Storage Futures Study - Distributed Solar and Storage Outlook: Methodology and Scenarios

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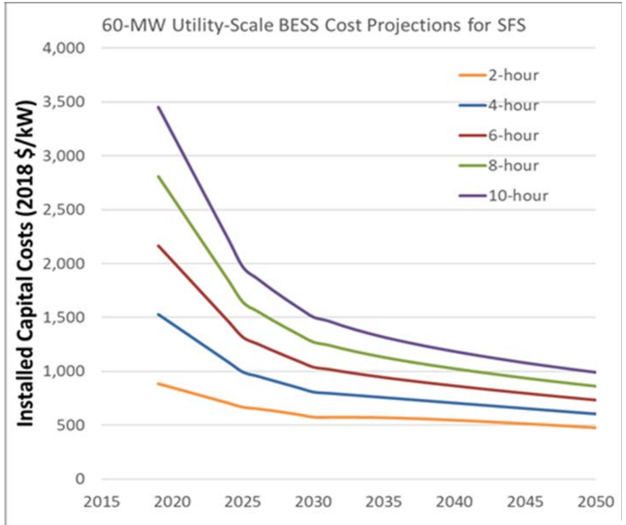
Storage Futures Study

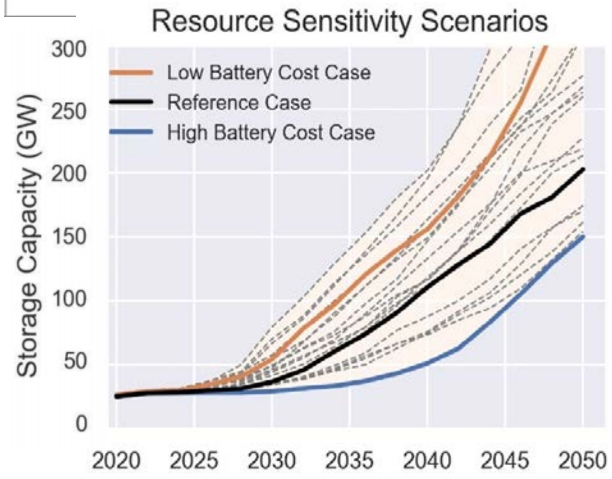
NREL is analyzing the rapidly increasing role of energy storage in the electrical grid through 2050.

- “Four Phases” - theoretical framework driving storage deployment
- Techno-Economic Analysis of Storage Technologies
- Deep dive on future costs of distributed and grid batteries
- Various cost-driven grid scenarios to 2050
- Distributed PV + storage adoption analysis
- Grid operational modeling of high-levels of storage

One Key Conclusion: Under all scenarios, dramatic growth in grid energy storage is the least cost option.

https://www.nrel.gov/analysis/storage-futures.html





SFS: Planned reports and discussed reports today

✓ = discussed today

The Four Phases of Storage Deployment: This report examines the framework developed around energy storage deployment and value in the electrical grid.

Storage Technology Modeling Input Data Report : A report on a broad set of storage technologies along with current and future costs for all modeled storage technologies including batteries, CSP, and pumped hydropower storage.

Grid-Scale Diurnal Storage Scenarios : A report on the various future capacity expansion scenarios and results developed through this project. These scenarios are modeled in the ReEDS model.

✓ **Distributed Storage Adoption Scenarios (Technical Report):** A report on the various future distributed storage capacity adoption scenarios and results and implications. These scenarios reflect significant model development and analysis in the dGen model.

Grid Operational Impacts of Storage (Technical Report): A report on the operational characteristics of energy storage, validation of ReEDS scenarioson capturing value streams for energy storage as well as impacts of seasonal storage on grid operations. Released late 2021

Key Learnings Summary: A final summary report that draws on the prior reports and related literature, generates key conclusions and summarizes the entire activity. Released late 2021

All reports are or will be linked to the SFS website: https://www.nrel.gov/analysis/storage-futures.html

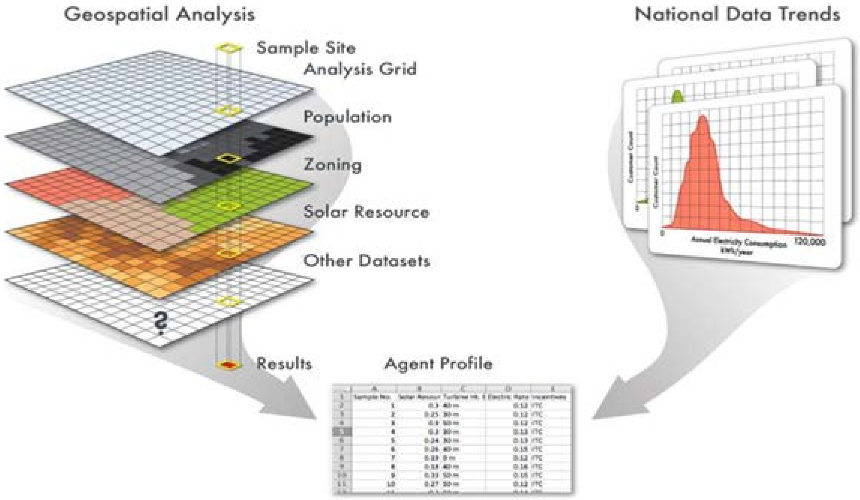
Distributed Solar and Storage Outlook: Methodology and Scenarios

Distributed Solar and Storage Outlook report analyzes customer adoption of distributed storage for several future scenarios.

Highlights:

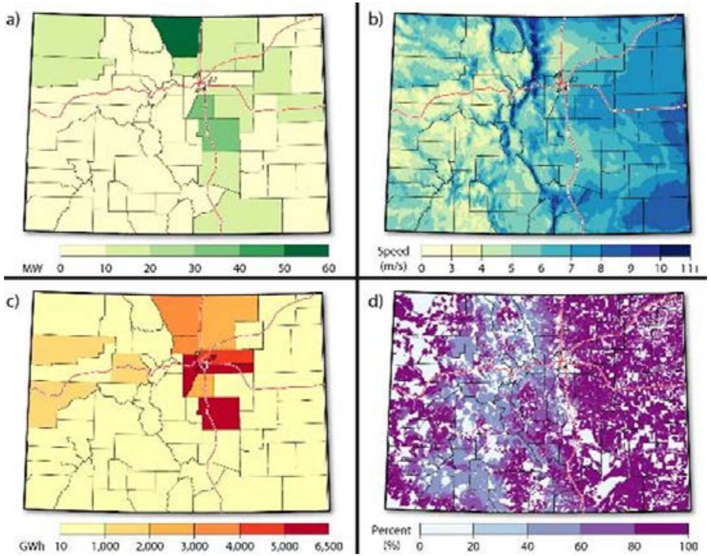
- dGen model development for storage adoption projections
- Value of backup power/resiliency
- Trends and the drivers of distributed solar and storage deployment

Schematic of spatial layers in dGen



dGen, an open-source tool developed at NREL, is used to run multiple scenarios through 2050

dGen



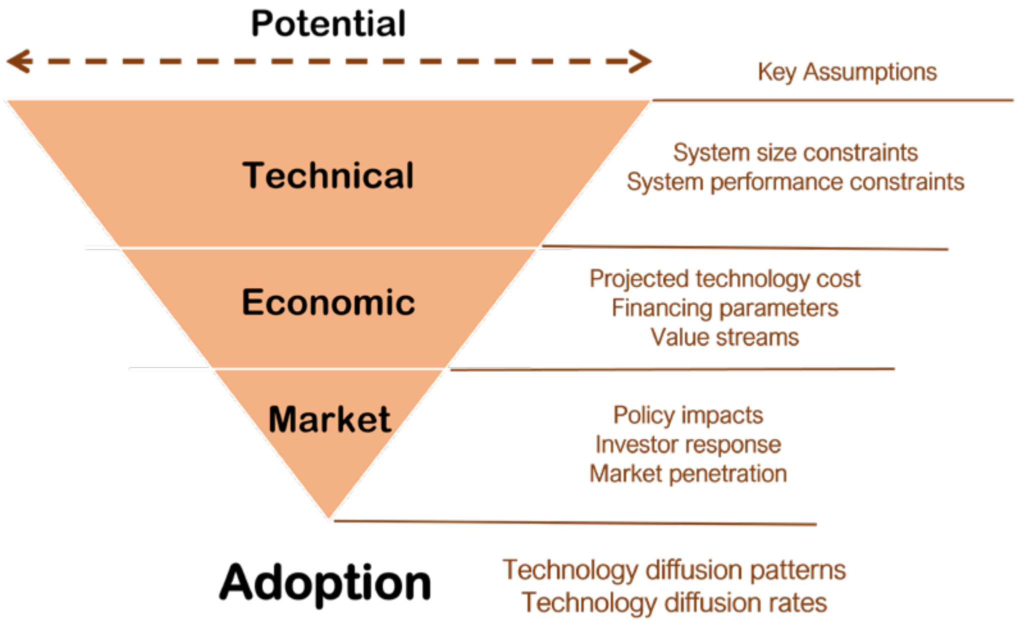
Economic potential for distributed wind in Colorado (a) combining wind speed, (b) electricity consumption (c), site suitability and (d) turbine siting availability at block level. McCabe, K et al. (2018).

The Distributed Generation Market Demand (dGen^{TM}) model forecasts adoption and operation of DERs at high spatial fidelity for power system planning in the United States or other countries through 2050.

- Incorporates detailed spatial data to distinguish individual and regional adoption trends
- Consumer decision-making based on cost-effectiveness of technology
- Identification of drivers of adoption by analysis of multiple scenarios
- Open-source tool available for download at :

  https://github.com/NREL/dgen

Methodology – From Technical Potential to Adoption



Potential

Key Assumptions

Technical

System size constraints
System performance constraints

Economic

Projected technology cost
Financing parameters
Value streams

Market

Policy impacts
Investor response
Market penetration

Adoption

Technology diffusion patterns
Technology diffusion rates

Technical Potential:

Maximum amount of technically feasible capacity.

Economic Potential:

A subset of technical potential, the total capacity that has a positive return on investment or a positive net present value (NPV).

Market Potential:

The fraction of economic potential representing the customer’s willingness to invest in a technology given a specified payback period.

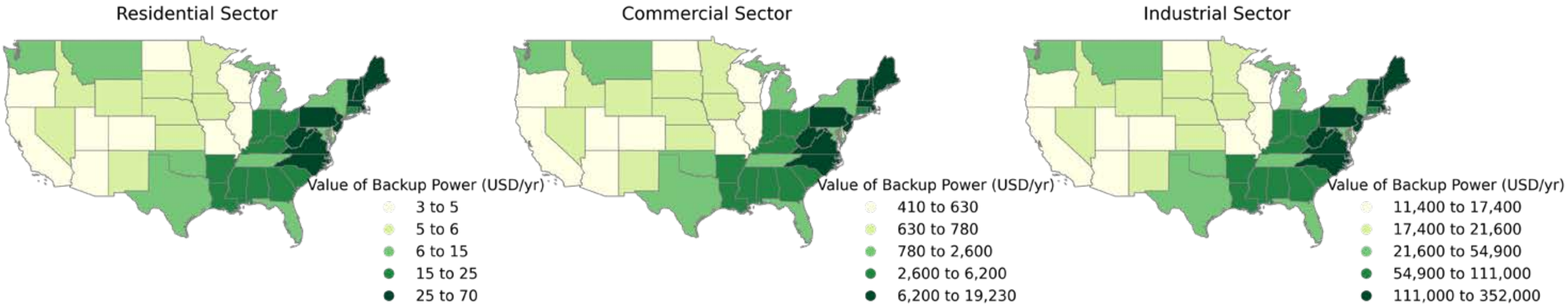
Adoption:

Capacity projected to be purchased by residential, commercial, and industrial building owners and installed at the customer premises in a behind-the-meter configuration.

Value of Backup Power

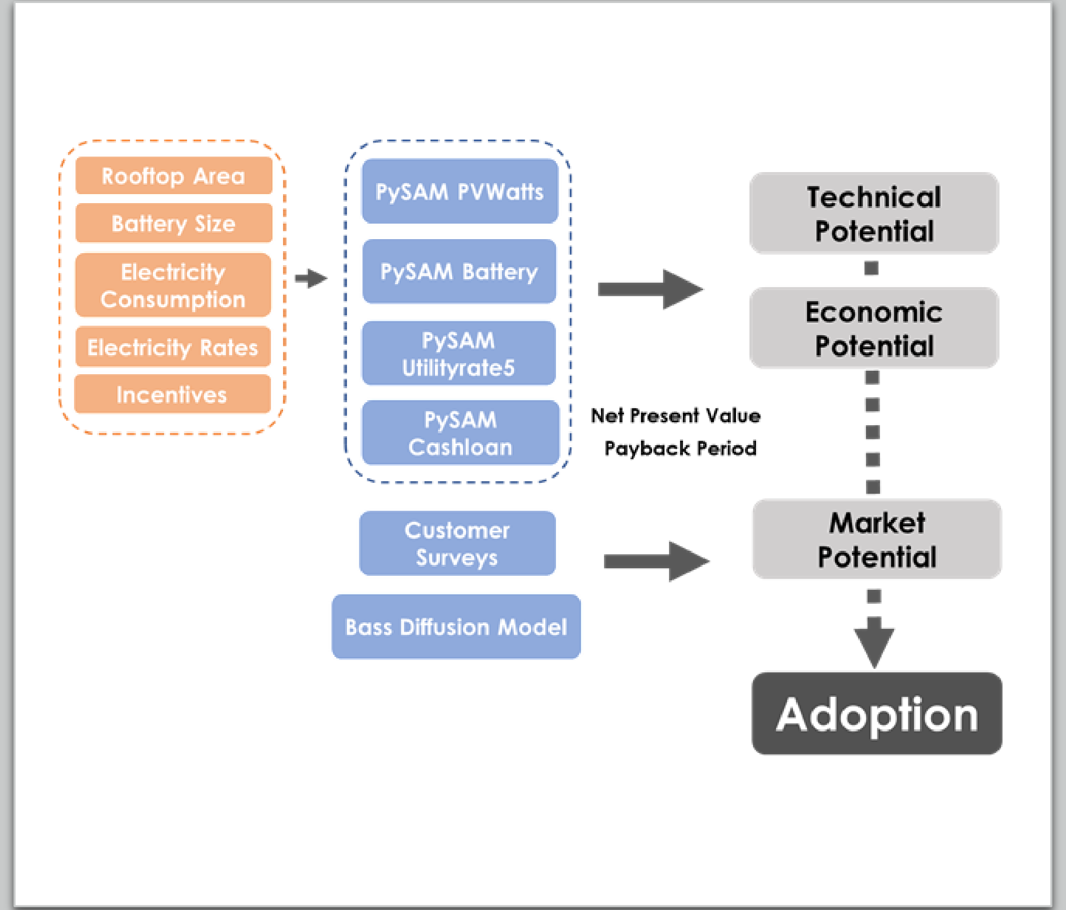
The value of backup power is assumed to be equal to the customer willingness to pay to avoid service disruptions.

EIA-861 data on average frequency and duration of service disruptions (#/year) from EIA 2020 is multiplied with the cost to avoid service disruptions/outages ($/event) from Sullivan et al. 2015 to calculate a region and sector specific value of backup power.

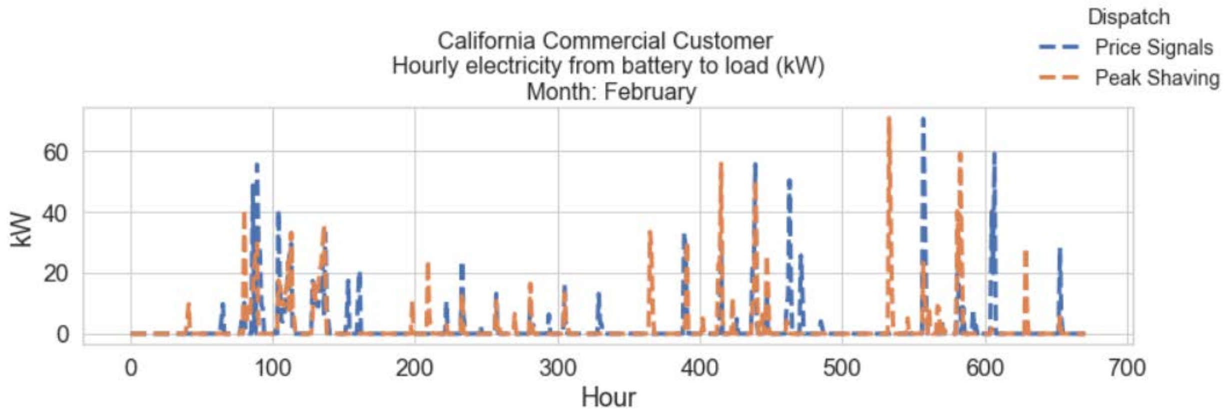


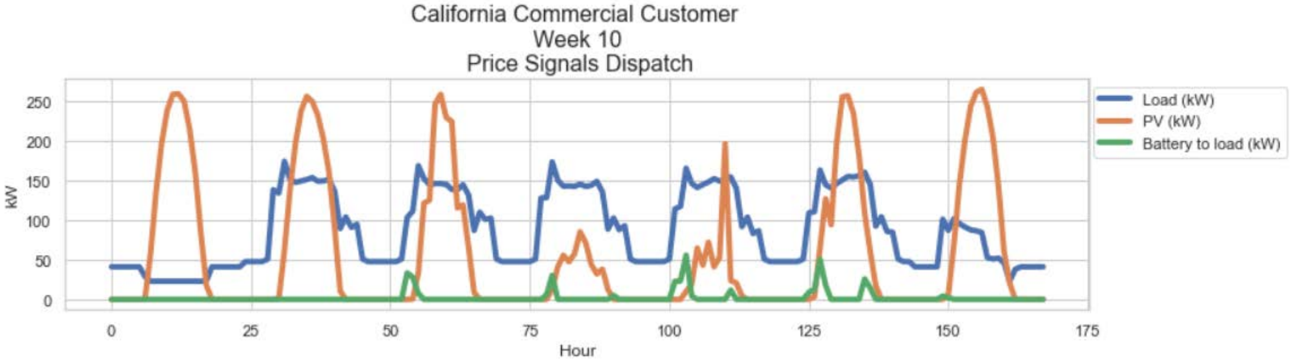
SAM Integration

Technical and financial models from the System Advisor Model (SAM) are integrated into the dGen framework via the python wrapper to SAM.



Storage Dispatch


California Commercial Customer
Hourly electricity from battery to load (kW)
Month: February


California Commercial Customer
Week 10
Price Signals Dispatch

The dispatch strategies used are the peak shaving dispatch (DiOrio 2017) and the price signals dispatch (Mirletz and Guittet 2021). Both dispatch strategies aim to minimize costs to the customer.

Peak shaving strategy: Peak shaving to reduce demand charges.

Price signals strategy: Combines forecasts of day-ahead load, generation, and the utility rates to dispatch the battery in the hours when retail rates are high.

Distributed Solar and Storage Scenarios

Combinations of these sensitivities are used to create a total of 10 scenarios

Technology Cost

- *Reference Cost*
- Low Battery Cost
- Low PV Cost

Value of Backup Power

- *Reference Value*
- No Value of Backup Power
- High Value of Backup Power

DER Valuation

- *Reference DER Value*
- Net Metering
- Net Billing

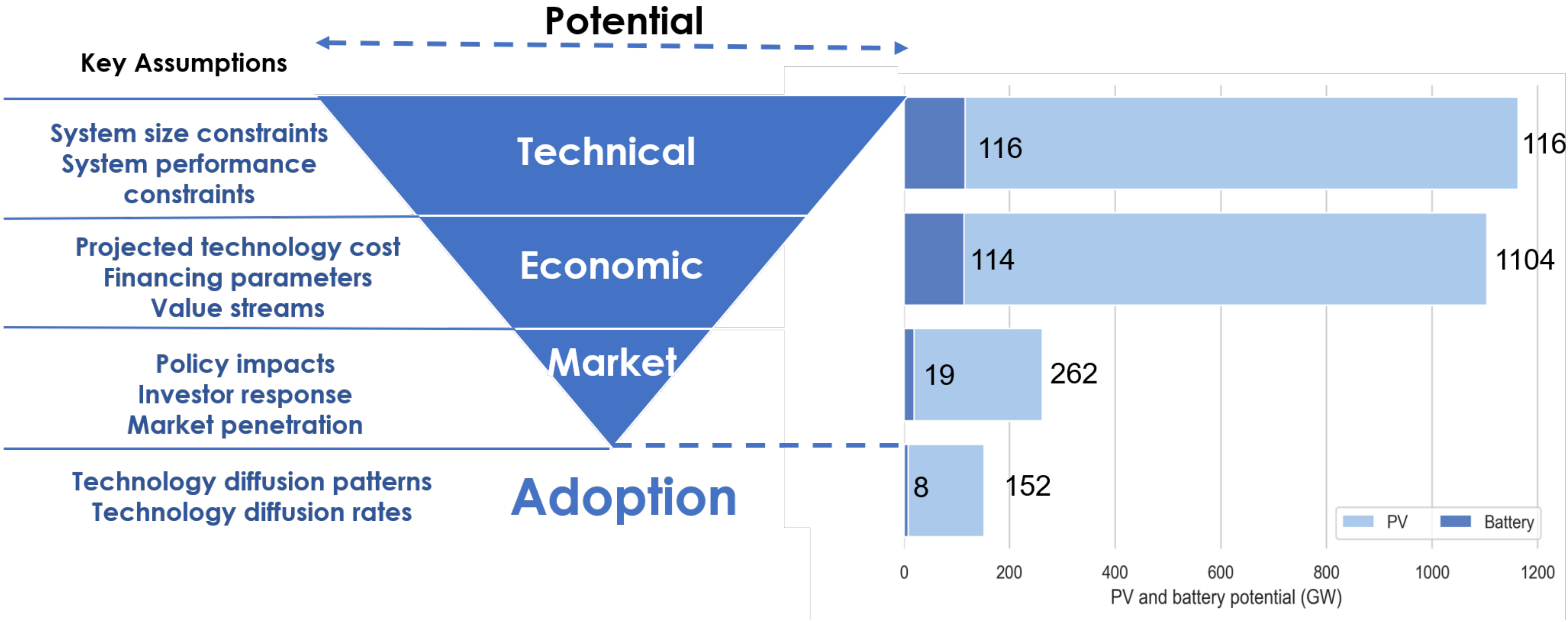
Distributed Solar and Storage Scenarios

Scenario Group	Scenario Name	Scenario Description
Technology Cost Scenarios	Base Case	Moderate cost projections for both PV and battery storage systems; all other incentives and rates inputs are default values, and the value of backup power is considered.
	Advanced Cost Batteries Scenario	Advanced (low) cost projections for batteries paired with moderate cost projections for PV
	Advanced Cost PV Scenario	Advanced (low) cost projections for PV paired with moderate cost projections for batteries
	Advanced Cost PV + Batteries Scenario	Advanced (low) cost projections for PV paired with advanced (low) cost projections for batteries
Value of Backup Power Scenarios	No Backup Value Scenario	Moderate cost projections for PV and batteries and no value of backup power
	No Backup Value + Advanced Cost Batteries Scenario	Advanced (low) cost projections for batteries and no value of backup power
	2x Backup Value Scenario	Moderate cost projections for PV and batteries and double the value of backup power across all states and sectors
	2x Backup Value + Advanced Cost Batteries Scenario	Advanced (low) cost projections for batteries and double the value of backup power across all states and sectors.
DER Valuation Scenarios	Net Metering Extensions Scenario	All states switch to net metering compensation from 2020 through 2050.
	National Net Billing Scenario	All states switch to net billing compensation from 2020 through 2050.

Distributed Solar and Storage Outlook

RESULTS

Technical Potential to Adoption



Base Case scenario in 2050

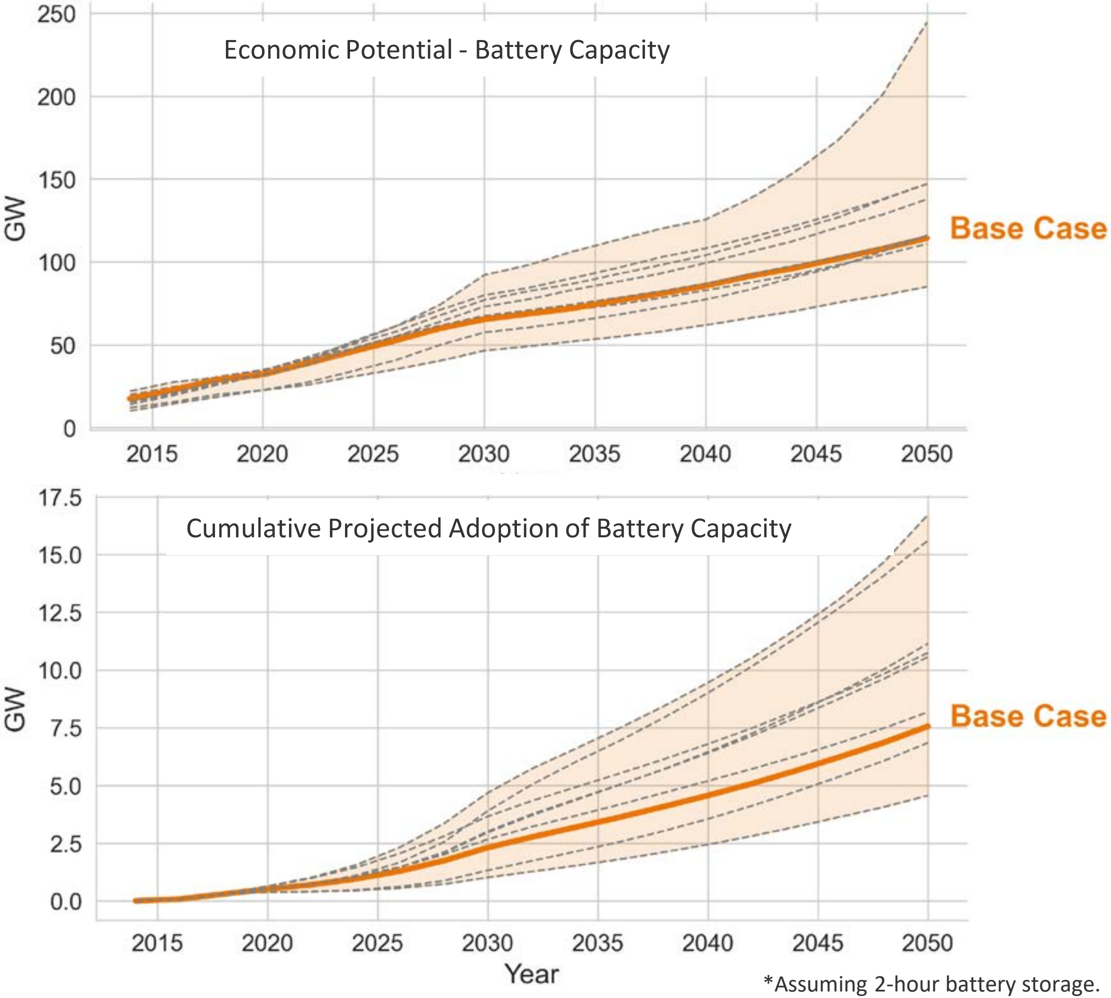
Assuming a 2 –hour battery storage

Economic Potential and Adoption

Economic potential is the total capacity in a given year that could return a positive NPV. A discounted cash flow analysis determines the NPV.

The NPV is based on value created through the sum of three value streams:

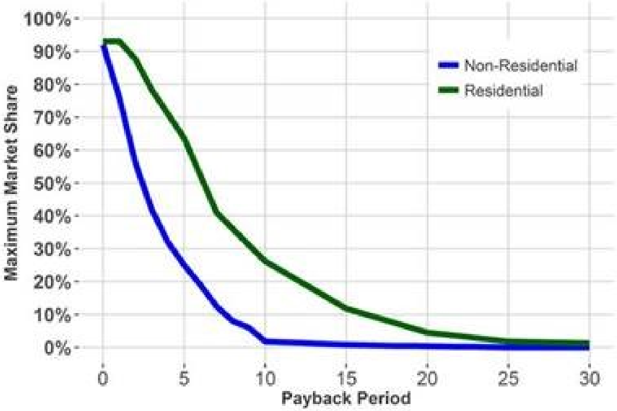
1. Value created by reducing electricity bills
2. Value of backup power
3. Revenue from selling excess PV generation.

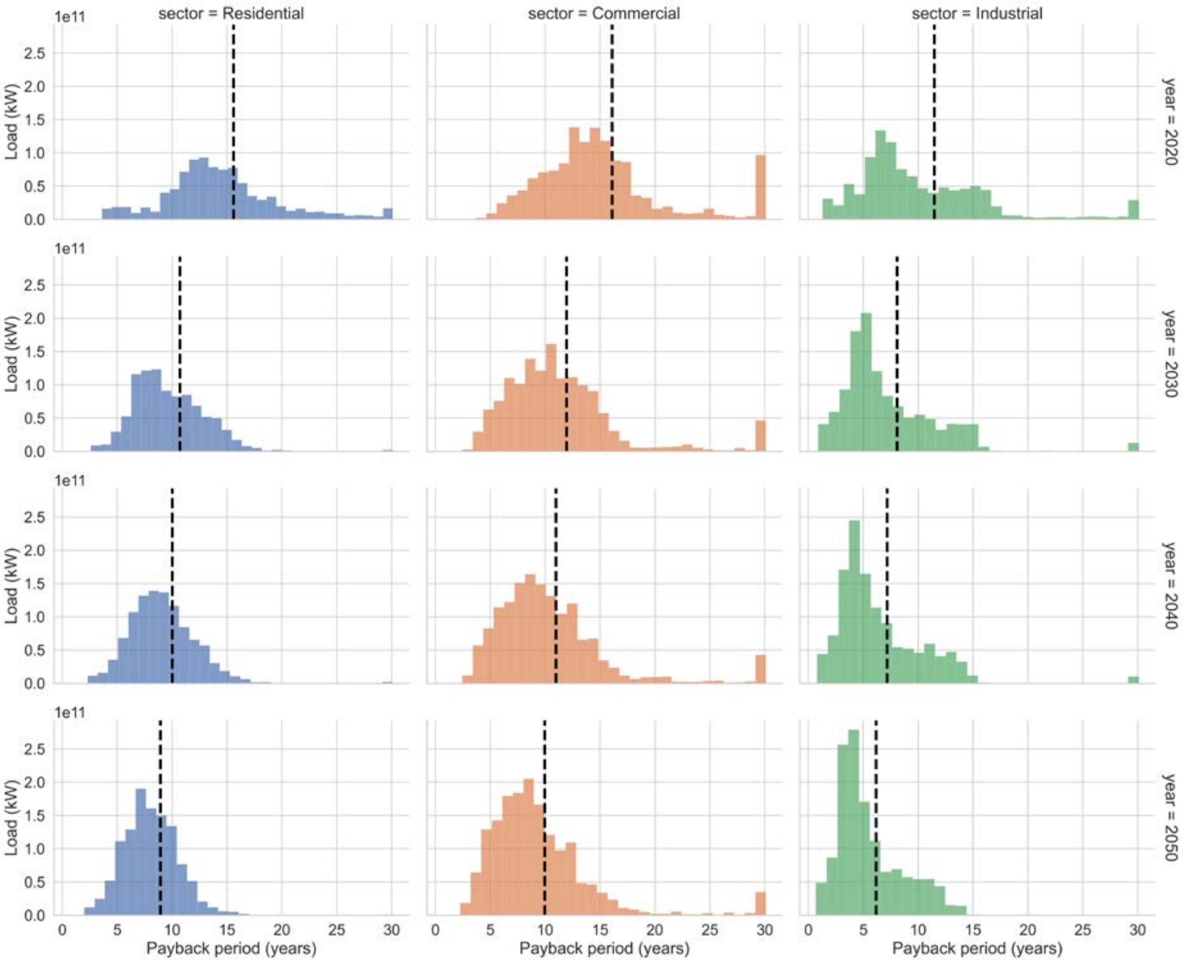


*Assuming 2-hour battery storage.

Payback period

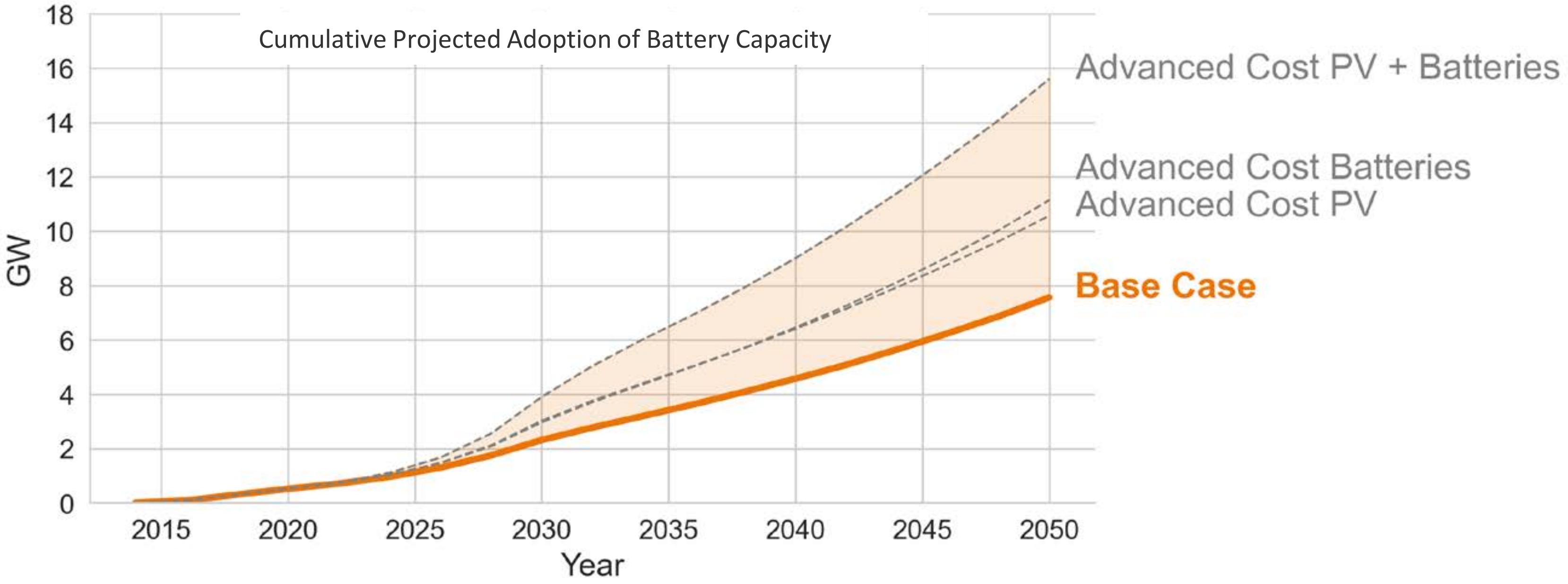
Modest amount of adoption is due to the length of payback periods and their translation to maximum market potential, which is the upper limit of adoption.





Technology Cost Scenarios

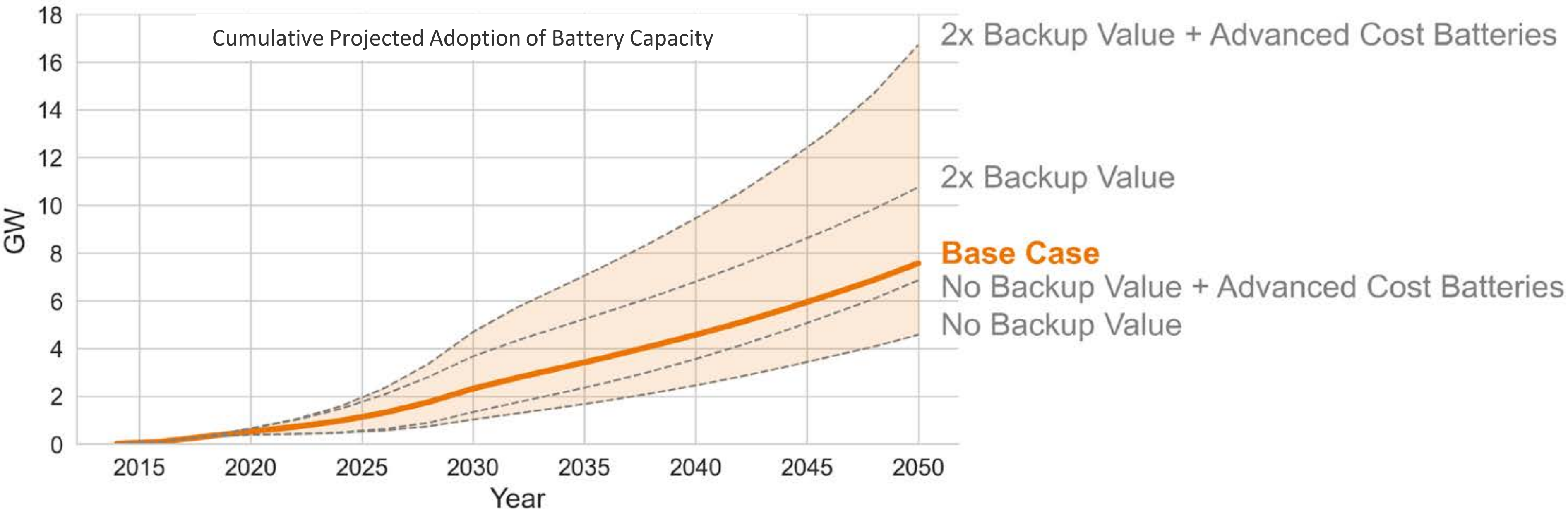
Cost reductions in both PV and storage technologies and the value added by the combined system drive additional adoption compared to cost reductions in either technology.



*Assuming 2-hour battery storage.

Value of Backup Power Scenarios

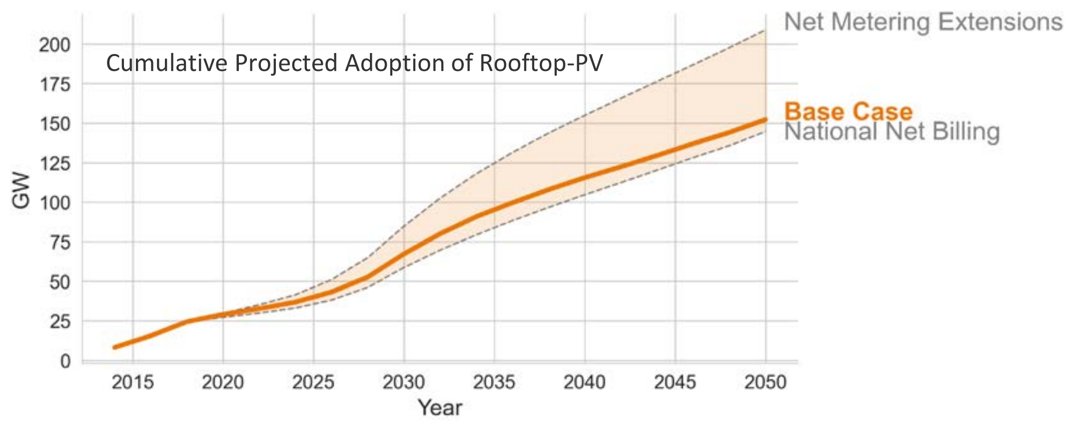
Including a monetary value for backup power increases battery adoption significantly.



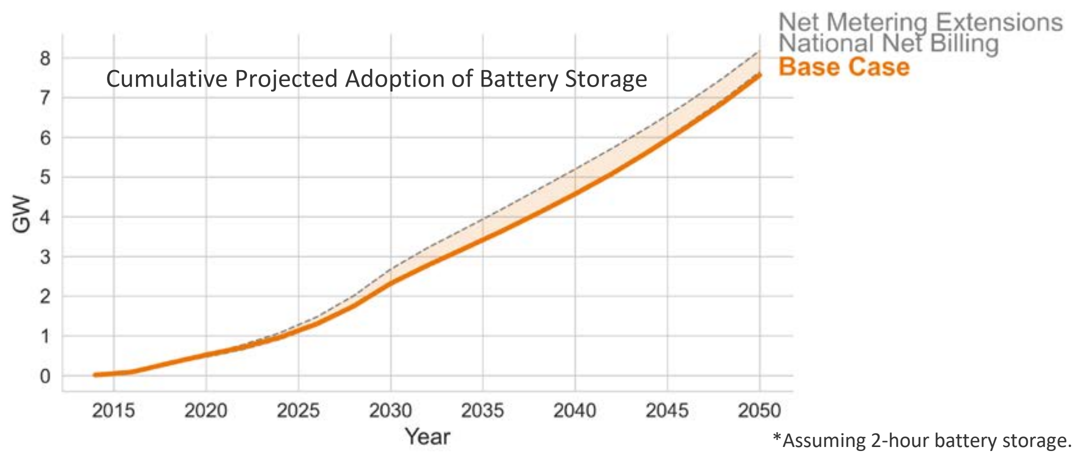
*Assuming 2-hour battery storage.

DER Valuation Scenarios

PV adoption is higher in the Net Metering Extensions Scenario compared to the National Net Billing Scenario, but cumulative battery capacity varies less.



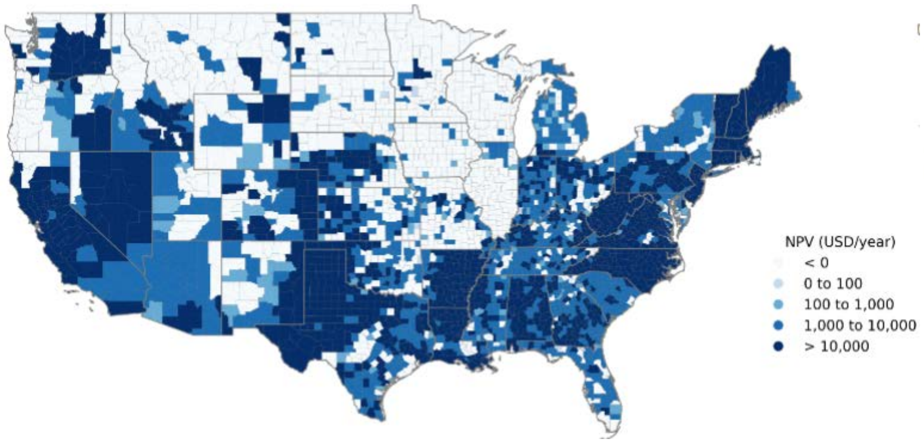
Cumulative Projected Adoption of Rooftop-PV



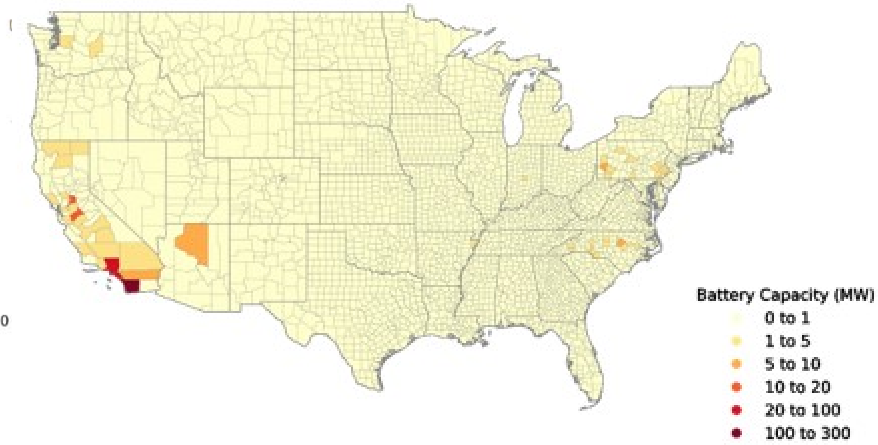
Cumulative Projected Adoption of Battery Storage

*Assuming 2-hour battery storage.

Base Case 2050 - Average NPV of PV + Battery Storage Systems



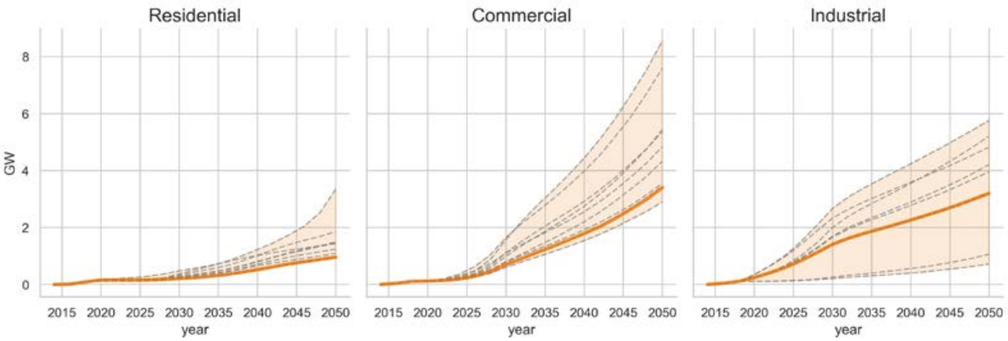
Base Case - Cumulative Battery Capacity in 2020

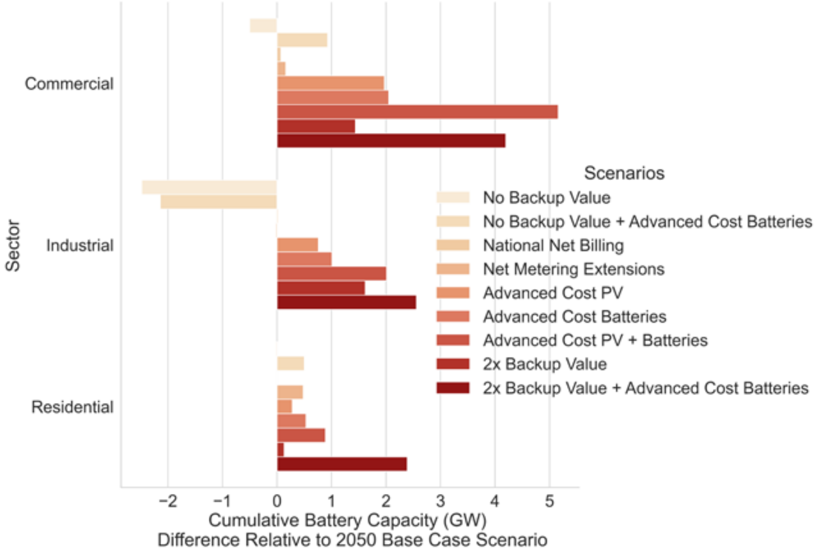


County-Level Results

Several factors influence battery adoption, with the most important being retail electricity tariffs, the value of backup power, incentives, and historical adoption.

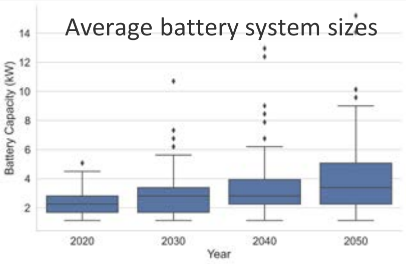
Sector-Level Results



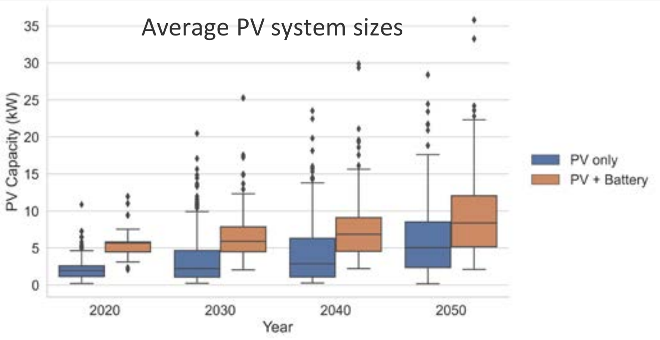


- Residential sector adoption is driven by a reduction in technology costs.
- In the commercial sector peak shaving makes PV + battery storage systems economically viable
- The value of backup power plays an important role in driving battery adoption in the industrial sector.

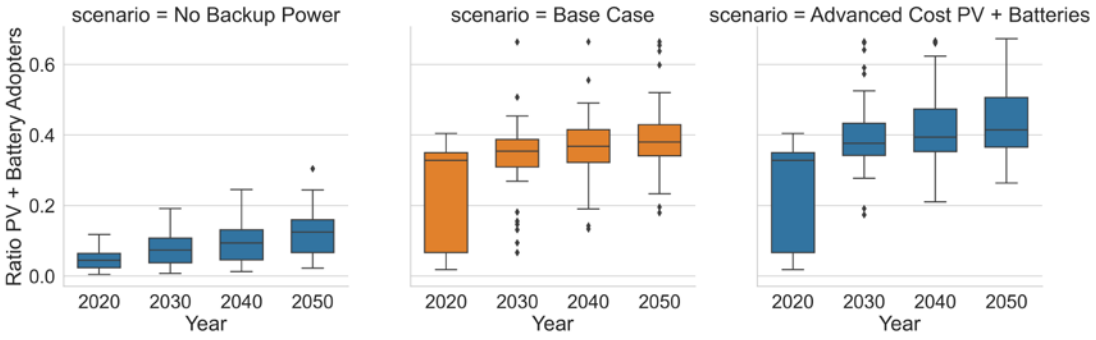
Average System Size and Co-Adoption



Average battery system sizes



Average PV system sizes



Co-adoption of battery storage

Average PV system size in PV + battery storage systems is larger than in PV-only systems.

Limitations

- Standalone batteries are not evaluated
- The method used to calculate the value of backup power presented has limitations. Average values might not reflect extreme cases where longer or more frequent service disruptions occur.
- Emerging sources of revenue for PV + battery storage systems such as participation in wholesale markets, demand response programs, or grid services are not considered in this analysis.
- New DER valuation mechanisms such as the Value of Distributed Energy Resources (VDER) or the Value Stack (NYSERDA 2020b) are not considered, future more complex tariff structures are not evaluated.
- Sensitivities considering owning vs. leasing PV + battery storage systems are not included in this analysis. Sensitivities on financial parameters such as the discount rate are also not considered.
- Significant electrification of the transportation or heating sectors and their impact on residential, commercial, and industrial load profiles are not considered in this analysis.

Distributed Solar and Storage Scenarios - Key Takeaways

Significant economic potential for distributed PV + battery storage systems under all modeled scenarios

Low future battery cost and a high value for backup power are the most important drivers at a national scale

Modest growth in distributed PV + battery storage deployment

New dGen capability to model storage adoption

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Questions and Discussion

https://www.nrel.gov/analysis/storage-futures.html

www.nrel.gov

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