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Recent Developments of PV Power Systems with Storage in the U.S.

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Quick Facts

- Solar + storage has a symbiotic relationship,
- Wide-scale adoption of solar will lead to the wide-scale adoption of storage,
- Solar companies view storage as a business growth opportunity.

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Key Drivers for PV + Storage

- Rapid growth of utility-scale photovoltaic (PV) deployment
- Declining costs of energy storage technologies
- Mitigation of PV value loss by providing a technical solution to the mismatch between PV output and customer load
- Provide dispatchable energy (i.e., energy on demand) and reliable capacity (i.e., grid stability)

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Advantages of PV + Storage

- Co-locating the PV and storage subsystems leads to cost savings for,
  - ✓ Site preparation,
  - ✓ Land acquisition,
  - ✓ Permitting,
  - ✓ Interconnection,
  - ✓ Installation labor,
  - ✓ Hardware (via sharing of hardware such as switchgears, transformers, and controls).
- In most US states, the long-term success of the solar industry and its ability to scale beyond about 20% of total electricity generation depends on the cost-effective integration of storage

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NREL Benchmarking Study on PV + Storage

- 2018 NREL Study focuses on U.S. utility-scale applications
- Consists of bottom-up modeling to benchmark the installed costs of various application of lithium-ion storage:
  - ✓ Storage connected to the grid only and
  - ✓ PV-plus-storage (with storage connected to PV and the grid)

Source: NREL, 2018 U.S. Utility-Scale Photovoltaics Plus-Energy Storage System Costs Benchmark

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Stand Alone Li-Ion Energy Storage

- Figure ES-1 exhibits modeled costs of standalone lithium-ion energy storage systems
  - ✓ Installed capacity of 60 MW
  - ✓ Provide electricity for several different durations
- System costs vary from
  - ✓ $380/kWh (4-hour duration system) – to -
  - ✓ $895/kWh (0.5-hour duration system).
- The battery cost accounts for
  - ✓ 55% of total system cost in the 4-hour system,
  - ✓ 23% in the 0.5-hour system.
- Non-battery costs increase in proportion as duration declines

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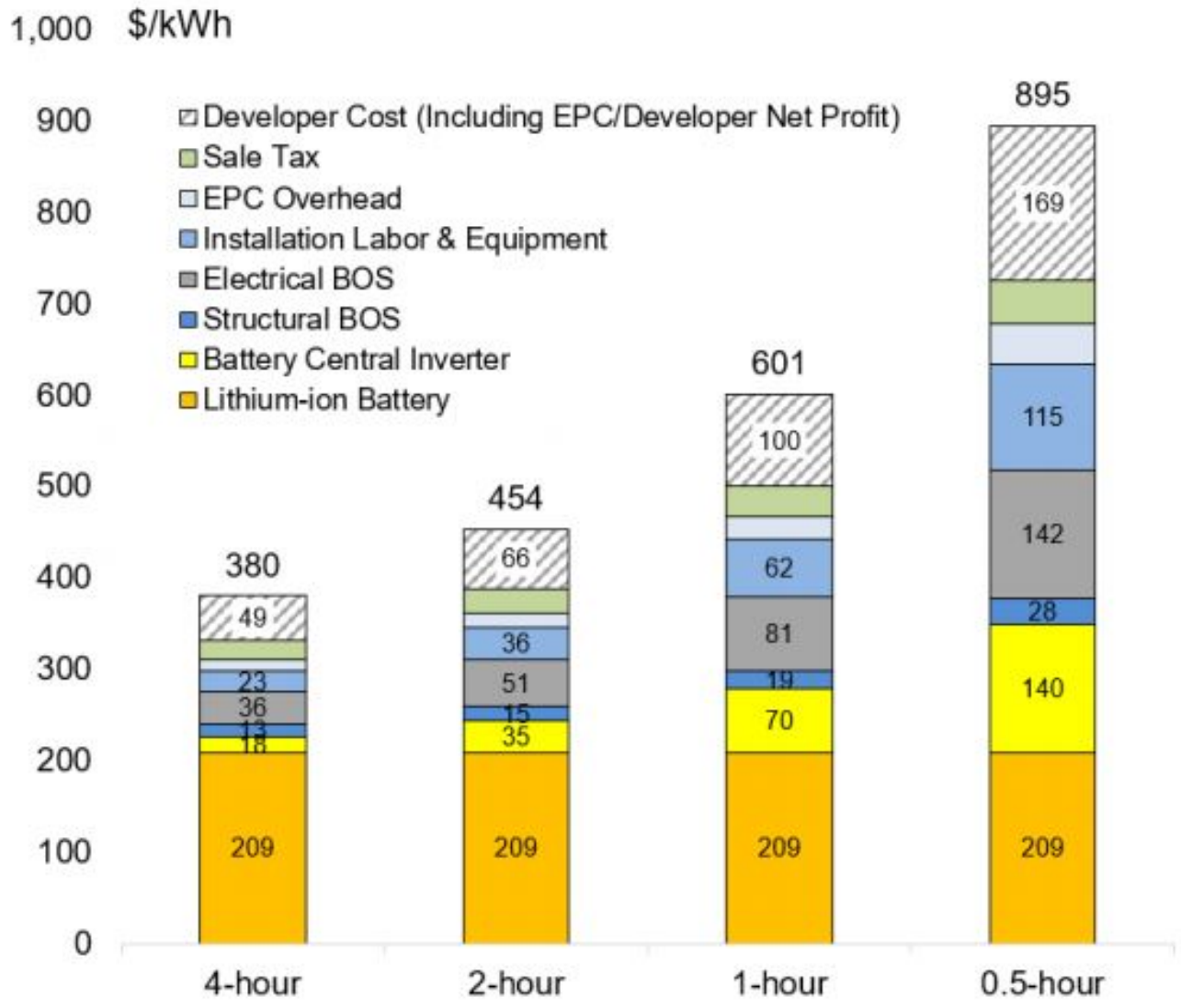

Figure ES-1. 2018 U.S. utility-scale lithium-ion standalone storage costs for durations of 0.5–4 hours (60 MW_{DC})

Source: NREL, 2018 U.S. Utility-Scale Photovoltaics Plus-Energy Storage System Costs Benchmark

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NREL results PV + Storage

- Figure ES-2 summarizes PV + storage results for several system types and configurations
- All systems include 100-MW PV system and a 60-MW lithium-ion battery:
  - ✓ Standalone 100-MW PV system with one-axis tracking
  - ✓ Standalone 60-MW/240-MWh, 4-hour-duration energy storage system
  - ✓ Co-located, DC-coupled PV (100 MW) plus storage (60 MW/240 MWh, 4-hour duration) system
  - ✓ Co-located, AC-coupled PV (100 MW) plus storage (60 MW/240 MWh, 4-hour duration) system
  - ✓ PV (100 MW) plus storage (60 MW/240 MWh, 4-hour duration) system with PV and storage components sited in different locations ($202 million)

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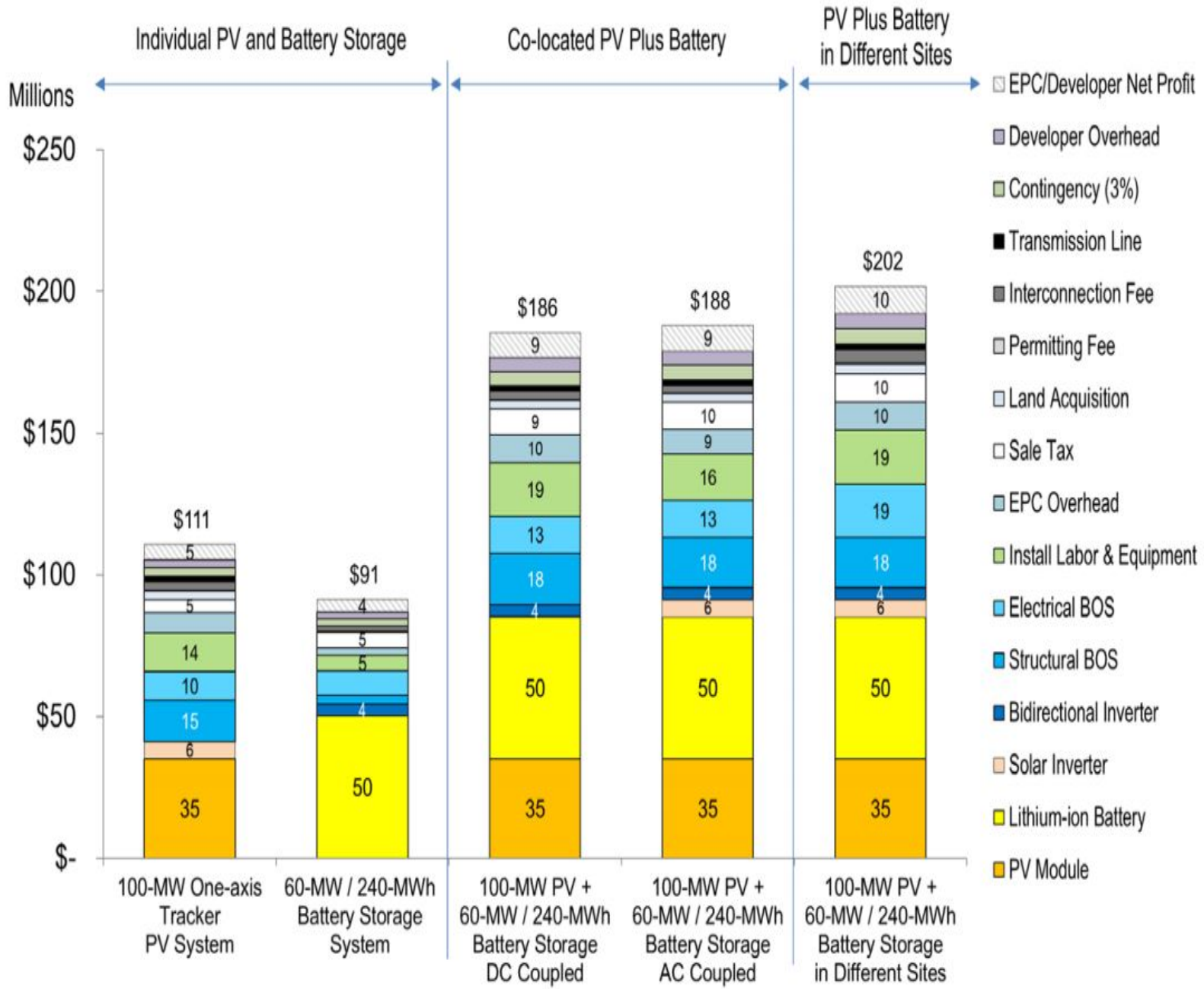

Figure ES-2. 2018 Cost benchmarks for PV-plus-storage systems (4-hour duration) in different sites and the same site (DC-coupled and AC-coupled cases)

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Benchmarking Results

- Cost of the co-located, DC-coupled system is 8% lower than the cost of the system with PV and storage that are on separate sites,
- Cost of the co-located, AC-coupled system is 7% lower.
- Using DC-coupling rather than AC-coupling results in a 1% lower total cost
- For an actual project, however, cost savings may not be the only factor in choosing DC or AC coupling.

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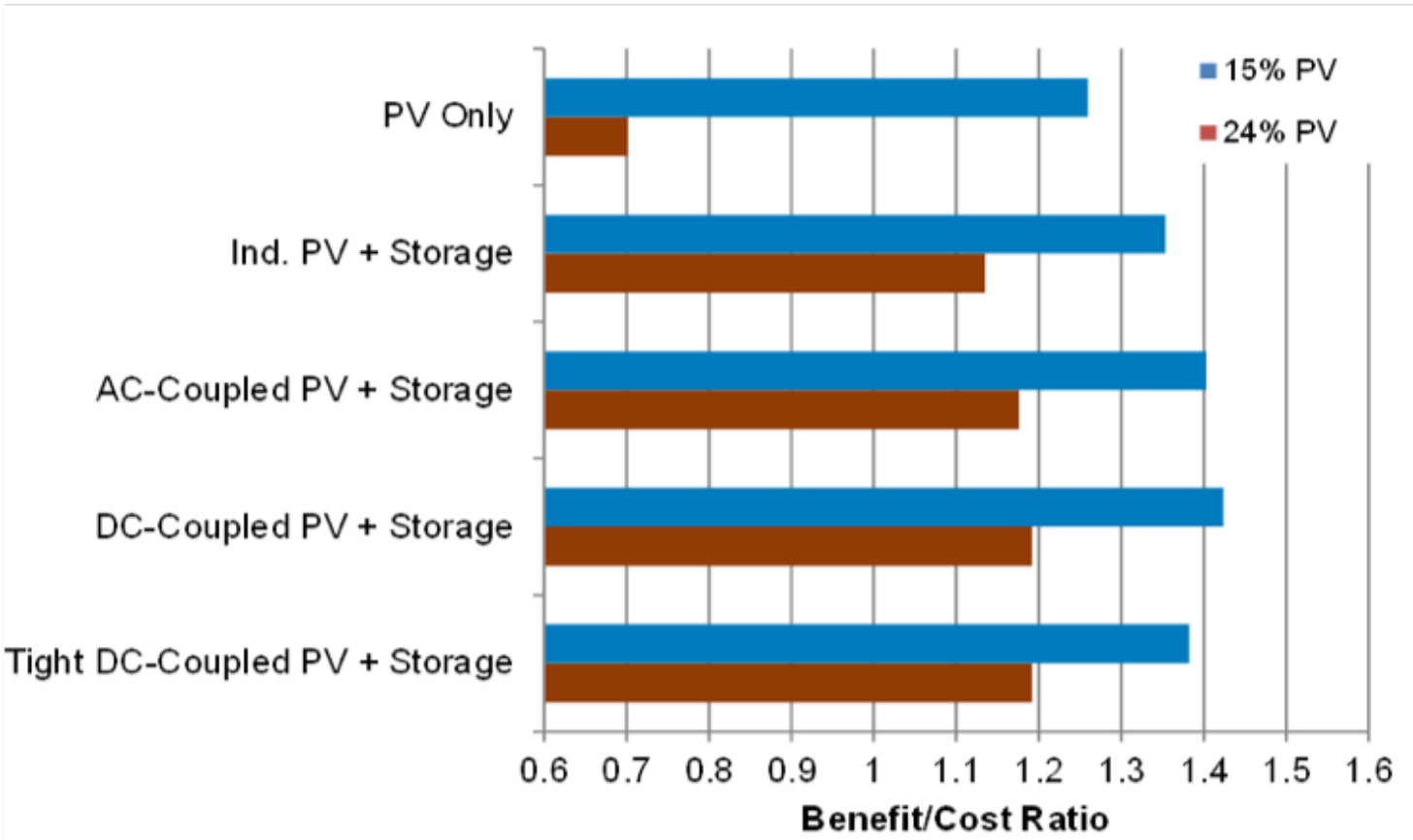
Benefit/Cost Ratio

- Benefit/Cost ratio for solar and solar + storage at different levels of penetration into US grid



Source: NREL, *Evaluating the Technical and Economic Performance of PV Plus Storage Power Plants*

Considerations for Implementing PV+ Storage Systems at Federal Buildings and Campuses

- Federal agencies are using PV systems and battery storage at remote sites to offset costly diesel fuel.
- New opportunities for PV + storage to be deployed cost-effectively at grid-connected sites.
- Example installations as of August 2018:
  - ✓ Fort Carson in Colorado Springs, Colorado, was in the process of implementing a lithium-ion battery
  - ✓ National Archives in San Bruno, California, and the U.S. Geological Survey in Menlo Park, California, were installing lithium-ion batteries
  - ✓ U.S. Marine Corps Station Miramar and Fort Hunter Liggett , both in California, are installing storage

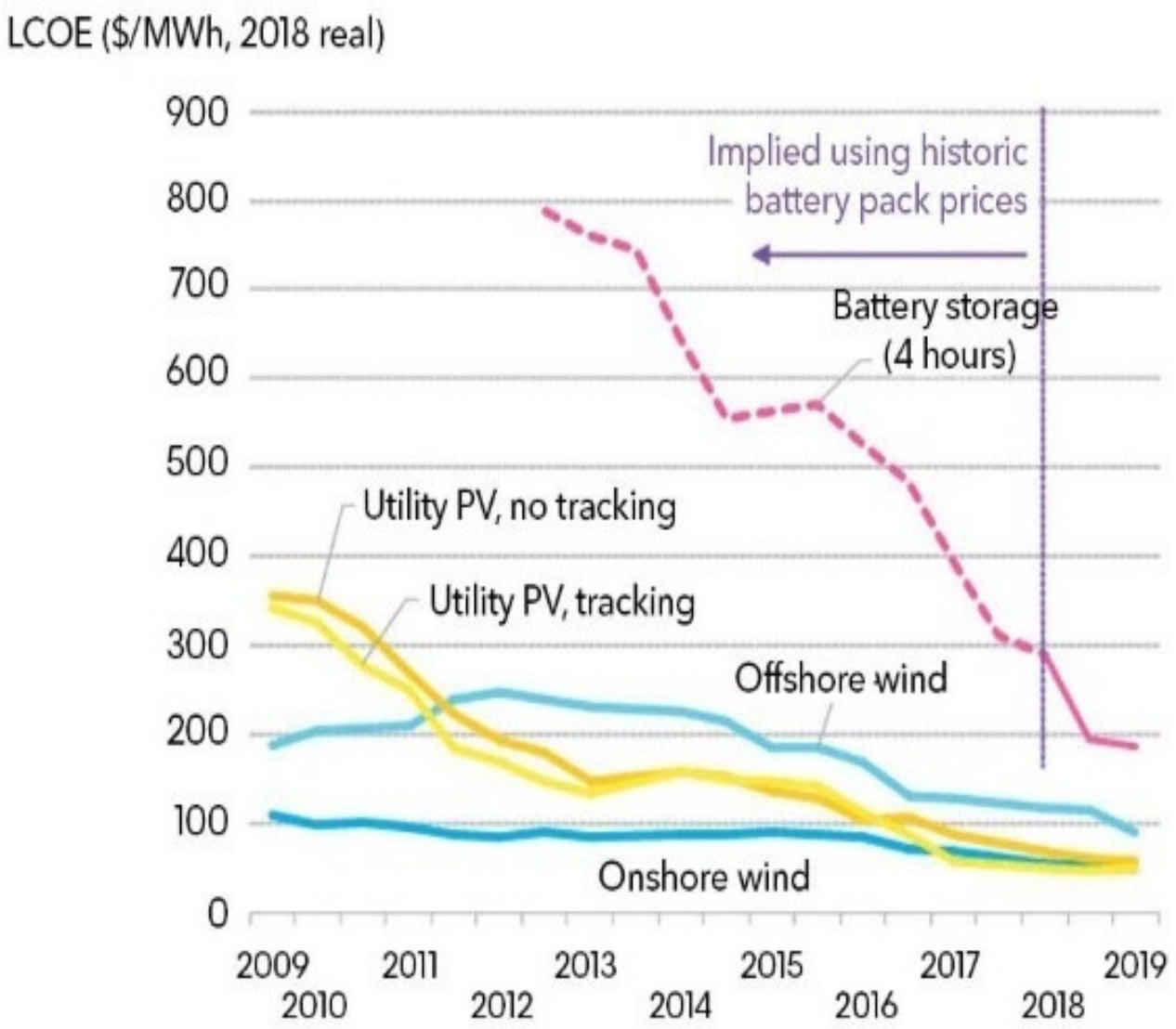
California Decision on Net Metering for PV + Storage

- On January 31, 2019, the California Public Utility Commission (CPUC) modified Decision 14-05-033, which governs current Net Energy Metering (NEM) policies in California.
- The modification allows DC-coupled energy storage systems to adopt an inverter firmware modification that enables solar-plus-storage projects to become eligible for NEM.
  - ✓ Solar-plus-storage asset owners can export battery power onto the grid and receive NEM credits on all solar and storage exports,
  - ✓ Developers can increase the size of their projects in California beyond 1 MW
  - ✓ Energy storage manufacturers can now develop NEM-ready products for California and other markets

Florida utility to build world's largest solar battery

- Florida Power & Light Company (FPL) plans to build the world's largest energy storage battery with a capacity of 409 MW
- The Manatee Energy Storage Center will be operational by late 2021 and will be charged by an existing solar plant in Manatee County
- The falling costs of renewable sources and storage is prompting action by other large utilities across the US

Lithium-ion battery costs have fallen 35% since early 2018



Source: Bloomberg NEF, March 26, 2019

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In Summary

- PV + storage is an attractive enhancement for solar power penetration to the electricity grid
- Policies are required to enable receiving energy subsidies for the storage augmented power
- Adding storage to existing solar power plants is a business opportunity

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Thank you for your attention

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