

Unlocking Solar's Full Potential

Workshop on Battery Storage, Hybrid Resources,
Frequency Response and Grid Services, Sept 17, 2019

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First Solar

Leading the World's
Sustainable Energy Future

Solar Power Provides Energy, Flexibility and Capacity



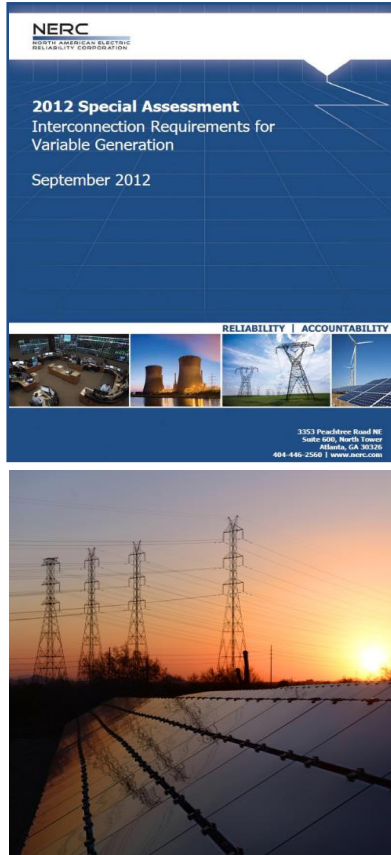
- Utility-scale Solar is now able to provide *grid flexibility & essential reliability services*
- Leveraging this innovative resource leads to a more efficient power system with *lower system costs and reduced emissions*
- *Regulatory, market and policy reforms* may be necessary to make an effective use of solar (VRE) flexibility

Source: Also, "Status of Power System Transformation", 2018, IEA Report, <https://webstore.iea.org/status-of-power-system-transformation-2018> ; VRE: Variable Renewable Energy



Requirements for Being A Good Grid Citizen

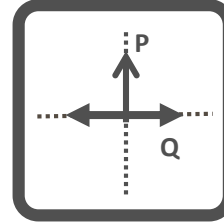
PV Solar Supports Grid Reliability & Stability



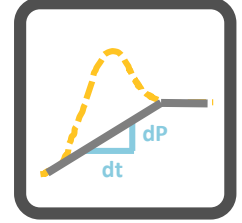
Grid Friendly Features Required by NERC:

- Voltage regulation
- Active power control (ramping, Curtailment)
- Grid disturbance ride through (voltage and frequency excursions)
- Primary Frequency droop response
- Short circuit duty control

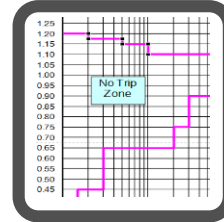
Voltage Support



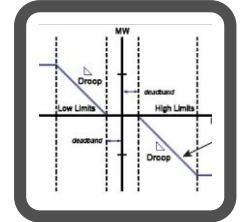
Power Control



Ride Through



Frequency Droop



Base Capability

Sources: (1) NERC: 2012 Special Assessment Interconnection Requirements for Variable Generation
(2) M. Morjaria, D. Anichkov, V. Chadliev, and S. Soni. "A Grid-Friendly Plant." *IEEE Power and Energy Magazine* May/June (2014)



Solar Provides Essential Reliability Services

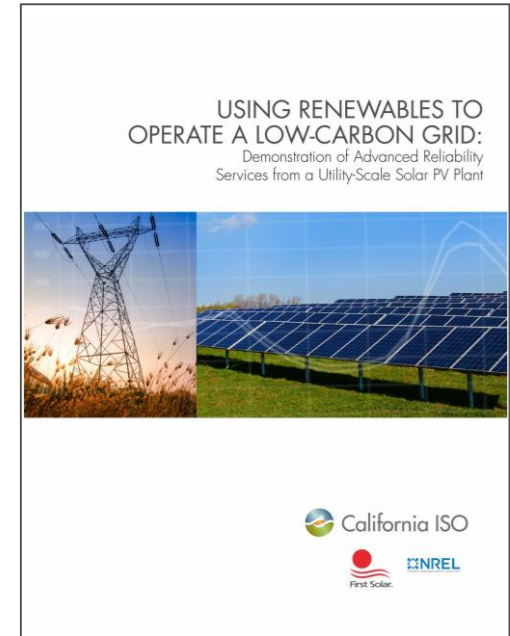
Solar Provides Reliability Services (when/if needed)

NERC identified essential reliability services to integrate higher levels of renewable resources, including:

- Frequency Control
- Ramping capability or flexible capacity

Reduces need for conventional generation

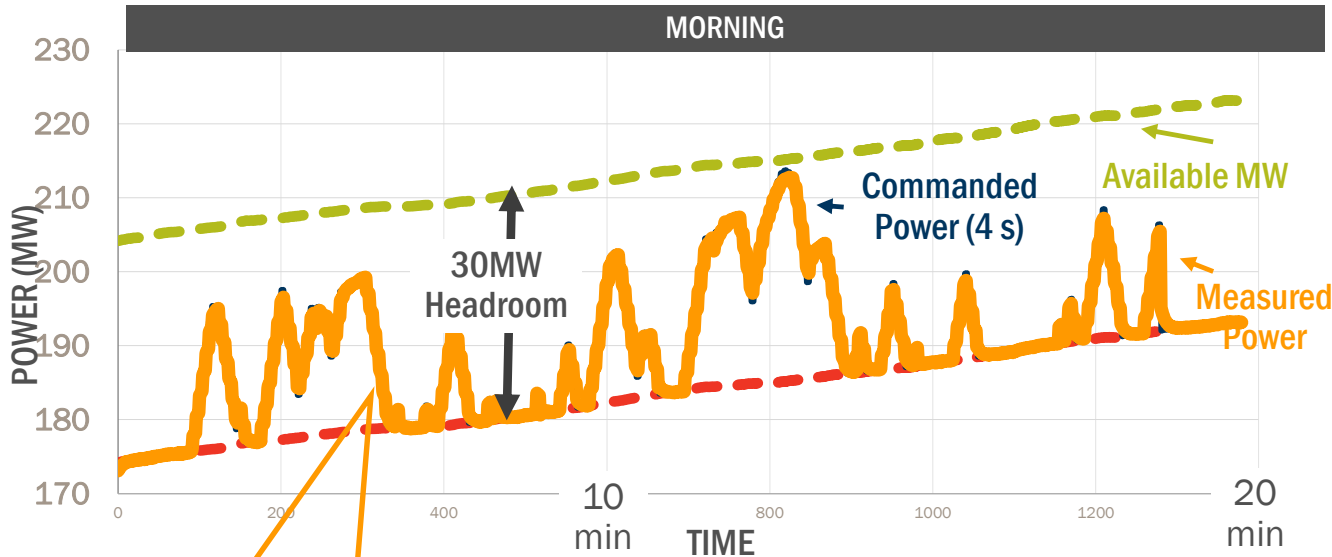
- Goes beyond simple PV energy value
- Enables additional solar
- Reduces need for expensive storage



2017 NARUC
Award Winner

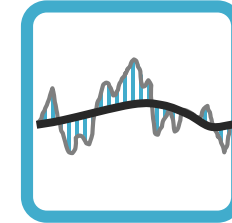
2018 Intersolar
Outstanding
Project Winner

Solar Plant Follows Grid Operator Commands (AGC) Very Accurately



Regulation is ~27 %points more accurate than best conventional generation

Power Regulation



- AGC
- Up-Regulation
- Down-Regulation
- Frequency Regulation
- Flexibility

Grid Reliability Services

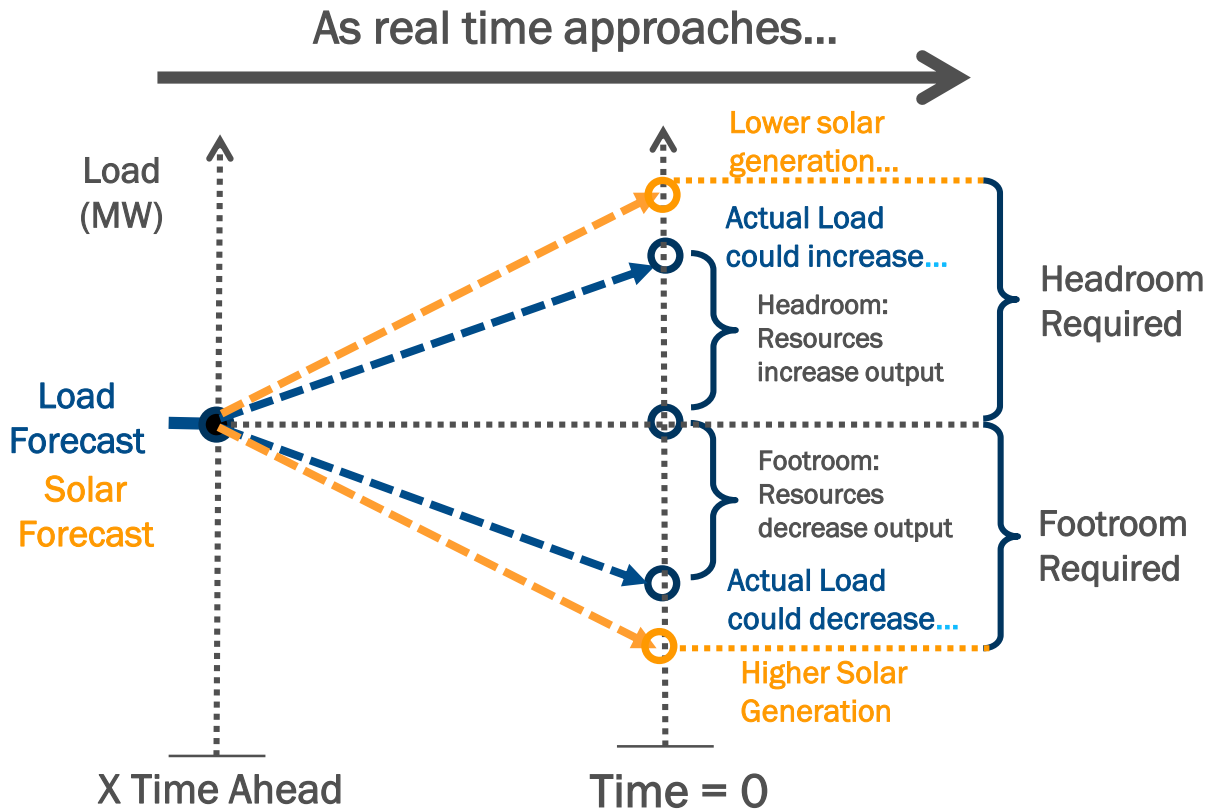


Source:
<http://www.caiso.com/Documents/TestsShowRenewablePlantsCanBalanceLow-CarbonGrid.pdf>
AGC: Automated Generator Control

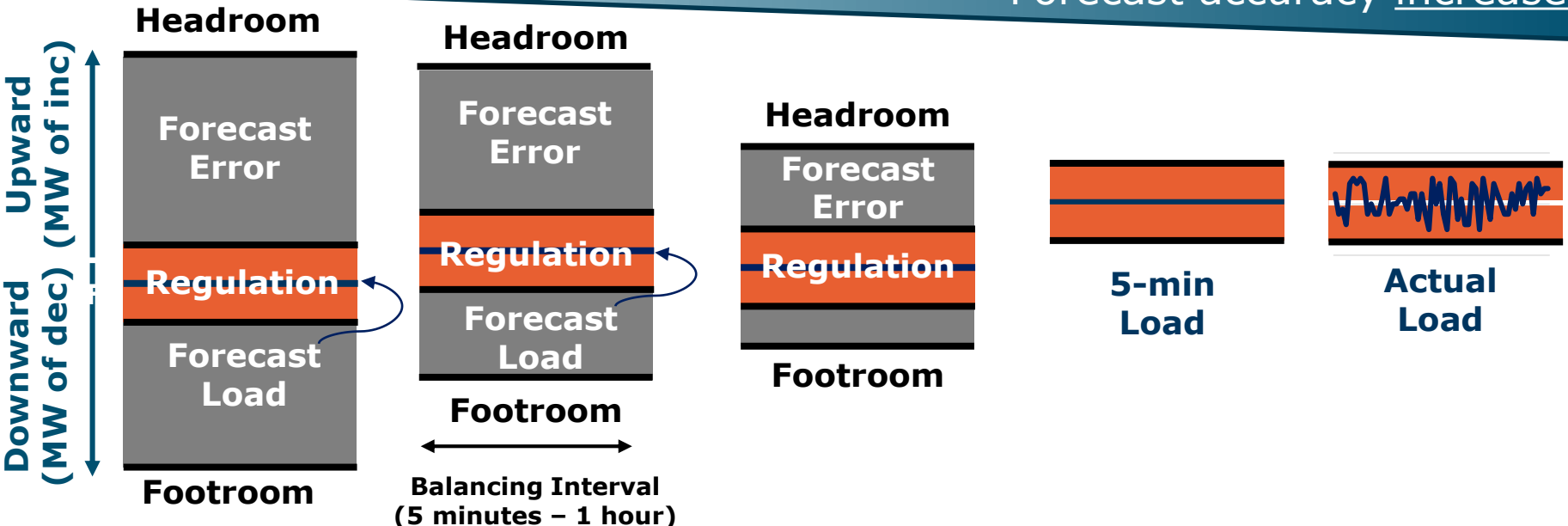
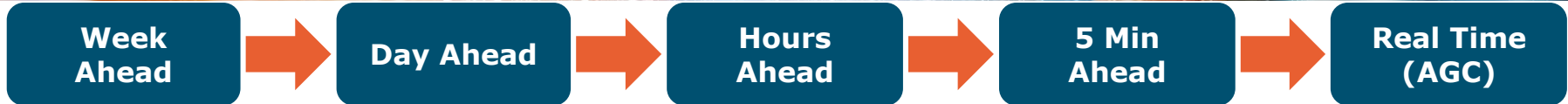


Solar Contributes to System Flexibility

Operational Flexibility Needed to Balance System While Managing Variability & Forecast Uncertainty



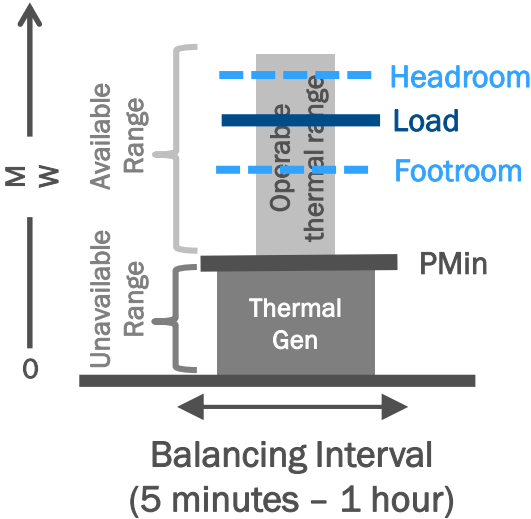
Head and Foot Room are Needed to Ensure Operational Control



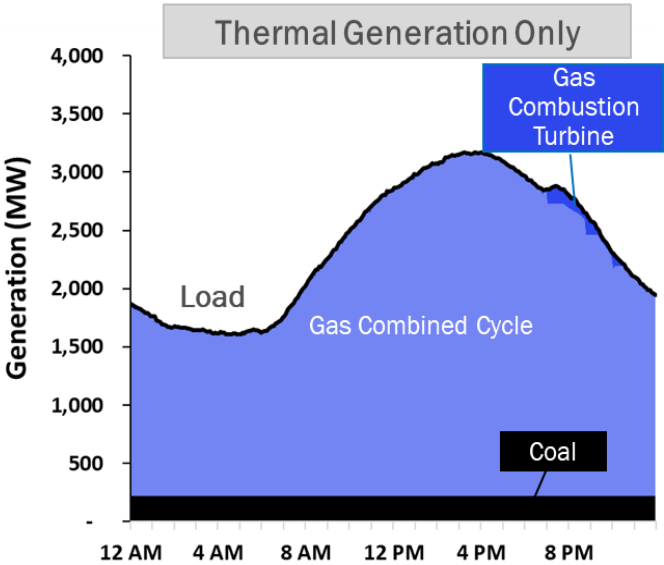
Generation Dispatch For Thermal Generation Only

Thermal Generation Only

Required headroom & footroom fit within operating range of generation fleet



Generation Dispatch on a Spring Day



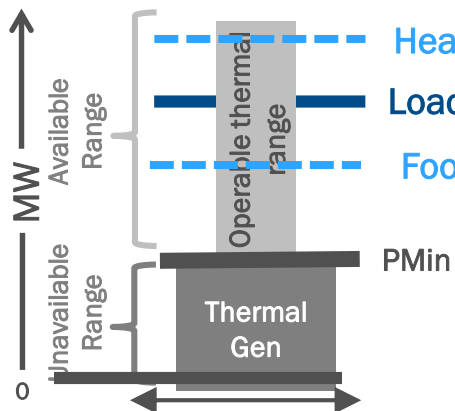
Generation Dispatch with Must-Take Solar

– Infeasible Under Higher Penetration

Thermal Generation Only

Required headroom & footroom fit within operating range of generation fleet

Solar increases balancing needs

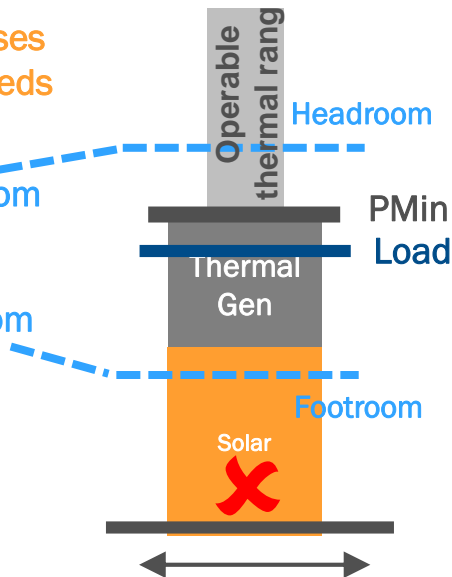


Balancing Interval
(5 minutes – 1 hour)

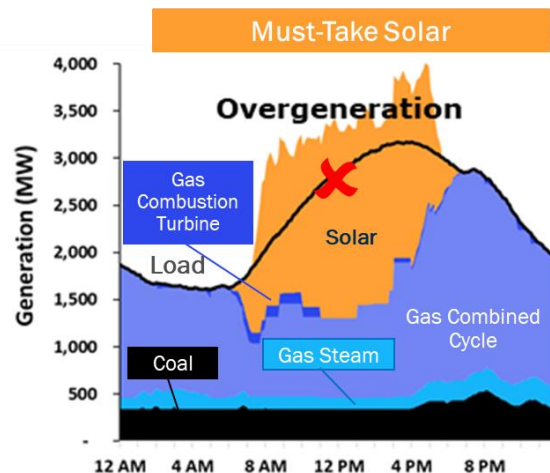
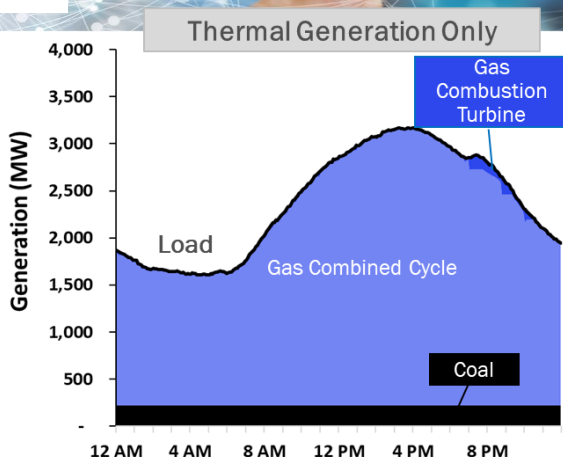
Must-Take Solar

Infeasible:

Minimum thermal dispatch (PMin) above footroom --
no feasible range available



Balancing Interval
(5 minutes – 1 hour)

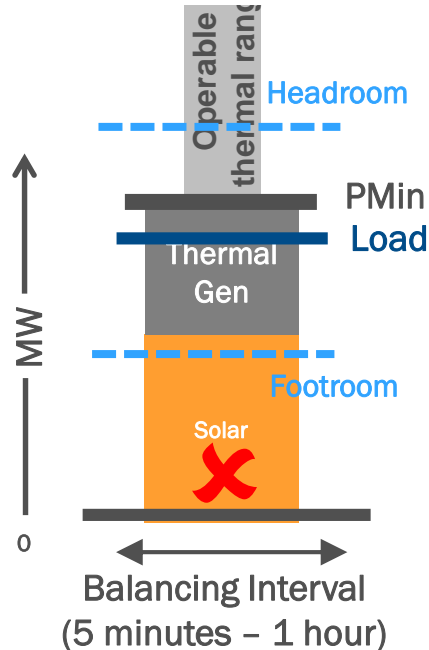


Generation Dispatch with Curtailable Solar – Feasible but Higher Curtailment

Must-Take Solar

Infeasible:

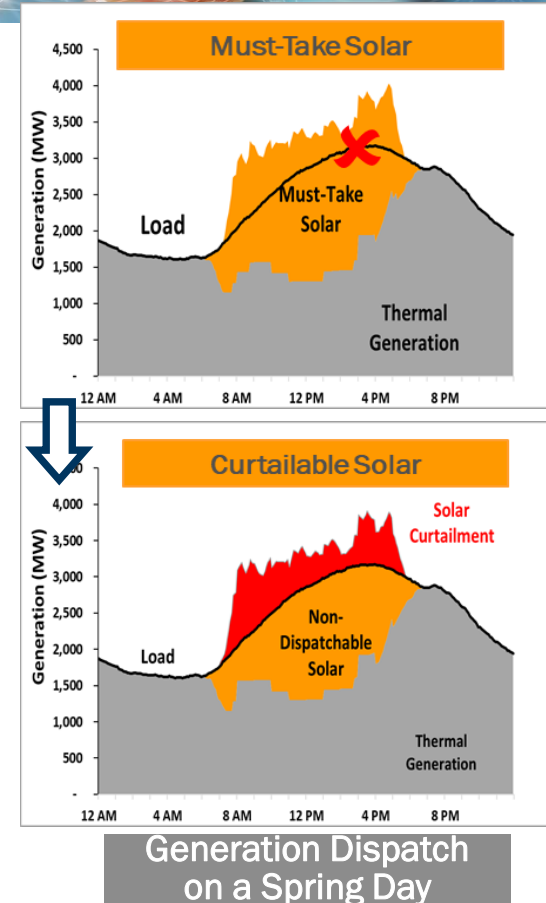
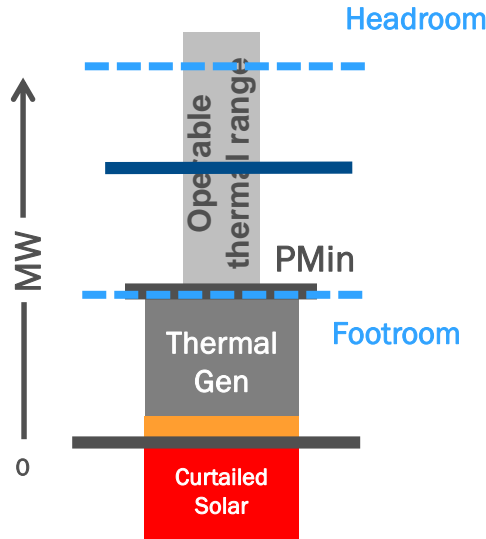
Minimum thermal dispatch (PMin) above footroom – *no feasible range available*



Curtailable Solar

Feasible:

Solar is curtailed until thermal dispatch is within operable range

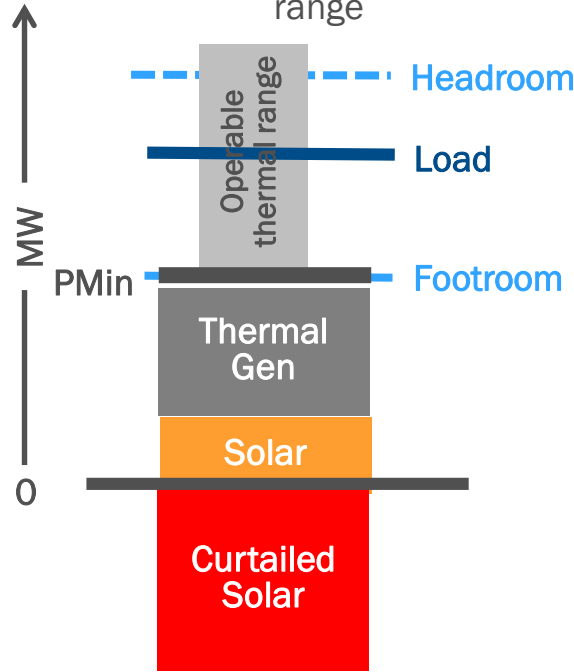


Generation Dispatch with Downward Dispatch Solar – *Increases Value*

Curtailable Solar

Feasible:

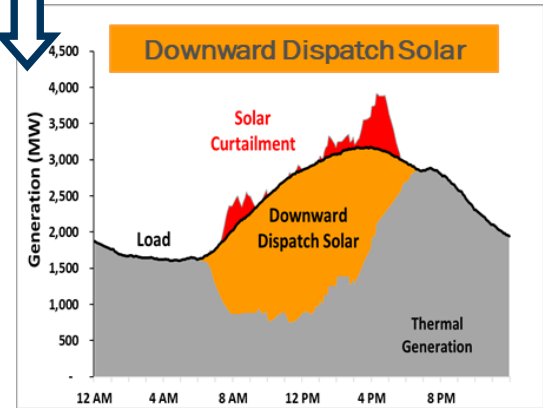
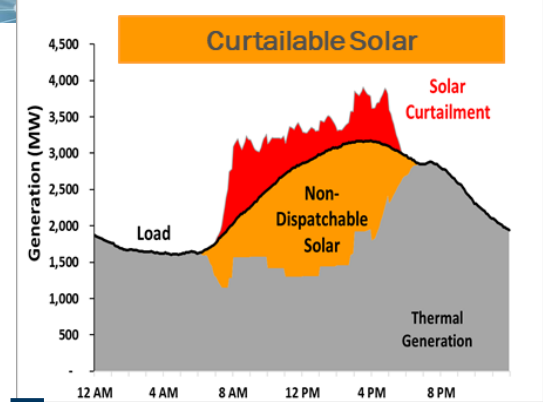
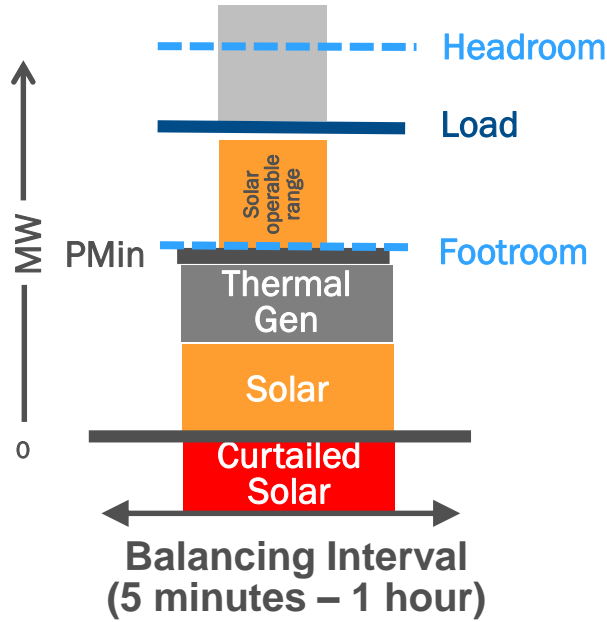
Solar is curtailed until thermal dispatch is within operable range



Downward Dispatch Solar

Increased Value:

Curtailment reduced because solar contributes to footroom



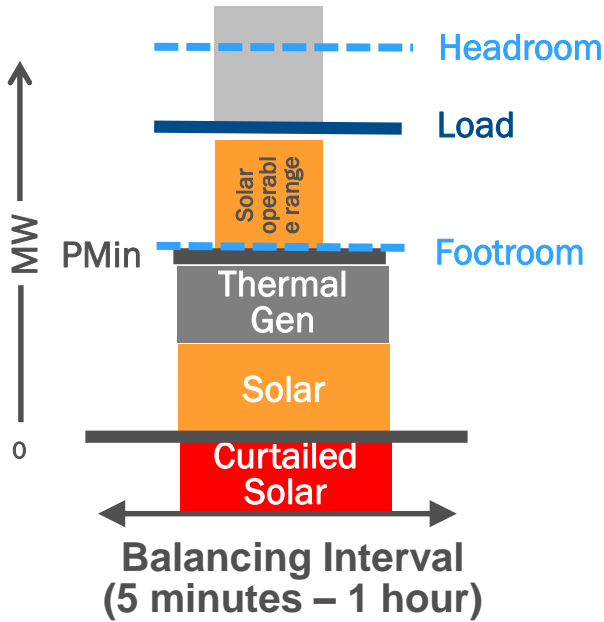
Generation Dispatch
on a Spring Day

Generation Dispatch with Fully Flexible Solar – *Optimizes Value*

Downward Dispatch Solar

Increased Value:

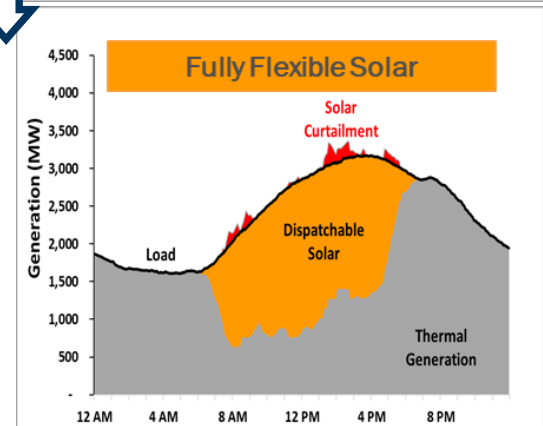
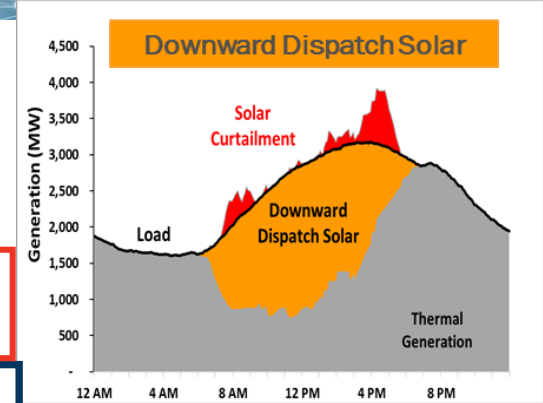
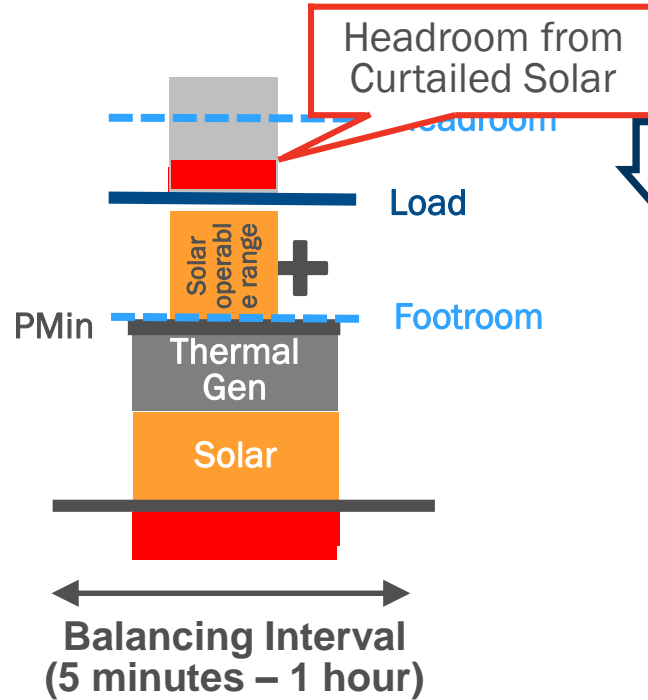
Curtailment reduced
because solar contributes
to footroom



Fully Flexible Solar

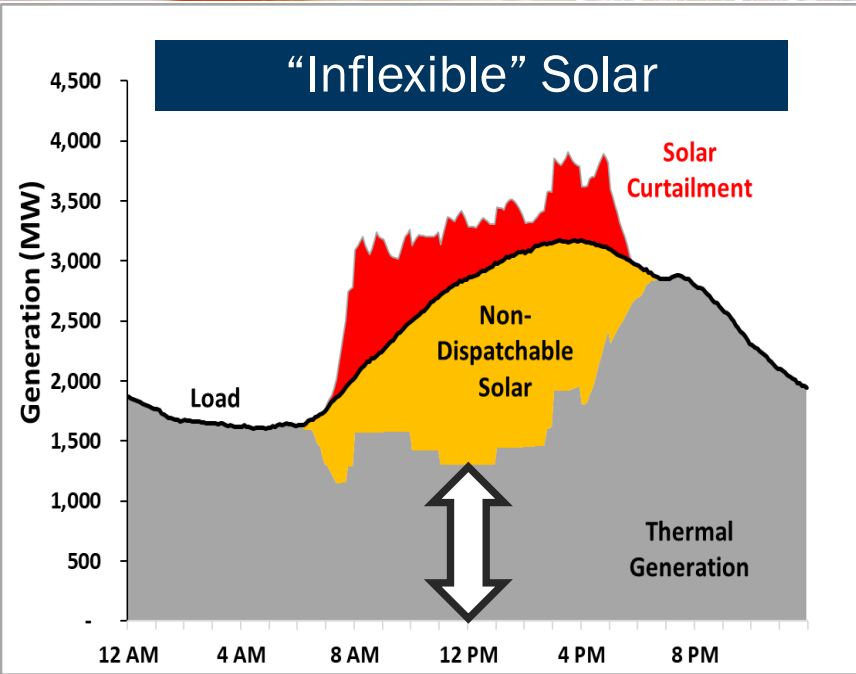
Optimal Value:

Solar contributes to both
footroom & headroom

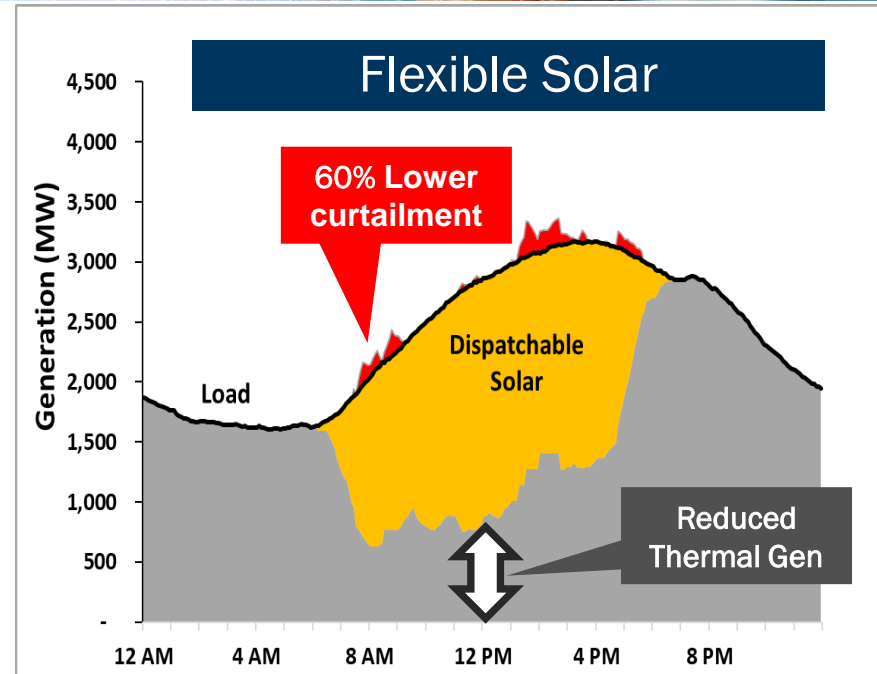


Generation Dispatch
on a Spring Day

Flexible Solar Reduces Curtailment – An Illustration (2,400 MW Solar)



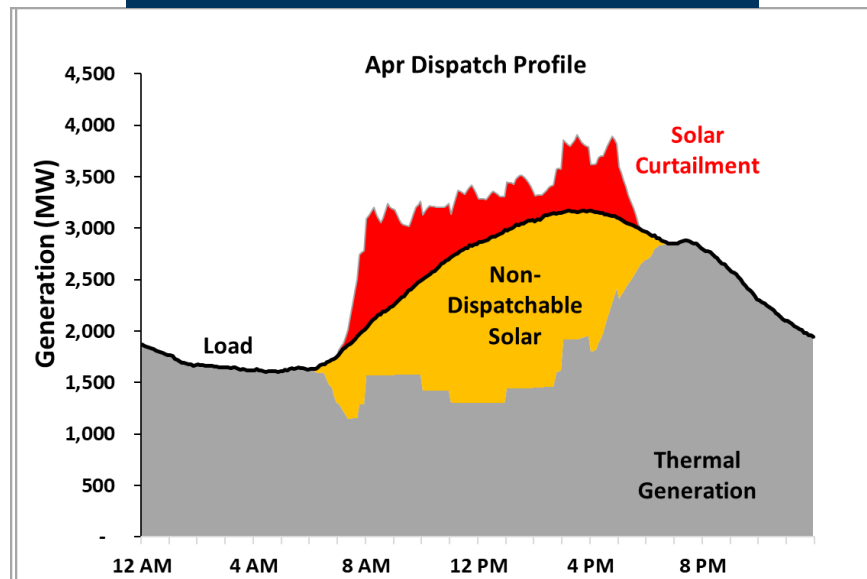
Solar Provides No Regulation Reserves



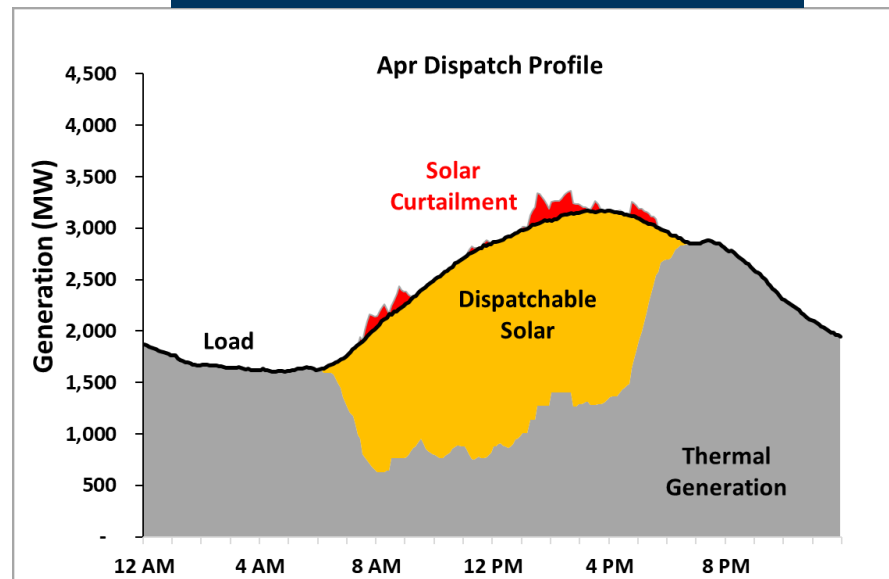
Flexible Solar: Provides regulation reserves.

Comparison of Dispatch Profiles Over The Year (Animated)

Non-Dispatchable Solar



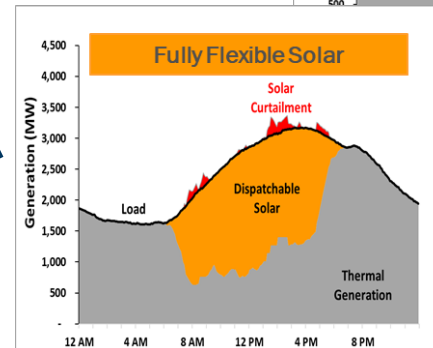
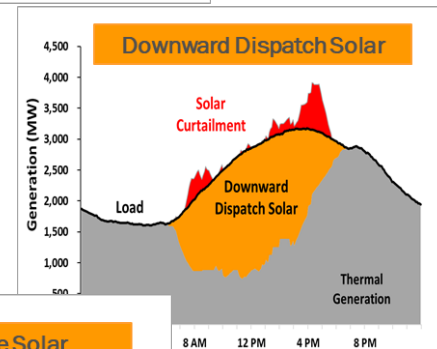
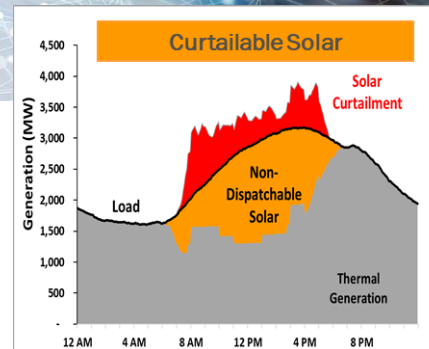
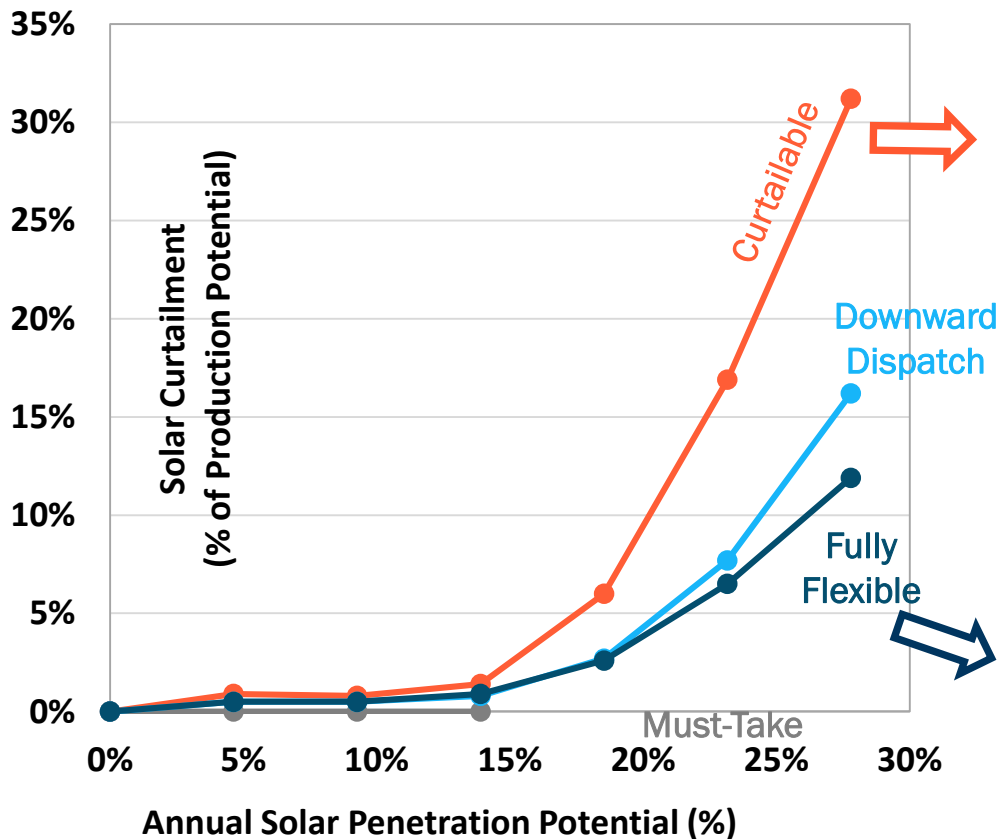
Fully Flexible Solar



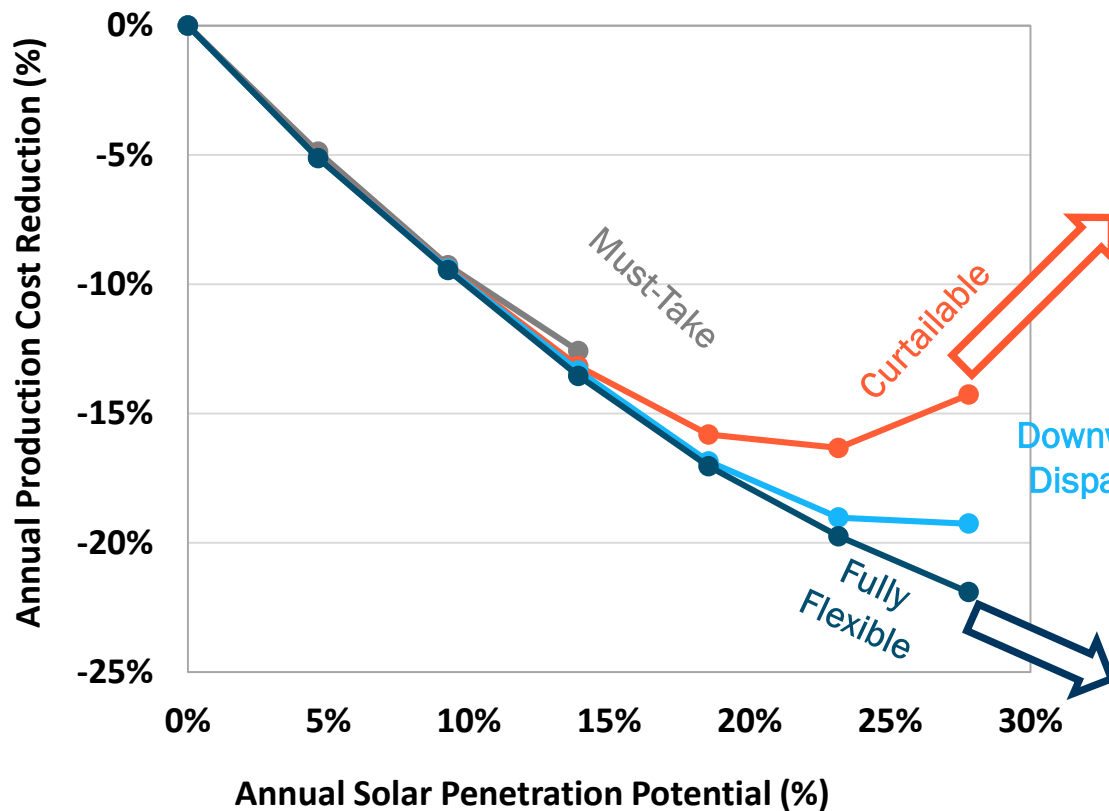
Source: E3,TECO, First Solar Report "Dispatchable Solar: The Key to Unlocking the Clean Energy Grid of the Future", under review.

Dispatchable or Grid Flexible Solar: operating solar plants at an optimal point which may be lower than available resource and providing regulation reserves. Non-dispatchable solar refers to where solar plant is only used to avoid oversupply and not provide any reserves.

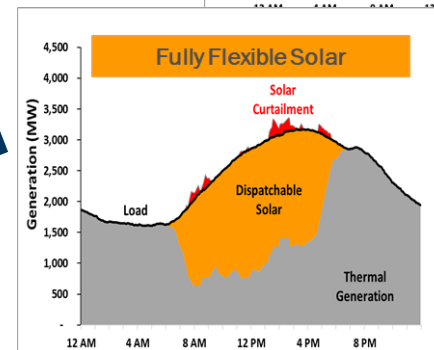
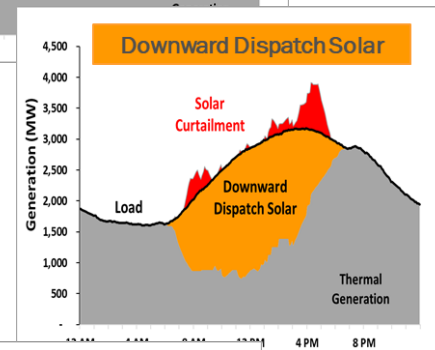
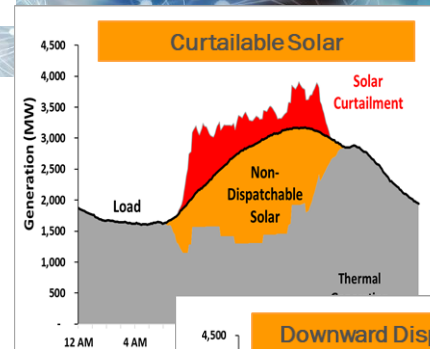
Flexible Solar Reduces Curtailment



Flexible Solar Reduces Production Costs



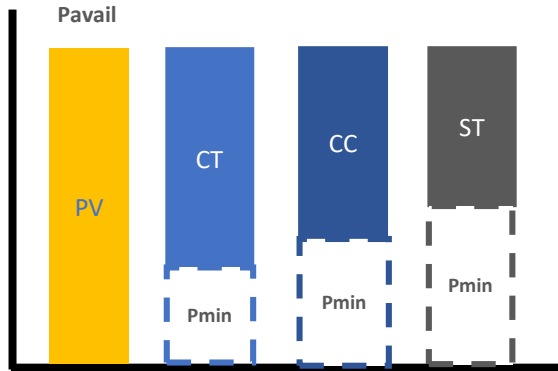
Assumes Solar \$0 Variable Cost



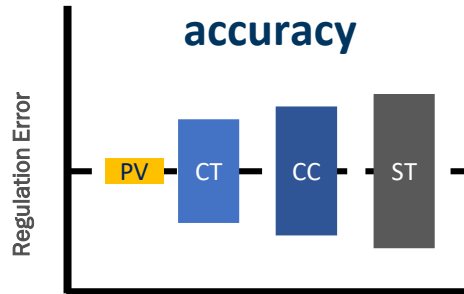
Flexibility = Key Resource Attribute of the Future Grid

Utility-scale PV is more flexible and responsive than today's fossil fleet:

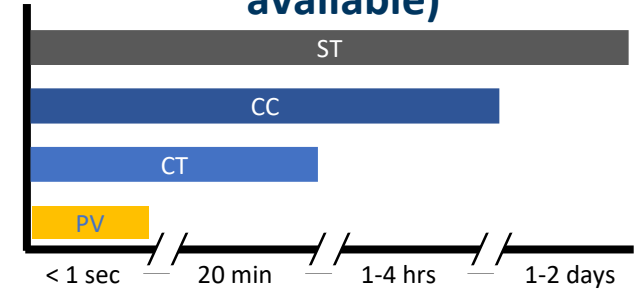
PV can operate flexibly from 0 to available power (P_{avail})



PV follows AGC (4-sec) signal with high accuracy



PV can start up in seconds (when solar resource is available)



CT Combustion Turbine
CC Combined Cycle
ST Steam Turbine

System Flexibility Sources

Increasing Cost



Markets & Operations



Demand Response



Grid Expansion



Flexible Generation



Energy Storage



Increasing Flexibility



Solar Provides Firm Capacity

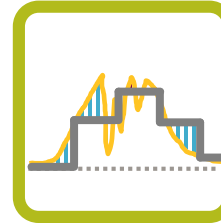
Firm Dispatchable Solar with Storage



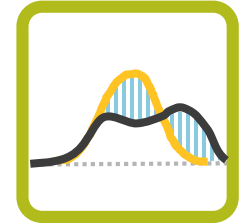
- **Storage enhances Grid Flexible Solar to:**
 - Firm and/or shift solar energy delivery to the grid
 - Meet resource adequacy requirements
 - Potentially provide black start capabilities
- **Unique attributes compared to conventional resources:**
 - No Pmins with quick ramping across its entire operating range
 - Reduces solar forecasting errors to near zero
 - No startup, or no minimum down times or run time

Firm Dispatchable Solar

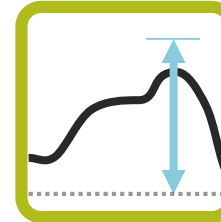
Firming



Energy Shifting



Resource Adequacy



Black Start



Solar+Storage designed to deliver firm capacity and enhanced grid services

Grid Capabilities Enhanced w Storage



Summary

Next Steps

Policymakers

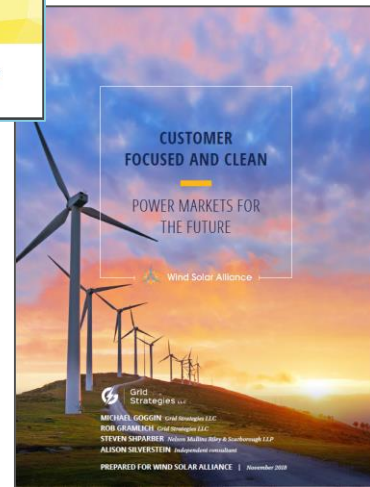
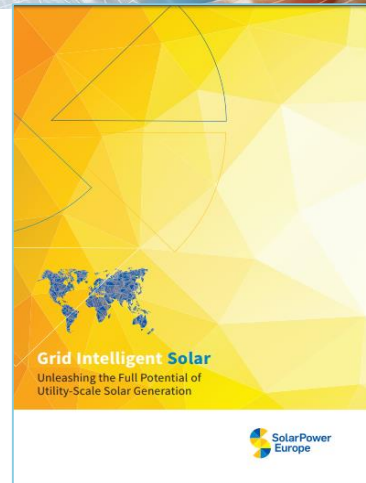
- Ensure proper value is placed on solar's capacity, energy, and grid flexibility
- Collaborate on new PPA constructs that contemplate the provision of (and payment for) flexible dispatch
- Variable renewable energy resources should be modeled as having dispatch flexibility in IRP processes

Grid Operators

- Value flexibility in all resources
- Prioritize units that are the most efficient in meeting dispatch signals
- Increase reliance on variable renewable energy resources to provide capacity and essential grid services

Regulatory, Market and Policy Recommendations

- Attract flexible solar (VRE) through open participation and efficient market pricing
- Allow flexible solar to participate in all reliability services markets
- Ensure capacity markets reflect true capacity contribution of solar
- Favor lowest cost resources with the most flexible capabilities



Lower system costs and reduce emissions

Solar Power Provides Energy, Flexibility and Capacity



- Utility-scale PV Solar **contributes to Grid Stability & Reliability**



- Utility-scale PV Plants provides **Essential Reliability Services & Grid Flexibility**



- Combined with **Storage**, Solar provides Clean & Competitive **Firm Capacity**