Optimizing Energy Storage for Solar Integration

UVIG Fall Meeting – October 11, 2017

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Stem Company Overview

Stem's Headquarters in Millbrae, California

Year Founded:	**2009**
Headquarters:	**Millbrae, California**
Operations:	**California, Hawaii, New York, and Texas**
Employees:	**135**
Network:	**Over 700 sites, 150 MWh and 222 customers**
Grid Participation:	**500 virtual power plant dispatches since 2015**
Interconnections:	**8 utility territories with interconnections**
Permitting:	**75 municipalities with permitted systems**

Investors

GE, TOTAL, RWE, MITHRIL, Constellation. An Exelon Company, ANGELENO GROUP, MITSUI & CO., LTD., IBERDROLA, stem

Distinguished Honors & Awards

WORLD ECONOMIC FORUM, ENERGY EXCELERATOR, THE GRIDEDGE 20, Global Cleantech 100, Bloomberg NEW ENERGY PIONEER 2015 WINNER, RED HERRING 100 N. AMERICA FINALIST

Solution components

Athena™ Artificial Intelligence

Automatically controls when energy storage charges and discharges to optimize timing, maximize savings, and create virtual power plants.

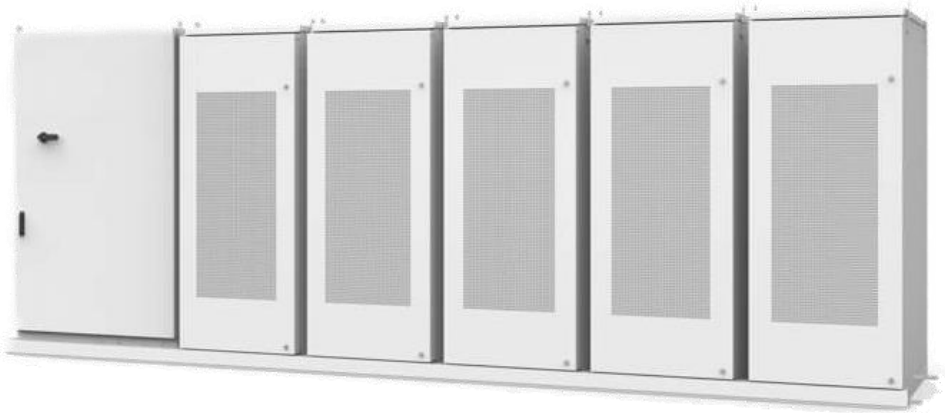
Energy Storage Systems

Modular options for all facility sizes and locations.
Batteries from leading global manufacturers.

Medium indoor
132 kW modules
(server rack size)

Small indoor
18 kW modules
(gym locker size)

Large outdoor
Scalable from 100 kW to 5+ MW



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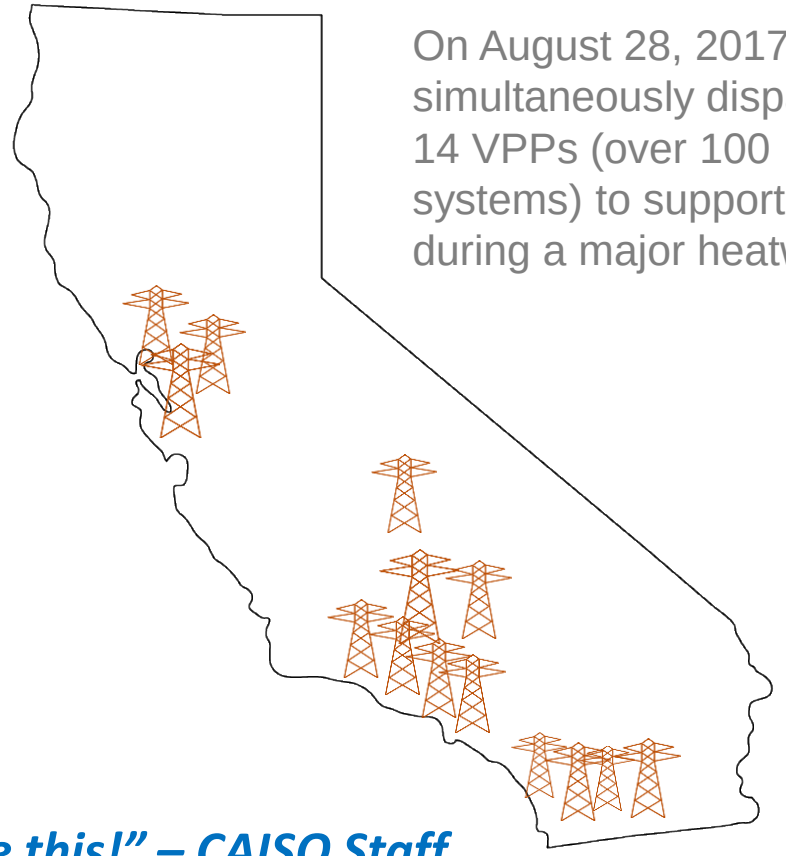
Virtual Power Plants are working today

Stem's network is instantly ready when called.

- Stem's network, powered by Athena™, has responded to over 500 grid dispatch requests
- Supported the grid during heatwaves on June 20 and August 28
- No manual intervention
- Delivered on-time and more than promised
- Customers enjoyed helping California avoid blackouts



On August 28, 2017 Stem simultaneously dispatched 14 VPPs (over 100 systems) to support the grid during a major heatwave.

"That's awesome. Wish all "DR" would respond like this!" – CAISO Staff

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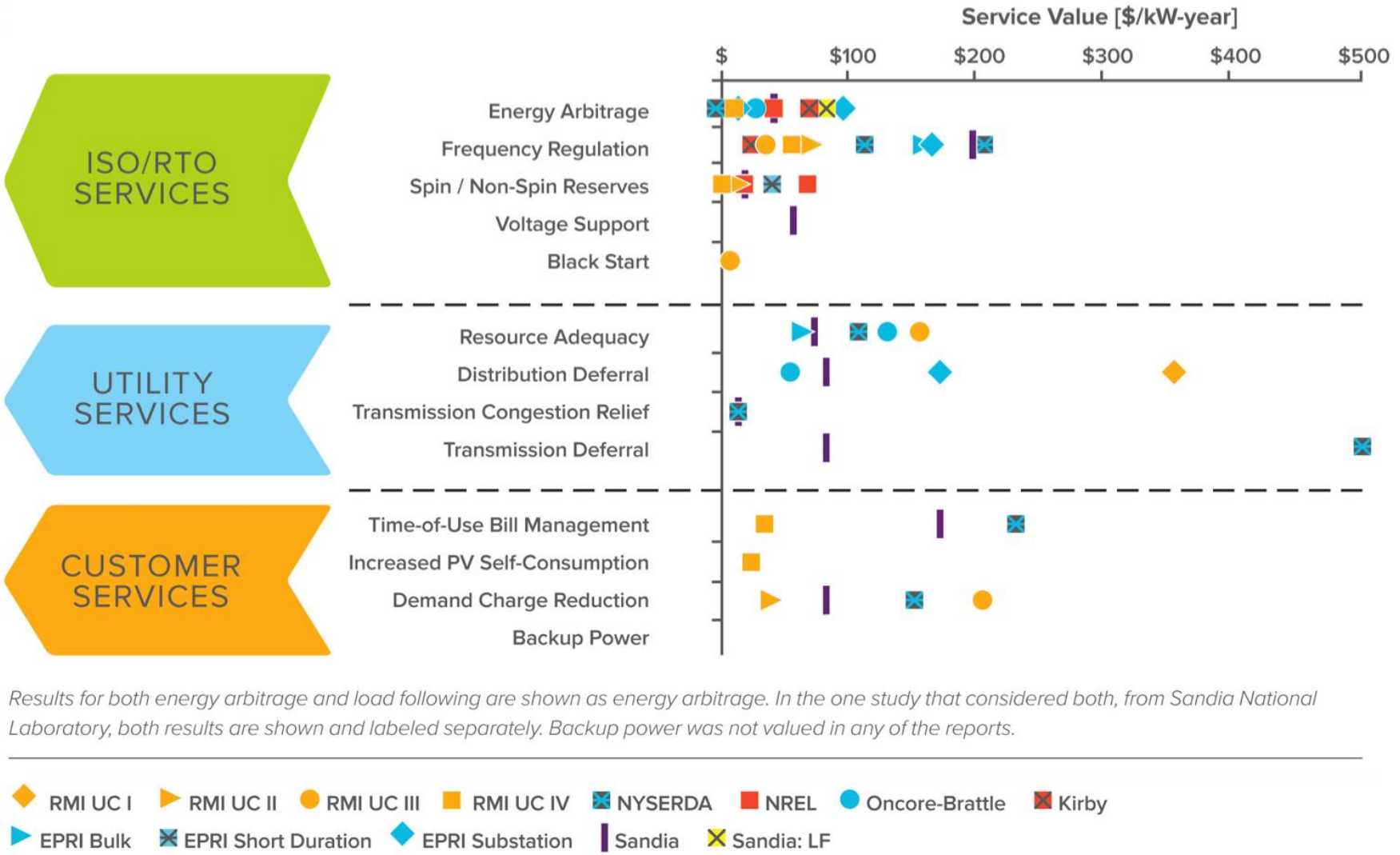
Energy storage provides a range of utility values



Results for both energy arbitrage and load following are shown as energy arbitrage. In the one study that considered both, from Sandia National Laboratory, both results are shown and labeled separately. Backup power was not valued in any of the reports.

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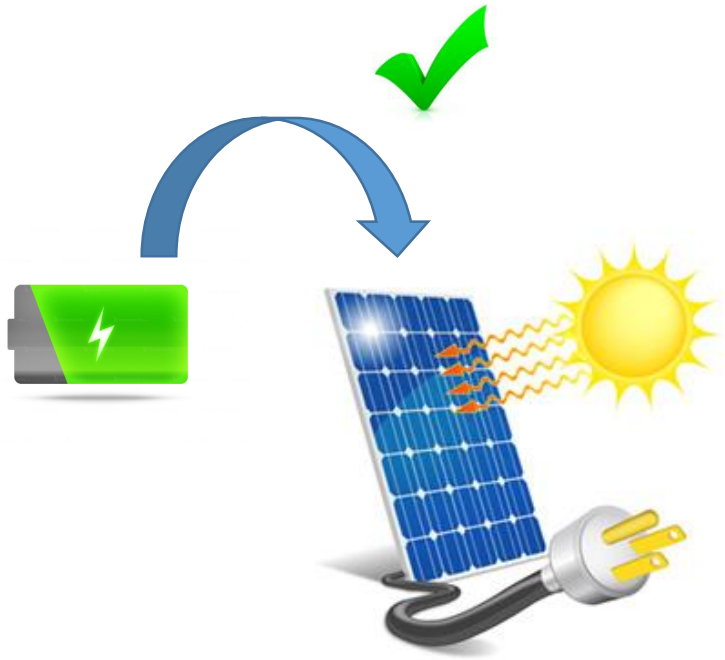
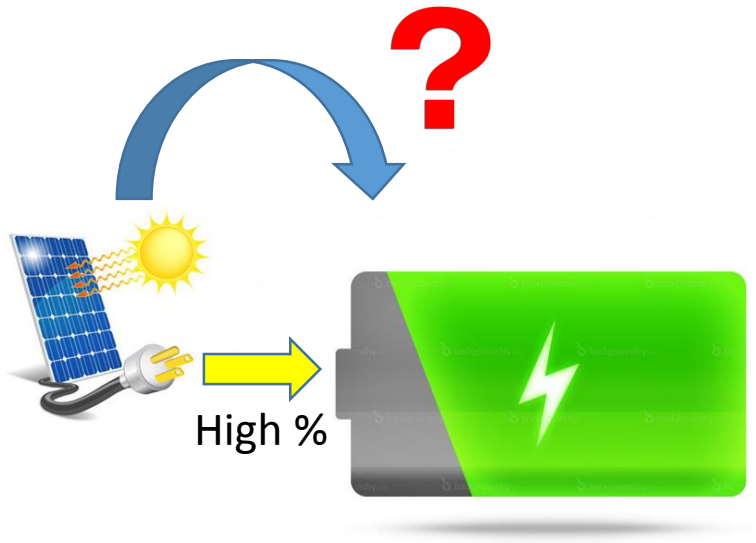
Solar & Storage



Solar becomes Dispatchable Grid Asset
Customer maximizes solar value



Storage operations constrained
Storage value to grid reduced
Customer loses storage value

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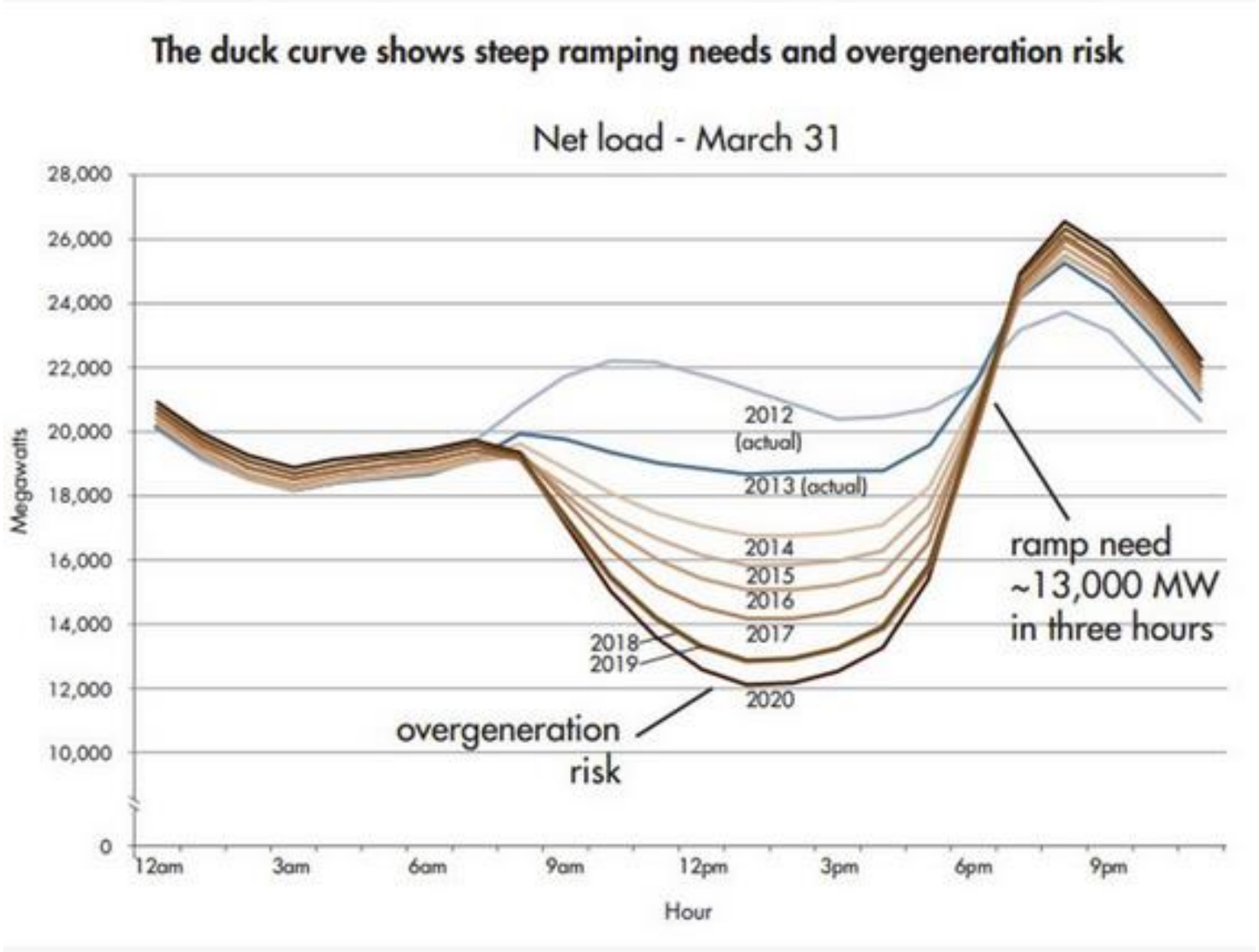
Forced PV Charging: Fattening the Duck



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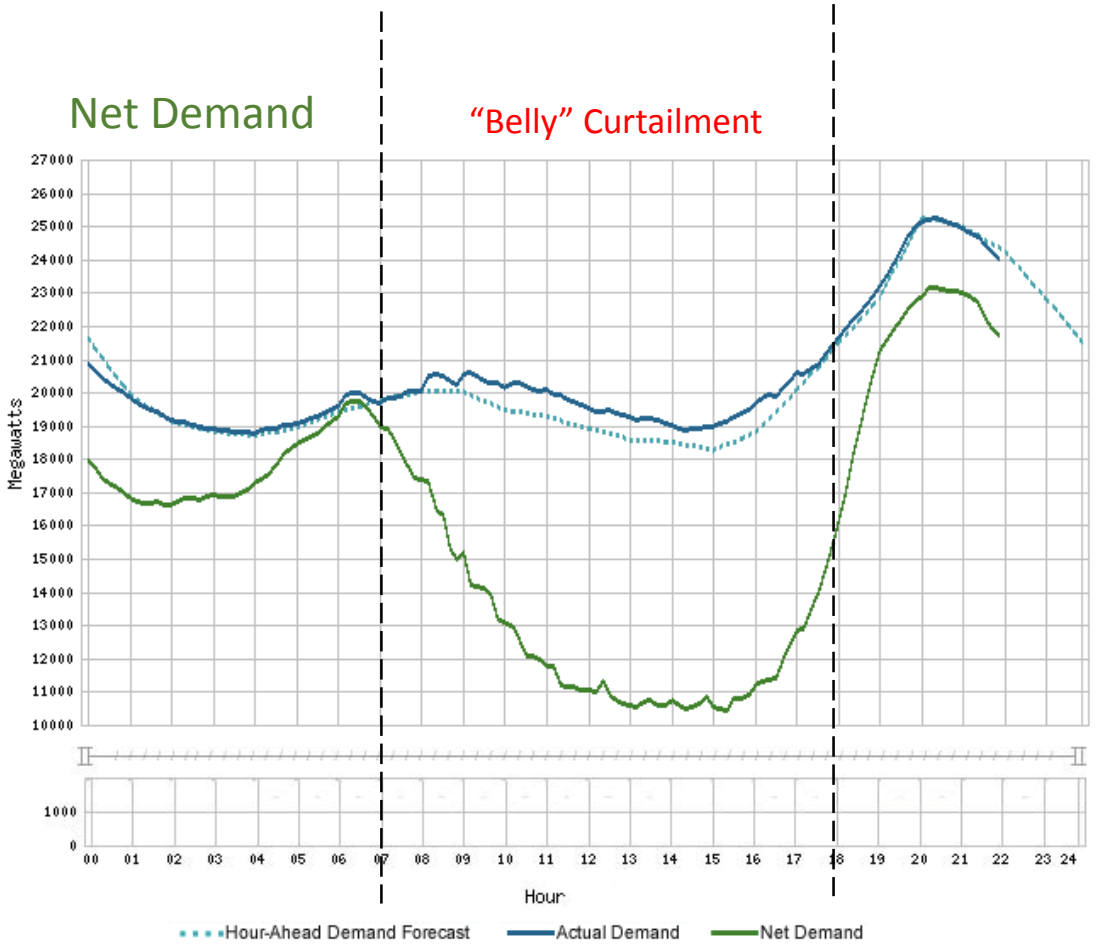
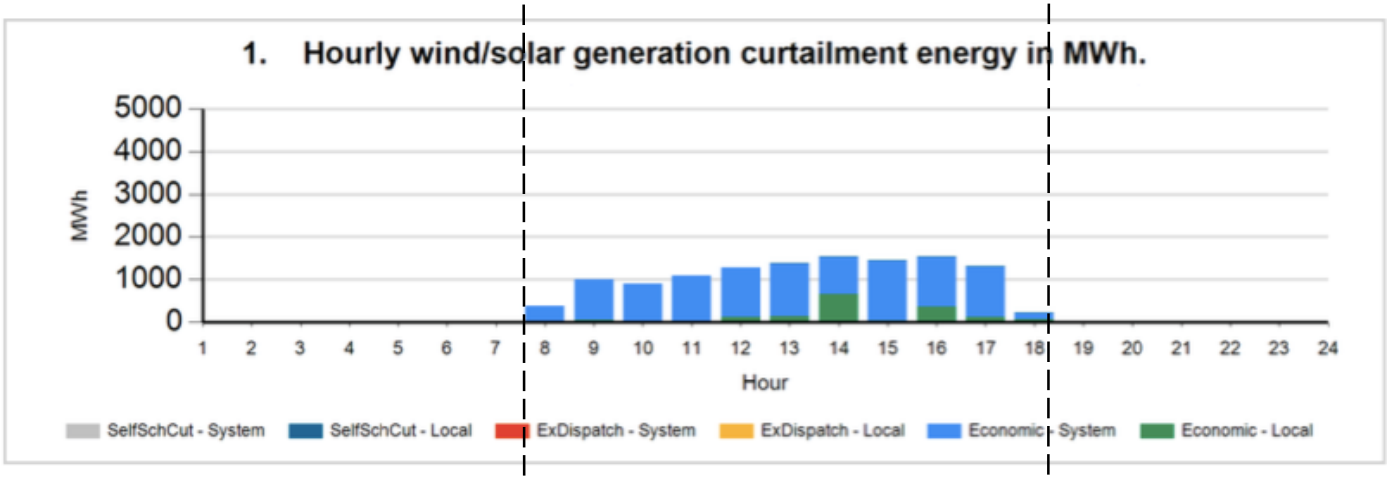
Curtailment: Spring day in April 2017

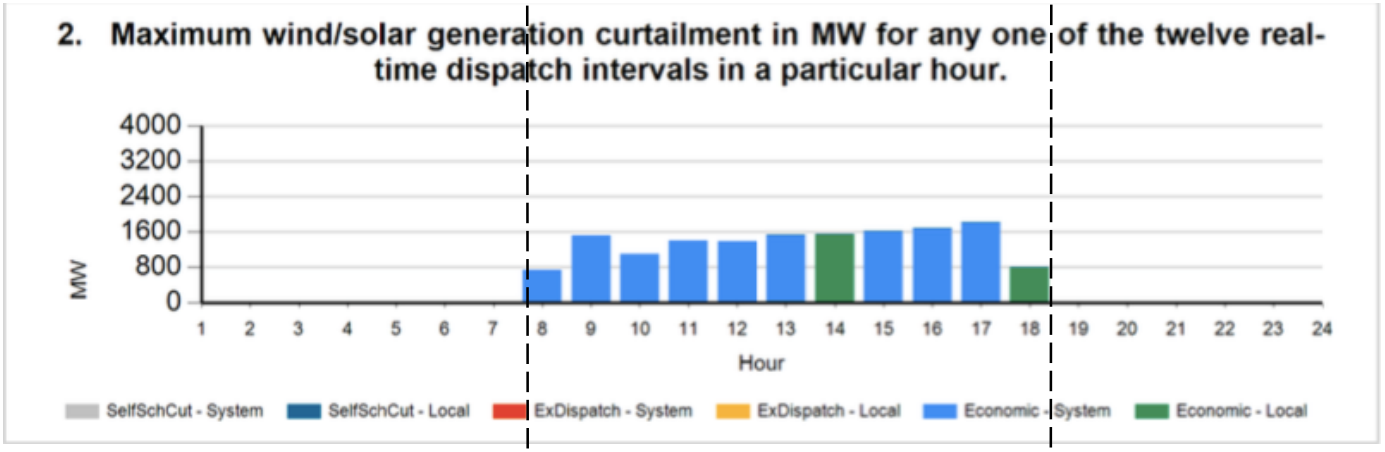
Net Demand

"Belly" Curtailment



Total = 10,000 MWh





Peak = 1,600 MW

Belly already deeper than CAISO 2020 prediction

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Forced PV charging: Deepening the Belly

Structure	Deployment	Description	Curtailed Energy (MWh)	Peak Curtailment (MW)
Spring Day 2017	Current System	All curtailment during belly is PV	10,000	1,600
Standalone Storage Customer-sited	1 GWh new storage (500 MW x 2 hrs)	Storage full charge at max negative pricess	9,000	1,100
Forced PV Charging Co-sited	1 GWh new storage 1 GW new PV	PV production = 2x storage capacity Storage full charge during belly	**> 11,000**	**> 2,100**

Storage cannot slim the ”belly” if forced to charge with on-site solar PV

1 MWh of storage forced to pair with PV nets **at least 2 MWh more curtailment**

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Assumptions

- SGIP funding of storage
  - Current Step budgets for >10 Kw storage installations; incentive drops $0.10 each step
  - Yields approx. 1.4 GWh of standalone storage (rounded down to 1 GWh)
- Spring Day Current System
  - Curtailment numbers are actual from April 2, 2017
- Standalone storages
  - 2 Hour batteries are “empty” before belly period
  - Charging done at maximum negative pricing, full offsetting curtailment
- Forced PV Charging
  - Installed PV is 2x capacity of max discharge of battery (1 MW PV for 500 Kw battery)
  - Battery is able to full charge from PV during belly (PV production net of site load is sufficient)
  - Onsite PV produces 2x what storage can absorb during belly

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Forced PV Charging Emissions Impacts

Storage emissions with grid signal

Scenario	Description	Charging (kg CO2/MWh)	Discharging (kg CO2/MWh)	Net Emissions (kg CO2/MWh)
CPUC Assumptions	*Charge with CCGT* *Discharge offsets CT*	382	408	-26
Standalone - Overgen	Standalone storage charges during grid overgen times	0	408	-408
Retrofit – storage added to solar				
Solar Charging – all overgen	Storage charges from solar only during grid overgen times	0	408	-408
Solar Charging – no overgen	Storage charges from solar, no grid overgen	382	408	-26
Solar Charging - realistic	Storage charges from solar during grid overgen when economic	95.5	408	-312.5
New Solar				
Solar alone	Impact of new solar w/o storage	0	379.1	-379.1
Storage enabled solar	Storage enables new solar installation	0	787.1	-787.1

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Emissions Assumptions

- Gas-fired power plant emissions
  - Combined Cycle Gas Turbine (CCGT) = 382 kg/MWh
  - Peaker (CT) = 544 kg/MWh
- Storage RTE = 75%
- Realistic percentage of solar charging happening during grid overgen: 75%
- Solar alone – production profile
  - Percentage of solar production curtailed: 5%
  - Percentage of solar production offsetting CT: 10%
  - Percentage of solar production offsetting CCGT: 85%

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A More Effective Solution: CAISO Load Shift Product

Being Designed to Allow Behind-the-Meter Storage to Absorb Excess Generation

Key Elements Under Consideration

- Load Shift vs Consumption avoids concerns about simply increasing loads
- Need to modify existing 24x7 settlement requirement
- Limited to non-export to simplify
- Design to qualify for Resource Adequacy
- Bid, dispatch structure: Continuous bid curve vs discrete

NOPR related issues

- Retail / Wholesale prohibition or Double Compensation issue is not significant here
- No wholesale charging – retail discharging problem
- No special T&D coordination

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California ISO Storage Categories

CAISO has Proxy Demand Resource (PDR) and Distributed Energy Resource Provider (DERP)

	Strengths	Weaknesses
PDR	Non 24x7 Settlement Resource Adequacy (RA) with use limitations No double compensation concerns No T&D Coordination issues (for now) Dispatch as Bid Retail interconnect	No credit for export Not allowed to do frequency regulation Can't get paid for load increase (currently) Very high administrative burden
DERP (NGR)	Can export to the grid Allowed to do all CAISO services Can get paid to charge batteries	24x7 Settlement Doesn't qualify for RA T&D Coordination issues likely but not tried yet Wholesale interconnect (in most cases)

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