APPENDIX B

Unforced Capacity Framework

Appendix B

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This appendix documents the calculation of the Unforced Capacity (UCAP) value for dispatchable thermal units (peakers, combined cycle, combined heat and power, biomass, biomass/wood, and internal combustion engine), nuclear units, standalone battery storage, and co-located battery storage.

I. Unforced Capacity Principles

The following principles will guide the Resource Adequacy (RA) program's UCAP framework and the selection of unit outage types for the purpose of calculating the expected forced outage rate:

1. Unit outage types that indicate unplanned equipment failure that impacts the performance or availability of a resource to provide future capacity should be included in the forced outage rate.
2. Implementing UCAP into the RA program should incentivize load-serving entities (LSE) to procure more effective and reliable resources.
3. Unit outage types should be consistent between resource accreditation for RA and the inputs used for RA Loss of Load Expectation (LOLE) modeling (used in the development of planning reserve margins (PRM)) so the efforts are consistent.
    - To support the reliability modeling, the forced outage rate will exclude derates for temperature because it will be calculated separately.

4. To be consistent with the 1-in-2 load forecast, a typical weather year will be used to calculate a separate set of hourly weather-normalized derations due to ambient temperature.
5. To the extent possible, the data will rely on publicly available data.
6. Per Decision (D.) 25-06-048, the preference is for UCAP to be applied on a unit-specific basis.
7. The Commission supported using the best three out of the last four years of outage data.
    - This will account for force majeure or highly unusual events that occurred in the past and may not be expected to occur in the future. Therefore, the exclusion of the Nature-of-Work (NOW) codes from the UCAP calculation should be very limited.

II. Data Sources

The UCAP Framework will depend on California Independent System Operator's (CAISO) outage and curtailment data. CAISO maintains the Outage Management System (OMS), which allows generation operators to submit information about each outage event. Reports are published in several formats and cadences including the Curtailed Non-Operational Generator Prior Trade-Day Reports.[1] This daily digest of outages and curtailments, available since June 21, 2021, will be the data source used to evaluate Equivalent Forced Outage Rates during Demand (EFORd) and UCAP. Currently, only reductions to capacity are included in the reports.

III. Definition of Forced Outage

A forced outage is an unplanned event that requires immediate, delayed, or postponed removal of a unit from service, derating, or another outage state due to equipment failure (or risk of imminent equipment failure) or due to factors that prevent a unit from operating at its full Pmax level.

IV. UCAP Framework

The UCAP framework will apply to RA capacity accreditation and LOLE reliability modeling using consistent methodologies, with the only distinction being the treatment of ambient temperature derating. UCAP RA capacity accreditation will apply to dispatchable thermal, nuclear, geothermal, and storage resources that are not

[1] https://www.caiso.com/market-operations/outages/curtailed-and-non-operational-generators.

considered hybrid. CAISO outage data will be used for both the UCAP framework for RA capacity accreditation and for LOLE reliability modeling.

The UCAP methodology involves the following analytical steps:

1. Filter outages and curtailments data for applicable resources and forced outages.
2. Calculate outage and curtailment MWh during demand hours, defined as the RA Measurement Hours, each UCAP season and year, for each resource and NOW code as the product of Outage MW and duration of overlap between outages or curtailments during demand hours.
3. Calculate the total possible energy output for each resource and season as the product of its Net Dependable Capacity (NDC) or Pmax and the total demand hours within the season, excluding any hours prior to the resource's commercial operation date (COD).
4. Evaluate the contributory EFORd from each NOW code for each resource within each season as the quotient of the outage or curtailment MWh from Step 2 divided by the total possible energy from Step 3.
    a. Historic derations reported with the NOW code "AMBIENT_DUE_TO_TEMP" will be weather-normalized in a process described in a later section.
    b. Resulting weather-normalized EFORd values will be used in place of the historic values for thermal generators.
5. Determine the total EFORd within each season as the sum of the contributory EFORd values from each of the natures-of-work included in UCAP.
6. Calculate class-averaged EFORd values for each season and year, and apply the contemporaneous averages prior to each resource's COD if applicable.
7. Determine annual EFORd values for each resource, including class averages where applicable, and exclude data from the year with the highest overall EFORd in subsequent steps.
8. Re-calculate class-averaged EFORd values for each resource, excluding data from the years determined in Step 7.
9. Evaluate seasonal EFORd values for each resource, applying the re-calculated class-averaged EFORd values where applicable.
    a. Weight class-averaged seasons according to the applicable total class capacity within the season and year.
    b. Weight class-averaged and individually assessed EFORd values based on the number of demand hours applicable to each, i.e., a resource with a

COD halfway through the most recent "Summer" season included after Step 7 will receive weightings equivalent to 0.5 for individually assessed EFORd and 2.5 for class-averaged EFORd.

10. Calculate the individually assessed resource-specific UCAP values as the products of their NDC or Pmax and the combined seasonal EFORd values.

Two seasons are defined for the purpose of calculating and applying UCAP values:

- "Summer" includes the months of June through October
- "Non-Summer" includes the months of January through May, November, and December

Historic outage and curtailment data will be assessed in full calendar years, thus the "Non-Summer" season in a given year includes two discontinuous blocks of months. A resource's individually assessed seasonal UCAP value will be its capacity eligible towards the Commission's RA obligations.

A. Evaluation Period and Excluded Historic Data

The four complete prior calendar years of historic data will be used to evaluate UCAP values for a given resource. The best three calendar years of outage data will be assessed individually for each resource so the excluded calendar year may differ between resources.

For new units, or units without four years of data, the missing data will use a capacity-weighted class average. For example, a unit that has been in operation for one year would have unit-specific data for the most recent year and contemporaneous class-averages for all prior seasons and years.

B. Evaluation Time Period

The RA Measurement Hours adopted by the Commission will be used to determine when forced outages are included in the EFORd calculation. As the Commission may change the specific hours between years, the UCAP framework will apply the contemporaneous hours adopted during each historic year.

C. Outage Types to Include in UCAP

Forced outage rates will be calculated to determine units' UCAP for the RA Slice of Day (SOD) program, as well as inputs for reliability modeling. Therefore, outage types that are likely to occur in the future will be included when evaluating the EFORd used to calculate UCAP.

Outages and curtailments reported with the following NOW outage codes will be excluded categorically from the UCAP evaluation:

- New Generator Test Energy
- Transmission Induced Outages

Using the adopted UCAP principles as guidance, Energy Division will maintain a list of CAISO NOW codes to include in the EFORd calculation. Energy Division is authorized to adjust the NOW codes that are included or excluded in the EFORd calculation based on the UCAP principles, in the event that CAISO adds new outages codes or modifies how existing codes are used. Energy Division will maintain a publicly available UCAP user's guide that documents the NOW codes included in the EFORd calculations, and that explains the formulas.

D. New Resources and Missing Resource-Level Outage Data

As new resources are brought online, the historic outage data that would otherwise be used for UCAP evaluation will be substituted with capacity-weighted class-average EFORd values for each resource type. Within its first year of operation, a new resource's applicable UCAP value will be determined based solely on its class. As a new resource's outage data becomes available in subsequent years, UCAP will be determined using individual, rather than class-averaged, outages.

Incorporating class-averaged EFORd values into individual UCAP assessments will take place in two steps:

First, each year and season of class-averaged data to be applied will be weighted by the contemporaneous total capacity of the class multiplied by the applicable demand hours within the year and season, in MWh. In the year of a resource's COD, the class-averaged EFORd value will apply only to demand hours prior to the COD, and the class-average only includes the outages and capacities of resources operational within the season. The group-averaged seasons are then calculated as the sum of the product of group-averaged EFORds and coincident MWh divided by the sum of the coincident MWh.

Second, the group and individually assessed EFORd values are combined by weighting according to the applicable demand hours for both.

E. UCAP Calculations

Evaluation of UCAP will occur in two stages. The first stage involves downloading, cleaning, and aggregating large amounts of curtailment and weather data. The results from the first stage will be a set of total historic and weather-normalized outage MWh values for each individual resource, aggregated by nature-of-work, year, and season. The second stage involves processing the outage MWh from the first stage to determine

each resource's applicable seasonal EFORd and UCAP value. The second stage also will involve calculating class-averaged EFORd values to apply wherever individual historic data is not available, i.e., prior to a resource's COD, determining and excluding the year with the overall highest outage rate for each resource, assessing each resource's seasonal EFORd values, and finally evaluating the seasonal UCAP values.

i. Cleaning Outage Data

Because CAISO's Prior Trade-Day Curtailment Reports constitute daily snapshots of the OMS database, the data across the four-year historical review period is highly redundant and reflects revisions to ongoing curtailments. It therefore is necessary to identify and filter out duplicative outage and curtailment records, retaining only the most accurate and complete instance of each outage. Additionally, outages spanning multiple contiguous or separate time blocks must be correctly identified, and the proper partial curtailment or full outage amount must be applied.

Each of the necessary Curtailed and Non-Operational Prior Trade-Day Report files will be downloaded, and the outage and curtailment data will be extracted. Outage and curtailment data will then be grouped by Resource ID and Outage MRID and the most recent instance of each time block will be selected. The reported outage or curtailment MW for each retained record will then be applied to each time block, discarding any earlier versions of the report. In the case that the most recent record does not include an end datetime, an end datetime of 12:00 midnight the day of the Report from which the record was sourced will be assumed.

ii. Yearly and Seasonal EFORd Values by Resource and Nature-of-Work

The cleaned outage and curtailment reports will be compared against a set of identified demand hours, defined as the RA Measurement Hours. The overlap between each curtailment or outage time block and the demand hours for each year and season will be calculated, and the duration of the overlaps for each year and season will be multiplied by the outage or curtailment MW to determine an outage or curtailment MWh for each outage time block. The outage and curtailment MWh then will be summed for each resource and nature-of-work within each year and season and divided by the resource's NDC or Pmax to produce the seasonal resource-level EFORd values by nature-of-work.

Two types of seasonal resource-level curtailment and outage MWh will be evaluated: one containing the historical EFORd for each of the NOW reported excluding ambient due to temperatures, and a second containing weather-normalized EFORd values only for derations reported with the NOW code "AMBIENT_DUE_TO_TEMP."

iii. Yearly and Seasonal EFORd Values by Resource, Year, and Season

Yearly and seasonal EFORd values will be calculated for each resource type, year, and season to determine class-averaged EFORd values applicable to resources prior to their COD. This calculation will be evaluated twice: once including all historical data from each resource and once excluding each resource's single worst year of outage data within the four-year historic evaluation period. These two iterations are necessary for ensuring class-averaged EFORd values exclude the same outages as individually assessed values.

iv. Yearly EFORd Values by Resource

EFORd values will be assessed on an annual basis for each resource for the purpose of determining the calendar year with the highest overall outage rate.

v. Yearly and Seasonal EFORd Values by Resource Type

Yearly and seasonal EFORd values will be assessed across multiple resources within each resource type, as defined in the Master Resource Database (MRD). The resulting values will reflect the yearly and seasonal values applied toward each resource's overall seasonal EFORd before its COD; however, other calculations will rely on the individual terms within the formula rather than the evaluated results.

vi. Seasonal EFORd by Resource Type

The aggregate seasonal EFORd for each resource type will be presented for informational purposes, as the final UCAP values are dependent on individually assessed outage rates. The calculations closely match the second iteration of the yearly and seasonal EFORd values calculated, differing by aggregating across all four years in the historical review period.

vii. Seasonal EFORd by Resource

The final individually assessed EFORd values will aggregate across all selected NOW codes and years, excluding the outage rates for the year identified as showing each resource's highest yearly EFORd value. By accounting for each resource's COD in both the numerator and denominator of the group-assessed outage rates for the resource's resource type, they effectively will be capacity-weighted across each year, ensuring that as new capacity comes online, UCAP values for new resources are not unduly influenced by an older fleet with a potentially different class-average outage rate.

viii. UCAP Values

The final UCAP values for each resource and season will be the product of its individually assessed EFORd and its NDC or Pmax from the MRD. The calculation of UCAP is as follows:

Equation 1 – Seasonal Resource UCAP

$$UCAP_{Resource,Season} = (1 - EFORd_{Resource,Season}) \cdot Pmax_{Resource}$$

Where:

$UCAP_{Resource,Season}$ is the UCAP value for resource and season;

$EFORd_{Resource,Season}$ is the equivalent forced outage rate for the same resource and season, combining both historic forced outages and weather-normalized derations due to ambient temperatures where applicable; and

$Pmax_{Resource}$ is the maximum output or net dependable capacity for the resource.

F. Resource Classes

Classes will be defined according to the Resource Type specified in the MRD, published on the RA Compliance Materials webpage.[2] The following resource types are included in the UCAP evaluation: biogas, biomass, combined cycle gas turbine (CCGT), combined heat and power (CHP), combustion turbine (CT), geothermal, nuclear, reciprocating engine, and stand-alone and co-located battery storage. Among each of these resource types, except for nuclear, the UCAP evaluation will only apply for dispatchable resources.

G. Derations due to Ambient Temperatures

Special treatments for derations will be reported with the outage type of "FORCED" and the nature-of-work code "AMBIENT_DUE_TO_TEMPERATURE." For all resource types, excluding thermal power plants, this type of outage will be treated as any other forced outage.

i. Pairing Weather Data and Resources

Each thermal resource will be matched with the geographically closest weather station that reports to the National Oceanic and Atmospheric Administration's (NOAA) Global Hourly Integrated Surface Database (ISD), and for which NOAA has published a typical weather year based on historical data from 1991-2020. Publicly available historic and typical hourly dry-bulb temperatures will be retrieved from the ISD website and merge the data with curtailment data from CAISO for further analysis.

ii. Deration Curves

For thermal power plants, resource-level deration curves will be defined based on reported derations due to ambient temperatures and historic weather data. These

[2] https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/resource-adequacy-homepage/resource-adequacy-compliance-materials.

curves will consist of a piecewise-linear function defined for all temperatures with three distinct regimes:

a. Full capacity (i.e., no deration) for low temperatures up to a specified cut-off temperature;
b. Linearly decreasing capacity with increasing temperature; and
c. Zero capacity above a very high temperature.

The slope of the second regime will be determined for each thermal resource based on a linear regression analysis performed on four prior years of historic curtailment and weather data for each resource type weighted by resource capacity but not by year. The cut-off temperature between the first and second regimes will be determined for each individual resource through a second set of linear analyses on the same curtailment and weather data sets, constraining the slopes to those determined in the multilinear analysis. The cut-off temperature for the third regime, determined by the slope in the second regime and the low-temperature cut-off, should be far above expected ambient temperatures, and this regime ensures negative capacities are not possible.

This methodology therefore assumes that ambient temperatures at each resource are correlated with temperatures at their selected weather stations. Since the same weather stations are used in the regression analyses to determine derating curves and for calculating weather-normalized derations, any approximately constant offsets in temperature between the two locations due to, for example, differences in elevation, are cancelled out. Additionally, this deration model can be used for purposes beside UCAP, such as to forecast derations in future years using climate-informed weather predictions.

iii. Capacity Accreditation

Resource-level derate curves will be applied to the current 30-year typical weather data set, published by NOAA, for the purpose of capacity accreditation. This data set provides hourly temperatures for the weather stations available in NOAA's ISD. Each resource's hourly derations will thus be calculated by evaluating the value of the deration curve at each hour's temperature. The typical weather year is not associated with a particular calendar year, and does not include the date February 29, so when evaluating the contributary EFORd due to ambient temperatures using weather-normalized derations, demand hours during leap day during any leap years must be excluded from the denominator of the EFORd calculations as presented in the earlier section, UCAP Formulas.

iv. Loss-of-Load Expectation Modelling

Derations due to ambient temperatures for LOLE modelling will be calculated similar to capacity accreditation, substituting Energy Division's full 25-year ensemble of historical weather data in place of the single normalized weather year.

v. Incorporating Derations due to Ambient Temperatures into UCAP

Derations will be evaluated due to ambient temperatures by applying each resource's deration curve on an hourly basis for one typical weather year (8,760 hours in total), using weather normals prepared by NOAA based on historic weather for each weather station from 1992-2020. These hourly deration values will then be processed as curtailment reports: derations will be filtered for demand hours and aggregated to determine curtailed MWh within either season of the typical weather year. The resulting curtailed MWh will then be used as substitutes for the historic curtailment reports with the nature of work code "AMBIENT_DUE_TO_TEMPERATURE" in evaluating EFORd and UCAP.

V. UCAP Implementation

For the first RA compliance year (2028), in early 2027, Energy Division will publish preliminary UCAP values and parties will have an opportunity to review and submit comments. Energy Division will publish a second set of preliminary UCAP values in July or August during the annual process to update the MRD, with final UCAP values distributed in September. In subsequent years, preliminary UCAP values will be published in July or August during the annual process to update the MRD, with final UCAP values distributed in September.

For units with four years of historical data, the UCAP value will utilize the best three out of four calendar years of each unit's historical EFORd data. For units with less than four years of data, the UCAP value will be based upon a progressive calculation using more of the unit's historical data and class average EFORd data. This process is described in Section IV.A. A new unit without a full calendar year of historical data will have the UCAP based upon the class average historical EFORd data.

VI. Planning Reserve Margin Adjustment

The PRM calculated from the reliability model accounts for unit forced outages. Since UCAP reduces a resource installed capacity value due to forced outages, using the current PRM would double count the need to have additional resources to account for

forced outages. The forced outage component must be removed from the PRM to calculate a UCAP reserve margin for the Commission's SOD process.

The reliability model SERVM is used to identify if a given resource portfolio achieves a 0.1 LOLE. Once SERVM has confirmed that a portfolio has met the LOLE target, that portfolio is input into the SOD PRM Calibration workbook to calculate the equivalent SOD monthly PRM of that portfolio. To estimate the impact of UCAP, capacity values for dispatchable thermal, nuclear, and storage resources were updated on the "SERVM Units" worksheet of the SOD PRM Calibration workbook.

A. Applying UCAP Values to PRM Calibration Workbook

To update the UCAP resource values in the PRM Calibration workbook, the following steps were taken.

(1) The resource-specific EFORd values, derived from the CAISO Prior Trade-Day Curtailment Reports, were loaded into the workbook.
(2) Lookup formulas were incorporated into the SERVM Units worksheet to apply resource-specific EFORd values to the monthly net qualifying capacity (NQC) values of the relevant resource types. These categories included: dispatchable biogas, biomass, CCGT, CHP, CT, geothermal, nuclear, reciprocating engines, as well as stand-alone and co-located battery storage. Approximately 300 resource IDs, totaling ~39 GW of nameplate capacity, were adjusted to UCAP values.
(3) In some cases, the SERVM resource ID did not match the UCAP resource ID list; this mismatch can be attributed to custom ID that were used when under-construction resources were added to the SERVM baseline. In cases where there were non-matches, and the resource type was a UCAP-relevant category, the class-average EFORd values were applied to the resources' monthly NQC. This subset of non-matching resources included 70 resources IDs, totaling ~4 GW of nameplate capacity.
(4) Once the UCAP values were updated the PRM solver was run to calculate the monthly PRMs.

(END OF APPENDIX B)