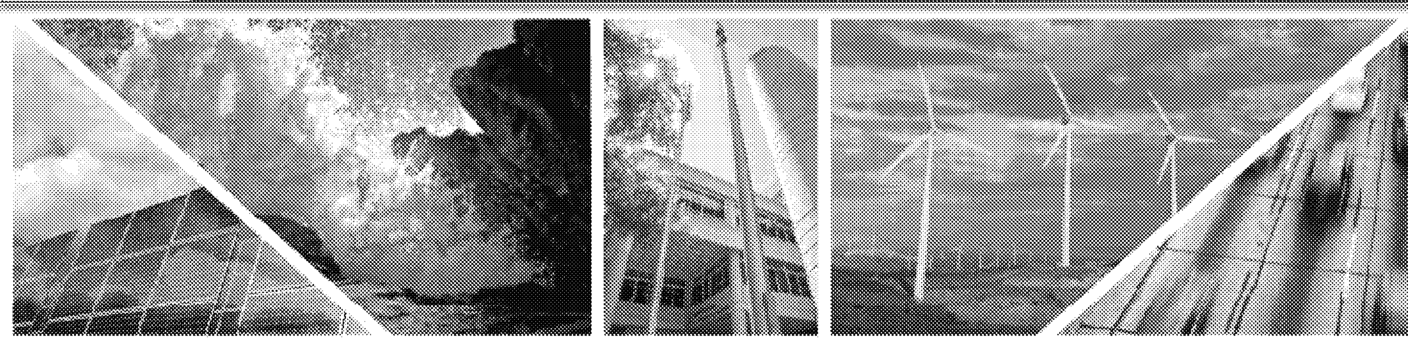
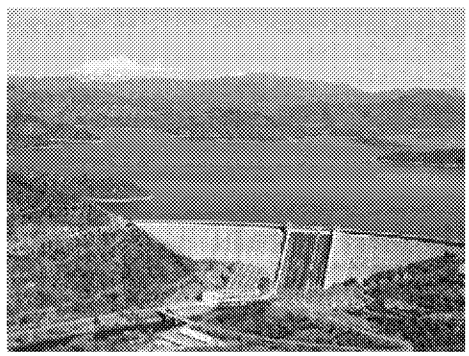


Hydroelectric Power in California



Hydroelectric power is a major source of California's electricity. In 2017, hydroelectric power plants produced approximately 43,333 megawatt-hours (MWH) of electricity, or 21 percent of the total in-state electricity generation, up from 14 percent in 2016. The amount of hydroelectricity produced varies each year, and is largely dependent on rainfall.

Drought Impacts

In 2014, the Energy Commission began tracking conditions affecting generation from hydroelectric resources due to the ongoing drought which started in 2012. Lower than expected precipitation and snowpack conditions reduced electricity generation from hydroelectric resources. That put pressure on utilities to make short-term market purchases, increase generation from existing natural gas-fired resources, and rely on renewables and imports to make up for the shortfall. In 2015, generation from hydroelectric resources was at the lowest level since 2001 and declined by 44 percent compared to hydroelectric generation in 2012. Recovery from the drought began in late 2016, as greater than normal precipitation brought much needed relief to the state's water supply system which was approaching near record-low conditions. Further, record precipitation and snowpack conditions in early 2017 restored the state to above normal hydrological conditions with major reservoirs filled to capacity.

Lower than expected precipitation late in 2017 and 2018 renewed concerns that drought like conditions had returned. To gauge the potential impact of below normal hydrological conditions on hydroelectric generation, Energy Commission staff has made use of the following sources of data:

- Quarterly Fuel and Energy Report (QFER) power plant generation data which contains data on fuel consumption and electricity generation from in-state power plants that are 1 MW;
- the Department of Water Resources' (DWR) Bulletin 120 report (B120) which is issued each month between February and May, and provides a rolling update of expected precipitation and snowpack conditions for major watersheds;
- DWR's water year index which classifies each water year into one of five categories including wet, above normal, below normal, dry, and critical.

Data from QFER and DWR is combined to estimate a relationship between historical generation and hydrological conditions by watershed using linear regression. Linear regression is a statistical method to predict the value of a dependent variable based on values of several independent variables. A variety of variables were tested and examined for fit to historical data based on statistical tests. Some hydroelectric generation facilities are not directly located in a watershed but instead are part of the broader water supply and management infrastructure (such as canals and aqueducts) and take advantage of their relative position in the system to generate electricity. These facilities were not considered in this analysis. Further, pumped hydro storage facilities are also excluded since these facilities generate based on electricity prices and so their generation would not necessarily correlate well with hydrological conditions.

2018 Preliminary Results

Related Websites

- FERC - Federal Energy Regulatory Commission
- U.S. Dept of Agriculture - Natural Resources Conservation Service
- U.S. Fish and Wildlife Service
- U.S. Fish and Wildlife Service, Yreka, California Office - Klamath Hydro Page

Related Links

- Map of California Hydroelectric Power Plants

While the early part of 2018 was off to a slow start, record precipitation and snowpack levels by March dramatically changed the outlook with storage in reservoirs ending at slightly above normal by May. While hydrological conditions improved substantially compared to conditions earlier in the year, water year 2018 will still have below normal hydrological conditions compared to an average water year, renewing concerns about expected generation from hydrologic resources. Hydrological conditions for water year 2018 will be significantly below water year 2017 since water year 2017 was a wet year. On a statewide basis, the expected precipitation for water year 2018 is 75% of average while the expected precipitation for water year 2017 was 170% of average. Recently, the California Independent System Operator (California ISO), which manages roughly 80 percent of the state's electric load in its balancing area, issued a report which notes a decrease in both capacity and energy from hydroelectric resources due to below normal precipitation and snowpack. The conclusion reached by the California ISO's report is in line with staff's assessment of hydrological data from DWR.

Figure 1 and Table 1 below show the 2018 projected generation by watershed along with historical average generation and the most recent historical generation data. Projected 2018 hydroelectric generation will be below normal compared to average hydroelectric generation by major watershed, though several watersheds will be slightly above normal and some watersheds will be close to their normal level of generation. In an average year, the top five watersheds account for nearly 70 percent of the total statewide hydroelectric generation. It is clear from Figure 1 that generation in 2017 was significantly above normal conditions and that the projected generation for 2018 will be below both the 2017 reported generation and the average generation for most watersheds.

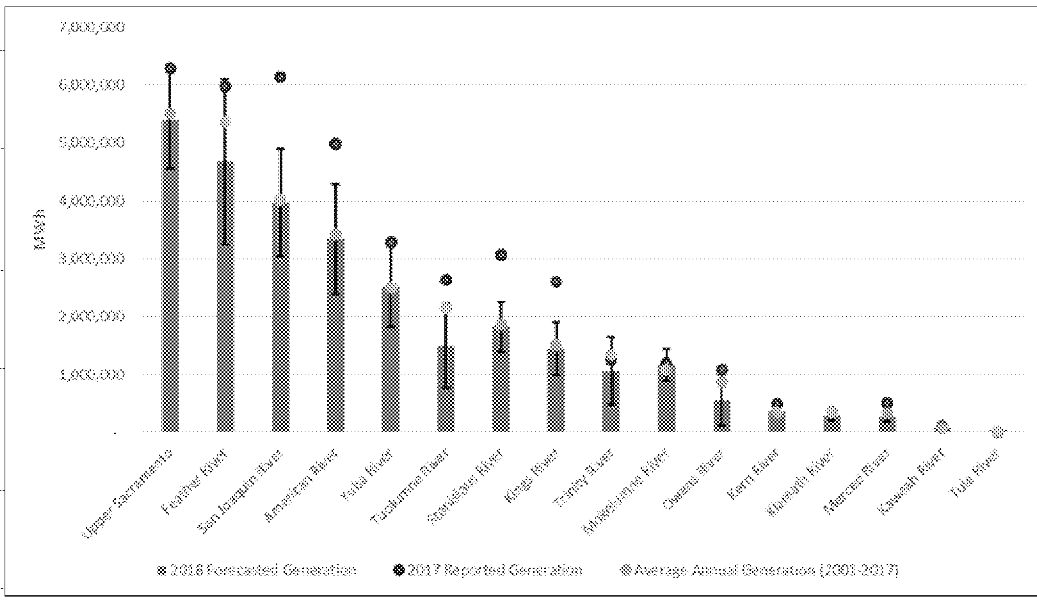


Figure 1 -- May 2018 Version: Hydroelectric Generation Summary by Watershed

May 2018 Version: Watershed Projected Hydroelectric Generation in 2018 by Comparison to Average and 2017 Actual Generation Data						
Watershed Areas	Average Annual Generation (2001-2017, MWh)	Cumulative Total Generation by Watershed - Based on Average Annual Generation (%)	2017 Reported Generation (QFER, MWh)	CEC Estimated 2018 Generation (May 1 18, MWh)	2017 Generation as Percent of Average Annual Generation	2018 CEC Estimated Generation as Percent of Average Annual Generation
Upper Sacramento	5,502,973	17.9%	6,298,753	5,405,818	114%	98%
Feather River	5,373,215	35.4%	5,980,274	4,681,813	111%	87%
San Joaquin River	4,031,400	48.5%	6,137,827	3,975,812	153%	99%
American River	3,459,472	59.6%	4,979,499	3,393,997	144%	98%
Yuba River	2,487,204	67.7%	3,233,567	2,520,987	130%	101%
[illegible]	2,137,426	74.7%	2,638,793	1,496,350	123%	[illegible]
Stanislaus River	1,865,279	80.8%	3,062,333	1,825,889	164%	98%
Kings River	1,506,510	85.7%	2,608,545	1,448,913	173%	96%
Trinity River	1,382,781	90.0%	1,245,809	1,054,095	90%	76%
Mokelumne River	1,066,613	93.6%	1,197,186	1,160,653	112%	109%
[illegible]	858,598	96.4%	1,085,764	559,206	126%	[illegible]
Kern River	343,300	97.5%	490,680	382,459	143%	111%
Klamath River	340,852	98.6%	362,735	284,435	106%	83%
Merced River	303,375	99.7%	508,025	270,767	167%	89%
Kaweah River	73,535	99.9%	107,199	77,558	146%	105%
Tule River	35,834	100.0%	8,171	37,299	23%	104%
Total	30,732,066		40,005,154	28,521,050	130%	93%
						>=100%
						75% to <100%
						[illegible]

Table 1 -- May 2018 Version: Watershed -- Projected Hydroelectric Generation in 2018

Table 2 depicts that hydroelectric generation is also expected to be below normal for major electric transmission balancing areas.

May 2018 Version: Balancing Area Projected Hydroelectric Generation in 2018 W/ Comparisons to Average and 2017 Actual Generation Data					
Balancing Authority	Average Annual Generation (2002-2017, MWh)	2017 Reported Generation (QFER, MWh)	CEC Estimated 2018 Generation May 1 UF, MWh)	2017 Generation as Percent of Average Annual Generation	2018 CEC Estimated Generation as Percent of Average Annual Generation
CAISO	20,885,522	29,261,130	19,708,382	140%	94%
BANC	5,992,841	8,692,162	5,652,563	145%	94%
[redacted]	549,459	862,551	382,869	157%	[redacted]
[redacted]	440,624	826,575	286,979	188%	[redacted]
Total	**27,868,446**	**39,642,419**	**26,030,792**	**142%**	**93%**
					>=100%
					75% to <100%

Table 2 – May 2018 Version: Balancing Area – Projected Hydroelectric Generation in 2018

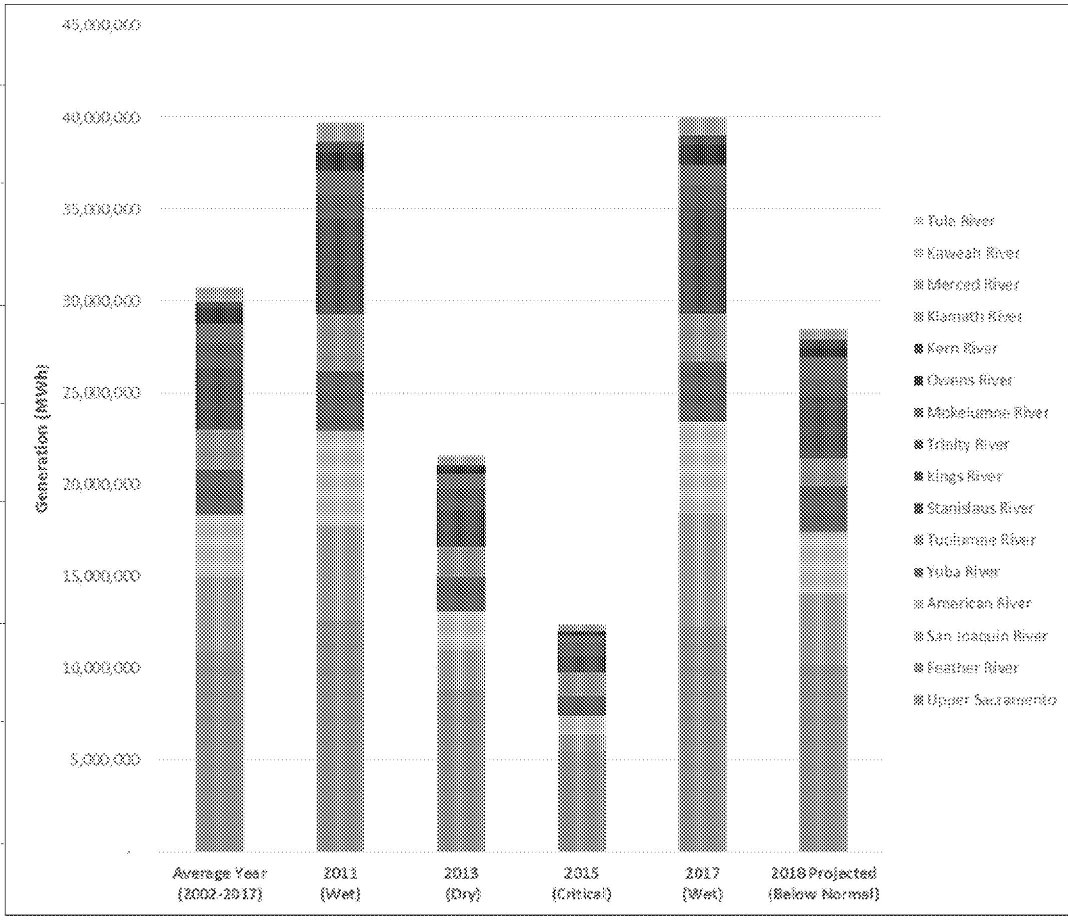


Figure 2 – May 2018 Version: Statewide Hydroelectric Generation by Watershed

Figure 2 depicts how hydrological conditions impact total statewide hydroelectric generation relative to normal year conditions. In 2011 and 2017, both years considered a wet year, record precipitation significantly impacted hydroelectric generation in large watersheds along with higher levels of generation from relatively smaller watersheds. In 2015, the fourth year of a sustained drought, total hydroelectric generation from all sixteen watersheds was only slightly above the expected generation from the top two watersheds for an average year, indicating the severity of the prolonged drought period on hydroelectric generation.

Historically, California has seen above-average precipitation totals for one water year followed by a below-average water year. Those below-average water years have yielded near-average amounts of hydroelectric generation for the next calendar year. Most-likely, this can be attributed to above-normal reservoir levels as a result of the previous year's abundant precipitation.

Hydroelectric Facilities

Hydro facilities are broken down into two categories:

- Facilities larger than 30 MW of generation capacity are called "large" hydro.
- Facilities smaller than 30 MW of generation capacity are considered "small" hydro and qualify as renewable under the Renewables Portfolio Standard.

California has 269 hydro generation plants, which are mostly located in the eastern mountain ranges and have a total nameplate capacity of about 14,000 MW.

The state also imports approximately 15 percent of its hydro-generated electricity from the Pacific Northwest and the Southwest. The larger hydro plants on dams in California (such as Shasta [pictured], Folsom and Oroville) are operated by the U.S. Bureau of Reclamation and the state's Department of Water Resources. Smaller hydro plants are operated by utilities, mainly Southern California Edison, Pacific Gas and Electric Company and the Sacramento Municipal Utility District.

Three types of conventional hydroelectric facilities are:

- Dams (pondage) which raise the water level of a stream or river to an elevation necessary to create a sufficient elevation difference. Dams can be constructed of earth, concrete, steel or a combination of such materials. Dams may create secondary benefits such as flood control, recreation opportunities and water storage;
- Run-of-river, or water diversion which divert water from a natural channel to a course with a turbine, and then usually return the water to the channel downstream of the turbine;
- Pumped storage facility where water is pumped during off-peak demand periods from a reservoir at a lower elevation for storage in a reservoir at a higher elevation. Electricity is then generated during peak demand periods by releasing the pumped water from the higher reservoir and allowing it to flow downhill through the hydraulic turbine(s) connected to generators. During the off-peak pumping cycle, the pumped storage facility is a consumer of electricity. In fact, the amount of electricity required to pump the water uphill is greater than the amount of electricity that is generated when the water is released during peak demand periods. Pumped storage facilities, however, can be economical and beneficial to the electricity system because they consume low-cost off-peak electricity and generate high-value on-peak electricity.

Such conventional methods offer the potential for low-cost electricity, but their output is dependent on the time of year as well as annual precipitation. By contrast, pumped storage methods are typically used to provide power during peak demand periods on very short notice and are not solely dependent on runoff. Pumped storage methods include both typical on-stream conventional and modular off-stream technologies. The major differences between modular pumped storage (MPS) and conventional pumped storage is that MPS systems are much smaller, use closed water systems that are artificially created instead of natural waterways or watersheds, and sites are selected with predetermined elevation differences so that modular pre-engineered equipment can be used. With the exception of evaporative losses, reservoirs are charged only once, either with groundwater or even municipal wastewater.

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