Solar-Plus-Storage: The Future Market for Hybrid Resources

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Executive summary

Co-located "solar+storage" deployments will increase dramatically

- Solar+storage provides clean, flexible energy and capacity
- Tax incentives create a financial advantage for storage when co-located with solar
- Solar+storage accounts for over 40% of capacity in California ISO interconnection queue
- PUC of Nevada approved solar+storage contracts equal to 15% of NV Energy peak demand

Competing factors will affect future solar+storage deployment levels

- Factors favoring solar+storage include co-location efficiencies, cost savings, continued technology cost declines, and operational benefits
- These benefits must be weighed against the relative advantage of standalone storage projects and the impact of declining federal incentives

The industry focus is now on solar+storage project evaluation and design

- Solar+storage projects will remain competitive with other resources in the future, and the need for firm capacity and flexibility will emphasize deploying storage with solar
- However, standalone storage will become more competitive with hybrid projects as federal tax incentives decline
- Solar+storage sizing and dispatch strategies are critical to achieving economic benefits

I. Introduction

Solar and storage are complementary resources

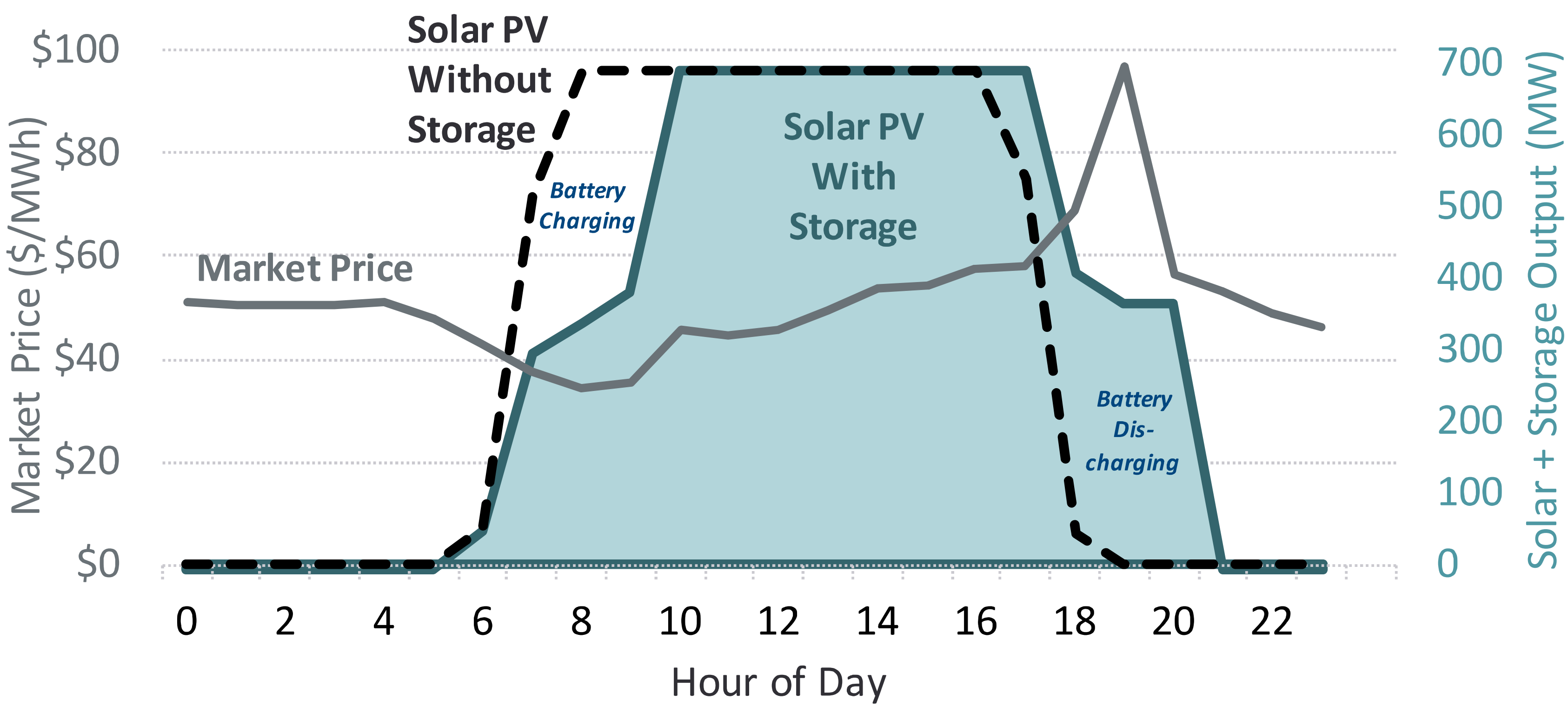
Co-locating storage with solar facilities (i.e., "solar+storage") allows valuable features of both resources to be captured at a single site

Attribute	Standalone Solar PV	Standalone Storage	Solar+Storage
Zero-carbon energy	✓		✓
Eligible for Federal Investment Tax Credit	✓		✓
Flexible/dispatchable		✓	✓
Firm capacity		✓	✓
Co-location efficiencies (cost savings)			✓

Note: This report focuses exclusively on utility-scale solar+storage projects.

The addition of storage turns solar PV into a dispatchable clean resource

Solar PV generates carbon-free electricity in the middle of the day. Storage shifts this output to times when it is most valuable, contributing significantly to resource adequacy.

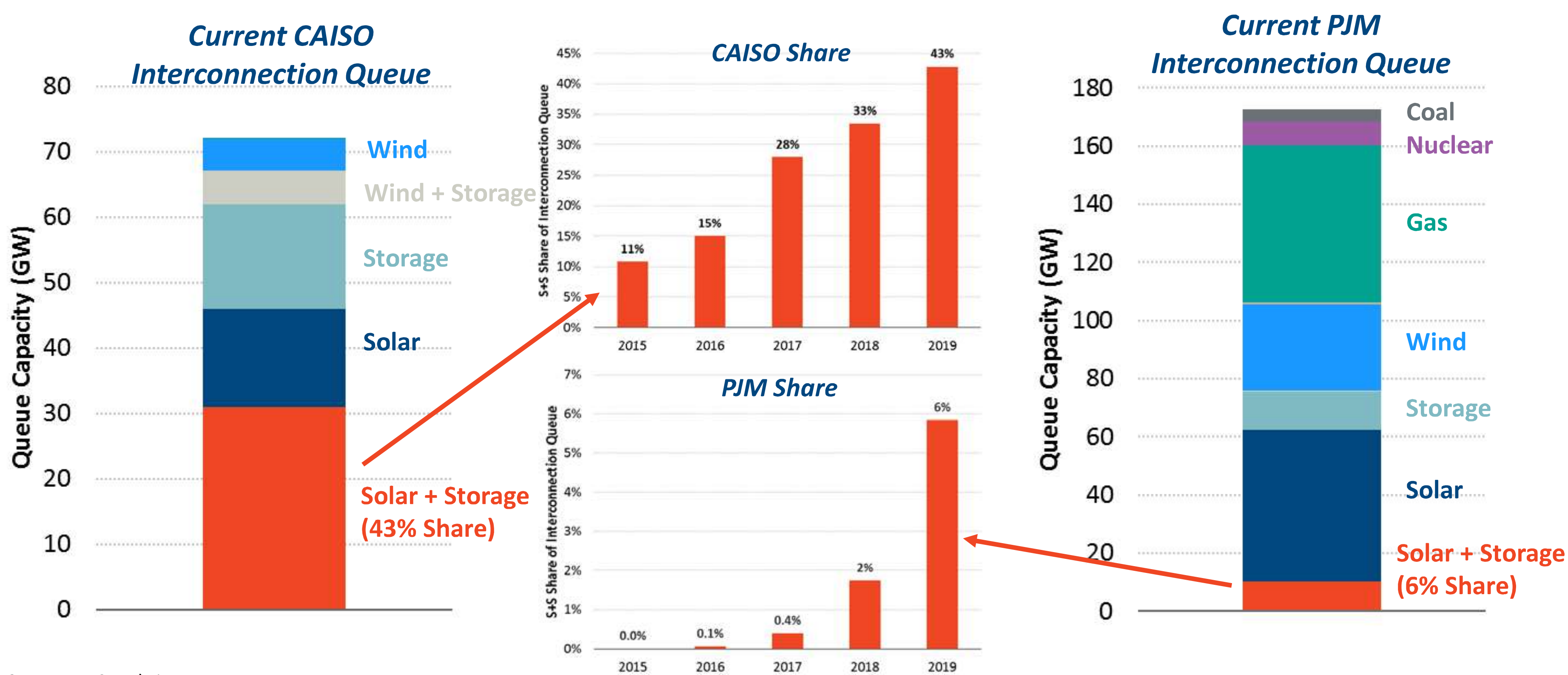


Source: Adapted from Direct Testimony of Ryan Hledik on Behalf of Arevia, Public Utilities Commission of Nevada Docket No. 19-06039, September 26, 2019.

Solar+storage deployments will increase dramatically in the next couple of years

Solar+storage accounts for over 40% of all capacity in the California ISO interconnection queue. PJM also has seen sizeable growth in applications.

Capacity in ISO Generation Interconnection Queues



Source: RTO websites.

Notes: PJM data downloaded 11/27/2019. Counts Maximum Facility Output; CAISO data as of 11/27/2019. Counts Net MW Total. PJM and CAISO report hybrid solar+storage projects independently; projects including other resources (e.g. gas + solar + storage) are excluded. Queues are filtered to include generation resources only (no transmission resources).

Reasons for the solar+storage boom

Favorable economics and policies are driving the trend toward co-locating energy storage with solar PV.

- **Efficiencies of co-location** reduce costs and increase revenues, such as shared facilities and permitting, reduced interconnection costs, and avoided "clipping" of solar PV output
- **Demand for firmed solar generation** as a capacity resource (and growing reluctance to contract for new gas capacity) is evidenced by recent utility procurements
- **Falling costs** of both solar and storage make solar+storage increasingly competitive with other resources
- **The Federal Investment Tax Credit** (ITC) provides up to a 30% reduction in storage costs if paired with solar
- **State solar and storage mandates** favor deployment of those resources, reflecting priorities of policymakers and regulators

II. Case Study: Nevada

Recent case study: Nevada

In December 2019, the Nevada Public Utilities Commission (PUCN) approved 1,190 MW of solar+storage projects, equal to 15% of NV Energy peak demand

NV Energy Solar+Storage PPAs
Approved December 2019

Project Name	Online Date	Solar Capacity	Storage Capacity
Gemini	Dec 2023	690 MW	**380 MW 1,416 MWh**
Southern Bighorn	Sept 2023	300 MW	135 MW 540 MWh
Moapa	Dec 2022	200 MW	75 MW 375 MWh
Total		**1,190 MW**	**590 MW 2,331 MWh**

Largest battery in the world with regulatory approval *

** Based on energy storage capacity (MWh)*

The Solar+Storage Power Purchase Agreement

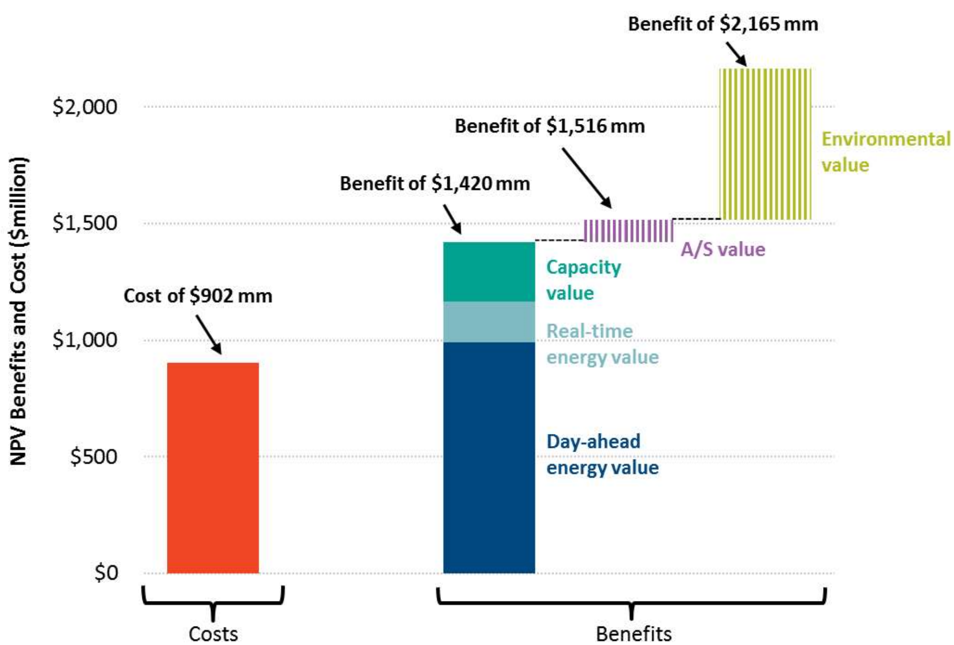
NV Energy's solicitation for solar capacity was designed specifically to attract solar+storage projects. The PPA structure pays a price during system peak hours (4 to 9 pm) that is 6.5x higher than the price paid for output during other hours. This ensures that the projects will provide capacity value in addition to energy value. NV Energy additionally has the flexibility to dispatch the plant during non-peak hours to minimize system costs.

Note: Additionally, in 2018, NVE contracted for approximately 400 MW of solar+storage, with storage capacity of 100 MW / 400 MWh.

Recent case study: Nevada

Brattle's testimony before the PUC of Nevada concluded that the benefits of solar+storage significantly outweigh the costs.

Benefits and Costs of Gemini Solar+Storage PPA



Source: Direct Testimony of Ryan Hledik on Behalf of Arevia, PUCN Docket No. 19-06039, September 26, 2019.

Key Findings

- Net benefits to customers of the Gemini solar+storage project range between $500 million and $1.3 billion (present value)
- Benefit-cost ratio of between 1.6 and 2.4, depending on which value streams are counted as benefits
- Energy value alone exceeds the costs of the project
- Significant storage capacity provides ability to respond to real-time fluctuations in supply and demand, resulting in operational flexibility that will "future proof" the resource as market conditions evolve

Recent case study: Nevada

NV Energy's solar+storage PPAs will advance the state's dual objective of transitioning to clean energy and meeting resource adequacy needs.

Nevada Storage Procurements and Pending Targets (MW)

Note: Draft targets were filed by the PUCN on November 26, 2019 and are still subject to approval and adoption.

The Economic Potential for Energy Storage in Nevada

Brattle's 2018 assessment for the PUCN and the Governor's Office of Energy identified at least 1,000 MW of cost-effective storage potential by 2030, statewide. Benefits analyzed in the study included avoided capacity costs, production cost savings (i.e., energy and ancillary services), distribution investment deferral, and improved customer reliability. Modeling accounted for the ability of storage facilities to realistically capture multiple value streams.

III. Drivers of Future Solar+Storage Deployment

Will the solar+storage boom persist?

Determining the outlook for new solar+storage opportunities requires assessment of several competing factors

- Technology cost declines
- The future of the ITC
- Benefits of avoided "peak clipping"
- Cost-efficiencies of co-location
- Operational strategies
- Competitiveness with standalone solar and storage projects

Brattle's bSTORE modeling platform accounts for the unique characteristics of solar+storage projects to produce a realistic assessment of resource value

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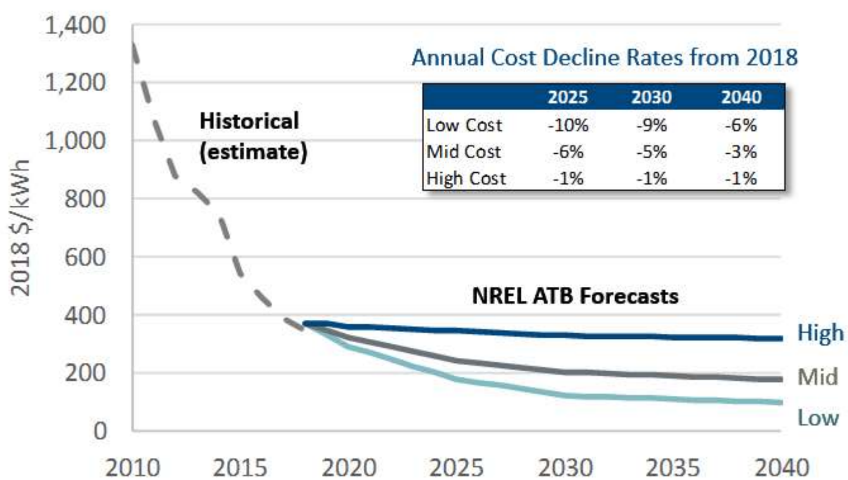
Future cost declines

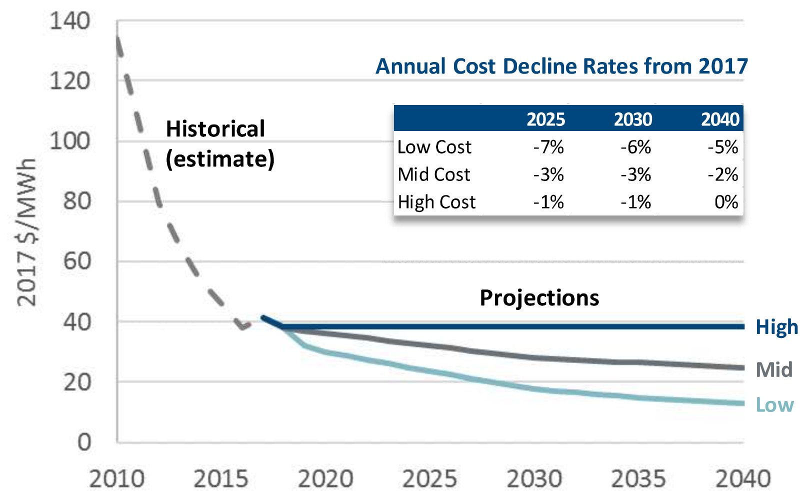
The costs of solar and storage are expected to continue to decline, though at a pace that is lower than historical trends

Battery Installed Costs



Source: Bloomberg New Energy Finance, *A Behind the Scenes Take on Lithium-Ion Battery Prices* (2018) and NREL Annual Technology Baseline (2019) with Brattle analysis.
Notes: Historical estimate assumes Bloomberg NEF battery pack cost estimate plus a constant non-pack cost estimate of approximately $170/kWh. NREL costs are for a 4-hour, utility-scale lithium ion battery.

Utility Scale Solar PV PPA Prices

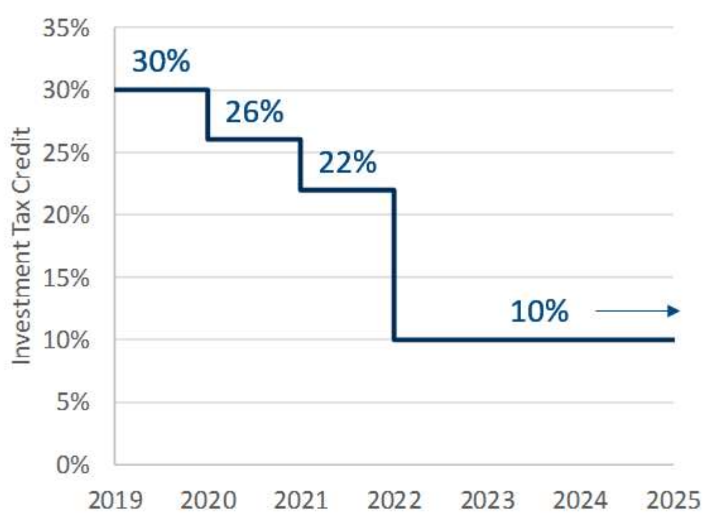


Source: LBNL, *Utility Scale Solar: Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States* (2018) and NREL (2019) with Brattle analysis.
Notes: PPA price projections based on LCOE cost decline rates from 2019 NREL ATB, applied to historical observed prices.

The Future of the Federal ITC

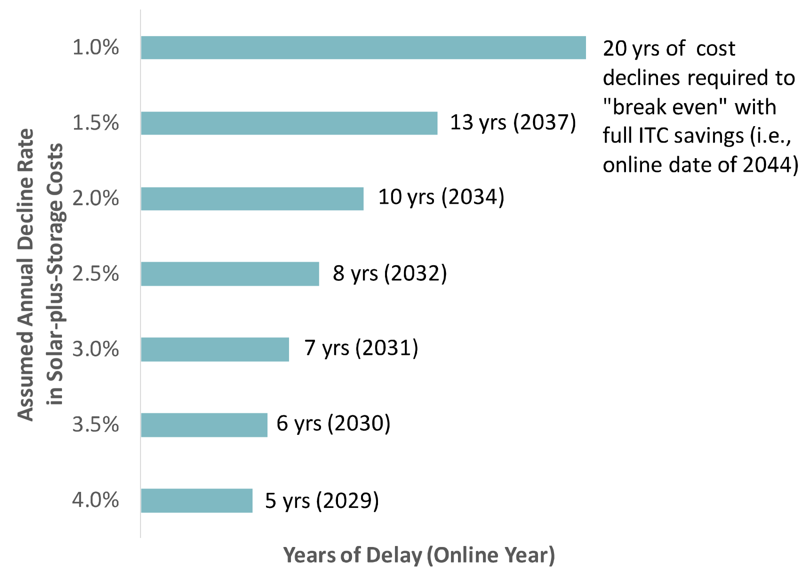
Scheduled reductions in the ITC will significantly impact solar+storage economics

Federal ITC for Solar+Storage Projects



Solar+storage projects currently receive a 30% tax credit. By 2022, it will drop to 10%

Years of Consecutive Technology Cost Declines Required to Offset Loss of ITC



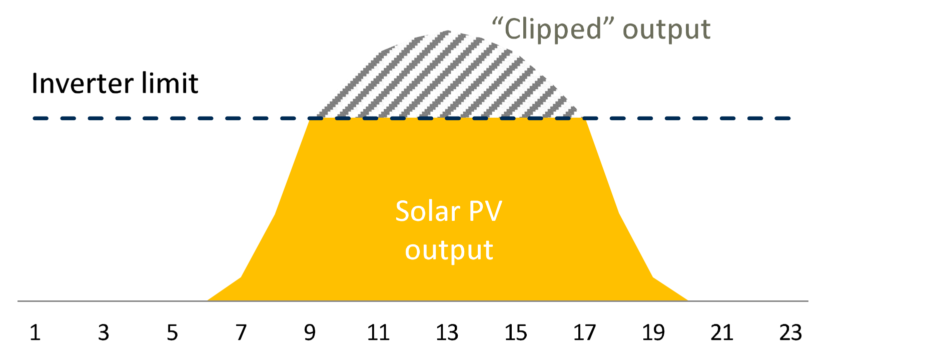
If the ITC is reduced from 30% to 10%, **more than a decade** of continued technology cost declines could be needed for project economics to return to current levels

Notes: Analysis assumes project which has secured the full 30% ITC and has an online date in 2024. Analysis assumes no compounding of the annual cost declines. Accounting for compounding would lead to slightly larger estimates of the number of years that would be needed to offset the loss of the full ITC. Annual cost decline rates are shown in nominal terms.

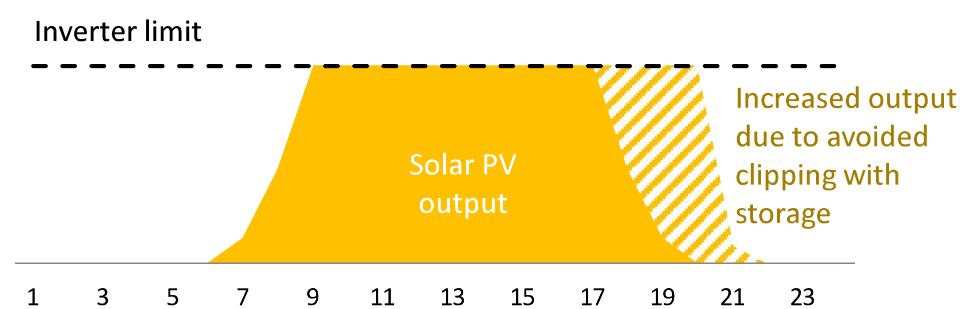
Benefits of avoided "peak clipping"

Storage can charge from solar PV output that otherwise would be wasted due to inverter capacity limits. That energy can be discharged at other times.

- Solar PV facilities are typically developed with solar panel capacity that exceeds the capacity of the inverter that converts the output from DC to AC
- At times when the output of the panels exceeds the inverter capacity, that energy is "clipped" (i.e. unused)



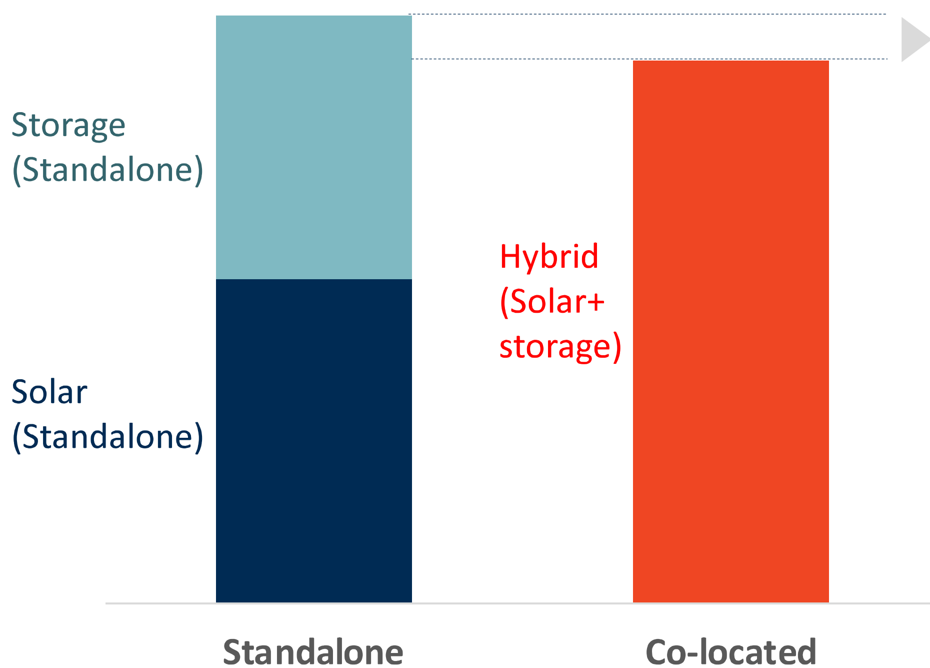
- Batteries that are connected to the solar PV facility behind the inverter (i.e., DC-coupled) are able to charge from the output that otherwise would be "clipped"
- **Brattle analysis for a utility in PJM found that, under certain configurations, avoided peak clipping could account for nearly 10% of the battery's revenues**
- This finding is highly dependent on the sizing of the battery, solar array, and inverter



Cost efficiencies of co-location

Co-locating storage with solar provides cost savings relative to standalone projects

Total Unsubsidized Installed Cost: Solar and Storage



8% cost savings: NREL estimate of the reduction in total unsubsidized installed cost of solar and storage projects due to savings from co-location

Cost savings are related to land acquisition, installation labor, hardware, interconnection, and other factors

Additionally, transmission system interconnection-related costs can be reduced if taken into account when developing the sizing and dispatch strategy for the hybrid system

Source: NREL, 2018 U.S. Utility Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark, with Brattle analysis.
Notes: Assumes 60 MW / 240 MWh battery, 100 MW solar PV, and a DC-coupled hybrid project.

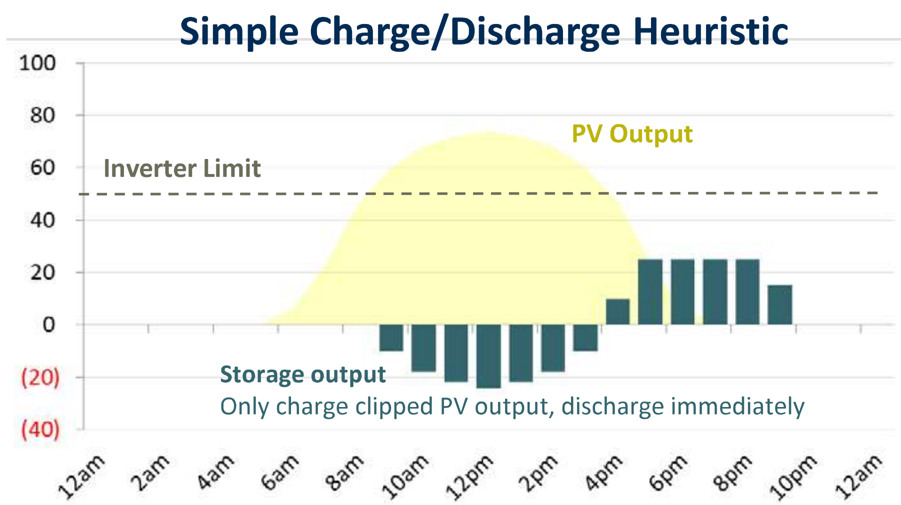
Operational strategies

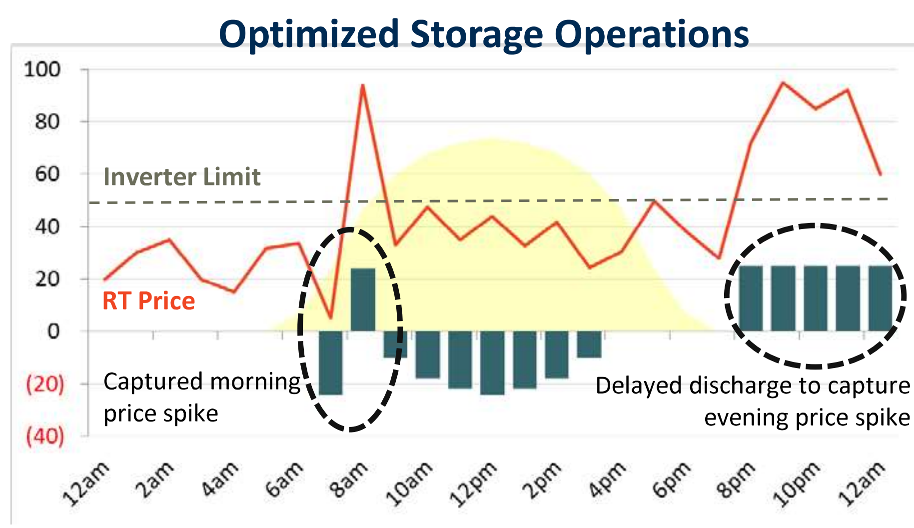
Optimizing Solar+Storage Project Value

Sophisticated dispatch and sizing strategies will need to account for factors such as:

- *Inverter and interconnection costs and associated capacity limits*
- *Real-time fluctuations in energy value*
- *Tradeoffs in pursuing competing value streams (e.g., energy versus capacity)*
- *Benefits of frequent cycling versus costs of battery degradation*

Brattle's bSTORE model has been used to simulate a range of dispatch and sizing strategies to optimize project value



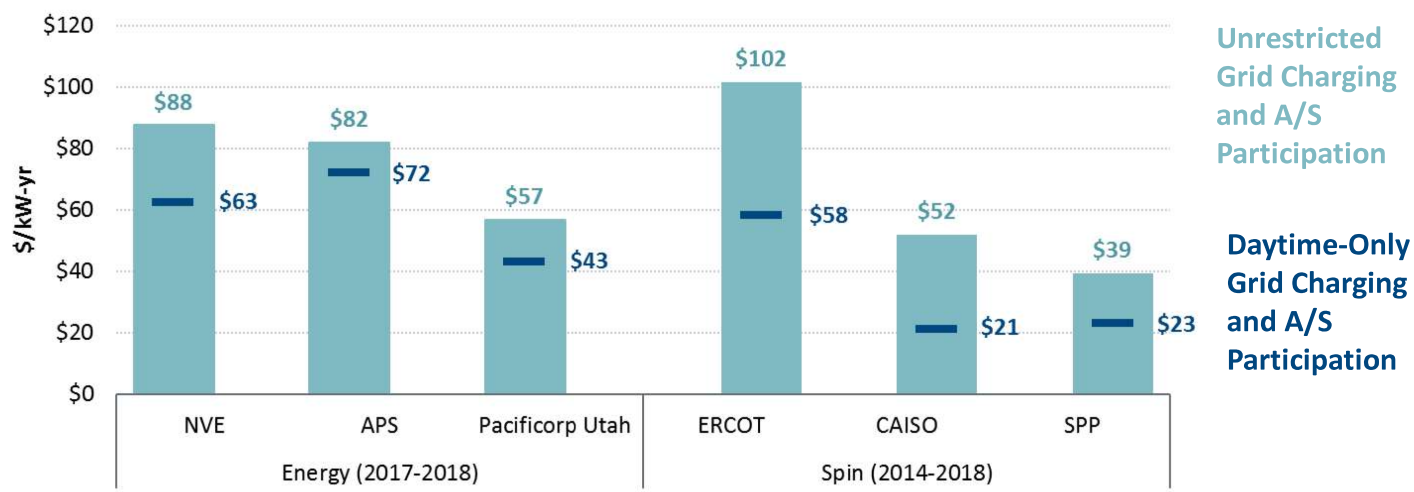


Competitiveness with standalone projects: Energy value

Restricting charging to maximize ITC benefits can reduce the energy value of storage. The extent will be market-specific and depend on project configuration.

- To maximize ITC benefits, storage only can charge from the solar PV facility (for the first 5 years)
- Brattle simulated the effects of pairing storage with solar by restricting charging to daytime hours
- Resulted in a 12-28% decrease in potential storage-related energy revenues across locations analyzed
- Ancillary services revenues decrease by a greater amount (41-60%)

Energy and A/S Revenue With and Without Limits on Grid Charging



Note: Results shown for 4hr, 100 MW battery. Energy revenues are for CAISO Energy Imbalance Market pricing locations.

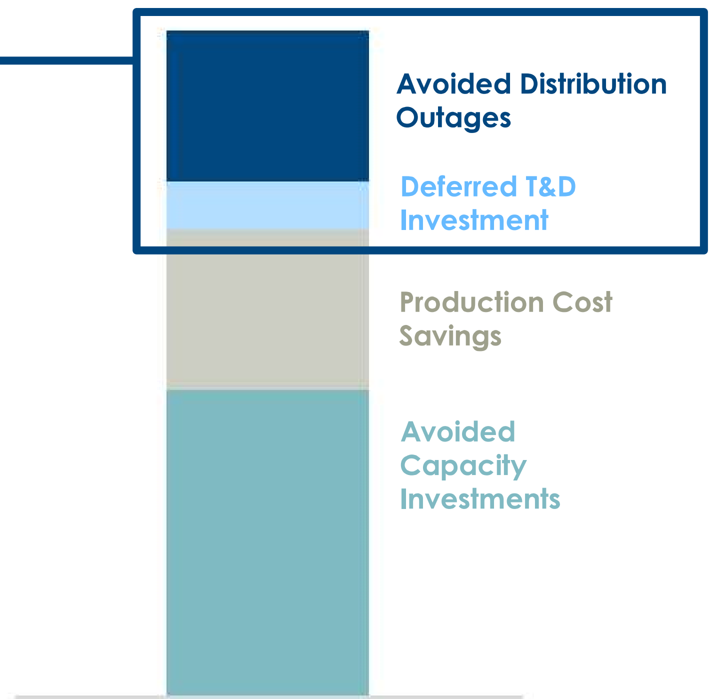
Competitiveness with standalone projects: Locational value

Co-locating storage with solar may require foregoing location-specific benefits that otherwise could be achieved with a standalone storage project

In Nevada, 30% of the estimated total potential benefit of storage was dependent on the resource's **locational flexibility**

Solar+storage projects require a **larger footprint**, with more limited siting options; analysis will be needed to assess the relative advantages of standalone and hybrid projects

Share of Total Benefits of Standalone Storage
(Nevada 2030)



Source: Hledik, Chang, Lueken, Pfeifenberger, Imon Pedtke, and Vollen, "The Economic Potential for Energy Storage in Nevada," October 2018. Based on 1,000 MW storage deployment scenario in 2030.

IV. Conclusions

The outlook for solar+storage

Even as the ITC declines, solar+storage projects are likely to remain competitive with other resources

- Recent Brattle analysis in California, Nevada, New England, and Virginia has found that the potential value of solar+storage projects can significantly exceed estimates of unsubsidized costs

Utilities and markets increasingly will select solar+storage projects over standalone solar projects, particularly in regions where capacity is needed

- PPAs can be structured to emphasize the capacity value of solar+storage
- Revenue opportunities for standalone solar PV in wholesale markets will decline as deployment increases

A decline in the ITC will lead to greater competition between solar+storage projects and standalone storage projects

- The unique advantages of each resource type will lead to different regional outcomes depending on system needs and market conditions
- Standalone storage will be more attractive in jurisdictions placing high value on avoided T&D costs and customer reliability improvements, while solar+storage will be more attractive in cases where cost savings from co-location benefits are significant

Recommendations for utilities, developers, and regulators

Recommendation 1: Evaluate benefits, not just costs

- Focusing exclusively on the levelized cost of a solar+storage project overlooks the added value that storage provides
- Comparing the economics of solar+storage to other resources requires accounting for all possible value streams

Recommendation 2: Optimize sizing & dispatch of solar+storage projects

- A reduced ITC will emphasize the need to maximize solar and storage benefits through improved project evaluation and design; the benefits of co-located projects often are not fully captured due to sub-optimal sizing of the storage facility relative to the solar PV facility
- The storage sizing and dispatch decision requires co-optimization with site interconnection decisions and solar inverter limits, accounting for market rules, system load and cost characteristics, and uncertainty in the solar generation profile

Recommendations for utilities, developers, and regulators

Recommendation 3: Evaluate hybrid projects vs standalone projects

- A key question will be whether the benefits of solar and storage are maximized when co-located versus deployed as standalone projects
- This will be a market- and project-specific consideration, as each deployment strategy has relative advantages and disadvantages

Recommendation 4: Consider “virtual” solar+storage projects

- Utility procurements of solar and storage do not need to require that both resources be physically located at the same site
- In cases where standalone projects are more beneficial, utilities could solicit bids for a “package” of solar and storage projects that are in different (optimized) locations