



Energy+Environmental Economics

+ Solar power and resource planning in California and beyond

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CSP Program Summit



Energy and Environmental Economics, Inc. (E3)

- + **E3 completes about 200 projects a year across the energy sector, emphasizing electricity**
- + **This focus allows for constant innovation and development of best-in-class tools and analysis that leads to key insights, answers, and recommendations**

DERs & Rates

Analyzes distributed energy resources, emphasizing their costs and benefits now and in the future

Supports rate design and distribution system planning



Asset Valuation

Determines asset values from multiple perspectives

Uses proprietary in-house models and in-depth knowledge of public policy, regulation and market institutions



E3 has five defined working groups that create continual innovation from cutting edge projects and constant cross-fertilization of best practices across the groups

Planning & Procurement

Develops and deploys proprietary tools to aid resource planners

Informs longer-term system planning and forecasting



Clean Energy

Provides market and policy analysis on clean energy technologies and climate change issues

Includes comprehensive and long-term GHG analysis



Market Analysis

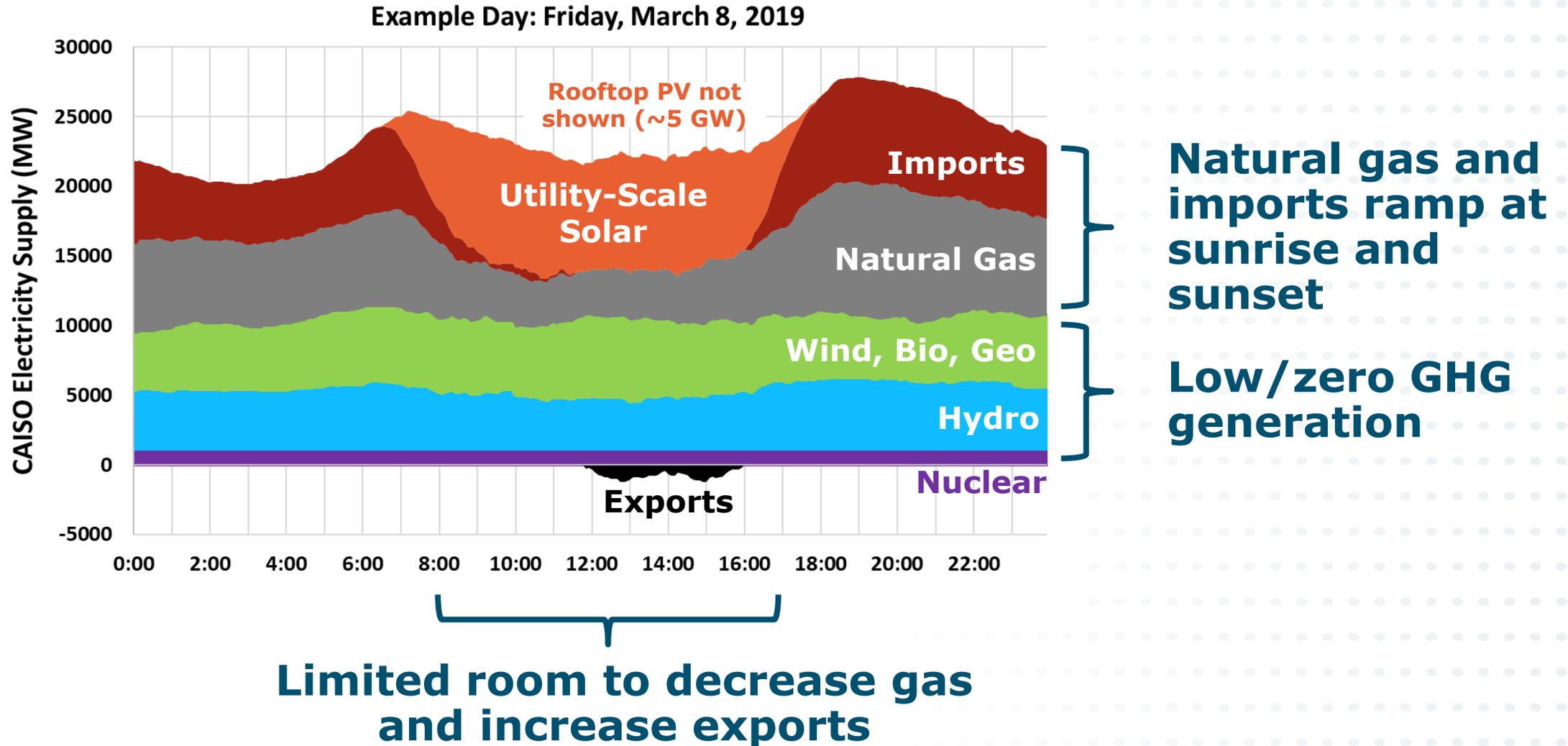
Models wholesale energy markets both in isolation and as part of broader, more regional markets

Key insights to inform system operators and market participants



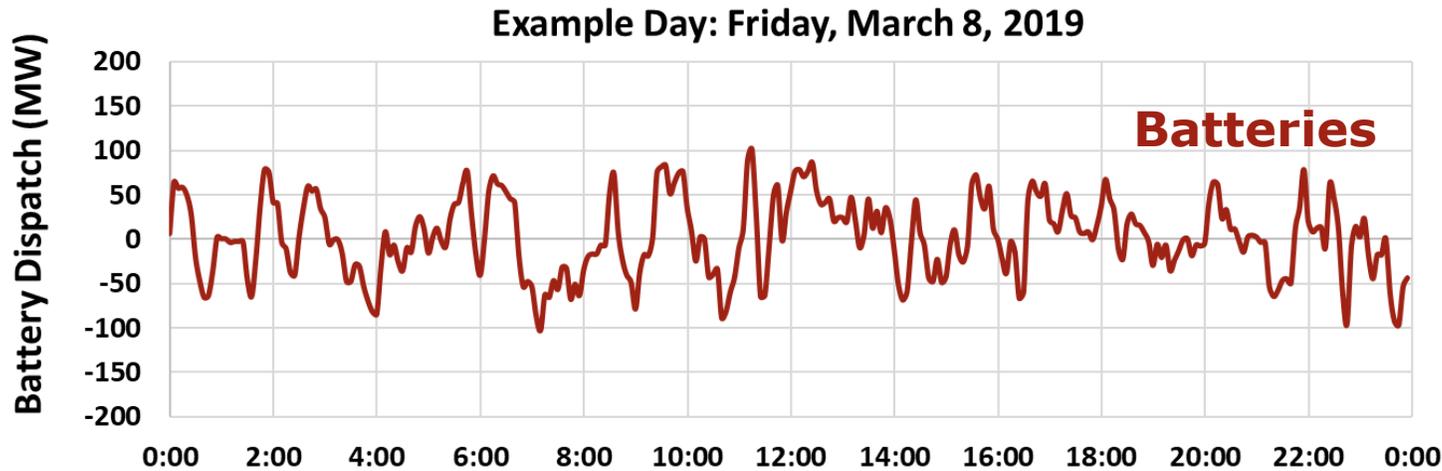


Current California market conditions – Spring example





Current role of batteries

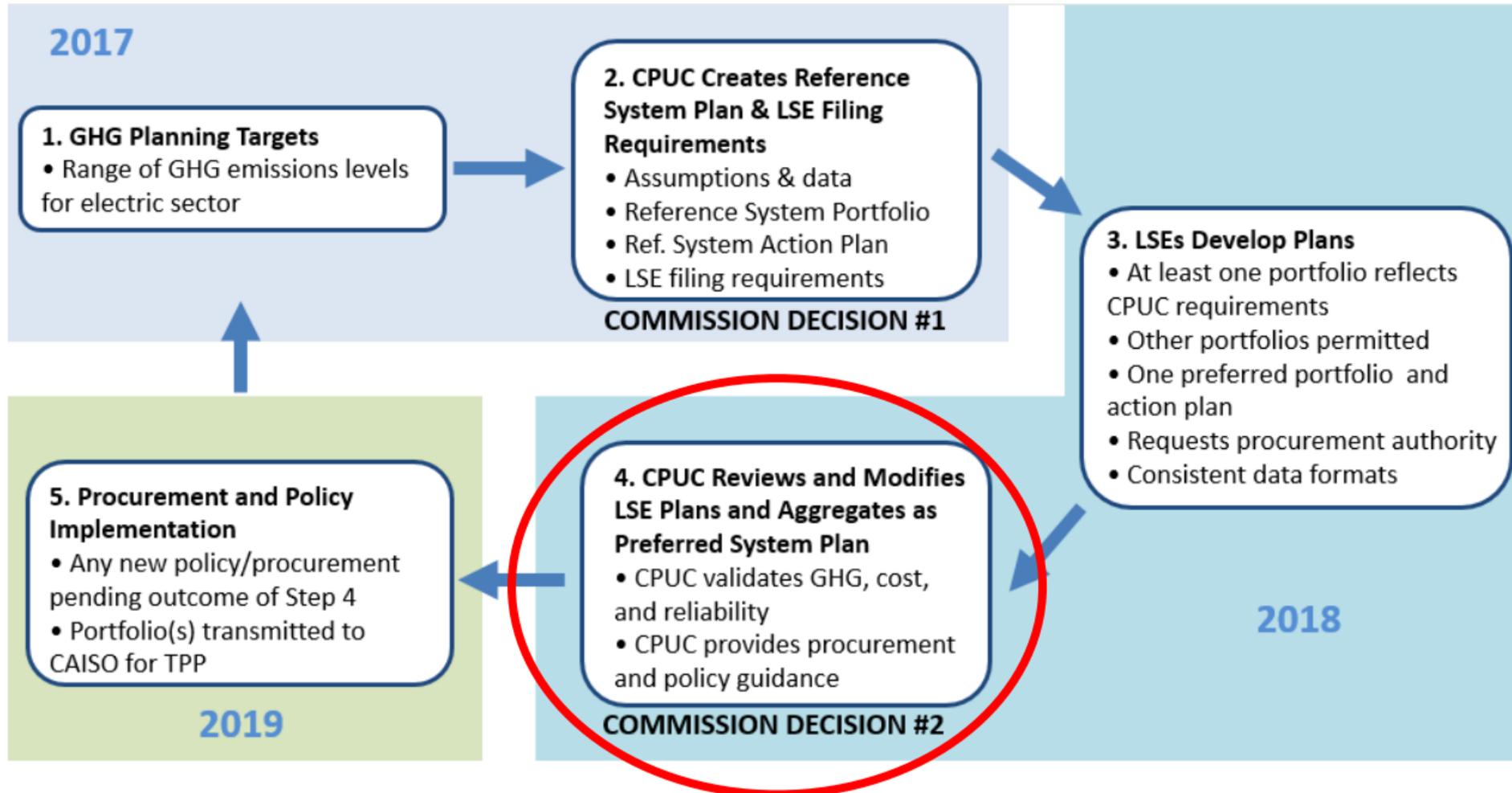


Batteries in the CAISO market are currently used for short-timescale balancing

- + The storage market is expanding and fast-paced, with many different use cases and value streams
- + Battery capacity has also been procured to address local reliability issues
- + But... most battery capacity is not yet being used to serve load at night with solar energy



California Public Utilities Commission Integrated Resource Planning (CPUC IRP) Process



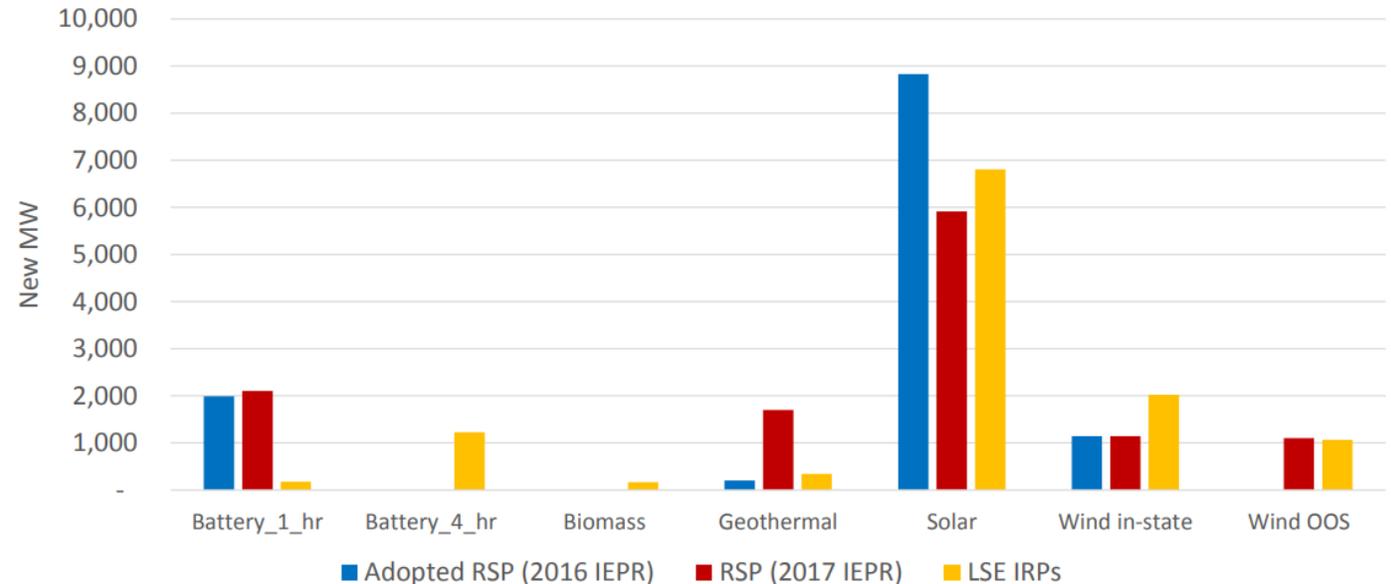
Disclaimer: E3 is not speaking on behalf of the CPUC. All views are those of E3 alone.



IRP resource portfolios

- + **E3's RESOLVE capacity expansion model was used to create resource portfolios for the CPUC IRP process (Blue and Red bars)**
- + **Load Serving Entities were required to design at least one portfolio consistent with the reference portfolios**
 - LSE portfolios were combined to create aggregate portfolio (Yellow bars)

New Resources in LSE portfolios compared to 2030 Reference System Plan (RSP)



- Compared to the Reference System Plan (RSP) calibrated with the 2017 IEPR, LSEs plan to purchase:
 - 4-hour batteries generally in lieu of 1-hour batteries
 - About 1,400 MW less geothermal
 - About 900 MW more in-state wind
 - Similar amounts of OOS wind from specific regions like NM and WY

Note: The RSP updated to reflect the 2017 IEPR includes 1,500 MW more geothermal and 2,900 MW less solar PV than the adopted RSP based on the 2016 IEPR, which is provided for comparison purposes. The 2017 IEPR included more BTM PV than the 2016 IEPR, which decreased the value of Utility-Scale PV and increased the value of geothermal and wind in the RSP updated to reflect the 2017 IEPR. See the 3/29/2018 MAG webinar materials located at <http://www.cpuc.ca.gov/General.aspx?id=6442451195> for further details.



2014 California utility study found that 50%+ RPS penetrations are feasible

+ 50% (and higher) renewable penetration is feasible, under one condition:

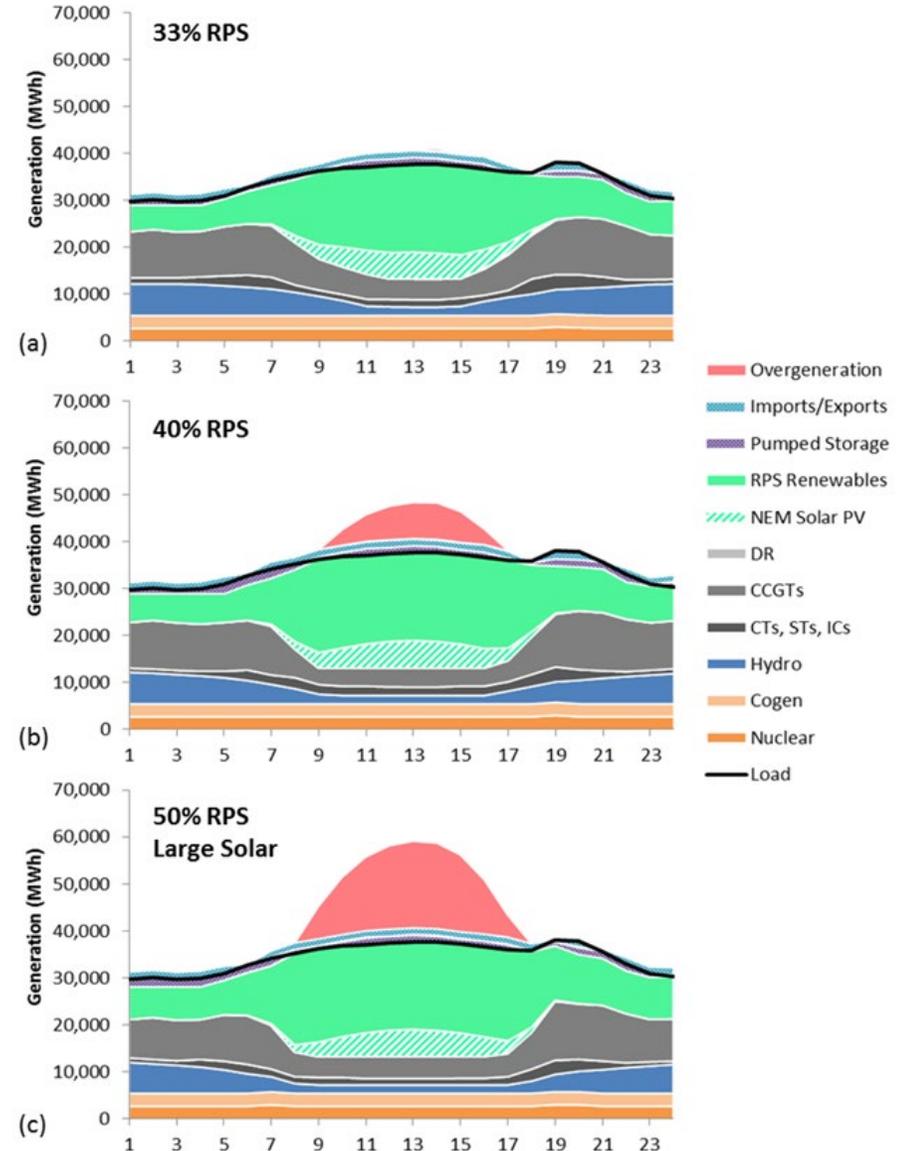
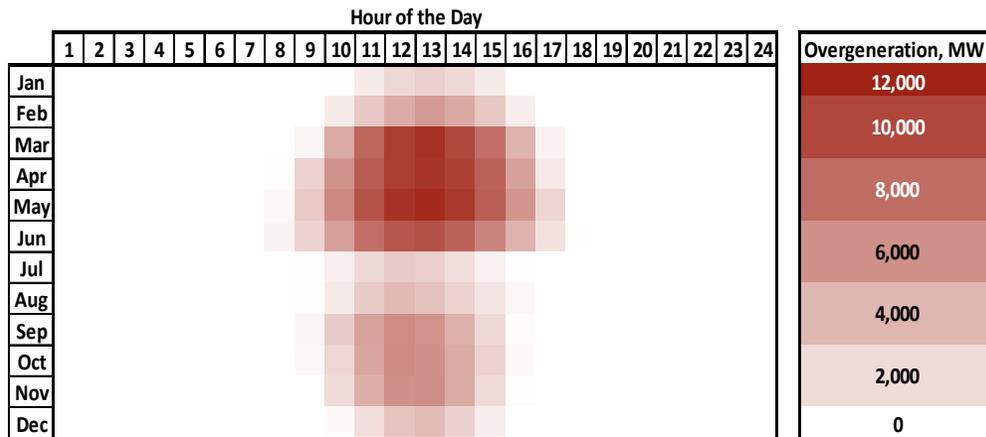
- Renewables must be dispatchable based on the needs of the system

+ Renewable dispatch has little cost

- Lost production tax credit and renewable energy certificate value

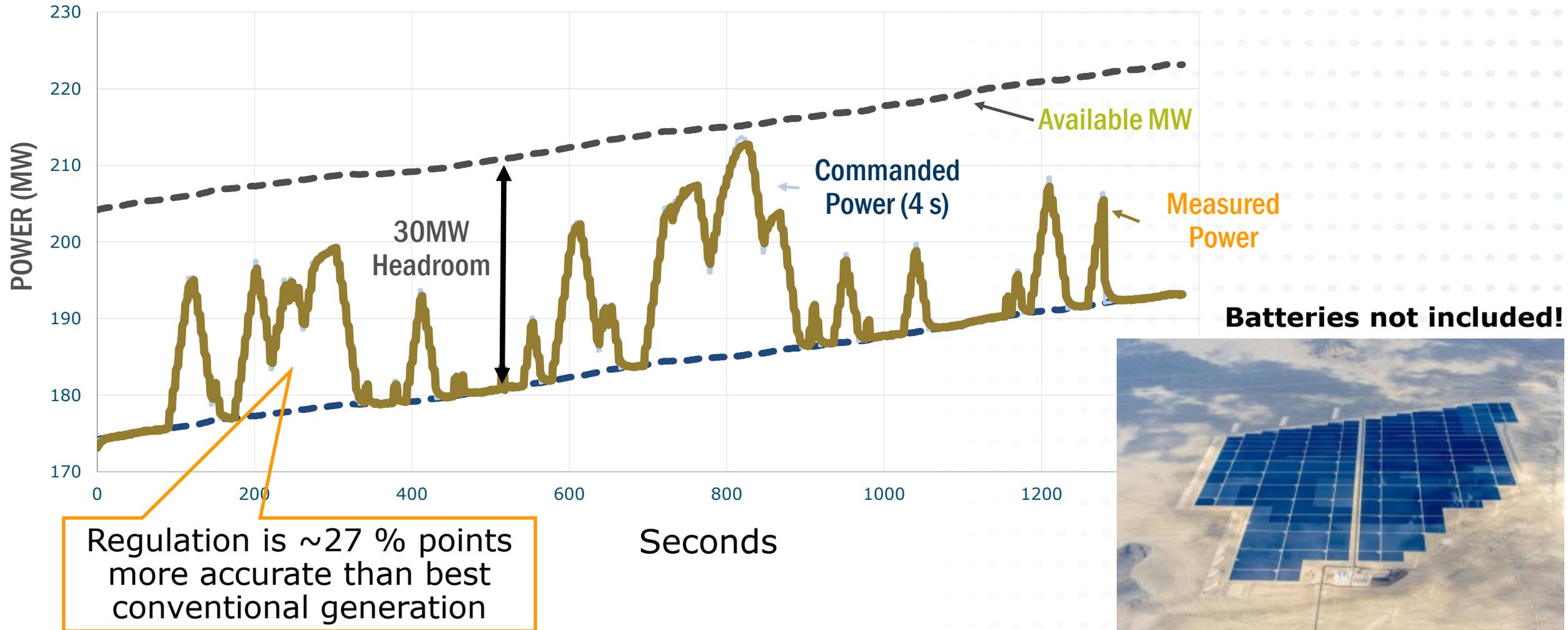
+ Curtailment increases at higher penetrations

- Up to 20% of hours by 2030





Solar PV follows grid operator commands





Role of system operations

Investigating the Economic Value of Flexible Solar Power Plant Operation

October 2018



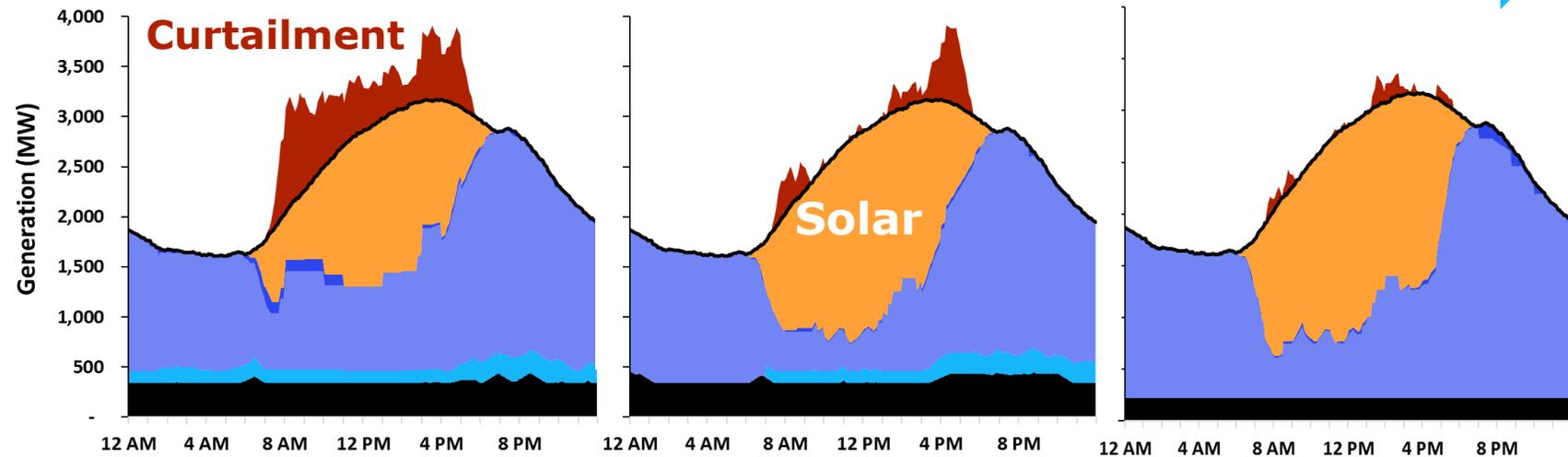
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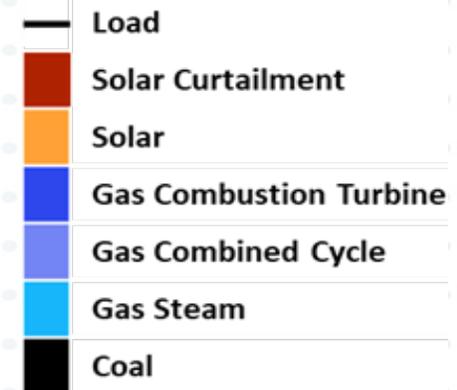
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Increasing solar dispatch flexibility *without* storage



+ In a report sponsored by First Solar, E3 studied Tampa Electric's system under high solar PV penetrations

+ Study highlights role of system operator in reducing solar curtailment and increasing solar value by operating solar flexibly





100% and long-duration storage

Ambitious Targets:

- + SB100 sets California on a path to 100% GHG free electricity sales by 2045, and Former Gov. Brown's Executive Order set an economy-wide GHG neutrality goal for the same year

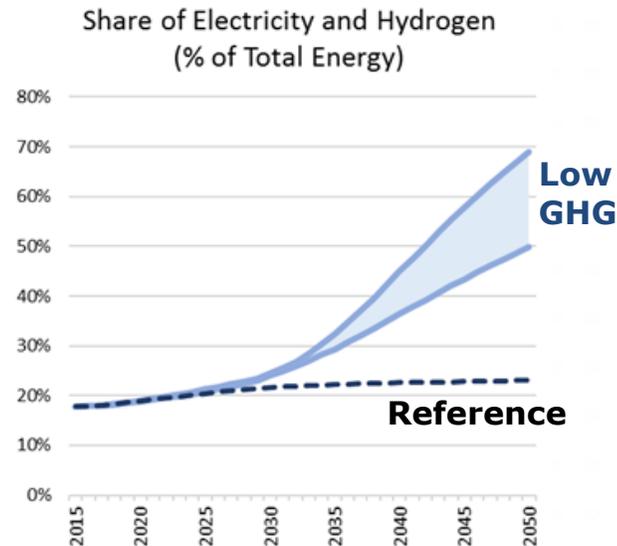


- + Nation-wide, 100% renewable energy has entered the political conversation

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Role of Electricity:

- + Electrification of fossil fuel end uses is a key pillar of economy-wide decarbonization



Role of Storage:

- + Long-duration storage – with days, weeks, or months of duration – is needed to maintain electricity reliability

- Chemical bonds of natural gas and coal dominate current long-duration storage

- + Reaching much higher levels (up to 100%) of GHG-free electricity with predominantly wind and solar power would require dramatic investment in new long-duration storage