOS 230kV	101%	PG&E
MALIN	ROUND MT	500	2			
ROUND MT	TABLE MT	500	1	WESTLEY – LOS BANOS 230kV	103%	PG&E
ROUND MT	TABLE MT	500	2			
TABLE MT	TESLA	500	1	WESTLEY – LOS BANOS 230kV	108%	PG&E
TABLE MT	VACA-DIX	500	1			
TABLE MT	TESLA	500	1	WESTLEY – LOS BANOS 230kV	106%	PG&E
VACA-DIX	TESLA	500	1			
TESLA	LOSBANOS	500	1	WESTLEY – LOS BANOS 230kV	101%	PG&E
TESLA	TRACY	500	1			
TESLA	LOSBANOS	500	1	WESTLEY – LOS BANOS 230kV	103%	PG&E
TRACY	LOSBANOS	500	1			
S.ONOFRE	TALEGA	230	1	OCNSDETP – STUARTTP 69kV	112%	SDG&E
S.ONOFRE	TALEGA	230	2	JAPANESE MESA – TALEGATP 69kV	109%	SDG&E
				STUARTTP – LASPULGS 69kV	105%	SDG&E
PEN	ESCNDIDO	230	1	NORTHCTY-PENSQTOS 69kV	108%	SDG&E
PEN	ESCNDIDO	230	2	MELRSTP – SANLUSRY 69kV	109%	SDG&E
				MELRSTP – SANMRCOS 69kV	106%	SDG&E
				POWAY – POMERADO 69kV	101%	SDG&E

Contingency				Impacted Element	Case B2 % Overload	Area
IMPERLVLY	ECO	500	1			
IMPERLVLY	CENTRALX	500	1			
w/ cross trip	IV-ROA 230			BARRE – ELLIS 230kV	166%	SCE
w/ cross trip	OM-TJI 230			BARRE – ELLIS 230kV	159%	SCE

These overloads are due to the dispatch of new renewable resources located in the identified CREZs and would have to be mitigated by local transmission reinforcements or by new operating procedures.

Also, without the addition of Barren Ridge-Vincent 500 kV line or the Barren-Ridge-Whirlwind 500kV line, the outages of both Barren Ridge-Haskell 230 kV lines would result in system collapse.

6.2.4.3 B2 Sensitivity Case without GPNP

The B2 case was also used to study the sensitivity of the GPNP. In this sensitivity, all elements of GPNP were removed from the system representation. Results show that in addition to the overloads found in B2 case shown in Table 28, the following overloads shown in Table 29 were also revealed. These overloads could be worse if the amount of renewables from the Imperial area is higher than the amount simulated.

Table 29: Overloads in Case B2 without GPNP Sensitivity

Contingency				Impacted Element	Case B2 % Overload	Area
DEVERS	VALLEYSC	500	1	DEVERS – ELCASCO 230kV	115%	SCE
DEVERS	VALLEYSC	500	2	DEVERS –SANBERDNO 230kV	111%	SCE
				JHINDMWD – JHINDSCE 230kV	130%	SCE

6.2.5 Post-Transient Stability Analysis

Post-transient performances showed no voltage violations for all studied contingencies in B0, B1, and B2 cases.

6.2.6 Stability Analysis

System swings were well damped and stable for all studied contingencies in B0, B1 and B2 cases. No violations of WECC transient voltage dip and transient frequency criteria were found.

6.2.7 Conclusions

1. Additional transmission enhancements would mitigate identified reliability criteria violations related to new renewable resources in the following CREZs:
    - Tehachapi assuming significant amounts of new renewable resources in this area are connected to Barren Ridge substation
    - Kramer
    - Pisgah
    - Central Nevada/Inyokern

2. Projected renewable resource additions are concentrated in southern California. At the same time a significant portion of the fossil-fired generation that will be displaced by renewable generation is located in northern California. Under heavy summer conditions, these facts will result in a change in the historical direction of flows on Path 26, from North-to-South to South-to-North and exacerbate the existing South-to-North direction of Path 15 flows.

   With this change in flow patterns, there are N-2 contingency overloads on certain 230 kV facilities which could be mitigated by generation dropping and/or load dropping or with transmission reinforcements. Such reinforcements could include reconductoring the Westley-Los Banos 230 kV line and/or new transmission additions along the path connecting the southern and northern California load centers.

3. Local overloads in the load centers would have to be mitigated by local transmission reinforcements or by new operating procedures.

4. In the absence of the GPNP, additional reinforcements would be required along the Devers-Mira Loma 230 kV lines.

6.2.8 Proposed New Transmission Enhancements

Based on the results from the B Case, the following are proposed new transmission enhancements.

1. New Barren Ridge – Vincent 500 kV line or Barren Ridge – Whirlwind 500 kV line

2. New Kramer – Lugo 500kV Line

3. Existing Eldorado – Lugo 500kV looping in at the new Pisgah 500kV Substation

4. New Pisgah – Barstow 500 kV line

5. New Barstow - Kramer 500 kV Line

6. Additional Control-Inyokern 230kV Line

7. Reconductoring Westley – Los Banos 230kV Lines

6.3 Case C

The purpose of Case C is to identify reliability criteria violations and potential mitigation options with increasing amounts of renewable generating capacity, under expected (1-in-2 year) summer peak demand conditions in year 2020. These violations are identified for system conditions where all pre-contingency grid power flows are determined through the power flow solution; i.e., where inter-tie and intra-tie path flows are allowed to flow freely.

The case was developed according to the methodology outlined in Section 5.1 and is further described for Case C as follows.

Case C0: Based on the WECC 2019 Heavy Summer, the 2020 Southern California 1-in-2 peak loads were modeled along with the 2020 Northern California 1-in-2 peak loads. The remainding loads across the WECC are at levels that correspond, approximately, to the time of California's expected summer peak demand.

Case C1: CREZ and other renewable development areas were connected to C0 grid configuration by adding "gen ties" or "looping in" to adjacent existing transmission lines. No generation was dispatched from the new renewable generators modeled in this case.

Case C2: Renewable generators in each CREZ and other renewable development areas were dispatched in increments. These increments were offset by equal decrements of fossil-fired generation, assuming a 70/30 ratio between fossil units within California and fossil units in other parts of the WECC. Renewable generation was incremented in all CREZs until an N-1 thermal limit was reached. The renewable generation was then limited for the CREZ most proximate to the thermal violation, and the remaining generation in other CREZs incremented until the next N-1 thermal limit was reached. This process was repeated until all renewable generation was either constrained or dispatched up to the maximum expected output of the CREZ for the condition studied (e.g., 20% of the nameplate capacity for wind resources in a CREZ).

N-1 post-transient voltage violations and N-2 thermal and post-transient voltage violations were noted but not considered constraining for the purposes of identifying constrained renewable generation.

Sensitivity Cases: Case C2 without Green Path North Project (GPNP), Case C2 with the 230 kV variant of GPNP, and Case C2 with the completion of the 230 kV double-circuit backbone through IID between Highline and Imperial Valley substations.

6.3.1 Grid Configuration

The C cases are intended to establish the capability of the existing grid, along with new transmission included in the 2019 "Heavy Summer" power flow base case, to accommodate new renewable resource development. Accordingly, the CREZ connections shown in Table 30 below assume renewable resources are either connected to (a) an existing substation located within or near the CREZ, or (b) a new substation that loops in one or more existing lines that run through or are adjacent to the CREZ.

Table 30: Case C1 - Grid Configuration Changes to enable CREZ Network Connection

CREZ/Renewable Development Area		
Location	**CTPG-Identified Renewable Resource Additions: Installed Capacity (MW)**	**Grid Configuration Change**
Washington	963	Connect renewables to existing McNary 500 kV bus
Montana	103.5	Connect renewables to existing South Cutbank 115 kV bus
	309	Connect renewables to existing Great Falls 230 kV bus
Idaho	130	Connect renewables to existing Goshen 345 kV bus
Oregon	573.6	Connect renewables to existing Malin 500 kV bus
	1063	Connect renewables to existing Grizzly 500 kV bus
Round Mountain-B	78	Connect renewables to existing Round Mountain 500 kV bus
Round Mountain-A	0	N/A
Lassen South	0	N/A
Lassen North	873	Add new Raven 500 kV substation
		Build 500 kV Raven-Round Mountain #1 line
		Connect renewables to new Raven 500 kV substation
Humboldt	11	Connect renewables to existing Humboldt 115 kV bus
Solano	408	Build new Solano 500 kV substation
		Build 500 kV Solano-Vaca Dixon #1 line
		Connect renewables to existing Vaca Dixon 500 kV bus via new radial 500 kV line
Cuyama	0	N/A
Carrizo North	0	N/A
Carrizo South	1545	Build new 230 kV Carrizo substation looping in existing 230 kV Morro Bay-Midway #1 and #2 lines
		Reconductor existing 230 kV Morro Bay-Midway #1 and #2 lines
		Connect renewables to new Carrizo 230 kV bus
Nevada N	0	N/A
Nevada C	120	Remove existing 115 kV Control-Inyokern #1 and #2 lines
		Build 230 kV Control-Inyokern #1 line
		Connect renewables to existing Control 230 kV bus via new radial 230 kV line
	69.2	Connect renewables to existing Dixie Valley 230 kV bus ("Oxbow A")

CREZ/Renewable Development Area		
Location	**CTPG-Identified Renewable Resource Additions: Installed Capacity (MW)**	**Grid Configuration Change**
	50	Connect renewables to existing Oxbow 230 kV bus ("Oxbow B") with radial 230 kV line
Nevada S	217	Connect renewables to existing Marketplace 500 kV bus
Owens Valley	0	N/A
Inyokern	242	Remove existing 115 kV Inyokern-Kramer #1 and #2 lines
		Add 230 kV capability at existing Inyokern substation
		Add 230 kV Inyokern-Kramer #1 and #2 lines on double-circuit towers
		Connect renewables to new Inyokern 230 kV bus
Kramer	343.7	Connect renewables to existing Kramer 230 kV bus
Mountain Pass	768	Build new Mountain Pass 500 kV substation looping in existing 500 kV Marketplace-Adelanto line
		Connect renewables to new Mountain Pass 500 kV bus
San Bernardino - Baker	825	Build new Baker 500 kV substation looping in existing 500 kV Marketplace-Adelanto line
		Connect renewables to new Baker 500 kV bus
Barstow	850	Build new Barstow 500 kV substation looping in existing 500 kV Marketplace-Adelanto line
		Connect renewables to new Barstow 500 kV bus
Pisgah	3248	Build new Pisgah 500 kV substation looping in existing 500 kV El Dorado-Lugo #1 line and existing 500 kV Mohave-Lugo #1 line
		Connect renewables to new Pisgah 500 kV bus
Victorville	0	N/A
San Bernardino - Lucerne	174	Build new Lucerne 500 kV substation
		Build 500 kV Lucerne-Lugo #1 line
		Connect renewables to new Lucerne 500 kV bus
Twentynine Palms	0	N/A
Tehachapi	3250.8	Connect renewables to new Barren Ridge 230 kV bus
	617.5	Connect renewables to new Windhub 230 kV bus added as part of Tehachapi Segments 4-11
Fairmont	345	Build new Fairmont 500 kV substation looping in existing 500 kV Adelanto-Rinaldi and 500 kV Victorville-Rinaldi lines
		Connect renewables to new Fairmont 500 kV bus
Arizona	333	Connect renewables to existing Westwing 500 kV bus
Riverside East	1562	Connect renewables to new Colorado River 500 kV bus

CREZ/Renewable Development Area		
Location	**CTPG-Identified Renewable Resource Additions: Installed Capacity (MW)**	**Grid Configuration Change**
Needles	0	N/A
Iron Mountain	0	N/A
Palm Springs	146.6	Connect renewables to existing Devers 230 kV bus
Imperial North-A	352	Build new SS6 230 kV substation
		Build new 230 kV SS6-Midway #1 and #2 lines on double circuit towers
		Connect renewables to new SS6 230 kV bus
Imperial North-B	386	Connect renewables to existing Midway 230 kV bus
Imperial South	16.5	Connect renewables to existing Rockwood 92 kV bus
	100	Connect renewables to existing Dixieland 230 kV bus
	349.4	Connect renewables to existing Imperial Valley 230 kV bus
Imperial East	15	Connect renewables to existing Pilot Knob 92 kV bus
Baja-A (La Rumorosa)	0	N/A
Baja-B (Santa Catarina)	0	N/A
San Diego South	0	N/A
San Diego	23	Build new Bullmoose 13.8 kV substation connected radially to existing Border 69kV bus
		Connect renewables to new Bullmoose 13.8 kV bus
San Diego North Central	0	N/A
Santa Barbara	92	Connect renewables to PG&E’s existing Mesa 230 kV bus
TOTAL	**20552.8**	

6.3.2 Power Flow Analysis

Transformers and transmission lines within California operated at 230 kV or higher voltages were monitored for thermal violations and buses within California at 200 kV and higher were monitored for voltage violations (steady-state and delta-V) with WECC Category B and C contingencies applied. Renewables were considered constrained by Category B thermal violations. Voltage violations and Category C thermal violations were noted but not considered to constrain the dispatch of new renewable resources. Selecting and confirming effective mitigation strategies for identified Category C reliability criteria violations (e.g., overloads that result from N-2 contingencies) will be undertaken in future phases of CTPG’s work.

6.3.2.1 (N-0) Normal Conditions

Power flows of case C0 and C1 have revealed some overloaded lines, located in SCE's distribution service area. The Kramer-Lugo 230 kV lines were overloaded in the benchmark cases C0 and C1 as shown in Table 31.

Table 31: N-0 Thermal Violations in C0 and C1 Cases

Overload Component	Case C0 % Overload	Case C1 % Overload	Area
KRAMER - LUGO 230kV Line 1	102%	103%	SCE
KRAMER - LUGO 230kV Line 2	102%	103%	SCE

Finally, power flow analysis for the C2 case with 10,400 MW of new renewable generation dispatched, reveals three N-0 (all-facilities-in-service) overloads shown on Table 32.

Table 32: Overloads in C2 Case

Overloaded Component	Case C2 %Overload	Area
KRAMER - LUGO 230kV Line 1	151%	SCE
KRAMER - LUGO 230kV Line 2	151%	SCE
JHINDMWD - JHINDSCE 230kV	105%	SCE

6.3.3 Single Contingency Conditions

6.3.3.1 C0 and C1 Cases

Full analyses of all N-1 outages listed in Section 11Appendix 1: Contingencies, indicate that the existing and planned system should be able to sustain every studied contingency except for the two contingencies listed in Table 33 below:

Table 33: (N-1) Overloads in Co and C1 Cases

Contingency				Impacted Element	Case C0 % Overload	Case C1 % Overload	Area
Serrano	Valley	500	1	**JHINDMWD - JHINDSCE 230kV**	101%	101%	SCE
Devers LA	Indian Hills	500	1	**JHINDMWD - JHINDSCE 230kV**	103%	103%	SCE

6.3.3.2 C2 Case

The Julian Hinds SCE-MWD 230 kV sectionalizing breaker and both Kramer-Lugo 230 kV lines were overloaded for all studied contingencies. Other N-1 overloads were found as a result of the contingencies listed in Table 34.

Table 34: (N-1) Overloads in C2 Cases

Contingency				Impacted Elements	Case C2 % Overload	Area
Serrano	Valley	500	1	Devers-El Casco 230 kV	100.2%	SCE
N. Gila	W. Gila	500	1	Barre-Ellis 230 kV	109.1%	SCE
W. Gila	Imperial Valley	500	1	Barre-Ellis 230 kV	110.4%	SCE

Note that SCE has a planned upgrade of the Barre-Ellis 230 kV line that is not reflected in the C2 case. It is expected that this upgrade will mitigate thermal violations on the 230 kV Barre-Ellis line.

Also, note that the powerflow case diverged for the contingency of Imperial Valley-Miguel 500 kV followed by SPS action tripping the Imperial Valley generation and cross-tripping of the Tijuana-Otay Mesa 230 kV or the Imperial Valley-La Rosita 230 kV lines, indicating a possible voltage collapse situation. However, this SPS cross-trip action would only occur for conditions where the 230 kV network within CFE became overloaded after loss of the IV-Miguel 500 kV line and where this overload was not relieved by tripping the Imperial Valley generation. This condition was not observed in the C2 case, therefore the cross-trip SPS probably would not be activated for the IV-Miguel 500 kV contingency.

Also, note that the system as studied includes a 75 MVA 115/230 kV transformer at the Oxbow substation. Normally, this would limit the dispatch at Dixie Valley to no more than 75 MW unless this bank was upgraded. However, since the case assumes the 115 kV system between Inyokern and Control would be upgraded before any additional renewables would be connected, it is reasonable to assume this transformer would be bypassed and the Dixie Valley renewables connected directly to the assumed new 230 kV lines in the Owens Valley.

The total renewable generation output in the C2 case is approximately 10,400 MW. The following renewable areas are considered constrained by thermal limitations of the transmission system:

Table 35: Constrained Renewables in Case C2

CREZ	Constraining Element	Contingency	CREZ On-Peak Available Capacity	Max On-Peak Allowable Dispatch
Imperial North Geothermal	Coachella-Mirage 230 KV Coachella-Ramon 230 kV	Indian Hills-Devers 500 kV	317 MW	155 MW
Palm Springs Wind	Devers-El Casco 230 kV	Valley-Serrano 500 kV	83 MW	0 MW
Pisgah Solar Thermal	Pisgah-Lugo 500 kV ckt. 1 or 2	Pisgah-Lugo 500 kV ckt. 1 or 2	2423 MW	1800 MW
Riverside East Solar Thermal	Devers-El Casco 230 kV	Valley-Serrano 500 kV	1016 MW	900 MW

Note that if the Kramer-Inyokern-Control upgrades assumed in the C2 case are not done, a limited amount of new renewables connecting at Control, Inyokern, or Dixie Valley may be dispatchable. Studies done during the initial phases of RETI Phase 2a suggested thermal and voltage stability limitations of the existing 115 kV system north of Kramer would seriously limit any additional generation in the aforementioned areas. This should be considered when assessing the true capability of the system as planned in 2020 and when developing the study plans for the next phase of CTPG analysis.

6.3.4 Double Contingency Conditions

6.3.4.1 C0 and C1 Cases

Simulation of all credible N-2 contingencies revealed the following thermal overloads in Cases C0 and C1, as listed in Table 36 below:

Table 36: (N-2) Overloads in C0 and C1 Cases

Contingency	Impacted Element	Case C0 % Overload	Case C1 % Overload	Area
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #3	119%	118%	PG&E
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #2	108%	107%	PG&E
Round Mt-Table Mt 500 KV 1&2	CPVSTA-Cortina 230 kV	115%	114%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	Cottonwood-Round Mt 230 kV #3	106%	105%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	CPVSTA-Cortina 230 kV	111%	111%	PG&E
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Imperial Valley-La Rosita 230 kV	114%	113%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Otay Mesa-Tijuana 230 KV	116%	116%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Barre-Ellis 230 kV	110%	110%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip & Crosstrip SPS of IV-La Rosita	Barre-Ellis 230 kV	141%	142%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip & Crosstrip SPS of TJ-OM	Barre-Ellis 230 kV	140%	141%	SCE

6.3.4.2 C2 Case

Full analysis of all credible N-2 contingencies revealed the following thermal overloads in Case C2, as listed in Table 37 below.

Table 37: (N-2) Overloads in C2 Case

Contingency	Impacted Element	Case C2 % Overload	Area
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #3	113%	PG&E
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #2	102%	PG&E
Round Mt-Table Mt 500 KV 1&2	CPVSTA-Cortina 230 kV	114%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	CPVSTA-Cortina 230 kV	111%	PG&E
Tesla-Los Banos & Tracy-Los Banos 500 kV	Westley-Los Banos 230 kV	133%	SCE
Los Banos-Gates & Los Banos-Midway 500 kV	Gates 500/230/13.8 kV Xfmr	105%	SCE
Midway-Gates & Los Banos-Midway 500 kV	Gates-Midway 230 kV	136%	SCE
Midway-Gates & Los Banos-Midway 500 kV	Arco-Midway 230 kV	128%	SCE
San Onofre-Talega 230 kV 1&2	Escondido-Talega 230 kV	104%	SDG&E

Note that the overload of the Barre-Ellis 230 kV line for the N-2 outage of the Imperial Valley-Central and Imperial Valley-Miguel 500 kV lines does not appear in the C2 case because this contingency causes the powerflow case to diverge, an indication of a possible voltage collapse situation.

It is expected that these overloads can be mitigated by existing RAS, new operating procedures, or with local transmission reinforcements. Note that existing and new operating procedures do and can include controlled load drop since this is permitted mitigation for N-2 reliability criteria violations. By design, the C case series did not model or evaluate mitigation measures for N-2 reliability criteria violations. For all cases--A, B and C--any identified N-2 reliability criteria violations will need to be addressed at some point.

Table 38: Case C2 – Results of Contingency Analysis

Case C2 - Expected WECC Summer Peak Load Condition
(July 8, 2020 at Hour-Ending 4:00 pm)
Year 2020 WECC Power Flow Case
with California Load Serving Entities'
Incremental Renewable Resource Additions
Ramped Up to 92% of Potential Energy Production

Location (Region/CREZ)	Installed Capacity (MW)	Identified Potential Annual Renewable Energy Production (GWh)	Maximum Possible Dispatch for Hour Studied (MW)	Actual Dispatch for Hour Studied (MW)	Limiting Contingency	Limiting System Element	Installed Capacity implied by Actual Dispatch (MW)	Expected Annual Renewable Energy Production (GWh)	Expected Annual Renewable Energy Production as a fraction of Identified Potential
British Columbia	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Washington	963	2593.9	193	193	No limiting contingency	No limiting element	963	2593.9	100%
Montana	413	1111.1	83	83	No limiting contingency	No limiting element	413	1111.1	100%
Idaho	130	350.2	26	26	No limiting contingency	No limiting element	130	350.2	100%
Oregon	1637	4408.2	327	327	No limiting contingency	No limiting element	1637	4408.2	100%
Round Mountain-A	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Round Mountain-B	78	319.4	33	33	No limiting contingency	No limiting element	78	319.4	100%
Lassen North	873	2261.7	200	200	No limiting contingency	No limiting element	873	2261.7	100%
Lassen South	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Nevada N	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Nevada C	239	1885.9	215	215	No limiting contingency	No limiting element	239	1885.9	100%
Nevada S	217	502.1	174	174	No limiting contingency	No limiting element	217	502.1	100%
Owens Valley	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Inyokern	242	467.2	197	197	No limiting contingency	No limiting element	242	467.2	100%
Kramer	344	988.1	275	275	No limiting contingency	No limiting element	344	988.1	100%
Mountain Pass	768	1776.9	566	566	No limiting contingency	No limiting element	768	1776.9	100%
San Bernardino-Baker	825	1870.3	220	220	No limiting contingency	No limiting element	825	1870.3	100%
Barstow	850	1984.7	624	624	No limiting contingency	No limiting element	850	1984.7	100%
Pisgah	**3248**	**7763.0**	**2423**	**1800**	**500 kV Pisgah-Lugo #1 or #2**	**500 kV Pisgah-Lugo #1 or #2**	**2413**	**5766.5**	**74%**
San Bernardino-Lucerne	174	559.7	96	96	No limiting contingency	No limiting element	174	559.7	100%
Twentynine Palms	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Victorville	0	0.0	0	0	n/a	n/a	0	0.0	n/a

Tehachapi	3868	10189.4	1770	1770	No limiting contingency	No limiting element	3868	10189.4	100%
Fairmont	345	862.1	272	272	No limiting contingency	No limiting element	345	862.1	100%
Needles	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Iron Mountain	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Arizona	333	739.9	266	266	No limiting contingency	No limiting element	333	739.9	100%
Riverside East	**1562**	**3470.6**	**1016**	**900**	**230 kV Devers-El Casco #1**	**500 kV Valley-Serrano #1**	**1383**	**3073.4**	**89%**
Palm Springs	**147**	**499.8**	**83**	**0**	**230 kV Devers-El Casco #1**	**500 kV Valley-Serrano #1**	**0**	**0.0**	**0%**
Imperial North-A	**352**	**2775.2**	**317**	**155**	**500 kV Indian Hills-Devers #1**	**230 kV Coachella Valley-Mirage #1 AND 230 kV Coachella Valley-Ramon #1**	**172**	**1357.8**	**49%**
Imperial North-B	386	1842.6	302	302	No limiting contingency	No limiting element	386	1842.6	100%
Imperial South	466	1090.8	329	329	No limiting contingency	No limiting element	466	1090.8	100%
Imperial East	15	42.5	3	3	No limiting contingency	No limiting element	15	42.5	100%
Baja-B (Santa Catarina)	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Baja-A (La Rumorosa)	0	0.0	0	0	n/a	n/a	0	0.0	n/a
San Diego South	0	0.0	0	0	n/a	n/a	0	0.0	n/a
San Diego North Central	0	0.0	0	0	n/a	n/a	0	0.0	n/a
San Diego	23	171.3	23	23	No limiting contingency	No limiting element	23	171.3	100%
Humboldt	11	81.9	11	11	No limiting contingency	No limiting element	11	81.9	100%
Solano	408	1248.2	266	266	No limiting contingency	No limiting element	408	1248.2	100%
Cuyama	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Carrizo North	0	0.0	0	0	n/a	n/a	0	0.0	n/a
Carrizo South	1545	3428.8	1045	1045	No limiting contingency	No limiting element	1545	3428.8	100%
Santa Barbara	92	249.4	31	31	No limiting contingency	No limiting element	92	249.4	100%
subtotals	**20553**	**55534.7**	**11386**	**10402**			**19212**	**51223.8**	**92%**
Existing renewable resources as of end of 2008								32532.0	
Renewable resources under construction in 2009								6792.0	
Miscellaneous other renewables								2670.0	
subtotal projected renewable energy production in year 2020								**93217.8**	
California's forecast retail load subject to RPS goals in year 2020								**289698.0**	
Projected renewable energy production as a fraction of retail loads								**32.2%**	

6.3.5 Post-Transient Stability Analysis

6.3.5.1 C0 and C1 Cases

N-1 post-transient voltage violations were observed in the C0 and C1 cases at the Indian Hills 230 kV bus for loss of the Devers-Indian Hills 500 kV line, and the O'Banion 230 kV bus for loss of the Sutter-O'Banion 230 kV line. It was also noted that the system voltage performance improved slightly with the topology modifications made to accommodate the renewable generation.

6.3.5.2 C2 Case

As noted above, certain contingencies resulted in case divergence, indicating possible voltage collapse conditions. A slight voltage violation was still observed at the Coachella Valley 230 kV bus for loss of the Indian Hills-Devers 500 kV line, although it improved from the C0 and C1 cases. The post-transient voltage violation at the O'Banion 230 kV bus disappeared entirely in the C2 case.

However, it was observed that as the amount of renewable dispatch increased and fossil generation was ramped down, the steady-state voltage profile in the SDG&E and SCE 230 kV systems noticeably deteriorated. This did not lead to violations of the post-transient voltage deviation criteria, but it is indicative of the need to examine the reactive resources in these areas, particularly since this analysis did not include a reactive margin test.

6.3.6 Stability Analysis

System swings were well damped and stable for all studied contingencies in C0, C1 and C2 cases. No violations of WECC transient voltage dip and transient frequency criteria were found.

6.3.7 Interface Flows

Table 39: Comparison of Major Inter-tie and Intra-tie Flows for C0, C1 and C2 Cases

Path Name	Current Rating (MW)	C0 Case (MW)	C1 Case (MW)	C2 Case (MW)	Difference C2 - C0 Case (MW)
COI	4800	3834	3834	3129	-705
Path 15	3265 (N-S) 5400 (S-N)	470 (S-N)	457 (S-N)	3559 (S-N)	3089
Path 26	4000 (N-S) 3000 (S-N)	2015 (N-S)	2017 (N-S)	117 (S-N)	-2132
EOR	9300	5103	5124	3771	-1332
WOR	10623	6199	6233	4833	-1366
PDCI	3100	2900	2900	2900	0
IPP DC	2400	1789	1789	1789	0

Figure 4: Case C Interface Flows - COI

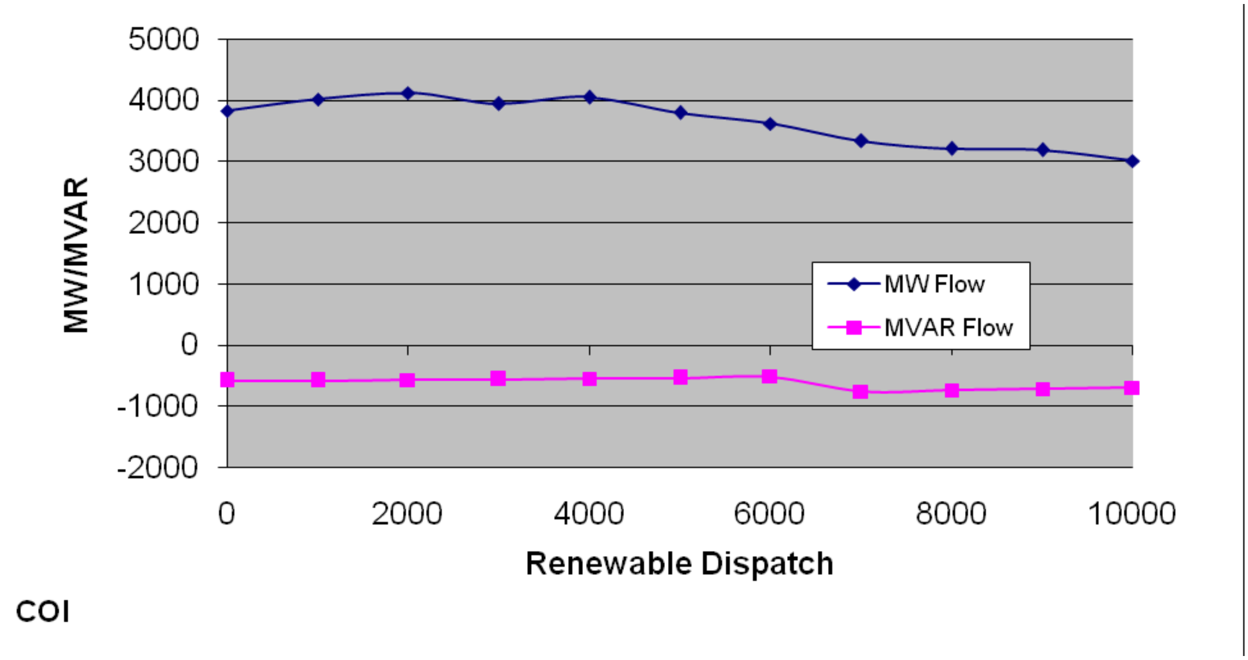


Figure 5: Case C Interface Flows - Path 15

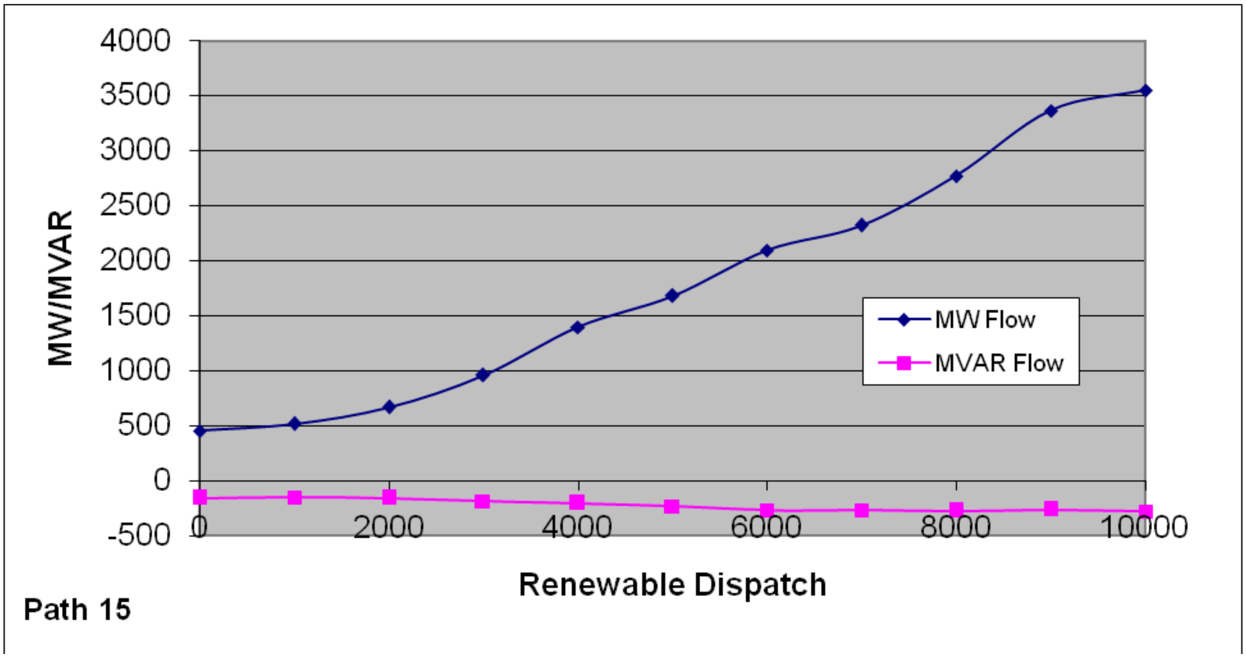


Figure 6: Case C Interface Flows – Path 26

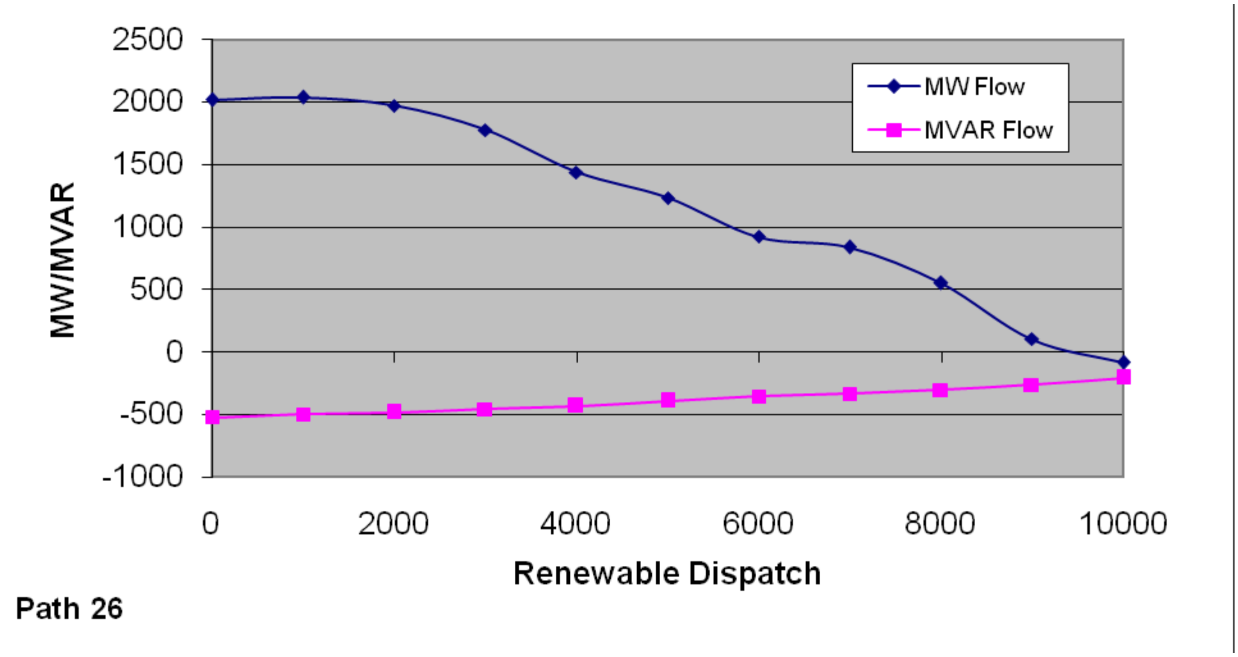


Figure 7: Case C Interface Flows – Path 26

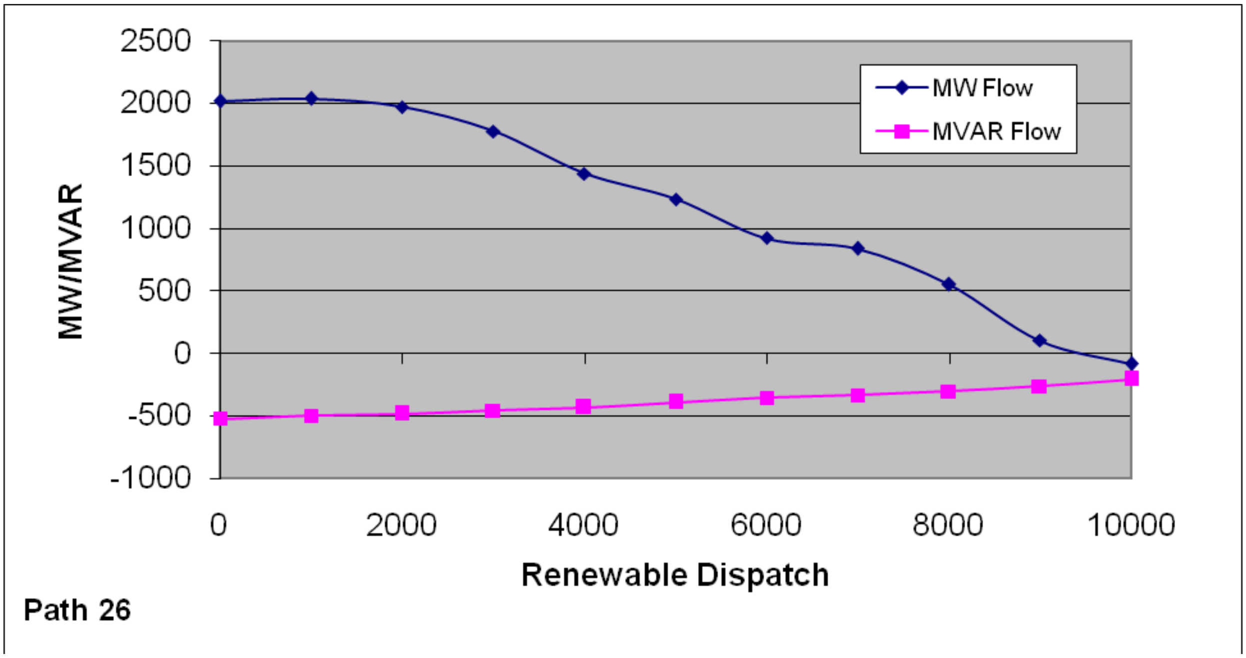


Figure 8: Case C Interface Flows - EOR

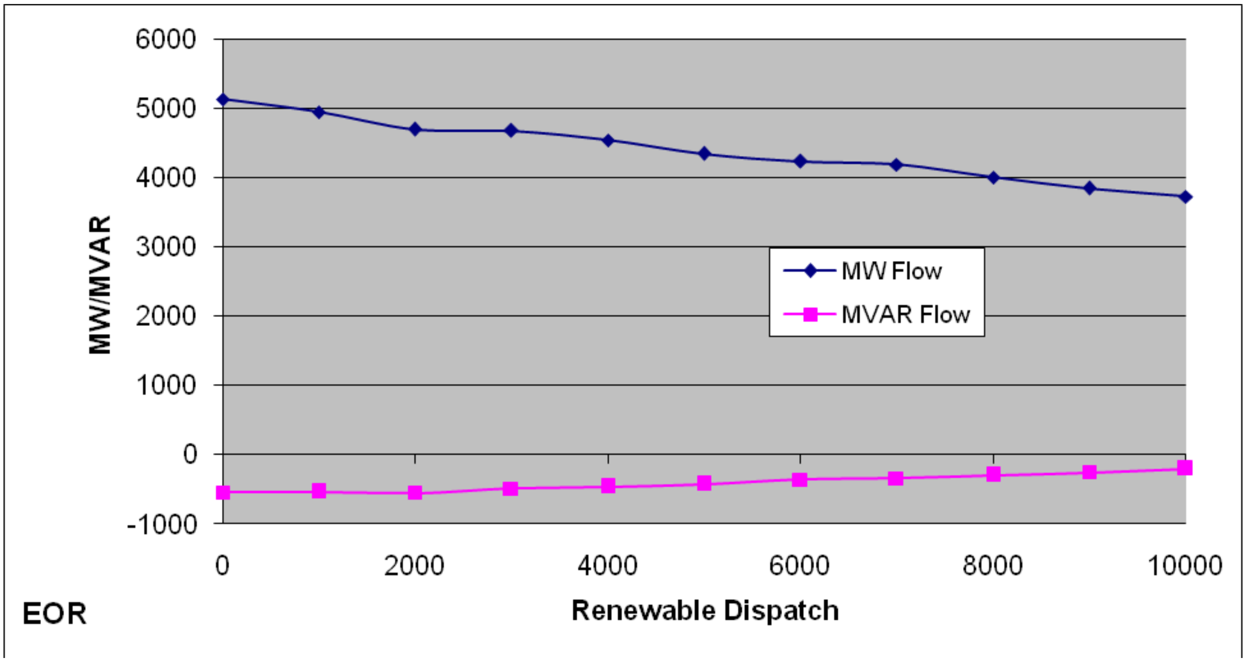
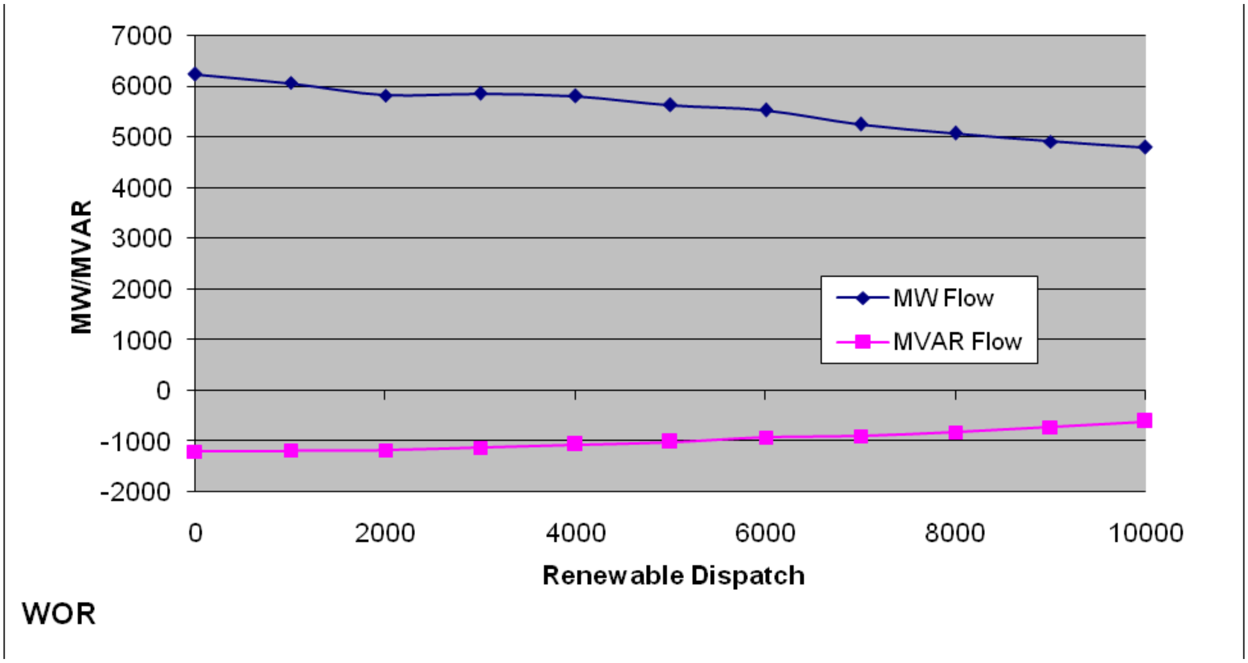


Figure 9: Case C Interface Flows - WOR



6.3.8 Sensitivity Studies

To analyze the impact of different transmission assumptions, three sensitivity cases were studied for case C:

- S1: Case C2 with the completion of the 230 kV double-circuit backbone through IID between Highline and Imperial Valley substations;
- S2: Case C2 without Green Path North Project (GPNP);
- S3: Case C2 with the 230 kV variant of the Green Path North Project (GPNP)

Table 40: Comparison of Major Inter-tie and Intra-tie Flows for C1S1 and C2S1 Cases

Path Name	Current Rating (MW)	C1S1 Case (MW)	C2S1 Case (MW)	Difference C2S1 – C1S1 (MW)
COI	4800	3838	2866	-972
Midway-Los Baños	3265 (N-S) 5400 (S-N)	455 (S-N)	3706 (S-N)	3251 (S-N)
Midway-Vincent	4000 (N-S) 3000 (S-N)	2019 (N-S)	267 (S-N)	-2286
EOR	9300	5121	3598	-1523
WOR	10623	6269	4415	-1854
PDCI	3100	2900	2900	0
IPP DC	2400	1789	1789	0

Table 41: Comparison of Major Inter-tie and Intra-tie Flows for C1S2 and C2S2 Cases

Path Name	Current Rating (MW)	C1S2 Case (MW)	C2S2 Case (MW)	Difference C2S2 – C1S2 (MW)
COI	4800	3831	2987	-844
Midway-Los Baños	3265 (N-S) 5400 (S-N)	461 (S-N)	3585 (S-N)	3124 (S-N)
Midway-Vincent	4000 (N-S) 3000 (S-N)	2013 (N-S)	119 (S-N)	-2132
EOR	9300	5126	3723	-1403
WOR	10623	6412	4758	-1654
PDCI	3100	2900	2900	0
IPP DC	2400	1789	1789	0

Table 42: Comparison of Major Inter-tie and Intra-tie Flows for C1S3 and C2S3 Cases

Path Name	Current Rating (MW)	C1S3 Case (MW)	C2S3 Case (MW)	Difference C2S3 – C1S3 (MW)
COI	4800	3823	2973	-850
Midway-Los Baños	3265 (N-S) 5400 (S-N)	469 (S-N)	3596 (S-N)	3127 (S-N)
Midway-Vincent	4000 (N-S) 3000 (S-N)	2005 (N-S)	130 (S-N)	-1875
EOR	9300	5135	3733	-1402
WOR	10623	6052	4507	-1545
PDCI	3100	2900	2900	0
IPP DC	2400	1789	1789	0

Details of this sensitivity analysis are provided in Appendix 2. Conclusions from these sensitivity studies are as follows:

6.3.8.1 Conclusions from C series Sensitivity studies

- Based on the C2S1 study, the completion of the IID backbone 230 kV loop, plus the anticipated 3rd 500/230Kv transformer at Imperial Valley Substation, will allow the dispatch of 10,973 MW of renewable generation (573 MW more than the 10,400MW in the C2 case).
- Based on the C2S2 study, without the planned GPN project, the total dispatchable renewable generation is 10,128 MW (272 MW less than 10,400MW in the C2 case).
- Based on the C2S3 study, with the 230 kV variant of GPN in place (and assuming two 400MW phase shifters installed on this path), dispatchable renewable generation is 9,882 MW (518 MW less than 10,400MW in the C2 case).

6.3.9 Conclusions

1. Additional transmission enhancements, or other mitigation measures such as generation tripping, would be required to allow full dispatch of the following CREZs under the studied conditions:
    a. North Imperial Valley
    b. Palm Springs
    c. Pisgah
    d. East Riverside County

2. Projected renewable resource additions are concentrated in southern California. At the same time a significant portion of the fossil-fired generation that will be displaced by renewable generation is located in northern California. Under heavy summer conditions, these facts will result in a change in the historical direction of flows on Path 26 and Path 15, from North-to-South to South-to-North.

3. Local overloads in the load centers would have to be mitigated by local transmission reinforcements or by new operating procedures.

4. Further study of reactive energy sources (voltage support) is advised, particularly in the SDG&E and SCE areas.

5. Cross-tripping generation for certain contingency conditions should be studied as a potentially quick and cost-effective way to facilitate the connection of new renewable generation to the existing grid.

6.3.10 Proposed New Transmission Enhancements

Based on the results from the C2 Case, the following are proposed new transmission enhancements that, while not specifically tested, are expected to mitigate identified limitations in the dispatch of new renewable resources:

1. Completion of a 230 kV double-circuit loop in the IID control area (Highline-El Centro-Imperial Valley)
2. New Imperial Valley-Bannister-Devers 500 kV Line
3. New Mira Loma-Pisgah 500 kV Line or new Pisgah – Barstow - Kramer 500 kV Line
4. New Devers-Mira Loma 500 kV Line
5. Development of generation SPS and/or related operating procedures

6.4 Case L

Case L, 2020 Light Load, is designed to evaluate California’s transmission facilities that are needed under system light load conditions, such as early spring morning. The Renewable Portfolio dispatch reflected a Spring morning dispatch in contrast to the peak cases: A, B, and C.

The case was built up following three steps:

Step 0: Develop benchmark base case from the WECC 2019 Heavy Winter case.

Step 1: Add renewable projects and Case A1 and B1 transmission upgrades, status off renewable generation.

Step 3: Dispatch renewable generation according to a spring morning output in increments offset by equal decrements of fossil generation.

Table 43 Comparison of Major Inter-tie and Intra-tie Flows for L0, L1, L2 Cases

Path Name	Current Rating (MW)	L0 Case (MW)	L1 Case (MW)	L2 Case (MW)
COI	4800	875	843	2
Path 15	3265 (N-S) 5400 (S-N)	1537 (S-N)	1594 (S-N)	5305 (S-N)
Path 26	4000 (N-S) 3000 (S-N)	631 (N-S)	594 (N-S)	3112 (S-N)
EOR	9300	4129	4186	2741
WOR	10623	5750	5792	3451
PDCI	3100	1000	1000	1000
IPP	2400	1949	1948	1950

6.4.1 Grid Configuration

The L Case grid configuration is the same as case A and B. Please refer to Section 6.1.1. The objective of the L case was to determine if any additional transmission upgrades would be needed for a light load condition. The proposed Central California Clean Energy (C3ET) Project (a Midway – Gregg 500kV DCTL) was modeled in the L2 case to support heavy South-to-North flows on Path 15 as recommended by Case A. Without this upgrade or something similar, the L2 case could not dispatch the new renewable generation to the required level under the current portfolio assumptions.

6.4.2 Power Flow Analysis

6.4.2.1 (N-0) Normal Conditions

There were no base case overloads for California load serving entities. However, South-to-North flows on Path 15 and LBN exceeded current IRAS limitations for L2 as explained in the following section.

Note: There were some thermal overloads in Area 40 in all L0, L1, and L2 base cases. However, these were not considered to have any impact on the study results.

6.4.2.1.1 Path 15 and LBN IRAS Limitations

The available IRAS are limited as shown in the table below:

Table 44: Path 15 and Los Banos North IRAS

	Los Banos North	Path 15
Pump	-	1405
Load	1056	1056
Generation	333	333
Eff. IRAS	397	1045
PBase:	1442	3400 (MWN)
Operating Limit with Available IRAS	**1839**	**4445**

The L2 Base Case flows on Path 15 and LBN are:

- Path 15 S-N = 5305 MW
- Los Banos North flow (S-N) = 2272 MW

Based on the available IRAS and the renewable generation dispatched, Path 15 is approximately 850 MW over its limit and LBN is approximately 400 MW over its limit. C3ETP was modeled to accommodate the required new renewable generation in the L2 base case.

6.4.3 Single Contingency Conditions

There were no thermal overloads for single contingency conditions.

6.4.4 Double Contingency Conditions

6.4.4.1 L0 and L1 Cases

There were no thermal overloads for double contingency conditions for L0 and L1.

6.4.4.2 L2 Case

Table 45: (N-2) Overloaded Elements in L2 Case

Contingency				Impacted Element	Case L2 % Overload	Area
GATES LOSBANOS	MIDWAY MIDWAY	500 500	1 1	WARNERVL-WILSON 230 kV	109%	PG&E
LOSBANOS LOSBANOS	GATES MIDWAY	500 500	1 1	WARNERVL-WILSON 230 kV	113%	PG&E
TESLA TRACY	LOSBANOS LOSBANOS	500 500	1 1	WESTLEY-LOS BANOS 230kV	132%	PG&E

6.4.5 Post-Transient Stability Analysis

Post-transient performances showed no voltage violations for all studied contingencies in L0, L1, and L2 cases.

6.4.6 Stability Analysis

6.4.6.1 L0 and L1 Cases

Transient stability issues were identified if three Helms units operated as pumps for the L0 and L1 cases. Operating only one Helms unit alleviates any stability issues. Operating standards for a light load condition would normally only have one pump online.

6.4.6.2 L2 Case

The modeling of the proposed Central California Clean Energy (C3ET) Project (a Midway – Gregg 500kV DCTL) in the L2 case, as a unintended benefit, supported three Helms units in pumping operation. Stability issues noted in the L0 and L1 case were resolved by this transmission support to the Fresno area.

6.4.7 Conclusions

- The new Midway – Gregg 500 kV line is needed to support flow on the Path 15 S-N (Approx. 5,500 MW) post CREZ generation dispatch.

- Re-conductor Los Banos – Westley 230 kV line and station equipments including upgrade the associate circuit breakers to 1,800A normal / 2,200A emergency may be needed to address the Los Banos north loading concern for power flow contingency. The recommendation is based on Los Banos North available IRAS of approx. 1,400 MW.

- Path 26 S-N upgrade is recommended to support higher S-N flow (increase in CREZ dispatch) from Vincent to Midway. This can be accomplished by different options such as:

    - New Midway – Kramer 500 kV lines (RETI project)
    - New Tehachapi – Kramer 500 kV lines (RETI project)
    - Re-conductor of the Midway – Whirl Wind # 3 500 kV line section
    - New Path 26 S-N RAS: Trip up to 500 MW of generation in the south of Vincent and up to 500 MW of load/pumps north of Midway substations

6.4.8 Proposed New Transmission Enhancements

The recommended upgrades identified for Case L are consistent with the upgrades identified by Case A and B.

Table 46: L Case Transmission Enhancement Comparison

Transmission Enhancement	Case A	Case B
Path 15 Upgrades	X	-
Los Banos North Upgrades	X	X
Path 26 Upgrades	X	X

No additional transmission enhancements were identified by Case L alone.

7 2010 Phase 1 Report CTPG Conceptual Transmission Plan

Table 47: 2010 Phase 1 Report - CTPG Conceptual Transmission Plan

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
C2 (C2 = Expected summer peak conditions)	Possible voltage collapse for the N-2 outage of 500 kV Imperial Valley-Central & 500 kV Imperial Valley-Miguel lines with (a) SPS tripping of Imperial Valley generation, and (b) SPS cross-trip of either of the two 230 kV ties between the U.S. and CFE	For the studied contingency, disable the SPS cross-trip of either of the two ties between the U.S. and CFE.	• Controlled load drop	Studies indicate that SPS tripping of Imperial Valley generation will prevent overloads on CFE's 230 kV network such that it will not be necessary to SPS cross-trip either of the two ties between the U.S. and CFE and the possibility of voltage collapse is avoided.
C2	Possible voltage collapse for N-1 outage of 500 kV Imperial Valley-Miguel 500 kV line with (a) SPS tripping of Imperial Valley generation, and (b) SPS cross-trip of either of the two 230 kV ties between the U.S. and CFE.	For the studied contingency, disable the SPS cross-trip of either of the two ties between the U.S. and CFE.		Studies indicate that SPS tripping of Imperial Valley generation will prevent overloads on CFE's 230 kV network such that it will not be necessary to SPS cross-trip either of the two ties between the U.S. and CFE and the possibility of voltage collapse is avoided.
A2I (A2I = w/COI and Path 26 N to S flows pre-set at max prior to adding renewables)	Overload of 230 kV Barre-Ellis line with all facilities in service	Not identified	• SCE's planned upgrades to the 230 kV Barre-Ellis line	Likelihood of max north to south flows needs to be evaluated
B2 (B2 = Adverse summer peak conditions in southern CA, expected elsewhere)	Overload of the 230 kV Barre-Ellis line for the N-2 outage of 500 kV Imperial Valley-Central & 500 kV Imperial Valley-Miguel lines with the cross trip of either of the 230 kV ties between the U.S. and CFE	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of 500 kV Imperial Valley-Central & 500 kV Imperial Valley-Miguel lines • SCE's planned upgrades to the 230 kV Barre-Ellis line	
A2SN (A2SN = A2 with Path 26 and Path 15 S to N flows pre-set at max prior to adding renewables + C3ETP + Gregg-Bay Area-Sacramento project) and A2SN+TEWA (TEWA = w/ new 500 kV Tesla-Warnerville #1 line)	Overload of the 230 kV Barre-Ellis line for the N-2 outage of the 230 kV SONGS-Santiago #1 & #2	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 230 kV SONGS-Santiago #1 & #2 lines • SCE's planned upgrades to the 230 kV Barre-Ellis line	Likelihood of max south to north flows needs to be evaluated

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
C2, A2 (Adverse summer peak conditions in northern CA, expected elsewhere), A2I, A2SN and A2SN+TEWA	Overload of 230 kV Barre-Ellis line for N-1 outage of 500 kV North Gila-Imperial Valley line	Not identified	• SCE's planned upgrades to the 230 kV Barre-Ellis line	Likelihood of max north to south and max south to north flows needs to be evaluated
A2, A2I, A2SN and A2SN+TEWA	Overload of 230 kV Barre-Ellis line for N-1 outage of 500 kV Imperial Valley-Miguel line with SPS cross-trip of either of the two 230 kV ties between the U.S. and CFE.	Not identified		Likelihood of max north to south and max south to north flows needs to be evaluated
A2, A2I, A2SN and A2SN+TEWA	Overload of 230 kV Barre-Ellis line for N-1 outage of either SONGS generator	Not identified		Likelihood of max north to south and max south to north flows needs to be evaluated
C2 and B2	Overload of SCE-MWD 230 kV sectionalizing breaker at Julian Hinds substation for all studied N-1 contingencies	Completion of SPS Development		
C2 and B2	Overload of 230 kV Kramer-Lugo #1 & #2 lines for all studied N-1 contingencies	500 kV Kramer-Lugo #1 line		Considering the large number of contingencies that would need to be included in any SPS, generator tripping is not a practical solution for mitigating identified reliability criteria violations
C2	Overload of 230 kV Devers-El Casco line for N-1 outage of 500 kV Serrano-Valley #1 line with either (a) dispatched generation within the Palm Springs CREZ exceeding 0 MW, or (b) dispatched generation within the Riverside East CREZ exceeding 900 MW	500 kV Devers-Mira Loma #1 line	• Trip up to 1150 MW of generation within the Riverside East, Imperial North-A and/or Imperial North-B CREZs for the N-1 outage of the 500 kV Serrano-Valley #1 line	
C2	Voltage violation at the Coachella Valley 230 kV bus and overload of 230 kV Coachella Valley-Mirage and Coachella Valley-Ramon lines for the N-1 outage of 500 kV Indian Hills-Devers line with dispatched generation within the Imperial North-A CREZ exceeding 155 MW	Complete 230 kV double circuit loop in IID control area by adding • 230 kV Imperial Valley-El Centro #2 • 230 kV El Centro-Highline #1 & #2	• Add voltage support at the Coachella Valley 230 kV bus • 500 kV Imperial Valley-Bannister-Devers #1 line • Trip up to 1150 MW of generation within the Imperial North-A and/or Imperial North-B CREZs for the N-1 outage of the 500 kV Indian Hills-Devers line	

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
B2	Voltage collapse for the N-1 outage of the 230 kV Control-Inyokern #1 line	230 kV Control-Inyokern #2	• Add voltage support at Control substation	Voltage collapse occurs with the following amounts of new geothermal generation: 120 MW connected to the Control 230 kV bus, 69.2 MW connected to the Dixie Valley 230 kV bus ("Oxbow A") and 50 MW connected to the Oxbow 230 kV bus ("Oxbow B"). Sensitivities around Case C could be used to determine how much new generation at these buses can be added without triggering voltage collapse.
C2and B2	Overload of 75 MVA 115/230 kV transformer at Oxbow substation ("Oxbow B") to the extent the sum of connected generation at Oxbow substation ("Oxbow B") and Dixie Valley substation ("Oxbow A") exceeds 75 MW	Disconnect 115/230 kV transformer at Oxbow substation ("Oxbow B") such that all generation at Oxbow substation and at Dixie Valley substation ("Oxbow A") is delivered to southern California via the assumed replacement of the existing 115 kV Control-Inyokern #1 & #2 lines with a 230 kV Control-Inyokern #1 line	• Upgrade 115/230 kV transformation capability at Oxbow substation ("Oxbow B")	
C2	Overload of 500 kV Pisgah-Lugo #1 or #2 lines for the N-1 outage of either 500 kV Pisgah-Lugo #2 or #1 lines with dispatched generation within the Pisgah CREZ exceeding 1800 MW	500 kV Pisgah-Mira Loma #1 line	• 500 kV Pisgah-Barstow #1 line • 500 kV Barstow-Kramer #1 line • Trip up to 1150 MW of generation within the Pisgah CREZ for the N-1 outage of the 500 kV Pisgah-Lugo #2 or #1 lines	Case B2 studies suggest the possibility of looping the existing 500 kV El Dorado-Lugo #1 line into the new Pisgah substation. However, this connection scheme is already reflected in Case C2 and does not, by itself, mitigate the indicated N-1 reliability criteria violations.
A2 and A2I	Overload of 500 kV Pisgah-Mira Loma #1 line for the N-2 outages of • 500 kV Lugo-Mira Loma #2 & 500 kV Lugo-Mira Loma #3 lines • 500 kV Lugo-Mira Loma #2 & 500 kV Lugo-Mira Loma #3 lines with different switching • 500 kV Lugo-Mira Loma #2 and & 500 kV Lugo-Rancho Vista #1 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation	Likelihood of max north to south flows needs to be evaluated
A2I	Overload of 500 kV Pisgah-Mira Loma #1 line with all facilities in service	Not identified		Likelihood of max north to south flows needs to be evaluated
A2I	Overload of 500 kV Barstow-Lugo #1 line with all facilities in service	Not identified		Likelihood of max north to south flows needs to be evaluated
A2I	Overload of the Vincent 500/230 kV transformer with all facilities in service	Not identified		Likelihood of max north to south flows needs to be evaluated

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
B2	Voltage collapse for the N-2 outage of the 230 kV Barren Ridge-Haskell Canyon #1 & #2 lines	500 kV Barren Ridge-Vincent #1 line	• Controlled load drop • Trip up to 1400 MW of generation in the Tehachapi and/or Kramer CREZs for the N-2 outage of the 230 kV Barren Ridge-Haskell Canyon #1 & #2 lines • 500 kV Barren Ridge-Whirlwind #1 line	
C2	Overload of 230 kV Cottonwood-Round Mountain #2 and #3 lines for the N-2 outage of the 500 kV Round Mountain-Table Mountain #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of 500 kV Round Mountain-Table Mountain #1 & #2 lines	
C2	Overload of 230 kV CPVSTA-Cortina line for the N-2 outage of the 500 kV Round Mountain-Table Mountain #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Round Mountain-Table Mountain #1 & #2 lines	
C2	Overload of 230 kV CPVSTA-Cortina line for the N-2 outage of the 500 kV Tesla-Table Mountain #1 and 500 kV Vaca Dixon-Table Mountain #1 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Tesla-Table Mountain #1 and 500 kV Vaca Dixon-Table Mountain #1 lines	
A2SN and A2SN+TEWA	Overload of 230 kV Westley-Los Banos line for stuck-breakers tripping • 500 kV Metcalf-Los Banos #1 & the 500/230 kV Metcalf transformer • 500 kV Tracy-Los Banos & 500 kV Gates-Los Banos lines	Reconductor 230 kV Westley-Los Banos line and upgrade associated station equipment. Circuit breaker upgrades to 1800 Amps normal/2200 Amps emergency may also be needed	• Controlled load drop	Single phase fault with stuck breaker is a Category C contingency. Controlled load drop is permitted mitigation Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Westley-Los Banos #1 line with all facilities in service			New transmission along the paths connecting the northern and southern California load centers may also mitigate this criteria violation Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Westley-Los Banos line for the N-1 outages of • 230 kV O'Banion-Sutter line • Pacific DC Intertie bipole • 500 kV Moss Landing-Metcalf line • 500 kV Moss Landing-Los Banos line		• Trip up to 1150 MW of generation	
A2SN+TEWA	Overload of 230 kV Westley-Los Banos line for the N-1 outages of • 500 kV Moss Landing-Metcalf line • 500 kV Moss Landing-Los Banos Line • 230 kV Gregg-Rancho Seco #1 line • 500 kV Gregg-Midway #1 line		• Trip up to 1150 MW of generation	

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
A2SN and A2SN+TEWA	Overload of 230 kV Westley-Los Banos line for the N-2 outage of • 500 kV Tesla-Los Banos #1 & 500 kV Tracy-Los Banos #1 lines • 500 kV Tracy-Tesla #1 & 500 kV Tracy-Los Banos #1 lines	Reconductor 230 kV Westley-Los Banos line and upgrade associated station equipment. Circuit breaker upgrades to 1800 Amps normal/2200 Amps emergency may also be needed	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Tesla-Loss Banos #1 and 500 kV Tracy-Los Banos #1 lines	New transmission along the paths connecting the northern and southern California load centers may also mitigate this criteria violation Likelihood of max south to north flows needs to be evaluated
C2, B2, A2SN and A2SN+TEWA	Overload of 230 kV Westley-Los Banos line for the N-2 outage of • 500 kV Tesla-Los Banos #1 & 500 kV Tracy-Los Banos #1 lines		• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Tesla-Loss Banos #1 and 500 kV Tracy-Los Banos #1 lines	

B2	Overload of 230 kV Westley-Los Banos line for the N-2 outages of
	• 500 kV Malin-Round Mountain #1 & #2 lines
	• 500 kV Table Mountain—Round Mountain #1 & #2 lines
	• 500 kV Table Mountain-Tesla#1 line & 500 kV Table Mountain-VacaDixon #1 line
	• 500 kV Table Mountain-Tesla#1 line & 500 kV Vaca Dixon-Tesla #1 line
	• 500 kV Tesla-Los Banos #1 line & 500 kV Tesla-Tracy #1 line
			• Controlled load drop
			• Trip up to 1400 MW of generation for the N-2 outages of:
			  • 500 kV Malin-Round Mountain #1 & #2 lines
			  • 500 kV Table Mountain—Round Mountain #1 & #2 lines
			  • 500 kV Table Mountain-Tesla#1 line & 500 kV Table Mountain-VacaDixon #1 line
			  • 500 kV Table Mountain-Tesla#1 line & 500 kV Vaca Dixon-Tesla #1 line
			  • 500 kV Tesla-Los Banos #1 line & 500 kV Tesla-Tracy #1 line	

C2	Overload of Gates 500/230/13.8 kV transformer for the N-2 outage of the 500 kV Gates-Los Banos #1 and 500 kV Midway-Los Banos #1 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Gates-Los Banos #1 and 500 kV Midway-Los Banos #1 lines	
C2	Overload of 230 kV Gates-Midway #1 line for the N-2 outage of the 500 kV Gates-Midway#1 and 500 kV Midway-Los Banos #1lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Gates-Midway#1 and 500 kV Midway-Los Banos #1lines	
C2	Overload of 230 kV Arco-Midway #1 line for the N-2 outage of the 500 kV Gates-Midway#1 and 500 kV Midway-Los Banos #1lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Gates-Midway#1 and 500 kV Midway-Los Banos #1lines	

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
C2	Overload of 230 kV Escondido-Talega #1 line for the N-2 outage of the 230 kV San Onofre-Talega #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Gates-Midway#1 and 500 kV Midway-Los Banos #1lines	
B2	Overload of 115 kV Palermo-Honc JT1 #1 line for all facilities in service	Not identified		Can be mitigated through simple enhancements and therefore deemed not critical for purposes of this study
B2	Overload of 115 kV Tesla-AEC TP1 #1 line for all lines in service	Not identified		Can be mitigated through simple enhancements and therefore deemed not critical for purposes of this study
B2	Overload of 230 kV Imperial Valley-El Centro #1 line for the N-1 outage of 500 kV North Gila-Imperial Valley line	Implement SPS to cross-trip 230 kV Imperial Valley-El Centro #1 line for the outage of 500 kV North Gila-Imperial Valley line	• Trip up to 1150 MW of generation for the N-1 outage of 500 kV North Gila-Imperial Valley line	
B2 w/o 500 kV Green Path North project	Overload of 230 kV Devers-El Casco line for the N-1 outage of the 500 kV Devers-Valley #1 line	Not identified	• Trip up to 1150 MW of generation within the Riverside East, Palm Springs, Imperial North-A and/or Imperial North-B CREZs for the N-1 outage of the 500 kV Devers-Valley #1 line	Additional reinforcements along the existing Devers-Mira Loma 230 kV lines may mitigate the identified reliability criteria violations
B2 w/o 500 kV Green Path North project	Overload of 230 kV Devers-San Bernardino line & 230 kV MWD-SCE tie at Julian Hinds substation for the N-1 outage of the Devers-Valley #2 line	Not identified		
A2, A2SN and A2SN+TEWA	Overload of 115 kV Tesla-AEC_TP1 line with all facilities in service	Not identified		Likelihood of max south to north flows needs to be evaluated
A2	Overload of 115 kV SFWY_TP1-AEC_TP1 line with all facilities in service			
A2, A2I, A2SN and A2SN+TEWA	Overload of both VIEJOSC 230/66 kV transformers with all facilities in service			Likelihood of max north to south and max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Warnerville-Cottle B #1 line with all facilities in service		• Reconductor Warnerville-Cottle B #1 line	Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Bellota-Cottle B #1 line with all facilities in service			Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Borden-Gregg #1 line with all facilities in service			Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Templeton-Morro Bay #1 line with all facilities in service	Not identified		Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Templeton-Morro Bay #1 line for stuck breaker at Midway substation	Not identified	• Controlled load drop	Single phase fault with stuck breaker is a Category C contingency. Controlled load drop is permitted mitigation Likelihood of max south to north flows needs to be evaluated

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
A2SN	Overload of 230 kV Templeton-Morro Bay #1 line for N-1 outage of 500 kV Gates-Midway #1 line	Not identified	• Trip up to 1150 MW of generation for N-1 outage of 500 kV Gates-Midway #1 line	Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Templeton-Morro Bay #1 line for the N-1 outages of • 500 kV Los Banos-Midway #1 line • 500 kV Gregg-Midway #1 line	Not identified	Trip up to 1150 MW of generation for the N-1 outages of • 500 kV Los Banos-Midway #1 line • 500 kV Gregg-Midway #1 line	Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Templeton-Morro Bay #1 line for the N-2 outage of 500 kV Midway-Gates #1 & 500 kV Midway-Los Banos #1 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of 500 kV Midway-Gates #1 & 500 kV Midway-Los Banos #1 lines	Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of Corcoran 115/70 kV transformer with all facilities in service	Not identified		Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 500 kV Gates-Midway #1 with all facilities in service	Not identified		Likelihood of max south to north flows needs to be evaluated
A2I	Overloads of 230 kV Devers-San Bernardino and 230 kV Devers-El Casco lines for the N-2 outage of the 500 kV Devers-Valley #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Devers-Valley #1 & #2 lines	Likelihood of max north to south flows needs to be evaluated
A2 and A2I	Overload of the 500 kV Table Mountain 500/230 kV transformer for the N-2 outage the 500 kV Table Mountain-Tesla & 500 kV Table Mountain-Vaca Dixon 500 kV lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage the 500 kV Table Mountain-Tesla & 500 kV Table Mountain-Vaca Dixon 500 kV lines	Likelihood of max north to south flows needs to be evaluated
A2I	Overload of 500 kV Round Mountain-Table Mountain #1or #2 lines for the N-1 outage of 500 kV Round Mountain-Table Mountain #2 or #1 lines	Not identified	• Trip up to 1150 MW of generation for the N-1 outage of 500 kV Round Mountain-Table Mountain #2 or #1 lines	Likelihood of max north to south flows needs to be evaluated
A2, A2I, A2SN and A2SN+TEWA	Overload of 230 kV Brandow-Kyrene #1 line for the N-2 outage of 500 kV Palo Verde-Westwing #1 & #2	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of 500 kV Palo Verde-Westwing #1 & #2	Likelihood of max north to south and max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Hurley S-Procter #1 line with all facilities in service	Not identified		Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Hurley S-Procter #1 line with N-1 outages of • 500 kV Los Banos-Midway #1 line • 500 kV Los Banos-Gates #1 line	Not identified	Trip up to 1150 MW of generation for the N-1 outages of • 500 kV Los Banos-Midway #1 line • 500 kV Los Banos-Gates #1 line	Likelihood of max south to north flows needs to be evaluated

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
A2SN	Overload of 230 kV Hurley S-Procter #1 line with N-2 outage of the 500 kV Tracy-Tesla #1 & 500 kV Tracy-Los Banos #1 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Tracy-Tesla #1 & 500 kV Tracy-Los Banos #1 lines	Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Hurley S-Procter line for the N-1 outages of the 230 kV O'Banion-Sutter line	Not identified	• Trip up to 1150 MW of generation for the N-1 outages of the 230 kV O'Banion-Sutter line	Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Hurley S-Procter line for the N-2 outage of the 230 kV Tracy-Hurley #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 230 kV Tracy-Hurley #1 & #2 lines	Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Hurley S-Procter line for stuck breaker tripping the 500 kV Tracy-Los Banos & 500 kV Gates-Los Banos lines	Not identified	• Controlled load drop	Single phase fault with stuck breaker is a Category C contingency. Controlled load drop is permitted mitigation Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Panoche-McMulln1 #1 line for the N-2 outage of the 500 kV Midway-Gregg #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the	Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Kearney-McMulln1 #1 line for the N-2 outage of the 500 kV Midway-Gregg #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Midway-Gregg #1 & #2 lines	Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 230 kV McCall-Hentap2 #1 line for the N-2 outage of the 500 kV Midway-Gregg #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Midway-Gregg #1 & #2 lines	Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 230 kV Gates-Hentap1 #1 line for the N-2 outage of the 500 kV Midway-Gregg #1 & #2 lines	Not identified	• Controlled load drop • Trip up to 1400 MW of generation for the N-2 outage of the 500 kV Midway-Gregg #1 & #2 lines	Likelihood of max south to north flows needs to be evaluated
A2SN	Overload of 500 kV Gates-Midway #1 line for the N-1 outage of the 500 kV Los Banos-Midway line	Not identified	• Trip up to 1400 MW of generation for the N-1 outage of the 500 kV Los Banos-Midway line	Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 230 kV Folsom-Roseville #1 line for the N-1 outage of 230 kV O'Bannion-Elverta line	Not identified	• Trip up to 1400 MW of generation for the N-1 outage of 230 kV O'Bannion-Elverta line	Likelihood of max south to north flows needs to be evaluated
A2SN and A2SN+TEWA	Overload of 500 kV Midway-Whirlwind #1 line for the N-2 outage the 500 kV Midway-Vincent #1 & #2 lines	500 kV Kramer-Midway #1 line	• Trip 1500 MW of generation south of Vincent and 1500 MW of load north of Vincent	Likelihood of max south to north flows needs to be evaluated

Cases in Which Reliability Criteria Violation was Identified	Reliability Criteria Violation	Transmission Upgrade Mitigating Criteria Violation	Possible Alternatives Mitigating Criteria Violation	Comments
Not studied but included in Cases A2 and B2	Not studied	500 kV Mountain Pass-El Dorado #1		These network upgrades were assumed for purposes of connecting the Mountain Pass, Baker, Barstow and Pisgah CREZs in Cases A2 and B2. Case C2 used a different connection scheme for these CREZs (see Table 30) and the only potential network upgrade suggested is the 500 kV Pisgah-Mira Loma #1 line
Not studied but included in Cases A2 and B2	Not studied	500 kV Mountain Pass-Baker #1 line		
Not studied but included in Cases A2 and B2	Not studied	new Mountain Pass2 287 kV substation looping in existing 287 kV Mead-Victorville #1 line		
Not studied but included in Cases A2 and B2	Not studied	500 kV Baker-Barstow #1		
Not studied but included in Cases A2 and B2	Not studied	500 kV Barstow-Lugo #1 line		
Not studied but included in Cases A2 and B2	Not studied	500 kV Pisgah-Barstow #1 line	• Case C2 suggests a 500 kV Pisgah-Mira Loma #1 line would be an alternative to constructing these two lines	
Not studied but included in Cases A2 and B2	Not studied	500 kV Barstow-Kramer #1 line		

Red text indentifies upgrades included in the CTPG conceptual transmission plan

8 Comparison of CTPG and RETI Phase 2A Conceptual Transmission Plans

Table 48: Comparison of CTPF and RETI Phase 2A Conceptual Transmission Plans - Network Upgrades

Transmission Project	RETI Phase 2A Conceptual Plan	WECC 2019 Seed Case	CASE A	CASE A S-N	CASE A S-N TEWA	CASE B	CASE C	Comments
500 kV Selkirk-Devil’s Gap-NEO #1 line	X							
500 kV Selkirk-Devil’s Gap-NEO #2 line	X							
+/- 500 kV DC Neo-Collinsville #1 line	X							
230 kV Collinsville-Pittsburg #1 line	X							
230 kV Collinsville-Pittsburg #2 line	X							
500 kV Collinsville-Tracy2 #1 line	X							
500 kV Zeta1-Round Mountain #1 line	X							
500 kV Zeta1-Olinda #1 line	X							
500 kV Olinda-Dillard Road #1 line	X							
230 kV Dillard Road-Tracy2 #1 line	X							
230 kV Tracy2-Livermore #1 line	X							
230 kV Livermore-Delta #1 line	X							
500 kV Tracy2-Tracy #1 line	X							
500 kV Tracy2-Alpha4 #1 line	X							
500 kV Tracy2-Alpha4 #2 line	X							
230 kV Alpha4-Park #1 line	X							
230 kV Alpha4-Park #2 line	X							
230 kV Alpha4-Alpha1 #1 line	X							
230 kV Alpha4-Alpha1 #1 line	X							
230 kV Tesla-Newark #1 line	X							
500 kV Gregg-Alpha4 #2 line	X							
500 kV Tesla-Warnerville #1 line					X			
230 kV Westley-Los Banos #1 reconductor				X	X			
500 kV Gregg-Warnerville #1 line				X	X			
500 kV Gregg-Rancho Seco #1 line				X	X			
500 kV Midway-Gregg #1 line				X	X			

Transmission Project	**RETI Phase 2A Conceptual Plan**	**WECC 2019 Seed Case**	**CASE A**	**CASE A S-N**	**CASE A S-N TEWA**	**CASE B**	**CASE C**	**Comments**
500 kV Midway-Gregg #2 line				X	X			
500 kV Midway-Kramer #1 line	X			X	X			
230 kV Gates-Morro Bay #1 upgrade project	X							
230 kV Midway-Carrizo #1 upgrade project	X	X	X	X	X	X	X	
500 kV Midway-Kramer #2 line	X							
500 kV Midway-Whirlwind #1 upgrade project	X	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Windhub-Antelope #1 line		**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Windhub-Whirlwind #1 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Whirlwind-Antelope #1 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Whirlwind-Vincent #1 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Antelope-Vincent #1 replacement project	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Antelope-Vincent #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
220 kV kV Chino-Mira Loma #1 replacement project	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
220 kV Chino-Mira Loma #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
220 kV Chino-Mira Loma #3 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
220 kV Gould-Eagle Rock #1 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Mesa-Vincent #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
230 kV Pardee-Vincent #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
230 kV Rio Hondo-Vincent #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Vincent-Mira Loma #1 replacement project	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Tehachapi Segments 4-11
500 kV Kramer-Windhub #1 line	**X**							
230 kV Control-Lone Pine #1 rebuild project	**X**							Northern portion of 230 kV Control-Inyokern #1 line
230 kV Lone Pine-Inyokern #1 rebuild project	**X**							Southern portion of 230 kV Control-Inyokern #1 line
230 kV Control-Inyokern #2 line						**X**		
500 kV Inyokern-Kramer #1 line	**X**					**X**		Included as 230 kV Inyokern-Kramer #1 & #2 lines
Reconductor short 230 kV tie between SCE						**X**	**X**	Case C identified base case

Transmission Project	RETI Phase 2A Conceptual Plan	WECC 2019 Seed Case	CASE A	CASE A S-N	CASE A S-N TEWA	CASE B	CASE C	Comments
and MWD at Julian Hinds substation								overload at this line. The reconductor of this line can be a mitigation for this overload
500 kV Iron Mountain-Jontry Junction #1 rebuild project	**X**							
500 kV Iron Mountain-Jontry Junction #2 line	**X**							
500 kV Jontry Junction-Camino #1 rebuild project	**X**							
500 kV Jontry Junction-Pisgah #1 line	**X**							
500 kV Jontry Junction-Pisgah #2 line	**X**							
500 kV Pisgah-Lucerne Valley #1 line	**X**							
500 kV Lucerne Valley-Lugo #1 line	**X**							
New Mountain Pass 287 kV substation loop-in LADWP's existing 287 kV Mead-Victorville #1 line	**X**		**X**			**X**		These network upgrades were assumed for purposes of connecting the Pisgah, Mountain Pass, Baker and Barstow CREZs in CTPG's A2 and B2 cases. CTPG's C2 case used a different connection scheme for these CREZs that did include any new network line segments and did not include the new Mountain Pass 287 kV substation.
500 kV Mountain Pass1-El Dorado #1 replacement project	**X**		**X**			**X**		
500 kV Mountain Pass1-Baker1 #1 replacement project	**X**		**X**			**X**		
500 kV Baker1-Barstow1 #1 replacement project	**X**		**X**			**X**		
500 kV Pisgah-Barstow1 #1 line	**X**		**X**			**X**		
500 kV Barstow1-Kramer #1 line	**X**		X	X	X	X		
500 kV Barstow1-Lugo #1 line	**X**		**X**			**X**		
500 kV Kramer-Lugo #1 line	**X**		**X**	**X**	**X**	**X**		Case C identified a base case overload on the 230 kV Kramer-Lugo #1& #2 lines. It is expected that a 500 kV Kramer-Lugo #1 line would mitigate the overloads but was not tested in the Case C studies.

Transmission Project	RETI Phase 2A Conceptual Plan	WECC 2019 Seed Case	CASE A	CASE A S-N	CASE A S-N TEWA	CASE B	CASE C	Comments
500 kV Lugo-Victorville #2 line	**X**							
230 kV Barren Ridge-Haskell Canyon #1 upgrade project	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Included in the 2019 WECC seed case as part of the Barren Ridge upgrade project
230 kV Barren Ridge-Haskell Canyon #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
230 kV Castaic-Haskell Canyon #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
230 kV Haskell Canyon-Rinaldi #1 upgrade project	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
500 kV Barren Ridge-Vincent #1 line						**X**		Changing the assumed connection pattern of renewables in the Tehachapi area may eliminate the criteria violation that this upgrade mitigates.
500 kV Colorado River-Desert Center #2 line[5]	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Eastern portion of 500 kV Colorado River-Devers #2 line included in 2019 WECC seed case. Cases A, B and C excluded the new Desert Center substation assumed by RETI.
500 kV Desert Center-Devers #2 line[6]	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Western portion of 500 kV Colorado River-Devers #2 line included in 2019 WECC seed case. Cases A, B and C excluded the Desert Center substation assumed by RETI.
500 kV Desert Center-Devers #3 line	**X**							
Replacement of existing small 500/230 kV transformer at Imperial Valley substation	**X**							
Third 500/230 kV transformer at Imperial Valley substation	**X**							
230 kV El Centro-Imperial Valley #2 line	**X**							Case C studies suggest (i) a 500

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[5] According to the CPUC-approved plan of service, the existing 500 kV Palo Verde-Devers #1 line will be looped into the new Colorado River substation. RETI assumed that a new Desert Center substation would also be looped into the existing 500 kV Palo Verde-Devers #1 line. These loop-ins would create a 500 kV Colorado River-Desert Center #1 and 500 kV Desert Center-Devers #1 lines. CTPG does not assume a Desert Center substation.

[6] See footnote above.

Transmission Project	RETI Phase 2A Conceptual Plan	WECC 2019 Seed Case	CASE A	CASE A S-N	CASE A S-N TEWA	CASE B	CASE C	Comments
230 kV El Centro-Highline #1 upgrade project	**X**							kV Imperial Valley-Bannister-Devers #1 line, or (ii) 230 kV El Centro-Imperial Valley #2 line + 230 kV El Centro-Highline #1 & #2 lines would be useful in maximizing the dispatch of renewable resources in the Imperial Valley.
230 kV El Centro-Highline #2 line	**X**							
500 kV Imperial Valley-Bannister #1 line	**X**							
500 kV Bannister-Devers #1 line	**X**							
230 kV Dixieland-Bannister #1 rebuild project	**X**							
230 kV Bannister-El Centro #1 line	**X**							
230 kV Bannister-Geo #1 line	**X**							
230 kV Bannister-Geo #2 line	**X**							
230 kV Midway-Geo #1 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Included in the 2019 WECC seed case
230 kV Midway-Geo #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
230 kV Bannister-Coachella Valley #1 line	**X**							
230 kV Bannister-Avenue58 #1 rebuild project	**X**							
230 kV Avenue58-Coachella Valley #1 rebuild project	**X**							
230 kV Coachella Valley-Mirage #1 upgrade project	**X**							
230 kV Coachella Valley-Mirage #2 upgrade project	**X**							
230 kV Mirage-Devers #1 upgrade project	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
230 kV Mirage-Devers #2 upgrade project	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
230 kV Coachella Valley-Devers2 #1 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of 500 kV GPN Project included in 2019 WECC seed case
230 kV Coachella Valley-Devers2 #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	CTPG labels this as 230 kV Coachella Valley-Indian Hill #2 line
230 kV Devers2-Century #1 line	**X**							RETI included this as part of the 230 kV version of the Green Path North Project
230 kV Devers2-Victorville #1 line	**X**							RETI included this as part of the

Transmission Project	RETI Phase 2A Conceptual Plan	WECC 2019 Seed Case	CASE A	CASE A S-N	CASE A S-N TEWA	CASE B	CASE C	Comments
								230 kV version of the Green Path North Project
500 kV Devers-Devers2 #1 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	CTPG labels this as 500 kV Devers-Indian Hill #1 line. RETI included this as part of the "230 kV" version of the Green Path North Project
500 kV Devers-Mira Loma #1 line	**X**							
500 kV Devers-Mira Loma #2 line	**X**							
500 kV Devers-Valley #2 line	**X**	**X**	**X**	**X**	**X**	**X**	**X**	Part of Colorado River-Devers #2 project included in 2019 WECC seed case
500 kV Devers-Valley #3 line	**X**							
500 kV Lee Lake-Camp Pendleton #1 line	**X**							The 500 kV Talega-Escondido/Valley-Serrano (TE/VS) transmission project was not included.
230 kV Camp Pendleton-Escondido #1 upgrade project	**X**							
230 kV Camp Pendleton-Escondido #2 line	**X**							
230 kV Camp Pendleton-Talega #1 upgrade project	**X**							
230 kV Camp Pendleton-Talega #2 line	**X**							

9 Conclusions

Below are key conclusions based on the cases studied to date. CTPG will be evaluating more scenarios in the future and it is expected that these studies will find other reliability criteria violations that will need to be mitigated. And, as noted elsewhere in this report, CTPG intends to evaluate alternatives that could prove to be effective, practical and economic ways of addressing the reliability criteria violations described in this report. These alternatives may suggest changes to elements of CTPG's current conceptual transmission plan. These additions and changes will be reflected in future updates of CTPG's state-wide transmission plan.

Conclusions from the current studies are:

1. Provided identified Category C reliability criteria violations can be mitigated through controlled load drop and/or generation-tripping schemes, and provided other localized criteria violations can be addressed through relatively simple mitigation measures, California can make substantial progress towards its renewable resource goals with those transmission upgrades listed on Table 11 and Table 30.

2. Significant upgrades will be required to both Path 26 and Path 15 to accommodate flows near 4500 MW and 8500 MW, respectively.

3. In the north to south studies, potential reliability concerns arise in the Sacramento and San Diego areas, primarily due to increased imports into the respective areas resulting from the reduction in fossil-fired generation.

4. Additional transmission enhancements or other mitigation would be required to address reliability criteria violations that arise from increased renewable generation in the following CREZs: (a) Tehachapi in the event a significant amount of new generation is connected at Barren Ridge, (b) Kramer, (c) Pisgah, (d) Central Nevada/Inyokern, and (e) East Riverside County.

5. Under heavy summer conditions, the historical direction of flows on Path 26 and Path 15 will change from north-to-south to south-to-north. With these changed flows N-2 contingency overloads appear on certain 230 kV facilities along the path connecting the southern and northern California load centers. Mitigation for these reliability criteria violations, which can include controlled load drop and/or generation tripping, will be required.

6. Several local overloads in the load centers would have to be mitigated by local transmission reinforcements or by new operating procedures.

7. Further studies are needed to assess the practicality, benefits and costs of other measures that would be effective in addressing identified reliability criteria violations

assuming renewable resource development at levels sufficient to meet California's 33% RPS goal. These measures may include:

a. Reactive energy sources (voltage support), particularly in the SDG&E and SCE areas.
b. Cross-tripping of generation for certain contingency conditions as a potentially quick and cost-effective way to facilitate the connection of new renewable generation to the existing grid.
c. Development of generation SPS and/or related operating procedures, including generation tripping to allow full dispatch of renewable resources within CREZs, and cross-tripping generation for certain contingency conditions, as potentially quick and cost-effective ways to facilitate the connection of new renewable generation to the existing grid.
d. Alternative connection configurations for CREZs located close to existing transmission. For certain CREZs it may possible to locate new substations close to existing transmission and loop the new substation into the existing transmission. This may avoid the need to construct costly and environmentally disruptive network transmission lines and therefore be an easier and faster way to obtain required project approvals and environmental permits.

10 Next Steps

CTPG emphasizes that the studies conducted to date reflects Phase 1 of CTPG's work. Only a limited number of scenarios have been considered. The following studies and scenario assessments are recommended as next-steps to be completed before a comprehensive transmission plan is developed:

1. Input from stakeholder meeting: Develop cases and scenarios as may be requested by stakeholders and determined to be potentially helpful in improving the efficacy of CTPG's conceptual transmission plan.

2. Test a range of renewable net-short estimates: This range could be based on different assumptions concerning load growth, energy efficiency and demand response impacts, rooftop solar photovoltaic additions, renewable and non-renewable distributed generation additions, and the expected energy production from existing and under construction renewable generators. RETI could define a reasonable range of net short estimates.

3. Generation Redispatch Alternatives: Test other fossil-fired generation dispatch patterns that would accommodate the projected increase in renewable energy production. Such patterns could include departures from a strict merit-order redispatch approach, for example, assuming old peakers are not the first units dispatched down, or assuming variations around the assumed 70/30 split between in-state and out-of-state fossil-fired redispatch.

4. Procurement Scenarios: Test other renewable resource development scenarios (location, type and quantity of renewable resource additions). For instance: out of state scenarios and Owens Lake development. These alternative renewable resource expansion scenarios could be developed based on data provided by entities responsible for serving retail loads in California and with guidance from RETI.

5. Tehachapi -Barren Ridge Renewable Split: Adjust the renewable split to reflect a more likely pattern of renewable generator connection configurations in the Tehachapi area.

6. Once-through Cooling (OTC) Study: Continue the OTC studies and update the CTPG's conceptual transmission plan as appropriate. The results of the OTC studies could indicate the need for additional renewable generation in specific locations, new transmission infrastructure not in CTPG's current conceptual transmission plan, and/or operational measures that would provide continued grid reliability with fewer coastal fossil-fired generating units in-service

7. Owens Lake Solar Development Assessment: Develop transmission plans to access 2000 to 3000 MW of solar capacity developed at Owens Lake by 2020.

8. Deliverability: Develop cases to test the deliverability of renewable resources considering that the renewable resources at given locations and at given points in time may be simultaneously operating at or near peak capacity.

11 Appendix 1: Contingencies

N-1 Contingencies[7]

<u>PDCI bipole outage</u>

[All 230 kV, 287 kV, and 500 kV lines in California]

[Selected major external 230, 345, and 500 kV lines]

[Selected major lower voltage lines in California]

[All generators exceeding 500 MW in California]

[Selected external generators exceeding 500 MW]

N-2 Contingencies[8]

Malin - Round Mt. #1 and #2 500kV

Round Mt. - Table Mt. #1 and #2 500 kV

Table Mt. – Tesla and Table Mt.- Vaca 500 kV

Table Mt. – Tesla and Vaca – Tesla 500 kV

Tesla – Los Banos and Tesla – Tracy 500 kV

Tesla – Los Banos and Tracy – Los Banos 500 kV

Diablo – Midway #1 and #2 500 kV

Los Banos - Gates #1 and Los Banos – Midway #2 500 kV

Los Banos – Midway #2 and Gates – Midway #1 500 kV

IPP DC 500 kV Bipole

Midway - Vincent #1 and #2 500 kV

Palo Verde - Westwing #1 and #2 500 kV

McCullough – Victorville #1 and #2 500 kV

Lugo – Mira Loma #2 and #3 500 kV

Lugo – Mohave and Lugo – Eldorado 500 kV

Lugo – Vincent #1 and #2 500 kV

Adelanto-Rinaldi 500 kV and Victorville-Rinaldi 500 kV

Adelanto-Victorville #1 and #2 500 kV

Victorville-Century #1 and 2 287 Kv

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[7] Including all transmission line segments added as part of the RETI upgrades.

[8] Including all transmission line segments added as part of the RETI upgrades.

12 Appendix 2: Case C Sensitivities

12.1 Power Flow Analysis:

12.1.1 C1 Sensitivities (N-0) Normal Conditions:

12.1.1.1 C1S1

Power flow analysis for the C1S1 sensitivity case indicated the 230 kV Kramer-Lugo #1 & 2 lines are loaded at 100% of their N-0 normal rating.

Table 49: N-0 Thermal Violations in C1S1 Cases

OVERLOADED COMPONENT	Case C1S1 % OVERLOAD	AREA
KRAMER - LUGO 230kV Line 1	100%	SCE
KRAMER - LUGO 230kV Line 2	100%	SCE

12.1.1.2 C1S2

Power flow analysis for the C1S2 sensitivity case indicated the Julian Hinds SCE-MWD 230 kV sectionalizing breaker was overloaded at 101% of its N-0 normal rating.

Table 50: N-0 Thermal Violations in C1S2 Cases

OVERLOADED COMPONENT	Case C1S2 % OVERLOAD	AREA
JHINDMWD - JHINDSCE 230kV	101%	SCE

12.1.1.3 C1S3

Power flow analysis for the C1S3 sensitivity case indicated that there were no N-0 overloads.

12.1.2 C2 Sensitivities (N-0) Normal Conditions:

12.1.2.1 C2S1

Power flow analysis for the C2S1 sensitivity case, with total renewable generation output of approximately 10,973 MW, reveal three N-0 overloads shown in Table 51:

Table 51: Overloads in C2S1 Case

OVERLOADED COMPONENT	Case C2S1 %OVERLOAD	AREA
KRAMER - LUGO 230kV Line 1	156%	SCE
KRAMER - LUGO 230kV Line 2	156%	SCE
JHINDMWD - JHINDSCE 230kV	103%	SCE

12.1.2.2 C2S2

Power flow analysis for the C2S2 sensitivity case, with total renewable generation output of approximately 10,128 MW, revealed three N-0 overloads shown in Table 52:

Table 52: Overloads in C2S2 Case

OVERLOADED COMPONENT	Case C2S2 %OVERLOAD	AREA
KRAMER - LUGO 230kV Line 1	156%	SCE
KRAMER - LUGO 230kV Line 2	156%	SCE
JHINDMWD - JHINDSCE 230kV	101%	SCE

12.1.2.3 C2S3

Power flow analysis for the C2S3 sensitivity case, with total renewable generation output of approximately 9,882 MW, revealed two N-0 overloads shown in Table 53:

Table 53: Overloads in C2S3 Case

OVERLOADED COMPONENT	Case C2S3 %OVERLOAD	AREA
KRAMER - LUGO 230kV Line 1	156%	SCE
KRAMER - LUGO 230kV Line 2	156%	SCE

12.1.3 C1 Sensitivities - Single Contingency Conditions:

12.1.3.1 C1S1

In the C1S1 base case sensitivity, with the IID backbone 230 kV system in place, the Julian Hinds SCE-MWD 230 kV sectionalizing breaker does not violate any thermal limits.

12.1.3.2 C1S2

In the C1S2 base case sensitivity, without the Green Path North project in place, the Julian Hinds SCE-MWD 230 kV sectionalizing breaker was overloaded for all studied contingencies.

12.1.3.3 C1S3

In the C1S3 base case sensitivity, with the 230 kV variant of GPN in place, N-1 contingencies revealed the thermal violations listed in Table 54 below. Note that this N-1 contingency overload in the benchmark C1S3 case was mitigated as the renewable dispatch increases in the IID area.

Table 54: Overloads in C1S3 Case

CONTINGENCY	IMPACTED ELEMENT	Case C1S3 % OVERLOAD	AREA
Palo Verde ColRiver 500 1	JHINDSCE - Mirage 230kV	104%	SCE

12.1.4 C2 Sensitivities - Single Contingency Conditions:

12.1.4.1 C2S1

In the C2S1 sensitivity case (with the IID backbone 230kV system in place and 10,973 MW of renewable generation dispatched), the Julian Hinds SCE-MWD 230 kV sectionalizing breaker and both Kramer-Lugo 230 kV lines were overloaded for all studied contingencies. In addition, the N-1 contingencies listed below produced the indicated thermal overloads:

Table 55: Overloads in C2S1 Case

CONTINGENCY	IMPACTED ELEMENT	Case C2S1 % OVERLOAD	AREA
Imperial Valley 500/230 xfmr 1	Imperial Valley 500/230kV xfmr 2	103.8%	SDG&E

SDG&E anticipates the addition of a 3rd 1120MVA 500/230 kV transformer at Imperial Valley substation that is not reflected in the C2S1 case. It may be added in connection with the interconnection of Stirling Energy's 300 MW solar thermal project in the Imperial Valley. The third bank at IV is expected to mitigate the above thermal violation.

The total renewable generation output in the C2S1 case is approximately 10,973 MW. In this case, there is only one renewable area that is constrained by thermal limitations of the transmission system:

Table 56: Constrained Renewables in Case C2S1

CREZ	Constraining Element	Contingency	CREZ On-Peak Available Capacity	Max On-Peak Allowable Dispatch
Pisgah Solar Thermal	Pisgah-Lugo 500 kV ckt. 1 or 2	Pisgah-Lugo 500 kV ckt. 1 or 2	2423 MW	2000 MW

12.1.4.2 C2S2

In the C2S2 sensitivity case (without the Green Path North project in place and with 10,128 MW of renewable generation dispatched), the Julian Hinds SCE-MWD 230 kV sectionalizing breaker and both Kramer-Lugo 230 kV lines were overloaded for all studied contingencies. In addition the N-1 contingencies listed below produced the indicated thermal overloads.

Table 57: (N-1) Overloads in C2S2 Case

CONTINGENCY	IMPACTED ELEMENT	Case C2S2 % OVERLOAD	AREA
Imperial Valley-ECO 500 kV w/Gentrip SPS	Barre-Ellis 230 kV	100%	SCE
ECO-Miguel 500 kV w/Gentrip SPS	Barre-Ellis 230 kV	100%	SCE
N.GILA-W.GILA 500 kV	Barre-Ellis 230 kV	113%	SCE
N.GILA-W.GILA500 kV w/ Crosstrip SPS of IV-Dixie Land 230Kv	Barre-Ellis 230 kV	114%	SCE
IV-W.GILA 500 kV	Barre-Ellis 230 kV	113%	SCE
IV-W.GILA500 kV w/ Crosstrip SPS of IV-Dixie Land 230Kv	Barre-Ellis 230 kV	115%	SCE

Note that SCE has a planned upgrade of the Barre-Ellis 230 kV line that is not reflected in the C2S2 case. It is expected that this upgrade will mitigate the identified thermal violations.

Also note that without the Green Path North project in place, almost none of the renewables in the IID control area are dispatchable. The total renewable generation output in the C2S2 case is approximately 10,128 MW. Renewable development areas considered constrained by thermal limitations of the transmission system are as follows:

Table 58: Constrained Renewables in Case C2S2

CREZ	Constraining Element	Contingency	CREZ On-Peak Available Capacity	Max On-Peak Allowable Dispatch
Imperial North-A Geothermal	Coachella-Mirage 230 KV	Coachella-Ramon 230 kV	317 MW	8 MW
	Coachella-Ramon 230 kV	Coachella-Mirage 230 KV		
	Ramon-Mirage 230 kV	Coachella-Mirage 230 KV		
Imperial North-B Solar	(Same as above)	(Same as above)	132 MW	0 MW
Imperial North-B Geo	(Same as above)	(Same as above)	54 MW	0 MW
Imperial North-B Bio	(Same as above)	(Same as above)	6 MW	0 MW
Palm Springs Wind	Devers-El Casco 230 kV	Valley-Serrano 500 kV	83 MW	0 MW
Pisgah Solar Thermal	Pisgah-Lugo 500 kV ckt. 1 or 2	Pisgah-Lugo 500 kV ckt. 1 or 2	2423 MW	1995 MW
Riverside East Solar Thermal	Devers-El Casco 230 kV	Valley-Serrano 500 kV	1016 MW	760 MW

12.1.4.3 C2S3

In the C2S3 sensitivity case (with the 230 kV variant of GPN in place and 9,882 MW of renewable generation dispatched), both Kramer-Lugo 230 kV lines were overloaded for all studied contingencies. The N-1 contingencies listed below resulted in the identified thermal overloads.

Table 59: (N-1) Overloads in C2S3 Case

CONTINGENCY	IMPACTED ELEMENT	Case C2S3 % OVERLOAD	AREA
Serrano - Valley 500 kV #1	JHINDMWD - JHINDSCE 230kV	100%	SCE
N.GILA-W.GILA 500 kV	Barre-Ellis 230 kV	113%	SCE
N.GILA-W.GILA500 kV w/ Crosstrip SPS of IV-Dixie Land 230Kv	Barre-Ellis 230 kV	114%	SCE
IV-W.GILA 500 kV	Barre-Ellis 230 kV	113%	SCE
IV-W.GILA500 kV w/ Crosstrip SPS of IV-Dixie Land 230Kv	Barre-Ellis 230 kV	114%	SCE

Note that SCE has a planned upgrade of the Barre-Ellis 230 kV line that is not reflected in the C2S3 case. It is expected that this upgrade will mitigate the thermal violations.

Also note that with the 230 kV variant of GPN in place, the total renewable generation output in the C2S3 case is approximately 9,882MW, which is 246MW less than the S2 case (10128MW). The 230 kV variant, includes two 400MW phase shifters (one in Century City, another in Victorville). The proposed setting of these phase shifters forced large amounts of flow north and consequently, caused the heavy transmission constraints on the Lugo-Victorville 500 kV line. Such constraints can probably be mitigated by changing the phase shifter settings or by bypassing at least one of the phase shifters. Modification of the phase shifter settings is beyond the scope of this sensitivity study.

The renewable areas listed below were constrained by thermal limitations of the transmission system:

Table 60: Constrained Renewables in Case C2S3

CREZ	Constraining Element	Contingency	CREZ On-Peak Available Capacity	Max On-Peak Allowable Dispatch
Imperial North-A Geothermal	Coachella-Midway 230 KV	Coachella-Midway 230 kV	317 MW	143 MW

CREZ	Constraining Element	Contingency	CREZ On-Peak Available Capacity	Max On-Peak Allowable Dispatch
Imperial North-B Solar	(Same as above)	(Same as above)	132 MW	0 MW
Imperial North-B Geo	(Same as above)	(Same as above)	54 MW	0 MW
Imperial North-B Bio	(Same as above)	(Same as above)	6 MW	0 MW
Fairmount Solar thermal	Lugo- Victorville 500 kV ckt. 1	Eldorado-Pisgah 500 kV ckt 1 Mohave-Pisgah 500Kv ckt 1 N.GILA-W.GILA 500 kV ckt 1 IV-W.GILA 500 kV ckt 1	246 MW	0 MW
Fairmount Wind	(Same as above)	(Same as above)	19.7 MW	0 MW
Fairmount Bio	(Same as above)	(Same as above)	6 MW	0 MW
Barstow Solar thermal	(Same as above)	(Same as above)	624.1MW	80 MW
Pisgah Solar Thermal	Pisgah-Lugo 500 kV ckt. 1 or 2	Pisgah-Lugo 500 kV ckt. 1 or 2	2423 MW	2090 MW

12.1.5 C1 Sensitivities - Double Contingency Conditions:

12.1.5.1 C1S1

For the C1S1 base case sensitivity, simulation of all credible (N-2) contingencies revealed the thermal overloads listed on Table 61 below:

Table 61: (N-2) Overloads in C1S1 Case

CONTINGENCY	IMPACTED ELEMENT	Case C1S1 % OVERLOAD	AREA
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #3	118%	PG&E
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #2	107%	PG&E
Round Mt-Table Mt 500 KV 1&2	CPVSTA-Cortina 230 kV	113%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	Cottonwood-Round Mt 230 kV #3	105%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	CPVSTA-Cortina 230 kV	109%	PG&E
Imperial Valley-Central & Miguel 500 kV	Imperial Valley-La Rosita 230 kV	114%	SDG&E

CONTINGENCY	IMPACTED ELEMENT	Case C1S1 % OVERLOAD	AREA
w/Gentrip SPS			
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Otay Mesa-Tijuana 230 KV	118%	SDG&E
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Barre-Ellis 230 kV	104%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip & Crosstrip SPS of IV-La Rosita	Barre-Ellis 230 kV	135%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip & Crosstrip SPS of TJ-OM	Barre-Ellis 230 kV	136%	SCE

12.1.5.2 C1S2

For the C1S2 base case sensitivity, simulation of all credible (N-2) contingencies revealed the thermal overloads listed on Table 62 below:

Table 62: (N-2) Overloads in C1S2 Case

CONTINGENCY	IMPACTED ELEMENT	Case C1S2 % OVERLOAD	AREA
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #3	118%	PG&E
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #2	107%	PG&E
Round Mt-Table Mt 500 KV 1&2	CPVSTA-Cortina 230 kV	113%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	Cottonwood-Round Mt 230 kV #3	105%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	CPVSTA-Cortina 230 kV	109%	PG&E
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Imperial Valley-La Rosita 230 kV	113%	SDG&E
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Otay Mesa-Tijuana 230 KV	116%	SDG&E
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Barre-Ellis 230 kV	104%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip & Crosstrip SPS of IV-La Rosita	Barre-Ellis 230 kV	135%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip & Crosstrip SPS of TJ-OM	Barre-Ellis 230 kV	136%	SCE

Also note that the C1S2 sensitivity case (without the Green Path North project, before any renewable generation is dispatched) diverged for the N-2 contingency loss of both lines comprising Path 42. This indicates a possible voltage collapse situation in the IID system.

12.1.5.3 C1S3

For the C1S3 base case sensitivity, simulation of all credible (N-2) contingencies revealed the following thermal overloads, as listed in Table 63 below:

Table 63: (N-2) Overloads in C1S3 Case

CONTINGENCY	IMPACTED ELEMENT	Case C1S3 % OVERLOAD	AREA
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #3	118%	PG&E
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #2	107%	PG&E
Round Mt-Table Mt 500 KV 1&2	CPVSTA-Cortina 230 kV	112%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	Cottonwood-Round Mt 230 kV #3	105%	PG&E
Table Mt-Tesla & Table Mt-VacaDix 500 KV	CPVSTA-Cortina 230 kV	109%	PG&E
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Imperial Valley-La Rosita 230 kV	112%	SDG&E
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Otay Mesa-Tijuana 230 KV	115%	SDG&E
Imperial Valley-Central & Miguel 500 kV w/Gentrip SPS	Barre-Ellis 230 kV	103%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip & Crosstrip SPS of IV-La Rosita	Barre-Ellis 230 kV	134%	SCE
Imperial Valley-Central & Miguel 500 kV w/Gentrip & Crosstrip SPS of TJ-OM	Barre-Ellis 230 kV	135%	SCE
JHINDSCE - MIRAGE 230kV	DEVERS-COLRVR 500Kv 1&2	104%	SCE

12.1.6 C2 Sensitivities – Double Contingency Conditions:

12.1.6.1 C2S1

Full analysis of all credible (N-2) contingencies revealed the thermal overloads listed on Table 64 below:

Table 64: (N-2) Overloads in C2S1 Case

CONTINGENCY	IMPACTED ELEMENT	Case C2S1 % OVERLOAD	AREA
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #3	105%	PG&E
Round Mt-Table Mt 500 KV 1&2	CPVSTA-Cortina 230 kV	110%	PG&E
Tesla-Los Banos & Tracy-Los Banos 500 kV	Westley-Los Banos 230 kV	140%	SCE
Los Banos-Gates & Los Banos-Midway 500 kV	Gates 500/230/13.8 kV Xfmr	107%	SCE
Midway-Gates & Los Banos-Midway 500 kV	Gates-Midway 230 kV	142%	SCE
Midway-Gates & Los Banos-Midway 500 kV	Arco-Midway 230 kV	133%	SCE
San Onofre-Talega 230 kV 1&2	Escondido-Talega 230 kV	105%	SDG&E

12.1.6.2 C2S2

Full analysis of all credible (N-2) contingencies revealed the thermal overloads listed on Table 65 below:

Table 65: (N-2) Overloads in C2S2 Case

CONTINGENCY	IMPACTED ELEMENT	Case C2S2 % OVERLOAD	AREA
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #3	109%	PG&E
Round Mt-Table Mt 500 KV 1&2	CPVSTA-Cortina 230 kV	112%	PG&E
Tesla-Los Banos & Tracy-Los Banos 500 kV	Westley-Los Banos 230 kV	135%	PG&E
Los Banos-Gates & Los Banos-Midway 500 kV	Gates 500/230/13.8 kV Xfmr	105%	PG&E
Midway-Gates & Los Banos-Midway 500 kV	Gates-Midway 230 kV	137%	SCE
Midway-Gates & Los Banos-Midway 500 kV	Arco-Midway 230 kV	129%	SCE
San Onofre-Talega 230 kV 1&2	Escondido-Talega 230 kV	104%	SDG&E

12.1.6.3 C2S3

Full analysis of all credible (N-2) contingencies revealed the thermal overloads listed on Table 66 below:

Table 66: (N-2) Overloads in C2S3 Case

CONTINGENCY	IMPACTED ELEMENT	Case C2S2 % OVERLOAD	AREA
Round Mt-Table Mt 500 KV 1&2	Cottonwood-Round Mt 230 kV #3	108%	PG&E
Round Mt-Table Mt 500 KV 1&2	CPVSTA-Cortina 230 kV	112%	PG&E
Tesla-Los Banos & Tracy-Los Banos 500 kV	Westley-Los Banos 230 kV	135%	PG&E
Los Banos-Gates & Los Banos-Midway 500 kV	Gates 500/230/13.8 kV Xfmr	105%	PG&E
Midway-Gates & Los Banos-Midway 500 kV	Gates-Midway 230 kV	137%	SCE
Midway-Gates & Los Banos-Midway 500 kV	Arco-Midway 230 kV	129%	SCE
San Onofre-Talega 230 kV 1&2	Escondido-Talega 230 kV	104%	SDG&E
VCTRVL-FRMT&ADLNTO-FRMT 500KV	LUGO-Victorville 500KV	100.7%	SCE
FAIRMONT-RINALDI 500KV 1&2	LUGO-Victorville 500KV	101.1%	SCE
JHINDSCE-MIRAGE 230kV	DEVERS-COLRVR 500Kv 1&2	107%	SCE

These overloads would have to be mitigated by local transmission reinforcements or by new operating procedures. Note that these new operating procedures could include controlled load drop since this is permitted mitigation for N-2 reliability criteria violations.

Similar to C2 cases, the C2S1, C2S2 and C2S3 powerflow cases diverged for the contingency of Imperial Valley-Miguel 500 kV followed by SPS action tripping the Imperial Valley generation and cross-tripping of the Tijuana-Otay Mesa 230 kV or the Imperial Valley-La Rosita 230 kV lines, indicating a possible voltage collapse situation. However, after loss of the IV-Miguel 500 kV line there is no thermal overload observed within CFE, therefore the cross-trip SPS probably would not be activated for the IV-Miguel 500 KV contingency. The C2S1, C2S2 and C2S3 powerflow cases also diverged for the contingency of the Table Mt-Tesla and Table Mt-VacaDix 500 kV lines. It is believed that this is likely a program solution problem rather than a voltage collapse situation.

12.2 Post-Transient Stability Analysis:

12.2.1 C1S1, C1S2, and C1S3 Case:

N-1 post-transient voltage violations were observed in the C1S1, C1S2 and C1S3 cases at the O'Banion 230 kV bus for the N-1 contingency of the Sutter-O'Banion 230 kV line.

12.2.2 C2S1, C2S2, and C2S3 Case:

The post-transient voltage violation at the O'Banion 230 kV bus worsens slightly in the C2S1, C2S2 and C2S3 cases.

For the C2S1 case, one additional Category C voltage violation was observed at the Talega 230 kV bus for the N-2 contingency of the 230 kV Talega-San Onofre # 1 and 2 lines.

Overall, it was observed that as the amount of renewable dispatch increased and fossil generation was ramped down, the steady-state voltage profile in the SDG&E and SCE 230 kV systems noticeably deteriorated.