

Date of Hearing: April 2, 2025

ASSEMBLY COMMITTEE ON UTILITIES AND ENERGY

Cottie Petrie-Norris, Chair

AB 443 (Bennett) – As Introduced February 6, 2025

SUBJECT: Energy Commission: integrated energy policy report: curtailed solar and wind generation: hydrogen production

SUMMARY: Requires the California Energy Commission (CEC) to assess, as specified, the potential for using curtailed solar and wind generation to produce hydrogen. Specifically, **this bill** requires the assessment:

- 1) Be part of the CEC’s 2027 edition of the integrated energy policy report (IEPR).
- 2) Provide an estimate of monthly solar and wind generation curtailment and whether that curtailment is due to excess generation or lack of transmission capacity.
- 3) Identify regions of the state where curtailment is occurring and assign whether the curtailment is due to excess generation or a lack of transmission capacity.
- 4) Provide estimates of how much hydrogen could feasibly and reliably be produced from curtailed solar and wind energy, and identify policy actions to optimize the curtailed generation for hydrogen production.
- 5) Be repealed on January 1, 2029.

EXISTING LAW:

- 1) Establishes the California Independent System Operator (CAISO) governing board with five members appointed for three-year terms by the governor and subject to confirmation by the Senate. (Public Utilities Code § 337 et seq.)
- 2) Charges CAISO with management of the transmission grid and related energy markets in order to ensure the reliability of electric service and the health and safety of the public. (Public Utilities Code § 345.5)
- 3) Establishes the policy that 100% of the state's retail electricity be supplied with a mix of Renewables Portfolio Standard (RPS)-eligible and zero-carbon resources by December 31, 2045 and 100% of electricity procured to serve all state agencies by December 31, 2035, for a total of 100% clean energy. Sets interim targets of 90% by December 31, 2035, and 95% by December 31, 2040. (Public Utilities Code § 454.53)
- 4) Requires retail sellers and publicly owned utilities (POUs) to increase purchases of renewable energy such that at least 60% of retail sales are procured from eligible renewable energy resources by December 31, 2030. This is known as the RPS. (Public Utilities Code § 399.11 et seq.)
- 5) Permits the California Public Utilities Commission (CPUC) to waive enforcement of the RPS if it finds that the retail seller (usually the utility) has demonstrated conditions beyond the control of the seller, including “unanticipated curtailment of eligible

renewable energy resources” so long as the CPUC RPS waiver would not “result in an increase in greenhouse gas emissions.” (Public Utilities Code § 399.15 (b)(5)(C))

- 6) Permits the CPUC to prohibit, upon a complaint made by a geothermal energy producer, any electrical corporation from curtailing the generation, production, or transmission of electricity from a geothermal powerplant, if the CPUC deems such curtailment is not in the public interest. (Public Utilities Code § 782)

BACKGROUND:

California’s Supply of Renewable Resources – According to the CEC, in 2023 total generation for California was 281,141 gigawatt-hours (GWh). Approximately 58% was due to zero-carbon generation (nuclear, large hydroelectric, and renewables), while 17% and 11%, respectively, were solely from solar and wind generation,¹ as shown in Table 1 below.

Table 1: 2023 Total System Electric Generation²

Fuel Type	In state Generation (GWh)	% in state	Total Imports (GWh)	Total Energy Mix (GWh)	% of Total Mix
Coal	257	0.12	4,724	4,981	1.77
Natural Gas	94,192	43.68	8,582	102,774	36.56
Oil	36	0.02	0	36	0.01
Other (Waste Heat / Petroleum Coke)	206	0.10	0	206	0.07
Unspecified	-		10,373	10,373	3.69
Biomass	5,037	2.34	753	5,790	2.06
Geothermal	10,999	5.10	2,569	13,567	4.83
Large Hydro	27,066	12.55	5,821	32,886	11.70
Nuclear	17,714	8.22	8,558	26,272	9.34
Small Hydro	4,853	2.25	135	4,988	1.77
Solar	41,344	19.17	6,525	47,869	17.03
Wind	13,920	6.46	17,479	31,399	11.17
Total Zero Carbon	120,933	56.09	41,840	162,771	57.90
California Total	215,623			281,141	

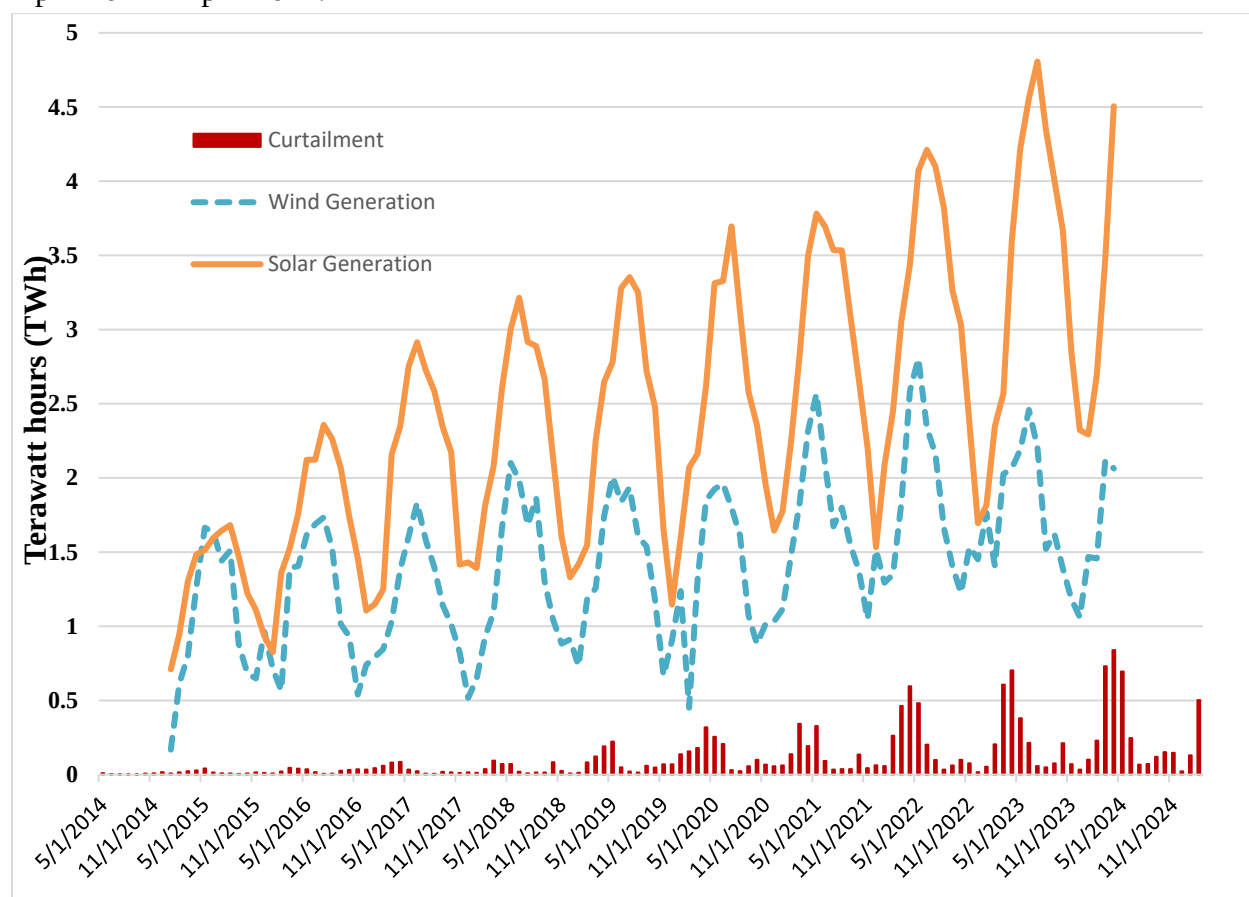
The Curtailment Landscape – Grid operators must constantly match the amount of power being produced (supply) with the amount of power needed to run homes and businesses (demand) to

¹ CEC “2023 Total System Electric Generation;” website; accessed 03.25.2025; <https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2023-total-system-electric-generation#:~:text=In%202023%2C%20total%20generation%20for,percent%20in%202022.%20California's%20wide>

² Reproduced from Citation #1

prevent the grid from overloading. During the middle of the day, California’s renewable resources, especially solar generation facilities, sometimes generate more electricity than is needed to serve demand. For those resources in the CAISO market, the market automatically reduces,³ or curtails, the renewable generation to match supply with demand. Renewable curtailment occurs most frequently in spring and fall when supply is high due to California’s characteristic sunny and breezy climate, but demand is low due to that same moderate climate. Such conditions produce an abundant supply of solar and wind generation, as shown in Figure 1.⁴ Curtailment, therefore, is the deliberate reduction in generator output – either through negative market prices or a direct order to reduce output – below what would have otherwise been produced.

Figure 1: CAISO reported monthly metered generation of solar (orange, solid line) and wind (blue, dashed line),⁵ alongside monthly curtailment of solar and wind combined (red bars)⁶ from April 2014 - April 2024.



³ Often by reducing the resource price to below zero, making the generator pay to put electrons on the grid.

⁴ Solar is the majority of the energy curtailed in CAISO: 95% in 2022 and 94% in 2023;
<https://www.eia.gov/todayinenergy/detail.php?id=60822>

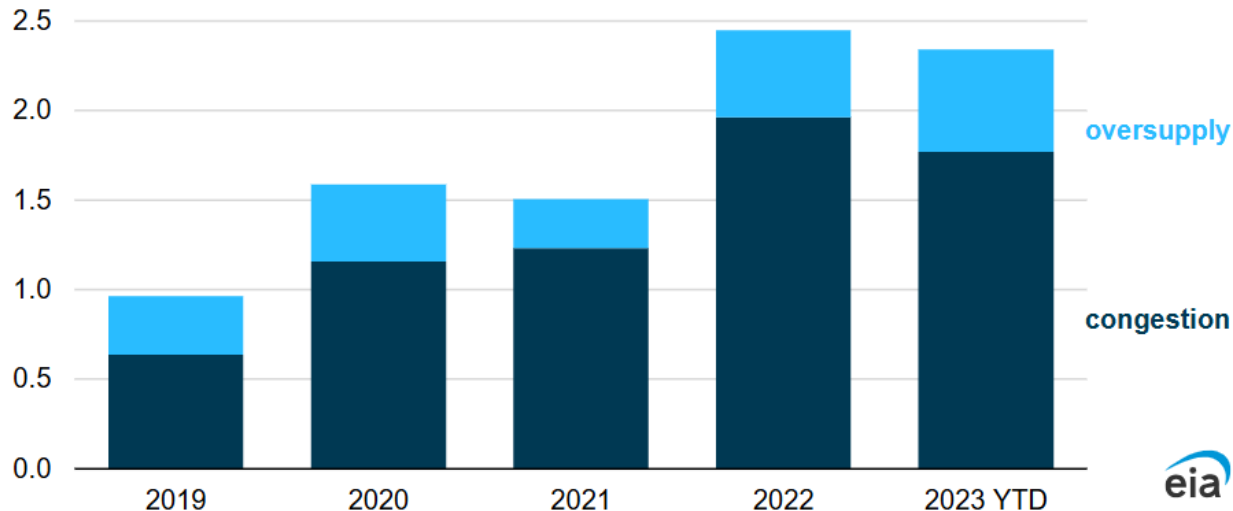
⁵ CAISO Monthly Metered Renewable Generation data, in terawatt-hours; last accessed 03.25.2025;
<https://www.caiso.com/documents/monthlyrenewablesperformancereport-apr2024.html>

⁶ CAISO wind and solar curtailments data, in terawatt-hours; last accessed 03.30.2025;
<https://www.caiso.com/about/our-business/managing-the-evolving-grid#renewable-curtailment>

Curtailment is a common operational tool. Yet, as increasing amounts of renewable generation come online without commensurate amounts of demand to consume generation midday, oversupply conditions will continue to occur. As also shown in Figure 1, over the last decade both solar and wind generation and curtailment have increased. However, the proportion of curtailment relative to generation has grown over the last decade. While only a little more than 0.4% of total wind and solar production were curtailed in 2015, that number has grown to a little more than 4% curtailed in 2023;⁷ representing a 900% increase in under a decade. In recent years, during spring months those percentages can reach 12-13% of monthly wind and solar generation curtailed.⁸ These high percentages of curtailment seem to suggest more than just oversupply conditions are occurring.

Oversupply vs. Congestion – Today’s solar and wind resources can often generate electricity at almost zero cost. These generators can bid negative prices (i.e., pay someone) to use their clean electricity when supply exceeds demand. Generators are motivated to do this because they only gain access to federal production tax credits and accrue renewable energy credits (RECs) when they produce energy.⁹ In these circumstances, the tax credits and sale of RECs are worth more than the negative market price.¹⁰

Figure 2: Curtailment by cause: sky blue (oversupply) and navy blue (congestion); CAISO 2019-Sept 2023 (million MWh)¹¹



⁷ Averaging over the entire year’s wind+solar generation and wind+solar curtailment.

⁸ In March and April of 2023 and 2024 – see CAISO source data in Citations #3 and #4.

⁹ Melody Peterson, “Solar power glut boosts California electric bills. Other states reap the benefits.” *LA Times*; November 24, 2024; <https://www.latimes.com/environment/story/2024-11-24/california-has-so-much-solar-power-that-increasingly-it-goes-to-waste>

¹⁰ Mohit Chhabra, “Feasting on the Glut: Putting Renewable Curtailment in Context,” *NRDC Blog*; December 4, 2024; <https://www.nrdc.org/bio/mohit-chhabra/feasting-glut-putting-renewable-curtailment-context>

¹¹ U.S. Energy Information Administration, “Solar and wind power curtailments are rising in California,” October 23, 2023; <https://www.eia.gov/todayinenergy/detail.php?id=60822>

The CAISO curtails renewables in these times of oversupply only if no one is willing to get paid to consume excess clean electricity. As shown in Figure 2, curtailment due to oversupply is around 30% of total curtailment.¹² The remaining curtailment is due to congestion: traffic jams in electric transmission lines. As shown in Figure 2, congestion related curtailments have increased significantly since 2019. The federal Energy Information Administration (EIA) notes this is due to solar generation development outpacing upgrades in transmission capacity.¹³ While curtailment is a loss of otherwise useful energy, it is important to note that to utilize the surplus power completely, often expensive and time-intensive methods are required, such as building new power lines or storage resources.

FISCAL EFFECT: Unknown. This bill is keyed fiscal and will be referred to the Assembly Committee on Appropriations for review.

CONSUMER COST IMPACTS: Unknown. This bill seeks to maximize existing renewable resources whose production would otherwise be reduced for the purposes of hydrogen production. Such an effort should maximize grid benefits, but is likely to still bear a cost to consumers for hydrogen production.

COMMENTS:

- 1) *Author's Statement.* According to the author, "California has done an amazing job trying to meet its clean energy goals with over 32,000 megawatts of installed renewable resources. This has meant that at times we have too much of a good thing and curtail our renewable resources. As we add more renewables, the problem of seasonally available electricity will grow, having too much in spring and summer while not enough in winter and fall. We must focus on how to harness this energy, and make best use of it. Having the California Energy Commission assess this issue and provide recommendations on how we can use curtailed energy to address long-term storage concerns using hydrogen just makes sense. AB 443 will give us all a better understanding of how to use and design our system to maximize the use of renewable resources."
- 2) *Benefits and Purpose.* This bill requires the CEC to assess the potential for using curtailed solar and wind generation to produce hydrogen, and specifically to estimate monthly solar and wind generation curtailment; identify regions of the state where curtailment is occurring; assign whether that curtailment is due to excess generation (oversupply) or lack of transmission capacity (congestion); and provide estimates of how much hydrogen could feasibly and reliably be produced from the curtailed solar and wind energy. While some elements of these assessments are available with public CAISO data, such as the monthly solar and wind generation curtailment (Figure 1) or curtailment causes (Figure 2), the granular data needed for a regional analysis called for in this bill

¹² U.S. Energy Information Administration, "Solar and wind power curtailments are rising in California;" October 23, 2023; <https://www.eia.gov/todayinenergy/detail.php?id=60822>

¹³ U.S. Energy Information Administration, "Solar and wind power curtailments are rising in California;" October 23, 2023; <https://www.eia.gov/todayinenergy/detail.php?id=60822>

could be highly valuable, especially given transmission congestion is the primary cause for curtailment. Moreover, the CAISO’s public databases label curtailments with vague reasons such as “local” or “system,”¹⁴ or label their generator outages as “transmission-induced;”¹⁵ this provides little clarity on whether incidents involve oversupply or congestion conditions. The bill also includes within the assessment areas and balancing authorities outside of CAISO – such as the Balancing Authority of Northern California¹⁶ and the Los Angeles Department of Water and Power – regions currently with little public visibility as to their curtailment volumes and causes.

- 3) *Harnessing the Negative.* As noted above, one of the key strategies to encourage curtailment – before CAISO issues a direct order to reduce output – is for the market to reduce resource prices to below zero, such that solar and wind farms are paying folks to take their power. These negative prices encourage putting clean electricity, which would otherwise be wasted, to good use. Through strategies such as the Western Energy Imbalance Market (WEIM), utilities outside the state may choose to meet their real-time demand with California’s solar, since our negative solar prices make their in-state resources more expensive. This not only reduces GHGs, as many of the replacement resources are fossil, but it also helps reduce system costs. According to CAISO, since 2024, the WEIM has helped mitigate total curtailment by 1%, with over \$6 billion in cumulative savings for participants.¹⁷

Negative prices are also a signal to battery storage developers that they can make money by storing excess clean electricity and then outbidding polluting power plants a few hours later. As battery storage prices keep decreasing,¹⁸ more batteries are likely to come online to harness this excess power. In fact, California has increased battery storage capacity by 1,250% in the last five years.¹⁹ And a growing share of new renewable contracts are for hybrid generators that pair solar or wind with storage.²⁰

¹⁴ CAISO Annual “Production and Curtailments Data” – 2025 source last accessed on 03.20.2025; <https://www.caiso.com/documents/production-and-curtailments-data-2025.xlsx>

¹⁵ CAISO “Curtailed and non-operational generator prior trade date report, March 28, 2025;” updated 03.29.2025; <https://www.caiso.com/documents/curtailed-non-operational-generator-prior-trade-date-report-20250328.xlsx>; full listing on <https://www.caiso.com/market-operations/outages/curtailed-and-non-operational-generators>

¹⁶ <https://thebanc.org/>

¹⁷ CAISO press release; “Western Energy Imbalance Market surpasses the \$6 billion benefit milestone;” October, 28, 2024; <https://www.caiso.com/about/news/news-releases/western-energy-imbalance-market-surpasses-the-6-billion-benefit-milestone>

¹⁸ Wesley Cole and Akash Karmakar; NREL; *Cost Projections for Utility-Scale Battery Storage: 2023 Update*; June 2023; <https://www.nrel.gov/docs/fy23osti/85332.pdf>

¹⁹ For a host of reasons, not just negative prices; Governor Newsom Office, press release; “California Achieves Major Clean Energy Victory: 10,000 Megawatts of Battery Storage;” April 2024; <https://www.gov.ca.gov/2024/04/25/california-achieves-major-clean-energy-victory-10000-megawatts-of-battery-storage/>

²⁰ Kavya Balaraman, “CAISO approves hybrid storage policies as California preps to add 1.5 GW by 2022; *Utility Dive*; November 24, 2020; <https://www.utilitydive.com/news/caiso-approves-hybrid-storage-policies-as-california-preps-for-addition-of/589609/>

But while battery and hybrid resource installations are growing, so is curtailment. Additional strategies to address curtailment, such as increasing transmission capacity or expanding market operations may take years to reach their potential. This bill proposes examining an additional option – treating hydrogen production as a battery, and harnessing the growing percentage of curtailed power to generate hydrogen fuel for later use.

- 4) *A Sense of Scale from the Back of the Envelope.* It takes roughly 50-55 kilowatt-hours to make 1 kilogram of electrolytic hydrogen.²¹ As shown in Figure 1, the total solar and wind curtailment in CAISO for 2023 was approximately 2.65 terawatt-hours.²² Harnessing every electron of that curtailed electricity would therefore generate roughly 50 million kilograms of electrolytic hydrogen per year.²³ (Assuming curtailment doesn't increase, which is unlikely.) This level of production is roughly a third of what California's Hydrogen Hub, ARCHES, intends to use per year.²⁴ In order for this curtailed energy to be fully captured, locational considerations and grid constraints must be considered; otherwise, local congestion issues might interfere with accessing the excess generation. This bill recognizes these complexities, in the hopes of maximizing curtailment opportunities, by having the CEC identify regions where the curtailment is occurring.
- 5) *What's in a Definition?* "Curtailment" appears, but is undefined, within the Public Utilities Code. This bill provides a definition of "curtailed solar and wind generation" to include the difference between the reduced solar and wind generation output and the amount of solar and wind energy that could be produced without demand or transmission constraints. While this bill's definition may capture some common understanding of "curtailment," the committee is unaware of how this definition compares to ones used by CAISO or the CEC in evaluating grid conditions. For example, the meaning of solar and wind energy "produced without demand" is unclear. The author may consider reflecting on the content and the necessity of the definition used in this measure.

6) *Prior Legislation.*

²¹ Bart Kolodziejczyk; "Seawater electrolysis: a hydrogen revolution or technological dud? Here are the numbers;" Sep. 29, 2023; *World Economic Forum*; <https://www.weforum.org/stories/2023/09/seawater-electrolysis-a-hydrogen-revolution-or-technological-dead-end-here-are-the-numbers/#:~:text=In%20perfect%20conditions%2C%20production%20of,50%20%E2%80%93%2055%20kWh/kg.>

²² CAISO wind and solar curtailments data, in terawatt-hours; last accessed 03.30.2025; <https://www.caiso.com/about/our-business/managing-the-evolving-grid#renewable-curtailment>

²³ (2.65TWh x 10⁹ kWh)/53 kWh

²⁴ ARCHES notes planned "use [of] over 400 metric tons per day;" 400 metric tons x 1000kg x 365 days = 146 million kg H₂/year.

<https://archesh2.org/publications/#:~:text=What%20is%20the%20scale%20of,or%20in%20our%20recent%20presentations.>

AB 1172 (Calderon) requires the CEC to evaluate various fusion technologies and to analyze the feasibility of using nuclear fusion in the state as part of its 2027 IEPR. Status: Chapter 360, Statutes of 2023.

SB 664 (Stern, 2023) among other provisions requires the CEC to include extreme weather events within the existing energy demand forecasts of the IEPR. Status: Vetoed, citing duplicating existing requirements.

AB 2587 (E. Garcia, 2022) requires the CEC to additionally include firm renewable energy resources in the IEPR. Status: Died – Senate Committee on Appropriations.

- 7) *Double Referral*. This bill is double referred. Should it pass out of this committee it will be referred to the Assembly Committee on Natural Resources for its consideration.

REGISTERED SUPPORT / OPPOSITION:

Support

Invenergy, LLC
Marin Clean Energy (MCE)

Opposition

None on file.

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