DESTINATION 2050
Juan Artega, Ph.D., ENVERUS
Andrew Chen, CIT Group
Mark Scherluebbe, EY Parthenon
Energy storage financials: What model makes the most sense?
POWERGEN INTERNATIONAL
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ERCOT Energy Storage
Shifting Strategies
Juan Arteaga, PhD
Sr Analyst Enverus Intelligence Research
juan.arteaga@enverus.com
February 2023

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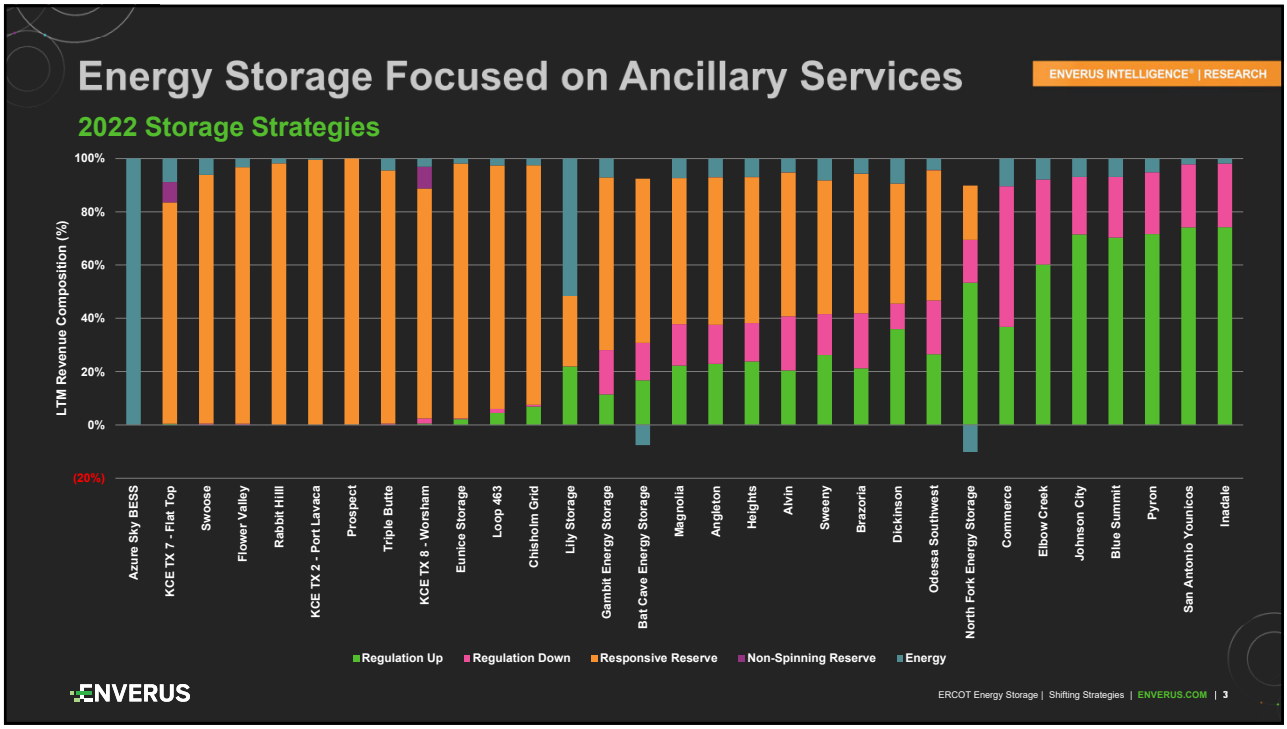
Energy Storage Focused on Ancillary Services
ENVERUS INTELLIGENCE® | RESEARCH
2022 Storage Strategies
LTM Revenue Composition (%)
100%
80%
60%
40%
20%
0%
(20%)
Azure Sky BESS
KCE TX 7 - Flat Top
Swoose
Flower Valley
Rabbit Hill
KCE TX 2 - Port Lavaca
Prospect
Triple Butte
KCE TX 8 - Worsham
Eunice Storage
Loop 463
Chisholm Grid
Lily Storage
Gambit Energy Storage
Bat Cave Energy Storage
Magnolia
Angleton
Heights
Alvin
Sweeny
Brazoria
Dickinson
Odessa Southwest
North Fork Energy Storage
Commerce
Elbow Creek
Johnson City
Blue Summit
Pyron
San Antonio Younicos
Inadale
Regulation Up
Regulation Down
Responsive Reserve
Non-Spinning Reserve
Energy
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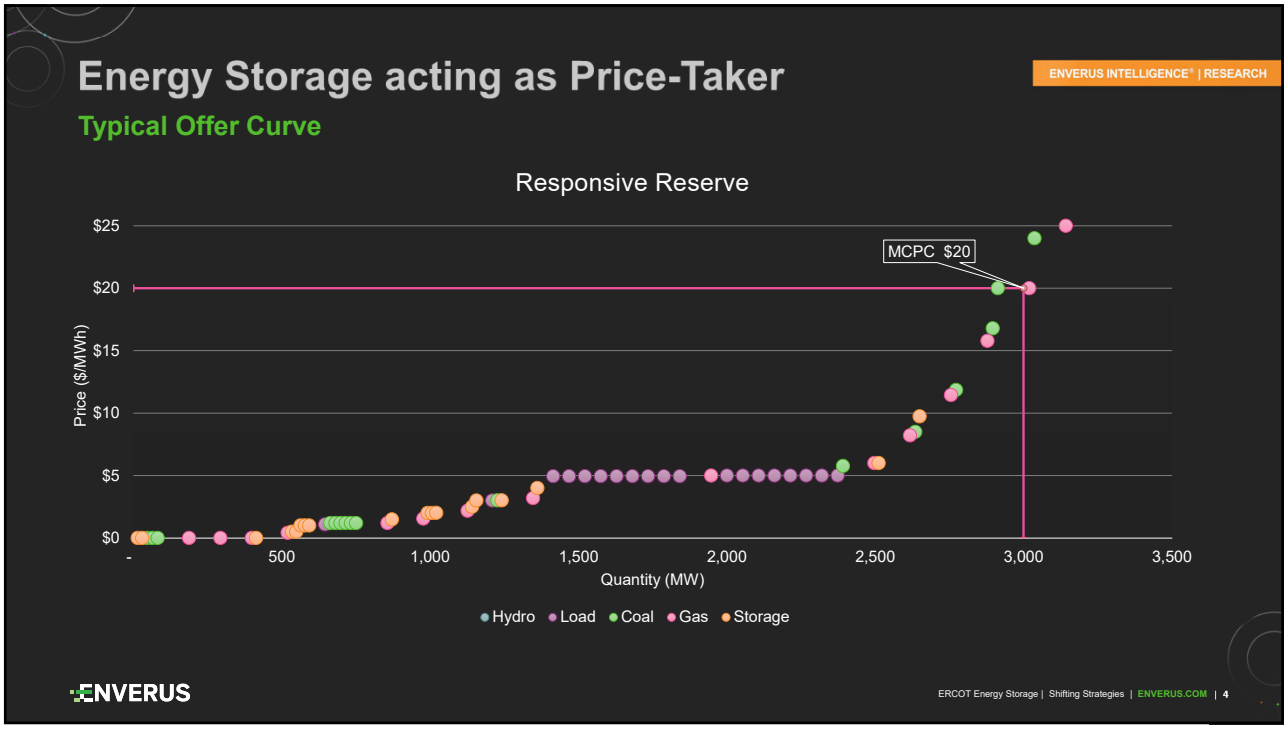
Energy Storage acting as Price-Taker
ENVERUS INTELLIGENCE® | RESEARCH
Typical Offer Curve
Responsive Reserve
MCPC $20
Price ($/MWh)
$25
$20
$15
$10
$5
$0
-
500
1,000
1,500
2,000
2,500
3,000
3,500
Quantity (MW)
Hydro
Load
Coal
Gas
Storage
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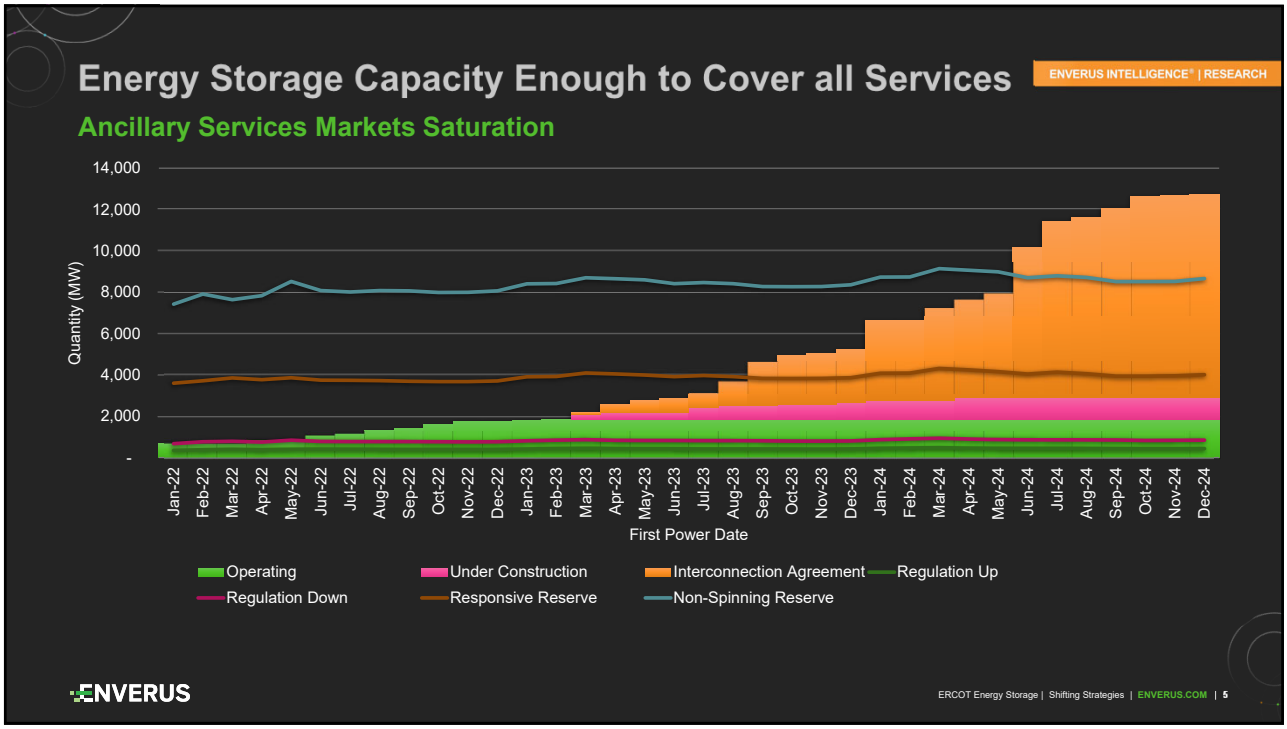
Energy Storage Capacity Enough to Cover all Services
ENVERUS INTELLIGENCE® | RESEARCH
Ancillary Services Markets Saturation
Quantity (MW)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Jan-22 Feb-22 Mar-22 Apr-22 May-22 Jun-22 Jul-22 Aug-22 Sep-22 Oct-22 Nov-22 Dec-22 Jan-23 Feb-23 Mar-23 Apr-23 May-23 Jun-23 Jul-23 Aug-23 Sep-23 Oct-23 Nov-23 Dec-23 Jan-24 Feb-24 Mar-24 Apr-24 May-24 Jun-24 Jul-24 Aug-24 Sep-24 Oct-24 Nov-24 Dec-24
First Power Date
Operating
Under Construction
Interconnection Agreement
Regulation Up
Regulation Down
Responsive Reserve
Non-Spinning Reserve
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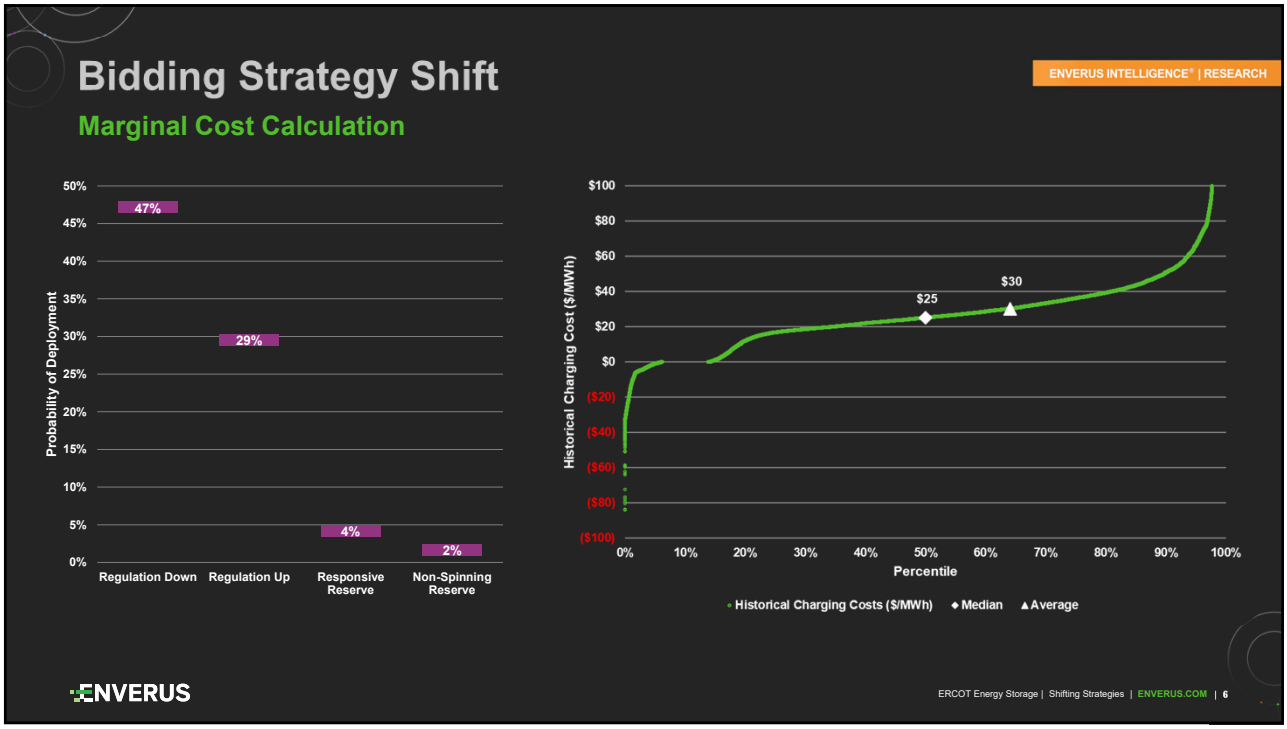
Bidding Strategy Shift
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Marginal Cost Calculation
Probability of Deployment
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
47%
29%
4%
2%
Regulation Down
Regulation Up
Responsive Reserve
Non-Spinning Reserve
Historical Charging Cost ($/MWh)
$100
$80
$60
$40
$20
$0
($20)
($40)
($60)
($80)
($100)
$25
$30
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Percentile
Historical Charging Costs ($/MWh)
Median
Average
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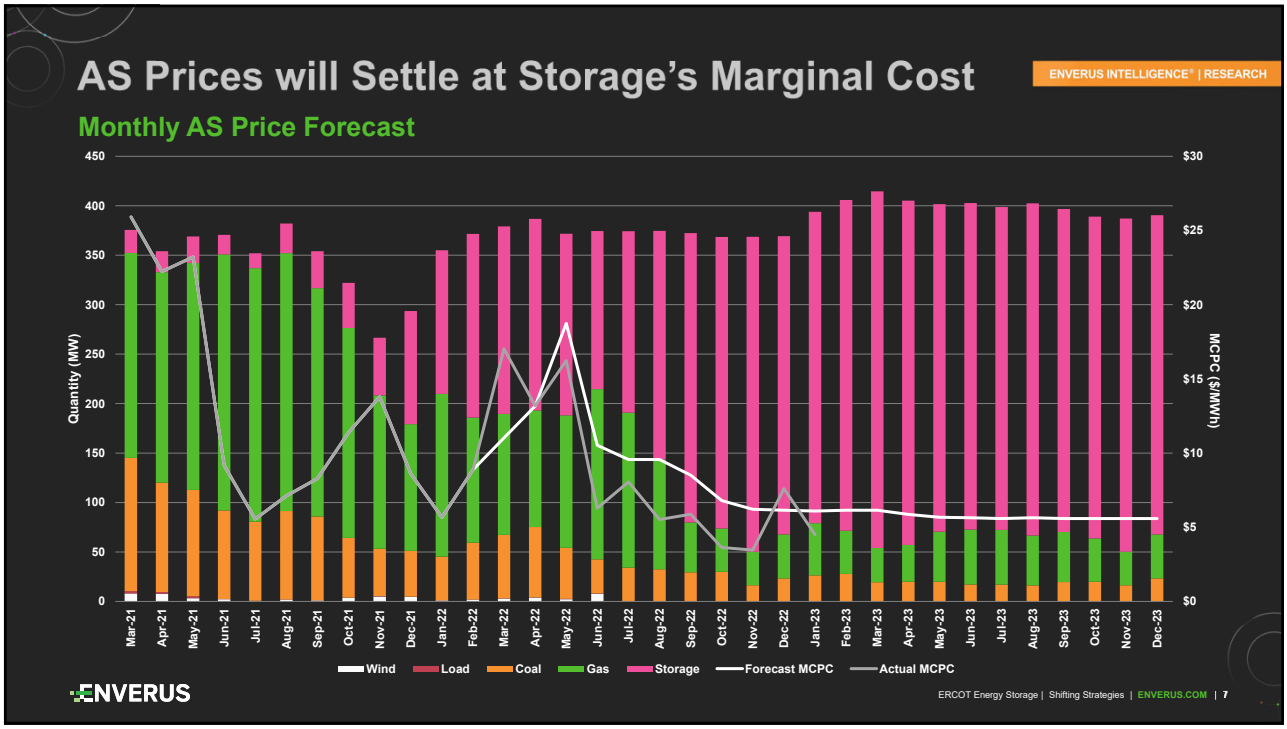
AS Prices will Settle at Storage's Marginal Cost
ENVERUS INTELLIGENCE® | RESEARCH
Monthly AS Price Forecast
Quantity (MW)
MCPC ($/MWh)
Wind
Load
Coal
Gas
Storage
Forecast MCPC
Actual MCPC
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Multiple Service Strategies get Better Returns
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Future Storage Strategies
ATAX Equity IRR (%)
41%
27%
36%
17%
Regulation
Reserve
Combo
Arbitrage
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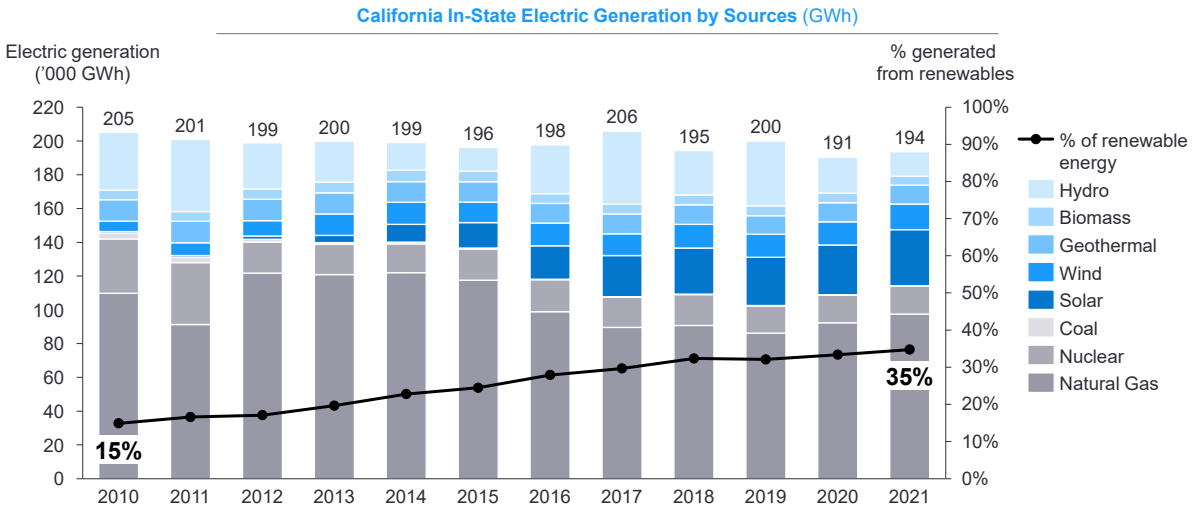
California has been a leader in renewable energy with ~35% energy generated from renewable sources in 2021, a significant increase from ~15% in 2010



Source: California Energy Commission

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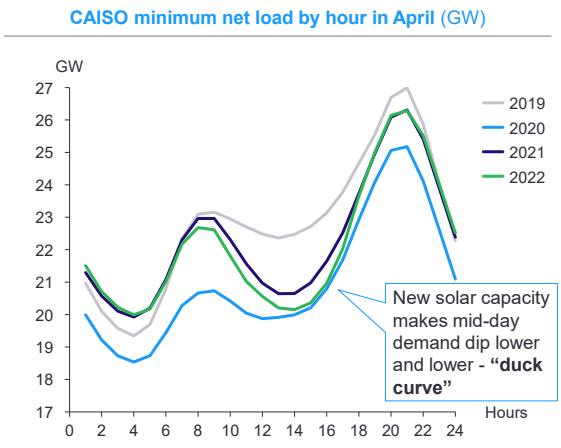
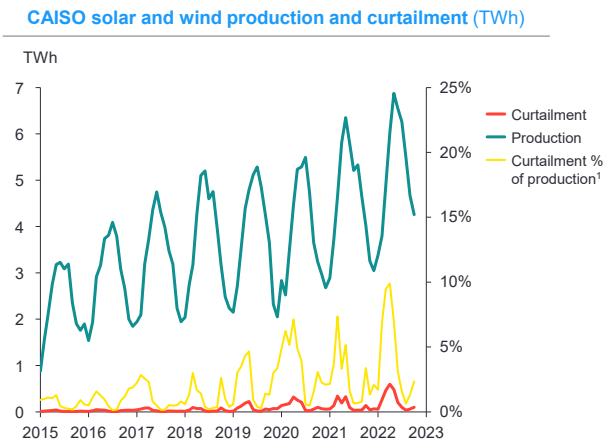
Rising penetrations of variable renewable energy in power systems have increased curtailments in California





The most common reason for curtailment in California is the excessive supply during low load periods

1. Curtailing % calculated by dividing curtailment and production each year

Source: CAISO

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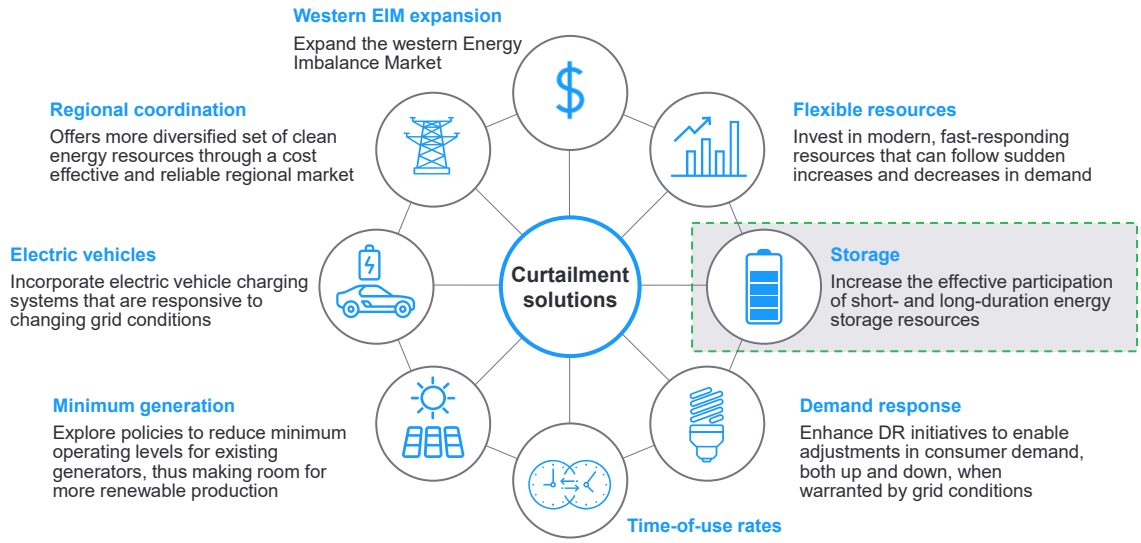
To minimize oversupply and curtailment, CAISO is working with stakeholders and state leaders to implement several solutions, including investing in energy storage



Source: CAISO

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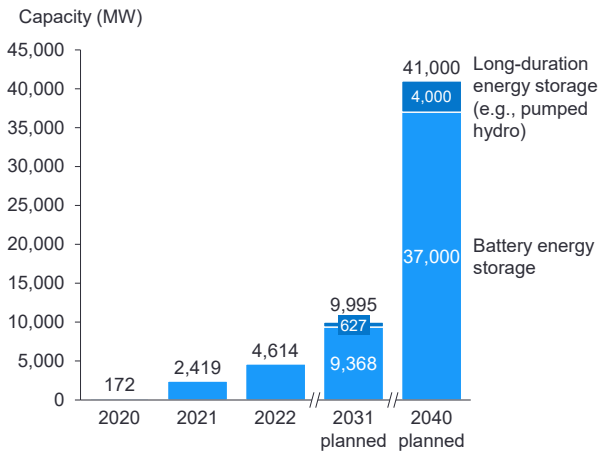
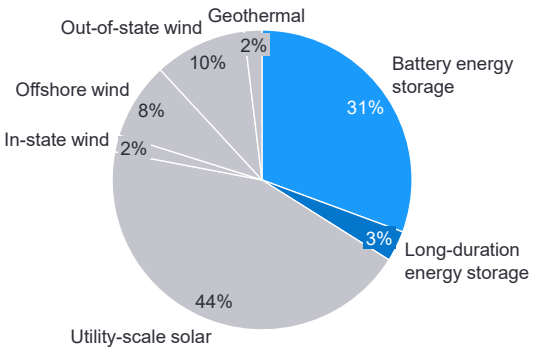
CAISO plans to continue aggressively investing in battery energy storage, while building out long-duration energy storage capacity by 2040

CAISO historical and planned energy storage capacity (MW)



Planned CAISO resource capacity by 2040 (% of total)



Source: CAISO 20-year Transmission Outlook; CAISO Key Statistics of 2022

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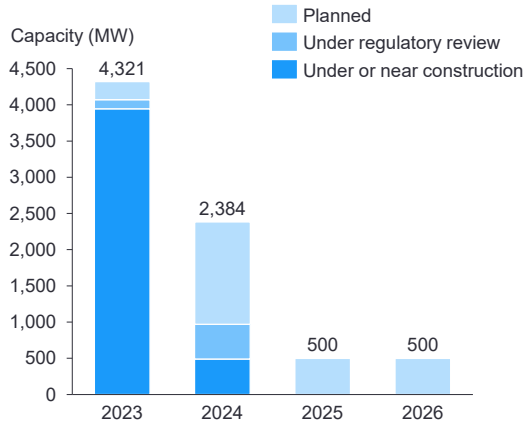
Significant progress towards CAISO's 2040 goal is expected in the near-term as utility-scale battery energy storage systems are developed

Energy storage partnerships in California

- PG&E's Tesla **megapack battery energy storage system (BESS)** entered operation in April 2022
  - It is the largest utility-owned lithium-ion system in the world
- Features 256 battery units with a capacity to store and dispatch up to **730 MWh** of electricity at **182.5 MW for up to 4 hours** during periods of high demand
- Energy Vault and PG&E entered partnership to deploy the largest U.S. **green hydrogen long-duration energy storage system** in 2024
- Energy Vault will own, operate, and maintain system and provide dispatchable power to PG&E under 10.5 year rolling agreement
- **System capacity of 293 MWh (expandable to 700 MWh)**; system will power Calistoga, CA for 48 hours during outages

Near-term battery capacity installations in California (MW)



Source: EIA Monthly Electric Generator Inventory; Utility Dive; AP News

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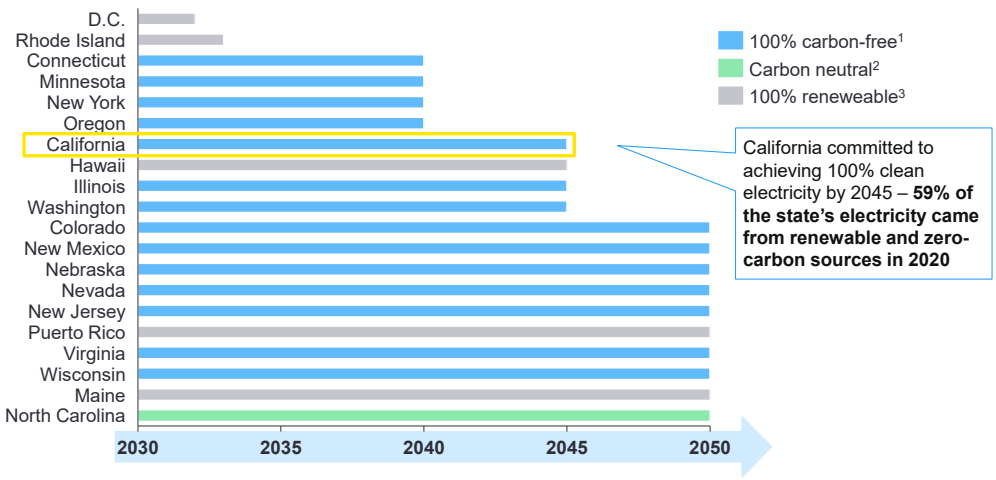
Among 20 states and districts that have legislations and executive orders for creating a carbon-free power sector, California remains ahead of clean electricity goals

Progress towards a carbon-free power sector, by state and district



California committed to achieving 100% clean electricity by 2045 – **59% of the state's electricity came from renewable and zero-carbon sources in 2020**

1. 100% carbon-free means no carbon was emitted from the get-go, so no carbon needs to be captured or offset
2. Carbon neutral refers to achieving net zero carbon emissions by balancing a measured amount of carbon released with an equivalent amount sequestered or offset, or buying enough carbon credits to make up the difference
3. 100% renewable refers to companies buying enough renewable energy sources (e.g., solar power) to match its annual use

Source: Clean Energy States Alliance; California Energy Commission

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The federal government has announced fundings and tax credits to advance energy storage technologies and drive new installations

Incentive type	Program	Agency	Description	Amount	Timeline
Grant	**Energy Storage Demonstration and Pilot Grant Program**	Department of Energy	▸ Carry out 3 energy storage system demonstration projects	$355M	Application estimated opening Q3 2023
Grant	**Research to Enable Next-Generation Batteries and Energy Storage**	Department of Energy	▸ Advance fundamental knowledge for next-gen rechargeable batteries	$125M	Application close in May 2023
Grant	**Long-Duration Energy Storage Demonstration Initiative and Joint Program**	Department of Energy	▸ Composed of demonstration projects focused on the development of long-duration energy storage technologies	$150M	Closed in Q4 2022
Tax credits	**Investment Tax Credits for Standalone Energy Storage under Inflation Reduction Act**	Department of Energy	▸ Standalone option decouples developers from need to pair with solar PV ▸ Energy storage projects of 5kWh or more will be eligible	6% or 30%[1] investment tax credits, potential for higher percentages[2]	Effective 2023 - 2033

1. Projects not meeting prevailing wage and apprenticeship requirements receive 6% instead of 30%
2. 10% adder for domestic content, location in energy communities and/or disadvantaged communities
Source: U.S. Department of Energy Funding Opportunities

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Hydrogen can be used to store surplus renewable energy for long periods of time, resulting in reduced curtailments and increased power system flexibility

Hydrogen production and energy storage

Decreases in hydrogen production costs are driven by electrolyzer and renewable energy costs

- Electrolyzer prices are down 50% from five years ago and renewable energy costs have fallen 50-60%;
  - Further decreases of 60-70% expected by 2030[1]
- Improvements in electrolyzer technology are expected to reduce the cost of green hydrogen production 60% by 2030[2]

Hydrogen is a more efficient form of long-duration storage than batteries

- Hydrogen can be stored underground in geological salt domes for long periods of time at a very low cost
- Hydrogen provides an energy storage material with significant energy density

Hydrogen energy storage projects

MITSUBISHI POWER

- Based in central Utah, Advanced Clean Energy Storage Project (ACES) is one of the world's largest integrated clean hydrogen production and storage hub capable of providing long-term seasonal energy storage

MAGNUM Development

- Aims to produce up to 100 metric tons (i.e., 26,847 gallons of liquid) per day of hydrogen from water and renewable energy sources using a 220-MW alkaline electrolyzer bank
- Hydrogen will be stored in two gigantic solution-mined caverns sited in the only salt dome in the Western U.S.

NASA

- NASA contracts McDermott to build its largest hydrogen cryogenic sphere
- Once completed, NASA will be able to store and process over 2m usable gallons of liquid hydrogen (i.e., 7,450 metric tons) for space launch support[4]

By 2050, **green hydrogen** could supply up to **25% of the world's energy needs** and become a **U.S. $10 trillion addressable market**[3]

Source: 1. BofA Securities; 2. PV Magazine; 3. Goldman Sachs; 4. Storage Terminals Magazine

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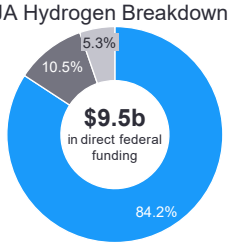
IIJA and IRA provide hydrogen-related funding programs that will serve as the backbone for future hydrogen generating facilities

IIJA and IRA allot $11.2B for the development of hydrogen value chain across 4 programs, of which $8B is to develop clean hydrogen hubs, $1.7B is for fuel cell technology and $1.5B is for R&D. An additional program will incentivize clean hydrogen production through tax credits.

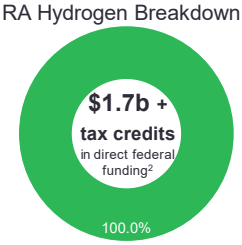
IIJA Section	Program Name	Available Funds	Eligible Entities
813	**Regional Clean Hydrogen Hubs**	**$8.0B**	Industry, institutions, government, organizations, tribal
Develop 6 – 10 regional hydrogen hubs that demonstrate production, processing, delivery, storage and end use of clean hydrogen and form the foundation of a national hydrogen network. The initial launch will fund $6-7 billion, but DOE may issue a second launch.			
815	**Clean Hydrogen Manufacturing and Recycling**	**$0.5B**	Industry partners *(still being defined)*
Provides federal financial assistance to advance new equipment manufacturing technologies and techniques for clean hydrogen processing, delivery, storage and use equipment as well as materials and component recycling processes.			
816	**Clean Hydrogen Electrolysis Program**	**$1.0B**	Industry partners *(still being defined)*
Fund research, development, demonstration, and deployment efforts to reduce the cost of clean hydrogen production to $2/kg[1] by 2026 using Electrolysis.			

IIJA Hydrogen Breakdown



IRA Section	Program Name	Available Funds	Eligible Entities
22002	**Rural Energy for America Program**	**$1.7B**	Rural communities, agricultural producers *(still being defined)*
Provide grants for hydrogen and fuel cell technology projects and underutilized renewable energy technology projects.			
13204	**Clean Hydrogen Tax Credits**	**$0.60 - $3 / kg**	Hydrogen producers *(still being defined)*
Provide credit for facilities that produce clean hydrogen. Credit amount depends on the facility's lifecycle greenhouse gas emissions and compliance with workforce guidance.			

IRA Hydrogen Breakdown



1. 2020 cost of hi carbon grey hydrogen is ~$2/kg and green hydrogen is $2.5-6.80/kg at point of production
2. Federal hydrogen funding breakdown does not include the funding available through the Clean Hydrogen Tax Credits from the IRA

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The Infrastructure Investment and Jobs Act promotes a clean hydrogen economy through a $8 billion program for regional clean hydrogen hubs among other programs

Overview of hydrogen programs

In November 2021, President Biden signed the Bipartisan Infrastructure Bill into law, which covers $9.5b for clean hydrogen programs:

- $8 billion for regional clean hydrogen hubs across the U.S.
- $1 billion for clean hydrogen electrolysis program
- $0.5 billion for clean hydrogen technology manufacturing and recycling RD&D activities

In June 2021, the Department of Energy (DOE) announced its Hydrogen Energy Earthshot, which aims to reduce the cost of clean hydrogen by 80% to $1 per kilogram in one decade:

Regional clean hydrogen hubs (H2Hubs)

H2Hubs will form networks of hydrogen producers, consumers, and local connective infrastructure to accelerate the use of clean hydrogen that can deliver or store huge amounts of energy

- H2Hubs selection criteria used by the DOE includes feedstock diversity, end-use diversity, geographic diversity, hubs in natural gas-producing regions, employment, etc.
- DOE will prioritize hubs that can provide significant training and long-term job opportunities for residents of the region
- DOE has until May 14, 2023 to select at least four H2Hubs from the proposals that are to be submitted this year

In May 2022, California announced its intent to seek a H2Hub, making it well equipped to lead the hydrogen market in the U.S.

- CA formed Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES), a public-private hydrogen hub consortium, to accelerate the adoption and production of clean hydrogen technology in the state
- ARCHES unites public and private stakeholders to build a framework for a California H2Hub

Overall, these efforts are crucial to the DOE's strategy for achieving 100% clean electrical grid by 2035 and net-zero carbon emissions by 2050

Source: Energy.Gov; White House Statement Release

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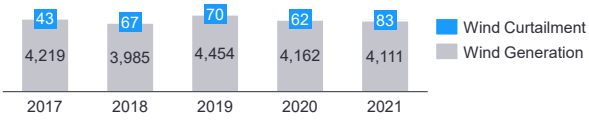
New York is a rising pioneer in renewable energy as the state aims to reach 6-GW of energy storage by 2030

Roadmap to 6-GW of energy storage

In December 2022, NYSERDA and the New York State Department of Public Service (DPS) filed New York's 6 GW Energy Storage Roadmap

- Proposes to expand New York's energy storage programs to address the increase in renewable energy across the state and enhance grid reliability and customer resilience
- Aims to support storage deployments estimated to decrease future statewide electric system costs by ~$2 billion
- Supports NYSERDA-led programs that can procure an additional 4.7 GW of new storage projects across three categories:
  - bulk (large-scale)
  - retail (community, commercial and industrial)
  - residential energy storage sectors
- Supports goal to generate 70% of state's electricity from renewables by 2030; 100% zero carbon by 2040

NYISO wind generation and curtailment in NY (GWh)



If this power (i.e., 83 GWh) were stored and then available on demand, it would be enough to power 11,500 homes in NY for a year

NY state energy profile

- In 2021, NY accounted for 11% of U.S. hydroelectricity net generation, and the state was the third-largest producer of hydropower in the nation, after Washington and Oregon
  - New York's 2,500-megawatt Robert Moses Niagara power plant is the nation's third-largest conventional hydroelectric power plant
- Natural gas, nuclear energy, and hydropower consistently generate more than 90% of New York's electricity

Source: Utility Dive; Power Magazine; NYISO Power Trends 2022; U.S. EIA

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Curtailments result in revenue loss for operators and increased cost for customers who are not served by the lowest cost resources

Types of curtailments

- **Economic dispatch**
  - While low-priced energy can push some renewable energy generators out of the market, negative-priced energy can give generators a strong incentive to curtail
  - Generators offer "decremental" bids to the ISO to reduce their output
  - Considered "market-based" because ISO's market software automatically adjusts supply with demand
- **Self-scheduled cut**
  - Targets generators who have contracts directly with utilities and other power retailers
  - ISO's market software will pick some self-scheduled generators to curtail based on location and other operational impacts but not on price
- **Exceptional dispatch**
  - ISO operators manually intervene and order generators to reduce output, thus preventing or mitigating conditions that risk grid reliability
  - Not preferred because it does not ensure the lowest cost resources are used to serve customers and it can reduce output of renewable plants

All types of curtailment can happen at the local level, to reduce congestion, or at the system-wide level, to reduce oversupply

Source: CAISO

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