

## **APPENDIX G: Production Cost Simulation and Economic Assessment Detailed Results**

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## Appendix G

# Production Cost Simulation and Economic Assessment Detailed Results

### G.1 Introduction

The ISO's economic planning study is an integral part of the ISO's transmission planning process and is performed on an annual basis as part of the transmission plan. The economic planning study complements the reliability-driven and policy-driven analysis documented in this transmission plan, exploring economic-driven transmission solutions that may create opportunities to reduce ratepayer costs within the ISO.

Each cycle's study is performed after the completion of the reliability-driven and policy-driven transmission studies performed as part of this transmission plan.

### G.2 Technical Study Approach and Process

Different components of ISO ratepayer benefits are assessed and quantified under the economic planning study. First, production benefits are quantified by the production cost simulation that computes unit commitment, generator dispatch, locational marginal prices and transmission line flows over 8,760 hours in a study year. With the objective to minimize production costs, the computation balances supply and demand by dispatching economic generation while accommodating transmission constraints. The study identifies transmission congestion over the entire study period. In comparison of the "pre-project" and "post-project" study results, production benefits can be calculated from savings of production costs or ratepayer payments.

The production benefit relied upon by the ISO includes three components of ISO ratepayer benefits: consumer energy cost decreases; increased load serving entity owned generation revenues; and increased transmission congestion revenues. Additionally, other benefits including capacity benefits are also assessed. Capacity benefits may include system and flexible resource adequacy (RA) savings and local capacity savings. The system RA benefit corresponds to a situation where a transmission solution for importing energy leads to a reduction of ISO system resource requirements, provided that out-of-state resources are less expensive to procure than in-state resources. The local capacity benefit corresponds to a situation where a transmission solution leads to a reduction of local capacity requirement in a load area or accessing an otherwise inaccessible resource.

The production cost simulation plays a major role in quantifying the production cost reductions that are often associated with congestion relief. Traditional power flow analysis is also used in quantifying other economic benefits such as system and local capacity savings.

Such an approach is consistent with the requirements of tariff Section 24.4.6.7 and TEAM principles. The calculation of these benefits is discussed in more detail below.

In the production benefit assessments, the ISO calculates ISO ratepayer's benefits<sup>1</sup> as follows:

- ISO ratepayers' production benefit = (ISO Net Payment of the pre-upgrade case) – (ISO Net Payment of the post-upgrade case)
- ISO Net Payment = (ISO load payment) – (ISO generator net revenue benefiting ratepayers) – (ISO transmission revenue benefiting ratepayers)

The above calculation reflects the benefits to ISO ratepayers – offsetting other ISO ratepayer costs – of transmission revenues or generation profits from certain assets whose benefits accrue to ISO ratepayers. These include:

- PTO owned transmission
- Generators owned by the utilities serving the ISO's load
- Wind and solar generation or other resources under contract with an ISO load-serving entity to meet the state renewable energy goal, and
- Other generators under contracts where information available for the public may be reviewed for consideration of the type and the length of contract.

How ISO ratepayer benefits relate to (and differ from) the ISO production cost benefits are shown in

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<sup>1</sup> WECC-wide societal benefits are also calculated to assess the overall reasonableness of the results and to assess the impact of the project being studied on the rest of the WECC-wide system, but not as the basis for determining whether the project is in the interests of the ISO ratepayer to proceed with. The WECC-wide societal benefits are assessed according to the following formula: *WECC society production benefit = (WECC Production Cost of the pre-upgrade case) – (the WECC Production Cost of the post-upgrade case)*

Figure G.2-1.

Figure G.2-1: Ratepayer Benefits vs. Production Cost Savings

| ISO Net Ratepayer Benefits from Production Cost Simulations are the sum of: | Types of Revenues and Costs calculated in Production Cost Studies  | ISO “Production Cost” Savings are the sum of: |
|---|--|---|
| <b>Load Payments at Market Prices for Energy</b>                            |  |   |
| Yes ←   | Reductions in ISO Ratepayer Gross Load Payments  |   |
| <b>Generation Revenues and Costs</b>  |  |   |
| Yes ←   | Increases in generator profits inside ISO for generators owned by or under contract with utilities or load serving entities, being the sum of: |   |
|   | Increases in these generators' revenues  |   |
|   | Decreases in these generators' costs → Yes   |   |
|   | Increases in merchant (benefits do not accrue to ratepayers) generator profits inside the ISO, being the sum of:                               |   |
|   | Increases in these generators' revenues  |   |
|   | Decreases in these generators' costs → Yes   |   |
| Yes ←   | Increases in profits of dynamic scheduled resources under contract with or owned by utilities or load serving entities, being the sum of:      |   |
|   | Increases in these dynamic scheduled resource revenues   |   |
|   | Decreases in these dynamic scheduled resource costs  |   |
| <b>Transmission-related Revenues</b>  |  |   |
| Yes ←   | Increases in transmission revenues that accrue to ISO ratepayers   |   |
|   | Increases in transmission revenue for merchant (e.g. non-utility owned but under ISO operational control) transmission                         |   |

In addition to the production and capacity benefits, any other benefits under TEAM — where applicable and quantifiable — can also be included. All categories of benefits identified in the TEAM document<sup>2</sup> and how they are addressed in the economic study process are summarized and set out in detail in

<sup>2</sup> Transmission Economic Assessment Methodology (TEAM), California Independent System Operator, Nov. 2 2017  
[http://www.caiso.com/Documents/TransmissionEconomicAssessmentMethodology-Nov2\\_2017.pdf](http://www.caiso.com/Documents/TransmissionEconomicAssessmentMethodology-Nov2_2017.pdf)

Table G.2-1.

Table G.2-1: Summary of TEAM Benefit Categories

| Categorization of Benefits  | Individual sections in TEAM describing each potential benefit.   | How are benefits assessed in TPP?   |
|---|--|---|
| Production benefits: Benefits resulting from changes in the net ratepayer payment based on production cost simulation as a consequence of the proposed transmission upgrade.  | In addition to production cost benefits themselves, focusing on ISO net ratepayer benefits;  | Benefits focused on ISO net ratepayer benefits through production cost modeling.  |
|   | <p>2.5.2 Transmission loss saving benefit (AND IN CAPACITY BENEFITS FOR CAPACITY)</p> <p>Transmission upgrade may reduce transmission losses. The reduction of transmission losses will save energy hence increase the production benefit for the upgrade, which is incorporated into the production cost simulation with full network model. In the meantime, the reduction of transmission losses may also introduce capacity benefit in a system that potentially has capacity deficit.</p>   | Energy-related savings are reflected in production cost modeling results.   |
| Capacity benefits: Benefits resulting from increased importing capability into the ISO BAA or into an LCR area. Decreased transmission losses and increased generator deliverability contribute to capacity benefits as well. | <p>2.5.1 Resource adequacy benefit from incremental importing capability</p> <p>A transmission upgrade can provide RA benefit when the following four conditions are satisfied simultaneously:</p> <ul style="list-style-type: none"> <li>• The upgrade increases the import capability into the ISO's controlled grid in the study years.</li> <li>• There is capacity shortfall from RA perspective in ISO BAA in the study years and beyond.</li> <li>• The existing import capability has been fully utilized to meet RA requirement in the ISO BAA in the study years.</li> <li>• The capacity cost in the ISO BAA is greater than in other BAAs to which the new transmission connects.</li> </ul> | These benefits are considered where applicable; note that local capacity reduction benefits are discussed below.  |
|   | <p>2.5.2 Transmission loss saving benefit (AND IN PRODUCTION BENEFITS FOR ENERGY)</p> <p>Transmission upgrade may reduce transmission losses. The reduction of transmission losses will save energy hence increase the production benefit for the upgrade, which is incorporated into the production cost simulation with full network model. In the meantime, the reduction of transmission losses may also introduce capacity benefit in a system that potentially has capacity deficit.</p>   | These benefits are considered, where applicable.  |
|   | <p>2.5.3 Deliverability benefit</p> <p>Transmission upgrade can potentially increase generator deliverability to the region under study through the directly increased transmission capacity or the transmission loss saving. Similarly to the resource adequacy benefit as described in Section 2.5.1 in TEAM (and in this table), such deliverability benefit can only be materialized when there will be capacity deficit in the region under study. Full assessment for assessing the deliverability benefit will be on case by case basis.</p>  | This is primarily considered if the renewables portfolios identify the need for additional deliverability (as deliverability is used in TEAM and in ISO planning and generator interconnection studies) in which case the benefits may be policy benefits that have already been addressed in the development of portfolios, and further project development for this purpose for reducing local needs at this time is considered separately below. |
|   | 2.5.4 LCR benefit  | LCR benefits are assessed, and valued according to prudent assumptions at this time given the   |



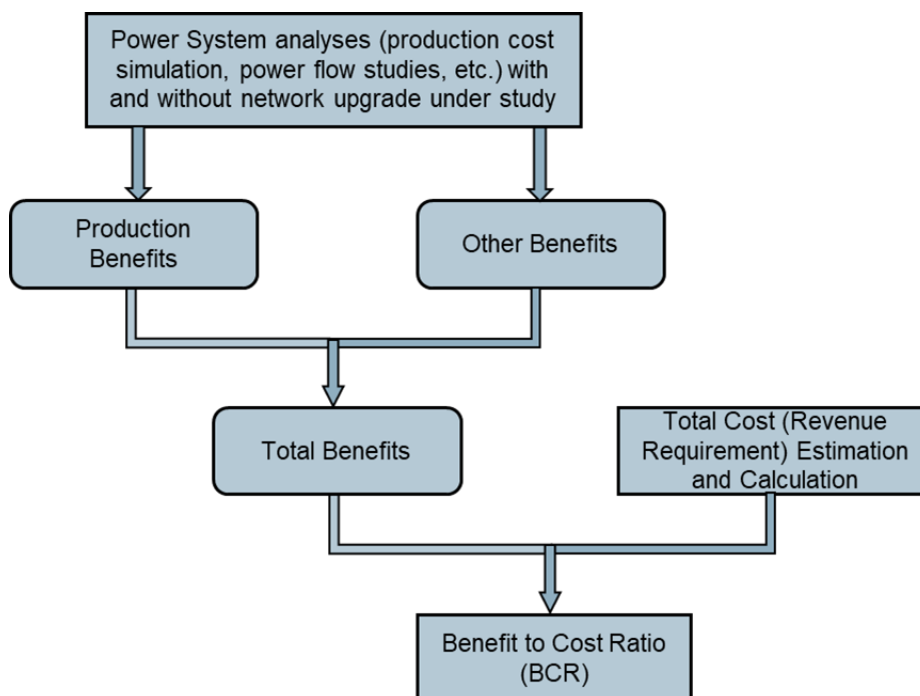
| Categorization of Benefits   | Individual sections in TEAM describing each potential benefit.   | How are benefits assessed in TPP?   |
|--|--|---|
|  | <p>Some projects would provide local reliability benefits that otherwise would have to be purchased through LCR contracts. The Load Serving Entities (LSE) in the ISO-controlled grid pay an annual fixed payment to the unit owner in exchange for the option to call upon the unit (if it is available) to meet local reliability needs. LCR units are used for both local reliability and local market power mitigation. LCR benefit is assessed outside the production cost simulation. This assessment requires LCR studies for scenarios with and without the transmission upgrades in order to compare the LCR costs. It needs to consider the difference between the worst constraint without the upgrade and the next worst constraint with the upgrade. The benefit of the proposed transmission upgrade is the difference between the LCR requirement with and without the upgrade.</p>   | <p>state of the IRP resource planning at the time – and supported by the CPUC.</p>  |
| <p>Public-policy benefit. Transmission projects can help to reduce the cost of reaching renewable energy targets by facilitating the integration of lower-cost renewable resources located in remote areas, or by avoiding over-build.</p> | <p><b>2.5.5 Public-policy benefit</b></p> <p>If a transmission project increases the importing capability into the ISO-controlled grid, it potentially can help to reduce the cost of reaching renewable energy targets by facilitating the integration of lower cost renewable resources located in remote areas.</p> <p>When there is a lot of curtailment of renewable generation, extra renewable generators would be built or procured to meet the goal of renewable portfolio standards (RPS). The cost of meeting the RPS goal will increase because of that. By reducing the curtailment of renewable generation, the cost of meeting the RPS goal will be reduced. This part of cost saving from avoiding over-build can be categorized as public-policy benefit.</p>   | <p>With the current coordination of resource portfolios with the CPUC and CEC in place, these issues are addressed in the course of the portfolio development process.</p>                    |
| <p>Renewable integration benefit. Interregional transmission upgrades help mitigate integration challenges, such as over-supply and curtailment, by allowing sharing energy and ancillary services (A/S) among multiple BAAs.</p>          | <p><b>2.5.6 Renewable integration benefit</b></p> <p>As the renewable penetration increases, it becomes challenging to integrate renewable generation. Interregional coordination would help mitigating integration problems, such as over-supply and curtailment, by allowing sharing energy and ancillary services (A/S) among multiple BAAs.</p> <p>A transmission upgrade that increases the importing and exporting capability of BAAs will facilitate sharing energy among BAAs, so that the potential over-supply and renewable curtailment problems within a single BAA can be relieved by exporting energy to other BAAs, whichever can or need to import energy.</p> <p>A transmission upgrade that creates a new tie or increases the capacity of the existing tie between two areas will also facilitate sharing A/S. Sharing between the areas, if the market design allow sharing A/S. The total A/S requirement for the combined areas may reduce when it is allowed to share A/S. The lower the A/S requirement may help relieving over-supply issue and curtailment of renewable resources.</p> <p>It is worth noting that allowing exporting energy, sharing A/S, and reduced amount of A/S requirement will change the unit commitment and economic dispatch. The net payment of the ISO's ratepayers and the benefit because of a transmission upgrade will be changed thereafter.</p> | <p>This can be considered as applicable, particularly for interregional transmission projects.</p> <p>Re-dispatch benefits would be included in the production cost savings in any event.</p> |

| Categorization of Benefits   | Individual sections in TEAM describing each potential benefit.  | How are benefits assessed in TPP?                                 |
|--|---|---|
|  | However, such a type of benefit can be captured by the production cost simulation and will not be considered as a part of renewable integration benefit.  |   |
| Avoided cost of other projects: If a reliability or policy project can be avoided because of the economic project under study, then the avoided cost contributes to the benefit of the economic project. | <p>2.5.7 Avoided cost of other projects</p> <p>If a reliability or policy project can be avoided because of the economic project under study, then the avoided cost contributes to the benefit of the economic project. Full assessment of the benefit from avoided costs is on a case-by-case basis.</p> | This can be considered on a case by case basis, where applicable. |

Once the total economic benefit is calculated, the benefit is weighed against the cost, which is the total revenue requirement of the project under study, as described in the TEAM. To justify a proposed transmission solution, the ISO ratepayer benefit must be considered relative to the cost of the network upgrade. If the justification is successful, the proposed transmission solution may qualify as an economic-driven transmission solution. Note that other benefits and risks are taken into account – which cannot always be quantified – in the ultimate decision to proceed with an economic-driven transmission solution.

The technical approach of the economic planning study is depicted in Figure G.2-2. The economic planning study starts from an engineering analysis with power system simulations (using production cost simulation and snapshot power flow analysis). Based on results of the engineering analysis, the study enters the economic evaluation phase with a cost-benefit analysis, which is a financial calculation that is generally conducted in spreadsheets.

Figure G.2-2: Technical approach of economic planning study



## G.3 Financial Parameters Used in Cost-Benefit Analysis

A cost-benefit analysis is made for each economic planning study performed where the total costs are weighed against the total benefits of the potential transmission solutions. In these studies, all costs and benefits are expressed in 2024 U.S. dollars and discounted to the assumed operation year of the studied solution to calculate the net-present values.

### G.3.1 Cost analysis

In these studies, the “total cost” is considered to be the present value of the annualized revenue requirement in the proposed operation year. The total revenue requirement includes impacts of capital cost, tax expenses, O&M expenses and other relevant costs.

In calculating the total cost of a potential economic-driven transmission solution, when necessary, the financial parameters listed in Table G.3-1 are used. The net present value of the costs (and benefits) is calculated using a social discount rate of 7% (real) with sensitivities at 5% as needed.

Table G.3-1: Parameters for Revenue Requirement Calculation

| Parameter                  | Value in TAC model |
|----------------------------|--------------------|
| Debt Amount                | 50%                |
| Equity Amount              | 50%                |
| Debt Cost                  | 6.0%               |
| Equity Cost                | 11.0%              |
| Federal Income Tax Rate    | 21.00%             |
| State Income Tax Rate      | 8.84%              |
| O&M                        | 2.0%               |
| O&M Escalation             | 2.0%               |
| Depreciation Tax Treatment | 15 year MACRS      |
| Depreciation Rate          | 2% and 2.5%        |

In the initial planning stage, detailed cash-flow information is typically not provided with the proposed network upgrade to be studied. Instead, lump-sum capital-cost estimates are provided. The ISO then uses typical financial information to convert them into annual revenue requirements, and from there to calculate the present value of the annual revenue requirements stream. As an approximation, the present value of the utility’s revenue requirement is calculated as the capital cost multiplied by a “CC-to-RR multiplier”. For screening purposes, the multiplier used in this assessment is 1.3, reflective of a 7% real discount rate. This is an update to the 1.45 ratio set out in the ISO’s TEAM documentation<sup>3</sup> that was based on prior experiences of the utilities in the ISO. The update reflects changes in federal income-tax rates and more current rate of return inputs. It should be noted that this screening approximation is generally replaced

<sup>3</sup> The ISO expects to update the TEAM documentation dated November 2, 2017 to reflect this change.

on a case-by-case basis with more detailed modeling as needed if the screening results indicate the upgrades may be found to be needed.

As the “capital cost to revenue requirement” multiplier was developed on the basis of the long lives associated with transmission lines, the multiplier is not appropriate for shorter lifespans expected for current battery technologies. Accordingly, levelized annual revenue requirement values can be developed for battery storage capital costs and can then be compared to the annual benefits identified for those projects. This has the effect of the same comparative outcome, but adapts to both the shorter lifespans of battery storage and the varying lifespans of different major equipment within a battery storage facility that impact the levelized cost of the facility.

### G.3.2 Benefit analysis

In the ISO’s benefit analysis, total benefit refers to the present value of the accumulated yearly benefits over the economic life of the transmission solution. The yearly benefits are discounted to the present value in the proposed operation year before the dollar value is accumulated towards the total economic benefit. Because of the discount, the present worth of yearly benefits diminishes very quickly in future years.<sup>4</sup>

In general, when detailed analysis of a high priority study area is required, production-cost simulation and subsequent benefits calculations are conducted for the 10<sup>th</sup> planning year. For years beyond the 10<sup>th</sup> planning year the benefits are estimated by extending the 10<sup>th</sup> year benefit with an assumed escalation rate. In this planning cycle, however, as indicated in section 4.5, the 10<sup>th</sup> year and the 15<sup>th</sup> year- in this case, the 2034-year and the 2039-year, load forecast and resource assumption were used in the planning PCM cases. Accordingly, the 15<sup>th</sup> year case, i.e. the 2039-year case was used as the main case for economic assessment.

The following financial parameters for calculating yearly benefits for use in determining the total benefit in this year’s transmission planning cycle are:

- Economic life of new transmission facilities = 50 years;
- Economic life of upgraded transmission facilities = 40 years;
- Benefits escalation rate beyond year 2039 = 0% (real), and
- Benefits discount rate = 7% (real) with sensitivities at 5% as needed.

### G.3.3 Cost-benefit analysis

Once the total cost and benefit of a transmission solution is determined, a cost-benefit comparison is made. For a solution to qualify as an economic transmission solution under the tariff, the benefit has to be greater than the cost or the net benefit (calculated as gross benefit

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<sup>4</sup> Discount of yearly benefit into the present worth is calculated by  $b_i = B_i / (1 + d)^i$ , where  $b_i$  and  $B_i$  are the present and future worth respectively;  $d$  is the discount rate; and  $i$  is the number of years into the future. For example, given a yearly economic benefit of \$10 million, if the benefit is in the 30th year, its present worth is \$1.3 million based a discount rate of 7%. Likewise, if the benefit is in the 40th or 50th years, its present worth is \$0.7 million or \$0.3 million, respectively. In essence, going into future years the yearly economic benefit worth becomes very small.

minus cost) has to be positive. If there are multiple alternatives, the alternative that has the largest net benefit is considered the most economical solution. As discussed above, the traditional ISO approach is to compare the present value of annualized revenue requirements and benefits over the life of a project using standardized capital cost-to-revenue requirement ratios based on lifespans of conventional transmission. Given the relatively shorter lifespans anticipated for battery storage projects, battery storage projects can be assessed by comparing levelized annual revenue requirements to annual benefits. As indicated above, the ISO must also assess any other risks, impacts, or issues.

### **G.3.4 Valuing Local Capacity Requirement Reductions**

As noted in Chapter 1 and earlier in this Appendix, the ISO recognizes that additional coordination on the long-term resource requirements for gas-fired generation for system capacity and flexibility requirements will need to take place with the CPUC through future integrated resource planning processes. This is particularly important in considering how to assess the value to ratepayers of proposals to reduce gas-fired generation local capacity requirements in areas where, based on current planning assumptions, the gas-fired generation is sufficient to meet local capacity needs. If there are sufficient gas-fired generation resources to meet local capacity needs over the planning horizon, there is not a need for reliability-driven reinforcement; rather, the question shifts to the economic value provided by the reduction in local capacity requirement for the gas-fired generation. However, it cannot be assumed that gas-fired generation no longer required for local capacity purposes will not continue to be needed for system or flexible capacity reasons, albeit through competition with other system resources. While future IRP efforts are expected to provide more guidance and direction regarding expectations for the gas-fired generation fleet at a policy level, without that broader system perspective available at this time, the ISO has taken a conservative approach in assessing the value of a local capacity reduction benefit when considering a transmission reinforcement or other alternatives that could reduce the need for existing gas-fired generation providing local capacity.

In this planning cycle, the capacity costs in the 2022 CPUC Resource Adequacy Report<sup>5</sup>, which is the most recently available report at the time, were used in assessing local capacity reduction benefit.

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<sup>5</sup> [https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/resource-adequacy-homepage/2022-ra-report\\_05022024.pdf](https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/resource-adequacy-homepage/2022-ra-report_05022024.pdf)

## G.4 Study Steps of Production Cost Simulation in Economic Planning

While the assessment of capacity benefits normally uses the results from other study processes, such as resource adequacy and local capacity assessment, production benefits are assessed through production cost simulation. The study steps and the timelines of production cost simulation in economic planning are later than the other transmission planning studies within the same planning cycle. This is because the production cost simulation needs to consider upgrades identified in the reliability and policy assessments, and the production cost model development needs coordination with the entire WECC and management of a large volume of data. In general, production cost simulation in economic planning has three components, which interact with each other: production cost simulation database (also called production cost model or PCM) development and validation, simulation and congestion analysis, and production benefit assessment for congestion mitigation.

PCM development and validation mainly include the following modeling components:

1. Network model (transmission topology, generator location, and load distribution).
2. Transmission constraint model, such as transmission contingencies, interfaces, and nomograms, etc.
3. Generator operation model, such as heat rate and ramp rate for thermal units, hydro profiles and energy limits, energy storage model, renewable profiles, and renewable curtailment and price model.
4. Load model, including load profiles, annual and monthly energy and peak demand, and load modifiers.
5. Market and system operation model, and other models as needed, such as ancillary service requirements, wheeling rate, emission cost and assignment, fuel price and assignment, etc.

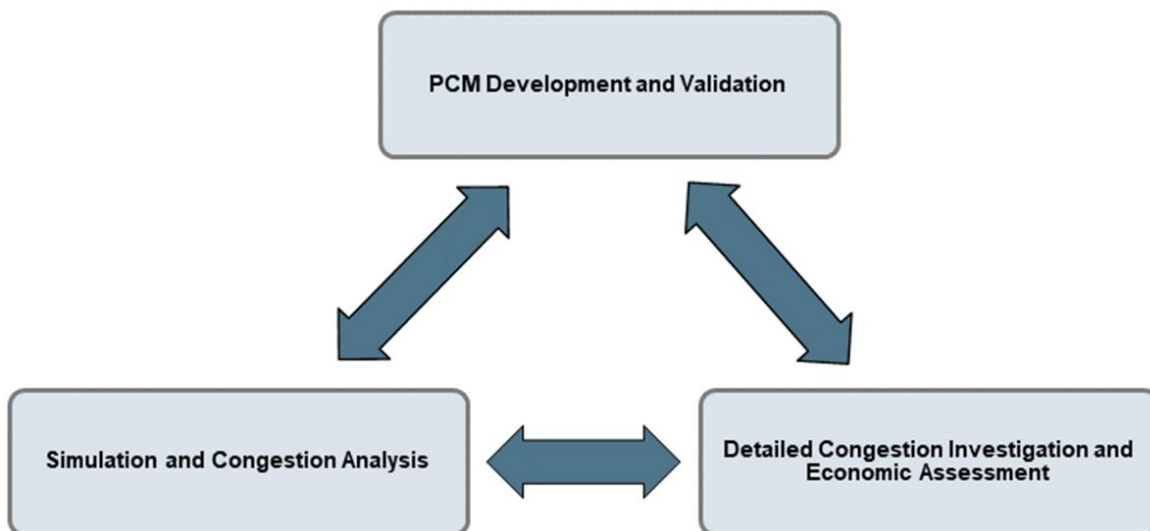
Congestion analysis is based on production cost simulation that is conducted for each hour of the study year. Congestion can be observed on transmission lines or transformers, or on interfaces or nomograms, and can be under normal or contingency conditions. In congestion analysis, all aspects of results may need to be investigated, such as locational marginal price (LMP), unit commitment and dispatch, renewable curtailment, and the hourly power flow results under normal or contingency conditions. Through these investigations, congestion can be validated, or some data or modeling issues can be identified. In either situation, congestion analysis is used for database validation. The simulated power flow pattern is also compared with the historical data for validation purposes, although it is not necessary to have identical flow pattern between the simulation results and the historical data. There are normally many iterations between congestion analysis and PCM development.

In the detailed congestion investigation and economic assessment step, the ISO quantifies economic benefits for each identified transmission solution alternative using the production cost simulation and other means. From the economic benefit information, a cost-benefit analysis is conducted to determine if the identified transmission solution provides sufficient economic benefits to be needed. Net benefits are compared with each other where the net benefits are calculated as the gross benefits minus the costs to compare multiple alternatives that would

address identified congestion issues. The most economical solution is the alternative that has the largest net benefit. In this step, the PCM and the congestion results are further validated.

Normally, there are a number of iterations among these three steps through the entire economic planning study process. Figure G.4-1 shows these components and their interaction.

Figure G.4-1: Steps of production cost simulation in Economic planning



## G.5 Production cost simulation tools

The ISO primarily used the software tools listed in Table G.5-1 for this economic planning study.

Table G.5-1: Economic Planning Study Tools

| Program name      | Version | Functionality  |
|-------------------|---------|--|
| Hitachi GridView™ | 10.3.80 | The software program is a production cost simulation tool with DC power flow to simulate system operations in a continuous time period, e.g., 8,760 hours in a study year (8784 hours for leap year) |

## G.6 ISO Production Cost Model Development

This section summarizes the major assumptions of system modeling used in the PCM development for the economic planning study. The section also highlights the major ISO enhancements and modifications to the Western Interconnection Anchor Data Set production cost simulation model (ADS PCM) database that were incorporated into the ISO's database. It is noted that details of the modeling assumptions and the model itself are not itemized in this document, but the final PCM is posted on the ISO's market participant portal once the study is final.

### G.6.1 Starting database

The 2024-2025 transmission planning process PCM development started from the ADS 2034 PCM. Using this databases, the ISO developed the base cases for the ISO 2024-2025 transmission planning process production cost simulation. These base cases included modeling updates and additions, which followed the ISO unified planning assumptions and are described in this section, and validated incremental changes in the ADS PCM.

It is worth noting that the ADS PCM is an evolving product, so the ISO's planning PCM only incorporated ADS PCM changes that were approved and validated before a cut-off date. In this planning cycle, the changes in the ADS 2034 PCM after January 15, 2025 were not included in the ISO's planning PCM. These changes will be validated and incorporated in the next cycle's planning PCM.

### G.6.2 Load

As a norm for economic planning studies, the production cost simulation models 1-in-2 weather conditions load in the system to represent typical or average load conditions across the ISO system. The CEC California Energy Demand Updated Forecast for 2034 and 2039, consistent with the demand forecast in the reliability assessment as described in Chapter 2, were used to develop the 2034 and 2039 planning PCM cases.

Load modifiers, including DR, DG, AAE, AATE, and AAFS, were modeled as generators with hourly output profiles. The locations of the load modifiers were consistent with the reliability power flow cases.



### G.6.3 Generation resources

Generator locations and installed capacities in the 2034 and 2039 PCM cases are consistent with the policy assessment power flow cases for 2034 and for 2039, respectively, including both conventional and renewable generators. Chapter 3 and Appendix F provides more details about the renewables portfolios.

The CPUC IRP base and sensitivity portfolios included out-of-state wind resources in different areas. Some of the out-of-state wind resources in the CPUC IRP portfolios expected to require new transmission, while some rely on existing transmission, to deliver their wind energy to the ISO load. For the out-of-state wind resources that require new transmission, the CPUC IRP portfolio provided specified injection points to the ISO system, but did not specify particular out-of-state transmission projects to deliver the resources to the ISO boundary.

In the planning PCM in this planning cycle, New Mexico wind generation that requires new transmission was modeled at the Pinal Central 500 kV bus in Arizona, which is consistent with the last planning cycle. This is equivalent to assuming that a new transmission line would be built to deliver New Mexico wind generation to the Pinal Central 500 kV bus.

The CPUC IRP portfolios included out-of-state wind in Wyoming areas and in Idaho areas, which are expected to require new transmission. In the planning PCM in this planning cycle, the Wyoming wind was modeled associated with the TransWest Express project, and the Idaho wind was modeled associated with the SWIP North project, as baseline assumption.

### G.6.4 Network modeling

The ADS PCM uses a nodal model to represent the entire WECC transmission network. However, the network model in the ADS PCM is based on a power flow case that is different from the ISO's policy power flow cases developed in the current planning cycle. The ISO took a more comprehensive approach and modified the network model for the ISO system to exactly match the policy assessment power flow cases for the entire ISO planning area. The transmission topology, transmission line and transformer ratings, generator location, and load distribution are identical between the PCM and policy assessment power flow cases. In conjunction with modeling local transmission constraints and nomograms, unit commitment and dispatch can accurately respond to transmission limitations identified in policy assessment. This enables the production cost simulation to capture potential congestion at any voltage level and in any local area.

### G.6.5 Transmission constraints

As noted earlier, the production cost database reflects a nodal network representation of the western interconnection. Transmission limits were enforced on individual transmission lines, paths (*i.e.*, flowgates) and nomograms. However, the original ADS PCM database only enforced transmission limits under normal condition for transmission lines at 230 kV and above, and for transformers at 345 kV and above.

The ISO made an important enhancement in expanding the modeling of transmission contingency constraints, which the original ADS PCM database did not model. In the updated database, the ISO modeled contingencies on multiple voltage levels (including voltage levels

lower than 230 kV) in the ISO transmission grid to make sure that in the event of losing one transmission facility (and sometimes multiple transmission facilities), the remaining transmission facilities would stay within their emergency limits. The contingencies that were modeled in the ISO's database mainly are the ones that identified as critical in the ISO's reliability assessments, local capacity requirement (LCR) studies, and generation interconnection (GIP) studies. While all N-1 and N-2 (common mode) contingencies were modeled to be enforced in both unit commitment and economic dispatch stages in production cost simulation, N-1-1 contingencies that included multiple transmission facilities that were not in common mode, were normally modeled to be enforced in the unit commitment stage only. This modeling approach reflected the system reliability need identified in the other planning studies in production cost simulations, and also considered the fact that the N-1-1 contingencies normally had lower probability to happen than other contingencies and that system adjustment is allowed between the two N-1 contingencies. In addition, transmission limits for some transmission lines in the ISO transmission grid at lower voltage than 230 kV are enforced.

Scheduled maintenance of transmission lines was modeled based on historical data. Only the repeatable maintenances were considered. The corresponding derates on transmission capability were also modeled.

PDCI (Path 65) south to north rating was modeled at 1050 MW to be consistent with the operation limit of this path identified by LADWP, which is the operator of PDCI within California.

### G.6.6 Fuel price and CO2 price

The forecast of Natural Gas prices, Coal prices, and CO2 prices were the same as in the ADS PCM 2034. All prices are in 2024 real dollars.

### G.6.7 Renewable curtailment price model

The 2024-2025 planning PCM continued to use the multi-block renewable generator model that was first developed and used in the 2019~2020 planning cycle PCM. This model was applied to all ISO wind and solar generators. Each generator was modeled as five equal and separate generators (blocks) with identical hourly profiles, and each block's Pmax was 20% of the Pmax of the actual generator. Each block had a different curtailment price around \$ -25/MWh, as shown in Table G.6-1

Table G.6-1: Multi-blocks renewable model

| Block | Price (\$/MWh) |
|-------|----------------|
| 1     | -23            |
| 2     | -24            |
| 3     | -25            |
| 4     | -26            |
| 5     | -27            |

### G.6.8 Battery cost model and depth of discharge

The ISO also refined its modeling of battery storage through the course of the 2019-2020 planning cycle, to reflect limitations associated with the depth of discharge of battery usage cycles (DoD or cycle depth) and replacement costs associated with the cycle life (i.e. the number of cycles) and depth of discharge the battery is subjected to. In this refined battery model, the battery's operation cost was modeled as a flat average cost. Cycle life represents available cycles until remaining energy is equivalent to average DoD, as further clarified in the updated DOE report for the storage cost forecast prepared by PNNL in 2022<sup>6</sup>. Based on this clarification of the cycle file definition, the battery's operation cost is calculated using the following equation:

$$\text{Average Cost} = (1 - \text{DoD}) * \frac{\text{Per unit replacement cost}}{\text{Cycle life} * \text{DoD} * 2}$$

The baseline assumptions for battery parameters in this planning cycle were also based on the 2030 forecast in the same DOE/PNNL report:

- DoD: 80%
- Cycle life: 2640 cycles
- Per unit replacement cost: \$109,450/MWh

With the above parameters, the average cost was \$5.18/MWh.

### G.6.9 Co-located and hybrid resource model

Starting with this planning cycle, co-located and hybrid resource were modeled in the planning PCM. A co-located or hybrid resource normally includes battery components and solar components, but can also be combination of battery and other types of resources such as wind or thermal generators. Except for where a hybrid resource has a single market ID and a co-located resource may have multiple market IDs, there are a lot of similarities between the hybrid and co-located resources from operation and modeling perspectives, although there may be differences in financial and operational requirements. As the policy and operation requirements for co-located and hybrid resources are still under development, the planning PCM in this planning cycle used the same approach to model co-located and hybrid resources.

To model co-located and hybrid resources in PCM, two constraints that are similar to the  $P_{max}$  and  $P_{min}$  constraints of the any other generators can be added:

- $P_{max}$  constraint

$$P_{solar} + P_{battery} + REGUP_{battery} + LFUP_{solar} + LFUP_{battery} + SPIN_{battery} + FR_{battery} \leq P_{max} \quad (1)$$

<sup>6</sup> <https://www.pnnl.gov/sites/default/files/media/file/ESGC%20Cost%20Performance%20Report%202022%20PNNL-33283.pdf>

- $P_{min}$  constraint (charging constraint)

$$P_{solar} + P_{battery} - REGDOWN_{battery} - LFDOWN_{solar} - LFDOWN_{battery} \geq P_{min} \quad (2)$$

The  $P_{max}$  is normally the allowed maximum output at the point of interconnection of the generator. The  $P_{min}$  can be negative if the co-located or hybrid resource can charge from the grid, or equal to zero if the battery component is not expected to charge from the grid.  $P_{battery}$  is positive when the battery is discharging, and negative when the battery is charging. Ancillary services and operating reserves are considered in the  $P_{max}$  and  $P_{min}$  constraints, including regulation up and down (REGUP and REGDOWN), load following up and down (LFUP and LFDOWN), spinning reserve (SPIN), and frequency response (FR).

It is noted that the  $P_{min}$  constraint was not used in this planning cycle, because there is a lack of clarity of charging requirement for co-located and hybrid resources. It will be considered in future planning cycles when there is additional clarity for the charging requirement.

#### G.6.10 PG&E Manning – Metcalf 500 kV upgrade

The Manning – Metcalf new 500 kV line and the associated Metcalf – Los Estores 230 kV line reconductoring have been recommended for approval as a reliability upgrade in this planning cycle. This upgrade is also effective to mitigate the congestion on the Moss Landing – Las Aguilas 230 kV line that was identified in the previous TPP cycles and in the preliminary PCM results presented in the 2024 November stakeholder meeting as well.

Two alternatives were considered for this upgrade as summarized below. The detailed scope of this upgrade can be found in Chapter 2 and Appendix B.

##### Alternative 1

- Build a new 500 kV line from Manning to Moss Landing looping-in to the new Loas Aguilas 500 kV substation and using the existing 230 kV line right of way.
- Reconfigure the 230 kV lines from Panoche to Las Aguilas to Coburn. Build a new Moss Landing – Metcalf 500 kV line

##### Alternative 2

- Build a new 500 kV line from Manning to Metcalf using new right of way.

Production cost simulations were conducted on the 2039 base portfolio PCM case with and without the Manning – Metcalf upgrade to show the effectiveness of the upgrade in terms of congestion mitigation. The results were shown in Table G.6-2. While the Moss Landing – Las Aguilas 230 kV congestion was eliminated by modeling the upgrade, it can be seen that the congestion in the Greater Bay area also reduced. In the meantime, congestion increased on the Path 15 and Path 26 corridor when the flow was from south to north. This is because that the power flow along these corridors from south to north increased after the bottleneck of the Moss Landing – Las Aguilas 230 kV line congestion was removed.

Table G.6-2: Congestion changes by modeling the Manning - Metcalf upgrade

| Area or Branch Group                   | Congestion Cost (\$M) 2039 Base Portfolio PCM | Congestion Cost (\$M) 2039 Base Portfolio with Manning - Metcalf upgrade Alternative 1 | Congestion Cost (\$M) 2039 Base Portfolio with Manning - Metcalf upgrade Alternative 2 |
|--|---|--|--|
| Path 15 Corridor                       | 391.71  | 468.49   | 521.80   |
| PG&E Moss Landing - Las Aguilas 230 kV | 289.89  | 0.00   | 0.00   |
| Path 26 Corridor                       | 171.79  | 194.06   | 206.28   |
| SWIP North                             | 66.56   | 58.14  | 51.61  |
| PG&E GBA                               | 14.36   | 6.96   | 5.79   |
| PG&E Manning - Moss Landing 500 kV     | 0.00  | 5.47   | 0.00   |
| PG&E Manning - Metcalf 500 kV          | 0.00  | 0.00   | 3.65   |

Production benefit of the Manning - Metcalf upgrade was also assessed based on the CAISO's TEAM methodology. The production benefit results as shown in Table G.6-3 demonstrated that the upgrade can provide significant production benefit to the CAISO ratepayers. The annual production cost savings from these two alternatives are \$83 million and \$120 million, respectively, based on the production cost simulation results on the 2039 Base portfolio PCM.

Table G.6-3: Production Benefit of the Manning – Metcalf upgrade

|                           | 2039 Base Portfolio without Manning - Moss Landing - Metcalf upgrade | 2039 Base Portfolio with Manning - Moss Landing - Metcalf upgrade Alternative 1 |               | 2039 Base Portfolio with Manning - Moss Landing - Metcalf upgrade Alternative 2 |               |
|---------------------------|--|---|---------------|---|---------------|
|                           | (\$M)  | (\$M)   | Savings (\$M) | (\$M)   | Savings (\$M) |
| ISO load payment          | 19,053   | 18,841  | 212           | 18,823  | 230           |
| ISO generator net revenue | 14,174   | 14,241  | 67            | 14,205  | 30            |
| ISO transmission revenue  | 1,838  | 1,642   | -196          | 1,698   | -140          |
| ISO Net payment           | 3,040  | 2,957   | 83            | 2,920   | 120           |
| WECC Production cost      | 23,942   | 23,872  | 70            | 23,874  | 68            |

Note that ISO ratepayer “savings” are a decrease in load payment, but an increase in ISO generator net revenue benefiting ratepayers and an increase in ISO transmission revenue benefiting ratepayers. WECC-wide “Savings” are a decrease in overall production cost. A negative saving is an incremental cost or loss.

These two alternatives provide similar production cost savings to the ISO's ratepayers, and both are effective to mitigate the congestion on the Moss Landing - Los Aguilas 230 kV line and the reliability constraints in the PG&E's Bay area. In the reliability assessment in this planning cycle, Alternative 2 was recommended for approval, as set out in Chapter 2. Therefore, the Alternative 2 of the Manning – Metcalf upgrade was modeled in the PCM cases for economic assessment in this planning cycle as a baseline assumption.

## G.7 Production Cost Simulation Results

Based on the economic planning study methodology presented in the previous sections, a congestion simulation of the ISO transmission network was performed to identify which facilities in the ISO-controlled grid were congested. Renewable curtailment and generation utilization were also summarized based on the production cost simulation results.

### G.7.1 2034 Base Portfolio PCM Congestion Results

The results of the congestion assessment in the 2034 base portfolio PCM are listed in Table G.7-1. Columns “Cost Forward” and “Duration Forward” are the cost and duration of congestion, respectively, when the flow is in forward direction as indicated in the constraint name. Columns “Cost Backward” and “Duration Backward” are the cost and duration of congestion, respectively, when flow is in backward direction. The last two columns were the total cost and total duration, respectively.

Table G.7-1: Congestion in the ISO-controlled grid in the 2034 base portfolio PCM

| No. | Area             | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 1   | Path 15 Corridor | MANNING-MN_GT_11 500 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 223,948              |
| 2   | Path 26 Corridor | P26 Northern-Southern California   | Interface          | _CISO                  | 100                 | 4                       | 6                 | 191,487              |
| 3   | SWIP North       | SWIP-North (Midpoint-Robinson)   | Interface          | _CISO                  | 50                  | 0                       | 0                 | 51,287               |
| 4   | Path 26 Corridor | MIDWAY-MW_WRLWND_31 500 kV line #3   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 49,165               |
| 5   | Path 15 Corridor | MN_GT_11-GATES 500 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 44,936               |
| 6   | Path 15 Corridor | PANOCHÉ-GATES E 230 kV line, subject to PG&E N-2 Gates-Gregg and Gates-McCall 230 kV | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 39,251               |
| 7   | Path 65 PDCI     | P65 Pacific DC Inter tie (PDCI)  | Interface          | _CISO                  | 52                  | 0                       | 0                 | 28,529               |
| 8   | Path 15 Corridor | MN_MW_21-MN_MW_22 500 kV line #2   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 26,234               |
| 9   | East of Pisgah   | LUGO-VICTORVL 500 kV line, subject to SCE N-1 ElDorado-Lugo 500 kV with RAS          | Contingency        | _CISO                  | 90                  | 0                       | 0                 | 22,817               |
| 10  | Path 15 Corridor | MANNING-MN_MW_21 500 kV line #2  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 22,288               |
| 11  | SCE Metro        | LCIENEGA-LA FRESA 230 kV line, subject to SCE N-2 La Fresa-El Nido #3 and #4 230 kV  | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 16,047               |
| 12  | SCE Northern     | WINDHUB_A 230/13.8 kV transformer #1   | Branch             | _CISO                  | 100                 | 14,037                  | 786               | 0                    |
| 13  | Path 42          | P42 IID-SCE  | Interface          | _CISO                  | 100                 | 11,289                  | 495               | 0                    |
| 14  | East of Pisgah   | ELDORADO-MCCULLGH 500 kV line, subject to SCE N-1 ElDorado-Lugo 500 kV with RAS      | Contingency        | _CISO                  | 1                   | 9,291                   | 830               | 0                    |
| 15  | SDG&E/CFE        | P45 SDG&E-CFE  | Interface          | _CISO                  | 50                  | 5,123                   | 961               | 3,549                |

| No. | Area                       | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|----------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 16  | Path 15 Corridor           | MN_MW_23-MIDWAY 500 kV line #2   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 7,880                |
| 17  | Path 15 Corridor           | GATES-GT_MW_11 500 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 7,555                |
| 18  | Path 15 Corridor           | GT_MW_11-MIDWAY 500 kV line #1   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 7,534                |
| 19  | PG&E North Valley 230 kV   | BRNY_FST_JCT-PIT 1 230 kV line, subject to PG&E N-1 Carberry-RM with HR SPS                      | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 6,763                |
| 20  | PG&E Kern 230kV            | GATES D-CALFLATSSS 230 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 6,564                |
| 21  | Path 41 Sylmar transformer | P41 Sylmar to SCE  | Interface          | _CISO                  | 100                 | 4,715                   | 298               | 0                    |
| 22  | Path 15 Corridor           | PANOCHÉ-GATES E 230 kV line, subject to PG&E N-2 LB-Gates and LB-Midway 500 kV                   | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 4,391                |
| 23  | SCE Northern               | VINCNT2-WINDSTAR1 230 kV line #1   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 4,267                |
| 24  | Path 15 Corridor           | MN_MW_22-MN_MW_23 500 kV line #2   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 3,957                |
| 25  | SDG&E Bulk                 | ECO 500/500 kV transformer #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 3,671                |
| 26  | SCE North of Lugo          | SANDLOT-KRAMER 230 kV line #1  | Branch             | _CISO                  | 100                 | 3,577                   | 1,482             | 0                    |
| 27  | COI Corridor               | P66 COI  | Interface          | _CISO                  | 67                  | 1,860                   | 35                | 1,018                |
| 28  | SCE Antelope 66kV          | NEENACH-TAP 85 66.0 kV line #1   | Branch             | _CISO                  | 100                 | 2,714                   | 1,098             | 0                    |
| 29  | SCE North of Lugo          | CALCITE-LUGO 230 kV line #1  | Branch             | _CISO                  | 100                 | 2,534                   | 1,673             | 0                    |
| 30  | PG&E North Valley 230 kV   | CARBERRY-ROUND MT 230 kV line, subject to PG&E N-1 Pit-Cottonwood 230 kV with HR SPS             | Contingency        | _CISO                  | 100                 | 2,501                   | 264               | 0                    |
| 31  | Path 46 WOR                | P46 West of Colorado River (WOR)   | Interface          | _CISO                  | 74                  | 2,375                   | 45                | 0                    |
| 32  | PG&E North Valley 230 kV   | CARBERRY-ROUND MT 230 kV line #1   | Branch             | _CISO                  | 100                 | 2,353                   | 194               | 0                    |
| 33  | East of Pisgah             | SLOAN_CYN_5-ELDORDO 500 kV line #1   | Branch             | _CISO                  | 100                 | 1,967                   | 200               | 0                    |
| 34  | SDG&E 230 kV               | SANLUSRY-S.ONOFRE 230 kV line, subject to SDGE N-2 SLR-SO 230 kV #2 and #3 with RAS              | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 1,963                |
| 35  | SDG&E/CFE                  | OTAYMESA-TJI-230 230 kV line #1  | Branch             | _CISO                  | 50                  | 0                       | 0                 | 1,615                |
| 36  | SDG&E 230 kV               | SILVERGT-BAY BLVD 230 kV line, subject to SDGE N-2 Miguel-Mission 230 kV #1 and #2               | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 1,608                |
| 37  | SCE North of Lugo          | P60 Inyo-Control 115 kV Tie  | Interface          | _CISO                  | 50                  | 964                     | 260               | 318                  |
| 38  | PG&E North Valley 230 kV   | CARBERRY-ROUND MT 230 kV line, subject to PG&E N-2 Pit-Cotw dF and Cotw dE-RM 230 kV with HR SPS | Contingency        | _CISO                  | 100                 | 1,255                   | 111               | 0                    |
| 39  | PG&E North Valley 230 kV   | CORTINA-VACA-DIX 230 kV line, subject to PG&E N-1 Delev n-Cortina 230 kV                         | Contingency        | _CISO                  | 100                 | 1,154                   | 646               | 0                    |
| 40  | East of Pisgah             | P61 Lugo-Victorville 500 kV Line   | Interface          | _CISO                  | 50                  | 915                     | 17                | 15                   |
| 41  | PG&E Sierra                | P24 PG&E-Sierra  | Interface          | CISO                   | 50                  | 0                       | 0                 | 927                  |

| No. | Area                      | Constraints Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|---------------------------|---|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 42  | Path 15 Corridor          | PANOCH-GATES E 230 kV line, subject to PG&E N-2 Mustang-Gates #1 and #2 230 kV                        | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 845                  |
| 43  | PG&E North Valley 230 kV  | COTWD_F2-BRNY_FST_JCT 230 kV line, subject to PG&E N-1 Carberry-RM with HR SPS                        | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 818                  |
| 44  | PG&E Sierra               | SUMMIT 2-DRUMPH1 115 kV line #1   | Branch             | _CISO                  | 100                 | 511                     | 108               | 114                  |
| 45  | PG&E GBA                  | USWP-JRW_JCT-CAYETANO 230 kV line, subject to PG&E N-2 C.Costa-Moraga 230 kV                          | Contingency        | _CISO                  | 100                 | 618                     | 60                | 0                    |
| 46  | SCE Northern              | PARDEE-VINCENT 230 kV line #2   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 590                  |
| 47  | SCE Northern              | VINCENT-vincen1i 500 kV line, subject to SCE N-1 Vincent Transformer 500 kV #4                        | Contingency        | _CISO                  | 100                 | 530                     | 75                | 0                    |
| 48  | PG&E Sierra               | HONEYLAK-SKEDADDLPS 60.0 kV line #1   | Branch             | _CISO                  | 50                  | 13                      | 4                 | 387                  |
| 49  | Path 25 PACW-PG&E 115 kV  | P25 PacifiCorp/PG&E 115 kV Interconnection  | Interface          | _CISO                  | 1                   | 390                     | 20                | 0                    |
| 50  | Path 15 Corridor          | PANOCH-GATES E 230 kV line, subject to PG&E N-1 Panoche-Gates #1 230kV                                | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 385                  |
| 51  | East of Pisgah            | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Lugo-Mohave 500 kV                                   | Contingency        | _CISO                  | 1                   | 281                     | 27                | 0                    |
| 52  | SDG&E Northern 69 kV      | SANLUSRY-OCEAN RANCH 69 kV line, subject to SDGE N-2 EN-SLR and EN-SLR-PEN 230 kV with RAS            | Contingency        | _CISO                  | 100                 | 279                     | 477               | 0                    |
| 53  | Path 26 Corridor          | MW_WRLWIND_32-WIRLWIND 500 kV line, subject to SCE N-2 Midway-Vincent 500 kV                          | Contingency        | _CISO                  | 100                 | 275                     | 30                | 0                    |
| 54  | SCE North of Lugo         | COLWATER 230/115 kV transformer #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 271                  |
| 55  | PG&E GBA                  | E. SHORE-SANMATEO 230 kV line, subject to PG&E N-2 Newark-Ravenswood 230kV and Tesla-Ravenswood 230kV | Contingency        | _CISO                  | 100                 | 224                     | 57                | 0                    |
| 56  | SCE North of Lugo         | TAP189-CONTROL 115 kV line #1   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 223                  |
| 57  | East of Pisgah            | HAE SVC-HAE SVCL 500 kV line #1   | Branch             | _CISO                  | 100                 | 203                     | 6                 | 0                    |
| 58  | PG&E POE - RIO OSO 230 kV | POE-RIO OSO 230 kV line #1  | Branch             | _CISO                  | 100                 | 174                     | 72                | 0                    |
| 59  | PG&E North Valley 230 kV  | CARIBOU-BELDENTP 230 kV line #1   | Branch             | _CISO                  | 100                 | 163                     | 35                | 0                    |
| 60  | PG&E GBA                  | LS ESTRS 230/230 kV transformer #1  | Branch             | _CISO                  | 100                 | 145                     | 53                | 0                    |
| 61  | SCE Eastern               | DEVERS-DVRS_RB_21 500 kV line #2  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 124                  |
| 62  | Path 15 Corridor          | QUINTO_SS-LOSBANOS 230 kV line, subject to PG&E N-1 LosBanos-Tesla 500kV                              | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 114                  |
| 63  | SCE Northern              | WINDHUB_A 230/13.8 kV transformer #2  | Branch             | _CISO                  | 100                 | 109                     | 26                | 0                    |
| 64  | SCE Eastern               | DVRS_RB_22-REDBLUFF 500 kV line #2  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 108                  |



| No. | Area                     | Constraints Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|--------------------------|---|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 65  | Path 15 Corridor         | TESLA E-WESTLEY 230 kV line #1  | Branch             | _CISO                  | 50                  | 0                       | 0                 | 103                  |
| 66  | SDG&E/CFE                | IV PFC1 230/230 kV transformer #1   | Branch             | _CISO                  | 100                 | 98                      | 16                | 0                    |
| 67  | Path 26 Corridor         | MW_VINCNT_22-VINCENT 500 kV line #2   | Branch             | _CISO                  | 100                 | 98                      | 16                | 0                    |
| 68  | SCE North of Lugo        | COLWATER-DUNNSIDE 115 kV line #1  | Branch             | _CISO                  | 100                 | 97                      | 164               | 0                    |
| 69  | East of Pisgah           | GAMEBIRD-GAMEBIRD 230 kV line, subject to VEA N-2 Pahump-Gamebird 230 kV no RAS                                 | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 77                   |
| 70  | PG&E GBA                 | LS PSTAS-NEWARK D 230 kV line, subject to PG&E N-2 C.Costa-Moraga 230 kV  | Contingency        | _CISO                  | 100                 | 74                      | 10                | 0                    |
| 71  | SCE Eastern              | DEVERS-DVRS_RB_21 500 kV line, subject to SCE N-1 RedBluff-Devers 500 kV with RAS                               | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 74                   |
| 72  | SCE Northern             | MAGUNDEN-ANTELOPE 230 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 71                   |
| 73  | SDG&E 230 kV             | SILVERGT-OLD TOWN 230 kV line, subject to SDGE N-1 Silverage-OldTown-Mission 230kV no RAS                       | Contingency        | _CISO                  | 100                 | 69                      | 25                | 0                    |
| 74  | SDG&E 230 kV             | SILVERGT-OLDTWNTP 230 kV line, subject to SDGE N-1 Silverage-OldTown 230kV no RAS                               | Contingency        | _CISO                  | 100                 | 61                      | 41                | 0                    |
| 75  | SCE Northern             | VINCNT2-vincen1i 230 kV line, subject to SCE N-1 Vincent Transformer 500 kV #4                                  | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 60                   |
| 76  | COI Corridor             | ROUND MT-RD MT 1M 500 kV line, subject to PG&E-BANC N-1 Olinda Xfmr 500 kV                                      | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 55                   |
| 77  | SCE North of Lugo        | KRAMER-VICTOR 230 kV line #1  | Branch             | _CISO                  | 100                 | 47                      | 96                | 0                    |
| 78  | PG&E Fresno 115 kV       | HERNDON-CHLDHOSP_JCT 115 kV line #1   | Branch             | _CISO                  | 100                 | 45                      | 15                | 0                    |
| 79  | Path 26 Corridor         | MW_VINCNT_11-MW_VINCNT_12 500 kV line, subject to SCE N-1 Midway-Vincent #2 500kV                               | Contingency        | _CISO                  | 100                 | 40                      | 15                | 0                    |
| 80  | SDG&E 230 kV             | TALEGA-S.ONOFRE 230 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 36                   |
| 81  | East of Pisgah           | IVANPAH-MTN PASS 115 kV line #1   | Branch             | _CISO                  | 100                 | 35                      | 36                | 0                    |
| 82  | PG&E Fresno 115 kV       | SANGER-MC CALL 115 kV line #3   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 35                   |
| 83  | PG&E North Valley 230 kV | CARIBOU 230/230 kV transformer #11  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 33                   |
| 84  | PG&E Fresno 230 kV       | GREGG-HENTAP1 230 kV line, subject to PG&E N-1 Wilson-Warnerville 230kV   | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 29                   |
| 85  | PG&E GBA                 | C.COSTAPPE-BDLSWSTA 230 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 26                   |
| 86  | SDG&E/CFE                | IMPRLVLY-IV PFC1 230 kV line, subject to SDGE N-2 Sycamore-Otay Mesa-Miguel and Bay Blvd-Otay Mesa-Miguel 230kV | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 24                   |

| No. | Area                       | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|----------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 87  | SCE Lugo - Vincent 500 kV  | LUGO-VINCENT 500 kV line #1  | Branch             | _CISO                  | 100                 | 23                      | 7                 | 0                    |
| 88  | SDG&E/CFE                  | IV PFC1 230/230 kV transformer #2  | Branch             | _CISO                  | 100                 | 22                      | 3                 | 0                    |
| 89  | PG&E Fresno 230 kV         | MCMULLN1-KEARNEY 230 kV line, subject to PG&E N-2 Mustang-Gates #1 and #2 230 kV             | Contingency        | _CISO                  | 100                 | 21                      | 20                | 0                    |
| 90  | Path 26 Corridor           | MIDWAY-MW_WRLWND_31 500 kV line, subject to SCE N-2 Midway-Vincent 500 kV                    | Contingency        | _CISO                  | 100                 | 20                      | 6                 | 0                    |
| 91  | SCE Northern               | PARDEE-SYLMAR 230 kV line, subject to SCE N-1 Sylmar-Pardee 230kV                            | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 20                   |
| 92  | PG&E North Valley 230 kV   | CORTINA-VACA-DIX 230 kV line, subject to PG&E N-2 LoganCR-Delev n and Delev n-Cortina 230 kV | Contingency        | _CISO                  | 100                 | 11                      | 18                | 0                    |
| 93  | PG&E GBA                   | MARSHLD2-C.COSTAPPD 230 kV line #2   | Branch             | _CISO                  | 100                 | 11                      | 3                 | 0                    |
| 94  | SCE Northern               | PARDEE-S.CLARA 230 kV line, subject to SCE N-2 MOORPARK-SCLARA #1 and #2 230 kV              | Contingency        | _CISO                  | 100                 | 8                       | 65                | 0                    |
| 95  | SCE North of Lugo          | KRAMER-VICTOR 230 kV line #2   | Branch             | _CISO                  | 100                 | 8                       | 18                | 0                    |
| 96  | SDG&E Northern 69 kV       | ESCNDIDO-VC69_TP 69 kV line, subject to SDGE N-2 EN-SLR and EN-SLR-PEN 230 kV with RAS       | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 8                    |
| 97  | Path 26 Corridor           | MW_WRLWND_32-WIRLWIND 500 kV line #3   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 7                    |
| 98  | SCE Eastern                | DVRS_RB_21-DVRS_RB_22 500 kV line #2   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 6                    |
| 99  | SDG&E Northern 69 kV       | LILAC-PALA 69 kV line, subject to SDGE N-2 EN-SLR and EN-SLR-PEN 230 kV with RAS             | Contingency        | _CISO                  | 100                 | 5                       | 71                | 0                    |
| 100 | Moenkope - Eldorado 500 kV | MOEN-ELD SC3-ELDORDO 500 kV line #1  | Branch             | _CISO                  | 1                   | 4                       | 1                 | 0                    |
| 101 | PG&E Fresno 230 kV         | HENTAP1-MUSTANGSS 230 kV line #1   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 4                    |
| 102 | East of Pisgah             | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Eldorado-Mohave 500 kV                      | Contingency        | _CISO                  | 1                   | 4                       | 3                 | 0                    |
| 103 | SDG&E Bulk                 | ECO 230/500 kV transformer #1  | Branch             | _CISO                  | 100                 | 3                       | 10                | 0                    |
| 104 | PG&E North Valley 230 kV   | BELDENTP-TABLE MTN D 230 kV line #1  | Branch             | _CISO                  | 100                 | 3                       | 1                 | 0                    |
| 105 | East of Pisgah             | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Eldorado-Moenkopi 500 kV                    | Contingency        | _CISO                  | 1                   | 3                       | 1                 | 0                    |
| 106 | PG&E Kern 230kV            | GATES D-TEMPLETN 230 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 3                    |
| 107 | PG&E Tesla 230 kV          | STAGG-J2-TESLA E 230 kV line, subject to PG&E N-1 EightMiles-TeslaE 230kV                    | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 2                    |
| 108 | SCE North of Lugo          | LUGO-lugo 2i 500 kV line, subject to SCE N-1 Lugo Transformer #1 500-230 kV with RAS         | Contingency        | _CISO                  | 100                 | 0                       | 0                 | 2                    |
| 109 | Path 26 Corridor           | MIDWAY-MW_VINCNT_11 500 kV line #1   | Branch             | _CISO                  | 100                 | 2                       | 1                 | 0                    |
| 110 | PG&E Sierra                | MARBLE 63.0/69.0 kV transformer #1   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 1                    |

| No. | Area                                  | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|---------------------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 111 | SCE Northern                          | MAGUNDEN-VESTAL 230 kV line, subject to SCE N-1 Magunden-Vestal #1 230kV           | Contingency        | _CISO                  | 100                 | 1                       | 3                 | 0                    |
| 112 | PG&E Kern 230kV                       | ARCO-MIDWAY-E 230 kV line #1   | Branch             | _CISO                  | 100                 | 0                       | 0                 | 1                    |
| 113 | SCE Northern                          | VINCNT2-S.CLARA 230 kV line, subject to SCE N-2 MOORPARK-SCLARA #1 and #2 230 kV   | Contingency        | _CISO                  | 100                 | 1                       | 6                 | 0                    |
| 114 | Path 26 corridor                      | MW_WRLWND_31- MW_WRLWND_32 500 kV line, subject to SCE N-2 Midway - Vincent 500 kV | Contingency        | _CISO                  | 100                 | 1                       | 3                 | 0                    |
| 115 | SCE North of Lugo                     | VICTOR-LUGO 230 kV line #1   | Branch             | _CISO                  | 100                 | 1                       | 2                 | 0                    |
| 116 | Path 84 Harry Allen - Eldorado 500 kV | P84 Harry Allen-Eldorado 500 kV  | Interface          | _CISO                  | 100                 | 0                       | 0                 | 0                    |
| 117 | PG&E Fresno 230 kV                    | Q0954Q1027-GATES F 230 kV line #1  | Branch             | _CISO                  | 100                 | 0                       | 1                 | 0                    |
| 118 | PG&E GBA                              | EIGHT MI-STAGG-J1 230 kV line, subject to PG&E N-1 EightMiles-TeslaE 230kV         | Contingency        | _CISO                  | 100                 | 0                       | 2                 | 0                    |
| 119 | SCE North of Lugo                     | INYOKERN-KRAMER 115 kV line #1   | Branch             | _CISO                  | 100                 | 0                       | 1                 | 0                    |
| 120 | Path 26 Corridor                      | MW_WRLWND_31- MW_WRLWND_32 500 kV line #3  | Branch             | _CISO                  | 100                 | 0                       | 0                 | 0                    |
| 121 | PG&E Fresno 230 kV                    | GATES E-GATESBK11JCT 230 kV line #2  | Branch             | _CISO                  | 100                 | 0                       | 1                 | 0                    |

In Table G.7-1, the second column shows the branch group or local-area where the congestions locate. The aggregated congestions across specific branch groups and local areas in 2034 is summarized in The results have been ranked based on the congestion cost.

Table G.7-2. The results have been ranked based on the congestion cost.

Table G.7-2: Aggregated congestion in the 2034 base portfolio PCM

| No. | Aggregated congestion                 | Cost (\$M) | Duration (Hr) |
|-----|---------------------------------------|------------|---------------|
| 1   | Path 15 Corridor                      | 389.42     | 5,468         |
| 2   | Path 26 Corridor                      | 241.10     | 4,503         |
| 3   | SWIP North                            | 51.29      | 716           |
| 4   | East of Pisgah                        | 35.61      | 1,378         |
| 5   | Path 65 PDCI                          | 28.53      | 1,679         |
| 6   | SCE Northern                          | 19.69      | 1,743         |
| 7   | SCE Metro                             | 16.05      | 179           |
| 8   | PG&E North Valley 230 kV              | 15.05      | 1,863         |
| 9   | Path 42                               | 11.29      | 495           |
| 10  | SDG&E/CFE                             | 10.43      | 1,577         |
| 11  | SCE North of Lugo                     | 8.04       | 4,492         |
| 12  | PG&E Kern 230kV                       | 6.57       | 997           |
| 13  | Path 41 Sylmar transformer            | 4.72       | 298           |
| 14  | SDG&E 230 kV                          | 3.74       | 634           |
| 15  | SDG&E Bulk                            | 3.67       | 374           |
| 16  | COI Corridor                          | 2.93       | 70            |
| 17  | SCE Antelope 66kV                     | 2.71       | 1,098         |
| 18  | Path 46 WOR                           | 2.37       | 45            |
| 19  | PG&E Sierra                           | 1.95       | 475           |
| 20  | PG&E GBA                              | 1.10       | 186           |
| 21  | Path 25 PACW-PG&E 115 kV              | 0.39       | 20            |
| 22  | SCE Eastern                           | 0.31       | 19            |
| 23  | SDG&E Northern 69 kV                  | 0.29       | 638           |
| 24  | PG&E POE - RIO OSO 230 kV             | 0.17       | 72            |
| 25  | PG&E Fresno 115 kV                    | 0.08       | 32            |
| 26  | PG&E Fresno 230 kV                    | 0.05       | 32            |
| 27  | SCE Lugo - Vincent 500 kV             | 0.02       | 7             |
| 28  | Moenkope - Eldorado 500 kV            | 0.00       | 1             |
| 29  | PG&E Tesla 230 kV                     | 0.00       | 1             |
| 30  | Path 84 Harry Allen - Eldorado 500 kV | 0.00       | 1             |

### G.7.2 2034 Base Portfolio PCM Curtailment Results

Table G.7-3 shows the wind and solar generation curtailment in the ISO system in the base portfolio PCM. In this table, the renewable resources were aggregated by zone based on the transmission constraints to which the resources in the same zone normally contributed in the same direction, or based on geographic locations if there were not obvious transmission constraints nearby.

Table G.7-3: Wind and solar curtailment summary in the 2034 base portfolio PCM

| Renewable zone         | Generation (GWh) | Curtailment (GWh) | Total potential (GWh) | Curtailment Ratio |
|------------------------|------------------|-------------------|-----------------------|-------------------|
| SCE Northern           | 31,216           | 1,300             | 32,516                | 4.00%             |
| SCE Eastern            | 20,184           | 277               | 20,461                | 1.36%             |
| PG&E Fresno            | 16,628           | 1,709             | 18,337                | 9.32%             |
| SDG&E Eastern and Bulk | 14,197           | 427               | 14,624                | 2.92%             |
| OSW-Diablo             | 13,365           | 769               | 14,134                | 5.44%             |
| East of Pisgah         | 12,585           | 764               | 13,349                | 5.72%             |
| PG&E Central Valley    | 11,073           | 416               | 11,488                | 3.62%             |
| OOS W-WY               | 10,761           | 468               | 11,229                | 4.17%             |
| SCE North of Lugo      | 10,633           | 411               | 11,044                | 3.72%             |
| OOS W-SunZia           | 8,375            | 1,183             | 9,558                 | 12.38%            |
| NM                     | 4,825            | 1,877             | 6,702                 | 28.00%            |
| PG&E Kern              | 6,053            | 322               | 6,375                 | 5.06%             |
| OSW-Humboldt           | 4,698            | 54                | 4,752                 | 1.14%             |
| PG&E Central Coast     | 4,228            | 144               | 4,372                 | 3.30%             |
| PG&E North Valley      | 3,124            | 147               | 3,271                 | 4.50%             |
| OOS W-ID               | 2,798            | 141               | 2,939                 | 4.80%             |
| AZ                     | 1,920            | 833               | 2,753                 | 30.26%            |
| SCE Metro              | 2,173            | 68                | 2,241                 | 3.04%             |
| IID                    | 1,408            | 1                 | 1,410                 | 0.08%             |
| PG&E Greater Bay Area  | 1,193            | 64                | 1,256                 | 5.08%             |
| San Diego              | 712              | 4                 | 716                   | 0.54%             |
| NW                     | 554              | 28                | 582                   | 4.77%             |
| SMUD                   | 379              | 29                | 408                   | 7.07%             |
| PG&E North Coast       | 387              | 10                | 397                   | 2.42%             |
| NV                     | 328              | 49                | 376                   | 12.91%            |
| PG&E North Bay         | 56               | 4                 | 60                    | 6.85%             |
| PG&E Humboldt          | 12               | 0                 | 12                    | 3.79%             |
| <b>Total</b>           | <b>183,865</b>   | <b>11,498</b>     | <b>195,364</b>        | <b>5.89%</b>      |

### G.7.3 2034 Base Portfolio PCM Gas-fired Generator Utilization

The utilization of gas-fired generators was assessed based on their annual capacity factors. The average capacity factors of gas-fired generators by area were summarized in Table G.7-4.

Table G.7-4: Gas-fired generator utilization in the 2034 base portfolio PCM

| Areas                 | Sum of Capacity (MW) | Sum of Generation (MWh) | Capacity Factor |
|-----------------------|----------------------|-------------------------|-----------------|
| PG&E Central Coast    | 1,260                | 1,405,204               | 0.13            |
| PG&E Central Valley   | 921                  | 690,841                 | 0.09            |
| PG&E Fresno           | 1,213                | 714,106                 | 0.07            |
| PG&E Greater Bay Area | 5,785                | 10,481,178              | 0.21            |
| PG&E Humboldt         | 163                  | 35,066                  | 0.02            |
| PG&E Kern             | 3,006                | 7,871,452               | 0.30            |
| PG&E North Valley     | 1,478                | 1,660,388               | 0.13            |
| SCE Blythe            | 494                  | 518,965                 | 0.12            |
| SCE Eastern LA Basin  | 1,986                | 1,369,350               | 0.08            |
| SCE Eldorado          | 495                  | 992,991                 | 0.23            |
| SCE North of Lugo     | 922                  | 1,170,252               | 0.14            |
| SCE North of Magunden | 61                   | 19,890                  | 0.04            |
| SCE South of Magunden | 818                  | 649,023                 | 0.09            |
| SCE Tehachapi         | 4                    | 492                     | 0.01            |
| SCE Ventura           | 219                  | 197,614                 | 0.10            |
| SCE Western LA Basin  | 3,877                | 5,584,422               | 0.16            |
| SDG&E Bulk            | 947                  | 1,410,297               | 0.17            |
| SDG&E San Diego       | 2,678                | 1,770,380               | 0.08            |
| <b>System Total</b>   | <b>26,326</b>        | <b>36,541,910</b>       | <b>0.16</b>     |

#### G.7.4 2039 Base Portfolio PCM Congestion Results

The results of the congestion assessment in the 2039 base portfolio PCM is listed in Table G.7-5. Columns “Cost Forward” and “Duration Forward” are the cost and duration of congestion, respectively, when the flow is in forward direction as indicated in the constraint name. Columns “Cost Backward” and “Duration Backward” are the cost and duration of congestion, respectively, when flow is in backward direction. The last two columns were the total cost and total duration, respectively.

Table G.7-5: Congestion in the ISO-controlled grid in the 2039 base portfolio PCM

| No. | Area              | Constraints Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|-------------------|---|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 1   | Path 15 Corridor  | MANNING-MN_GT_11 500 kV line #1   | 0                  | 0                      | 278,288             | 2,415                   | 278,288           | 2,415                |
| 2   | Path 26 Corridor  | P26 Northern-Southern California  | 3                  | 9                      | 173,554             | 3,127                   | 173,557           | 3,136                |
| 3   | Path 15 Corridor  | PANOCH-GATES E 230 kV line, subject to PG&E N-2 Gates-Gregg and Gates-McCall 230 kV | 0                  | 0                      | 85,856              | 1,628                   | 85,856            | 1,628                |
| 4   | SCE Metro         | LCIENEGA-LA FRESA 230 kV line, subject to SCE N-2 La Fresa-EI Nido #3 and #4 230 kV | 0                  | 0                      | 67,364              | 667                     | 67,364            | 667                  |
| 5   | Path 15 Corridor  | MN_GT_11-GATES 500 kV line #1   | 0                  | 0                      | 54,304              | 475                     | 54,304            | 475                  |
| 6   | SWIP North        | SWIP-North (Midpoint-Robinson)  | 0                  | 0                      | 51,610              | 748                     | 51,610            | 748                  |
| 7   | East of Pisgah    | LUGO-VICTORVL 500 kV line, subject to SCE N-1 ElDorado-Lugo 500 kV with RAS         | 0                  | 0                      | 40,639              | 418                     | 40,639            | 418                  |
| 8   | Path 15 Corridor  | MN_MW_21-MN_MW_22 500 kV line #2  | 0                  | 0                      | 38,600              | 559                     | 38,600            | 559                  |
| 9   | SCE Northern      | WINDHUB_A 230/13.8 kV transformer #1  | 35,517             | 1,202                  | 0                   | 0                       | 35,517            | 1,202                |
| 10  | Path 26 Corridor  | MIDWAY-MN_WRLWND_31 500 kV line #3  | 0                  | 2                      | 31,896              | 943                     | 31,897            | 945                  |
| 11  | East of Pisgah    | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 ElDorado-Lugo 500 kV with RAS      | 27,572             | 1,798                  | 0                   | 0                       | 27,572            | 1,798                |
| 12  | Path 15 Corridor  | MANNING-MN_MW_21 500 kV line #2   | 0                  | 0                      | 26,691              | 872                     | 26,691            | 872                  |
| 14  | SCE North of Lugo | CALCITE-LUGO 230 kV line #1   | 25,914             | 3,508                  | 0                   | 0                       | 25,914            | 3,508                |
| 15  | Path 42           | P42 IID-SCE   | 24,129             | 594                    | 0                   | 0                       | 24,129            | 594                  |
| 17  | Path 65 PDCI      | P65 Pacific DC Intertie (PDCI)  | 0                  | 0                      | 22,989              | 1,380                   | 22,989            | 1,380                |
| 18  | SCE Northern      | VINCENT-vincen1i 500 kV line, subject to SCE N-1 Vincent Transformer 500 kV #4      | 22,761             | 338                    | 0                   | 0                       | 22,761            | 338                  |
| 19  | Path 46 WOR       | P46 West of Colorado River (WOR)  | 19,526             | 308                    | 0                   | 0                       | 19,526            | 308                  |
| 20  | East of Pisgah    | SLOAN_CYN_5-ELDORDO 500 kV line #1  | 17,778             | 916                    | 0                   | 0                       | 17,778            | 916                  |
| 21  | SDG&E/CFE         | P45 SDG&E-CFE   | 6,355              | 1,080                  | 7,785               | 552                     | 14,140            | 1,632                |
| 22  | PG&E Kern 230kV   | GATES D-CALFLATSSS 230 kV line #1   | 0                  | 0                      | 11,531              | 1,250                   | 11,531            | 1,250                |
| 23  | SDG&E 230 kV      | SANLUSRY-S.ONOFRE 230 kV line, subject to SDGE N-2 SLR-SO 230 kV #2 and #3 with RAS | 0                  | 0                      | 11,298              | 789                     | 11,298            | 789                  |
| 24  | Path 15 Corridor  | GT_MW_11-MIDWAY 500 kV line #1  | 0                  | 1                      | 11,029              | 234                     | 11,030            | 235                  |



| No. | Area                          | Constraints Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|-------------------------------|---|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 25  | Path 15 Corridor              | MN_MW_23-MIDWAY 500 kV line #2  | 0                  | 0                      | 10,231              | 339                     | 10,231            | 339                  |
| 26  | PG&E MorroBay 230 kV          | MORROBAY-DIABLOCN 230 kV line #1  | 0                  | 0                      | 9,507               | 1,142                   | 9,507             | 1,142                |
| 27  | SCE Northern                  | PARDEE-VINCENT 230 kV line #2   | 0                  | 0                      | 8,485               | 549                     | 8,485             | 549                  |
| 28  | PG&E North Valley 230 kV      | BRNY_FST_JCT-PIT 1 230 kV line, subject to PG&E N-1 Carberry-RM with HR SPS                           | 0                  | 0                      | 8,435               | 507                     | 8,435             | 507                  |
| 29  | Path 41 Sylmar transformer    | P41 Sylmar to SCE   | 7,934              | 396                    | 0                   | 1                       | 7,934             | 397                  |
| 30  | Path 15 Corridor              | GATES-GT_MW_11 500 kV line #1   | 0                  | 0                      | 6,925               | 202                     | 6,925             | 202                  |
| 31  | SCE Antelope 66kV             | NEENACH-TAP 85 66.0 kV line #1  | 6,756              | 1,613                  | 0                   | 0                       | 6,756             | 1,613                |
| 32  | SCE Northern                  | VINCNT2-vincen1i 230 kV line, subject to SCE N-1 Vincent Transformer 500 kV #4                        | 0                  | 0                      | 6,460               | 106                     | 6,460             | 106                  |
| 33  | PG&E Sierra                   | P24 PG&E-Sierra   | 0                  | 0                      | 6,315               | 683                     | 6,315             | 683                  |
| 34  | SCE Eastern                   | VALLEYSC 500/115 kV transformer #3  | 5,911              | 10                     | 0                   | 0                       | 5,911             | 10                   |
| 35  | COI Corridor                  | P66 COI   | 2,462              | 30                     | 2,494               | 20                      | 4,956             | 50                   |
| 40  | PG&E North Valley 230 kV      | CARBERRY-ROUNDMT 230 kV line, subject to PG&E N-1 Pit-Cottonwood 230 kV with HR SPS                   | 4,481              | 362                    | 0                   | 0                       | 4,481             | 362                  |
| 41  | SCE North of Lugo             | SANDLOT-KRAMER 230 kV line #1   | 3,943              | 1,555                  | 0                   | 0                       | 3,943             | 1,555                |
| 42  | SDG&E Bulk                    | ECO 500/500 kV transformer #1   | 0                  | 0                      | 3,850               | 378                     | 3,850             | 378                  |
| 43  | Path 15 Corridor              | MN_MW_22-MN_MW_23 500 kV line #2  | 0                  | 0                      | 3,833               | 87                      | 3,833             | 87                   |
| 44  | SCE Northern                  | VINCNT2-WINDSTAR1 230 kV line #1  | 0                  | 0                      | 3,748               | 453                     | 3,748             | 453                  |
| 45  | Path 15 Corridor              | PANOCH-GATES E 230 kV line, subject to PG&E N-2 LB-Gates and LB-Midway 500 kV                         | 0                  | 0                      | 3,720               | 254                     | 3,720             | 254                  |
| 46  | PG&E GBA                      | E. SHORE-SANMATEO 230 kV line, subject to PG&E N-2 Newark-Ravenswood 230kV and Tesla-Ravenswood 230kV | 2,817              | 318                    | 0                   | 0                       | 2,817             | 318                  |
| 47  | PG&E Fresno 115 kV            | SANGER-MC CALL 115 kV line #3   | 0                  | 0                      | 2,765               | 110                     | 2,765             | 110                  |
| 48  | PG&E Manning - Metcalf 500 kV | MANNING-METCALF 500 kV line, subject to PG&E N-1 Mosslanding-LosBanos 500 kV                          | 2,735              | 95                     | 0                   | 0                       | 2,735             | 95                   |
| 49  | SDG&E/CFE                     | OTAYMESA-TJI-230 230 kV line #1   | 0                  | 0                      | 2,672               | 280                     | 2,672             | 280                  |

| No. | Area                          | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|-------------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 50  | PG&E GBA                      | LS PSTAS-NEWARK D 230 kV line, subject to PG&E N-2 C.Costa-Moraga 230 kV           | 2,369              | 102                    | 0                   | 0                       | 2,369             | 102                  |
| 51  | SCE Eastern                   | DEVERS-DVRS_RB_21 500 kV line, subject to SCE N-1 RedBluff-Devers 500 kV with RAS  | 0                  | 0                      | 2,318               | 83                      | 2,318             | 83                   |
| 52  | PG&E North Valley 230 kV      | COTWD_F2-BRNY_FST_JCT 230 kV line, subject to PG&E N-1 Carberry-RM with HR SPS     | 0                  | 0                      | 1,533               | 145                     | 1,533             | 145                  |
| 53  | PG&E North Valley 230 kV      | CARBERY-ROUNDMT 230 kV line #1   | 1,435              | 114                    | 0                   | 0                       | 1,435             | 114                  |
| 54  | PG&E Fresno 115 kV            | HERNDON-CHLDHOSP_JCT 115 kV line #1  | 1,375              | 52                     | 0                   | 0                       | 1,375             | 52                   |
| 55  | PG&E Sierra                   | HONEYLAK-SKEDADDLPS 60.0 kV line #1  | 0                  | 0                      | 1,186               | 213                     | 1,186             | 213                  |
| 56  | SCE North of Lugo             | P60 Inyo-Control 115 kV Tie  | 999                | 408                    | 137                 | 127                     | 1,136             | 535                  |
| 57  | Path 15 Corridor              | PANOCH-GATES E 230 kV line, subject to PG&E N-2 Mustang-Gates #1 and #2 230 kV     | 0                  | 0                      | 1,061               | 151                     | 1,061             | 151                  |
| 58  | PG&E Manning - Metcalf 500 kV | MANNING-METCALF 500 kV line #1   | 914                | 21                     | 0                   | 0                       | 914               | 21                   |
| 59  | PG&E Fresno 230 kV            | GATES E-GATESBK11JCT 230 kV line #2  | 851                | 98                     | 0                   | 0                       | 851               | 98                   |
| 60  | PG&E Sierra                   | SUMMIT 2-DRUMPH1 115 kV line #1  | 804                | 128                    | 24                  | 21                      | 828               | 149                  |
| 61  | SCE North of Lugo             | TAP189-CONTROL 115 kV line #1  | 0                  | 0                      | 807                 | 69                      | 807               | 69                   |
| 62  | SDG&E 230 kV                  | SILVERGT-BAY BLVD 230 kV line, subject to SDGE N-2 Miguel-Mission 230 kV #1 and #2 | 0                  | 0                      | 800                 | 33                      | 800               | 33                   |
| 63  | SCE Eastern                   | DEVERS-DVRS_RB_21 500 kV line #2   | 0                  | 0                      | 758                 | 19                      | 758               | 19                   |
| 64  | Path 15 Corridor              | FINKSWSTA-WESTLEY 230 kV line, subject to PG&E N-1 LosBanos-Tesla 500kV            | 657                | 21                     | 0                   | 0                       | 657               | 21                   |
| 65  | SDG&E/CFE                     | IV PFC1 230/230 kV transformer #1  | 632                | 85                     | 0                   | 0                       | 632               | 85                   |
| 66  | Moenkope - Eldorado 500 kV    | MOEN-ELD SC3-ELDORDO 500 kV line #1  | 599                | 15                     | 0                   | 0                       | 599               | 15                   |
| 67  | Path 15 Corridor              | PANOCH-GATES E 230 kV line, subject to PG&E N-1 Panoche-Gates #1 230kV             | 0                  | 0                      | 599                 | 105                     | 599               | 105                  |

| No. | Area                      | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|---------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 68  | SCE Metro                 | MESACALS-LAGUBELL 230 kV line #2   | 526                | 661                    | 0                   | 0                       | 526               | 661                  |
| 69  | SCE Eastern               | DVRS_RB_22-REDBLUFF 500 kV line #2   | 0                  | 0                      | 523                 | 13                      | 523               | 13                   |
| 70  | Path 49 EOR               | P49 East of Colorado River (EOR)   | 462                | 5                      | 0                   | 0                       | 462               | 5                    |
| 71  | SCE Northern              | PARDEE-SYLMAR220 230 kV line, subject to SCE N-1 Sylmar-Pardee 230kV   | 0                  | 0                      | 461                 | 12                      | 461               | 12                   |
| 72  | Path 26 Corridor          | MN_WRLWND_32-WIRLWIND 500 kV line, subject to SCE N-2 Midway-Vincent 500 kV                                      | 454                | 55                     | 0                   | 0                       | 454               | 55                   |
| 73  | SCE Northern              | MAGUNDEN-ANTELOPE 230 kV line #1   | 0                  | 0                      | 449                 | 236                     | 449               | 236                  |
| 74  | SCE Northern              | VINCNT2-S.CLARA 230 kV line, subject to SCE N-2 MOORPARK-SCLARA #1 and #2 230 kV                                 | 440                | 63                     | 0                   | 0                       | 440               | 63                   |
| 75  | PG&E North Valley 230 kV  | CARIBOU-BELDENTP 230 kV line #1  | 402                | 62                     | 0                   | 0                       | 402               | 62                   |
| 76  | SCE North of Lugo         | COLWATER 230/115 kV transformer #1   | 0                  | 0                      | 370                 | 444                     | 370               | 444                  |
| 77  | PG&E Tesla 230 kV         | STAGG-J2-TESLA E 230 kV line, subject to PG&E N-1 EightMiles-TeslaE 230kV  | 0                  | 0                      | 355                 | 3                       | 355               | 3                    |
| 78  | PG&E GBA                  | C.COSTAPPE-BDLSWSTA 230 kV line #1   | 0                  | 0                      | 354                 | 14                      | 354               | 14                   |
| 79  | SDG&E/CFE                 | IMPRVLVLY-IV PFC1 230 kV line, subject to SDGE N-2 Sycamore-Otay Mesa-Miguel and Bay Blvd-Otay Mesa-Miguel 230kV | 0                  | 0                      | 335                 | 66                      | 335               | 66                   |
| 80  | PG&E Fresno 115 kV        | KINGSBURGD-CONTADNA 115 kV line #1   | 0                  | 0                      | 317                 | 41                      | 317               | 41                   |
| 81  | East of Pisgah            | P61 Lugo-Victorville 500 kV Line   | 281                | 5                      | 25                  | 19                      | 306               | 24                   |
| 82  | Path 25 PACW-PG&E 115 kV  | P25 PacifiCorp/PG&E 115 kV Interconnection   | 294                | 19                     | 0                   | 0                       | 294               | 19                   |
| 83  | SCE Northern              | PARDEE-S.CLARA 230 kV line, subject to SCE N-2 MOORPARK-SCLARA #1 and #2 230 kV                                  | 282                | 374                    | 0                   | 0                       | 282               | 374                  |
| 84  | PG&E POE - RIO OSO 230 kV | POE-RIO OSO 230 kV line #1   | 281                | 75                     | 0                   | 0                       | 281               | 75                   |
| 85  | East of Pisgah            | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Lugo-Mohave 500 kV  | 271                | 25                     | 0                   | 0                       | 271               | 25                   |
| 86  | SCE North of Lugo         | KRAMER-VICTOR 230 kV line #1   | 264                | 198                    | 0                   | 0                       | 264               | 198                  |

| No. | Area                     | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|--------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 87  | PG&E Fresno 230 kV       | MCMULLN1-KEARNEY 230 kV line, subject to PG&E N-2 Mustang-Gates #1 and #2 230 kV           | 260                | 42                     | 0                   | 0                       | 260               | 42                   |
| 88  | SDG&E/CFE                | IV PFC1 230/230 kV transformer #2  | 256                | 38                     | 0                   | 0                       | 256               | 38                   |
| 89  | East of Pisgah           | HAE SVC-HAE SVCL 500 kV line #1  | 233                | 10                     | 0                   | 0                       | 233               | 10                   |
| 90  | PG&E North Valley 230 kV | CORTINA-VACA-DIX 230 kV line, subject to PG&E N-1 Delev n-Cortina 230 kV                   | 210                | 280                    | 0                   | 0                       | 210               | 280                  |
| 91  | SDG&E 230 kV             | TALEGA-S.ONOFRE 230 kV line #1   | 0                  | 0                      | 191                 | 461                     | 191               | 461                  |
| 92  | PG&E GBA                 | MARSHLD2-C.COSTAPPD 230 kV line #2   | 191                | 14                     | 0                   | 0                       | 191               | 14                   |
| 93  | Path 26 Corridor         | MN_VINCNT_22-VINCENT 500 kV line #2  | 161                | 19                     | 0                   | 0                       | 161               | 19                   |
| 94  | SDG&E Bulk               | ECO-MIGUEL 500 kV line, subject to SDGE N-1 Ocotillo-Suncrest 500 kV with RAS              | 113                | 16                     | 0                   | 0                       | 113               | 16                   |
| 95  | Path 26 Corridor         | MN_VINCNT_11-MN_VINCNT_12 500 kV line, subject to SCE N-1 Midway-Vincent#2 500kV           | 109                | 20                     | 0                   | 0                       | 109               | 20                   |
| 96  | PG&E Fresno 115 kV       | GWFHANFORDSS-CONTADNA 115 kV line #1   | 77                 | 14                     | 0                   | 0                       | 77                | 14                   |
| 97  | PG&E Fresno 230 kV       | GREGG-HENTAP1 230 kV line #1   | 0                  | 0                      | 73                  | 22                      | 73                | 22                   |
| 98  | SCE North of Lugo        | COLWATER-DUNNSIDE 115 kV line #1   | 59                 | 136                    | 0                   | 0                       | 59                | 136                  |
| 99  | Path 26 Corridor         | MN_WRLWND_32-WIRLWIND 500 kV line #3   | 0                  | 0                      | 58                  | 5                       | 58                | 5                    |
| 100 | SDG&E Northern 69 kV     | SANLUSRY-OCEAN RANCH 69 kV line, subject to SDGE N-2 EN-SLR and EN-SLR-PEN 230 kV with RAS | 58                 | 209                    | 0                   | 0                       | 58                | 209                  |
| 101 | SCE Eastern              | DEVERS-devers i 500 kV line, subject to SCE N-1 Valley-Alberhill 500 kV with RAS           | 57                 | 36                     | 0                   | 0                       | 57                | 36                   |
| 102 | PG&E Sierra              | MARBLE 63.0/69.0 kV transformer #1   | 50                 | 6                      | 6                   | 2                       | 56                | 8                    |
| 103 | PG&E GBA                 | TESLA E-NEWARK D 230 kV line, subject to PG&E N-1 Tesla-Ravenswood 230kV                   | 55                 | 2                      | 0                   | 0                       | 55                | 2                    |
| 104 | SDG&E 230 kV             | SILVERGT-OLD TOWN 230 kV line, subject to SDGE N-1 Silvergate-OldTown-Mission 230kV no RAS | 53                 | 10                     | 0                   | 0                       | 53                | 10                   |

| No. | Area                                  | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|---------------------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 105 | PG&E North Valley 230 kV              | BELDENTP-TABLE MTN D 230 kV line #1  | 49                 | 5                      | 0                   | 0                       | 49                | 5                    |
| 106 | PG&E North Valley 230 kV              | CARBERRY-ROUND MT 230 kV line, subject to PG&E N-2 Pit-Cotw dF and Cotw dE-RM 230 kV with HR SPS | 44                 | 3                      | 0                   | 0                       | 44                | 3                    |
| 107 | PG&E North Valley 230 kV              | CARIBOU 230/230 kV transformer #11   | 0                  | 0                      | 42                  | 6                       | 42                | 6                    |
| 108 | East of Pisgah                        | IVANPAH-MTN PASS 115 kV line #1  | 41                 | 38                     | 0                   | 0                       | 41                | 38                   |
| 109 | PG&E Fresno 230 kV                    | GREGG-HENTAP1 230 kV line, subject to PG&E N-1 Gregg-Borden #1 230kV                             | 0                  | 0                      | 40                  | 10                      | 40                | 10                   |
| 110 | SCE Eastern                           | DVRS_RB_21-DVRS_RB_22 500 kV line #2   | 0                  | 0                      | 37                  | 2                       | 37                | 2                    |
| 111 | PG&E Kern 230kV                       | GATES D-TEMPLETN 230 kV line #1  | 0                  | 0                      | 27                  | 59                      | 27                | 59                   |
| 112 | Path 84 Harry Allen - Eldorado 500 kV | P84 Harry Allen-Eldorado 500 kV  | 0                  | 0                      | 27                  | 2                       | 27                | 2                    |
| 113 | SDG&E Bulk                            | IMPRLVLY 500/500 kV transformer #1   | 0                  | 0                      | 25                  | 49                      | 25                | 49                   |
| 114 | SCE Vincent - MiraLoma 500kV          | VINCENT-MESA CAL 500 kV line #1  | 25                 | 1                      | 0                   | 0                       | 25                | 1                    |
| 115 | SCE North of Lugo                     | LUGO-lugo 2i 500 kV line, subject to SCE N-1 Lugo Transformer #1 500-230 kV with RAS             | 0                  | 0                      | 23                  | 27                      | 23                | 27                   |
| 116 | East of Pisgah                        | INNOVATION-INNOVATION 230 kV line, subject to VEA N-2 NWest-DesertView 230 kV with RAS           | 22                 | 12                     | 0                   | 0                       | 22                | 12                   |
| 117 | SCE North of Lugo                     | KRAMER-VICTOR 230 kV line #2   | 21                 | 48                     | 0                   | 0                       | 21                | 48                   |
| 118 | SCE Lugo - Vincent 500 kV             | LUGO-VINCENT 500 kV line #1  | 21                 | 13                     | 0                   | 0                       | 21                | 13                   |
| 119 | Path 26 Corridor                      | MIDWAY-MN_WRLWND_31 500 kV line, subject to SCE N-2 Midway-Vincent 500 kV                        | 20                 | 9                      | 0                   | 0                       | 20                | 9                    |
| 120 | PG&E Kern 230kV                       | ARCO-MIDWAY-E 230 kV line #1   | 0                  | 0                      | 18                  | 226                     | 18                | 226                  |
| 122 | Path 26 Corridor                      | MN_WRLWND_31-MN_WRLWND_32 500 kV line, subject to SCE N-2 Midway-Vincent 500 kV                  | 17                 | 5                      | 0                   | 0                       | 17                | 5                    |
| 123 | PG&E Tesla 230 kV                     | WEBER-TESLA E 230 kV line, subject to PG&E N-1 Bellota-TeslaE 230kV                              | 0                  | 0                      | 15                  | 2                       | 15                | 2                    |
| 125 | SCE Eastern                           | ALBERHIL-VALLEYSC 500 kV line #1   | 0                  | 0                      | 14                  | 5                       | 14                | 5                    |

| No. | Area                  | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|-----------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 126 | East of Pismo         | GAMEBIRD-GAMEBIRD 230 kV line, subject to VEA N-2 Pahrump-Gamebird 230 kV no RAS | 2                  | 19                     | 11                  | 73                      | 12                | 92                   |
| 127 | SCE Northern          | WINDHUB_A 230/13.8 kV transformer #2   | 12                 | 11                     | 0                   | 0                       | 12                | 11                   |
| 128 | PG&E Fresno 115 kV    | LPRNJCTSS-GWFHANFORDSS 115 kV line #1  | 11                 | 6                      | 0                   | 0                       | 11                | 6                    |
| 129 | SCE North of Lugo     | INYOKERN-KRAMER 115 kV line #1   | 11                 | 3                      | 0                   | 0                       | 11                | 3                    |
| 130 | SCE Eastern           | DEVERS-DVRS_RB_11 500 kV line #1   | 0                  | 0                      | 10                  | 3                       | 10                | 3                    |
| 131 | PG&E Fresno 230 kV    | HELM-MC CALL 230 kV line, subject to PG&E N-2 Mustang-Gates #1 and #2 230 kV     | 10                 | 5                      | 0                   | 0                       | 10                | 5                    |
| 132 | PG&E Fresno 115 kV    | HENRETTA-LPRNJCTSS 115 kV line #1  | 7                  | 4                      | 0                   | 0                       | 7                 | 4                    |
| 133 | PG&E GBA              | NEWARK D-NRS 230 kV line #1  | 5                  | 3                      | 0                   | 0                       | 5                 | 3                    |
| 134 | SCE North of Lugo     | VICTOR-LUGO 230 kV line #1   | 5                  | 7                      | 0                   | 0                       | 5                 | 7                    |
| 135 | PG&E Morro Bay 230 kV | TEMPLETN-MORROBAY 230 kV line #1   | 0                  | 0                      | 4                   | 26                      | 4                 | 26                   |
| 136 | COI Corridor          | ROUND MT-RM_FR_22 500 kV line #2   | 3                  | 2                      | 0                   | 0                       | 3                 | 2                    |
| 137 | Path 26 Corridor      | MN_VINCNT_12-VINCENT 500 kV line #1  | 2                  | 1                      | 0                   | 0                       | 2                 | 1                    |
| 138 | PG&E GBA              | NRS-SANJB230 230 kV line #1  | 0                  | 0                      | 1                   | 1                       | 1                 | 1                    |
| 139 | East of Pismo         | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Eldorado-Moenkopi 500 kV        | 1                  | 1                      | 0                   | 0                       | 1                 | 1                    |
| 140 | PG&E GBA              | DELTA PMP-SANDHLWJCT 230 kV line #1  | 0                  | 0                      | 1                   | 2                       | 1                 | 2                    |
| 141 | Path 26 Corridor      | MN_WRLWND_31-MN_WRLWND_32 500 kV line #3   | 0                  | 0                      | 1                   | 1                       | 1                 | 1                    |
| 142 | PG&E Kern 230kV       | GATES F-MIDWAY-F 230 kV line, subject to PG&E N-1 Arco-Midway 230kV              | 0                  | 0                      | 1                   | 9                       | 1                 | 9                    |
| 143 | Path 26 Corridor      | MIDWAY-MN_VINCNT_11 500 kV line #1   | 0                  | 1                      | 0                   | 0                       | 0                 | 1                    |
| 144 | PG&E GBA              | C.COSTAPPE-WINDMASTERJT 230 kV line #1   | 0                  | 0                      | 0                   | 2                       | 0                 | 2                    |
| 145 | SDG&E Bulk            | ECO 230/500 kV transformer #1  | 0                  | 4                      | 0                   | 0                       | 0                 | 4                    |
| 146 | SCE Northern          | MAGUNDEN-VESTAL 230 kV line, subject to SCE N-1 Magunden-Vestal #1 230kV         | 0                  | 4                      | 0                   | 0                       | 0                 | 4                    |

| No. | Area                     | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|--------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 147 | PG&E Kern 230kV          | GATES F-MIDWAY-F 230 kV line, subject to PG&E N-1 Gates-Arco 230kV                           | 0                  | 0                      | 0                   | 2                       | 0                 | 2                    |
| 148 | PG&E North Valley 230 kV | CORTINA-VACA-DIX 230 kV line, subject to PG&E N-2 LoganCR-Delev n and Delev n-Cortina 230 kV | 0                  | 1                      | 0                   | 0                       | 0                 | 1                    |
| 149 | PG&E Fresno 230 kV       | HENTAP1-MUSTANGSS 230 kV line #1   | 0                  | 0                      | 0                   | 3                       | 0                 | 3                    |
| 150 | PG&E Kern 230kV          | GATES F-MIDWAY-F 230 kV line #1  | 0                  | 0                      | 0                   | 1                       | 0                 | 1                    |
| 151 | PG&E Morro Bay 230 kV    | MORROBAY-ESTRELLA 230 kV line #1   | 0                  | 1                      | 0                   | 0                       | 0                 | 1                    |
| 152 | SCE Antelope 66kV        | ANTELOPE-NEENACH 66.0 kV line #1   | 0                  | 6                      | 0                   | 0                       | 0                 | 6                    |
| 153 | SCE North of Lugo        | VICTOR-LUGO 230 kV line #2   | 0                  | 1                      | 0                   | 0                       | 0                 | 1                    |
| 154 | PG&E GBA                 | WINDMASTERJT-DELTAPMP 230 kV line #1   | 0                  | 0                      | 0                   | 1                       | 0                 | 1                    |
| 155 | PG&E Kern 230kV          | GATES F-ARCO 230 kV line #1  | 0                  | 0                      | 0                   | 1                       | 0                 | 1                    |
| 156 | PG&E Fresno 230 kV       | HENTAP1-HENRIETTA_D 230 kV line #1   | 0                  | 0                      | 0                   | 2                       | 0                 | 2                    |

Table G.7-6 lists the aggregated congestion results across specific branch groups and local areas in the 2039 base portfolio PCM case, ranked by congestion cost.

Table G.7-6: Aggregated congestion in 2039 base portfolio PCM

| No. | Aggregated congestion    | Cost (\$M) | Duration (Hr) |
|-----|--------------------------|------------|---------------|
| 1   | Path 15 Corridor         | 521.80     | 7,343         |
| 2   | Path 26 Corridor         | 206.28     | 4,197         |
| 3   | East of Pispah           | 86.87      | 3,334         |
| 4   | SCE Northern             | 78.62      | 3,348         |
| 5   | SCE Metro                | 67.89      | 1,328         |
| 6   | SWIP North               | 51.61      | 748           |
| 7   | SCE North of Lugo        | 32.55      | 6,531         |
| 8   | Path 42                  | 24.13      | 594           |
| 9   | Path 65 PDCI             | 22.99      | 1,380         |
| 10  | Path 46 WOR              | 19.53      | 308           |
| 11  | SDG&E/CFE                | 18.03      | 2,101         |
| 12  | PG&E North Valley 230 kV | 16.63      | 1,485         |
| 13  | SDG&E 230 kV             | 12.34      | 1,293         |
| 14  | PG&E Kern 230kV          | 11.58      | 1,548         |
| 15  | SCE Eastern              | 9.63       | 171           |
| 16  | PG&E Morro Bay 230 kV    | 9.51       | 1,169         |
| 17  | PG&E Sierra              | 8.39       | 1,053         |

| No. | Aggregated congestion                 | Cost (\$M) | Duration (Hr) |
|-----|---------------------------------------|------------|---------------|
| 18  | Path 41 Sylmar transformer            | 7.93       | 397           |
| 19  | SCE Antelope 66kV                     | 6.76       | 1,619         |
| 20  | PG&E GBA                              | 5.79       | 459           |
| 21  | COI Corridor                          | 4.96       | 52            |
| 22  | PG&E Fresno 115 kV                    | 4.55       | 227           |
| 23  | SDG&E Bulk                            | 3.99       | 447           |
| 24  | PG&E Manning - Metcalf 500 kV         | 3.65       | 116           |
| 25  | PG&E Fresno 230 kV                    | 1.23       | 182           |
| 26  | Moenkope - Eldorado 500 kV            | 0.60       | 15            |
| 27  | Path 49 EOR                           | 0.46       | 5             |
| 28  | PG&E Tesla 230 kV                     | 0.37       | 5             |
| 29  | Path 25 PACW-PG&E 115 kV              | 0.29       | 19            |
| 30  | PG&E POE - RIO OSO 230 kV             | 0.28       | 75            |
| 31  | SDG&E Northern 69 kV                  | 0.06       | 209           |
| 32  | Path 84 Harry Allen - Eldorado 500 kV | 0.03       | 2             |
| 33  | SCE Vincent – Mira Loma 500kV         | 0.02       | 1             |
| 34  | SCE Lugo - Vincent 500 kV             | 0.02       | 13            |

### G.7.5 2039 Base Portfolio PCM Curtailment Results

Table G.7-7 shows the wind and solar curtailment results of the 2039 base portfolio PCM.

Table G.7-7: Wind and solar curtailment summary in the 2039 base portfolio PCM

| Renewable zone         | Generation (GWh) | Curtailment (GWh) | Total potential (GWh) | Curtailment Ratio |
|------------------------|------------------|-------------------|-----------------------|-------------------|
| SCE Northern           | 33,455           | 1,373             | 34,828                | 3.94%             |
| SCE Eastern            | 23,695           | 487               | 24,182                | 2.01%             |
| PG&E Fresno            | 20,931           | 2,585             | 23,516                | 10.99%            |
| East of Pisgah         | 16,944           | 952               | 17,896                | 5.32%             |
| PG&E Central Valley    | 17,073           | 595               | 17,668                | 3.37%             |
| OOS W-SunZia           | 13,268           | 2,592             | 15,860                | 16.34%            |
| SDG&E Eastern and Bulk | 14,953           | 525               | 15,477                | 3.39%             |
| OSW-Diablo             | 13,319           | 815               | 14,134                | 5.76%             |
| SCE North of Lugo      | 12,193           | 602               | 12,795                | 4.70%             |
| OOS W-WY               | 11,087           | 509               | 11,596                | 4.39%             |
| PG&E Kern              | 9,890            | 412               | 10,301                | 4.00%             |
| OSW-Humboldt           | 8,140            | 63                | 8,203                 | 0.77%             |
| NM                     | 4,447            | 2,255             | 6,702                 | 33.65%            |
| OOS W-Tesla            | 5,672            | 126               | 5,798                 | 2.18%             |
| PG&E Central Coast     | 4,917            | 281               | 5,198                 | 5.40%             |
| PG&E North Valley      | 4,156            | 192               | 4,348                 | 4.42%             |
| SCE Metro              | 3,008            | 107               | 3,115                 | 3.43%             |
| OOS W-ID               | 2,780            | 160               | 2,939                 | 5.44%             |



| Renewable zone        | Generation (GWh) | Curtailment (GWh) | Total potential (GWh) | Curtailment Ratio |
|-----------------------|------------------|-------------------|-----------------------|-------------------|
| OOS W-NW              | 1,819            | 983               | 2,802                 | 35.09%            |
| AZ                    | 1,708            | 1,045             | 2,753                 | 37.96%            |
| IID                   | 1,409            | 1                 | 1,410                 | 0.05%             |
| PG&E Greater Bay Area | 1,206            | 50                | 1,256                 | 4.01%             |
| San Diego             | 713              | 3                 | 716                   | 0.48%             |
| NW                    | 552              | 31                | 582                   | 5.25%             |
| SMUD                  | 384              | 25                | 408                   | 6.06%             |
| PG&E North Coast      | 393              | 4                 | 397                   | 0.89%             |
| NV                    | 322              | 54                | 376                   | 14.38%            |
| PG&E North Bay        | 56               | 4                 | 60                    | 6.27%             |
| PG&E Humboldt         | 12               | 0                 | 12                    | 2.95%             |
| <b>Total</b>          | <b>228,499</b>   | <b>16,830</b>     | <b>245,329</b>        | <b>6.86%</b>      |

### G.7.6 2039 Base Portfolio PCM Gas-fired Generator Utilization

The average capacity factors of gas-fired generators by area in the 2039 base portfolio were summarized in Table G.7-8.

Table G.7-8: Gas-fired generator utilization in the 2039 base portfolio PCM

| Areas                 | Sum of Capacity (MW) | Sum of Generation (MWh) | Capacity Factor |
|-----------------------|----------------------|-------------------------|-----------------|
| PG&E Central Coast    | 1,221                | 1,768,376               | 0.17            |
| PG&E Central Valley   | 872                  | 779,619                 | 0.10            |
| PG&E Fresno           | 1,098                | 880,502                 | 0.09            |
| PG&E Greater Bay Area | 5,538                | 12,717,381              | 0.26            |
| PG&E Humboldt         | 163                  | 65,957                  | 0.05            |
| PG&E Kern             | 2,013                | 6,033,211               | 0.34            |
| PG&E North Valley     | 1,446                | 2,151,166               | 0.17            |
| SCE Bly the           | 494                  | 552,888                 | 0.13            |
| SCE Eastern LA Basin  | 1,986                | 1,983,297               | 0.11            |
| SCE Eldorado          | 495                  | 790,179                 | 0.18            |
| SCE North of Lugo     | 922                  | 1,725,744               | 0.21            |
| SCE North of Magunden | 61                   | 30,465                  | 0.06            |
| SCE South of Magunden | 818                  | 1,137,368               | 0.16            |
| SCE Tehachapi         | 4                    | 804                     | 0.02            |
| SCE Ventura           | 171                  | 203,128                 | 0.14            |
| SCE Western LA Basin  | 3,572                | 5,677,020               | 0.18            |
| SDG&E Bulk            | 947                  | 1,523,164               | 0.18            |
| SDG&E San Diego       | 2,678                | 2,598,855               | 0.11            |
| <b>System Total</b>   | <b>24,498</b>        | <b>40,619,125</b>       | <b>0.19</b>     |

### G.7.7 2039 Sensitivity Portfolio PCM Congestion Results

The results of the congestion assessment in the 2039 sensitivity portfolio PCM is listed in Table G.7-9. Columns “Cost Forward” and “Duration Forward” are the cost and duration of congestion, respectively, when the flow is in forward direction as indicated in the constraint name. Columns “Cost Backward” and “Duration Backward” are the cost and duration of congestion, respectively, when flow is in backward direction. The last two columns were the total cost and total duration, respectively.

Table G.7-9: Congestion in the ISO-controlled grid in the 2039 sensitivity portfolio PCM

| No. | Area                       | Constraints Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|----------------------------|---|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 1   | Path 26 Corridor           | P26 Northern-Southern California  | 0                  | 1                      | 638,949             | 5,423                   | 638,949           | 5,424                |
| 2   | Path 15 Corridor           | MANNING-MN_GT_11 500 kV line #1   | 0                  | 0                      | 319,078             | 2,018                   | 319,078           | 2,018                |
| 3   | Path 26 Corridor           | MIDWAY-MN_WRLWND_31 500 kV line #3  | 0                  | 1                      | 209,792             | 2,757                   | 209,793           | 2,758                |
| 4   | East of Pisgah             | LUGO-VICTORVL 500 kV line, subject to SCE N-1 Eldorado-Lugo 500 kV with RAS         | 0                  | 0                      | 100,689             | 558                     | 100,689           | 558                  |
| 5   | Path 65 PDCI               | P65 Pacific DC Inter tie (PDCI)   | 0                  | 0                      | 99,235              | 3,219                   | 99,235            | 3,219                |
| 6   | SDG&E Bulk                 | IMPRLVLY 500/500 kV transformer #1  | 0                  | 0                      | 83,827              | 1,559                   | 83,827            | 1,559                |
| 7   | SCE North of Lugo          | CALCITE-LUGO 230 kV line #1   | 83,347             | 5,348                  | 0                   | 0                       | 83,347            | 5,348                |
| 8   | SWIP North                 | SWIP-North (Midpoint-Robinson)  | 0                  | 0                      | 72,551              | 726                     | 72,551            | 726                  |
| 9   | SCE Metro                  | LCIENEGA-LA FRESA 230 kV line, subject to SCE N-2 La Fresa-El Nido #3 and #4 230 kV | 0                  | 0                      | 65,527              | 868                     | 65,527            | 868                  |
| 10  | Path 15 Corridor           | PANOCH-GATES E 230 kV line, subject to PG&E N-2 Gates-Gregg and Gates-McCall 230 kV | 0                  | 0                      | 51,327              | 1,208                   | 51,327            | 1,208                |
| 11  | East of Pisgah             | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Eldorado-Lugo 500 kV with RAS      | 47,781             | 2,189                  | 0                   | 0                       | 47,781            | 2,189                |
| 12  | Path 46 WOR                | P46 West of Colorado River (WOR)  | 34,793             | 337                    | 0                   | 0                       | 34,793            | 337                  |
| 13  | SDG&E/CFE                  | P45 SDG&E-CFE   | 8,448              | 1,338                  | 23,265              | 838                     | 31,713            | 2,176                |
| 14  | Path 41 Sylmar transformer | P41 Sylmar to SCE   | 27,207             | 528                    | 0                   | 0                       | 27,207            | 528                  |
| 15  | Path 15 Corridor           | MANNING-MN_MW_21 500 kV line #2   | 0                  | 0                      | 23,759              | 811                     | 23,759            | 811                  |
| 16  | Path 15 Corridor           | MN_GT_11-GATES 500 kV line #1   | 0                  | 0                      | 23,267              | 260                     | 23,267            | 260                  |
| 17  | Path 15 Corridor           | GT_MW_11-MIDWAY 500 kV line #1  | 0                  | 0                      | 22,075              | 287                     | 22,075            | 287                  |
| 18  | SCE Northern               | WINDHUB_A 230/13.8 kV transformer #1  | 14,144             | 1,055                  | 0                   | 0                       | 14,144            | 1,055                |
| 19  | PG&E Morro Bay 230 kV      | MORROBAY-DIABLOCN 230 kV line #1  | 0                  | 0                      | 13,868              | 1,263                   | 13,868            | 1,263                |
| 20  | PG&E Sierra                | P24 PG&E-Sierra   | 0                  | 0                      | 12,797              | 1,436                   | 12,797            | 1,436                |
| 21  | Path 15 Corridor           | GATES-GT_MW_11 500 kV line #1   | 0                  | 0                      | 9,387               | 115                     | 9,387             | 115                  |
| 22  | COI Corridor               | P66 COI   | 8,797              | 122                    | 72                  | 2                       | 8,869             | 124                  |
| 23  | SCE North of Lugo          | INYOKERN-KRAMER 115 kV line #1  | 8,865              | 2,053                  | 0                   | 0                       | 8,865             | 2,053                |

| No. | Area                          | Constraints Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|-------------------------------|---|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 24  | PG&E North Valley 230 kV      | BRNY_FST_JCT-PIT 1 230 kV line, subject to PG&E N-1 Carberry-RM with HR SPS                           | 0                  | 0                      | 8,399               | 438                     | 8,399             | 438                  |
| 25  | Path 15 Corridor              | MN_MW_23-MIDWAY 500 kV line #2  | 0                  | 0                      | 7,910               | 201                     | 7,910             | 201                  |
| 26  | PG&E GBA                      | LS PSTAS-NEWARK D 230 kV line, subject to PG&E N-2 C.Costa-Moraga 230 kV                              | 7,623              | 154                    | 0                   | 0                       | 7,623             | 154                  |
| 27  | Path 15 Corridor              | MN_MW_21-MN_MW_22 500 kV line #2  | 0                  | 0                      | 7,591               | 215                     | 7,591             | 215                  |
| 28  | PG&E GBA                      | E. SHORE-SANMATEO 230 kV line, subject to PG&E N-2 Newark-Ravenswood 230kV and Tesla-Ravenswood 230kV | 5,990              | 470                    | 0                   | 0                       | 5,990             | 470                  |
| 29  | SCE Eastern                   | VALLEYSC 500/115 kV transformer #3  | 5,908              | 10                     | 0                   | 0                       | 5,908             | 10                   |
| 30  | Path 15 Corridor              | PANOCHÉ-GATES E 230 kV line, subject to PG&E N-2 LB-Gates and LB-Midway 500 kV                        | 0                  | 0                      | 5,837               | 631                     | 5,837             | 631                  |
| 31  | PG&E Manning - Metcalf 500 kV | MANNING-METCALF 500 kV line, subject to PG&E N-1 Mosslanding-LosBanos 500 kV                          | 4,395              | 201                    | 0                   | 0                       | 4,395             | 201                  |
| 32  | SDG&E/CFE                     | OTAYMESA-TJI-230 230 kV line #1   | 0                  | 0                      | 4,372               | 454                     | 4,372             | 454                  |
| 33  | PG&E North Valley 230 kV      | CARBERY-ROUNDMT 230 kV line #1  | 3,753              | 261                    | 0                   | 0                       | 3,753             | 261                  |
| 34  | PG&E Sierra                   | HONEYLAK-SKEDADDLPS 60.0 kV line #1   | 0                  | 0                      | 3,702               | 703                     | 3,702             | 703                  |
| 35  | East of Pisgah                | SLOAN_CYN_5-ELDORDO 500 kV line #1  | 3,698              | 236                    | 0                   | 0                       | 3,698             | 236                  |
| 36  | SDG&E 230 kV                  | SANLUSRY-S.ONOFRE 230 kV line, subject to SDGE N-2 SLR-SO 230 kV #2 and #3 with RAS                   | 0                  | 0                      | 3,417               | 317                     | 3,417             | 317                  |
| 37  | Path 15 Corridor              | FINKSWSTA-WESTLEY 230 kV line, subject to PG&E N-1 LosBanos-Tesla 500kV                               | 3,375              | 132                    | 0                   | 0                       | 3,375             | 132                  |
| 38  | SCE Northern                  | VINCNT2-WINDSTAR1 230 kV line #1  | 0                  | 0                      | 3,311               | 498                     | 3,311             | 498                  |
| 39  | SDG&E 230 kV                  | SILVERGT-BAY BLVD 230 kV line, subject to SDGE N-2 Miguel-Mission 230 kV #1 and #2                    | 0                  | 0                      | 3,061               | 122                     | 3,061             | 122                  |
| 40  | PG&E North Valley 230 kV      | CARBERY-ROUNDMT 230 kV line, subject to PG&E N-1 Pit-Cottonwood 230 kV with HR SPS                    | 2,874              | 251                    | 0                   | 0                       | 2,874             | 251                  |
| 41  | SCE Northern                  | PARDEE-SYLMAR220 230 kV line, subject to SCE N-1 Sylmar-Pardee 230kV                                  | 0                  | 0                      | 2,621               | 42                      | 2,621             | 42                   |
| 42  | PG&E Manning - Metcalf 500 kV | MANNING-METCALF 500 kV line #1  | 2,527              | 59                     | 0                   | 0                       | 2,527             | 59                   |
| 43  | PG&E North Valley 230 kV      | COTWD_F2-BRNY_FST_JCT 230 kV line, subject to PG&E N-1 Carberry-RM with HR SPS                        | 0                  | 0                      | 2,378               | 180                     | 2,378             | 180                  |
| 44  | SCE North of Lugo             | SANDLOT-KRAMER 230 kV line #1   | 2,353              | 1,484                  | 0                   | 0                       | 2,353             | 1,484                |
| 45  | SCE Metro                     | MESACALS-LAGUBELL 230 kV line #2  | 2,335              | 664                    | 0                   | 0                       | 2,335             | 664                  |

| No. | Area                     | Constraints Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|--------------------------|---|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 46  | SCE North of Lugo        | P60 Inyo-Control 115 kV Tie   | 925                | 333                    | 912                 | 581                     | 1,836             | 914                  |
| 47  | SCE Antelope 66kV        | NEENACH-TAP 85 66.0 kV line #1  | 1,825              | 854                    | 0                   | 0                       | 1,825             | 854                  |
| 48  | SDG&E Bulk               | ECO 500/500 kV transformer #1   | 0                  | 0                      | 1,769               | 244                     | 1,769             | 244                  |
| 49  | PG&E Fresno 115 kV       | SANGER-MC CALL 115 kV line #3   | 0                  | 0                      | 1,674               | 80                      | 1,674             | 80                   |
| 50  | SDG&E/CFE                | IMPRVLVY-IV PFC1 230 kV line, subject to SDGE N-2 Sycamore-Otay Mesa-Miguel and Bay Blvd-Otay Mesa-Miguel 230kV | 0                  | 0                      | 1,636               | 104                     | 1,636             | 104                  |
| 51  | SDG&E/CFE                | IV PFC1 230/230 kV transformer #1   | 1,632              | 185                    | 0                   | 0                       | 1,632             | 185                  |
| 52  | SCE North of Lugo        | KRAMER-VICTOR 230 kV line #1  | 1,526              | 608                    | 0                   | 0                       | 1,526             | 608                  |
| 53  | PG&E Sierra              | SUMMIT 2-DRUMPH1 115 kV line #1   | 1,509              | 214                    | 0                   | 0                       | 1,509             | 214                  |
| 54  | SCE Northern             | VINCENT-vincen1i 500 kV line, subject to SCE N-1 Vincent Transformer 500 kV #4                                  | 1,397              | 93                     | 0                   | 0                       | 1,397             | 93                   |
| 55  | SDG&E Bulk               | ECO-MIGUEL 500 kV line, subject to SDGE N-1 Ocotillo-Suncrest 500 kV with RAS                                   | 1,325              | 63                     | 0                   | 0                       | 1,325             | 63                   |
| 56  | SCE Northern             | PARDEE-VINCENT 230 kV line #2   | 0                  | 0                      | 1,315               | 311                     | 1,315             | 311                  |
| 57  | Path 25 PACW-PG&E 115 kV | P25 PacificCorp/PG&E 115 kV Interconnection   | 1,192              | 63                     | 0                   | 0                       | 1,192             | 63                   |
| 58  | PG&E Fresno 115 kV       | HERNDON-CHLDHOSP_JCT 115 kV line #1   | 1,150              | 37                     | 0                   | 0                       | 1,150             | 37                   |
| 59  | SCE Eastern              | DEVERS-DVRS_RB_21 500 kV line, subject to SCE N-1 RedBluff-Devers 500 kV with RAS                               | 0                  | 0                      | 1,097               | 90                      | 1,097             | 90                   |
| 60  | Path 15 Corridor         | MN_MW_22-MN_MW_23 500 kV line #2  | 0                  | 0                      | 1,077               | 30                      | 1,077             | 30                   |
| 61  | PG&E Tesla 230 kV        | STAGG-J2-TESLA E 230 kV line, subject to PG&E N-1 EightMiles-TeslaE 230kV                                       | 0                  | 0                      | 941                 | 8                       | 941               | 8                    |
| 62  | PG&E GBA                 | MARSHLD2-C.COSTAPPD 230 kV line #2  | 938                | 37                     | 0                   | 0                       | 938               | 37                   |
| 63  | East of Pisgah           | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Lugo-Mohave 500 kV   | 928                | 69                     | 0                   | 0                       | 928               | 69                   |
| 64  | Path 15 Corridor         | PANOCH-GATES E 230 kV line, subject to PG&E N-2 Mustang-Gates #1 and #2 230 kV                                  | 0                  | 0                      | 924                 | 262                     | 924               | 262                  |
| 65  | East of Pisgah           | HAE SVC-HAE SVCL 500 kV line #1   | 795                | 22                     | 0                   | 0                       | 795               | 22                   |
| 66  | SCE Eastern              | DEVERS-DVRS_RB_21 500 kV line #2  | 0                  | 0                      | 765                 | 24                      | 765               | 24                   |
| 67  | East of Pisgah           | INNOVATION-INNOVATION 230 kV line, subject to VEA N-2 NWest-DesertView 230 kV with RAS                          | 764                | 70                     | 0                   | 0                       | 764               | 70                   |
| 68  | Path 26 Corridor         | MN_WRLWND_32-WIRLWIND 500 kV line #3  | 0                  | 0                      | 652                 | 25                      | 652               | 25                   |
| 69  | Path 42                  | P42 IID-SCE   | 623                | 127                    | 0                   | 0                       | 623               | 127                  |

| No. | Area                       | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|----------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 70  | SCE Northern               | VINCNT2-vincen1i 230 kV line, subject to SCE N-1 Vincent Transformer 500 kV #4             | 0                  | 0                      | 622                 | 32                      | 622               | 32                   |
| 71  | PG&E North Valley 230 kV   | CARIBOU 230/230 kV transformer #11   | 0                  | 0                      | 597                 | 100                     | 597               | 100                  |
| 72  | SDG&E/CFE                  | IV PFC1 230/230 kV transformer #2  | 552                | 60                     | 0                   | 0                       | 552               | 60                   |
| 73  | COI Corridor               | ROUND MT-RM_FR_22 500 kV line #2   | 534                | 6                      | 0                   | 0                       | 534               | 6                    |
| 74  | SCE Northern               | MAGUNDEN-PASTORIA 230 kV line #2   | 449                | 514                    | 0                   | 0                       | 449               | 514                  |
| 75  | SCE North of Lugo          | COLWATER 230/115 kV transformer #1   | 0                  | 0                      | 420                 | 494                     | 420               | 494                  |
| 76  | SCE North of Lugo          | TAP189-CONTROL 115 kV line #1  | 0                  | 0                      | 406                 | 27                      | 406               | 27                   |
| 77  | PG&E POE - RIO OSO 230 kV  | POE-RIO OSO 230 kV line #1   | 381                | 78                     | 0                   | 0                       | 381               | 78                   |
| 78  | PG&E GBA                   | LS PSTAS-NEWARK D 230 kV line #1   | 339                | 4                      | 0                   | 0                       | 339               | 4                    |
| 79  | Path 26 Corridor           | MN_WRLWND_31-MN_WRLWND_32 500 kV line #3   | 0                  | 0                      | 333                 | 5                       | 333               | 5                    |
| 80  | East of Pisgah             | GAMEBIRD-GAMEBIRD 230 kV line, subject to VEA N-2 Pahrump-Gamebird 230 kV no RAS           | 10                 | 69                     | 322                 | 62                      | 332               | 131                  |
| 81  | PG&E Fresno 230 kV         | MCMULLN1-KEARNEY 230 kV line, subject to PG&E N-2 Mustang-Gates #1 and #2 230 kV           | 324                | 207                    | 0                   | 0                       | 324               | 207                  |
| 82  | Path 49 EOR                | P49 East of Colorado River (EOR)   | 319                | 3                      | 0                   | 0                       | 319               | 3                    |
| 83  | PG&E Fresno 115 kV         | KINGSBURGD-CONTADNA 115 kV line #1   | 0                  | 0                      | 306                 | 58                      | 306               | 58                   |
| 84  | PG&E North Valley 230 kV   | CORTINA-VACA-DIX 230 kV line, subject to PG&E N-1 Delev n-Cortina 230 kV                   | 296                | 364                    | 0                   | 0                       | 296               | 364                  |
| 85  | SCE Eastern                | DVRS_RB_22-REDBLUFF 500 kV line #2   | 0                  | 0                      | 257                 | 9                       | 257               | 9                    |
| 86  | Moenkope - Eldorado 500 kV | MOEN-ELD SC3-ELDORDO 500 kV line #1  | 244                | 14                     | 0                   | 0                       | 244               | 14                   |
| 87  | SCE Eastern                | DEVERS-devers i 500 kV line, subject to SCE N-1 Valley - Alberhill 500 kV with RAS         | 221                | 86                     | 0                   | 0                       | 221               | 86                   |
| 88  | SDG&E 230 kV               | SILVERGT-OLD TOWN 230 kV line, subject to SDGE N-1 Silvergate-OldTown-Mission 230kV no RAS | 174                | 32                     | 0                   | 0                       | 174               | 32                   |
| 89  | East of Pisgah             | VEA_PST_2-IS TAP 138 kV line #1  | 0                  | 0                      | 146                 | 22                      | 146               | 22                   |
| 90  | SCE Northern               | MAGUNDEN-VESTAL 230 kV line, subject to SCE N-1 Magunden-Vestal #1 230kV                   | 9                  | 20                     | 131                 | 327                     | 140               | 347                  |
| 91  | East of Pisgah             | P61 Lugo-Victorville 500 kV Line   | 0                  | 0                      | 122                 | 28                      | 122               | 28                   |
| 92  | SCE Eastern                | DEVERS-DVRS_RB_11 500 kV line #1   | 0                  | 0                      | 117                 | 6                       | 117               | 6                    |

| No. | Area                                  | Constraints Name   | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|---------------------------------------|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 93  | SCE Northern                          | MAGUNDEN-ANTELOPE 230 kV line #1   | 0                  | 0                      | 112                 | 126                     | 112               | 126                  |
| 94  | PG&E GBA                              | C.COSTAPPE-BDLSWSTA 230 kV line #1   | 0                  | 0                      | 112                 | 10                      | 112               | 10                   |
| 95  | SDG&E 230 kV                          | TALEGA-S.ONOFRE 230 kV line #1   | 0                  | 0                      | 108                 | 191                     | 108               | 191                  |
| 96  | PG&E Fresno 115 kV                    | LPRNJCTSS-GWFHANFORDSS 115 kV line #1  | 106                | 16                     | 0                   | 0                       | 106               | 16                   |
| 97  | Path 15 Corridor                      | PANOCHÉ-GATES E 230 kV line, subject to PG&E N-1 Panoche-Gates #1 230kV                    | 0                  | 0                      | 105                 | 42                      | 105               | 42                   |
| 98  | SCE North of Lugo                     | COLWATER-DUNNSIDE 115 kV line #1   | 97                 | 137                    | 0                   | 0                       | 97                | 137                  |
| 99  | SCE North of Lugo                     | KRAMER-VICTOR 230 kV line #2   | 96                 | 77                     | 0                   | 0                       | 96                | 77                   |
| 100 | PG&E Kern 230kV                       | GATES D-CALFLATSSS 230 kV line #1  | 0                  | 0                      | 75                  | 335                     | 75                | 335                  |
| 101 | East of Pisgah                        | IVANPAH-MTN PASS 115 kV line #1  | 69                 | 48                     | 0                   | 0                       | 69                | 48                   |
| 102 | PG&E Kern 230kV                       | ARCO-MIDWAY-E 230 kV line #1   | 0                  | 0                      | 67                  | 321                     | 67                | 321                  |
| 103 | SDG&E Northern 69 kV                  | SANLUSRY-OCEAN RANCH 69 kV line, subject to SDGE N-2 EN-SLR and EN-SLR-PEN 230 kV with RAS | 64                 | 224                    | 0                   | 0                       | 64                | 224                  |
| 104 | SCE Northern                          | WINDHUB_A 230/13.8 kV transformer #2   | 60                 | 20                     | 0                   | 0                       | 60                | 20                   |
| 105 | PG&E Fresno 115 kV                    | WOODWARD-CHLDHOSP_JCT 115 kV line #1   | 0                  | 0                      | 48                  | 2                       | 48                | 2                    |
| 106 | PG&E Fresno 230 kV                    | GREGG-HENTAP1 230 kV line, subject to PG&E N-1 Gregg-Borden #1 230kV                       | 0                  | 0                      | 48                  | 2                       | 48                | 2                    |
| 107 | SCE Lugo - Vincent 500 kV             | LUGO-VINCENT 500 kV line #1  | 47                 | 22                     | 0                   | 0                       | 47                | 22                   |
| 108 | Path 84 Harry Allen - Eldorado 500 kV | P84 Harry Allen-Eldorado 500 kV  | 0                  | 0                      | 42                  | 9                       | 42                | 9                    |
| 109 | PG&E GBA                              | TESLA E-NEWARK D 230 kV line, subject to PG&E N-1 Tesla-Ravenswood 230kV                   | 36                 | 1                      | 0                   | 0                       | 36                | 1                    |
| 110 | SCE Eastern                           | ALBERHIL-VALLEYSC 500 kV line #1   | 0                  | 0                      | 34                  | 7                       | 34                | 7                    |
| 111 | PG&E Sierra                           | MARBLE 63.0/69.0 kV transformer #1   | 17                 | 8                      | 13                  | 3                       | 29                | 11                   |
| 112 | PG&E Fresno 230 kV                    | GATES E-GATESBK11JCT 230 kV line #2  | 26                 | 14                     | 0                   | 0                       | 26                | 14                   |
| 113 | Path 26 Corridor                      | MN_VINCNT_22-VINCENT 500 kV line #2  | 16                 | 4                      | 0                   | 0                       | 16                | 4                    |
| 114 | PG&E Fresno 230 kV                    | GREGG-HENTAP1 230 kV line #1   | 0                  | 0                      | 15                  | 11                      | 15                | 11                   |
| 115 | COI Corridor                          | ROUND MT-RD MT 1M 500 kV line, subject to PG&E-BANC N-1 Olinda Xfmr 500 kV                 | 0                  | 0                      | 14                  | 2                       | 14                | 2                    |
| 116 | SCE Northern                          | PARDEE-S.CLARA 230 kV line, subject to SCE N-2 MOORPARK-SCLARA #1 and #2 230 kV            | 11                 | 84                     | 0                   | 0                       | 11                | 84                   |

| No. | Area                 | Constraints Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|-----|----------------------|---|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| 117 | PG&E Tesla 230 kV    | WEBER-TESLA E 230 kV line, subject to PG&E N-1 Bellota-TeslaE 230kV                     | 0                  | 0                      | 10                  | 3                       | 10                | 3                    |
| 118 | SCE North of Lugo    | VICTOR-LUGO 230 kV line #1  | 7                  | 12                     | 0                   | 0                       | 7                 | 12                   |
| 119 | PG&E Fresno 115 kV   | GWFHANFORDSS-CONTADNA 115 kV line #1  | 4                  | 4                      | 0                   | 0                       | 4                 | 4                    |
| 120 | SCE Metro            | MIRALOME-VSTA 230 kV line #2  | 0                  | 0                      | 4                   | 2                       | 4                 | 2                    |
| 121 | PG&E GBA             | USWP-JRW_JCT-CAYETANO 230 kV line, subject to PG&E N-2 C.Costa-Moraga 230 kV            | 4                  | 3                      | 0                   | 0                       | 4                 | 3                    |
| 122 | PG&E Kern 230kV      | COTWD_F2-GLENN 230 kV line #1   | 0                  | 0                      | 3                   | 3                       | 3                 | 3                    |
| 123 | East of Pisgah       | ELDORDO2-SLOAN CANYON 230 kV line #1  | 3                  | 15                     | 0                   | 0                       | 3                 | 15                   |
| 124 | SDG&E Northern 69 kV | ESCNDIDO-SANMRCOS 69 kV line, subject to SDGE N-2 EN-SLR and EN-SLR-PEN 230 kV with RAS | 3                  | 4                      | 0                   | 0                       | 3                 | 4                    |
| 125 | PG&E Fresno 230 kV   | HENTAP1-MUSTANGSS 230 kV line #1  | 0                  | 0                      | 2                   | 26                      | 2                 | 26                   |
| 126 | East of Pisgah       | ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Eldorado-Moenkopi 500 kV               | 2                  | 1                      | 0                   | 0                       | 2                 | 1                    |
| 127 | SCE Eastern          | DVRS_RB_21-DVRS_RB_22 500 kV line #2  | 0                  | 0                      | 2                   | 3                       | 2                 | 3                    |
| 128 | PG&E GBA             | SARATOGA-VASONA 230 kV line #1  | 0                  | 0                      | 1                   | 1                       | 1                 | 1                    |
| 129 | PG&E Fresno 230 kV   | BELLOTA-WEBER 230 kV line, subject to PG&E N-1 Bellota-TeslaE 230kV                     | 1                  | 2                      | 0                   | 0                       | 1                 | 2                    |
| 130 | SCE Northern         | VINCNT2-S.CLARA 230 kV line, subject to SCE N-2 MOORPARK-SCLARA #1 and #2 230 kV        | 1                  | 2                      | 0                   | 0                       | 1                 | 2                    |
| 131 | SCE Northern         | MAGUNDEN-SPRINGVL 230 kV line, subject to SCE N-1 Magunden-Vestal #1 230kV              | 0                  | 0                      | 1                   | 4                       | 1                 | 4                    |
| 132 | SCE North of Lugo    | VICTOR-LUGO 230 kV line #2  | 1                  | 1                      | 0                   | 0                       | 1                 | 1                    |
| 133 | East of Pisgah       | AMARGOSA-SANDY 138 kV line, subject to VEA N-2 NWest-DesertView 230 kV with RAS         | 0                  | 0                      | 0                   | 1                       | 0                 | 1                    |
| 134 | SDG&E Bulk           | ECO 230/500 kV transformer #1   | 0                  | 2                      | 0                   | 0                       | 0                 | 2                    |
| 135 | SCE North of Lugo    | VICTOR-LUGO 230 kV line #3  | 0                  | 1                      | 0                   | 0                       | 0                 | 1                    |
| 136 | PG&E Kern 230kV      | BUENAVJ2-BITTERWATRSS 230 kV line #2  | 0                  | 0                      | 0                   | 3                       | 0                 | 3                    |
| 137 | PG&E Kern 230kV      | GATES F-MIDWAY-F 230 kV line, subject to PG&E N-1 Arco-Midway 230kV                     | 0                  | 0                      | 0                   | 1                       | 0                 | 1                    |
| 138 | PG&E Kern 230kV      | GATES F-ARCO 230 kV line #1   | 0                  | 0                      | 0                   | 1                       | 0                 | 1                    |

Table G.7-10 lists the aggregated congestion results across specific branch groups and local areas in the 2039 base portfolio PCM case, ranked by congestion cost.

Table G.7-10: Aggregated congestion in 2039 sensitivity portfolio PCM

| No. | Aggregated congestion                 | Cost (\$M) | Duration (Hr) |
|-----|---------------------------------------|------------|---------------|
| 1   | Path 26 Corridor                      | 849.74     | 8,216         |
| 2   | Path 15 Corridor                      | 475.71     | 6,212         |
| 3   | East of Pisgah                        | 155.33     | 3,390         |
| 4   | Path 65 PDCI                          | 99.24      | 3,219         |
| 5   | SCE North of Lugo                     | 98.95      | 11,156        |
| 6   | SDG&E Bulk                            | 86.92      | 1,868         |
| 7   | SWIP North                            | 72.55      | 726           |
| 8   | SCE Metro                             | 67.87      | 1,534         |
| 9   | SDG&E/CFE                             | 39.91      | 2,979         |
| 10  | Path 46 WOR                           | 34.79      | 337           |
| 11  | Path 41 Sylmar transformer            | 27.21      | 528           |
| 12  | SCE Northern                          | 24.18      | 3,128         |
| 13  | PG&E North Valley 230 kV              | 18.30      | 1,594         |
| 14  | PG&E Sierra                           | 18.04      | 2,364         |
| 15  | PG&E GBA                              | 15.04      | 680           |
| 16  | PG&E Morro Bay 230 kV                 | 13.87      | 1,263         |
| 17  | COI Corridor                          | 9.42       | 132           |
| 18  | SCE Eastern                           | 8.40       | 235           |
| 19  | PG&E Manning - Metcalf 500 kV         | 6.92       | 260           |
| 20  | SDG&E 230 kV                          | 6.76       | 662           |
| 21  | PG&E Fresno 115 kV                    | 3.29       | 197           |
| 22  | SCE Antelope 66kV                     | 1.83       | 854           |
| 23  | Path 25 PACW-PG&E 115 kV              | 1.19       | 63            |
| 24  | PG&E Tesla 230 kV                     | 0.95       | 11            |
| 25  | Path 42                               | 0.62       | 127           |
| 26  | PG&E Fresno 230 kV                    | 0.42       | 262           |
| 27  | PG&E POE - RIO OSO 230 kV             | 0.38       | 78            |
| 28  | Path 49 EOR                           | 0.32       | 3             |
| 29  | Moenkope - Eldorado 500 kV            | 0.24       | 14            |
| 30  | PG&E Kern 230kV                       | 0.15       | 664           |
| 31  | SDG&E Northern 69 kV                  | 0.07       | 228           |
| 32  | SCE Lugo - Vincent 500 kV             | 0.05       | 22            |
| 33  | Path 84 Harry Allen - Eldorado 500 kV | 0.04       | 9             |

### G.7.8 2039 Sensitivity Portfolio PCM Curtailment Results

Table G.7-11 shows the wind and solar curtailment results of the 2039 sensitivity portfolio PCM.



Table G.7-11: Wind and solar curtailment summary in the 2039 sensitivity portfolio PCM

| Renewable zone         | Generation (GWh) | Curtailment (GWh) | Total potential (GWh) | Curtailment Ratio |
|------------------------|------------------|-------------------|-----------------------|-------------------|
| SCE Northern           | 39,752           | 3,291             | 43,043                | 7.65%             |
| SCE Eastern            | 30,829           | 330               | 31,159                | 1.06%             |
| PG&E Fresno            | 23,817           | 2,101             | 25,917                | 8.11%             |
| SDG&E Eastern and Bulk | 20,884           | 996               | 21,880                | 4.55%             |
| East of Pisgah         | 20,360           | 1,165             | 21,525                | 5.41%             |
| SCE North of Lugo      | 13,785           | 1,827             | 15,612                | 11.70%            |
| OOS W-SunZia           | 11,533           | 1,950             | 13,483                | 14.46%            |
| PG&E Central Valley    | 13,103           | 91                | 13,194                | 0.69%             |
| OOS W-WY               | 11,084           | 512               | 11,596                | 4.42%             |
| PG&E Kern              | 10,173           | 252               | 10,425                | 2.42%             |
| NM                     | 4,575            | 2,126             | 6,702                 | 31.73%            |
| PG&E North Valley      | 5,070            | 38                | 5,108                 | 0.75%             |
| PG&E Central Coast     | 4,786            | 139               | 4,925                 | 2.82%             |
| SCE Metro              | 4,247            | 191               | 4,437                 | 4.29%             |
| OOS W-ID               | 2,830            | 110               | 2,939                 | 3.74%             |
| AZ                     | 1,758            | 995               | 2,753                 | 36.13%            |
| IID                    | 1,409            | 0                 | 1,410                 | 0.02%             |
| PG&E Greater Bay Area  | 1,261            | 9                 | 1,270                 | 0.73%             |
| San Diego              | 711              | 5                 | 716                   | 0.73%             |
| NW                     | 568              | 14                | 582                   | 2.48%             |
| SMUD                   | 402              | 6                 | 408                   | 1.51%             |
| PG&E North Coast       | 396              | 1                 | 397                   | 0.14%             |
| NV                     | 330              | 46                | 376                   | 12.28%            |
| PG&E North Bay         | 59               | 0                 | 60                    | 0.48%             |
| PG&E Humboldt          | 12               | 0                 | 12                    | 0.15%             |
| <b>Total</b>           | <b>223,735</b>   | <b>16,195</b>     | <b>239,930</b>        | <b>6.75%</b>      |

### G.7.9 2039 Sensitivity Portfolio PCM Gas-fired Generator Utilization

The average capacity factors of gas-fired generators by area in the 2039 sensitivity portfolio were summarized in Table G.7-12.

Table G.7-12: Gas-fired generator utilization in the 2039 sensitivity portfolio PCM

| Areas                 | Sum of Capacity (MW) | Sum of Generation (MWh) | Capacity Factor |
|-----------------------|----------------------|-------------------------|-----------------|
| PG&E Central Coast    | 1,221                | 2,475,302               | 0.23            |
| PG&E Central Valley   | 872                  | 1,355,350               | 0.18            |
| PG&E Fresno           | 1,098                | 1,773,874               | 0.18            |
| PG&E Greater Bay Area | 5,538                | 16,354,038              | 0.34            |
| PG&E Humboldt         | 163                  | 198,186                 | 0.14            |
| PG&E Kern             | 2,013                | 7,293,711               | 0.41            |
| PG&E North Valley     | 1,446                | 3,111,923               | 0.25            |
| SCE Eastern LA Basin  | 964                  | 963,739                 | 0.11            |

| Areas                 | Sum of Capacity (MW) | Sum of Generation (MWh) | Capacity Factor |
|-----------------------|----------------------|-------------------------|-----------------|
| SCE Eldorado          | 495                  | 641,708                 | 0.15            |
| SCE North of Lugo     | 72                   | 7,532                   | 0.01            |
| SCE North of Magunden | 61                   | 35,746                  | 0.07            |
| SCE South of Magunden | 19                   | 13,475                  | 0.08            |
| SCE Tehachapi         | 4                    | 1,032                   | 0.03            |
| SCE Ventura           | 117                  | 178,568                 | 0.17            |
| SCE Western LA Basin  | 2,943                | 5,272,702               | 0.20            |
| SDG&E Bulk            | 947                  | 1,375,049               | 0.17            |
| SDG&E San Diego       | 2,678                | 2,570,278               | 0.11            |
| <b>System Total</b>   | <b>20,650</b>        | <b>43,622,213</b>       | <b>0.24</b>     |

## G.8 Economic Planning Study Requests

### G.8.1 Study request for Pacific Transmission Expansion (PTE) project

#### Study request overview

California Western Grid Development LLC (California Western Grid) submitted the PTE project, which consists of a 2,000 MW controllable HVDC subsea-transmission cable that connects Northern and Southern California via submarine cables to be located in the Pacific Ocean off the coast of California. The project, as proposed, will have one northern point of interconnection in the PG&E area and one interconnection in the SCE area for its southern terminal. The proposed project includes the Voltage Source Converter (VSC) stations as in the following:

- One 2,000 MW,  $\pm 525$  kV HVDC bipole converter station located at the northern terminus of the project, connecting either at the Diablo Canyon 500 kV AC station or the future Morro Bay 500 kV AC station.
- One 2,000 MW,  $\pm 525$  kV HVDC bipole converter station located near the El Segundo 220 kV AC substation, with underground HVDC cables from the shoreline to the converter, and the following AC connections:
  - Two 220 kV AC underground cable circuits to El Nido substation; and
  - Two 220 kV AC underground cable circuits to Redondo substation.

The project was proposed to have a total transfer capacity of 2,000 MW from the PG&E area into the southern California areas or vice versa.

#### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-1.

Table G.8-1: Evaluating study request – Pacific Transmission Expansion (PTE) HVDC Project

| Benefits category   | Benefits stated in submission  | ISO evaluation  |
|---|--|---|
| <b>Identified Congestion</b>  | The PTE project provides significant benefits in mitigating constraints on transfer capacity flows on Path 26 which continues to be identified as a congested path   | The PTE project can create a path parallel to Path 26, which potentially helps to mitigate the congestion on Path 26. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | California Western Grid states that the proposed project's location off shore offers California an option to interconnect and deliver up to 2,000 MW of offshore wind energy as well as support delivery of renewable energy between northern and southern California. | The PTE project can help to deliver offshore wind to southern California.   |
| <b>Local Capacity Area Resource requirements</b>  | California Western Grid states that the proposed project would reduce local capacity requirements in the Western LA Basin thereby allowing 1,993 MWs of gas plant generating capacity to retire.   | The PTE project can help to reduce local capacity requirement in the SCE's LA Basin area.                             |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | Congestion in the Western LA Basin area and on the Path 26 and Path 15 corridor can be impacted by the PTE project.   |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above  | The PTE project can help to deliver offshore wind to southern California.   |
| <b>Other</b>  | Not addressed in submission  | Not identified by the CAISO   |

### Conclusion

Based on the congestion analysis results and evaluation provided above, the PTE project was selected for detailed analysis as an alternative for mitigating Path 26 congestion and Western LA Basin congestion in this planning cycle, as set out in Section G.9, in which other potential benefits such as local capacity requirement reduction benefit were assessed as well.

## **G.8.2 Study request for Del Amo to El Nido Underground HVDC Project**

### Study request overview

Grid United LLC submitted the Del Amo to El Nido Underground HVDC Project to evaluate its potential to enhance deliverability, reduce congestion, and improve reliability in the Los Angeles Basin. The project proposes a new underground 1,200 MW HVDC VSC transmission line utilizing a repurposed oil and gas pipeline to provide a direct connection between Del Amo and El Nido substations.

The project, as proposed, includes the following:

- Construction of a 1,200 MW HVDC VSC transmission line from Del Amo Substation to El Nido Substation.
- Utilization of a repurposed underground oil and gas pipeline as a conduit for the transmission cable.

This project aims to improve intra-basin transmission deliverability, reduce reliance on Aliso Canyon storage, enhance voltage support in the coastal LA Basin, and provide wildfire-resistant system resilience.

Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-2.

Table G.8-2: Evaluating study request – Del Amo to El Nido underground HVDC Project

| Benefits category   | Benefits stated in submission  | ISO evaluation  |
|---|--|---|
| <b>Identified Congestion</b>  | Not addressed in submission  | The Del Amo to El Nido underground HVDC project can help to mitigate congestion in the SCE's Western LA Basin area.   |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | Grid United states that the Project would greatly expand intra-basin transmission deliverability and unlock access to new clean energy resources, primarily wind and solar from the Southern Area Reinforcement projects and other resources at Del Amo  | Not identified by the CAISO.  |
| <b>Local Capacity Area Resource requirements</b>  | Grid United states that by facilitating the delivery of resources from the South Area Reinforcement project and other resources at Del Amo deeper to the LA Basin, the Project helps meet the LA Basin LCR requirements and decreases LA's reliance on coastal natural gas generation.                                     | The Del Amo to El Nido underground 230 kV AC line project can help to reduce local capacity requirement in the SCE's El Nido sub-area, but cannot help to reduce local capacity requirement in the SCE's LA Basin area. |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | Not identified by the CAISO   |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above  | Not identified by the CAISO   |
| <b>Other</b>  | Grid United states that the project will:<br>(1) provide much needed voltage support that is essential to the safe operation of a power grid with a high penetration of renewable resources.<br>(2) wildfire resistance since it is fully underground<br>(3) increase the system's resiliency and operational flexibility. | Not identified by the CAISO   |

Conclusion

Based on the congestion analysis results and evaluation provided above, the Del Amo to El Nido underground HVDC project was selected for detailed analysis as an alternative for mitigating SCE's Western LA Basin congestion in this planning cycle, as set out in Section G.9, in which other potential benefits such as local capacity requirement reduction benefit were assessed as well.

### G.8.3 Study request for Del Amo to El Nido Underground 230 kV AC line Project

Study request overview

Grid United LLC submitted the Del Amo to El Nido Underground 230 kV AC Line Project to evaluate its potential to enhance transmission capacity and provide an alternative for delivering renewable energy from Del Amo deeper into the Los Angeles Basin. The project proposes a 510 MVA 230 kV AC transmission line, leveraging an existing underground right-of-way.

The project, as proposed, includes the following:

- Construction of a 230 kV AC transmission line with a capacity of up to 510 MVA from Del Amo to El Nido Substation.
- Utilization of an underground right-of-way to minimize environmental and land-use impacts.

This project aims to improve transmission reliability, enhance system flexibility, and provide an additional networked pathway for renewable energy integration in the LA Basin.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-3.

Table G.8-3: Evaluating study request – Del Amo to El Nido underground 230 kV AC line Project

| Benefits category   | Benefits stated in submission  | ISO evaluation  |
|---|--|---|
| <b>Identified Congestion</b>  | Not addressed in submission  | The Del Amo to El Nido underground HVDC project can help to mitigate congestion in the SCE's Western LA Basin area.   |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | Grid United states that the Project would greatly expand intra-basin transmission deliverability and unlock access to new clean energy resources, primarily wind and solar from the Southern Area Reinforcement projects and other resources at Del Amo  | Not identified by the CAISO.  |
| <b>Local Capacity Area Resource requirements</b>  | Grid United states that by facilitating the delivery of resources from the South Area Reinforcement project and other resources at Del Amo deeper to the LA Basin, the Project helps meet the LA Basin LCR requirements and decreases LA's reliance on coastal natural gas generation.                                     | The Del Amo to El Nido underground 230 kV AC line project can help to reduce local capacity requirement in the SCE's El Nido sub-area, but cannot help to reduce local capacity requirement in the SCE's LA Basin area. |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | Not identified by the CAISO   |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above  | Not identified by the CAISO   |
| <b>Other</b>  | Grid United states that the project will:<br>(1) provide much needed voltage support that is essential to the safe operation of a power grid with a high penetration of renewable resources.<br>(2) wildfire resistance since it is fully underground<br>(3) increase the system's resiliency and operational flexibility. | Not identified by the CAISO   |

### Conclusion

Based on the congestion analysis results and evaluation provided above, the Del Amo to El Nido underground 230 kV AC line project was selected for detailed analysis as an alternative for mitigating SCE's Western LA Basin congestion in this planning cycle, as set out in Section G.9, in which other potential benefits such as local capacity requirement reduction benefit were assessed as well.

## G.8.4 Study request for K-SEL Midway to El Nido HVDC Project

### Study request overview

Kern-Southland Energy Link LLC submitted the K-SEL Midway to El Nido HVDC Project to evaluate its potential to enhance transmission capacity, alleviate congestion on Path 26, and improve deliverability for renewable resources in Kern County and the Los Angeles Basin. The project proposes a new underground HVDC transmission link utilizing a repurposed oil and gas pipeline to provide a direct connection between Midway and El Nido substations.

The project, as proposed, includes the following:

- Construction of a 2,000 MW HVDC VSC transmission line from Midway 500 kV Substation to El Nido 230 kV Substation.
- Potential expansion to Del Amo 500 kV Substation, integrating with the South Area Reinforcement projects.

This project aims to expand deliverability for Kern County renewables, reduce congestion and curtailment on Path 26, lower reliance on Aliso Canyon storage, and improve system resilience through an underground, wildfire-resistant design.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-4.

Table G.8-4: Evaluating study request – K-SEL Midway to El Nido Underground HVDC Project

| Benefits category   | Benefits stated in submission  | ISO evaluation  |
|---|--|---|
| <b>Identified Congestion</b>  | Grid United states that by providing a controllable DC tie at Midway, K-SEL would provide CAISO operational flexibility to take control actions required to reduce congestion on Path 26.  | The Midway to El Nido underground HVDC project can help to mitigate congestion in the SCE's Western LA Basin area, and to reduce congestion in the Path 26 corridor |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | Grid United states that K-SEL would greatly expand intra-basin transmission deliverability and unlock access to new, in-state energy resources, primarily wind and solar in Kern County. C   | Not identified by the CAISO.  |
| <b>Local Capacity Area Resource requirements</b>  | Grid United states that By delivering resources deep into the LA Basin, K-SEL helps meet the LA Basin LCR requirements.  | The Midway to El Nido underground HVDC project can help to reduce local capacity requirement in the SCE's LA Basin area.  |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | Not identified by the CAISO   |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above  | Not identified by the CAISO   |
| <b>Other</b>  | Grid United states that the project will:<br>(1) provide voltage support that is essential to the safe operation of a power grid with a high penetration of renewable resources.<br>(2) wildfire resistance since it is fully underground<br>(3) increase the system's resiliency and operational flexibility. | Not identified by the CAISO   |

Conclusion

Based on the congestion analysis results and evaluation provided above, the Midway to El Nido underground HVDC project was selected for detailed analysis as an alternative for mitigating SCE's Western LA Basin and Path 26 congestions in this planning cycle, as set out in Section G.9, in which other potential benefits such as local capacity requirement reduction benefit were assessed as well.

**G.8.5 Study request for Sloan Canyon - Mead Project**Study request overview

GridLiance West (GLW) submitted the Sloan Canyon - Mead Project, proposing a second 230 kV connection from Sloan Canyon to Mead. The project aims to enhance transmission capacity, alleviate congestion in the Mead area, and improve deliverability for renewable resources in Southern Nevada.

The project, as proposed, includes the following:

- Addition of a circuit breaker to the existing 230 kV bay in Sloan Canyon substation.
- Construction of a new 14-mile circuit on the vacant position of the existing double circuit ready Sloan Canyon to Mead 230 kV line.
- Expansion of the 230 kV bay at WAPA's Mead substation or creation of a new bay if necessary.

Evaluation

The benefits described in the submission and the CAISO's evaluation of the study request were summarized in Table G.8-5.

Table G.8-5: Evaluating study request – Sloan Canyon - Mead Project

| Benefits category   | Benefits stated in submission   | ISO evaluation   |
|---|---|--|
| <b>Identified Congestion</b>  | GridLiance West stated that the proposed project is expected to provide economic benefits by alleviating congestion in the Mead area and reducing generation curtailment.   | Congestions in the GridLiance West/VEA area in this planning cycle was mainly observed on the Sloan Canyon – Eldorado 500 kV line and the VEA 138 kV system. The Sloan Canyon – Mead Project was not identified effective to mitigate any reliability, policy, or congestion issues in this area based on the resource assumption in the CPUC renewable portfolio. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | The Sloan Canyon - Mead Project will provide enhanced delivery for current proposed levels of renewable generation identified in the latest 2024-2025 CPUC Generation Resource mapping in the Mead area. The Sloan Canyon - Mead Project provides an additional interconnection path for the delivery of the combined expected FCDS and EODS generation and will enable around 890 MW of additional | No benefits identified by ISO  |

|  |   |   |
|--|---|---|
|  | transmission capacity from Mead area to CAISO.  |   |
| <b>Local Capacity Area Resource requirements</b>   | Not addressed in submission   | No benefits identified by ISO   |
| <b>Increase in Identified Congestion</b>           | Not addressed in submission   | No benefits identified by ISO   |
| <b>Integrate New Generation Resources or Loads</b> | See “Delivery of Location Constrained Resource Interconnection” above   | See “Delivery of Location Constrained Resource Interconnection” above |
| <b>Other</b>                                       | GridLiance West states that the proposed upgrades will:<br>(1) Project may provide reliability benefits to the system including potential contingency relief on existing Sloan Canyon-Mead 230kV circuit 1.<br>(2) Providing resilience enhancements within the CAISO grid<br>(3) A new GLW Sloan Canyon—Mead connection will reduce LSE's cost<br>(4) A new GLW Sloan Canyon—Mead connection would provide benefit to meeting 3 the CAISO's resource adequacy (RA) needs | No benefits identified by ISO   |

### Conclusion

Sloan Canyon – Mead 230 kV line congestion was not observed in this planning cycle due to the renewable generator assumption change in the GridLiance/VEA area compared with the previous planning cycle. No detailed production cost simulation was conducted for this study request.

## **G.8.6 Study request for GLW Upsize to Sagebrush Project**

### Study request overview

GridLiance West (GLW) submitted the GLW Upsize to Sagebrush Project, which proposes to upgrade segments of the existing GridLiance West/Valley Electric Association (GLW/VEA) system from 230 kV to 500 kV-capable towers while establishing a new interconnection with NV Energy's Sagebrush Substation, part of the Greenlink West project.

The project, as proposed, includes the following:

- Conversion of the Trout Canyon – Johnnie Corner segment from double-circuit 230 kV to double-circuit 500 kV, operating one circuit at 230 kV initially.
- Expansion of the Johnnie Corner Substation to accommodate 500/230 kV capabilities.
- Conversion of the Johnnie Corner – Lathrop Wells segment from double-circuit 230 kV to double-circuit 500 kV, operating one circuit at 230 kV.
- Conversion of the Lathrop Wells – Beatty segment from single-circuit 230 kV to double-circuit 500 kV-capable towers, maintaining the approved 230 kV circuit.
- Addition of a new 3000 MVA, 500 kV line from Lathrop Wells to Sagebrush, utilizing an available position on the planned Lathrop – Beatty double-circuit 500 kV towers.



The project is proposed to enhance transfer capability between CAISO and NV Energy (NVE), increase deliverability for renewable generation, and alleviate congestion in the GLW/VEA area. Additionally, it leverages existing right-of-way (ROW) and permitting efforts to expedite development, with an expected capacity increase of approximately 2.5-4.5 GW.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the study request were summarized in Table G.8-6.

Table G.8-6: Evaluating study request – GLW Upsize to Sagebrush Project

| Benefits category   | Benefits stated in submission  | ISO evaluation   |
|---|--|--|
| <b>Identified Congestion</b>  | GridLiance West stated that the proposed project is expected to provide economic benefits by alleviating congestion in the Mead area and reducing generation curtailment.  | Congestions in the GridLiance West/VEA area in this planning cycle was mainly observed on the Sloan Canyon – Eldorado 500 kV line and the VEA 138 kV system. The Sloan Canyon – Mead Project was not identified effective to mitigate any reliability, policy, or congestion issues in this area based on the resource assumption in the CPUC renewable portfolio. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | The double circuit upgrade to 500 kV and the new interconnection from Beatty to Sagebrush can enable other interconnections of new or existing facilities and improve the utilization of existing infrastructure, helping California achieve its renewable portfolio targets.  | No benefits identified by ISO  |
| <b>Local Capacity Area Resource requirements</b>  | Not addressed in submission  | No benefits identified by ISO  |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | No benefits identified by ISO  |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above  | See "Delivery of Location Constrained Resource Interconnection" above  |
| <b>Other</b>  | GridLiance West states that the proposed upgrades will:<br>(1) The connection allows greater operational flexibility by managing the supply-demand fluctuations across a larger geographical area. This increases the grid's responsiveness to changing operational conditions like variable weather or sudden equipment failures<br>(2) Providing resilience enhancements within the CAISO grid<br>(3) Increased capacity and connectivity to neighboring systems may improve Remedial Action Schemes since it provides a new path to load for Beatty generation.<br>(4) The project provides another tie-line to NVE system that can enhance Resource Adequacy and transfer capabilities from neighboring systems.<br>(5) The project provides a more robust networked delivery of generation resources in this area of the CAISO bulk system. | No benefits identified by ISO  |

Conclusion

No significant congestion was observed in the GridLiance/VEA area. The GLW Upsize to Sagebrush Project was not identified effective to mitigate the congestion in the GridLiance/VEA area observed in this planning cycle. No detailed production cost simulation was conducted for this study request.

**G.8.7 Study request for Mead - Mohave Project**Study request overview

GridLiance West (GLW) submitted the Mead - Mohave Project, which proposes to upgrade the existing Mead to Davis 230 kV line to 500 kV and extend a new 500 kV single circuit from Davis to Mohave. The project aims to enhance transmission capacity, alleviate congestion in the Mead area, and improve deliverability for renewable resources in Southern Nevada.

The project, as proposed, includes the following:

- Upgrade of the existing Mead – Davis transmission line from 230 kV to 500 kV
- Construction of a new 5-mile 500 kV transmission line from Davis to Mohave
- Development of a new 500 kV BAAH substation with 500/230 kV transformation at WAPA Davis
- Necessary bus work at Mead and Mohave to accommodate the upgraded transmission infrastructure.

Evaluation

The benefits described in the submission and the CAISO's evaluation of the study request were summarized in Table G.8-7.

Table G.8-7: Evaluating study request – Mead-Mohave Project

| Benefits category   | Benefits stated in submission  | ISO evaluation   |
|---|--|--|
| <b>Identified Congestion</b>  | GridLiance West stated that the proposed project is expected to provide economic benefits by alleviating congestion in the Mead area and reducing generation curtailment.  | Congestions in the GridLiance West/VEA area in this planning cycle was mainly observed on the Sloan Canyon – Eldorado 500 kV line and the VEA 138 kV system. The Mead-Mohave Project was not identified effective to mitigate any reliability, policy, or congestion issues in this area based on the resource assumption in the CPUC renewable portfolio. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | The Sloan Canyon - Mead Project will provide enhanced delivery for current proposed levels of renewable generation identified in the latest 2024-2025 CPUC Generation Resource mapping in the Mead area. The Sloan Canyon - Mead Project provides an additional interconnection path for the delivery of the combined expected FCDS and EODS generation and will enable around 890 MW of additional transmission capacity from Mead area to CAISO. | No benefits identified by ISO  |

| Benefits category                           | Benefits stated in submission   | ISO evaluation  |
|---|---|---|
| Local Capacity Area Resource requirements   | Not addressed in submission   | No benefits identified by ISO   |
| Increase in Identified Congestion           | Not addressed in submission   | No benefits identified by ISO   |
| Integrate New Generation Resources or Loads | See "Delivery of Location Constrained Resource Interconnection" above   | See "Delivery of Location Constrained Resource Interconnection" above |
| Other                                       | GridLiance West states that the proposed upgrades will:<br>(1) Project may provide reliability benefits to the system including potential contingency relief on existing Sloan Canyon-Mead 230kV circuit 1.<br>(2) Providing resilience enhancements within the CAISO grid<br>(3) A new GLW Sloan Canyon—Mead connection will reduce LSE's cost<br>(4) A new GLW Sloan Canyon—Mead connection would provide benefit to meeting 3 the CAISO's resource adequacy (RA) needs | No benefits identified by ISO   |

### Conclusion

Sloan Canyon – Mead 230 kV line congestion was not observed in this planning cycle due to the renewable generator assumption change in the GridLiance/VEA area compared with the previous planning cycle. No detailed production cost simulation was conducted for this study request.

## **G.8.8 Study request for GLW Upsize to Esmeralda Project**

### Study request overview

GridLiance West (GLW) submitted the GLW Upsize to Esmeralda Project, which proposes to upgrade the existing GridLiance West/Valley Electric Association (GLW/VEA) system from 230 kV to 500 kV-capable towers while adding a new interconnection with NV Energy's Esmeralda Substation, part of the Greenlink West project.

The project, as proposed, includes the following:

The Phase 1 GLW Upsize would consist of:

- Convert Trout Canyon – Johnnie Corner from double circuit 230kV to double circuit 500 kV (operate one circuit at 230 kV).
- Expand Johnnie Corner Substation to 500/230 kV
- Convert Johnnie Corner – Lathrop from double circuit 230kV to double circuit 500 kV (operate one circuit at 230 kV)
- Convert Lathrop Wells to Beatty from single circuit 230kV to double circuit capable 500 kV.
  - The approved single circuit Lathrop Wells to Beatty is to remain intact and operated at 230 kV.

- Add a new 3000 MVA Lathrop Wells to Beatty 500 kV line using the proposed empty position on the double circuit 500 kV
- Loop in the 500kV Lathrop Wells to Beatty into NVE's Sagebrush station
- Expand Beatty Substation to 500/230 kV

The Phase 2 Esmeralda extension would consist of:

- Add new Beatty – Esmeralda 108 mi, approximately 3000 MVA, Single Circuit 500 kV.
- Bus work to interconnect at NVE's Esmeralda.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the study request were summarized in Table G.8-8.

Table G.8-8: Evaluating study request – GLW Upsize to Esmeralda Project

| Benefits category   | Benefits stated in submission   | ISO evaluation   |
|---|---|--|
| <b>Identified Congestion</b>  | GridLiance West stated that the proposed project is expected to provide economic benefits by alleviating congestion in the GLW/VEA area and reducing generation curtailment.  | Congestions in the GridLiance West/VEA area in this planning cycle was mainly observed on the Sloan Canyon – Eldorado 500 kV line and the VEA 138 kV system. The Mead-Mohave Project was not identified effective to mitigate any reliability, policy, or congestion issues in this area based on the resource assumption in the CPUC renewable portfolio. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | GridLiance West stated the 500kV upsizing from Trout Canyon to Beatty transmission path provides a higher capacity alternative and optionality to maximize future renewable generation on the previously studied GLW upgrades. The GLW transmission capability expansion could support an increased volume of renewable resources – such as solar, wind, geothermal, and battery storage.       | The resources identified in the GLW economic study request was not included in the CPUC IPR portfolio in this planning cycle.  |
| <b>Local Capacity Area Resource requirements</b>  | Not addressed in submission   | No benefits identified by ISO  |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission   | No benefits identified by ISO  |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above   | See "Delivery of Location Constrained Resource Interconnection" above  |
| <b>Other</b>  | GridLiance West states that the proposed upgrades will:<br>(1) provide reliability benefits to the system while providing resilience enhancements within the CAISO grid.<br>(2) will provide a more robust networked delivery of generation resources in this area of the CAISO bulk system.<br>(3) improve Remedial Action Schemes since it provides a new path to load for Beatty generation. | No benefits identified by ISO  |

Conclusion

No significant congestion was observed in the GridLiance/VEA area. The GLW Upsize to Esmeralda Project was not identified effective to mitigate the congestion in the GridLiance/VEA area observed in this planning cycle. No detailed production cost simulation was conducted for this study request.

### **G.8.9 Study request for New 500 kV line from Colorado River - Red Bluff - Devers - Mira Loma Project**

Study request overview

EDF Renewables (EDFR) submitted a request to evaluate the addition of a 3rd 500 kV transmission line from Colorado River to Red Bluff, Devers, and Mira Loma to address severe congestion and support growing renewable integration, including New Mexico wind imports.

The project, as proposed, includes the following:

- Construction of a 3rd 500 kV circuit from Colorado River to Red Bluff to Devers to Mira Loma.
- Line rating of 3291/3880 MVA, matching existing circuits.

This upgrade aims to relieve congestion, reduce renewable curtailment, improve system reliability, and potentially increase Maximum Import Capability (MIC) for new out-of-state wind resources entering CAISO through the Palo Verde Interface.

Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-9.

Table G.8-9: Evaluating study request – New 500 kV line Colorado River - Red Bluff - Devers - Mira Loma Project

| Benefits category   | Benefits stated in submission   | ISO evaluation  |
|---|---|---|
| <b>Identified Congestion</b>  | EDF states that this project would relieve congestion, reduce curtailment of renewable resources, limit impacts of outages on the existing 500kV sys  | No significant congestion was identified in the SCE Eastern area. However, a new 500 kV line to Mira Loma can help to mitigate congestion on the Victorville to Lugo 500 kV line. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | EDF states that this project would provide potential increases in Maximum Import Capability (MIC) for new out of state wind resources that want to enter CAISO through the Palo Verde Interface | Not identified by the CAISO.  |
| <b>Local Capacity Area Resource requirements</b>  | Not addressed in submission   | Not identified by the CAISO   |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission   | This project potentially increase congestion on Path 46.  |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above   | Not identified by the CAISO.  |
| <b>Other</b>  | Not addressed in submission   | Not identified by the CAISO.  |

Conclusion

Based on the congestion analysis results and evaluation provided above, the new 500 kV line from Colorado River - Red Bluff - Devers - Mira Loma project was selected for detailed analysis as an alternative for mitigating Victorville – Lugo 500 kV line congestion in this planning cycle, as set out in Section G.9.

**G.8.10 Study request for Third Red Bluff Transformer Project**Study request overview

EDF Renewables (EDFR) submitted a request to evaluate the installation of a third transformer at Red Bluff Substation to address increasing congestion and curtailment caused by transformer limitations.

The project, as proposed, includes the following:

- Installation of a 3rd 230/500 kV AA transformer at Red Bluff.

This upgrade aims to improve deliverability for solar and storage resources in the Red Bluff area, enhance reliability, and prevent resources from being trapped under N-1 outages or transformer failures.

Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-10.

Table G.8-10: Evaluating study request – Third Red Bluff Transformer Project

| Benefits category   | Benefits stated in submission   | ISO evaluation  |
|---|---|---|
| <b>Identified Congestion</b>  | EDF states that this project would relieve congestion, reduce curtailment of renewable resources  | Red Bluff transformer was not congested in this planning cycle's production cost simulation |
| <b>Delivery of Location Constrained Resource Interconnection</b><br><b>Generators or similar high priority generators</b> | EDF states that this upgrade would increase deliverability in the Red Bluff area by providing adequate transformer capacity to reach the grid | Not identified by the CAISO.  |
| <b>Local Capacity Area Resource requirements</b>  | Not addressed in submission   | Not identified by the CAISO.  |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission   | Not identified by the CAISO.  |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above   | Not identified by the CAISO.  |
| <b>Other</b>  | Not addressed in submission   | Not identified by the CAISO.  |

Conclusion

Based on the congestion analysis results and evaluation provided above, the third Red Bluff transformer project was not selected for detailed analysis in this planning cycle.

**G.8.11 Study request for 230 kV Red Bluff tap to Buck Blvd - J. Hinds Project**Study request overview

EDF Renewables (EDFR) submitted a request to study the addition of a 230 kV transmission tap at Red Bluff to address transformer-related congestion and provide an additional outlet for generation during outages.

The project, as proposed, includes the following:

- Construction of a 230 kV line from Red Bluff to a new 230 kV switchyard tapping the Buck Blvd – J. Hinds 230 kV line.
- Alternative option: Loop the Buck Blvd – J. Hinds line into Red Bluff 230 kV.

This upgrade is expected to improve deliverability, increase transmission capacity, and reduce congestion and curtailments at Red Bluff.

Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-11.

Table G.8-11: Evaluating study request – 230 kV Red Bluff tap to Buck Blvd - J. Hinds Project

| Benefits category   | Benefits stated in submission  | ISO evaluation   |
|---|--|--|
| <b>Identified Congestion</b>  | EDF states that this project increase transmission outlet at the Red Bluff Substation by providing additional network connections to reach the grid, thereby increasing reliability, deliverability and reducing congestion and curtailments | Minor congestion was identified on the J.Hinds to Mirage 230 kV line, which can be mitigated by the reliability upgrade of recondutoring the congested line. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | EDF states that this project increase transmission outlet at the Red Bluff Substation by providing additional network connections to reach the grid, thereby increasing reliability, deliverability and reducing congestion and curtailments | Not identified by the CAISO.   |
| <b>Local Capacity Area Resource requirements</b>  | Not addressed in submission  | Not identified by the CAISO.   |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | Not identified by the CAISO.   |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above  | Not identified by the CAISO.   |
| <b>Other</b>  | Not addressed in submission  | Not identified by the CAISO.   |

Conclusion

Based on the congestion analysis results and evaluation provided above, the 230 kV Red Bluff tap to Buck Blvd - J. Hinds project was not selected for detailed analysis in this planning cycle.

## **G.8.12 Study request for Third Devers Transformer Project**

### Study request overview

EDF Renewables (EDFR) submitted a request to evaluate the installation of a 3rd transformer at Devers Substation to mitigate congestion and curtailment caused by operational outages on the existing transformer banks.

The project, as proposed, includes the following:

- Installation of a 3rd 230/500 kV AA transformer at Devers.

This upgrade is expected to improve system reliability, ensure deliverability for renewable resources in Riverside County, and provide long-term grid stability.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-12.

Table G.8-12: Evaluating study request – Third Devers Transformer Project

| Benefits category   | Benefits stated in submission  | ISO evaluation   |
|---|--|--|
| <b>Identified Congestion</b>  | EDF states that this upgrade would relieve congestion on the Devers 500/230 transformers                                       | Minor congestion on Devers transformers was identified in this planning cycle. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | EDF states that this upgrade would ensure that renewable resources located in the Riverside County remain deliverable to load. | Not identified by the CAISO.   |
| <b>Local Capacity Area Resource requirements</b>  | Not addressed in submission  | Not identified by the CAISO.   |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | Not identified by the CAISO.   |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above  | Not identified by the CAISO.   |
| <b>Other</b>  | Not addressed in submission  | Not identified by the CAISO.   |

### Conclusion

Based on the congestion analysis results and evaluation provided above, the third Devers transformer project was not selected for detailed analysis in this planning cycle as the Devers transformer congestion is minor.



### G.8.13 Study request for Temporary Reconfiguration Solutions to Relieve Devers 500/230 kV Transformer Congestion

#### Study request overview

EDF Renewables (EDFR) submitted a request to explore temporary transmission reconfiguration solutions to reduce congestion and curtailment while minimizing costs to ratepayers.

The project, as proposed, includes the following:

- Development of a methodology to study and implement reconfigurations and grid-enhancing technologies such as Dynamic Line Ratings.
- Evaluation of reconfiguration strategies similar to those implemented in other ISOs, such as MISO, to improve congestion management.

These solutions are expected to enhance grid flexibility, improve reliability, and optimize renewable energy integration while long-term transmission upgrades are being developed.

#### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-13.

Table G.8-13: Evaluating study request – Temporary Reconfiguration Solutions to Relieve Devers 500/230 kV Transformer Congestion

| Benefits category   | Benefits stated in submission  | ISO evaluation   |
|---|--|--|
| <b>Identified Congestion</b>  | EDF states that this upgrade would relieve congestion on the Devers 500/230 transformers | Minor congestion on Devers transformers was identified in this planning cycle. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | Not addressed in submission  | Not identified by the CAISO.   |
| <b>Local Capacity Area Resource requirements</b>  | Not addressed in submission  | Not identified by the CAISO.   |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | Not identified by the CAISO.   |
| <b>Integrate New Generation Resources or Loads</b>  | See "Delivery of Location Constrained Resource Interconnection" above                    | Not identified by the CAISO.   |
| <b>Other</b>  | Not addressed in submission  | Not identified by the CAISO.   |

#### Conclusion

Based on the congestion analysis results and evaluation provided above, the temporary reconfiguration solutions to relieve Devers 500/230 kV transformer congestion was not selected for detailed analysis in this planning cycle as the Devers transformer congestion is minor.

## G.8.14 Study request for Fourth Whirlwind Transformer Project

### Study request overview

EDF Renewables (EDFR) submitted a request to evaluate the installation of a 4th transformer at Whirlwind Substation to address congestion and curtailment issues caused by operational derates and outages on the existing transformer banks.

The project, as proposed, includes the following:

- Installation of a 4th 230/500 kV AA transformer at Whirlwind Substation.

This upgrade aims to ensure adequate transformer capacity for renewable resources at Whirlwind, improve reliability, and support future energy growth in the area.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request are summarized in Table G.8-14.

Table G.8-14: Evaluating study request – Fourth Whirlwind Transformer Project

| Benefits category  | Benefits stated in submission  | ISO evaluation   |
|--|--|--|
| Identified Congestion  | Not addressed in submission  | Congestion on the Whirlwind transformer was not identified by the CAISO. |
| Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators | EDF states that this upgrade would ensure that the resources located at the Whirlwind substation have adequate transformer capacity to reach the grid. | Not identified by the CAISO.   |
| Local Capacity Area Resource requirements  | Not addressed in submission  | Not identified by the CAISO.   |
| Increase in Identified Congestion  | Not addressed in submission  | Not identified by the CAISO.   |
| Integrate New Generation Resources or Loads  | See "Delivery of Location Constrained Resource Interconnection" above  | Not identified by the CAISO.   |
| Other  | Not addressed in submission  | Not identified by the CAISO.   |

### Conclusion

Based on the congestion analysis results and evaluation provided above, the fourth Whirlwind transformer project was not selected for detailed analysis in this planning cycle.

## G.8.15 Study request for Upgrades on PG&E 500 kV Lines

### Study request overview

EDF Renewables (EDFR) submitted a request to study upgrades on PG&E's 500 kV transmission network to address increasing congestion on Paths 15 and 26 and improve North-South transfer capacity.

The project, as proposed, includes the following:

- Construction of a 3rd 500 kV line on the following segments:
  - Los Banos – Gates
  - Gates – Midway
  - Tesla – Los Banos
  - Gates – Diablo

These upgrades aim to enhance reliability, reduce curtailments, and improve resiliency in Northern California's transmission system.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-15.

Table G.8-15: Evaluating study request – Upgrades on PG&E 500 kV Lines

| Benefits category  | Benefits stated in submission   | ISO evaluation  |
|--|---|---|
| Identified Congestion  | EDF states that this upgrade would relieve congestion on Path 15  | Path 15 corridor congestion was observed in this planning cycle |
| Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators | Not addressed in submission   | No benefits identified by ISO                                   |
| Local Capacity Area Resource requirements  | Not addressed in submission   | No benefits identified by ISO                                   |
| Increase in Identified Congestion  | Not addressed in submission   | No benefits identified by ISO                                   |
| Integrate New Generation Resources or Loads  | Not addressed in submission   | No benefits identified by ISO                                   |
| Other  | EDF states that this upgrade would improve the North-South transfer capacity, improve reliability in the region, and provide resiliency to the Northern California. | No benefits identified by ISO                                   |

### Conclusion

Path 15 corridor congestion was selected to receive detailed economic assessment in this planning cycles, with considering different alternatives including some segments of this study request, as set out in Section G.9.

## G.8.16 Study request for New 500kV line From Midpoint to Gregg and Gregg to Table Mountain

### Study request overview

EDF Renewables (EDFR) submitted a request to evaluate the construction of a new 500 kV transmission line to address congestion on Paths 15 and 26 and support North to South energy transfers.

The project, as proposed, includes the following:

- Construction of a new 500 kV transmission line from Midway to Gregg.
- Extension of the 500 kV line from Gregg to Table Mountain.

This upgrade is expected to reduce congestion, minimize solar curtailments, improve system reliability, and enhance CAISO's ability to transfer resources efficiently across Northern and Southern California.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-16.

Table G.8-16: Evaluating study request – New 500kV line From Midpoint to Gregg and Gregg to Table Mountain

| Benefits category  | Benefits stated in submission   | ISO evaluation  |
|--|---|---|
| Identified Congestion  | EDF states that this upgrade would relieve congestion on Path 15  | Path 15 corridor congestion was observed in this planning cycle |
| Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators | Not addressed in submission   | No benefits identified by ISO                                   |
| Local Capacity Area Resource requirements  | Not addressed in submission   | No benefits identified by ISO                                   |
| Increase in Identified Congestion  | Not addressed in submission   | No benefits identified by ISO                                   |
| Integrate New Generation Resources or Loads  | Not addressed in submission   | No benefits identified by ISO                                   |
| Other  | EDF states that this upgrade would increase reliability, and provide CAISO more resiliency to move the diverse resources between Northern and Southern regions more effectively | No benefits identified by ISO                                   |

### Conclusion

Path 15 corridor congestion was selected to receive detailed economic assessment in this planning cycles, with considering different alternatives including some segments of this study request, as set out in Section G.9.

## G.8.17 Study request for Monarch Project

### Study request overview

Golden State Clean Energy, LLC (GSCE) submitted the Monarch 500 kV Transmission Project to evaluate its potential to mitigate congestion on Path 15 and other key transmission corridors while facilitating renewable energy integration in the Greater Bay Area and San Joaquin Valley.

The project, as proposed, includes the following:

- Construction of a new 500 kV transmission line to improve north-south flows.
- Integration with existing infrastructure to enhance access to cost-effective renewables.
- Potential collaboration between CAISO and the Balancing Authority of Northern California to optimize capacity and reduce costs.

The Monarch project aims to alleviate increasing congestion in the PG&E Fresno area and improve overall system efficiency while supporting California's long-term clean energy goals.

### Evaluation

The benefits described in the submission and the CAISO's evaluation of the economic study request were summarized in Table G.8-17.

Table G.8-17: Evaluating study request – Monarch Project

| Benefits category   | Benefits stated in submission  | ISO evaluation  |
|---|--|---|
| <b>Identified Congestion</b>  | Golden State Clean Energy states that this upgrade would relieve congestion on Path 15 north of Los Banos and Moss Landing – Las Aguilas lines | Path 15 corridor congestion was observed in this planning cycle. This project can help to relieve congestion on the segments of north of Los Banos. |
| <b>Delivery of Location Constrained Resource Interconnection Generators or similar high priority generators</b> | Not addressed in submission  | No benefits identified by ISO   |
| <b>Local Capacity Area Resource requirements</b>  | Not addressed in submission  | No benefits identified by ISO   |
| <b>Increase in Identified Congestion</b>  | Not addressed in submission  | No benefits identified by ISO   |
| <b>Integrate New Generation Resources or Loads</b>  | Not addressed in submission  | No benefits identified by ISO   |
| <b>Other</b>  | Golden State Clean Energy states that this upgrade would provide policy benefits to California and the CAISO controlled grid                   | No benefits identified by ISO   |

### Conclusion

Path 15 corridor congestion was selected to receive detailed economic assessment in this planning cycles, with considering different alternatives including the Monarch project, as set out in Section G.9.

## G.9 Detailed Investigation of Congestion and Economic Benefit Assessment

### G.9.1 Selection of Detailed Studies

The ISO selected the high priority study areas listed in Table G.9-1 for further detailed assessment.

Table G.9-1: Areas receiving detailed economic assessment

| Detailed investigation                   | Alternative   | Reason for receiving detailed assessment   |
|--|---|--|
| East of Pisgah and Path 46 congestion    | The Trout Canyon to Lugo project to build a new Trout Canyon – Lugo 500 kV line with 70% compensation   | Recurring congestion on the Path 61 corridor under both contingency and normal condition when the flow was from Victorville to Lugo was observed. Large congestions on the Eldorado – McCullough 500 kV line and the Sloan Canyon – Eldorado 500 kV line, and the Path 46, were also observed. The congestion in this area is mainly attributed to renewable generation in the SCE's East of Pisgah area, GridLiance West/VEA area, and the out of state wind generation delivered to the Harry Allen and Eldorado area. Solar generation in Arizona and New Mexico wind generation in the CPUC portfolios also contributed to the Path 46 congestion. |
|  | The Marketplace to Adelanto project to convert the Marketplace-Adelanto 500 kV line to HVDC, and build a 500 kV line from Adelanto to Lugo and a 500 kV line from Marketplace to Eldorado |  |
|  | Build the second Sloan Canyon – Eldorado 500 kV line  |  |
|  | Build a new Adelanto – Lugo 500 kV line   |  |
|  | Build the third Colorado River – Red Bluff 500 kV line and a new Red Bluff – Mira Loma 500 kV line  |  |
| LA Basin and Path 26 corridor congestion | The PTE project   | Path 26 congestion is a recurring congestion with large congestion cost. La Fresa – La Cienega 230 kV congestion was also observed. The mitigation alternatives are expected to help to mitigate the congestion, and to reduce local capacity requirements.  |
|  | The K-SEL project (Midway – El Nido 2000 MW HVDC)   |  |
|  | The Del Amo – El Nido underground HVDC project  |  |
|  | The Del Amo – El Nido underground 230 kV AC line project  |  |
|  | Build the third Midway – Vincent 500 kV line  |  |
| Path 15 corridor congestion              | Alternative 1: Build a new Manning – Los Banos – Tesla 500 kV line  | Path 15 corridor congestion showed significant increase in this planning cycle compared with the results in previous planning cycles, as the resource assumption changed in the CPUC IRP portfolio.  |
|  | Alternative 2: A1 plus a new Midway – Gates – Manning 500 kV line   |  |
|  | Alternative 3: Monarch Option 1 Gates – Los Banos #3 500 kV line loops in new NewPoint 500 kV substation and build a new NewPoint to Tracy 500 kV line                                    |  |
|  | Alternative 4: A3 plus NewPoint – Tracy looping in Tesla  |  |
|  | Alternative 5: A4 plus build a new Midway – New Point 500 kV line   |  |
|  | Alternative 6: Monarch Option 2 Build a new Manning – NewPoint – Tracy 500 kV line  |  |
|  | Alternative 7: A6 plus NewPoint – Tracy looping in Tesla  |  |
|  | Alternative 8: A7 plus build a new Midway – New Point 500 kV line   |  |
|  | Alternative 9: Build a new 500 kV line from Midway to the new Gregg 500 kV substation to Tesla  |  |
|  | Alternative 10: Install a 10 ohm series reactor on each of the two Panoche – Gates 230 kV lines   |  |

In this planning cycle, the 2039 base portfolio PCM case was used as the main case for the detailed economic assessment.

## G.9.2 East of Pisgah area and Path 46 congestion mitigations

### Congestion analysis

Congestion in the East of Pisgah (EOP) area and on the Path 46 corridor was summarized in Table G.9-2.

Table G.9-2: Major East of Pisgah and Path 46 congestions in the 2039 Base portfolio PCM

| Constraint Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| LUGO-VICTORVL 500 kV line, subject to SCE N-1 Eldorado-Lugo 500 kV with RAS      | 0                  | 0                      | 40,639              | 418                     | 40,639            | 418                  |
| ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Eldorado-Lugo 500 kV with RAS   | 27,572             | 1,798                  | 0                   | 0                       | 27,572            | 1,798                |
| P46 West of Colorado River (WOR)   | 19,526             | 308                    | 0                   | 0                       | 19,526            | 308                  |
| SLOAN_CYN_5-ELDORDO 500 kV line #1   | 17,778             | 916                    | 0                   | 0                       | 17,778            | 916                  |
| P61 Lugo-Victorville 500 kV Line   | 281                | 5                      | 25                  | 19                      | 306               | 24                   |
| GAMEBIRD-GAMEBIRD 230 kV line, subject to VEA N-2 Pahrump-Gamebird 230 kV no RAS | 2                  | 19                     | 11                  | 73                      | 12                | 92                   |

### Congestion mitigation alternatives

Five mitigation alternatives for the East of Pisgah area and Path 46 congestion were assessed:

Alternative 1: The Trout Canyon to Lugo project to build a new Trout Canyon – Lugo 500 kV line with 70% series compensation.

Alternative 2: The Marketplace – Adelanto HVDC conversion project, including to convert the Marketplace to Adelanto 500 kV line to HVDC with 3,500 MW capacity, and to build a 17 miles 500 kV line from Adelanto to Vincent – Lugo 500 kV line and a new 1.5 miles 500 kV line from Marketplace to Eldorado.

Alternative 3: Build the second Sloan Canyon – Eldorado 500 kV line.

Alternative 4: Build a new Adelanto – Lugo 500 kV line.

Alternative 5: Build the third Colorado River – Red Bluff 500 kV line and a new Red Bluff – Mira Loma 500 kV line.

Table G.9-3 shows how these transmission alternatives impact East of Pisgah and Path 46 congestions.

Table G.9-3: Impact of transmission upgrade alternatives on EOP and Path 46 congestions

|  | Congestion Costs (\$K) |                         |                                 |                             |                     |  |
|--|------------------------|-------------------------|---------------------------------|-----------------------------|---------------------|--|
|  | Base                   | A1: Trout Canyon - Lugo | A2: Marketplace - Adelanto HVDC | A3: Sloan Canyon - Eldorado | A4: Adelanto - Lugo | A5: Colorado River - Red Bluff - Mira Loma |
| LUGO-VICTORVL 500 kV line, subject to SCE N-1 Eldorado-Lugo 500 kV with RAS      | 40,639                 | 13                      | 0                               | 42,019                      | 0                   | 21,288                                     |
| ELDORDO-MCCULLGH 500 kV line, subject to SCE N-1 Eldorado-Lugo 500 kV with RAS   | 27,572                 | 473                     | 36,067                          | 39,945                      | 49,620              | 27,097                                     |
| P46 West of Colorado River (WOR)   | 19,526                 | 5,575                   | 3,020                           | 21,768                      | 22,933              | 35,157                                     |
| SLOAN_CYN_5-ELDORDO 500 kV line #1   | 17,778                 | 79                      | 22,453                          | 0                           | 11,789              | 17,436                                     |
| P61 Lugo-Victorville 500 kV Line   | 306                    | 1,883                   | 2                               | 616                         | 0                   | 794  |
| GAMEBIRD-GAMEBIRD 230 kV line, subject to VEA N-2 Pahrump-Gamebird 230 kV no RAS | 12                     | 19,237                  | 13                              | 16                          | 14                  | 11   |

The Trout Canyon to Lugo 500 kV line upgrade can significantly reduce some congestions in the East of Pisgah area, such as Lugo – Victorville 500 kV line congestion when flow is from Victorville to Lugo, Eldorado – McCullough 500 kV congestion, Sloan Canyon – Eldorado 500 kV congestion. It can also reduce congestion on Path 46. On the other hand, the Trout Canyon to Lugo 500 kV line can aggravate flow from Lugo to Victorville in some hours, which may cause additional congestion on Path 61 in that direction.

The Marketplace to Adelanto HVDC project can help to reduce the Path 61 and Path 46 congestions. However, it aggravated congestions on Sloan Canyon – Eldorado 500 kV line and Eldorado – McCullough 500 kV line, because this project essentially increased flow from Sloan Canyon to Eldorado and from Eldorado to McCullough.

The second Sloan Canyon – Eldorado 500 kV line and the Adelanto – Lugo 500 kV line are effective to mitigate congestions on the Sloan Canyon – Eldorado 500 kV line and congestions on the Path 61 corridor. Both alternatives aggravate congestion on the Eldorado – McCullough 500 kV line, as the Sloan Canyon – Eldorado 500 kV line can push more flow to Eldorado, and the Adelanto – Lugo 500 kV line can attract more flow from Eldorado to McCullough.

The Colorado River to Red Bluff to Mira Loma 500 kV line can partially mitigate the congestions on Path 61 and Eldorado – McCullough 500 kV line, but it aggravated Path 46 (West of River) congestion. This is because the new 500 kV line provides a new path from Colorado River to the LA Basin load center and can potentially increase flow on the 500 kV lines from Palo Verde or Delany to Colorado River, which are part of Path 46.

### Production benefits

The production benefits of the mitigation alternatives in the East of Pisgah area and Path 46 for ISO ratepayers were summarized in Table G.9-4.



Table G.9-4: Production Benefits of EOP and Path 46 congestion mitigation alternatives

|   | Base case | A1: Trout Canyon – Lugo 500 kV line |               | A2: Marketplace-Adelanto HVDC |               | A3: the second Sloan Canyon – Eldorado 500 kV line |               | A4: Adelanto-Lugo 500 kV line |               | A5: Colorado River – Red Bluff – Mira Loma 500 kV line |               |
|---|-----------|-------------------------------------|---------------|-------------------------------|---------------|--|---------------|-------------------------------|---------------|--|---------------|
|   | (\$M)     | Post project (\$M)                  | Savings (\$M) | Post project (\$M)            | Savings (\$M) | Post project (\$M)                                 | Savings (\$M) | Post project (\$M)            | Savings (\$M) | Post project (\$M)                                     | Savings (\$M) |
| ISO load payment                                | 18,823    | 19,021                              | -198          | 18,913                        | -90           | 18,822   | 1             | 18,864                        | -41           | 18,773   | 50            |
| ISO generator net revenue benefiting ratepayers | 14,205    | 14,335                              | 130           | 14,272                        | 68            | 14,199   | -6            | 14,233                        | 29            | 14,188   | -16           |
| ISO transmission revenue benefiting ratepayers  | 1,698     | 1,696                               | -2            | 1,644                         | -54           | 1,684  | -13           | 1,652                         | -46           | 1,721  | 23            |
| ISO Net payment                                 | 2,920     | 2,990                               | -70           | 2,997                         | -76           | 2,939  | -18           | 2,978                         | -58           | 2,863  | 57            |
| WECC Production cost                            | 23,874    | 23,886                              | -12           | 23,816                        | 58            | 23,869   | 5             | 23,848                        | 26            | 23,841   | 33            |

Note that ISO ratepayer “savings” are a decrease in load payment, but an increase in ISO generator net revenue benefiting ratepayers and an increase in ISO transmission revenue benefiting ratepayers. WECC-wide “Savings” are a decrease in overall production cost. A negative savings is an incremental cost or loss.

Among the five mitigation alternatives for the East of Pisgah and Path 46 congestion, only Alternative 5, building a new 500 kV line from Colorado River to Red Bluff to Mira Loma, showed positive benefit to the CAISO’s ratepayer. The annual production cost saving from this alternative is \$57 million. Other alternatives showed negative production cost saving for the CAISO’s ratepayer.

### Cost estimate and benefit to cost ratio

Cost estimate and benefit to cost ratio were calculated only for the alternative with positive production cost saving. CAISO’s transmission per unit cost was used to estimate the capital cost of the upgrade. The capital cost estimate of the Colorado – Red Bluff – Mira Loma 500 kV line is \$2,644 million. Applying the CAISO’s screening factor of 1.3 to convert the capital cost of a project to the present value of the annualized revenue requirement, referred to as the “total” cost”, the total cost of the Colorado – Red Bluff – Mira Loma 500 kV line upgrade is about \$3,437 million in 2024 dollar.

The total benefit of the Colorado – Red Bluff – Mira Loma 500 kV line is the present value of the production cost savings plus other benefit. As no other benefit from this upgrade was identified in this planning cycle, only the present value of the production cost saving was calculated. Based on the assumptions of 7% real discount rate and 50-year economic life, the present value of the \$57 million annual production cost saving is \$842 million in 2024 dollar. The benefit to cost ratio is 0.245.

Conclusions

Five transmission upgrades were study as alternatives for mitigating the East of Pisgah and Path 46 congestions in this planning cycle. The economic assessment results showed that four out of five alternatives have negative benefit to the CAISO's ratepayers. Only the Colorado River to Red Bluff to Mira Loma 500 kV line upgrade has positive benefit but its benefit to cost ratio was less than 1.0. Therefore, there was no sufficient economic justification for recommending these five transmission upgrades as economic-driven projects in this planning cycle.

**G.9.3 Path 26 corridor and LA Basin congestion**Congestion analysis

The production cost simulation results demonstrated congestion occurring on the Path 26 corridor mainly when the flow was from south to north. Renewable generators in the Southern California area in the CPUC IRP portfolio were the main driver of the Path 26 corridor congestion, which is consistent with the results in the previous planning cycles. Congestion on the Path 26 corridor when the flow was from north to south was also observed, attributed to the increase of renewable generation in the PG&E area in the CPUC portfolio, including offshore wind generators. The congestion cost and hours of the Path 26 corridor congestion are shown in Table G.9-5.

Table G.9-5: Major Path 26 corridor and LA Basin congestions in the 2039 Base portfolio PCM

| Constraint Name  | Cost<br>Forward | Duration<br>Forward | Cost<br>Backward | Duration<br>Backward | Costs<br>Total (\$K) | Duration<br>Total (Hrs) |
|--|-----------------|---------------------|------------------|----------------------|----------------------|-------------------------|
| P26 Northern-Southern California   | 3               | 9                   | 173,554          | 3,127                | 173,557              | 3,136                   |
| LCIENEGA-LA FRESA 230 kV line, subject to SCE<br>N-2 La Fresa-El Nido #3 and #4 230 kV | 0               | 0                   | 67,364           | 667                  | 67,364               | 667                     |
| MIDWAY-MN_WRLWIND_31 500 kV line #3  | 0               | 2                   | 31,896           | 943                  | 31,897               | 945                     |

It was observed that the majority of the Path 26 corridor congestion was as a result of the Path 26 path rating binding and the Midway to Whirlwind 500 kV line congestion under normal condition. The 1503 MVA normal rating was applied for this 500 kV line in order to achieve higher emergency rating. This is one of the reasons that this line is congested under normal condition in more hours than the other Path 26 lines. Another reason is that there is a large volume of renewable and battery generators modeled at Whirlwind and Windhub 500 kV buses as suggested by the CPUC portfolios.

LA Basin congestion was mainly observed on the La Fresa to La Cienega 230 kV line under the N-2 contingency of the La Fresa – El Nido 230 kV lines. This congestion was aggravated from the previous planning cycle due to both the renewable generation increase in the SCE areas and the gas-fired generator retirement in the Western LA Basin area.

Congestion mitigation alternatives

Five mitigation alternatives for the Path 26 corridor and the LA Basin area congestion were assessed:

Alternative 1: The PTE project

Alternative 2: The K-SEL project building a 2000 MW HVDC line from Midway to El Nido

Alternative 3: The Del Amo – El Nido underground HVDC project

Alternative 4: The Del Amo – El Nido underground 230 kV AC project

Alternative 5: Build the third Midway – Vincent 500 kV line

Table G.9-6 shows the impact of these transmission alternatives on the congestions of the Path 26 corridor and the La Fresa – La Cienega 230 kV line.

Table G.9-6: Impact of Path 26 and LA Basin transmission alternatives on Path 26 and LA Basin congestions

|   | Congestion Costs (\$K) |         |           |                            |                                 |                                   |
|---|------------------------|---------|-----------|----------------------------|---------------------------------|-----------------------------------|
|   | Base                   | A1: PTE | A2: K-SEL | A3: Del Amo – El Nido HVDC | A4: Del Amo – El Nido 230 kV AC | A5: the third Midway-Vincent line |
| P26 Northern-Southern California  | 173,557                | 62,850  | 138,873   | 174,109                    | 173,500                         | 69,092                            |
| LCIENEGA-LA FRESA 230 kV line, subject to SCE N-2 La Fresa-El Nido #3 and #4 230 kV | 67,364                 | 0       | 0         | 0                          | 0                               | 65,736                            |
| MIDWAY-MN_WRLWND_31 500 kV line #3  | 31,897                 | 20,048  | 39,060    | 30,335                     | 29,847                          | 25,994                            |

The PTE project and the third Midway – Vincent 500 kV line can help to reduce Path 26 congestion significantly. The K-SEL project can also reduce Path 26 congestion, but is not as effective as the above two alternatives. The PTE project, the K-SEL project, and the Del Amo – El Nido HVDC or 230 kV AC projects are all sufficient to mitigate the La Fresa to La Cienega 230 kV line congestion. The transmission alternatives assessed in this section are not very effective to mitigate the congestion on the Midway – Whirlwind 500 kV line.

Production benefits

The production benefits of the transmission upgrades in the Path 26 corridor and LA Basin area for ISO's ratepayers were shown in Table G.9-7.

Table G.9-7: Production Benefits of Path 26 corridor and LA Basin area congestion mitigation alternatives

|   | Base case | A1: PTE            |               | A2: K-SEL          |               | A3: Del Amo – El Nido HVDC |               | A4: Del Amo – El Nido 230 kV AC |               | A5: the third Midway-Vincent line |               |
|---|-----------|--------------------|---------------|--------------------|---------------|----------------------------|---------------|---------------------------------|---------------|-----------------------------------|---------------|
|   | (\$M)     | Post project (\$M) | Savings (\$M) | Post project (\$M) | Savings (\$M) | Post project (\$M)         | Savings (\$M) | Post project (\$M)              | Savings (\$M) | Post project (\$M)                | Savings (\$M) |
| ISO load payment                                | 18,823    | 18,725             | 98            | 18,808             | 15            | 18,828                     | -5            | 18,804                          | 19            | 18,788                            | 35            |
| ISO generator net revenue benefiting ratepayers | 14,205    | 14,303             | 99            | 14,286             | 82            | 14,271                     | 67            | 14,257                          | 52            | 14,178                            | -27           |
| ISO transmission revenue benefiting ratepayers  | 1,698     | 1,459              | -239          | 1,588              | -110          | 1,633                      | -64           | 1,626                           | -72           | 1,677                             | -21           |
| ISO Net payment                                 | 2,920     | 2,963              | -42           | 2,933              | -13           | 2,923                      | -3            | 2,921                           | -1            | 2,933                             | -12           |
| WECC Production cost                            | 23,874    | 23,785             | 89            | 23,843             | 31            | 23,867                     | 7             | 23,859                          | 15            | 23,824                            | 50            |

Note that ISO ratepayer “savings” are a decrease in load payment, but an increase in ISO generator net revenue benefiting ratepayers and an increase in ISO transmission revenue benefiting ratepayers. WECC-wide “Savings” are a decrease in overall production cost. A negative savings is an incremental cost or loss.

### LCR reduction benefit

The PTE project, which is to build a HVDC line from Diablo Canyon to El Segundo, can potentially reduce LCR requirement in the LA Basin area, as indicated in the previous planning cycles TPP reports. The K-SEL project, which is to build a HVDC line from Midway to El Nido, is similar the PTE project in term of reducing LCR requirement in the LA Basin area. According to the previous TPP, the LCR requirement reduction for the LA Basin area by the PTE project was approximately equal to the capacity of the HVDC line coming into the LA Basin. In the meantime, the capacity requirements reduced in the local area will still be needed for system RA. Using the same assumption in this planning cycle, LCR reduction for the LA Basin area by the PTE and K-SEL projects is assumed to be approximately equal to the transmission capacity of the projects. According to the economic study request overview in section 8, the transmission capacity of these two projects are:

- PTE project – 2000 MW
- K-SEL project – 2000 MW

The Del Amo – El Nido HVDC project and the Del Amo – El Nido 230 kV AC project can mitigate congestion on the La Fresa – La Cienega 230 kV line, which is a binding constraint of the El Nido sub-area; hence these two project can help to reduce LCR requirement of the El Nido sub-area. However, as both the Del Amo and El Nido substations are within the LA Basin area, these two projects cannot help to reduce the overall LCR requirement of the LA Basin area.

It is worth noting that the assumption for LCR reduction in this study was used only for screening purpose. Detailed LCR study will be needed if the screening results show that a project may provide economic benefit to CAISO's ratepayers sufficient or close to compensate the cost of the project, i.e. have benefit to cost ratio greater than or close to 1.0.

The local and system capacity costs changed from year to year. In this planning cycle, the capacity costs in the latest CPUC 2022 Resource Adequacy Report were used to calculate the LCR reduction savings. The capacity costs for the southern California areas and the system capacity costs in the CPUC report are summarized in Table G.9-8. The costs converted to 2024 dollar based on the inflation rate in the CEC 2023 IEPR report<sup>7</sup> were also included in the table.

Table G.9-8: Capacity cost in CPUC Resource Adequacy Report

| Area     | Weighted average capacity cost (\$/kW-month) in CPUC 2022 RA report | In 2024 dollar |
|----------|---|----------------|
| System   | 7.62  | 8.08           |
| SP26     | 7.22  | 7.66           |
| LA Basin | 7.54  | 8.00           |

The LCR reduction benefit results assessed based the CPUC's capacity cost were summarized in Table G.9-9.

Table G.9-9: LCR reduction savings based on the capacity costs in the CPUC 2022 Resource Adequacy Report

|   | PTE                     |                        | K-SEL                   |                        |
|---|-------------------------|------------------------|-------------------------|------------------------|
|   | Local vs System RA cost | Local vs SP 26 RA cost | Local vs System RA cost | Local vs SP 26 RA cost |
| LCR reduction benefit (Western LA Basin) (MW) | 2,000                   |                        | 2,000                   |                        |
| Capacity value(\$/MW-year)                    | -1,018                  | 4,073                  | -1,018                  | 4,073                  |
| LCR Reduction Benefit (\$million/year)        | -2.04                   | 8.15                   | -2.04                   | 8.15                   |

For comparison, sensitivity assessment for LCR reduction savings was conducted using different capacity cost assumptions. Specifically, the capacity costs proposed in the PTE economic study request submitted by California Western Grid LLC were used in the sensitivity assessment for both of the PTE project and the K-SEL project. Note that the PTE economic study request did not provide SP26 capacity cost, so the capacity value was only evaluated using the LA Basin and the system capacity cost in this sensitivity study. The capacity costs in 2024 dollar for this sensitivity assessment were summarized in Table G.9-10.

<sup>7</sup> <https://efiling.energy.ca.gov/GetDocument.aspx?tn=254569&DocumentContentId=89994>

Table G.9-10: Capacity cost proposed in the PTE project economic study request

| Area     | Weighted average capacity cost (\$/kW-month) in 2024 dollar | Note   |
|----------|---|--|
| System   | Low : 2.34, High: 2.74                                      | The PTE economic study request assumed the system capacity marginal cost would be set by battery storage |
| LA Basin | Low : 5.15, High: 7.79                                      | The PTE economic study request provided the LA Basin capacity cost                                       |

Comparing Table G.9-8 and Table G.9-10, it was observed that both of the system capacity cost and the LA Basin cost in the CPUC report are higher than in the PTE economic study request. In this sensitivity study, the CPUC LA Basin cost and the low system capacity cost in the PTE economic study request were used to evaluate the capacity value.

The LCR reduction savings results of the sensitivity assessments are summarized in Table G.9-11.

Table G.9-11: LCR reduction savings of LA Basin congestion mitigation alternatives in Sensitivity Assessments

|   | PTE                     | K-SEL                   |
|---|-------------------------|-------------------------|
|   | Local vs System RA cost | Local vs System RA cost |
| LCR reduction benefit (Western LA Basin) (MW) | 2,000                   | 2,000                   |
| Capacity value(\$/MW-year)                    | 67,870                  | 67,870                  |
| LCR Reduction Benefit (\$million/year)        | 135.74                  | 135.74                  |

### Cost Estimate

The capital cost of the PTE project was based on the cost provided in the economic study request to the 2024-2025 transmission planning cycle, which is \$2,200 million. Applying the ISO's screening factor of 1.3 to convert the capital cost of a project to the present value of the annualized revenue requirement, referred to as the "total" cost, the total cost of the PTE project is about \$2,860 million.

The capital cost of the K-SEL project was estimated based on the ISO's transmission per unit cost with assuming each HVDC convertor station cost is about \$600 million based on industry practice. This gave the K-SEL project estimated capital cost at \$2,424 million. Applying the ISO's screening factor of 1.3, the total cost of the K-SEL project is about \$3,152 million.

The other three transmission alternatives had negative production cost savings and did not have LCR reduction benefit, which results in net negative benefit to the CAISO ratepayers, hence there is no need to further evaluate benefit to cost ratio for them.

Benefit-to-cost ratio

The present values of the economic benefit of the PTE project and the K-SEL project were shown in Table G.9-12 along with the calculation of the benefit-to-cost ratio. The economic life of the projects is assumed to be 50 years. Benefit to cost ratio was not assessed for the other three alternatives for Path 26 and LA Basin congestion mitigation as these alternatives did not show positive benefit to the CAISO's ratepayers.

Table G.9-12: Benefit-to-cost ratios (Ratepayer Benefits per TEAM) of PTE project and K-SEL project

|  | PTE                                 |                        |   | K-SEL                               |                        |   |
|--|-------------------------------------|------------------------|---|-------------------------------------|------------------------|---|
|  | Baseline study (CPUC capacity cost) |                        | Sensitivity assessment  | Baseline study (CPUC capacity cost) |                        | Sensitivity assessment  |
|  | Local vs System RA cost             | Local vs SP 26 RA cost | Local cost in CPUC report vs System cost (low) in PTE study request | Local vs System RA cost             | Local vs SP 26 RA cost | Local cost in CPUC report vs System cost (low) in PTE study request |
| Production cost savings (\$million/year)     | -42                                 | -42                    | -42   | -13                                 | -13                    | -13   |
| Capacity saving (\$million/year)             | -2.04                               | 8.15                   | 135.74  | -2.04                               | 8.15                   | 135.74  |
| Capital cost (\$million)                     | 2,200                               | 2,200                  | 2,200   | 2,424                               | 2,424                  | 2,424   |
| Cost to Revenue Ratio                        | 1.3                                 | 1.3                    | 1.3   | 1.3                                 | 1.3                    | 1.3   |
| Discount Rate                                | 7%                                  | 7%                     | 7%  | 7%                                  | 7%                     | 7%  |
| Economic life (year)                         | 50                                  | 50                     | 50  | 50                                  | 50                     | 50  |
| PV of Production cost savings (\$million)    | -620                                | -620                   | -620  | -192                                | -192                   | -192  |
| PV of Capacity saving (\$million)            | -30                                 | 120                    | 2,004   | -30                                 | 120                    | 2,004   |
| Total benefit (\$million)                    | -650                                | -500                   | 1,384   | -222                                | -72                    | 1,812   |
| Total cost (Revenue requirement) (\$million) | 2,860                               | 2,860                  | 2,860   | 3,152                               | 3,152                  | 3,152   |
| Benefit-to-cost ratio (BCR)                  | -0.23                               | -0.17                  | 0.48  | -0.07                               | -0.02                  | 0.58  |

Conclusion

Five transmission upgrades were assessed in this section as mitigation alternatives for the Path 26 corridor and LA Basin congestions. All five alternatives had negative production cost savings for the CAISO's ratepayers. LCR reduction benefit was assessed for the PTE project and the K-SEL project, based on different capacity cost assumptions. The benefit-to-cost ratio results showed that there was no sufficient economic justification for recommending the PTE project and the K-SEL project as an economic-driven project in this planning cycle. The other three alternatives were not recommended either because the benefit to the CAISO's ratepayers were negative.

It should be noted that the assumptions around the value of reducing capacity requirements directly affect the value of the projects that can potentially reduce LCR requirements. The potential benefit of reducing capacity requirements needs to be reassessed in future planning cycles as the assumptions change, particularly if the need to retain the existing gas-fired fleet for system-wide resource reliability purposes is relaxed, or if capacity cost is updated to show meaningful difference between the local capacity cost and the system capacity cost.

## G.9.4 PG&E Path 15 corridor congestion and mitigations

### Congestion analysis

Path 15 corridor and Path 26 corridor congestion showed significant increase in this planning cycle compared with the results in previous planning cycles. This change was expected since the resource assumption changed in the CPUC IRP portfolios for the 2024-2025 TPP cycle. Congestion on these two corridors correlated to each other in multiple ways. First of all, renewable resources in the PG&E's Fresno/Kern areas and the Path 26 flow from south to north contribute to the flows and congestion on both corridors. On the other hand, mitigations for one constraint may impact the flow and even aggravate the congestion on the other constraints because of the topology connection between these two constraints. Congestions on Path 15 corridor were summarized in Table G.9-13, while the Path 26 corridor congestions were discussed in section G.9.3.

Table G.9-13: PG&E Path 15 corridor congestions in the 2039 Base portfolio PCM

| Constraint Name  | Cost Forward (\$K) | Duration Forward (Hrs) | Cost Backward (\$K) | Duration Backward (Hrs) | Costs Total (\$K) | Duration Total (Hrs) |
|--|--------------------|------------------------|---------------------|-------------------------|-------------------|----------------------|
| MANNING-MN_GT_11 500 kV line #1  | 0                  | 0                      | 278,288             | 2,415                   | 278,288           | 2,415                |
| PANOCHÉ-GATES E 230 kV line, subject to PG&E N-2 Gates-Gregg and Gates-McCall 230 kV | 0                  | 0                      | 85,856              | 1,628                   | 85,856            | 1,628                |
| MN_GT_11-GATES 500 kV line #1  | 0                  | 0                      | 54,304              | 475                     | 54,304            | 475                  |
| MN_MW_21-MN_MW_22 500 kV line #2   | 0                  | 0                      | 38,600              | 559                     | 38,600            | 559                  |
| MANNING-MN_MW_21 500 kV line #2  | 0                  | 0                      | 26,691              | 872                     | 26,691            | 872                  |
| GT_MW_11-MIDWAY 500 kV line #1   | 0                  | 1                      | 11,029              | 234                     | 11,030            | 235                  |
| MN_MW_23-MIDWAY 500 kV line #2   | 0                  | 0                      | 10,231              | 339                     | 10,231            | 339                  |
| GATES-GT_MW_11 500 kV line #1  | 0                  | 0                      | 6,925               | 202                     | 6,925             | 202                  |
| MN_MW_22-MN_MW_23 500 kV line #2   | 0                  | 0                      | 3,833               | 87                      | 3,833             | 87                   |
| PANOCHÉ-GATES E 230 kV line, subject to PG&E N-2 LB-Gates and LB-Midway 500 kV       | 0                  | 0                      | 3,720               | 254                     | 3,720             | 254                  |
| PANOCHÉ-GATES E 230 kV line, subject to PG&E N-2 Mustang-Gates #1 and #2 230 kV      | 0                  | 0                      | 1,061               | 151                     | 1,061             | 151                  |
| FINKSWSTA-WESTLEY 230 kV line, subject to PG&E N-1 LosBanos-Tesla 500kV              | 657                | 21                     | 0                   | 0                       | 657               | 21                   |
| PANOCHÉ-GATES E 230 kV line, subject to PG&E N-1 Panoche-Gates #1 230kV              | 0                  | 0                      | 599                 | 105                     | 599               | 105                  |



Congestion mitigation alternatives

Several transmission alternatives for mitigating the Path 15 corridor congestion, including combinations of alternatives, were assessed in this planning cycle. Table G.9-14 shows the congestion costs on Path 15 corridor and Path 26 corridor, in the base portfolio PCM case and the PCM cases with mitigation alternative modeled. The columns “Congestion Cost Change (\$M)” show the congestion cost change from the base portfolio PCM case when mitigation alternatives are modeled. The last column in the table provided further discussion about how the alternatives affects congestions.

Table G.9-14: Impact of transmission alternatives on Path 15 corridor and Path 26 corridor congestion

|  | Path 15 corridor congestion |  | Path 26 corridor congestion |  |  |
|--|-----------------------------|--|-----------------------------|--|--|
|  | Congestion Cost (\$M)       |  | Congestion Cost (\$M)       |  |  |
| 2039 Base portfolio PCM case   | 521.80                      |  | 206.28                      |  |  |
| Alternatives   | Congestion Cost (\$M)       | Congestion Cost Change from Base (\$M) | Congestion Cost (\$M)       | Congestion Cost Change from Base (\$M) | Note   |
| Alternative 1: Build a new Manning – Los Banos – Tesla 500 kV line   | 574.52                      | 52.72                                  | 212.03                      | 5.75                                   | Congestion on the Path 15 south of Manning segments increased, which contributed to the Path 15 corridor congestion increased  |
| Alternative 2: A1 plus a new Midway – Gates – Manning 500 kV line  | 70.42                       | -451.37                                | 289.95                      | 83.67                                  | Path 15 south of Manning congestion was significantly reduced. The remaining Path 15 congestion was mainly observed on the Panoche - Gates 230 kV lines. Path 26 congestion increased. |
| Alternative 3: Monarch Option 1 Gates – Los Banos #3 500 kV line loops in new New Point 500 kV substation and build a new New Point to Tracy 500 kV line | 497.54                      | -24.26                                 | 215.59                      | 9.31                                   | The Gates - Los Banos #3 line looping-in to the New Point substation helps to reduce the Gates - Manning flow hence reduce the congestion on the Gates - Manning 500 kV lines.         |
| Alternative 4: A3 plus New Point – Tracy looping in Tesla  | 479.10                      | -42.70                                 | 220.51                      | 14.23                                  | The Gates - Los Banos #3 line looping-in to the New Point substation helps to reduce the Gates to Manning flow hence reduce the congestion on the Gates - Manning 500 kV lines.        |
| Alternative 5: A4 plus build a new Midway – New Point 500 kV line  | 211.25                      | -310.54                                | 311.96                      | 105.68                                 | Adding the Midway - New Point 500 kV line can help to reduce Path 15 south of Manning congestion but the Path 26 congestion increased significantly.                                   |
| Alternative 6: Monarch Option 2 Build a new Manning – New Point – Tracy 500 kV line  | 594.39                      | 72.60                                  | 212.22                      | 5.95                                   | Congestion on the Gates - Manning 500 kV lines significantly increased after modeling the Manning - New Point - Tracy 500 kV line.   |
| Alternative 7: A6 plus New Point – Tracy looping in Tesla  | 607.81                      | 86.01                                  | 215.70                      | 9.42                                   | Congestion on the Gates - Manning 500 kV lines significantly increased after modeling the Manning - New Point - Tracy 500 kV line.   |
| Alternative 8: A7 plus build a new Midway – New Point 500 kV line  | 217.84                      | -303.96                                | 313.95                      | 107.68                                 | Adding the Midway - New Point 500 kV line can help to reduce Path 15 south of Manning congestion but the   |

|   | Path 15 corridor congestion |  | Path 26 corridor congestion |  |   |
|---|-----------------------------|--|-----------------------------|--|---|
|   | Congestion Cost (\$M)       |  | Congestion Cost (\$M)       |  |   |
| 2039 Base portfolio PCM case  | 521.80                      |  | 206.28                      |  |   |
| Alternatives  | Congestion Cost (\$M)       | Congestion Cost Change from Base (\$M) | Congestion Cost (\$M)       | Congestion Cost Change from Base (\$M) | Note  |
|   |                             |  |                             |  | Path 26 congestion increased significantly .  |
| Alternative 9: Build a new 500 kV line from Midway to new Gregg 500 kV substation to Tesla      | 137.77                      | -384.02                                | 300.28                      | 94.00                                  | This alternative help to reduce the Path 15 congestion on both south of Manning segments and Panoche - Gates 230 kV lines, but increase the Path 26 congestion.                     |
| Alternative 10: Install a 10 ohm series reactor on each of the two Panoche – Gates 230 kV lines | 516.87                      | -4.93                                  | 200.97                      | -5.31                                  | Adding series reactors on the Panoche - Gates 230 kV lines can help to mitigate the congestion on the lines, but it aggravating the congestion on the Gates - Manning 500 kV lines. |

### Production benefits

The production cost savings of all transmission alternatives discussed above were summarized in Table G.9-15 .

Table G.9-15: Production Benefits of Path 15 corridor congestion mitigation transmission alternatives

| Scenarios  |              | ISO load payment (\$M) | ISO generator net revenue benefiting ratepayers (\$M) | ISO transmission revenue benefiting ratepayers (\$M) | ISO Net payment (\$M) | WECC Production cost (\$M) |
|--|--------------|------------------------|---|--|-----------------------|----------------------------|
| Base case  |              | 18,823                 | 14,205  | 1,698  | 2,920                 | 23,874                     |
| Alternative 1: Build a new Manning – Los Banos – Tesla 500 kV line   | Post project | 18,831                 | 14,182  | 1,759  | 2,890                 | 23,874                     |
|  | Savings      | -8                     | -22   | 61   | 31                    | 0                          |
| Alternative 2: A1 plus a new Midway – Gates – Manning 500 kV line  | Post project | 18,783                 | 14,452  | 1,319  | 3,012                 | 23,761                     |
|  | Savings      | 40                     | 247   | -379   | -91                   | 113                        |
| Alternative 3: Monarch Option 1 Gates – Los Banos #3 500 kV line loops in new New Point 500 kV substation and build a new New Point to Tracy 500 kV line | Post project | 18,804                 | 14,230  | 1,671  | 2,903                 | 23,851                     |
|  | Savings      | 19                     | 25  | -27  | 18                    | 23                         |
| Alternative 4: A3 plus New Point – Tracy looping in Tesla  | Post project | 18,827                 | 14,265  | 1,660  | 2,901                 | 23,849                     |
|  | Savings      | -4                     | 61  | -37  | 19                    | 24                         |
| Alternative 5: A4 plus build a new Midway – New Point 500 kV line  | Post project | 18,776                 | 14,404  | 1,470  | 2,902                 | 23,776                     |
|  | Savings      | 47                     | 199   | -228   | 18                    | 98                         |

| Scenarios   |              | ISO load payment (\$M) | ISO generator net revenue benefiting ratepayers (\$M) | ISO transmission revenue benefiting ratepayers (\$M) | ISO Net payment (\$M) | WECC Production cost (\$M) |
|---|--------------|------------------------|---|--|-----------------------|----------------------------|
| Base case   |              | 18,823                 | 14,205  | 1,698  | 2,920                 | 23,874                     |
| Alternative 6: Monarch Option 2<br>Build a new Manning – New Point – Tracy 500 kV line          | Post project | 18,855                 | 14,191  | 1,779  | 2,885                 | 23,878                     |
|   | Savings      | -32                    | -14   | 82   | 36                    | -4                         |
| Alternative 7: A6 plus New Point – Tracy looping in Tesla                                       | Post project | 18,861                 | 14,186  | 1,800  | 2,876                 | 23,885                     |
|   | Savings      | -38                    | -19   | 102  | 45                    | -12                        |
| Alternative 8: A7 plus Midway – New Point   | Post project | 18,782                 | 14,402  | 1,482  | 2,898                 | 23,761                     |
|   | Savings      | 41                     | 198   | -215   | 23                    | 113                        |
| Alternative 9: Build a new 500 kV line from Midway to new Gregg 500 kV substation to Tesla      | Post project | 18,777                 | 14,449  | 1,385  | 2,943                 | 23,769                     |
|   | Savings      | 46                     | 244   | -312   | -23                   | 105                        |
| Alternative 10: Install a 10 ohm series reactor on each of the two Panoche – Gates 230 kV lines | Post project | 18,843                 | 14,223  | 1,699  | 2,922                 | 23,873                     |
|   | Savings      | -20                    | 18  | 1  | -1                    | 1                          |

Note that ISO ratepayer “savings” are a decrease in load payment, but an increase in ISO generator net revenue benefiting ratepayers and an increase in ISO transmission revenue benefiting ratepayers. WECC-wide “Savings” are a decrease in overall production cost. A negative savings is an incremental cost or loss.

### Cost Estimate

The ISO per unit cost was used to estimate the capital cost of the transmission alternatives assessed for mitigating the Path 15 corridor congestion. The ISO’s screening factor of 1.3 then was applied to convert the capital cost of a project to the present value of the annualized revenue requirement, referred to as the “total” cost”. The cost estimate was summarized in Table G.9-16.

Table G.9-16: Cost estimate of Path 15 corridor congestion mitigation transmission alternatives

| Alternative   | Capital Cost Estimate (\$M) | Total Cost Estimate (\$M) |
|---|-----------------------------|---------------------------|
| Alternative 1: Build a new Manning – Los Banos – Tesla 500 kV line                              | 888                         | 1,155                     |
| Alternative 2: A1 plus a new Midway – Gates – Manning 500 kV line                               | 2,018                       | 2,624                     |
| Alternative 3: Monarch Option 1   | 950                         | 1,235                     |
| Alternative 4: A3 plus New Point – Tracy looping in Tesla                                       | 1,164                       | 1,513                     |
| Alternative 5: A4 plus build a new Midway – New Point 500 kV line                               | 2,068                       | 2,688                     |
| Alternative 6: Monarch Option 2   | 851                         | 1,107                     |
| Alternative 7: A6 plus New Point – Tracy looping in Tesla                                       | 1,065                       | 1,385                     |
| Alternative 8: A7 plus build a new Midway – New Point 500 kV line                               | 1,933                       | 2,513                     |
| Alternative 9: Build a new 500 kV line from Midway to new Gregg 500 kV substation to Tesla      | 1,781                       | 2,315                     |
| Alternative 10: Install a 10 ohm series reactor on each of the two Panoche – Gates 230 kV lines | 109                         | 142                       |

Benefit-to-cost ratio

The present values of the economic benefit of the Path 15 corridor congestion mitigation alternatives are shown in Table G.9-17 along with the calculation of the benefit-to-cost ratio. The economic life of transmission upgrade is 50 years for adding new transmission line or 40 years for reconductoring. Capacity saving was assumed to be zero for all these transmission alternatives since none of them has direct impact on the PG&E's local capacity areas.

Table G.9-17: Benefit-to-cost ratios (Ratepayer Benefits per TEAM) of Path 15 corridor congestion mitigation transmission alternatives

|  | A1: new Manning – Los Banos – Tesla 500 kV line | A2: A1 plus a new Midway – Gates – Manning 500 kV line | A3: Monarch Option 1 | A4: A3 plus NewPoint – Tracy looping in Tesla | A5: A4 plus new Midway – New Point 500 kV line | A6: Monarch Option 2 | A7: A6 plus NewPoint – Tracy looping in Tesla | A8: A7 plus build a new Midway – NewPoint 500 kV line | A9: new 500 kV line from Midway to Tesla | A10: series reactor on Panoche – Gates 230 kV lines |
|--|---|--|----------------------|---|--|----------------------|---|---|--|---|
| Production cost savings (\$million/year)     | 31  | -91  | 18                   | 19  | 18   | 36                   | 45  | 23  | -23                                      | -1  |
| Capacity saving (\$million/year)             | 0   | 0  | 0                    | 0   | 0  | 0                    | 0   | 0   | 0  | 0   |
| Capital cost (\$million)                     | 888   | 2,018  | 950                  | 1,164   | 2,068  | 851                  | 1,065   | 1,933   | 1,781                                    | 109   |
| Cost to Revenue Ratio                        | 1.3   | 1.3  | 1.3                  | 1.3   | 1.3  | 1.3                  | 1.3   | 1.3   | 1.3                                      | 1.3   |
| Discount Rate                                | 0.07  | 0.07   | 0.07                 | 0.07  | 0.07   | 0.07                 | 0.07  | 0.07  | 0.07                                     | 0.07  |
| Economic Life (year)                         | 50  | 50   | 50                   | 50  | 50   | 50                   | 50  | 50  | 50                                       | 50  |
| PV of Production cost savings (\$million)    | 452   | -1,348   | 259                  | 282   | 267  | 525                  | 661   | 337   | -335                                     | -20   |
| PV of Capacity saving (\$million)            | 0   | 0  | 0                    | 0   | 0  | 0                    | 0   | 0   | 0  | 0   |
| Total benefit (\$million)                    | 452   | -1,348   | 259                  | 282   | 267  | 525                  | 661   | 337   | -335                                     | -20   |
| Total cost (Revenue requirement) (\$million) | 1,155   | 2,624  | 1,235                | 1,513   | 2,688  | 1,107                | 1,385   | 2,513   | 2,315                                    | 142   |
| Benefit-to-cost ratio (BCR)                  | 0.39  | -0.51  | 0.21                 | 0.19  | 0.10   | 0.47                 | 0.48  | 0.13  | -0.14                                    | -0.14   |

### Conclusions

Multiple transmission alternatives for mitigating the congestion on the Path 15 corridor were assessed in this section. Transmission alternatives to increase transmission capacity at north of Manning in the Path 15 corridor showed positive benefit to the CAISO's ratepayers, but none of these alternatives have benefit to cost ratio greater than 1.0. These north of Manning alternatives normally aggravated congestions on the south of Manning segments of the Path 15 corridor and congestions on the Path 26 corridor, when flow is from south to north. This is because such upgrades at north of Manning helped to attract more flow to the north along the Path 26 and Path 15 corridors. The increase in Path 15 and Path 26 congestion caused by some north of Manning transmission upgrade alternatives can be significant, and may aggravate renewable curtailment and raise reliability concern in future system.

Transmission alternatives that combine transmission upgrades at north of Manning and south of Manning were assessed as well. While the congestion on the south of Manning segments of the Path 15 corridor was mitigated or reduced, the economic benefit of such transmission alternatives also reduced or even became negative. This happened when the congestion cost, which is considered as transmission revenue in TEAM methodology, reduced significantly as the south of Manning congestion in the Path 15 corridor was mitigated. These transmission alternatives may increase load payment savings and generation profit savings, but the increase was not large enough to compensate the transmission revenue reduction.

The benefit to cost ratio calculation in this section was based on the assumption that all transmission upgrade alternatives are fully rate-based projects, and the capital costs of the projects were estimated based on the CAISO transmission per unit cost. If these cost assumptions change, the benefit to cost ratios need to be recalculated, although the production cost simulation results may not change. It is worth noting that total capacity of renewable and battery resources in the Fresno/Kern area and in the southern California areas may continue increase in future CPUC IRP portfolios, which will aggravate congestions on the Path 15 and Path 26 corridors. Transmission upgrade alternatives for mitigating Path 15 and Path 26 corridors assessed in this planning cycle need to be reassessed in future planning cycles with consideration of the resource capacity changes in the Fresno/Kern area and in the southern California areas.