NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Maximizing The Value of Concentrating Solar Power

Paul Denholm

DOE Solar Energy Technology Office Summit

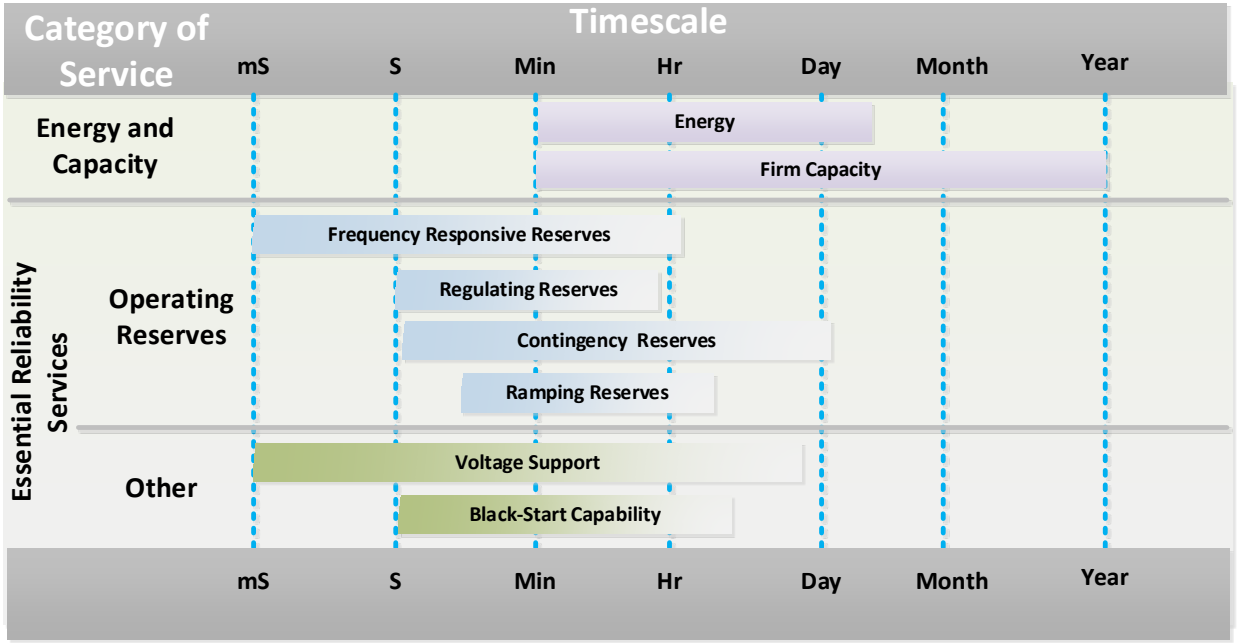
March 18, 2019

How Can CSP Maximize Value By Providing Grid Services?

- Energy and Capacity
- Operating Reserves
- Other Essential Reliability Services

Current Grid Services

- We separate energy and capacity services into one category and group the remaining services into a general essential reliability service (ERS) category.
- ERSs are further subdivided into operating reserves and other ERSs.

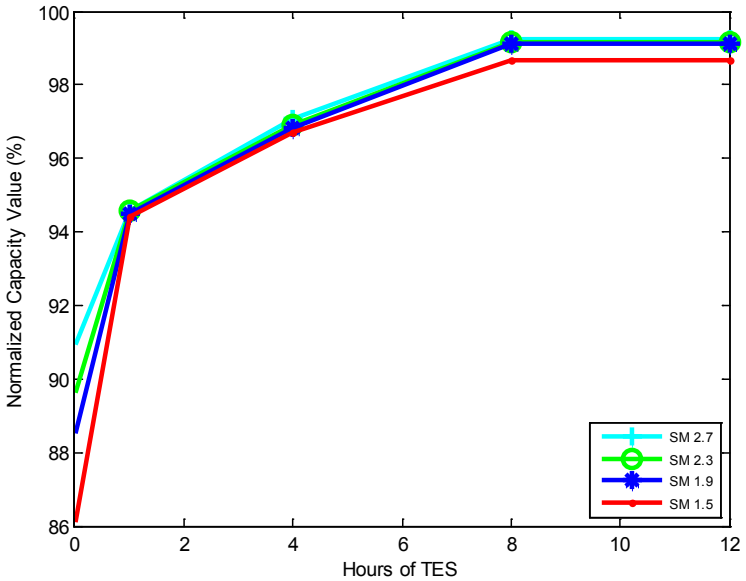


The Majority of Value Will Be Obtained from Energy and Capacity

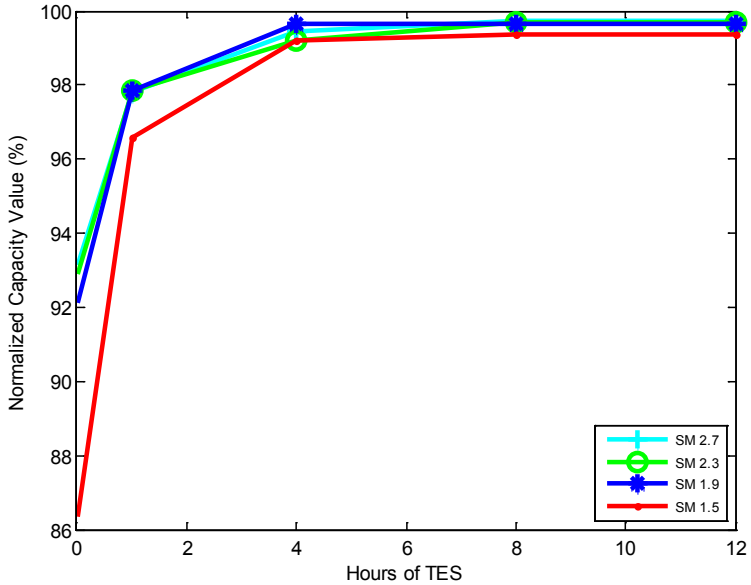
- Maximize energy flexibility
- Ensure high capacity value

Capacity Credit of CSP-TES

Imperial Valley, CA

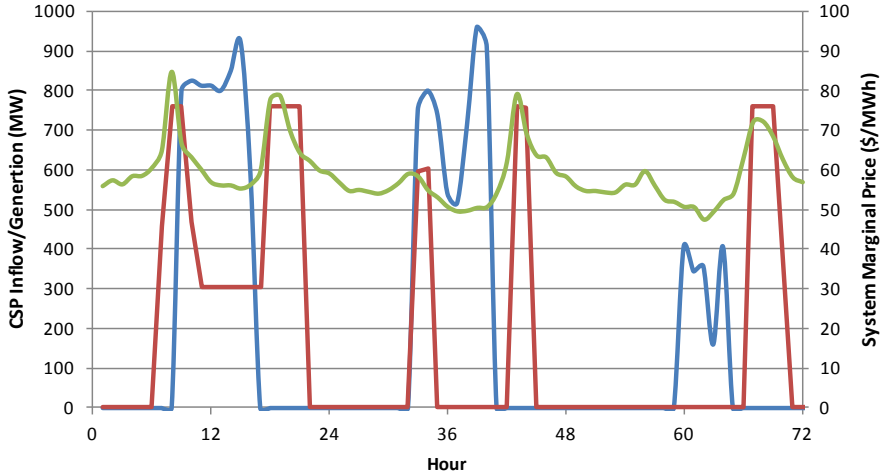


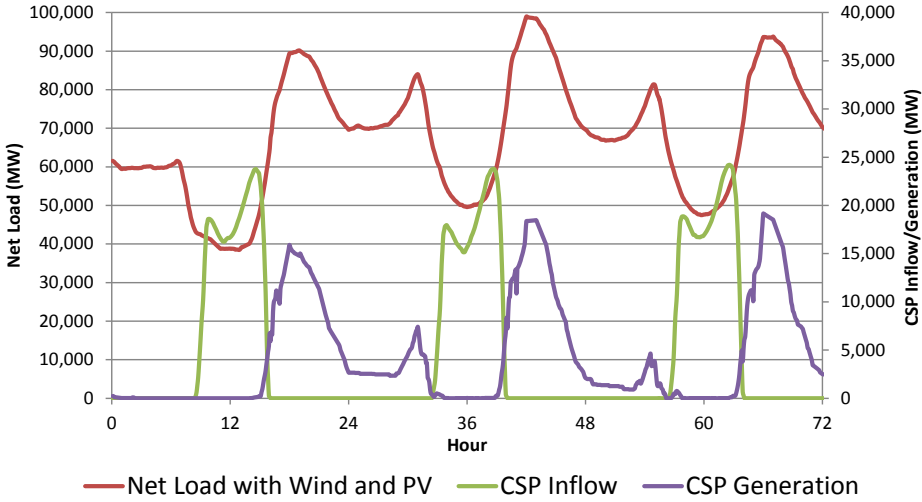
Death Valley, Ca



Maximizing Energy Flexibility

Optimal dispatch of CSP in a future scenario with additional PV.





During the spring, there may be hours where storing 100% of inflow is "optimal"

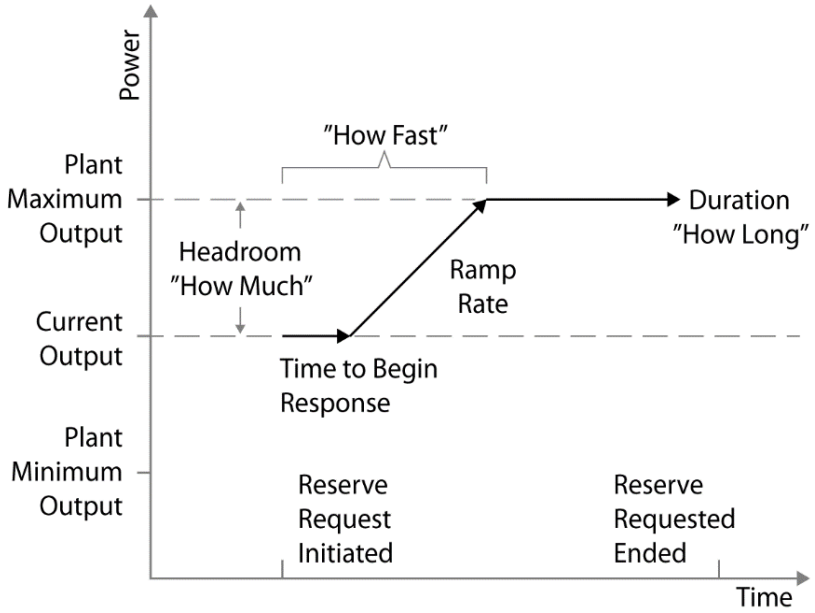
Operating Reserves

Defined as the capability above firm system demand required to provide for regulation, load forecasting error, equipment forced and scheduled outages, and local area protection.

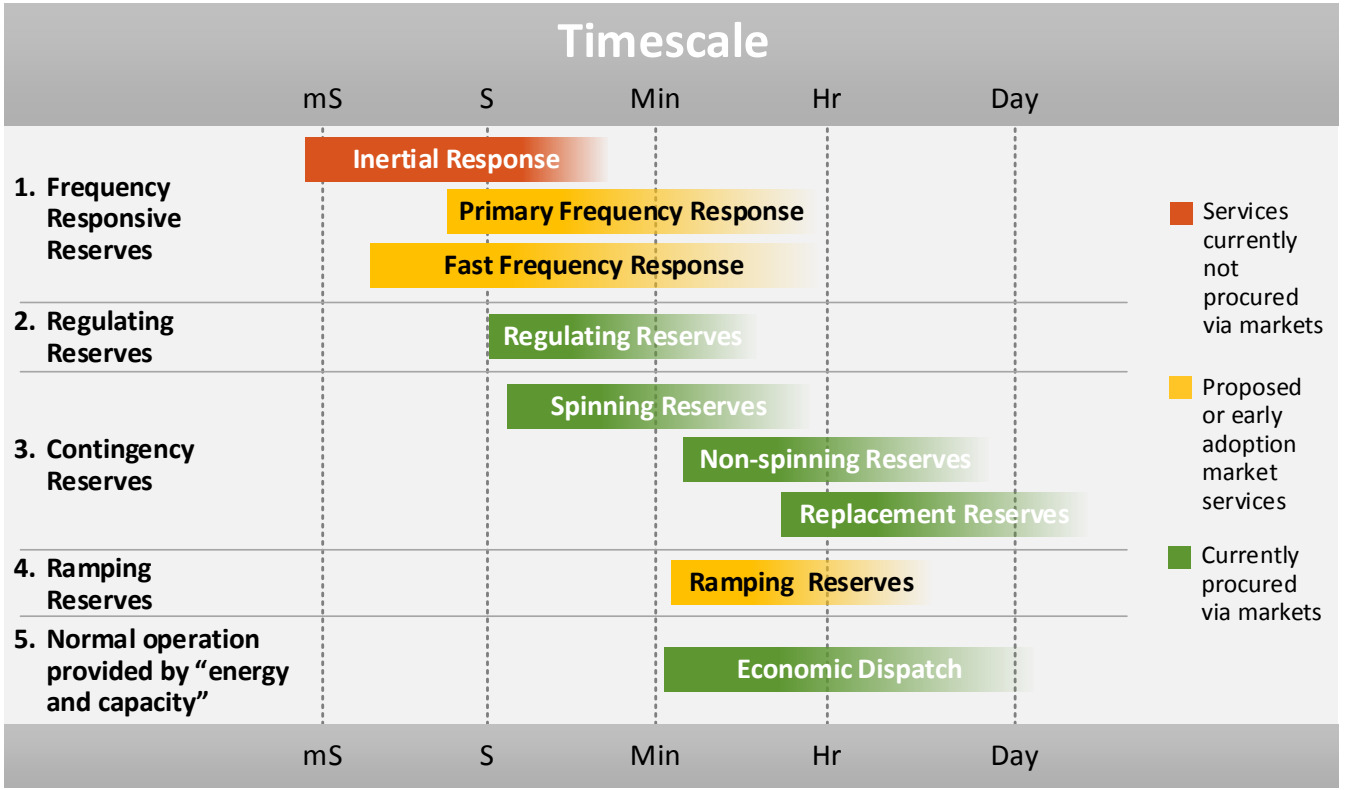
Distinctions can be characterized by three factors:

- **How much**
- **How fast**
- **How long**

There are no uniform definitions for various operating reserve products.



Timescales of Operating Reserve Requirements



Frequency-Responsive Reserve Requirements

- NERC has established minimum recommended standards for PFR for each of the three U.S. grids

Primary Frequency Response Obligation

Region	IFRO (MW/0.1Hz)[a]	MDF (Hz)[b]	Requirement (MW / % of Peak Demand)
CAISO	196.5	0.28	550 / 1.1%
Non-CAISO	661.5	0.28	1,852 / 1.7%

- Currently an uncompensated service
- Potentially a new market opportunity
- Like regulating reserves, limited in size

Regulating and Contingency Spinning Reserve Requirements and Costs

For the requirement in non-market regions, we multiply the percentage requirement of a large utility in that region by the total peak demand of the larger region in which it is located

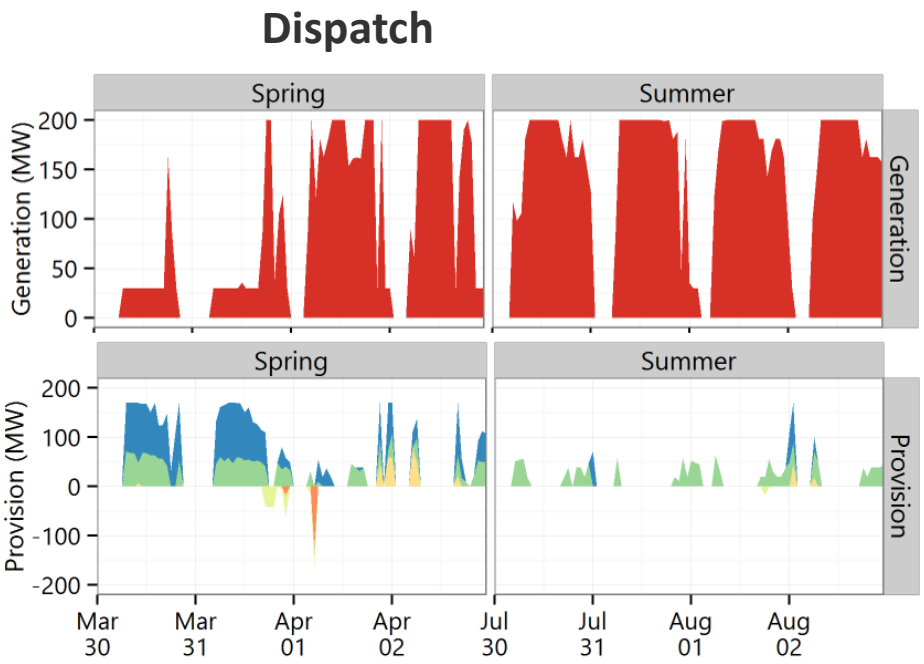
Regulating Reserve Requirements

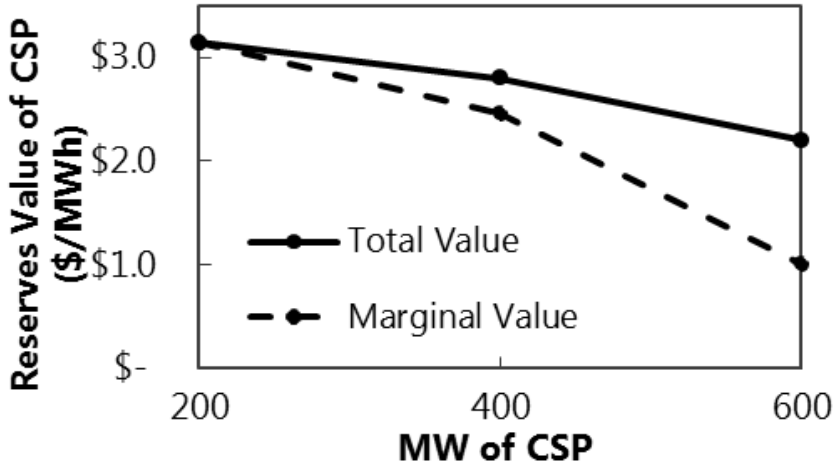
Market Regions	Average Regulation Requirement (% of Peak Demand / MW)	2017 Average Price ($/MW-hr)
CAISO	Regulation Up: 0.64% / 320 Regulation Down: 0.72% / 360[a]	Regulation Up: $12.13 Regulation Down: $7.69[b]
Regulated Regions[o]	(% of Peak Demand / Estimated Region Requirement in MW)	Tariff ($/kW-month / $/MW-hr)
Non-CAISO WECC (proxy utility: Arizona Public Service)	1.17% / 1,240[p]	$7.41/$10.29

Spinning Contingency Reserve Requirements

Market Regions	Spinning Requirement (% of Peak Demand / MW)	2017 Average Price ($/MW-hr)
CAISO	1.60% / 800 MW[a]	$10.13[b]
Non-CAISO WECC (Arizona Public Service)	1.50% / 1590	$6.26 / $8.69

Example of CSP Dispatch with Reserves Provision





Additional Value

Summary of Key Findings

- The majority of the value of CSP will be derived from capacity and energy services
  - Maximizing capacity value will be important
  - 6 Hours of storage appears sufficient
  - Direct storage will increase value by avoiding low-value generation in the spring
- Essential reliability services including operating reserves can provide an important supplement to value
  - But market is thin with increasing competition
  - Don’t expect inertia and other benefits of using synchronous generators to be the “savior” of CSP

Thank You

www.nrel.gov

Funding provided by the DOE Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Offices