EPRI Program 201 Back Pocket Insights

Insights on the Complementarity of Storage and Renewables

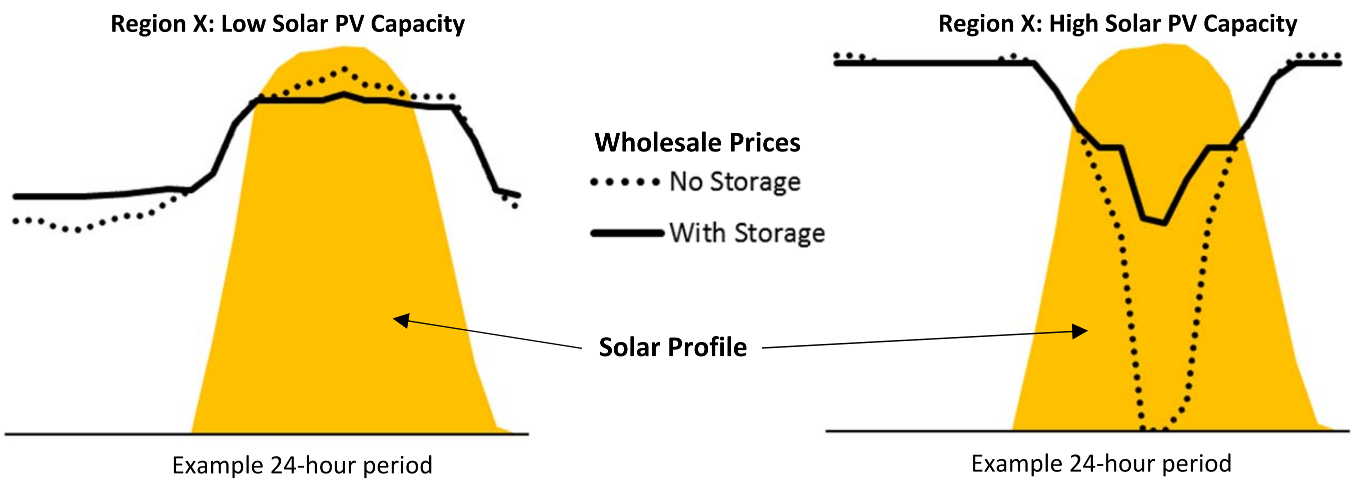
October 2017

EPRI uses the US-REGEN 8760-hour static equilibrium model to represent the arbitrage economics of storage

- **US-REGEN** is a long-horizon economic capacity expansion model, developed and maintained by EPRI.
- The **static equilibrium version** of US-REGEN solves for the least-cost capacity/dispatch mix for a given year in the future, and represents all 8760 hours in that year.

Insight: Storage Decreases Solar Revenues with Low Solar Penetration and Vice-Versa

- Storage recovers costs by charging when wholesale prices are lowest, and discharging when prices are highest
- Low prices typically don't coincide with peak solar generation in regions with low solar capacity



- With **low solar PV capacity**, storage charges mostly at night, when prices are lowest, and discharges during the day, concurrent with solar generation
- Lower prices for solar production reduce revenues, and thus reduce incentives to invest in new solar PV capacity

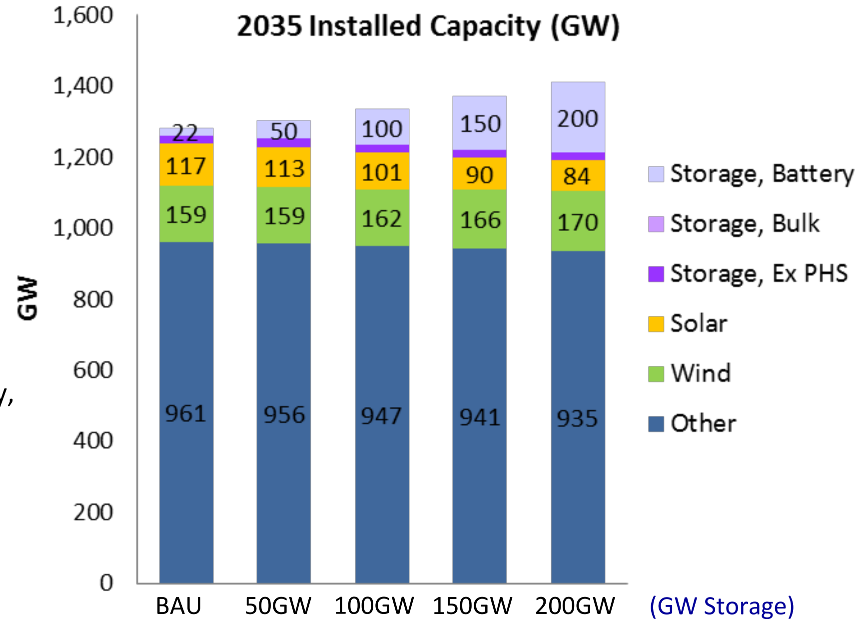
- **High solar PV capacity** pushes down prices during the day. Storage now charges concurrent with solar generation, and discharges later at night.
- Higher prices for solar production increase revenues, and thus incentives to invest in new solar PV capacity

Key assumptions and caveats

- Assumes battery storage costing $100/kW power rating ('door cost'), and $100/kWh energy capacity ('room cost'), with 10% loss factor.
- Solar PV resource based on NASA MERRA data. Wholesale prices depicted are the marginal cost of supplying electricity to meet load for the given period, including other generation sources apart from solar and storage.
- Assumes natural gas prices to the electric sector follow the Annual Energy Outlook 2017 reference case.
- US-REGEN does not represent voltage support or other reliability constraints.
- See EPRI Program 103 Back Pocket Insights "Modeling Storage Capacity Expansion with US-REGEN" for more information, or refer to the US-REGEN documentation at http://eea.epri.com/usregen.

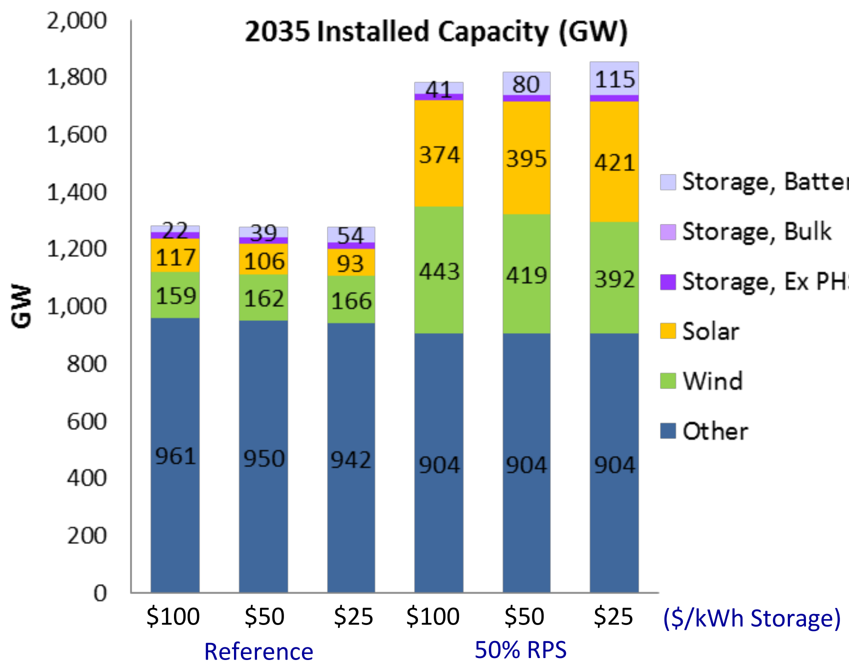
Implication: Storage Mandates May Reduce Solar PV Deployment Absent Other Drivers for Renewable Penetration

- US-REGEN experiments suggest that existing economic conditions would not incentivize enough solar PV to cause low wholesale prices during the day in most regions.
- This assumes the investment tax credit (applied only to solar, not to storage) and existing state renewable portfolio standards, as well as solar PV installation costs of ~$900/kW.
- Increasing storage mandates thus reduces revenues to solar PV for states with low capacity, per the insight on the previous page.
- **Increasing storage in these conditions thus reduces solar PV revenues**
- Result could be reversed if more solar PV was deployed for other reasons, such as policy support or lower costs.



Lower Storage Costs Increase Storage Deployment, Exacerbating the Economic Impacts Described Above

- Lowering battery capacity costs to $25/ kWh results in lower solar penetration under reference assumptions, because increasing storage reduces revenues to solar per the results above.
- Lowering battery capacity costs to $25/ kWh results in higher solar penetration under a national wind + solar mandate, because there is now sufficient solar to ensure low wholesale prices during the day, and increasing storage thus increases revenues to solar generation.
- Total renewable capacity penetration is lower in both cases as battery costs decline (even with RE mandate due to higher RE capacity factors with storage).



What About Wind?

Wind exhibits more daily variability than solar, but, in many regions, generates more at night than during the day. In these cases, the results above for solar are reversed for wind; i.e. storage will increase revenues to wind at low wind penetration and vice versa.

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