**Appendix A**

**Details of Data and Modeling Issues and Ancillary Services Price Models**

This document contains details of the data and modeling issues, and Ancillary Service price models, described in the Joint IOU Comments; and describes the attached Workpapers. Issues and Workpapers are referenced in the same order as they appear in Comments.

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| Issue | Workpaper References | Details |
| 2019 energy prices out of order | **Attch\_A\_Energy\_Prices\_2019\_NP15\_SP15.xlsb** tab “2019 Energy Prices”  2019 Day-Ahead Energy prices in ACC model and downloaded from CAISO are in, columns E-H.  Ranked prices are in columns I-L. | Ranked prices (price duration curves) match, but hourly prices do not (except for January 1).  Averages by hour and by month appear in columns O:AL; these do not match. |
| 2019 gas prices inaccurate | **Attch\_A\_Energy\_Prices\_2019\_NP15\_SP15.xlsb** tab “Heat Rates”  2019 gas prices at PG&E Citygate and SoCal Citygate, and gas transportation costs are in columns E:F and AG:AK.  Heat rates in ACC model and calculated from actual CAISO prices are in columns H:M  Reverse engineering of gas prices used in ACC model is in columns N:U  Heat rate duration curves are in columns V:AA  Original and corrected ratios for scarcity calculations are in columns AB:AF | Historical 2019 gas prices apparently used in ACC model (based on reverse engineering) are constant within each month and have a constant and inaccurate differential between NP and SP.  Ratios in ACC model documentation do not match those calculated from (incorrect) heat rates in ACC files, nor do they match those calculated from heat rates derived from actual CAISO prices. |
| SERVM detailed outputs: Generators operate below Pmin | **Attch\_B\_**  **NoDER\_XKWAU\_Final\_Unit\_Dispatch\_ debug\_00046\_week\_15\_Unit\_Output\_**  **sy\_2030\_sy\_2030\_Average.xlsb**  Minimum generation level (Pmin) is col. F  # hrs in week with generation between 0 and Pmin is in column P (added column)  Average generation over week is column Q (added column) | Minimum generation levels appear to be not enforced at all. Many generators never operate above Pmin, e.g. Gateway Generating Station (row 82).  For Gateway, unclear why generation should be constant for consecutive hours when prices are changing. **Need to see Ancillary Service awards to verify.** |
| Minimum up and down times not enforced | **Attch\_B\_NoDER\_XKWAU….xlsb**  Minimum up time is column J  Minimum down time is column K | See row 88, columns AY:BA and BN |
| Batteries and PSH not charging at negative prices | **Attch\_B\_NoDER\_XKWAU….xlsb**  Energy price in zone PGE\_Bay is row 3 (added row)  First hours with energy prices below -$100/MWh are columns CB:CD  PSH operation is row 16  Batteries operation are rows 114:143  Note: Large batteries through row 123 appear to be grid-scale 4-hr batteries. Smaller batteries rows 124:143 may be distribution-connected or BTM; some are 2-hr and some are 4-hr duration | PSH pumps at low level in first two negative price hours, not at all in third hour. But it pumps more in hours before the negative price hours, which is uneconomic  Some batteries do not charge at all during entire low price period; others charge slightly during first two hours (but again, more in earlier hours that have higher prices).  Most batteries hardly ever operate in HE17, no matter what the price. |
| Inconsistent Reg Down accounting | **Attch\_B\_NoDER\_XKWAU….xlsb**  Regulation down requirement (for PGE\_Bay zone) is row 39  Reg Down Supplied is Row 35  Reg Down Shortage is Row 31 | In first hour (column R) and many others, there is supposedly a Reg Down shortage but Reg Down Supplied is much greater than Reg Down Requirement. |
| Biogas generators rarely operate at Pmax | **Attch\_B\_NoDER\_XKWAU….xlsb**  Pmax is column E  Dispatch price at Max is column G  Max Incremental Dispatch Cost is column M | Biogas, biomass and some other generators rarely operate at Pmax even when prices are much higher than maximum dispatch costs.  Also, dispatch does not follow pattern of energy prices. Example row 63. |
| Battery duration less than 4 hours | **Attch\_C\_StorageDispatch2020.xlsb**  Total, A/S-related, and energy-related charging kW are in columns Q-S  Discharging kW are in columns U-W  Beginning of hour state of charge is column AS | Rows 5011:5014: Battery starts full (4000 kWh), discharges total of 3679 kWh and ends empty (3.679 hrs duration). Ratio of change in SOC to discharge is the same in all hours, not an outlier.  Rows 927:929: Battery starts at SOC of 1000 kWh, charges 3000 kWh and ends at SOC of 3760 kWh. Ratio change in SOC/total charge = 0.92, so takes 4/0.92 = 4.35 hours to charge from zero to full.  Check: 3.679/4.35 = 84.5% (documented efficiency 85%) |
| Figure 1: Forecasted heat rates do not follow historical or other forecast trajectories | **Attch\_D\_Historical\_forecasted\_EMHR\_**  **SERVM\_etc.xlsb**  Historical NP-15 Energy, gas and GHG prices and heat rates (2012-2019, from PG&E’s 2020 GRC Phase II Workpapers) are on Historical tab.  Month-hour averages of historical heat rates and forecasted heat rates from PG&E’s 2020 GRC Phase II Workpapers are in columns C:Z of tab “Hist. and Forecast”.  Annual averages, and average heat rate forecasts of raw and scarcity-adjusted SERVM prices are in columns AD:AV, rows 3:6.  Calculated annual averages of *average* (not marginal) heat rates from RSP and No New DER IRP RESOLVE runs are rows 10:11; multiplied by 2.5 to get comparable shapes in rows 7:8.  Annual imports from RSP and No New DER are rows 13:19.  Figure 1 is on Hist. and Forecast tab.  Heat rate calculations for IRP are on row 1110 of tab “Portfolio Analytics” in files **Attch\_E\_** and **Attch\_F\_**  **RESOLVE\_Results\_Viewer…xlsb** | Raw SERVM heat rates start off higher than 2019 historical and rise slowly; Scarcity-adjusted heat rates start lower and rise quickly.  Trend in historical data and all non-SERVM forecasts is generally downward (except for dry years such as 2015 and 2018; and years when Diablo Canyon Nuclear Generation is retiring (2024-2026; RESOLVE did not run for 2025 so first year with Diablo fully retired is 2026). Imports are lower in No New DER case, refuting E3’s suggestion in Workshop comments. |
| Figure 2: Historical and forecasted hourly heat rate shapes | **Attch\_G\_**  **SERVM\_vs\_2018\_2019\_Heat\_Rates.xlsb**  Raw data and hourly scarcity adjustment calculations are on tab “2018-2030 Data and Calcs”, with gas and GHG prices for 2018-2019 in tab “Gas+GHG”.  Historical NP-15 DA prices are columns H:I, with the erroneous 2019 prices used in ACC in column G (not used). Historical heat rates are in columns E:F, raw SERVM heat rates cols J:T.  Calculations for hourly scarcity (“Schourly”) adjustments are in columns V:BR, with month by hour heat maps of (historical; raw SERVM; scarcity SERVM; and schourly SERVM) prices for 2018, 2019, 2020, 2025 and 2030 above. Change cells W1 and W17 to change which year is displayed.  Calculations of approximate energy arbitrage “profit” (assuming 80% efficient battery, discharging in top 4 hours and charging in bottom five hours of each day if that yields net positive) are in columns BZ:CM, with a potential partial replacement for ACC Documentation’s Table 5 above the top/bottom hours calculations.  Calculated Schourly SERVM Heat Rates are in columns CO:CY, while SERVM Scarcity Heat Rates (which are calculated in file  **Attch\_H\_2020 ACC SERVM Prices v1a\_PGE.xlsx**) are in columns DA:DK.  On tab “Shapes and Duration Curves”, duration curves of historical and all three flavors of SERVM heat rates are in columns A:L, with graphs to the right.  Hourly average shapes of these data are in columns AK:BM, with graphs above and to the right. Figure 2 is bottom right. | Duration curves show increasing heat rates from 2020 through 2030 for all SERVM variants (raw, original scarcity adjusted, and schourly adjusted). Scarcity adjustments have a “kink” at a heat rate of approximately 8.5 in 2025 and especially 2030 results; corrections to raw data described above would probably generate a more reasonable curve, but would not fix the underlying problem.  All versions of SERVM prices (raw, original scarcity adjustments, and schourly adjustments) show increasing heat rates from 2020 through 2030. Joint IOUs therefore conclude that while schourly adjustments may be more realistic than the original scarcity adjustments, they will not fix the underlying problem of increasing SERVM heat rates over time.  Hourly shapes of all SERVM variants in all months displayed show flatter prices than in historical data, with higher heat rates than historical data especially mid-day and after the evening peak. Schourly adjustments are less flat and do not show unrealistic extension of the peak, but have unrealistically-high heat rates around the 8am mini-peak in some months. |
| NP-15 Ancillary services prices, in particular Regulation | **Attch\_I\_**  **Historical\_vs\_SERVM\_AncillaryServices.xlsb**  Historical energy heat rates and A/S heat rates (A/S prices divided by gas+GHG) are in columns E:F and J:K, P:S; modeled historical regulation prices based on the piecewise linear model are in columns T:Y; and modeled ratios and regulation forecasts are in columns AD:AO.  Correlations between A/S and energy heat rates are in cells H1:P3.  Parameters of the piecewise linear model are in cells Q3:W3, objective function calculation is in cells X3:AB4.  12x24 heat maps appear to the right of these calculations and show that the proposed disaggregation algorithm yields patterns of A/S prices that fit historical patterns much better than those in the current ACC.  Objective function calculations (cut and pasted values) for original 50:50 split are in cells AG3:AK4. These show much lower correlations with historical prices (cells AJ3:AK4) than the piecewise linear model (cells AA3:AB4). | A/S forecast prices in 2020 and beyond are about 80% lower for spin and 70% lower for regulation than those experienced in 2018-2019for all forecast years, including 2020 (*i.e.,* before significant energy storage penetration).  Correlation between energy heat rate and Reg up heat rate in NP-15 was positive in 2018 and 2019, but negative for SERVM forecasts in 2020 and 2025; while the correlation between energy heat rate and reg down heat rate was negative in 2018 and 2019 but is positive for SERVM forecasts in 2020 through 2030. Thus, the pattern of regulation prices modeled via SERVM in the ACC model is generally *opposite* to the pattern observed in recent years. |