Appendix G3d

Hydropower, Energy Grid, and Export Energy Analyses for the Proposed Voluntary Agreements

G3d.1 Introduction

This appendix describes the results for estimating energy effects of changes in hydrology and changes in water supply associated with the proposed Voluntary Agreements (VAs), including hydropower generation in the Sacramento River watershed and Delta eastside tributaries regions (Sacramento/Delta), an analysis of grid reliability, and energy required for conveyance of CVP and SWP exports.[1]

Appendix A5, *Hydropower, Energy Grid, and Export Energy Analyses*, describes background information and the methodology used to estimate energy effects for the 35, 45, 55, 65, and 75 model scenarios (the proposed Plan amendments, Low Flow Alternative, and High Flow Alternative). The methodology used for assessing the proposed VAs is the same as for these scenarios. As a result, this appendix focusses on model results. See Appendix A5 for information regarding background and methodology for the energy analysis.

G3d.2 Estimated Changes in Hydropower Generation in the Sacramento/Delta

G3d.2.1 Changes in Hydropower Generation Estimated Based on SacWAM Results

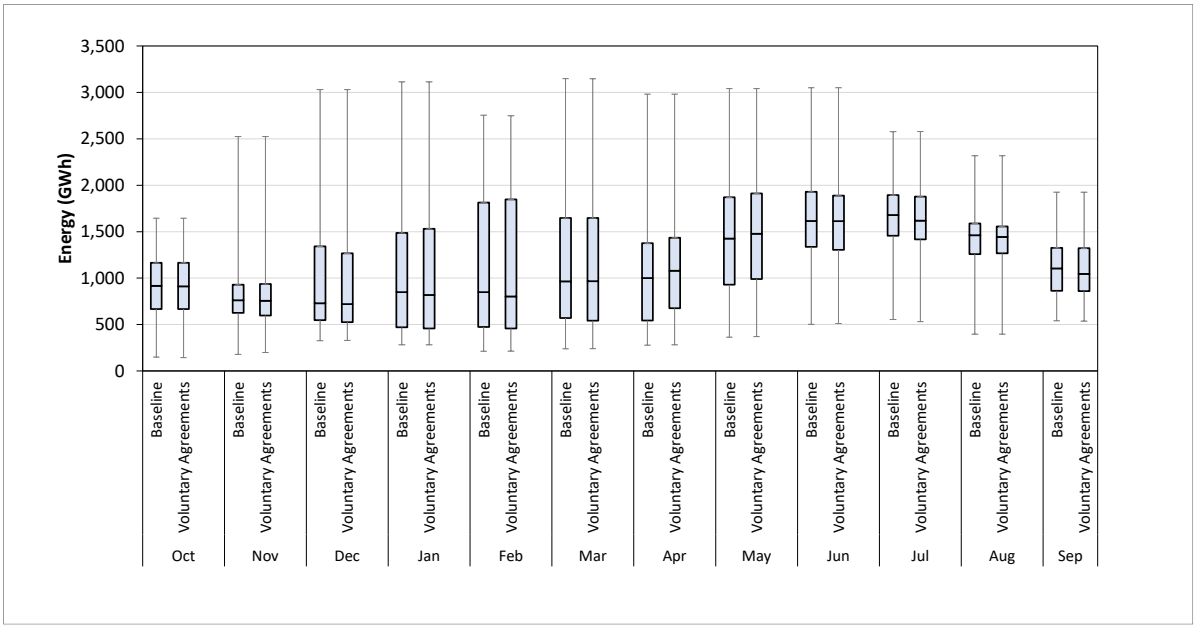
In general, the proposed VAs include flow assets that would generally be provided in January through June, but the timing varies by tributary system and flows may be shaped in timing and seasonality to test biological hypotheses and to respond to hydrologic conditions. Under baseline conditions, more of this water would be released from reservoirs at other times of the year, potentially causing a shift in the timing of some releases from some rim reservoir that could cause a slight shift in timing of hydropower generation.

As described in Chapter 9, *Proposed Voluntary Agreements*, the VAs include flow assets that would be provided through water purchase programs. The sources for the PWA Water Purchase Fixed Price Program are modeled in the Sacramento Water Allocation Model (SacWAM). However, the unspecified water purchases (Public Water Agency [PWA] Water Purchase Market Price Program and permanent state water purchases) would be from unspecified willing sellers, which could include inflow sources within the Sacramento/Delta watershed or reductions in exports, both of which could result in additional Delta outflows. These unspecified water purchases were not

[1] The Sacramento/Delta terminology is used here for brevity even though no hydropower generation occurs in the Delta. Hydropower generation in the Sacramento/Delta occurs upstream of the Delta in the Sacramento River watershed and Delta eastside tributaries region.

included in the SacWAM model run of the proposed VAs and therefore are not included in the basic hydropower calculations. They are included in an evaluation below in Section G3d.2.2, *Consideration of Proposed Voluntary Agreements Flow Assets Not Included in SacWAM*, to extrapolate total effect on the seasonal shift in hydropower generation associated with all VA assets combined.

Because the VA flow assets would represent a small fraction of total reservoir releases, the effect of the proposed VAs on hydropower is expected to be small, with percent change in Sacramento/Delta average monthly generation ranging from an increase of 6.0 percent in April to a decrease of 1.8 percent in September (Figure G3d-1, Table G3d-1), resulting primarily from changes in flow. Similarly, changes in average monthly hydropower generation by water year type show relatively small reductions and could range from increases of 16 percent in April of dry water years to decreases of 5 percent in September of below-normal water years (Table G3d-2).



Energy for baseline and proposed Voluntary Agreements was estimated with flow and storage simulated by SacWAM.
GWh = gigawatt hour

Figure G3d-1. Monthly Hydropower Generation at Sacramento/Delta Facilities

Table G3d-1. Average Monthly Hydropower Generation—Baseline Conditions and Change from Baseline Conditions (gigawatt hours)

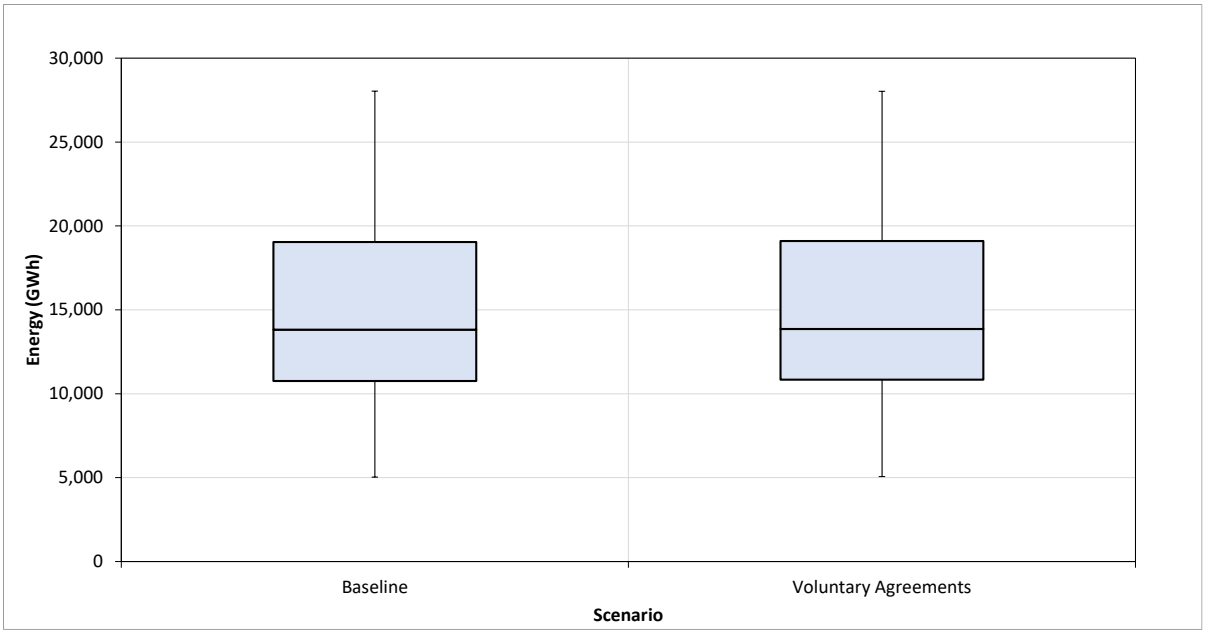
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	911	838	1,051	1,112	1,144	1,229	1,107	1,492	1,669	1,646	1,406	1,096
Proposed Voluntary Agreements	907	830	1,035	1,106	1,137	1,229	1,173	1,538	1,658	1,622	1,400	1,076
Difference	-4	-8	-16	-6	-7	0	66	46	-11	-24	-5	-20
Percent difference	-0.5	-0.9	-1.5	-0.5	-0.6	0.0	6.0	3.1	-0.7	-1.4	-0.4	-1.8

Table G3d-2. Average Monthly Hydropower Generation by Water Year Type—Baseline Conditions and Change from Baseline Conditions

Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline (GWh)												
C	928	641	547	385	357	429	422	671	995	987	865	746
D	892	778	695	544	603	723	676	1,021	1,421	1,481	1,280	890
BN	944	803	767	824	936	873	967	1,373	1,666	1,775	1,525	1,050
AN	820	815	913	1,348	1,523	1,663	1,223	1,744	1,699	1,782	1,500	1,280
W	936	1,018	1,817	2,001	1,936	2,067	1,832	2,250	2,206	1,986	1,676	1,386
Change from Baseline (GWh)												
C	-10	-1	-11	-10	-5	-11	10	19	-8	5	-7	-5
D	-5	-4	-20	-11	-11	9	111	85	-7	-26	11	-15
BN	-6	-14	-8	-9	-22	-1	127	84	-23	-43	-24	-54
AN	4	-12	-26	-2	-2	-8	123	64	-30	-38	-14	-36
W	-3	-9	-15	2	1	2	0	0	-1	-19	-2	-3
Percent Change from Baseline												
C	-1.1	-0.1	-1.9	-2.5	-1.4	-2.6	2.3	2.8	-0.8	0.5	-0.8	-0.7
D	-0.6	-0.5	-2.9	-2.1	-1.8	1.2	16.4	8.3	-0.5	-1.8	0.9	-1.7
BN	-0.6	-1.7	-1.1	-1.1	-2.3	-0.1	13.1	6.1	-1.4	-2.4	-1.6	-5.2
AN	0.5	-1.5	-2.9	-0.1	-0.2	-0.5	10.1	3.7	-1.8	-2.1	-0.9	-2.8
W	-0.3	-0.9	-0.8	0.1	0.0	0.1	0.0	0.0	0.0	-0.9	-0.1	-0.2

Water year type: AN = above normal; BN = below normal; C = critical; D = dry; W = wet
GWh = gigawatt hour

Annually, hydropower effects would be relatively small because the total volume of water running off the watersheds would not change, and reservoir storage is not expected to be greatly reduced. Hydropower calculations based on SacWAM results indicate minimal increases in average annual hydropower generation, 11 gigawatt hours on average (Figure G3d-2, Table G3d-3).



Energy for scenarios was estimated with flow and storage simulated by SacWAM.
GWh = gigawatt hour

Figure G3d-2. Annual Hydropower Generation for Sacramento/Delta Facilities

Table G3d-3. Cumulative Distribution of Annual Hydropower Generation—Baseline Conditions and Change from Baseline Conditions

Percentile	Baseline	Proposed Voluntary Agreements Minus Baseline (GWh)	Proposed Voluntary Agreements Percent Difference from Baseline (GWh)
0th	5,028	34	0.7
10th	8,729	52	0.6
25th	10,756	79	0.7
50th	13,820	43	0.3
75th	19,045	54	0.3
90th	22,044	-76	-0.3
100th	28,036	-5	0.0
Average	14,701	11	0.1

GWh = gigawatt hour

G3d.2.2 Consideration of Proposed Voluntary Agreements Flow Assets Not Included in SacWAM

Unspecified water purchases that were not included in the SacWAM modeling could contribute to a further shift in hydropower from summer through winter generation to spring generation. To understand the possible magnitude of this additional effect, the volume of the flow assets that would be provided through unspecified water purchases were compared to the portion of the tributary flow assets modeled in SacWAM that could contribute to a shift in timing of hydropower generation: assets from the Sacramento River, Feather River, Yuba River, American River, Mokelumne River, Putah Creek, and the PWA fixed price water purchases from the Sacramento Valley (Table G3d-4).

As modeled in SacWAM, export reductions, including reductions associated with PWA fixed price purchases of south-of-Delta water, were modeled by reducing spring exports. Spring releases from reservoirs did not need to be increased for the export reductions; consequently, summer water supply is not expected to have been affected. As such, the export reductions modeled in SacWAM likely contributed little to the shift in timing of hydropower generation.

Table G3d-4. Proposed Voluntary Agreements Flow Assets That Could Affect Seasonal Timing of Hydropower Generation That Were and Were Not Included in SacWAM

Water Year Type	Modeled in SacWAM (TAF)[a]	Unspecified Water Purchases (Not Modeled in SacWAM) (TAF)[b]
C	37	65
D	271	158
BN	241	69
AN	243	135
W	0	123

Water year type: AN = above normal; BN = below normal; C = critical; D = dry; W = wet
TAF = thousand acre-feet
[a] Sacramento, Feather, Yuba, American, and Mokelumne Rivers; Putah Creek; and the PWA fixed price water purchases from the Sacramento Valley.
[b] Public Water Agency market price water purchases plus permanent state water purchases.

To roughly extrapolate the effect of the unspecified water purchases, which were not included in SacWAM, to the hydropower calculations based on SacWAM results, the following steps were taken.

- Estimate the effect of each 100 thousand acre-foot (TAF) increment of VA asset on changes in monthly hydropower generation. This was done by calculating the ratio of change in monthly hydropower generation (shown in Table G3d-2) to 100 TAF of VA flow assets modeled in SacWAM that could affect timing of hydropower (values in Table G3d-4). This ratio was calculated for each month-water year type combination for dry, below-normal, and above-normal water year types.
- Use these ratios to calculate the additional change in hydropower generation that might be associated with the unspecified water purchases. Because the VA assets for critical water years and wet water years modeled in SacWAM were so small or nonexistent, the dry water year ratios were used for critical water years and the above-normal water year ratios were used for wet water years.
- Add this additional change to the original change in generation estimated by the hydropower calculations based on SacWAM results.

The result is an expansion of the values in Table G3d-2 to the values shown in Table G3d-5. This extrapolation causes spring increases in generation to increase to up to 26 percent (April of dry water year types). Change in summer generation is of more concern than change during other times of the year because peak demand for electricity occurs in summer. The extrapolated percent reduction values shown in Table G3d-5 for summer months remain largest for below-normal water years in September (6.7 percent).

Table G3d-5. Average Monthly Hydropower Generation by Water Year Type—Baseline Conditions and Change from Baseline Conditions Expanded to Account for Unspecified Water Purchases Not Simulated by SacWAM

Water Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline (GWh)												
C	928	641	547	385	357	429	422	671	995	987	865	746
D	892	778	695	544	603	723	676	1,021	1,421	1,481	1,280	890
BN	944	803	767	824	936	873	967	1,373	1,666	1,775	1,525	1,050
AN	820	815	913	1,348	1,523	1,663	1,223	1,744	1,699	1,782	1,500	1,280
W	936	1,018	1,817	2,001	1,936	2,067	1,832	2,250	2,206	1,986	1,676	1,386
Change from Baseline (GWh)												
C	-11	-2	-15	-13	-8	-9	36	39	-10	-1	-4	-9
D	-8	-6	-31	-18	-17	14	176	134	-12	-41	18	-24
BN	-7	-18	-11	-12	-28	-2	163	107	-30	-56	-30	-70
AN	6	-18	-41	-3	-4	-12	192	99	-47	-60	-22	-56
W	-1	-15	-28	1	0	-2	63	33	-16	-38	-9	-21
Percent Change from Baseline												
C	-1.2	-0.3	-2.8	-3.3	-2.2	-2.1	8.6	5.9	-1.0	-0.1	-0.5	-1.2
D	-0.9	-0.7	-4.5	-3.3	-2.9	1.9	26.0	13.1	-0.8	-2.8	1.4	-2.7
BN	-0.8	-2.2	-1.4	-1.5	-3.0	-0.2	16.9	7.8	-1.8	-3.1	-2.0	-6.7
AN	0.7	-2.3	-4.4	-0.2	-0.2	-0.7	15.7	5.7	-2.8	-3.3	-1.5	-4.4
W	-0.1	-1.5	-1.5	0.1	0.0	-0.1	3.4	1.4	-0.7	-1.9	-0.6	-1.5

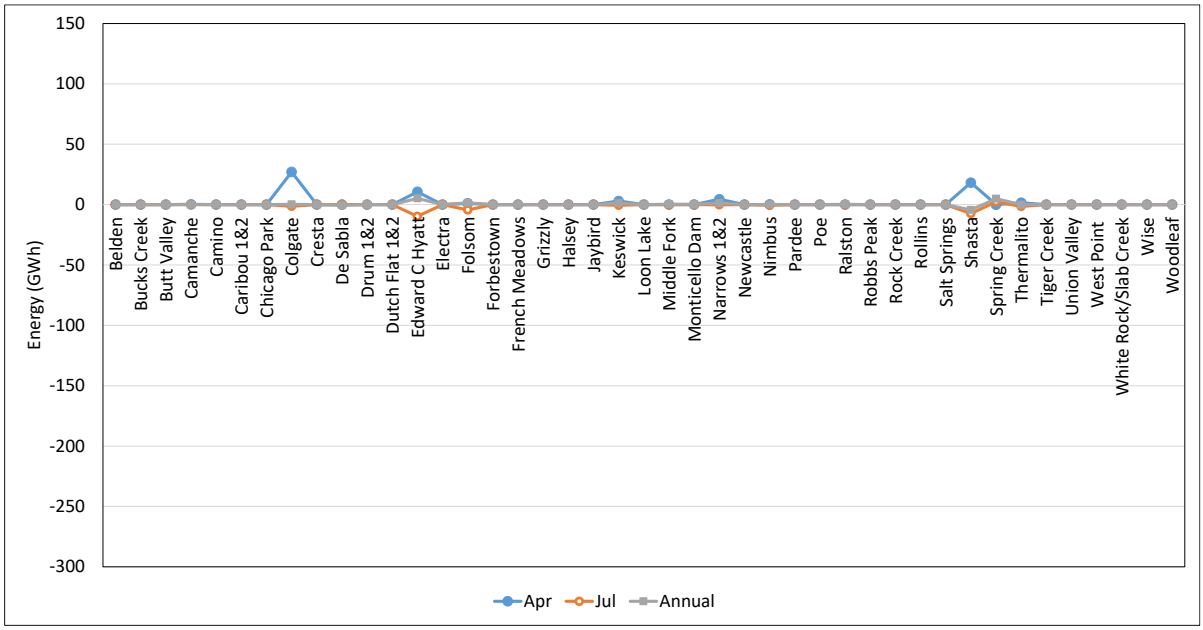
Water year type: AN = above normal; BN = below normal; C = critical; D = dry; W = wet
GWh = gigawatt hour

G3d.2.3 Effects at Individual Facilities

The largest changes in flow and hydropower would be expected to occur on VA tributaries at the rim reservoirs and downstream. As discussed above, the SacWAM model run of the proposed VAs does not assume any VA assets from unspecified water purchases given the unknown origin of these water purchases. Because unspecified water purchases could be provided by additional Delta inflows from Sacramento/Delta tributaries, there could be some additional changes in streamflows and reservoir levels beyond the modeled changes. Effects of unspecified water purchases on hydropower cannot be assessed for individual facilities. In addition, it is possible that some upstream reservoirs could be reoperated on some tributaries. Upstream effects were not modeled, but significant changes in upstream tributary or reservoir operations would be unlikely. The effect of unspecified water purchases on hydropower generation at individual facilities is unlikely to show a substantially different pattern from what was modeled (i.e., the net effect on annual average hydropower generation would be minimal), although there could be minor effects at additional facilities and increases in seasonal differences.

To show which facilities are expected to be most affected based on SacWAM model results, a summary of average changes at each of the facilities evaluated is provided in a figure that shows results for April (the month with the largest increases in hydropower generation), July (the summer month with the largest decreases in average hydropower generation with energy reductions similar to September), and the annual total (Figure G3d-3). As expected, based on facility size and location, the most noticeable changes occur at Shasta, Oroville (Hyatt Powerhouse), New Bullards Bar

(Colgate Powerhouse), and Folsom Reservoirs. Hydropower effects also occur at hydropower facilities downstream of these facilities (i.e., Keswick, Nimbus, Thermalito, Narrows 1+2). In addition, there could be a small increase in hydropower generation at Spring Creek Powerplant because of small operational changes resulting from changes in Lake Shasta operations. These effects at individual facilities are relatively small and are smaller than those estimated for the 35 scenario (see Figure A5-16 in Appendix A5, *Hydropower, Energy Grid, and Export Energy Analyses*). The largest reduction in average July generation, 10 GWh at Hyatt Powerplant, represents only 3.4 percent of the average July baseline generation of 295 GWh for this facility.

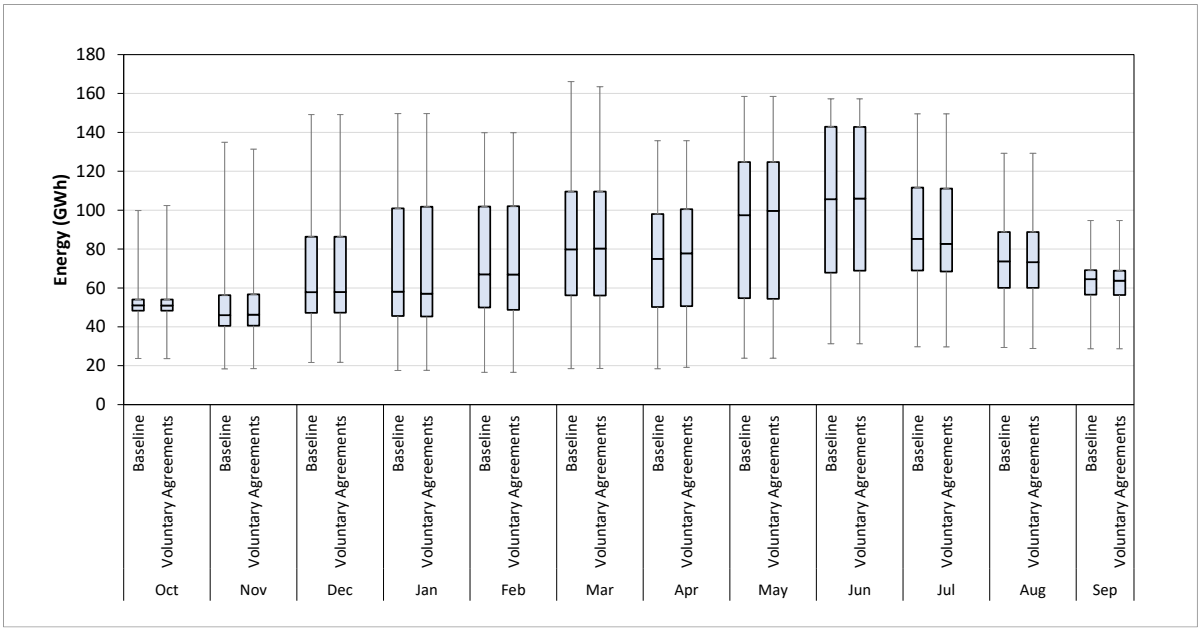


GWh = gigawatt hour

Figure G3d-3. Estimated Average Change in Hydropower Generation for the Proposed Voluntary Agreements at Individual Hydroelectric Facilities

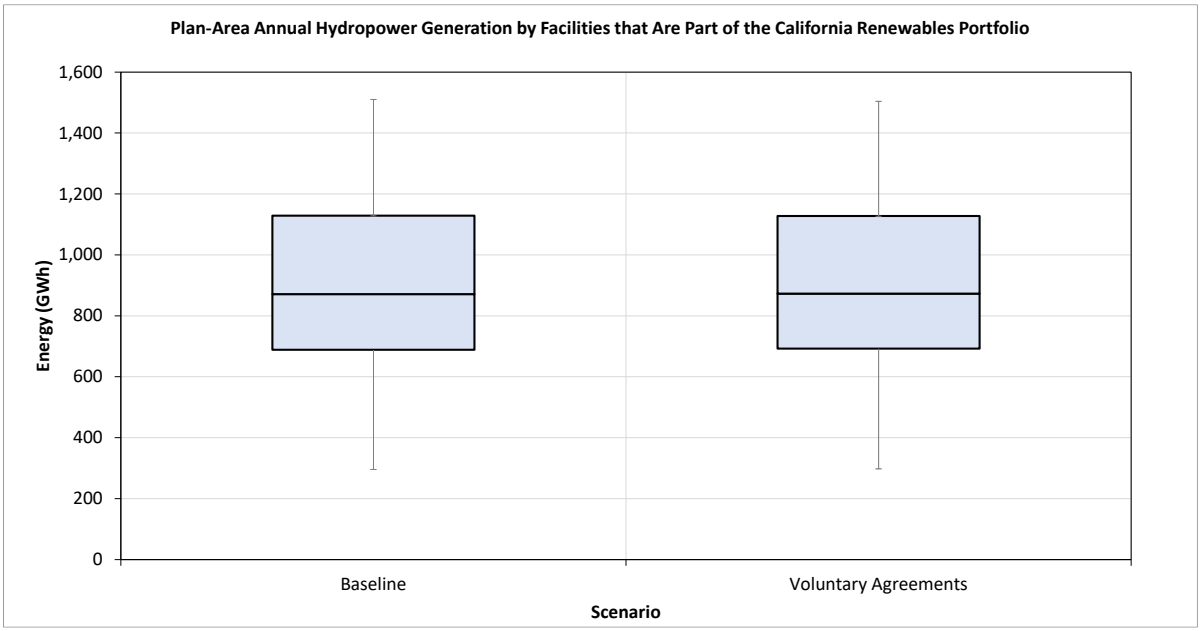
G3d.2.4 Effects at Small Hydropower Facilities That Contribute to the California Renewables Portfolio Standard

Generation at small hydropower facilities is important because it contributes to attainment of the Renewables Portfolio Standard (RPS), whereas generation at the larger facilities does not. As described in Appendix A5, *Hydropower, Energy Grid, and Export Energy Analyses*, generation at 16 of the 20 small hydropower facilities that contribute to the RPS (Table A5-5) were estimated with SacWAM results. VA hydropower effects at these 16 powerhouses represented in SacWAM are minimal as shown in Figure G3d-4 (monthly changes in hydropower generation), Figure G3d-5 (annual changes in hydropower generation), and Table G3d-6 (cumulative distribution of annual hydropower generation). Because estimated average annual effects of the VAs on hydropower generation at small hydropower facilities is zero, effects at the other small hydropower facilities in the Sacramento/Delta region that contribute to the RPS and effects associated with the unspecified water purchases also are expected to be minimal.



GWh = gigawatt hour

Figure G3d-4. Monthly Changes in Hydropower Generation at Sixteen Renewables Portfolio Standard Facilities with Flows Represented in SacWAM



GWh = gigawatt hour

Figure G3d-5. Annual Hydropower Generation at Sixteen Renewables Portfolio Standard Facilities with Flows Represented in SacWAM

Table G3d-6. Cumulative Distribution of Annual Hydropower Generation at Sixteen Facilities That Contribute to the California Renewables Portfolio Standard (gigawatt hours)

Percentile	Baseline	Proposed Voluntary Agreements Change from Baseline
0th	295	2
10th	562	-1
25th	688	4
50th	871	2
75th	1,129	-1
90th	1,271	1
100th	1,510	-6
Average	904	0

G3d.3 Energy Grid Analysis

As described in Appendix A5, *Hydropower, Energy Grid, and Export Energy Analyses*, Power Gem's Transmission Adequacy and Reliability Assessment (TARA) software was used to compare electrical grid reliability violations under the 75 scenario to baseline conditions. The 75 scenario was chosen for analysis because it has the largest instream flow requirement and would result in the largest reductions in reservoir storage (head) and the largest changes in flow for hydropower (see Section A5.2, *Hydropower Generation in the Sacramento/Delta*). The analysis of the 75 scenario used estimated hydropower generation for July of below-normal years because the largest reduction in summer hydropower generation in association with the 75 scenario occurred for this month and water year type and because July is a period of peak energy demand. With the VAs, results for July of below-normal years also show higher reductions in energy production compared with other months, with only the September values of below-normal years being slightly greater (Table G3d-2).

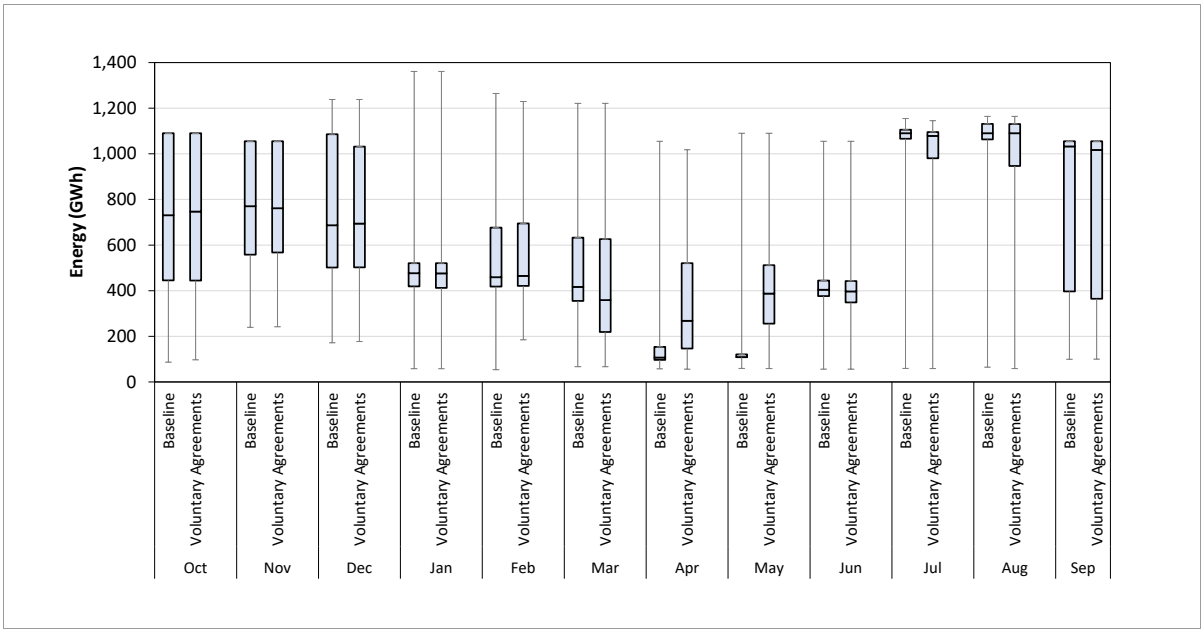
The 75 scenario did not cause reliability criteria violations under normal system conditions and did not cause reliability criteria violations at the transmission lines or substation transformers under the contingency scenarios that could not be rectified with a temporary increase in generation at natural gas facilities. Electricity generation at other facilities was able to compensate for a reduction in hydropower in the Sacramento/Delta. Because reductions in summer hydropower generation for the VAs would be far less than the reductions associated with the 75 scenario (average reduction in July generation during below-normal water year types of 43 GWh for the proposed VAs and 752 GWh for the 75 Scenario), the VAs are not expected to cause any violations of reliability criteria. With expansion of the July VA value for below-normal years to include unspecified water purchases, the estimated reduction of 43 GWh becomes 56 GWh (Table G3d-5), remaining well below the energy reduction for the 75 scenario.

G3d.4 Estimated Changes in Energy Use for SWP and CVP Export Pumping

A large amount of energy is required to pump CVP and SWP Delta exports uphill, and only a portion of this energy can be recaptured when some of the water drops in elevation on its way to its final destination. Potential energy effects associated with changes in CVP and SWP exports from the Delta through the Jones and Banks Pumping Plants were estimated using the energy factor methodology described in Appendix A5, *Hydropower, Energy Grid, and Export Energy Analyses*.

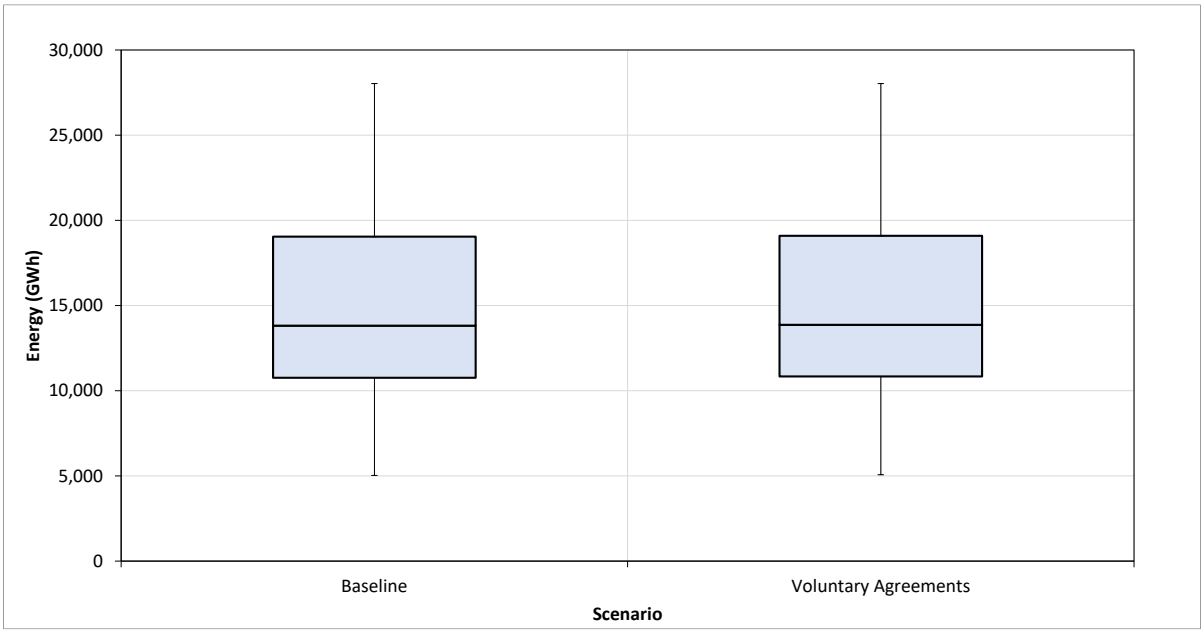
As estimated by SacWAM (i.e., without inclusion of unspecified water purchases), changes in hydrology associated with the VAs could result in small increases in water exports for the SWP and CVP. The estimated average annual increase in exports is 86 TAF, about 1.7 percent of baseline exports. The increase in exports would be largest during April and May, which could result in increased energy needs to convey CVP and SWP water during these months (Figure G3d-6). As a result of increased exports, the average annual energy needed to convey CVP and SWP could increase modestly (149 GWh/year) relative to the average annual energy of 7,393 GWh needed to convey baseline exports from the Delta (Figure G3d-7, Table G3d-7).

The actual change in exports associated with the proposed VAs is uncertain because some of the unspecified water purchases could cause reductions in exports that were not included in SacWAM. This could occur if unspecified water purchases come from water destined for Delta exports under baseline conditions. The Statewide Agricultural Production (SWAP) model indicates that more than half of the unspecified water purchases could come from Sacramento/Delta water originally destined be used in the San Joaquin Valley. If all unspecified water purchases were to come from Delta exports, as is evaluated with the High Export Cut scenario described in Chapter 9, *Proposed Voluntary Agreements*, average exports would decrease. In addition, simulated increases in exports associated with the proposed VAs are largely driven by the assumption in the VA scenario that the import to export (I:E) constraints are removed from the biological opinions and Incidental Take Permit but not from the baseline. In the absence of a shifting regulatory environment, the proposed VAs are expected to cause an average reduction in exports, which would reduce the energy needed for conveyance.



GWh = gigawatt hour

Figure G3d-6. Estimated Monthly Changes in Energy Required for CVP and SWP Exports Based on SacWAM Simulation of Delta Exports



GWh = gigawatt hour

Figure G3d-7. Estimated Annual Changes in Energy Required for CVP and SWP Exports Based on SacWAM Simulation of Delta Exports

Table G3d-7. Cumulative Distribution—Baseline Condition Energy for CVP and SWP Exports and Changes from Baseline Condition (gigawatt hours)

Percentile	Baseline	Proposed Voluntary Agreements Change from Baseline
0th	2,219	-22
10th	3,676	67
25th	6,090	201
50th	7,562	145
75th	8,785	466
90th	10,364	357
100th	12,919	-66
Average	7,393	149