

Grid Services from Solar: Challenges and Opportunities

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June 17, 2019
ARPA-e PERFORM
Workshop



OUR VISION
Leading the World's Sustainable Energy Future

Key Messages



- 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*
- However, *Grid Management Innovations* are needed to leverage solar flexibility given its inherent variability and uncertainty



Can Solar Provide Essential Reliability Services?

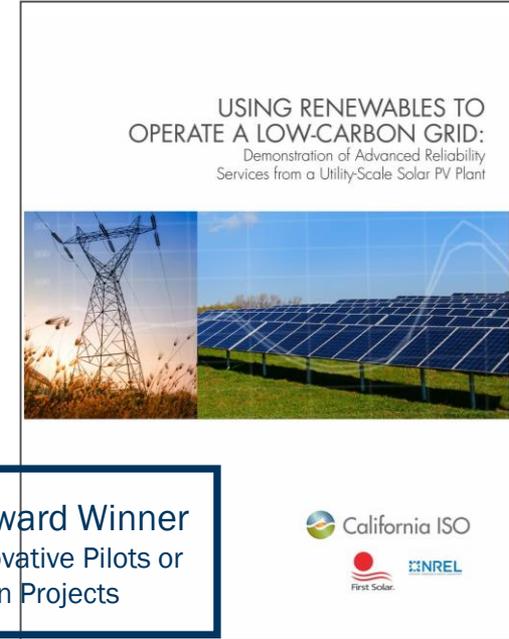
Solar Can Provide Reliability Services

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

- Frequency Control
- Ramping capability or flexible capacity

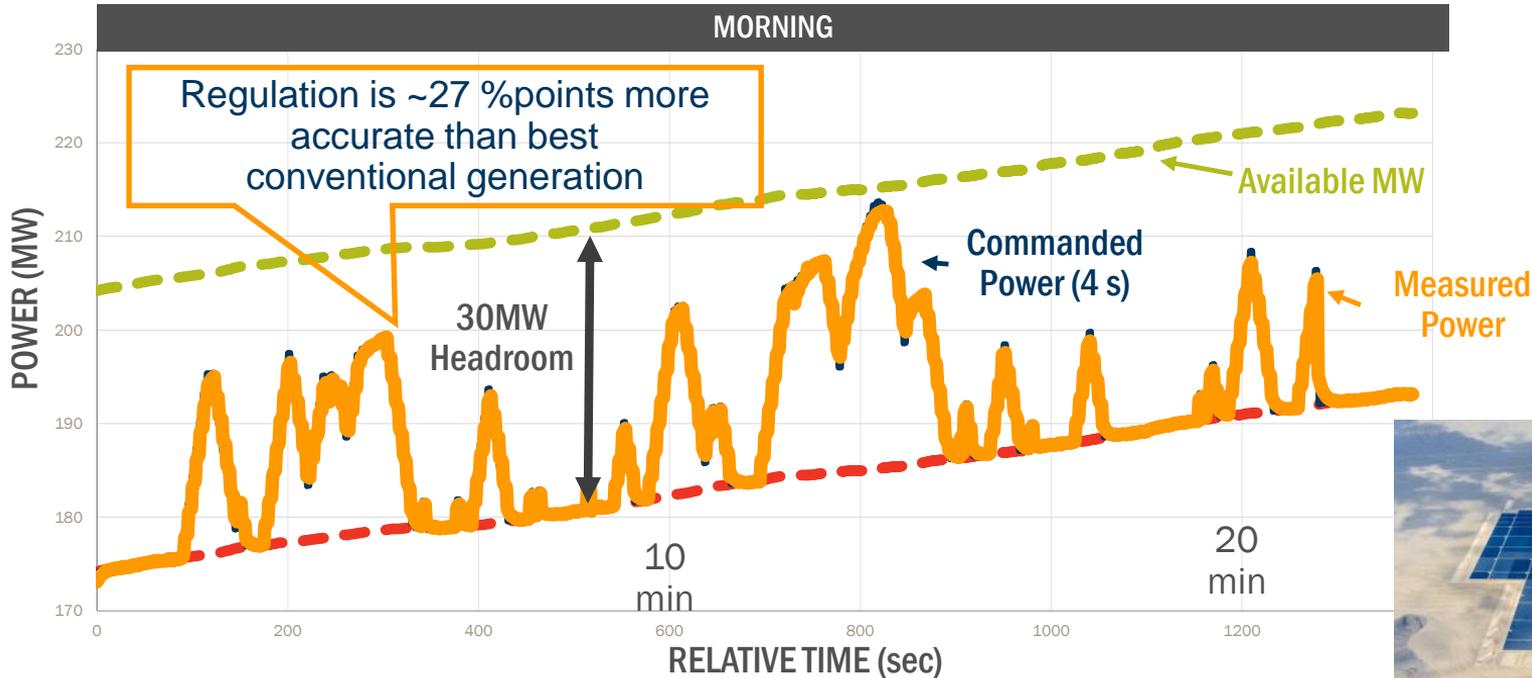
Reduces need for conventional generation

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



2018 Intersolar Outstanding
Project Winner

Solar Plant Follows Grid Operator Commands (AGC) Very Accurately



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

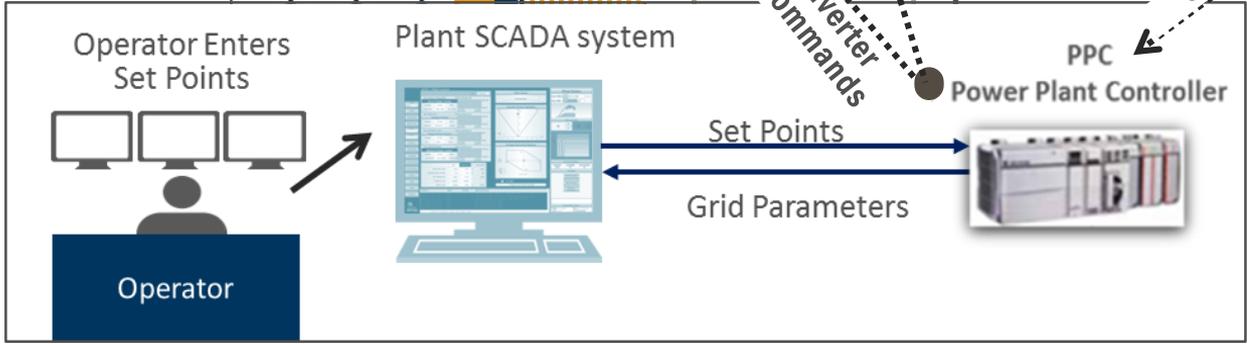
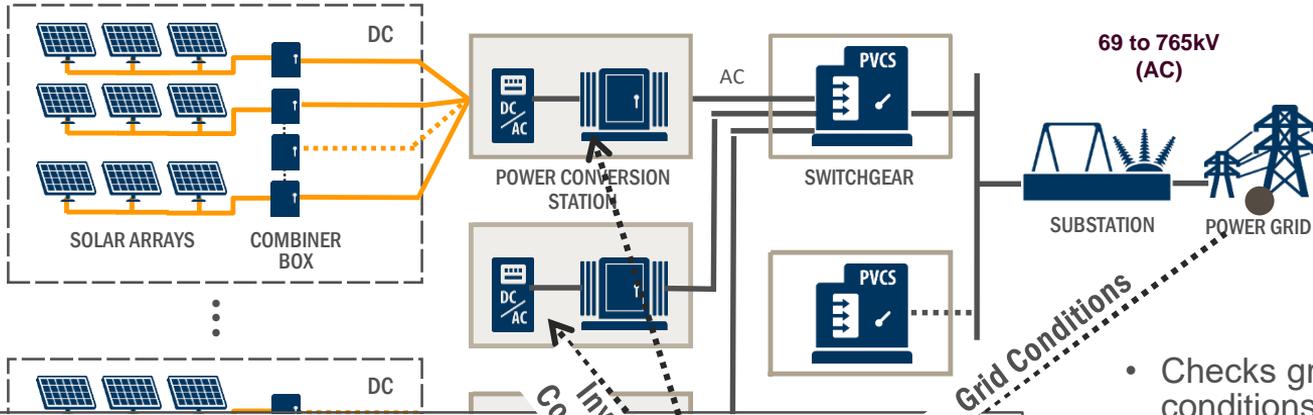
Plant Control System Enables Grid Friendly Features



Sunlight to DC Power

DC Power to AC Power

AC Power to Grid



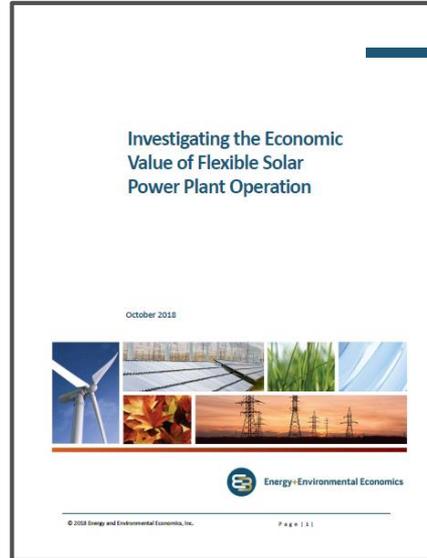
- Checks grid's actual conditions and required set points
- Sends individual instructions to each inverter based on location, losses, and performance
- Controls quality of power coming out of the PV plant

Closed-loop controls at 100 milliseconds!



Can Solar Contribute to System Flexibility?

Can Solar Contribute to System Flexibility?



Source: E3,TECO, First Solar Report "Investigating the Economic Value of Flexible Solar Power Plant Operation", <https://www.ethree.com/wp-content/uploads/2018/10/Investigating-the-Economic-Value-of-Flexible-Solar-Power-Plant-Operation.pdf>

Flexible (“Dispatchable”) Solar Maintains Value with Increased Penetration

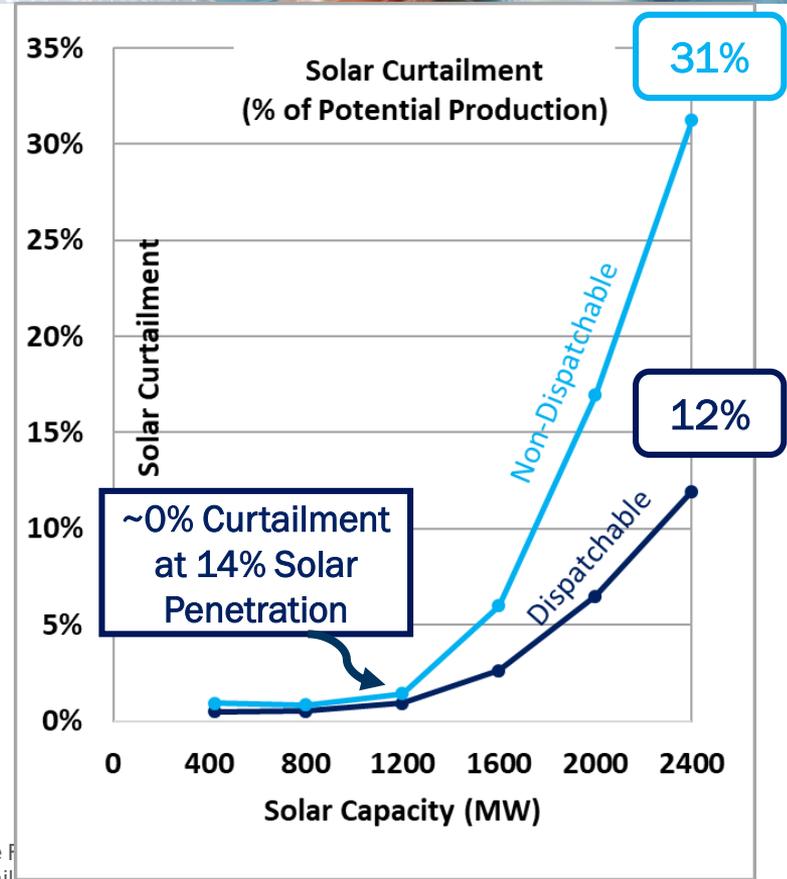


E3/TECO/FS Study Goal

- To quantify value of dispatchable (flexible) solar at an **integrated utility (~5GW peak) adding solar** to its generation portfolio

Key Study Results

- 2019 thermal fleet has **adequate flexibility** to integrate up to of 14% penetration of solar (1,200MW) **with nearly zero solar curtailment**
- Solar curtailment **rapidly increases to 31%** by doubling solar penetration (at 2,400MW)
- Dispatchable solar **reduces curtailment to 12%** (i.e. retains higher value even at 28% potential penetration)



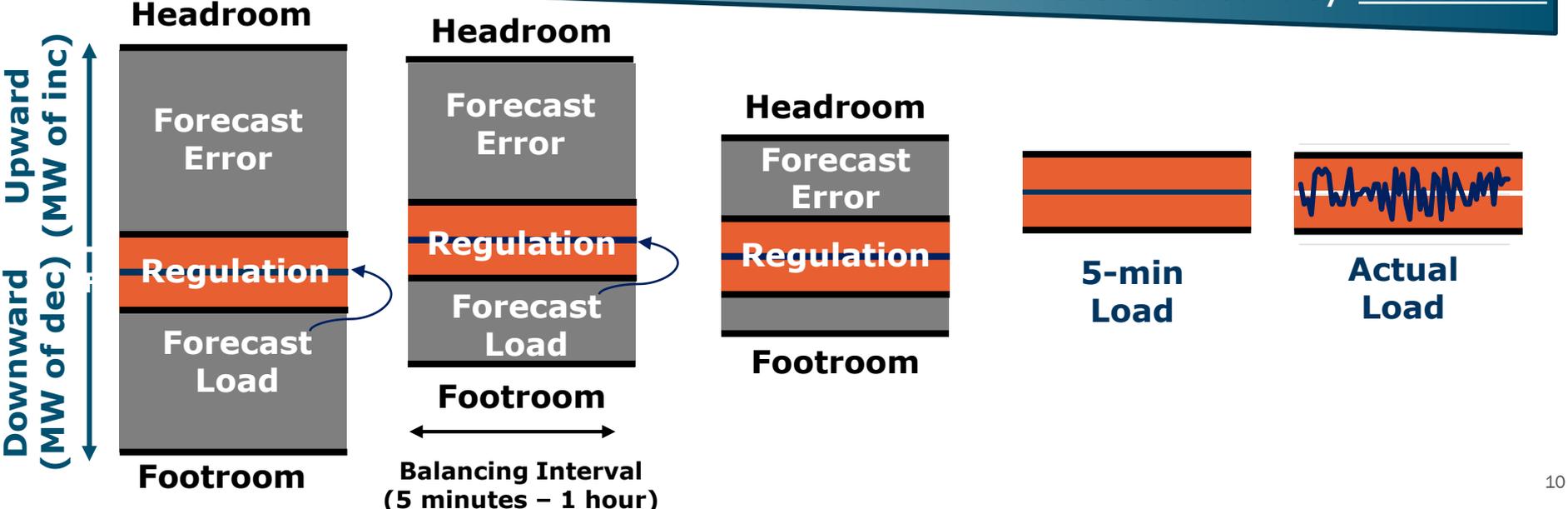
Source: E3,TECO, First Solar Report “Dispatchable Solar: The Key to Unlocking the Clean Energy Grid of the Future”
Dispatchable or Grid Flexible Solar: operating solar plants at an optimal point which may be lower than available resource and providing regulation reserves. Non-dispatchable solar refers to where solar plant is only used to avoid oversupply and not provide any reserves.

Head and Foot Room are Needed to Ensure Operational Control



Operational flexibility decreases

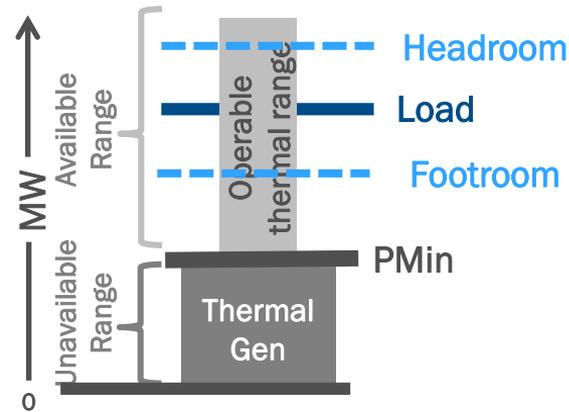
Forecast accuracy increases



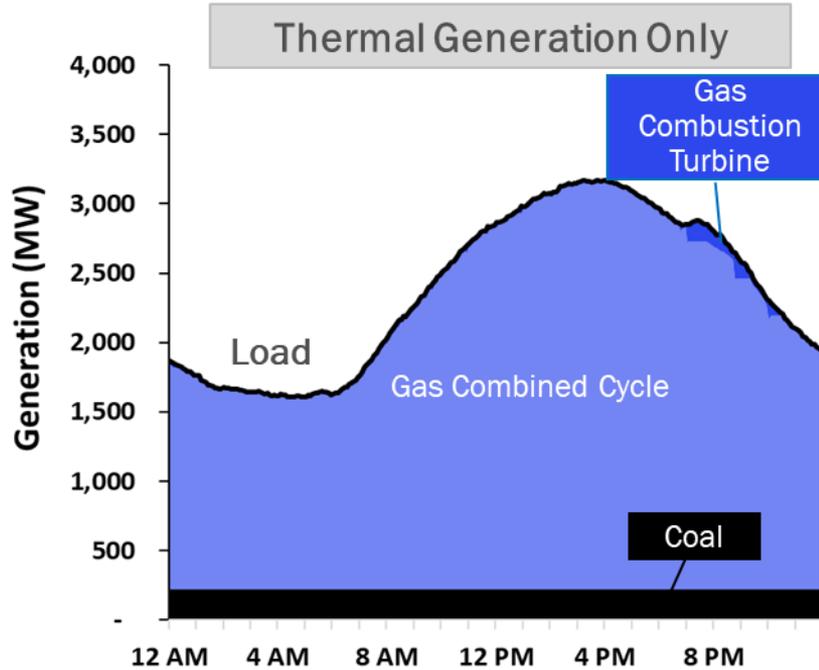
Dispatch For Thermal Generation Only

A: Thermal Generation Only

Required Headroom and Footroom fit within generation fleet available range



Generation Dispatch on A Spring Day



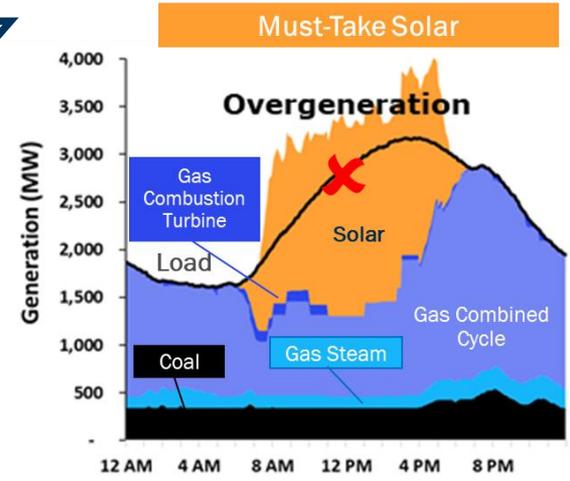
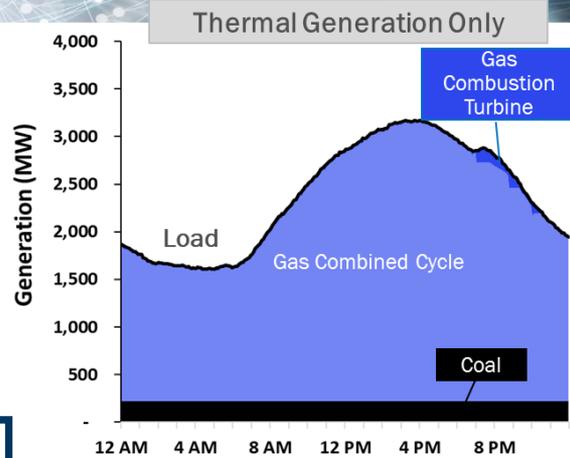
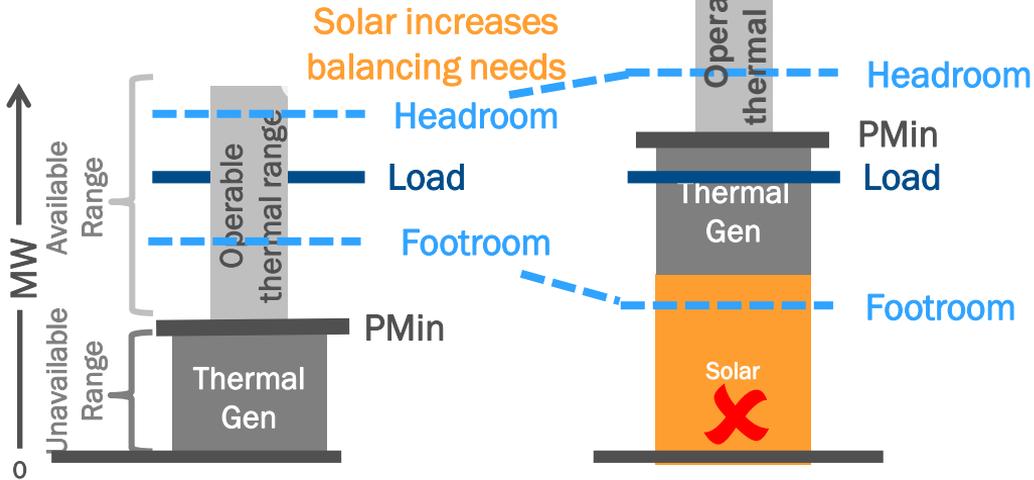
Dispatch with Must-Run Solar – *Infeasible Under Higher Penetration*

A: Thermal Generation Only

Required Headroom and Footroom fit within generation fleet available range

High Solar Penetration

Must-Run Solar
Infeasible:
Minimum thermal dispatch (PMin) above footroom – no feasible range available



Dispatch with Curtailable Solar – *Feasible But High Curtailment*

High Solar Penetration

Must-Run Solar

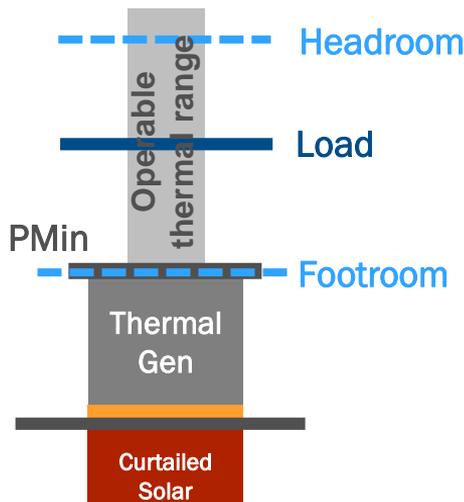
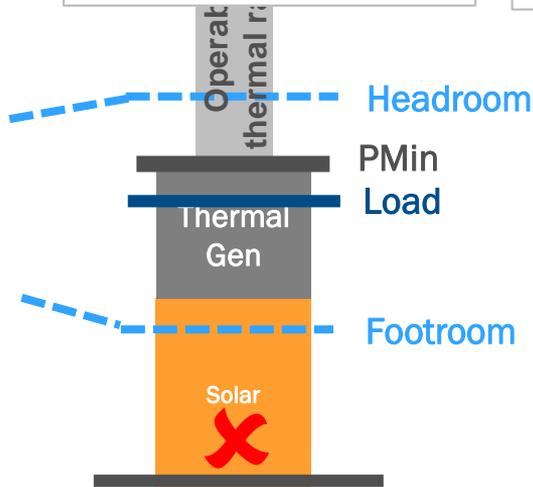
Infeasible:

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

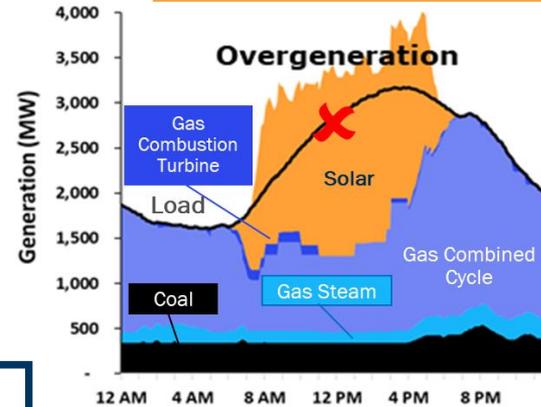
Non-Dispatchable Solar

Feasible:

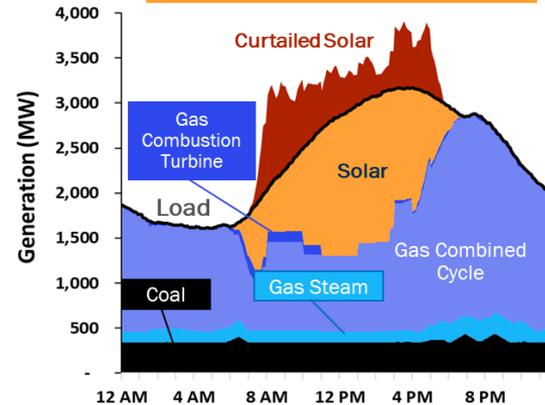
Solar **does not contribute** to headroom and footroom range



Must-Take Solar



Curtailable Solar



“Dispatchable or Grid Flexible” Solar Contributes to Reserves ... *Optimizes Value*

High Solar Penetration

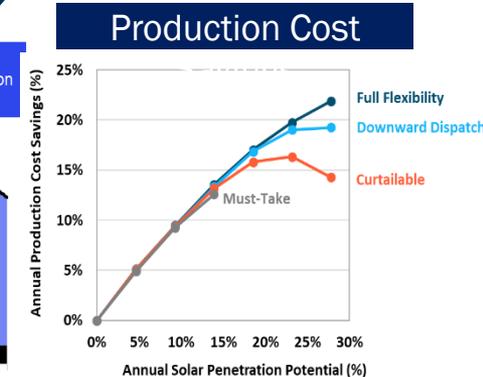
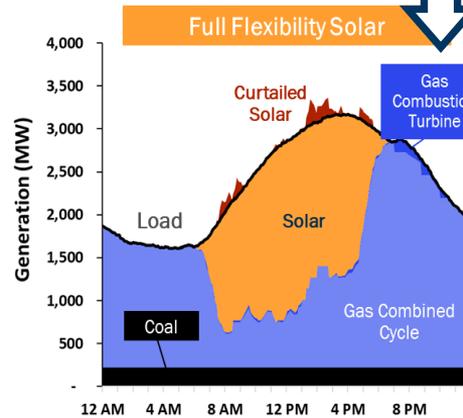
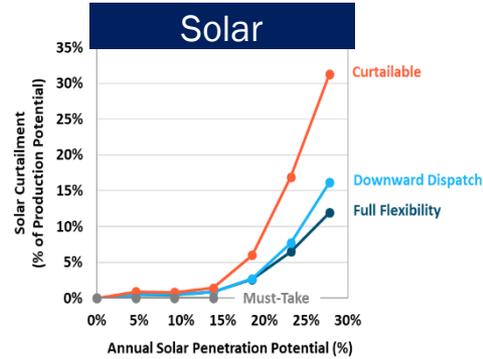
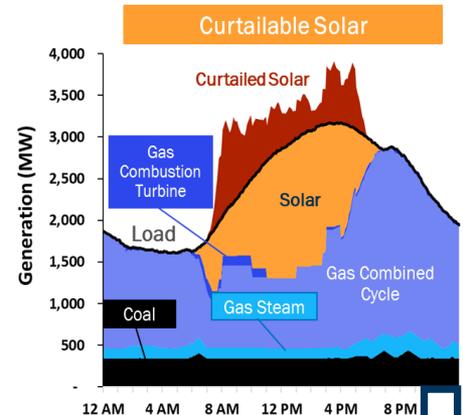
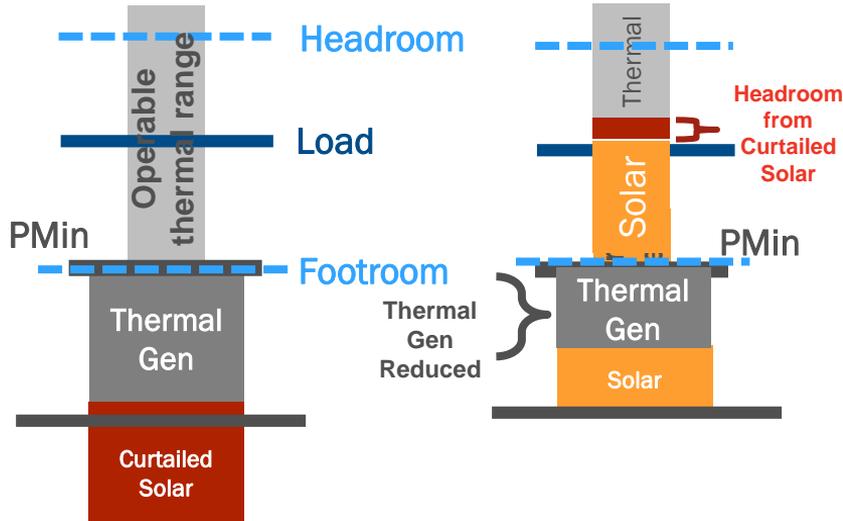
Non-Dispatchable Solar

Feasible:

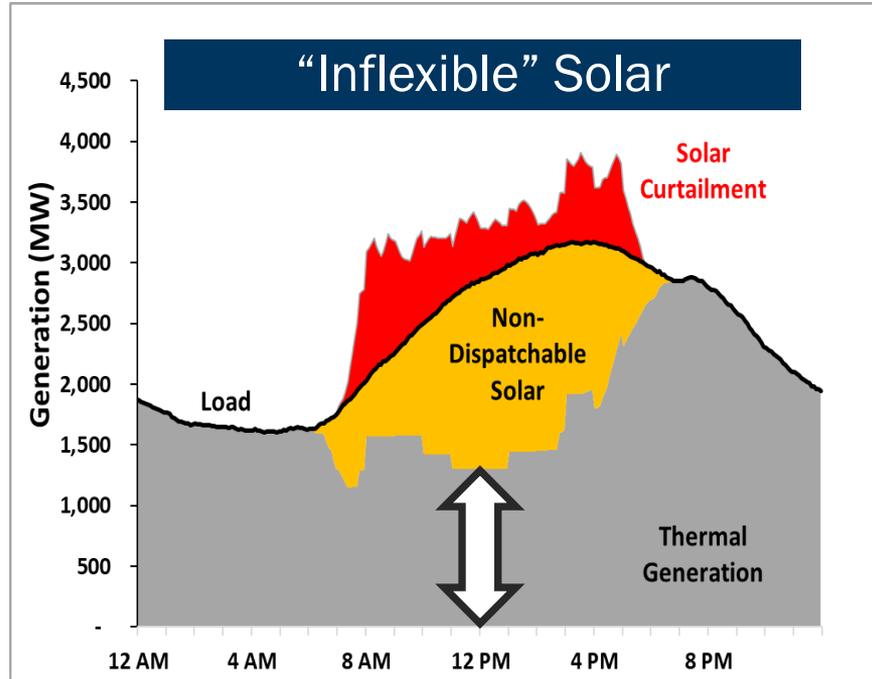
Solar **does not contribute** to headroom and footroom range

Dispatchable Solar
Optimal:

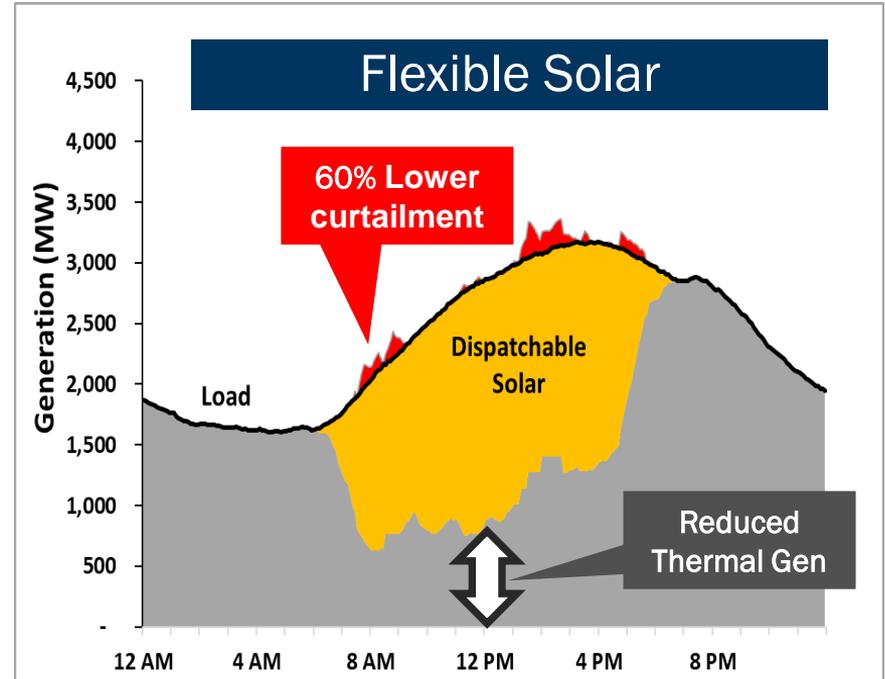
Solar **contributes** to footroom to headroom range



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



Solar Provides No Regulation Reserves

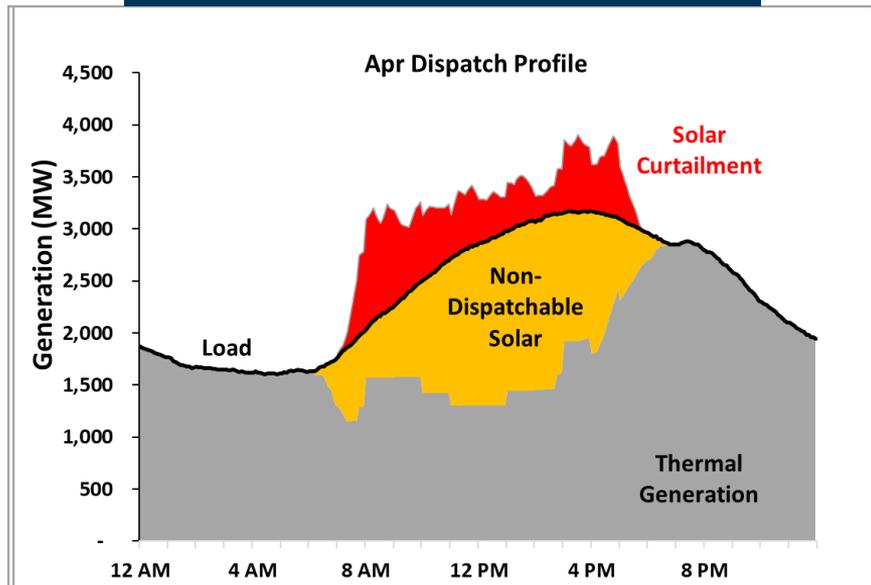


Flexible Solar: Provides regulation reserves

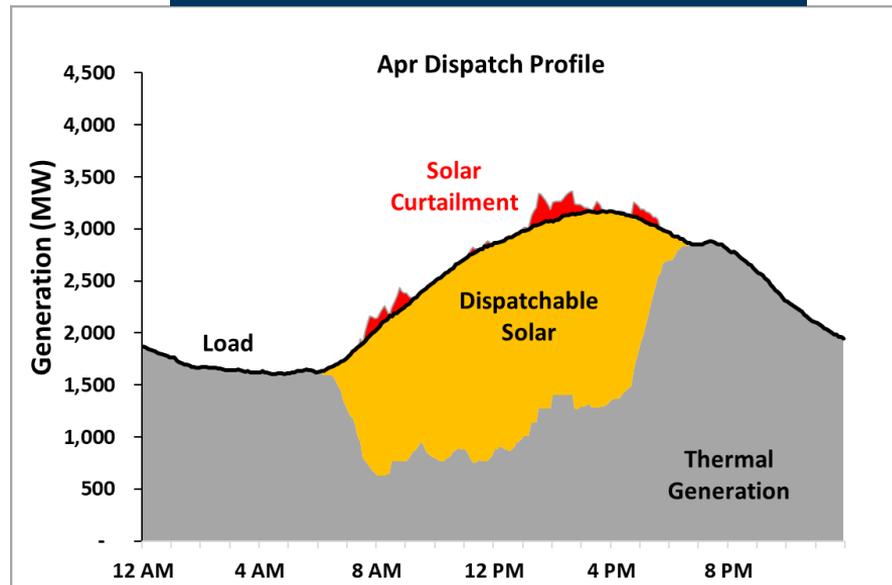
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Comparison of Dispatch Profiles Over The Year (Animated)

Non-Dispatchable Solar



Fully Flexible Solar

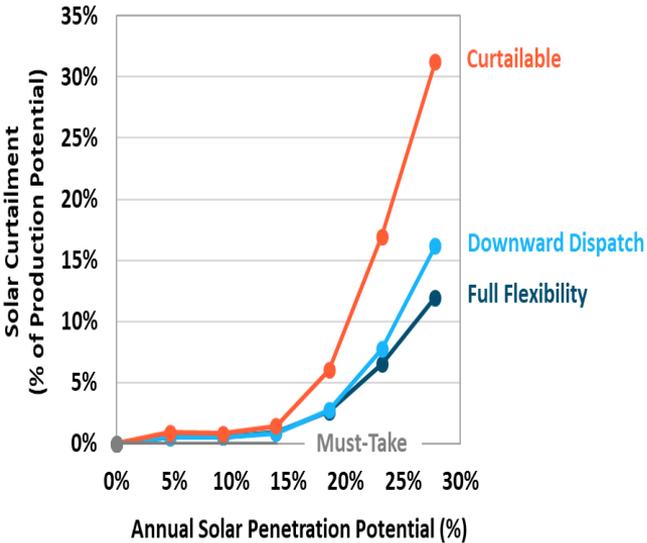


Source: E3,TECO, First Solar Report "Dispatchable Solar: The Key to Unlocking the Clean Energy Grid of the Future", under review.

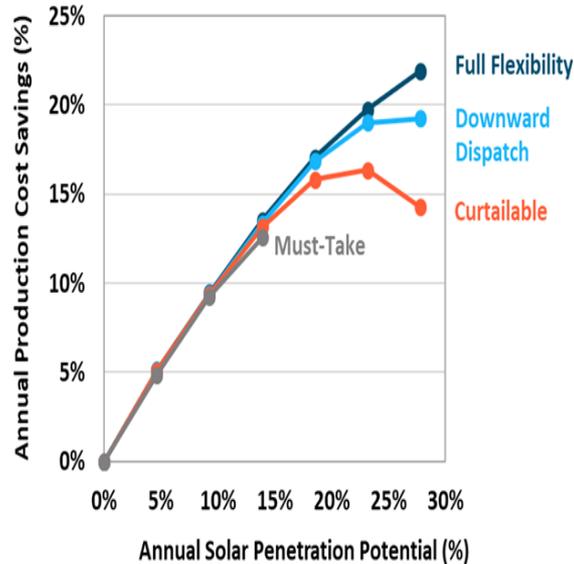
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Dispatchable Solar Saves System Costs

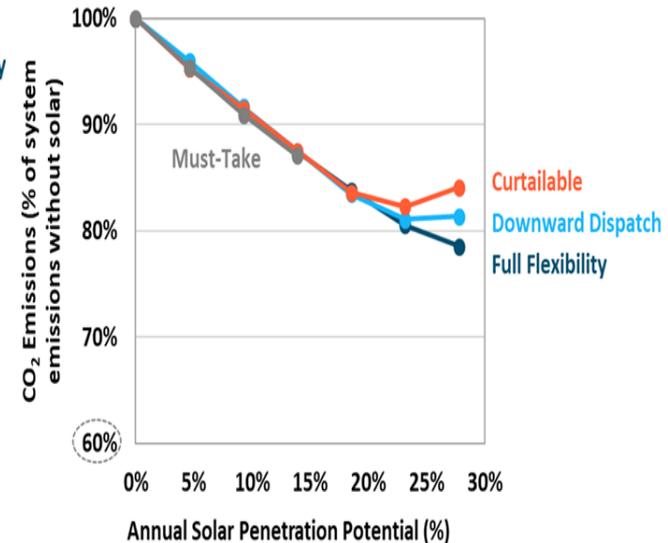
Reduces Curtailment



Increases Production Cost Savings



Reduces Emissions



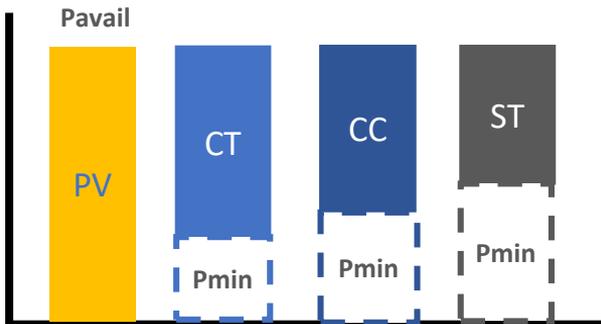
Flexible dispatch for utility-scale solar resources reduces solar curtailment, fuel consumption & emissions

Flexibility = Key Resource Attribute of the Future Grid

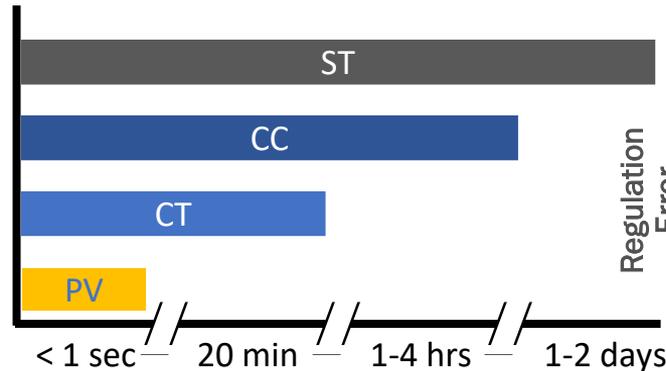
Utility-scale PV is more flexible and responsive than today's fossil fleet:

- Operates flexibly from 0 to Available Power (*no Pmin*)
- Can start up in seconds (*when solar resource is available*)
- Accurately follows dispatch (AGC – 4 second) signals

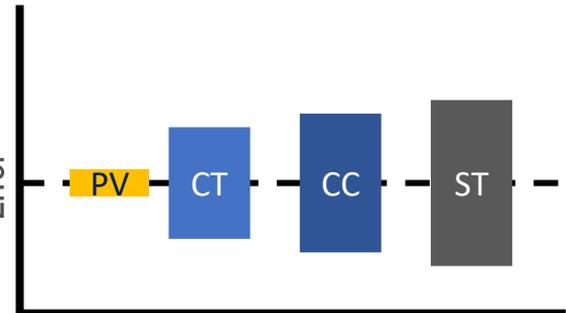
PV can operate flexibly from 0 to available power (P_{avail})



PV starts up in seconds



PV follows AGC signal with high accuracy





Challenges

Flexible Solar Requires Evolution In Operations (& Procurement)

Key Challenges

- Uncertainty around resource availability ... uncertainty generally reduces closer to real-time dispatch
... *how do we effectively incorporate uncertainty risk assessment?*
- Solar resources are typically prioritized on maximum production over flexibility and services ... plant revenue reduction concerns from IPP
... *how do we reconcile reduced production and delivery with value of flexibility?*
- Solar provide services at zero marginal costs (once curtailed) and with superior performance
... *how do we take advantage of that to reduce costs and emissions?*
- While vertically-integrated utilities can optimize dispatch of owned assets for the best benefit to reduce overall system costs
...*how do we make that possible in markets that balances risks and benefits of VRE?*



Summary

Solar Integration And Scale

Solar Energy

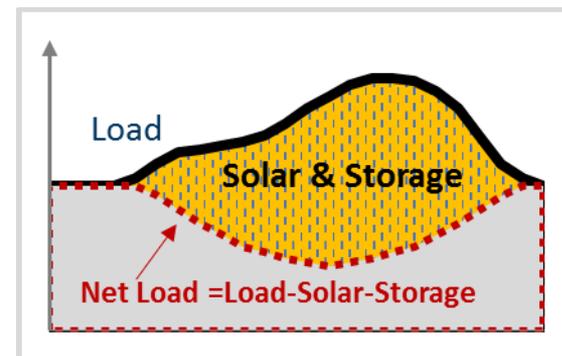
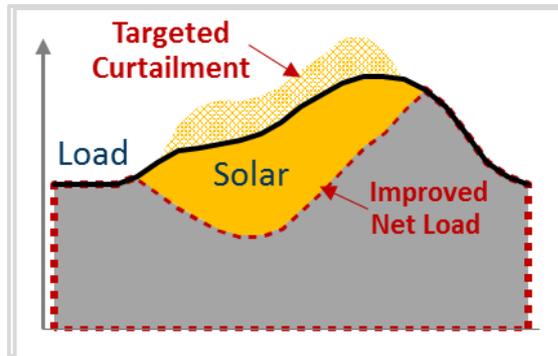
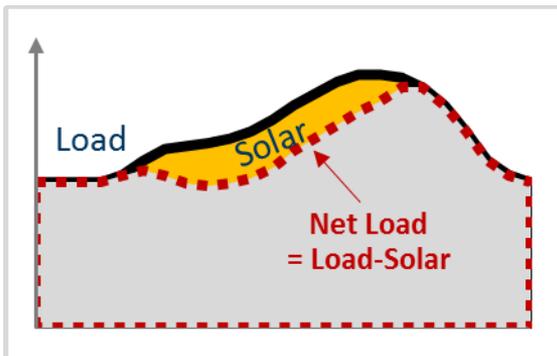
- Solar is part of mid-day load offsets peak or near-peak demand
- **Energy-Only Value**

Grid Flexible Solar

- Adds **Grid Reliability Services & Flexibility Value**

Fully Dispatchable Solar

- Storage (hours, not days) time-shifts solar – fully dispatchable
- Adds **Firm Generation Capacity Value**



Flexible & Dispatchable Solar ... Key to Market Expansion & Value Retention

Key Messages



- 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*
- However, *Grid Management Innovations* are needed to leverage solar flexibility given its inherent variability and uncertainty

