NATIONAL RENEWABLE ENERGY LABORATORY

Savings in Action: Lessons from Observed and Modeled Residential Solar Plus Storage Systems

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Study Overview

- The study performed two related analyses using data from a new-construction residential community equipped with rooftop solar and storage (S+S) in Arizona.
- **Analysis of customer bill savings:** The study analyzed the factors that determine customer electricity cost savings from S+S adoption.
- **Analysis of system performance:** The research compared the Arizona case study data to modeled system performance to understand how models deviate from real-world outcomes. Based on these findings, NREL explored ways to improve such models and, conversely, use modeled results to suggest improvements to S+S dispatches.

Mandalay Homes Case Study

- Data were gathered from a community of residential homes located in Clarkdale and Prescott, Arizona.
- At the time of analysis, the community comprised 107 owner-occupied housing units.
- Homes were equipped with rooftop PV systems ranging from 1.8-4.5 kW, and sonnen batteries with 10 or 12 kWh of storage capacity.
- The cost savings analysis is based on a subsample of 76 homes.

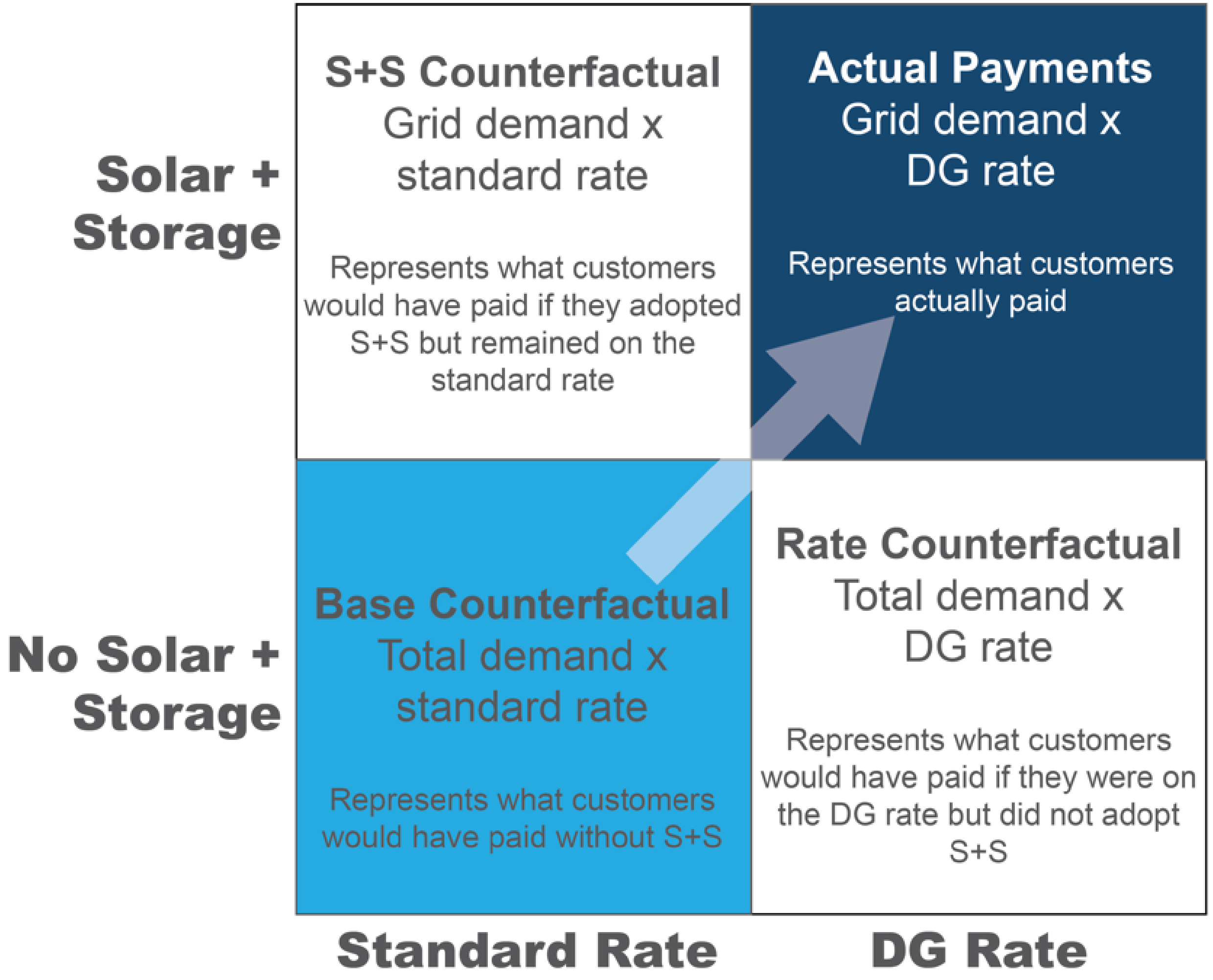
Customer Rate Structures

- Residential customers in Clarkdale and Prescott would typically be enrolled in a standard electricity rate with time-of-use charges.
- In this pilot, all homes were initially enrolled in experimental distributed generation (DG) rates, characterized by relatively high demand charges ($/kW based on peak demand) and significantly lower volumetric ($/kWh) time-of-use rates.

Analysis of Customer Bill Savings

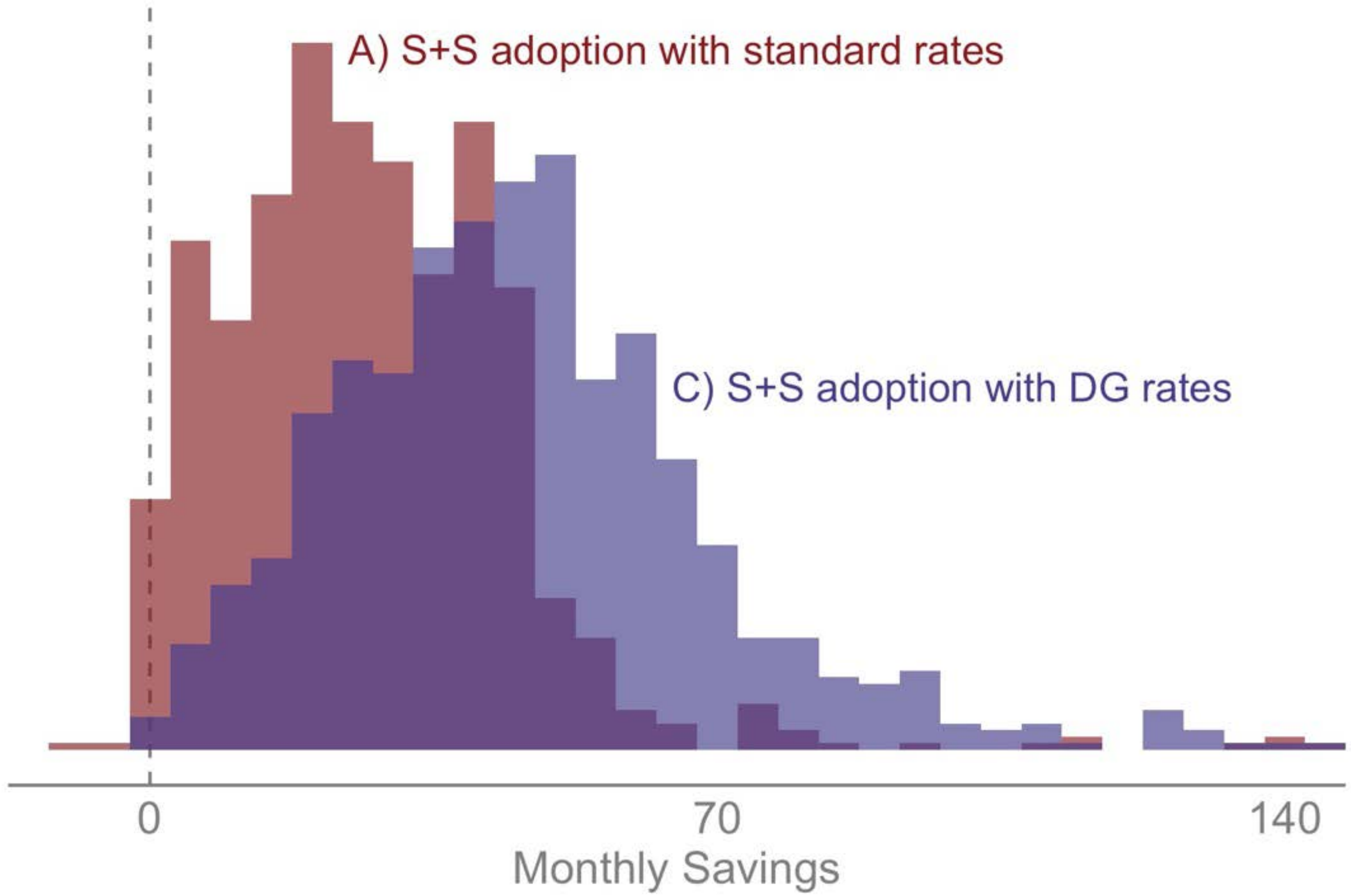
Cost Savings Under Multiple Scenarios

The study modeled customer cost savings under multiple scenarios to isolate the impacts of technological factors (S+S adoption), rate structures (e.g., shifting from standard to DG rates), and household-level factors (e.g., electricity demand, demand profiles).



Cost Savings From S+S Adoption

Most customers save money when adopting S+S. Bill savings are more significant for those customers already on the experimental DG rate.



Hypothetical distributions of customer bill savings from S+S adoption

Cost Savings or Increases From Rate Changes

- Most customers see higher bills under the experimental DG rate.
- S+S adoption can help mitigate but not fully offset these cost increases.
- These impacts significantly reduce incentives to adopt S+S, especially for solar.

Hypothetical distributions of customer bill savings or increases when shifting from standard to DG rates

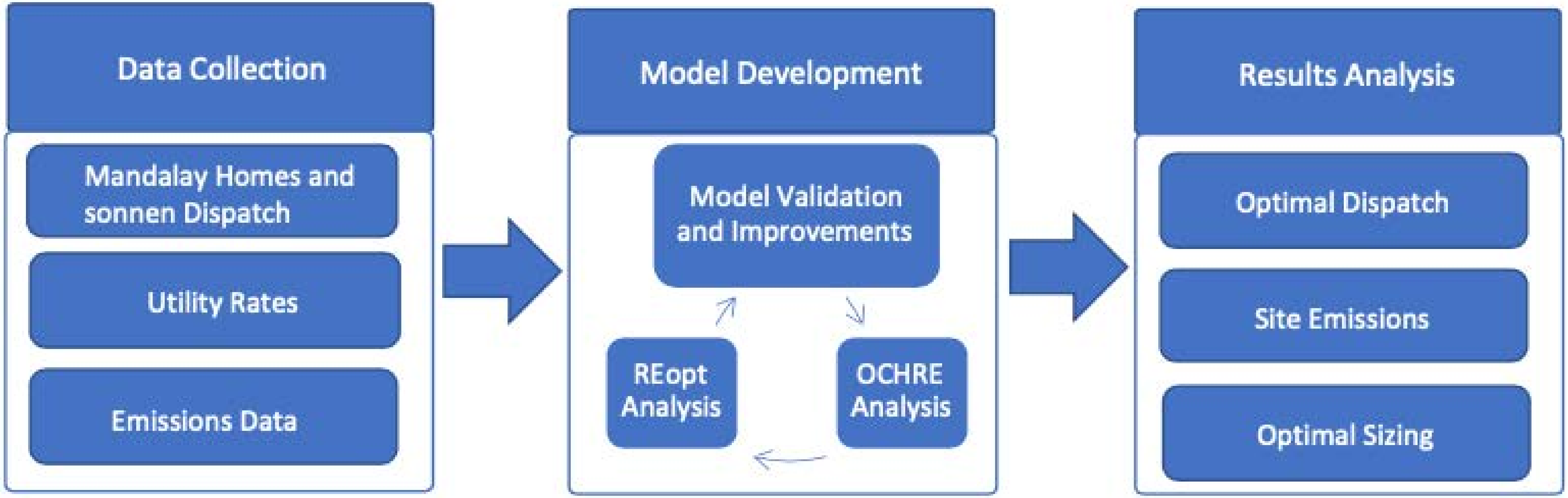
Regression Results

To further isolate the impacts of various factors on the customer bill savings from S+S adoption, researchers implemented a regression model (see report for full numeric results). Key findings include:

- Bill savings from S+S adoption are generally slightly lower in larger homes.
- Larger PV systems are associated with greater bill savings.
- Higher total electricity demand is generally associated with greater bill savings.
- Higher peak demand (i.e., demand during peak hours as defined by utility rates) is generally associated with lower bill savings.
- S+S adoption generates higher bill savings in the summer months, but these savings can be offset by challenging rate structures.

Analysis of System Performance

Analysis Process for Mandalay Homes Data



- Home load data from Mandalay
- PV and battery dispatch from sonnen
- Utility rates from URDB
- Emissions rates modeled with EPA's AVERT and NREL's Cambium data

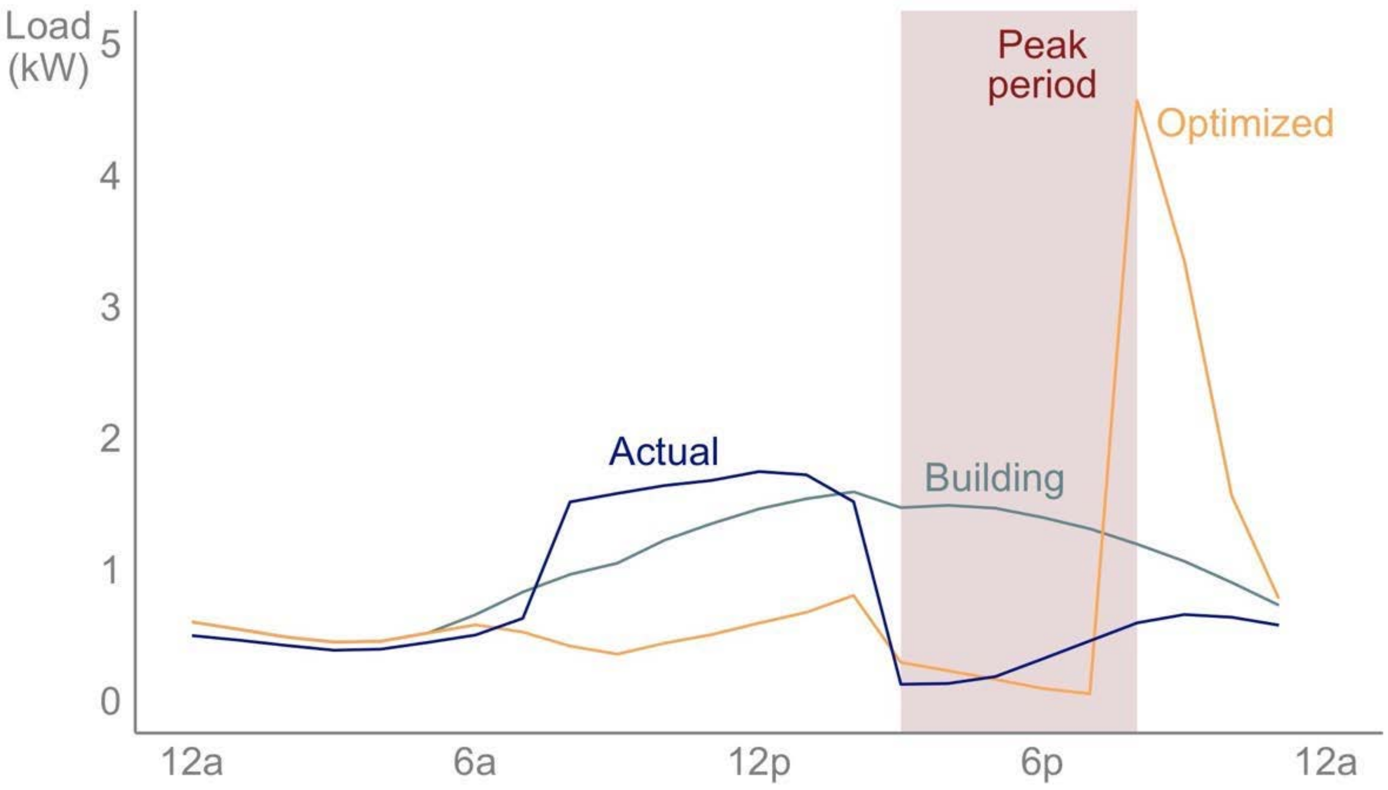
- Object-oriented Controllable High-resolution Residential Energy (OCHRE) simulates energy consumption and occupant comfort
- Renewable Energy Integration & Optimization (REopt) determines optimal PV and storage sizing and dispatch and calculates emissions impacts. Integrated with OCHRE for flexible HVAC dispatch.

Modeled Battery Dispatch and Sizing Reveals Opportunities for Additional Cost Savings

- Current battery systems could further reduce demand charges by moderating discharge during the peak demand period rather than attempting to reduce demand to zero.
- Modeled cost-optimal battery sizes are slightly smaller than those currently installed.
- The modeled results suggest that solar PV is not cost-effective under the experimental DG rate.
- The optimized results highlight potential opportunities to improve deployed system design and controls, while accounting for real-world constraints.

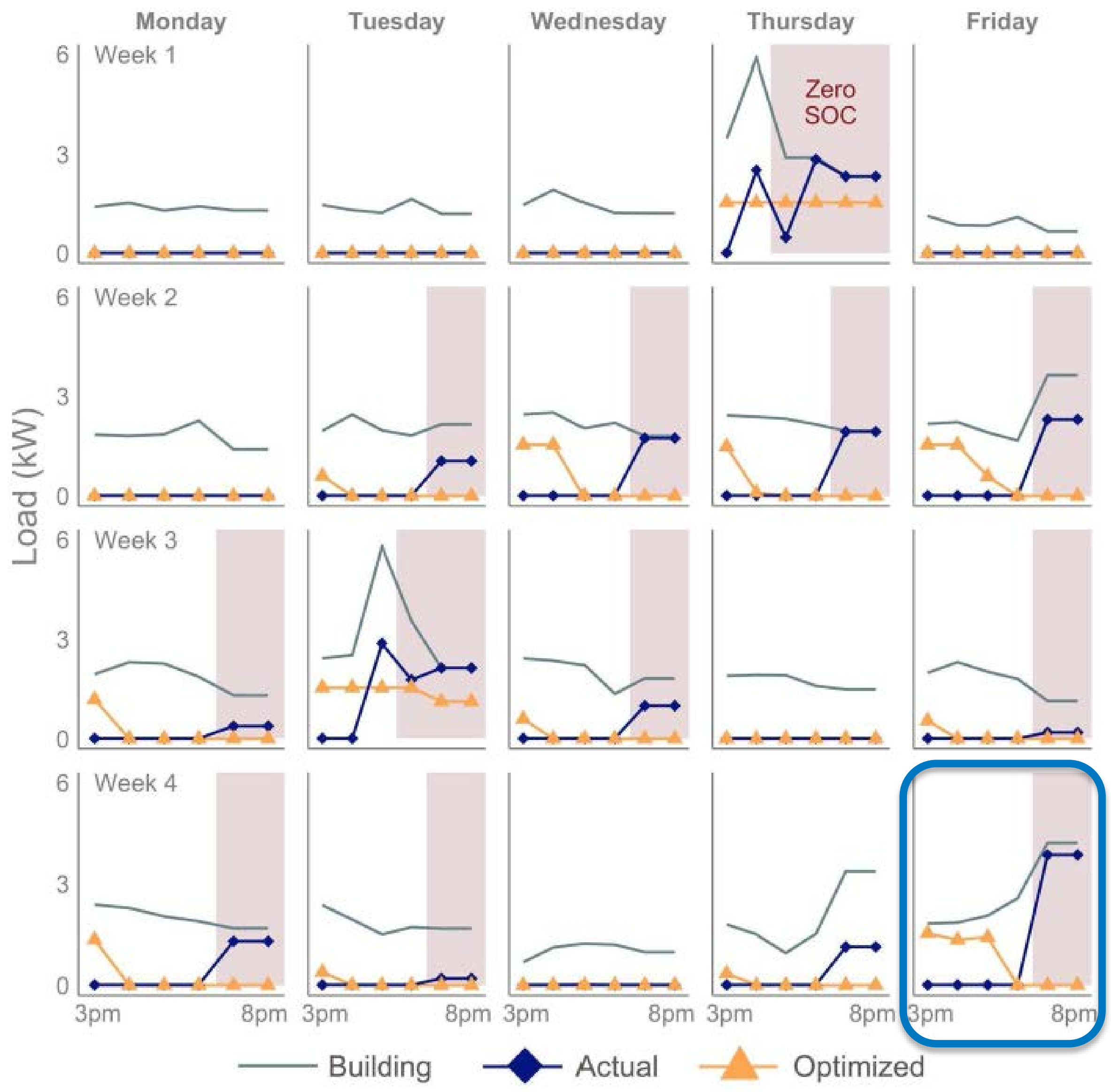
Modeled Battery Dispatch and Sizing Reveals Opportunities for Additional Cost Savings

The optimal dispatch more effectively avoids the need to rely on the grid during peak hours, thus reducing customer demand charges. Actual battery dispatch is lower than optimal dispatch in later peak hours due to the battery running out of charge. This increases actual peak load during the peak period.



Average hourly gross and net loads for weekday hours between May and November

Hourly net load during August demand periods for single home



- Demand charge set by peak hour across month.
- Actual dispatch algorithm attempts to zero net load during peak hours.
- Shaded area denotes hours where actual battery reaches a zero state of charge.
- Battery running out of charge results in spike in net load towards end of demand period.
- This spike reduces demand charge savings over entire month.

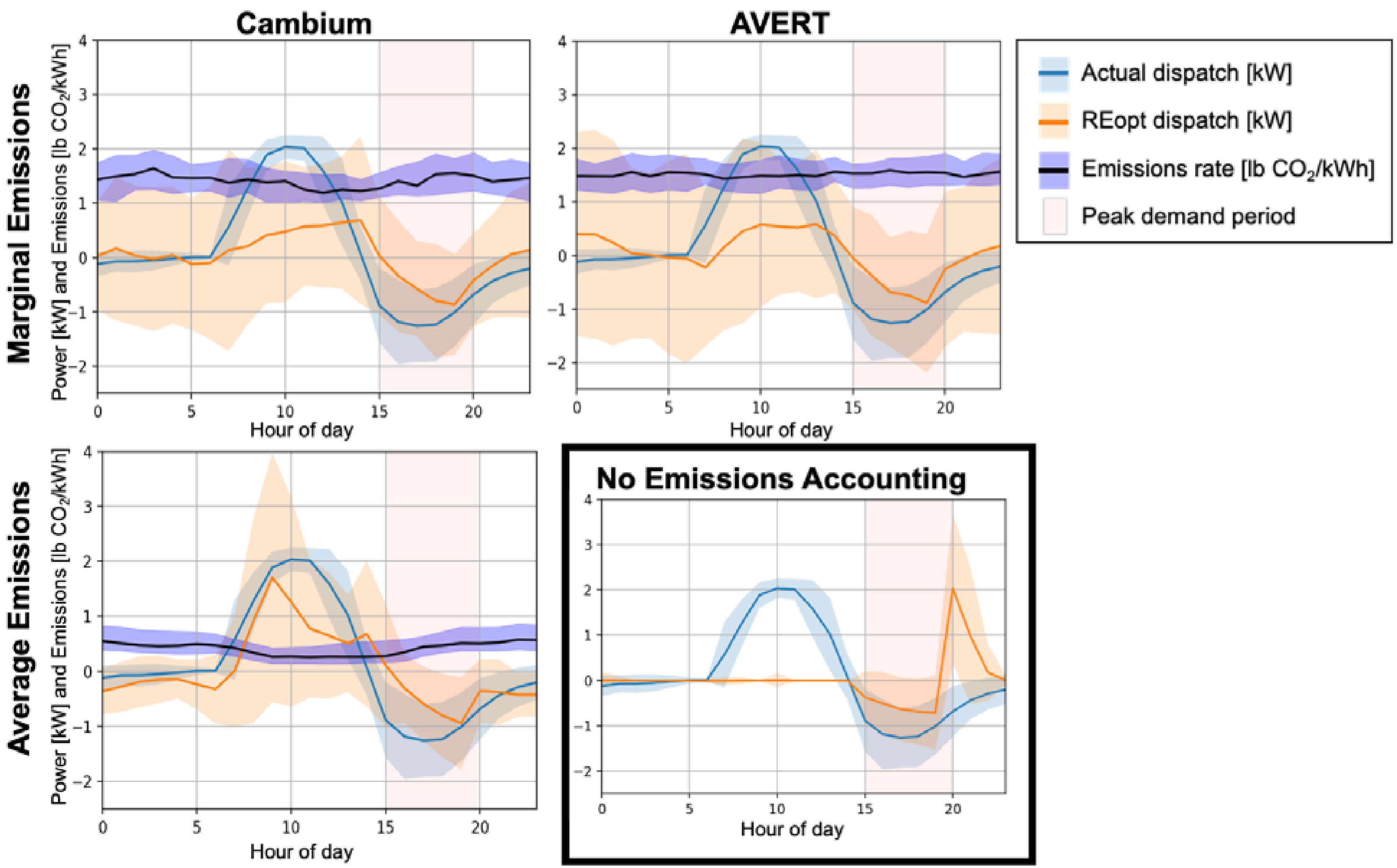
Optimal Dispatches Can Reduce Grid Emissions and Maximize Bill Savings

- Though not an explicit goal of the community in this case study, the research found that with optimal battery dispatch, grid emissions reductions can be a co-benefit of deploying S+S.
- Accounting for grid emissions has minimal impact on utility cost savings. Policymakers and rate designers could leverage this fact by implementing measures to incentivize developers to dispatch demand-side resources to simultaneously reduce grid emissions and maximize customer savings.

Cost of CO_2 ($51/t) from grid emissions included in REopt objective function to determine bill savings- and emissions-optimal dispatch.

In all emissions scenarios, more midday charging becomes optimal.

However, achieving modeled emissions reduction would require granular, real-time emissions information from the grid.



Average daily actual battery dispatch (blue) and REopt bill savings- and emissions-optimal dispatch when using varying emissions data sets (orange) for a single home.

Conclusions

- The experimental DG rate benefits the grid by reshaping customer grid demand profiles. However, the rate significantly reduces the incentives to adopt S+S. Further research is needed on rate designs that benefit both the grid and the customer.
- Optimal battery dispatches could help customers achieve more bill savings from S+S.
- Optimal battery dispatches can simultaneously maximize customer savings and minimize grid emissions.

For more information, download the full technical report:
O'Shaughnessy, Eric, Dylan Cutler, Amanda Farthing, Emma Elgqvist, Jeff Maguire, Michael Blonsky, Xiangkun Li, et al. 2022. *Savings in Action: Lessons from Observed and Modeled Residential Solar Plus Storage Systems*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-82103. https://www.nrel.gov/docs/fy22osti/82103.pdf.

For questions, contact Jeff.Cook@nrel.gov.

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