October 2023

Backup Power Performance of Solar-plus-Storage Systems during Routine Power Interruptions

A Case Study Application of Berkeley Lab's PRESTO Model

Supplementary Methodological Details

Our research methodology requires four time-series datasets as inputs to the PVESS dispatch model during power interruption events: 1) disaggregated end-use load profiles, 2) solar production profiles, 3) power interruption profiles, and 4) state of charge (SOC) of the battery.

- Load profiles are generated using NREL's ResStock model for selected counties. The ResStock model generates a comprehensive set of building models by utilizing probabilistic distributions of over 100 building stock characteristics, including insulation, HVAC technology, square footage, and heating fuel. A representative single-family detached home was chosen based on the median values for annual energy consumption in each county. Simulated load profiles for those homes are resolved at the 15-minute interval basis and disaggregated into individual end-uses.
- Solar generation profiles are derived for temporal and geospatial alignment, drawing from weather data used in the foundational ResStock building simulations. This involves merging ground-based measurements with solar radiation data from NREL's National Solar Radiation Data Base (NSRDB). Subsequently, NREL's System Advisor Model (SAM) is employed to generate hourly AC solar production profiles that ensure the annual PV generation matches the building's overall annual consumption profile.
- Power interruption profiles are created with PRESTO. PRESTO utilizes county-level hourly outage data (Poweroutage.US for the time period of mid-2017 through late 2021) to calibrate functions, generating annual outage time series with stochastic attributes. These functions are fine-tuned to match real data statistics, ensuring the simulated short-duration interruptions align with actual conditions.
- Simulating PVESS operation during power interruptions requires information about the battery's SoC at the beginning of the interruption event. To generate those initial SoC estimates, we use NREL's ReOPT model to simulate battery storage operation under blue-sky conditions, assuming that customers take service under the local utility's existing time-of-use (TOU) rate and operate storage in response to TOU rate structures. In the baseline set of scenarios, grid charging is not permitted, but grid exports are allowed.

We used the PVESS dispatch algorithm introduced by Gorman et al. (2023) to evaluate a PVESS's backup capacity. The storage dispatch model utilized to satisfy specific critical loads during power interruptions is described in detail in Section 3.2 of Gorman et al. (2023). In line with Gorman et al. (2023), we also adopt a 92% one-way battery efficiency and assume a 2-hour duration battery.

Supplementary Results

Additional results are provided below in support of results presented in the main body. Figure A1 provides information about the initial SoC on the battery at the beginning of the simulated power interruption events for Maricopa County. All of the remaining supplementary results provide comparative results across the three counties presented in the main body: Maricopa County, AZ; Middlesex County, MA; and Los Angeles County, CA. Figures A2 – A4 summarize PRESTO simulated power interruption events. Tables A1 A3 present summary statistics for PVESS backup performance under each backup load configuration. Figures A5 – A10 provide heat maps of PVESS backup performance for each county under the base-case scenario (10 kWh battery with no grid charging) and the two alternative scenarios (30 kWh battery with no grid charging and 10 kWh battery with grid charging); all results are based on a backup of critical loads that include heating and cooling.

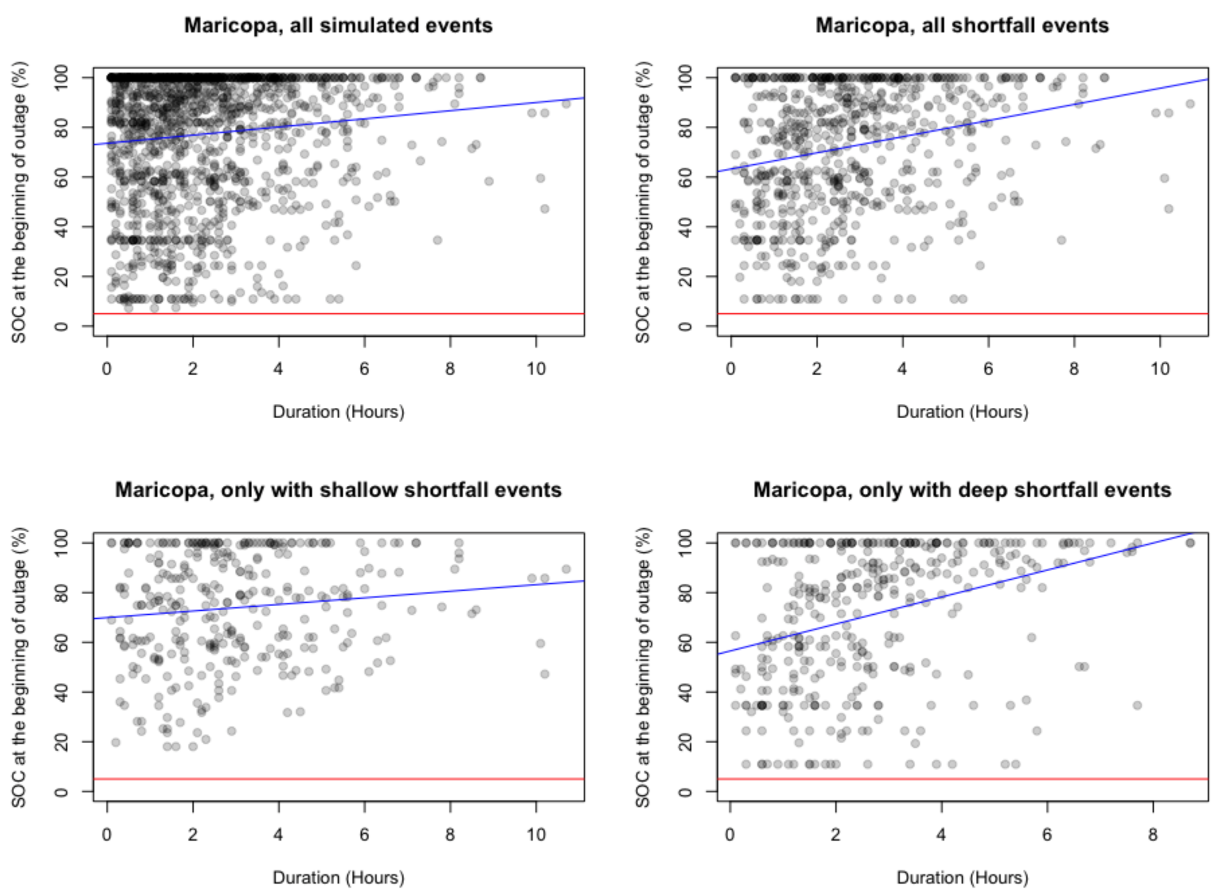

Figure A1. SOC at the beginning of power interruptions as a function of duration of simulated power interruptions in Maricopa, with all simulated events (top left) with all shortfall events (top right), only with shallow shortfall events (with percent load served greater than 50%, bottom left), and only with deep shortfall events (with percent load served less than or equal to 50%, bottom right). Red horizontal lines indicate the 5% minimum SoC allowed on the battery, and the blue lines indicate the linear relationship between the SOC at the beginning of power interruptions and their durations.

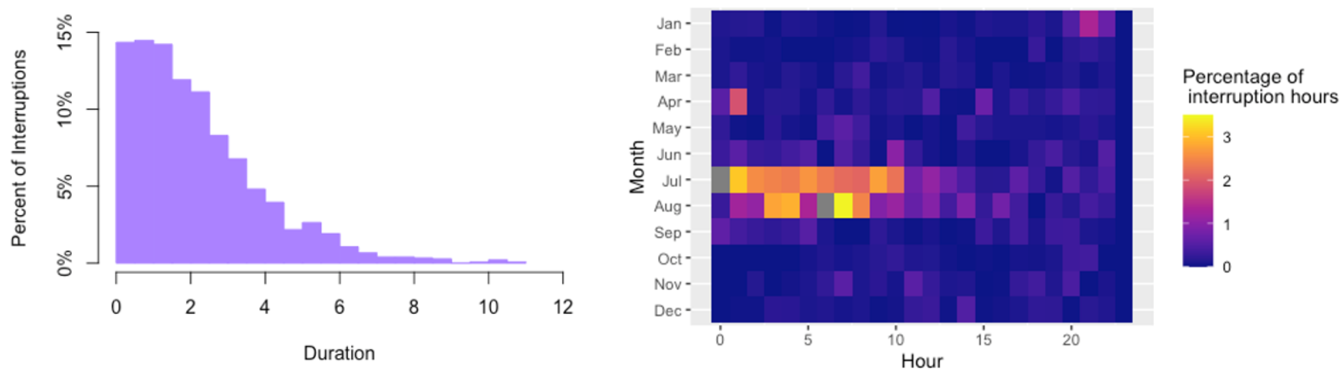

Figure A2. Maricopa County, AZ. (Left) Histogram of simulated power interruption duration. (Right) Heatmap of percentage of interruption hours by month and hour. (Figure in main body as well; repeated here for comparison to other counties)

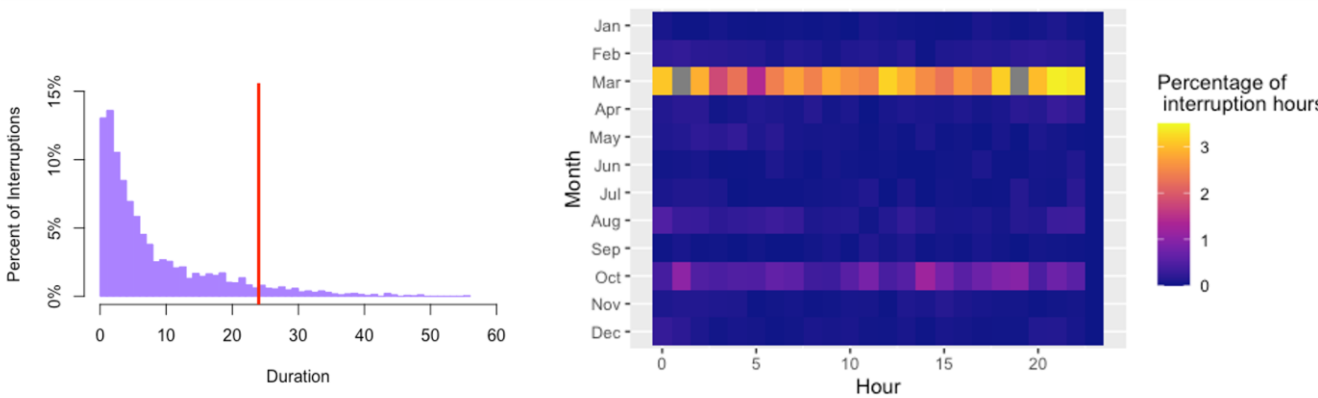

Figure A3. Middlesex County, MA. (Left) Histogram of simulated power interruption duration. (Right) Heatmap of percentage of interruption hours by month and hour. The red line signifies the 24 hour mark; only interruptions shorter than 24 hours were considered in this analysis.

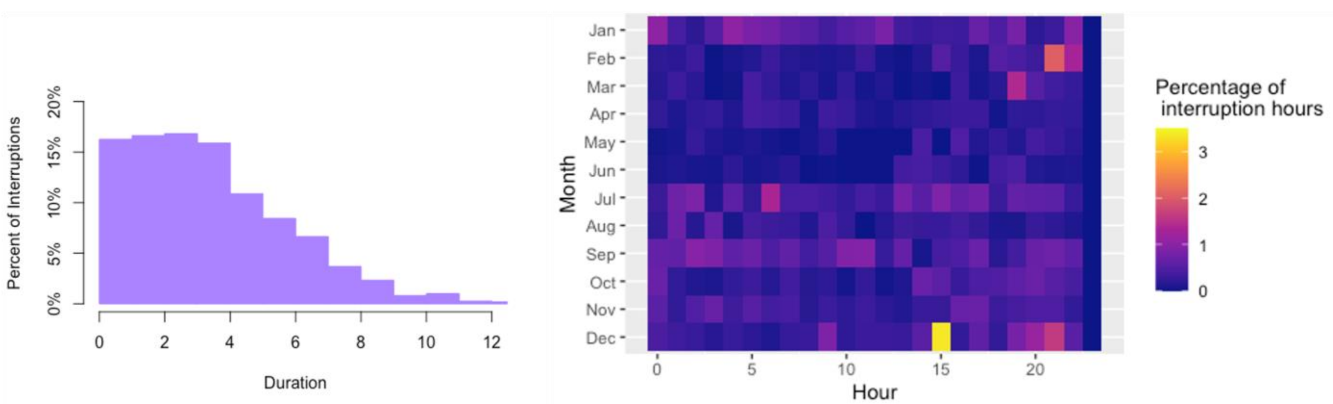

Figure A4. Los Angeles County, CA. (Left) Histogram of simulated power interruption duration for Los Angeles. (Right) Heatmap of percentage of interruption hours by month and hour.

Table A1. Maricopa County, AZ. Median and 10th to 90th percentiles of percent load served during short-duration power interruptions in Middlesex with 10kWh and 30kWh batteries without grid charging.

Load Backup	Battery Size	Percent of Load Served
Limited critical load w/o HVAC	10 kWh	100% (67%-100%)
	30kWh	100% (100%-100%)
Full critical load w/ HVAC	10 kWh	100% (21%-100%)
	30kWh	100% (52%-100%)
Total load	10kWh	82% (17%-100%)
	30kWh	100% (47%-100%)

Table A2. Middlesex County, MA. Median and 10th to 90th percentiles of percent load served during short-duration power interruptions with 10kWh and 30kWh batteries without grid charging.

Load Backup	Battery Size	Percent of Load Served
Limited critical load w/o HVAC	10 kWh	100% (71%-100%)
	30kWh	100% (100%-100%)
Full critical load w/ HVAC	10 kWh	100% (44%-100%)
	30kWh	100% (100%_100%)
Total load	10kWh	100% (28%-100%)
	30kWh	100% (100%-100%)

Table A3. Los Angeles County, CA. Median and 10th to 90th percentiles of percent load served during short-duration power interruptions with 10kWh and 30kWh batteries without grid charging.

Load Backup	Battery Size	Percent of Load Served
Limited critical load w/o HVAC	10 kWh	100% (67%-100%)
	30kWh	100% (100%-100%)
Full critical load w/ HVAC	10 kWh	100% (48%-100%)
	30kWh	100% (100%-100%)
Total load	10kWh	100% (31%-100%)
	30kWh	100% (100%-100%)

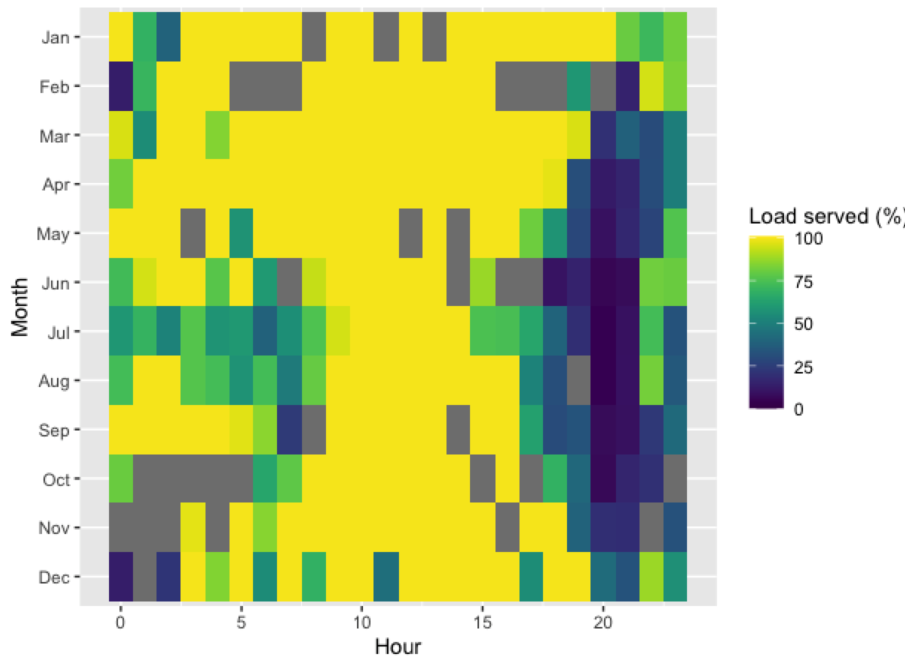

Figure A5. Maricopa County, AZ. Heatmap of percentage of load served during simulated power interruptions with a 10 kWh battery without grid charging. Grey boxes indicate no interruptions.

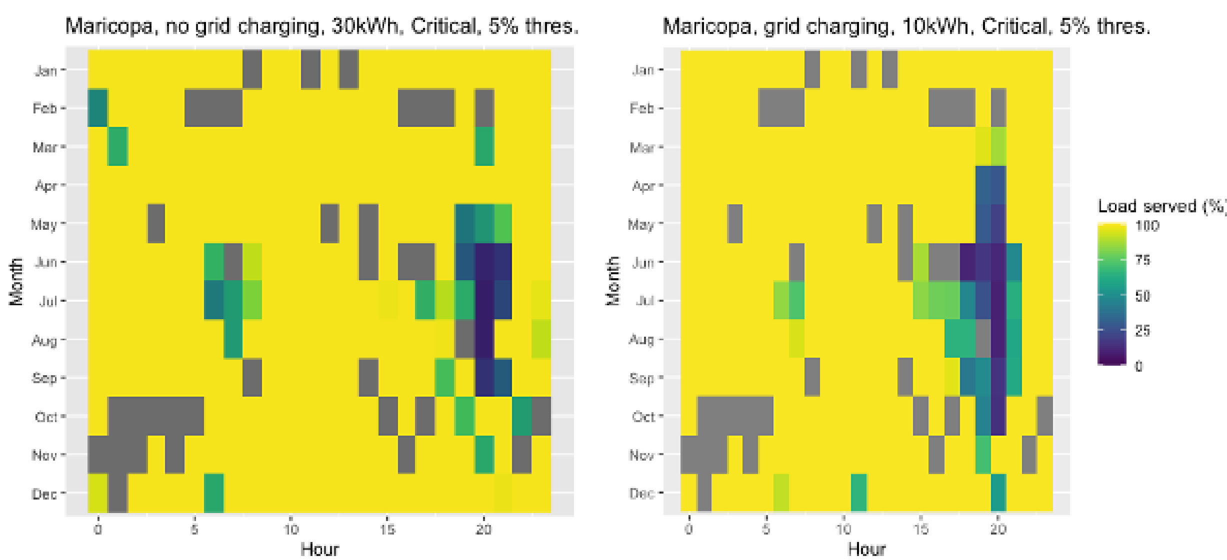

Figure A6: Maricopa County, AZ. Heatmaps of percentage of load served during simulated power interruptions with a 30 kWh battery without grid charging (left) and a 10 kWh battery with grid charging (right). Grey boxes indicate no interruptions.

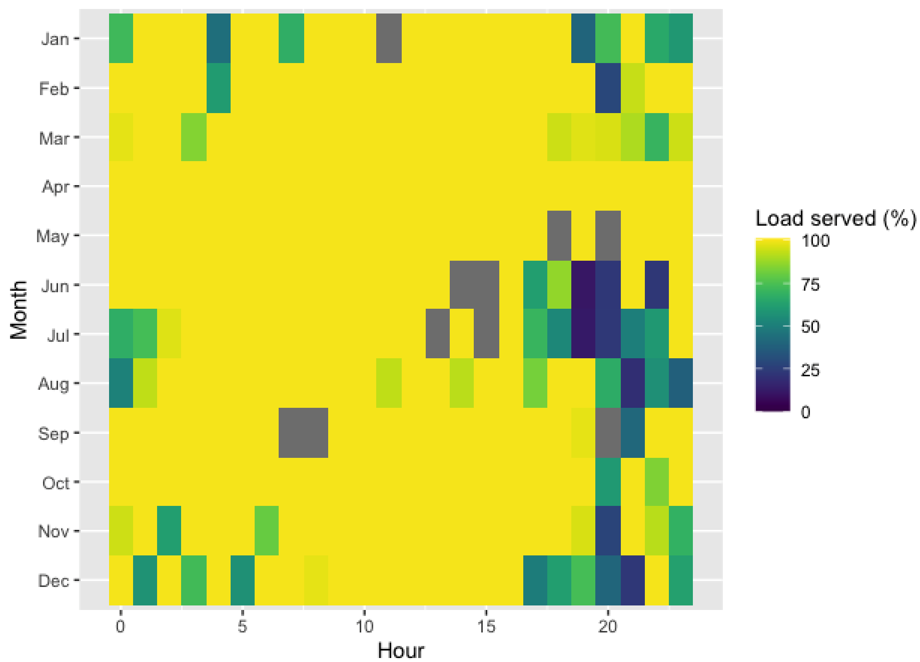

Figure A7. Middlesex County, MA. Heatmap of percentage of load served during simulated power interruptions with a 10 kWh battery without grid charging. Grey boxes indicate no interruptions.

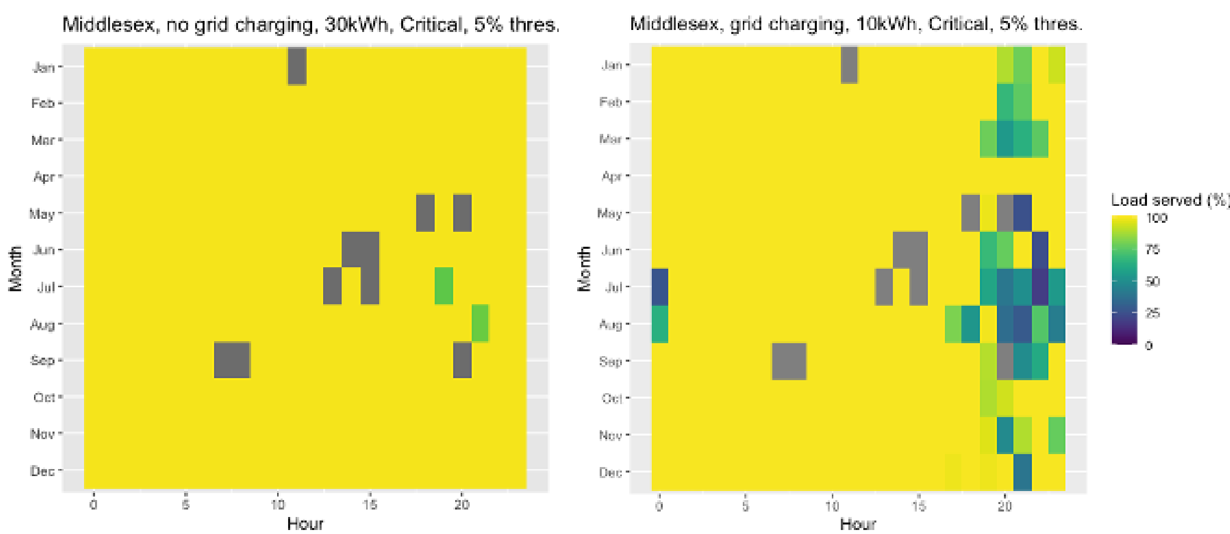

Figure A8: Middlesex County, MA. Heatmaps of percentage of load served during simulated power interruptions with a 30 kWh battery without grid charging (left) and a 10 kWh battery with grid charging (right). Grey boxes indicate no interruptions.

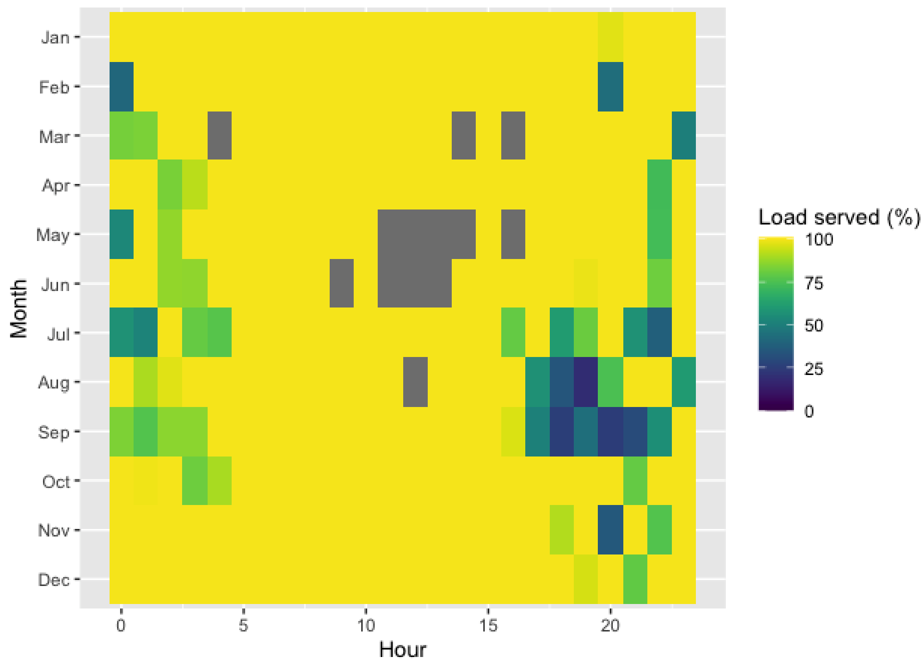

Figure A9. Los Angeles County, CA. Heatmap of percentage of load served during simulated power interruptions with a 10 kWh battery without grid charging. Grey boxes indicate no interruptions.

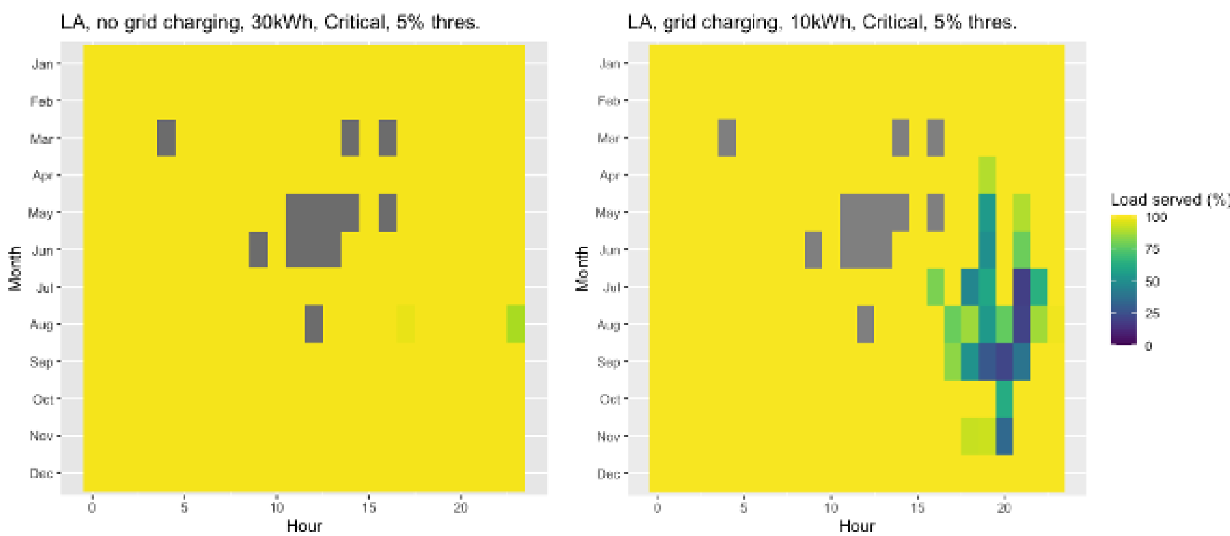

Figure A10: Los Angeles County, CA. Heatmaps of percentage of load served during simulated power interruptions with a 30 kWh battery without grid charging (left) and a 10 kWh battery with grid charging (right). Grey boxes indicate no interruptions.

Acknowledgements

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