Distributed Solar and Storage Adoption Modeling

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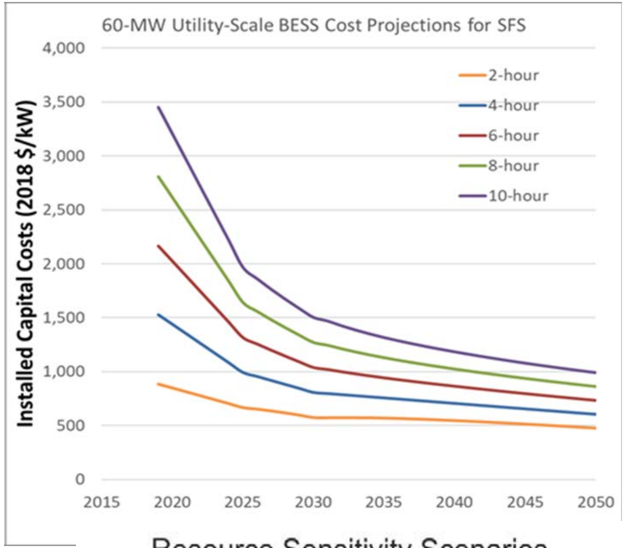
Storage Futures Study

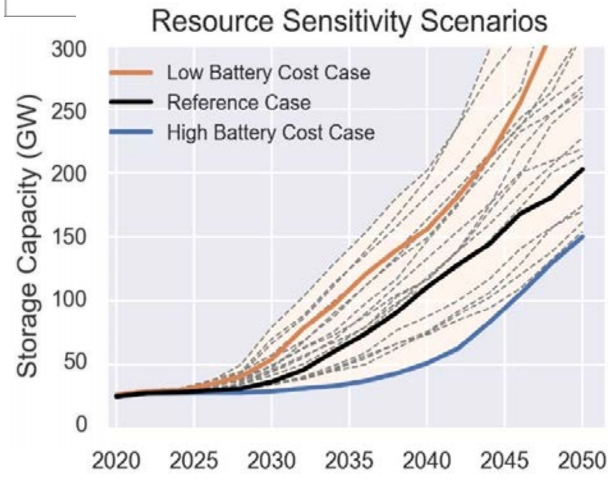
NREL is analyzing the rapidly increasing role of energy storage in the electrical grid through 2050.

- “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, concentrated solar power (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.

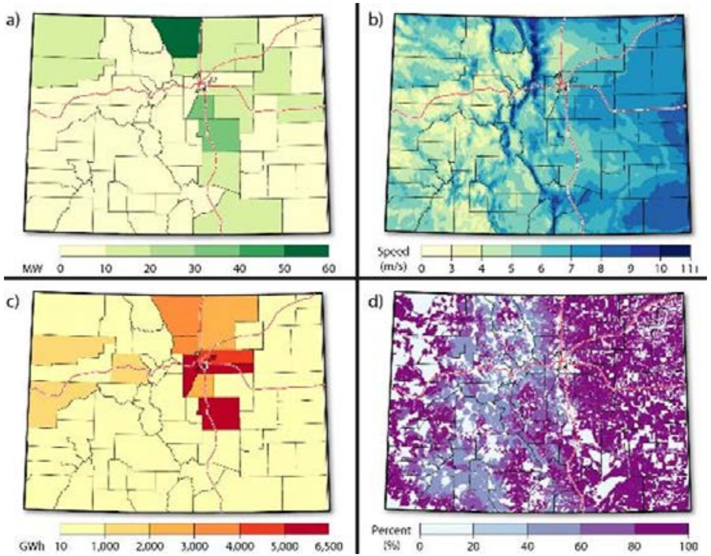
✓ **Distributed Storage Adoption Scenarios (Technical Report):** A report on the various future distributed storage capacity adoption scenarios and results and implications. These scenarios reflect significant model development and analysis in the dGen model.

Grid Operational Impacts of Storage (Technical Report): A report on the operational characteristics of energy storage, validation of ReEDS scenarios on capturing value streams for energy, 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.

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 et al. (2018).

The Distributed Generation Market Demand (dGen™) 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.

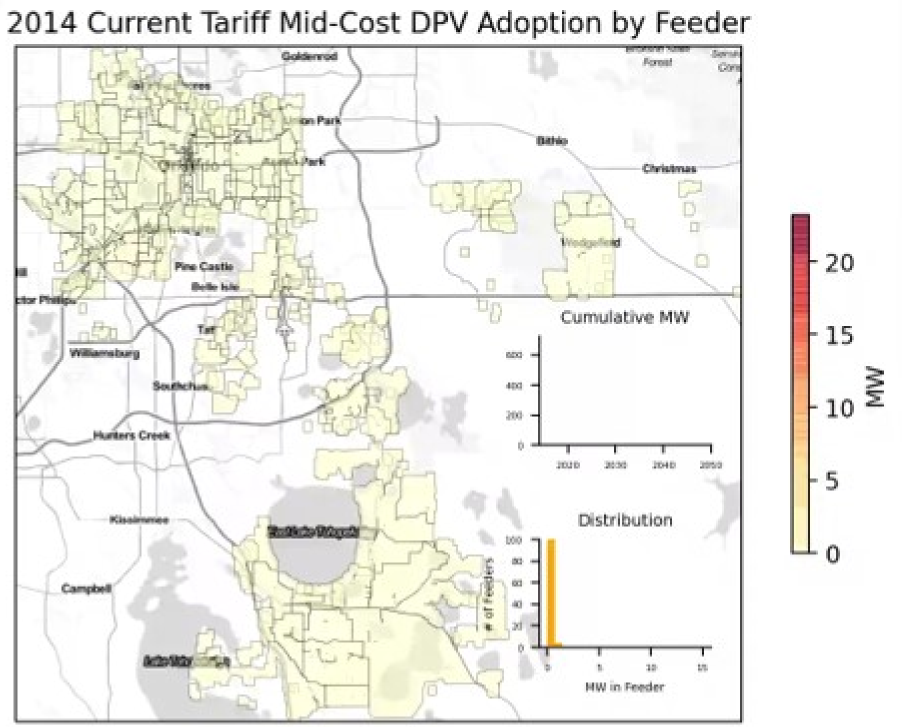
2021 R&D 100 Award Winner

Given annually, the R&D 100 Awards honor the 100 most innovative technologies of the past year and are chosen by an independent panel of judges.

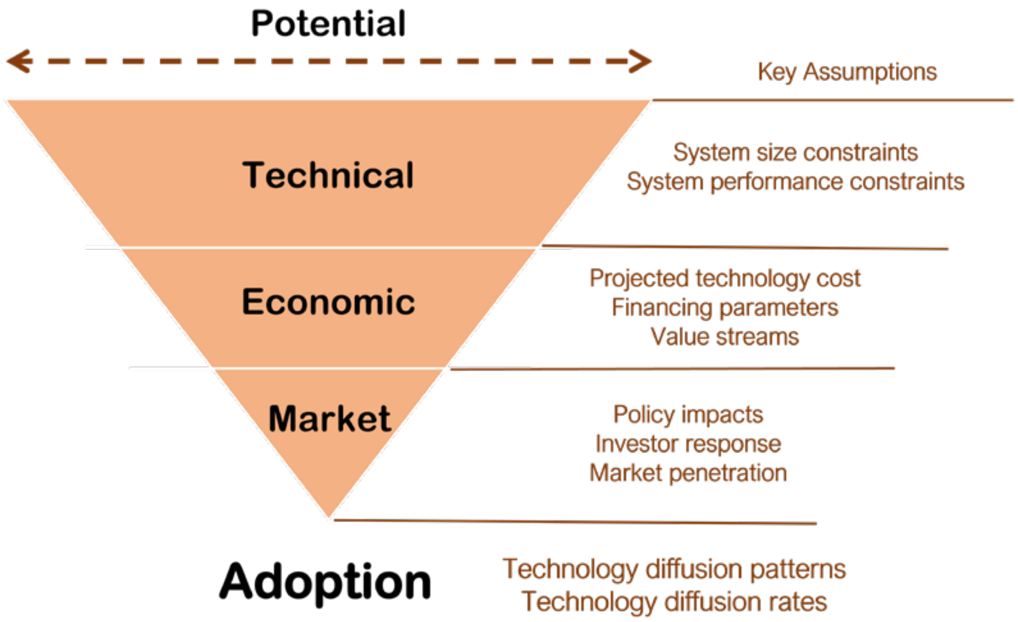
Model Applications

The dGen model can be used to explore forward-looking topics, such as understanding:

- Infrastructure needs for distribution grids to accommodate DER deployment
- How DERs influence retail electricity prices
- The impact of an electrifying economy
- Synergy between distributed-scale resources and transmission-scale resources.



Methodology: From Technical Potential to Adoption



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.

dGen: Future and Ongoing Development

Key Innovation: Use of parcel data to assess location-specific land use, resource, and siting. Assess each parcel's technical and economic viability:

- By technology: distributed wind (DW), solar (DPV), and storage
- By business model: behind-the-meter (BTM) vs front-of-meter (FTM).

*Parcel: Taxable plot of land

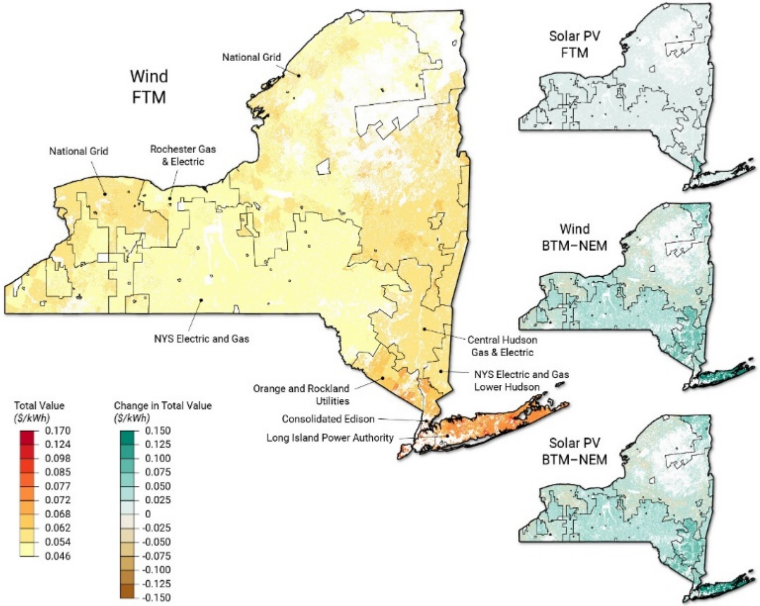


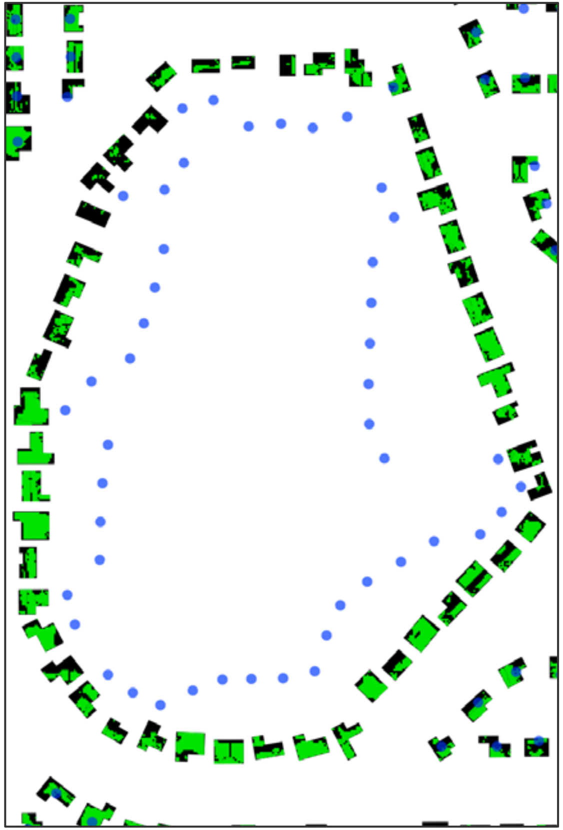
Figure: Example results for recent NY state analysis piloting the dGen parcel-level methods

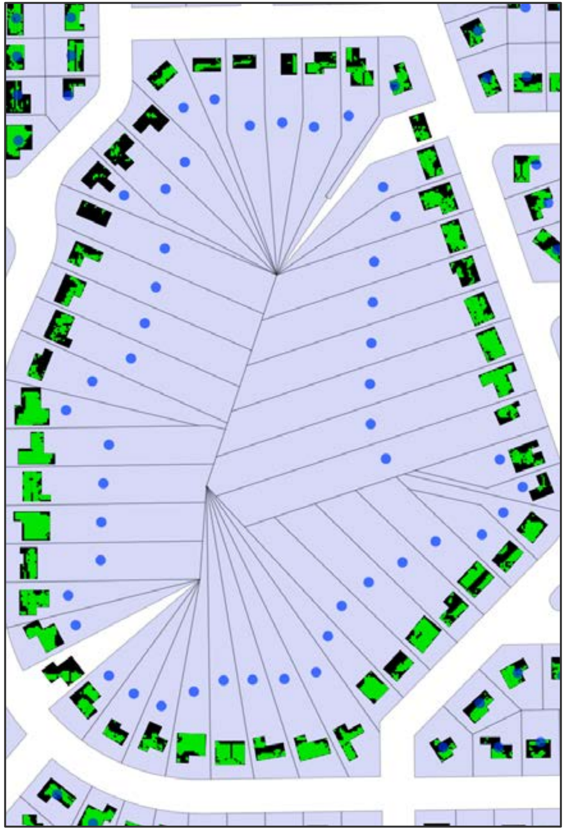
dGen: Future and Ongoing Development

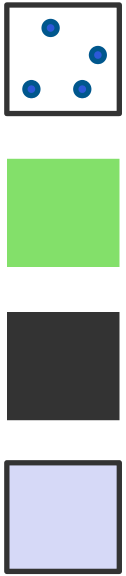
Aspects of ongoing development include:

- **Development of parcel-level database (n=~155m):** Assessing potential at the parcel-level allows detailed consideration of land use, zoning, sector, and geography, in urban and suburban settings.
- **Integration of reV resource processing:** reV is a spatiotemporal tool enabling bulk calculation of RE capacity/generation. We also incorporate improved meteorological data from the Wind Toolkit and NSRDB.
- **Integration of Cambium:** An NREL data source that provides information on the marginal conditions of the power system across the United States through 2050.
- **Integration of PySAM library:** PySAM offers the full capabilities of NREL's System Advisor Model, including wind, solar PV, and battery models, complex cashflow calculations, and retail tariff processing.
- **Integration of detailed battery modeling:** Via PySAM, we are actively integrating battery modules to enable hybrid system modeling.

Mapping Customer “Agents” to Buildings (With Parcels)







To join each customer “agent” to a developable area for solar, we spatially join with the underlying parcel.

Valuation Framework: Behind-the-Meter

- Load profile associated with parcel drawn from DOE residential and commercial building stock data sets based on land-use type.
- Utility Rate Database (URDB) used to determine billing and metering arrangement and retail tariff for parcel based on location.
- Hourly annual revenues for parcel based on applicable compensation mechanism and the balance of generation and consumption.

Tiered Energy Usage Charge Structure

Period	Tier	Max Usage ?	Max Usage Units ?	Rate $/kWh ?
1	1		kWh	0.04901
2	1		kWh	0.0674

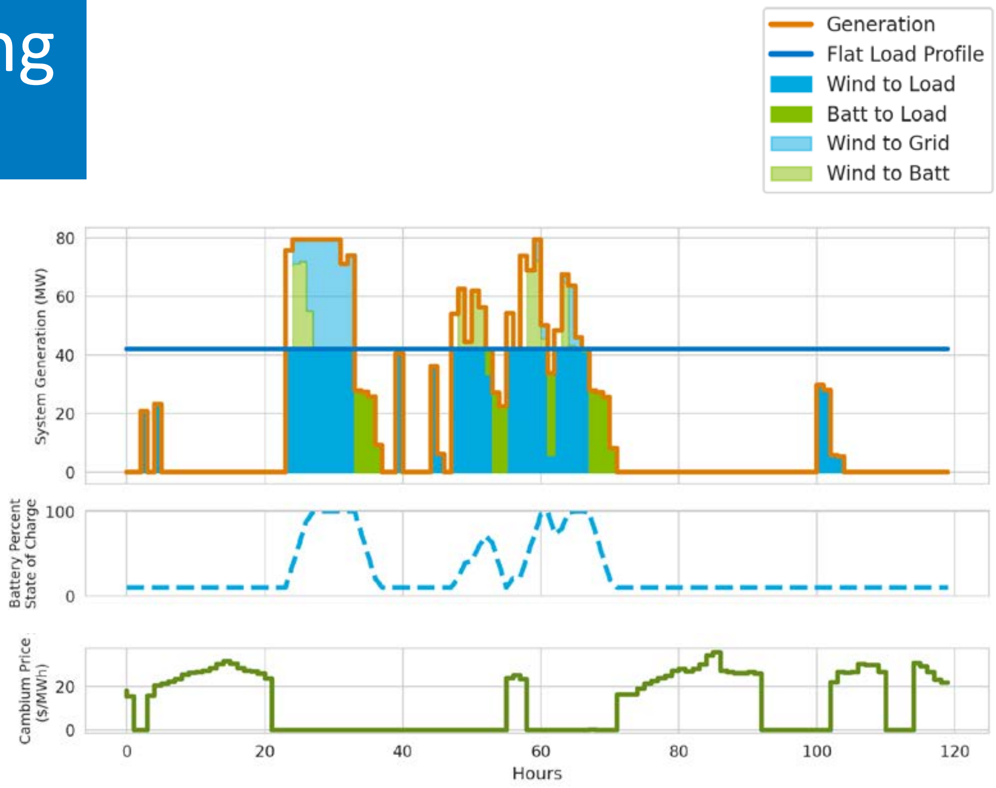
Weekday Schedule

	12 am	1 am	2 am	3 am	4 am	5 am	6 am	7 am	8 am	9 am	10 am	11 am	12 pm	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	7 pm	8 pm	9 pm	10 pm	11 pm
Jan	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	1	1	1
Feb	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	1	1	1
Mar	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	1	1	1
Apr	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	1	1	1
May	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	1	1	1
Jun	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1
Jul	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1
Aug	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1
Sep	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1
Oct	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	1	1	1
Nov	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	1	1	1
Dec	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	1	1	1

PySAM System Modeling

PySAM is a Python wrapper for NREL's System Advisor Model (SAM):

- Models technical performance of wind, solar PV, and **battery** systems:
  - Inputs: weather data from reV, system characteristics from parcel/sizing steps
  - Outputs: hourly operation of systems.
- Models financial performance of systems based on retail or wholesale revenues, depending on configuration (i.e., BTM vs. FTM):
  - Inputs: retail tariffs from URDB (BTM) or market revenues from Cambium (FTM)
  - Outputs: LCOE, NPV, and payback periods.



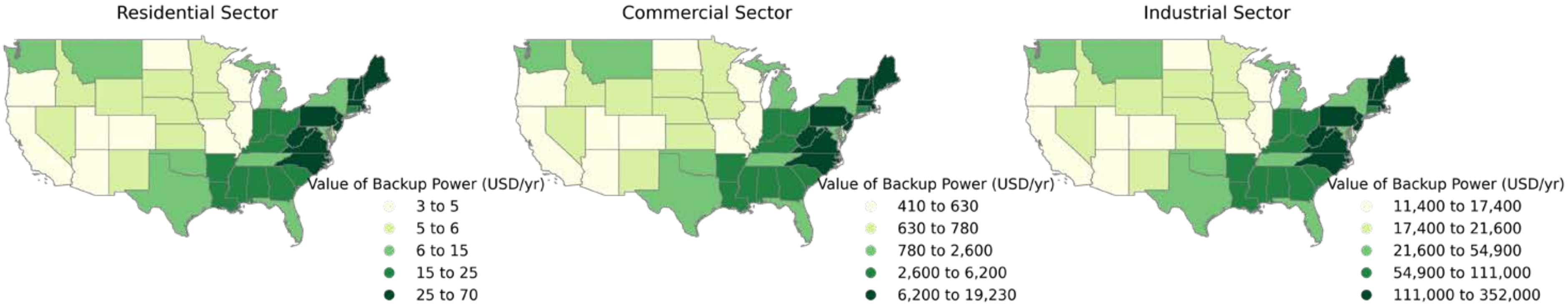
Theoretical dispatch of wind and battery system to meet load, compared to Cambium revenues

Source: Vapor, Cambium, PySAM

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.



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.

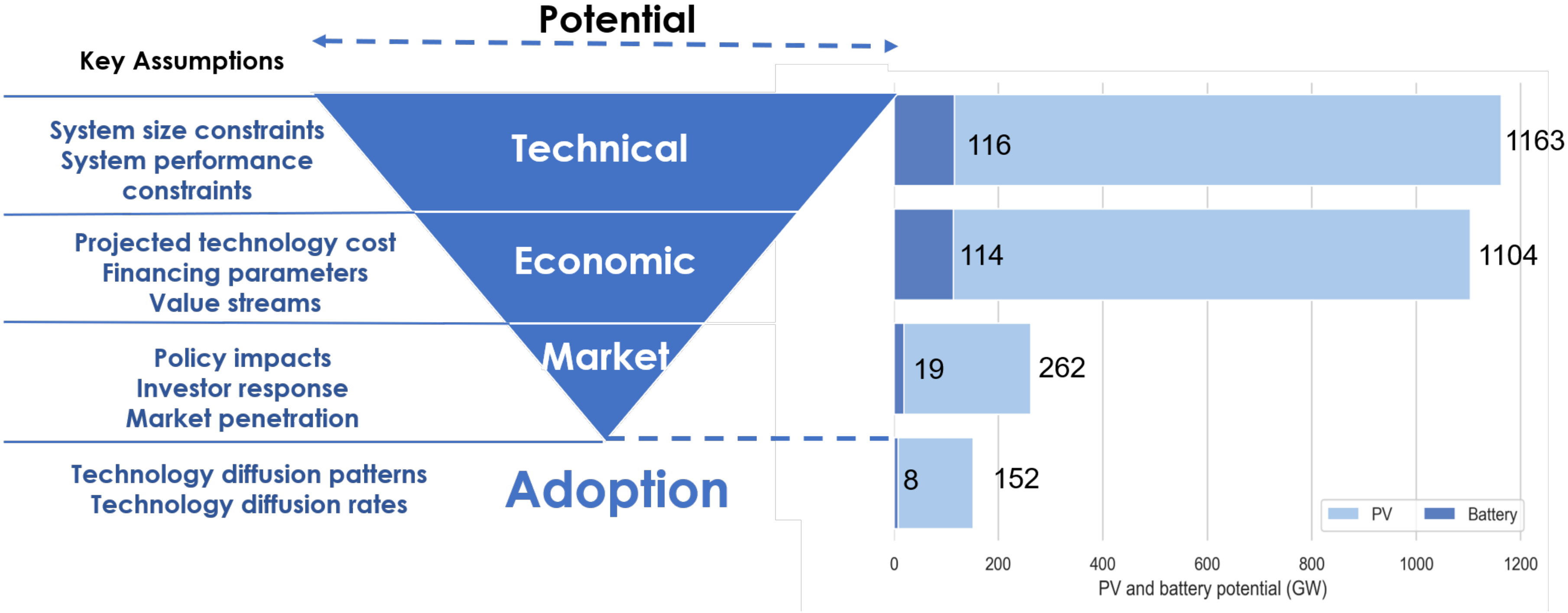
Distributed Solar and Storage Scenarios

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

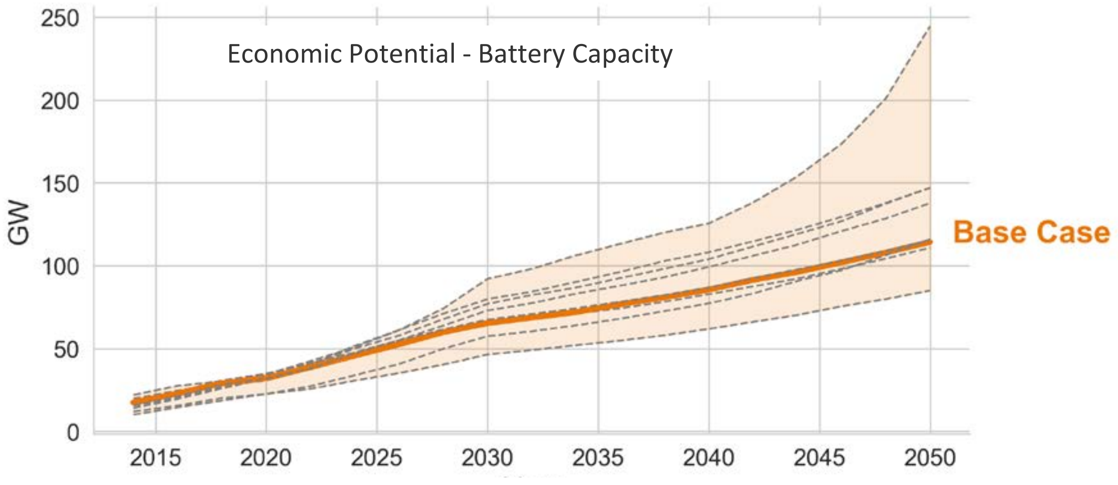
Assuming a 2 –hour battery storage

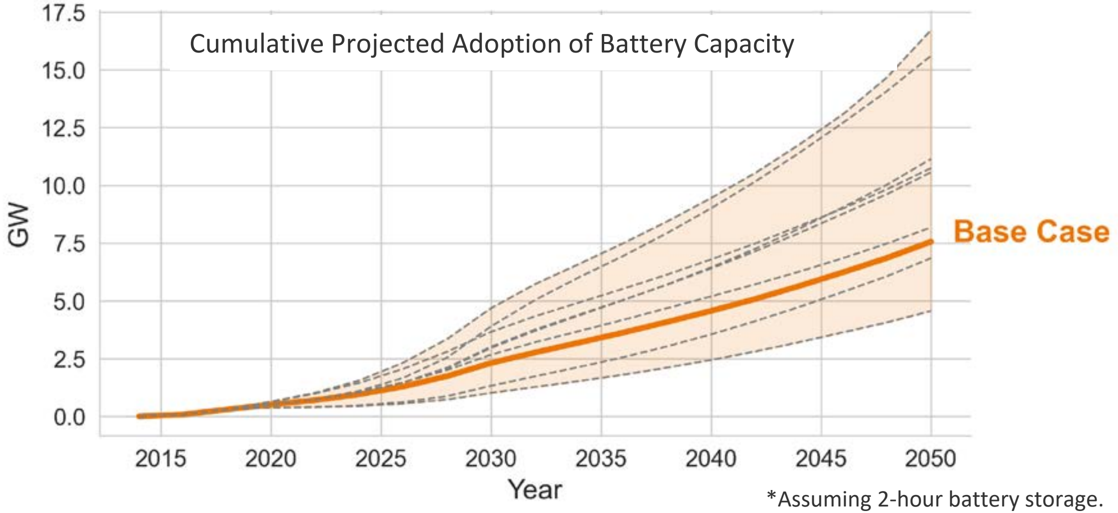
Economic Potential and Adoption

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.

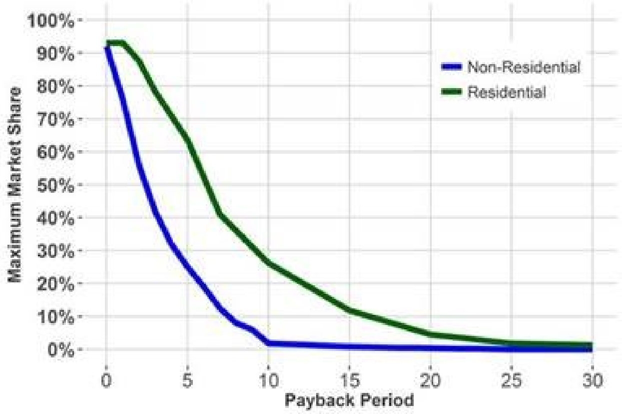


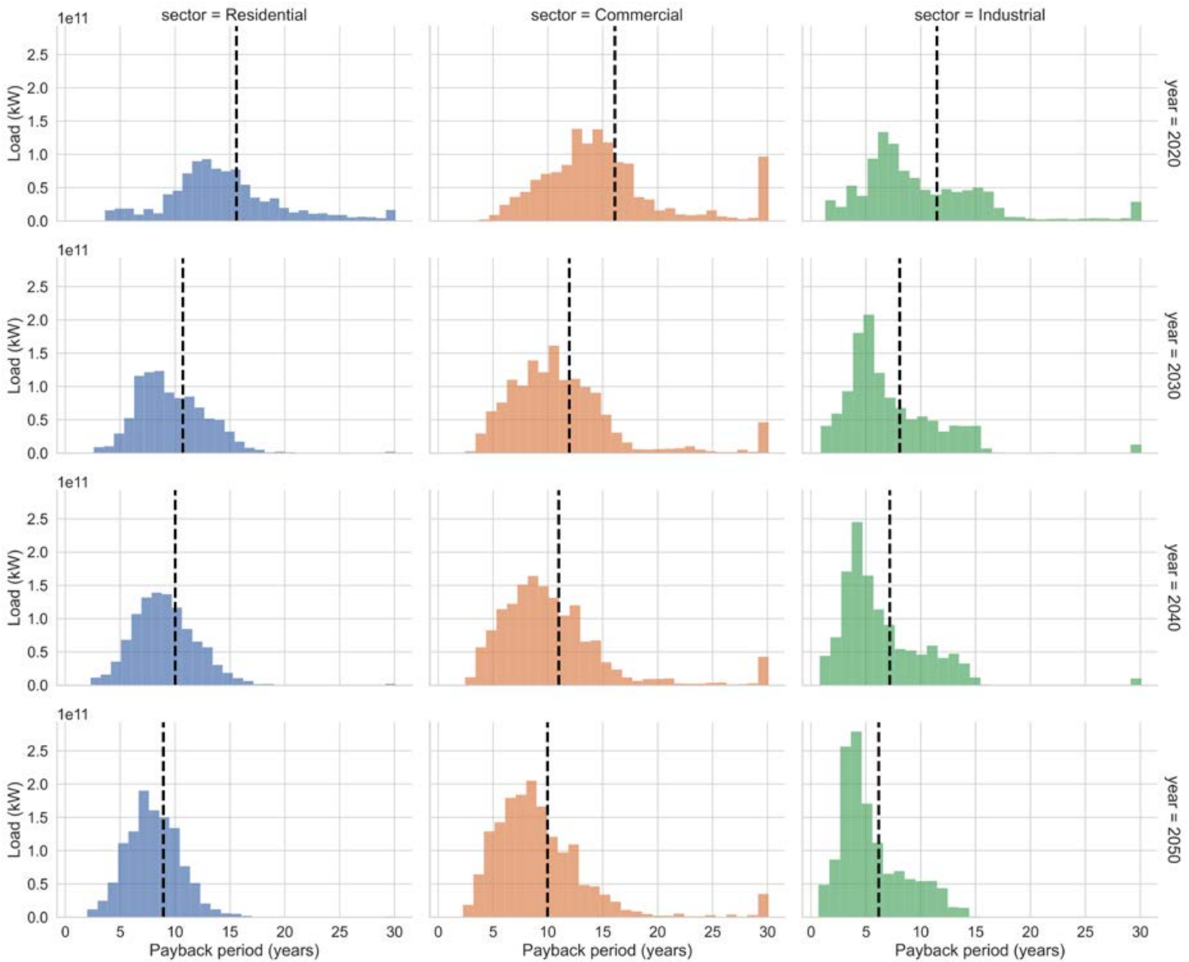


*Assuming 2-hour battery storage.

Payback period

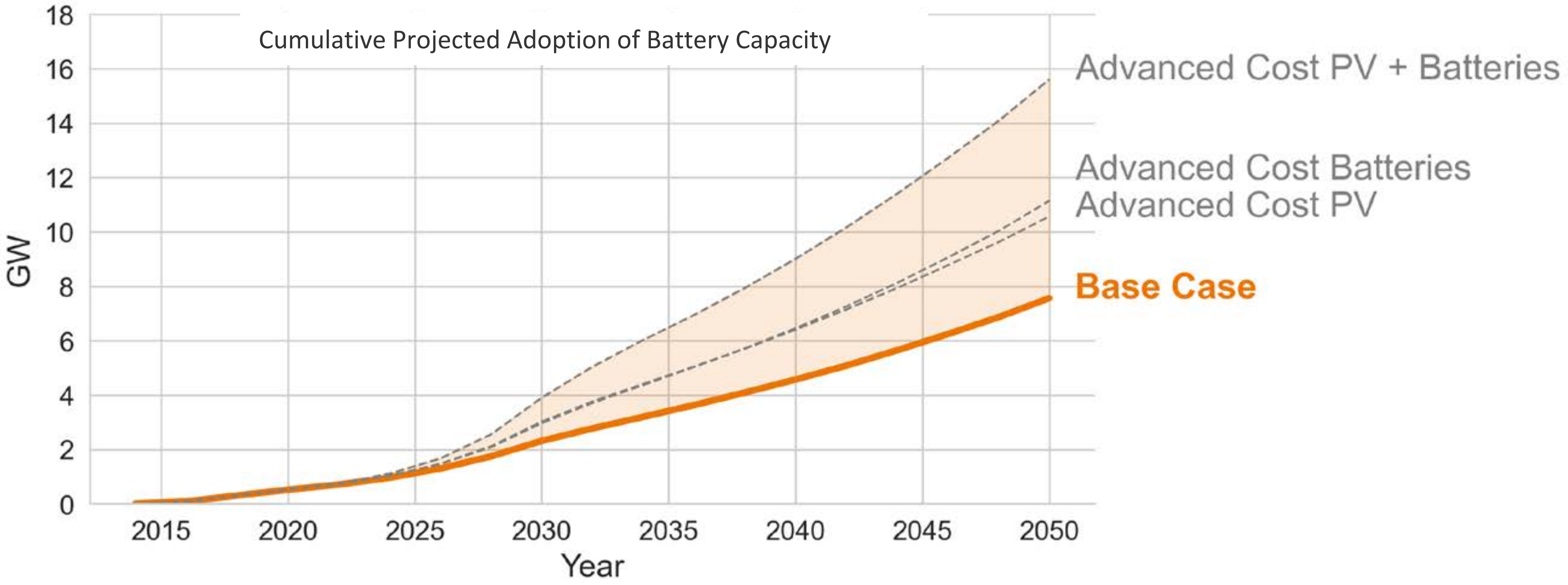
Modest amount of adoption is due to the length of payback periods and their translation to maximum market potential, which is the upper limit of adoption.





Technology Cost Scenarios

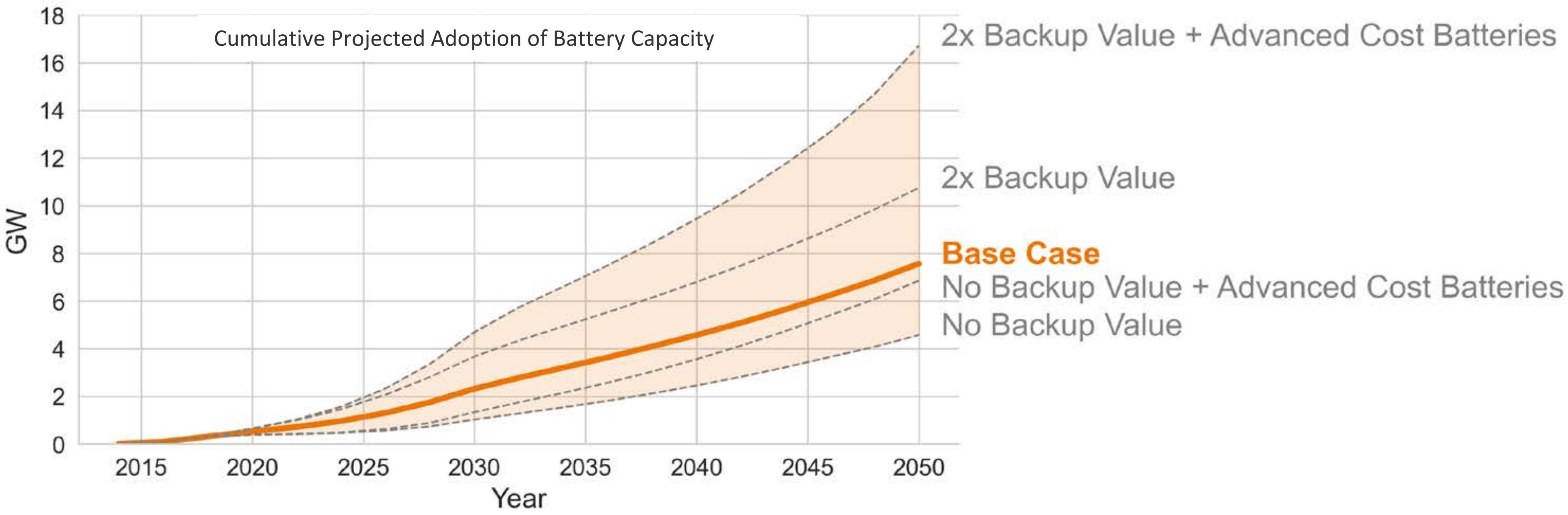
Cost reductions in both PV and storage technologies and the value added by the combined system drive additional adoption compared to cost reductions in either technology.



*Assuming 2-hour battery storage.

Value of Backup Power Scenarios

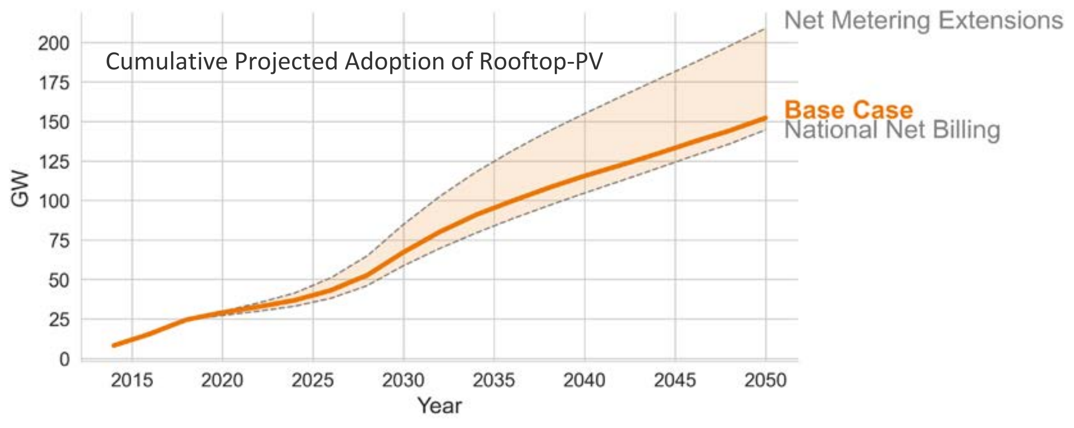
Including a monetary value for backup power increases battery adoption significantly.

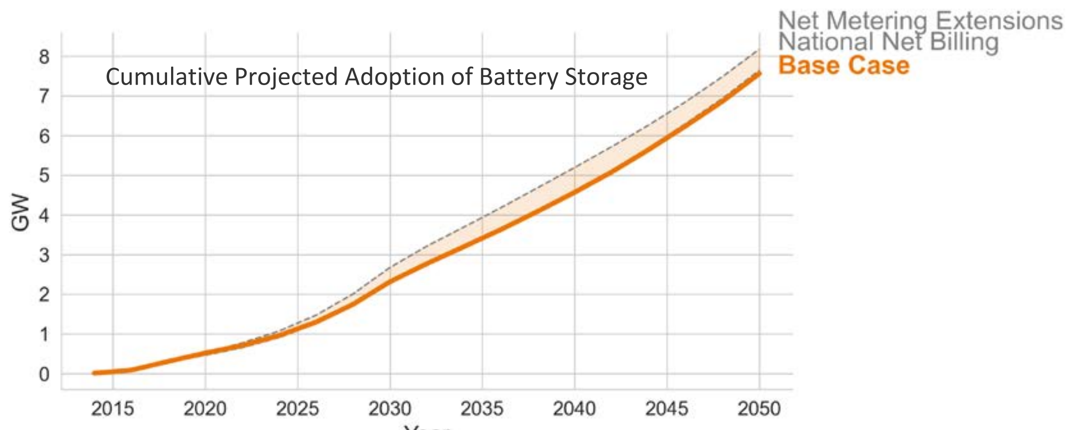


*Assuming 2-hour battery storage.

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.





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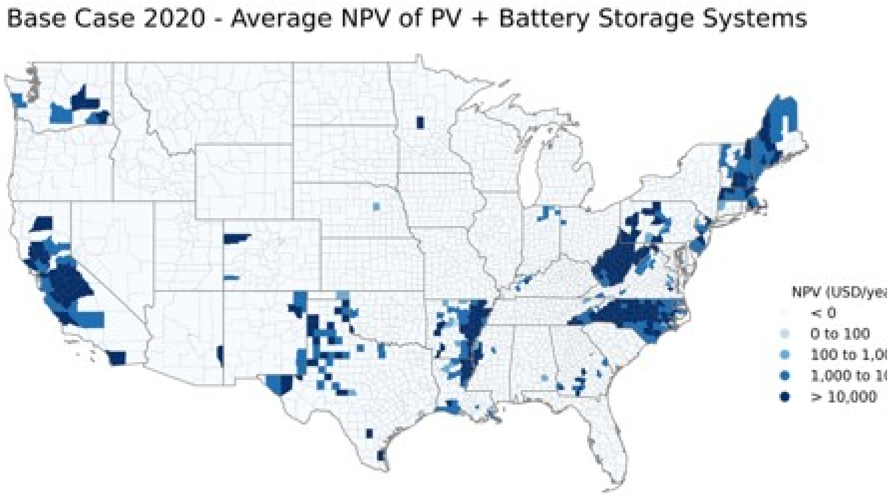

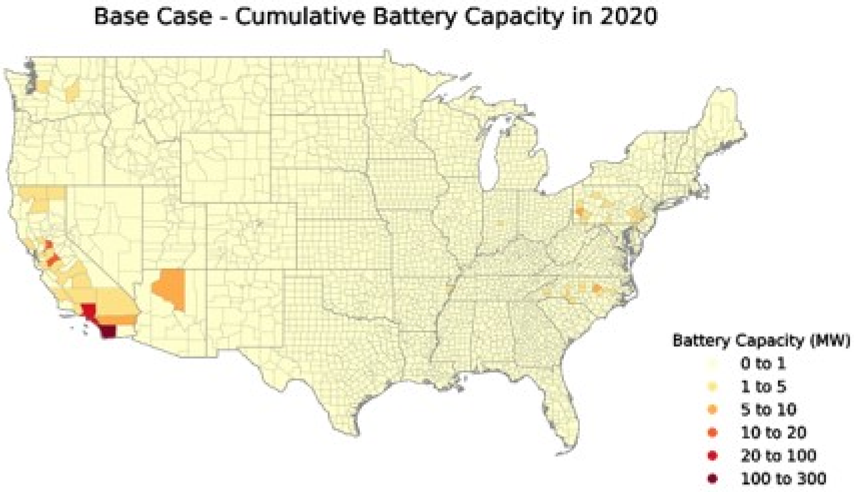

County-Level Results

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

Limitations

- Stand-alone 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, and 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.

References

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Questions and Discussion

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

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