sunrun

Load Impact Protocol Workshop

5.18.2022 | Yang Yu

Agenda

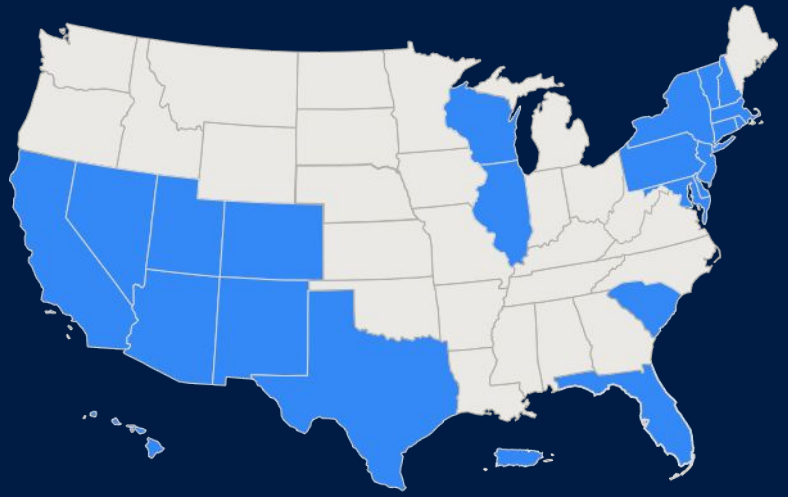
01 | Sunrun Introduction

02 | Sunrun Fleet & Operations

03 | LIP Approach for 2023

04 | Recommendations

Sunrun at a Glance



We have **more than 660,000 customers** and sell our solar service in **25 states,** the District of Columbia and Puerto Rico.

OUR MISSION

To create a planet run by the sun.

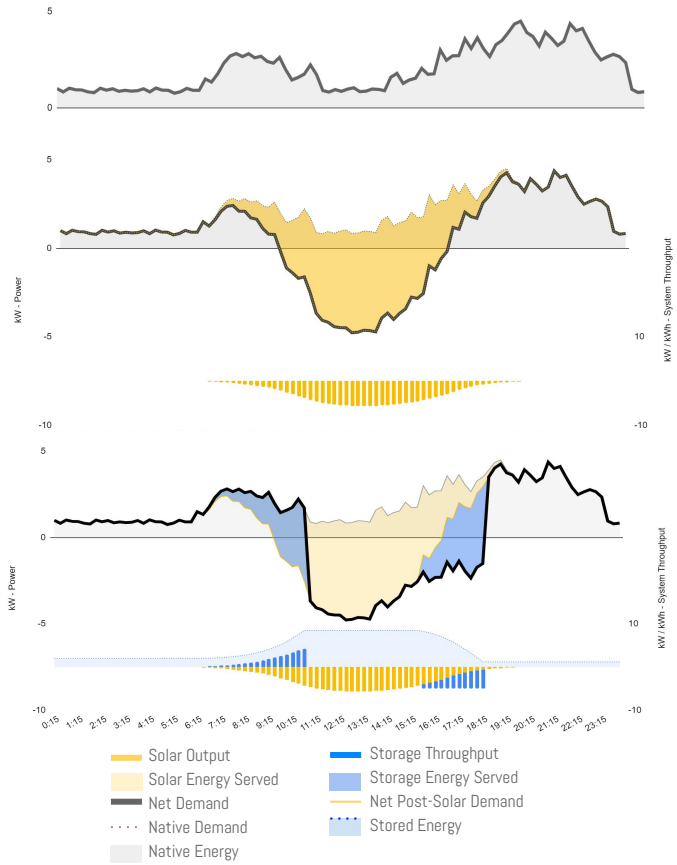
OUR BEGINNINGS

- Founded in 2007
- HQ in San Francisco
- Pioneered Residential Solar Service

OUR BUSINESS MODEL

- Single and multi-family residential
- Solar only from 2007 – 2016; growing solar + storage since 2016.
- Focused on provision of customer energy historically; since 2018 have begun providing customer services (ie - demand charge and TOU management) and grid services (ie – reliability capacity and distribution loading management).

Sunrun's Brightbox: Solar + Storage



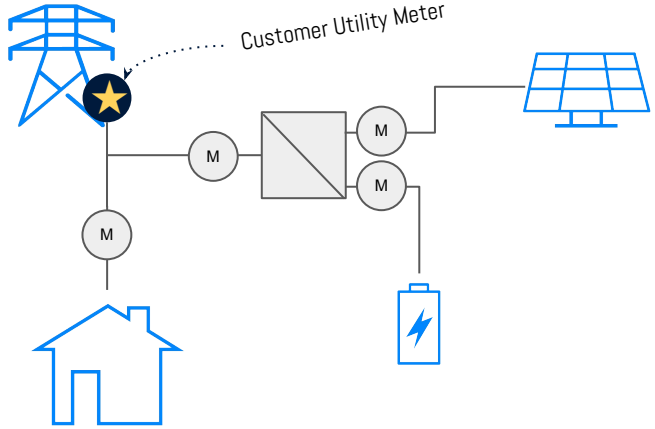
Customer Load

Customer Load
+ Solar PV

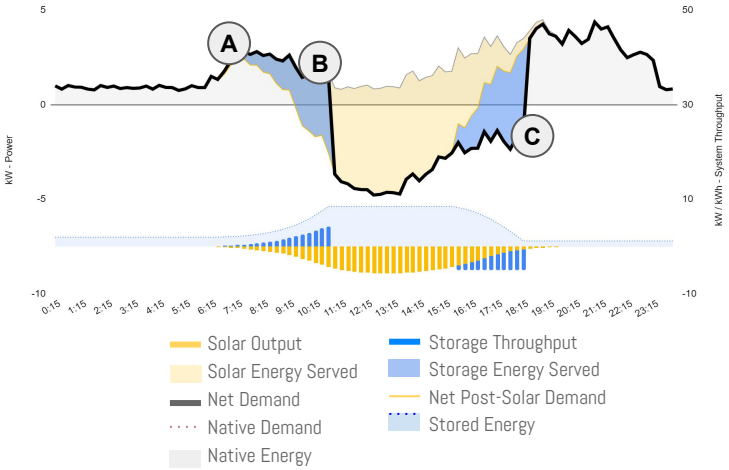
Customer Load
+ Solar PV
+ Energy Storage

Sunrun deploys integrated solar + storage systems interconnected behind the customer's utility meter. All energy generated by the systems serve the customer first, displacing energy served by the grid.

This means Sunrun Brightboxes do not change customer behavior, but they do reduce utility demand.

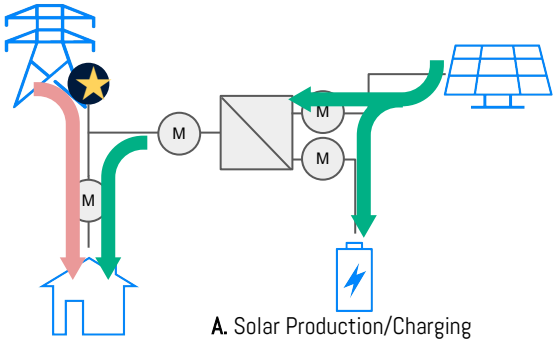


Typical Brightbox Activities

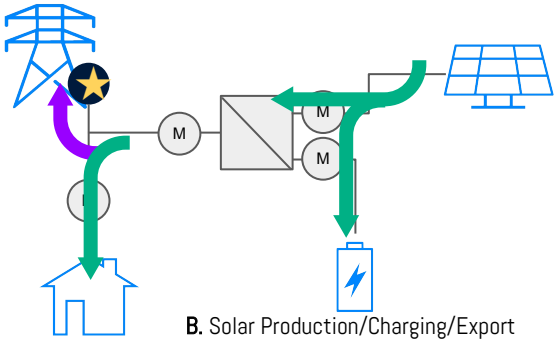


In California, Sunrun typically provides services to customers including, but not limited to:

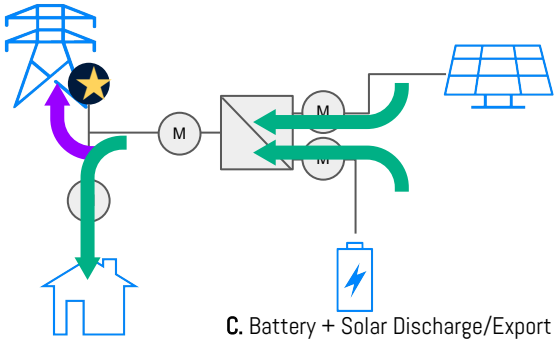
- **TOU bill management** by discharging during TOU windows
- **Minimizing solar export** by charging exclusively from solar
- **Backup power** capacity reserved exclusively for grid outage
- **Distribution system capacity, voltage controls and other grid services** by responding to utility / market signals.



A. Solar Production/Charging



B. Solar Production/Charging/Export



C. Battery + Solar Discharge/Export

Final Sunrun LIP Report for 2023

Regarding the Calculation of Ex Post Load Impact:

- Sunrun operationalized BTM solar and battery assets in PG&E territory only starting in 2021
- Actual load reduction is measured as the difference between the the 5-in-10 Day-Matching adjusted load baseline and actual customer utility meter data between the hours of 5:00 PM and 9:00 PM on event days
- In parallel, Sunrun also provided submetering data on BTM battery to measure the average battery output between the hours of 5:00 PM and 9:00 PM on event days.

Regarding the Calculation of Ex Ante Load Impact:

- Engineering models are created for single family behind-the-meter energy storage systems participating in event-based demand response between the hours of 5:00 PM and 9:00 PM on event days
- Engineering models assume systems are called on a daily basis, requiring daily system recharge from on-site solar.
- Calculations are made for both reference load and observed load, at both the site (measured at point of interconnection) and aggregate / fleet level
- Load Impact is estimated using event-day and non-event-day load calculated with a site net load 5-10 baseline
- Sunrun did not have active assets in SCE & SDG&E providing RA in 2021. Hence, ex ante models will continue to be based on engineering models and best available data.

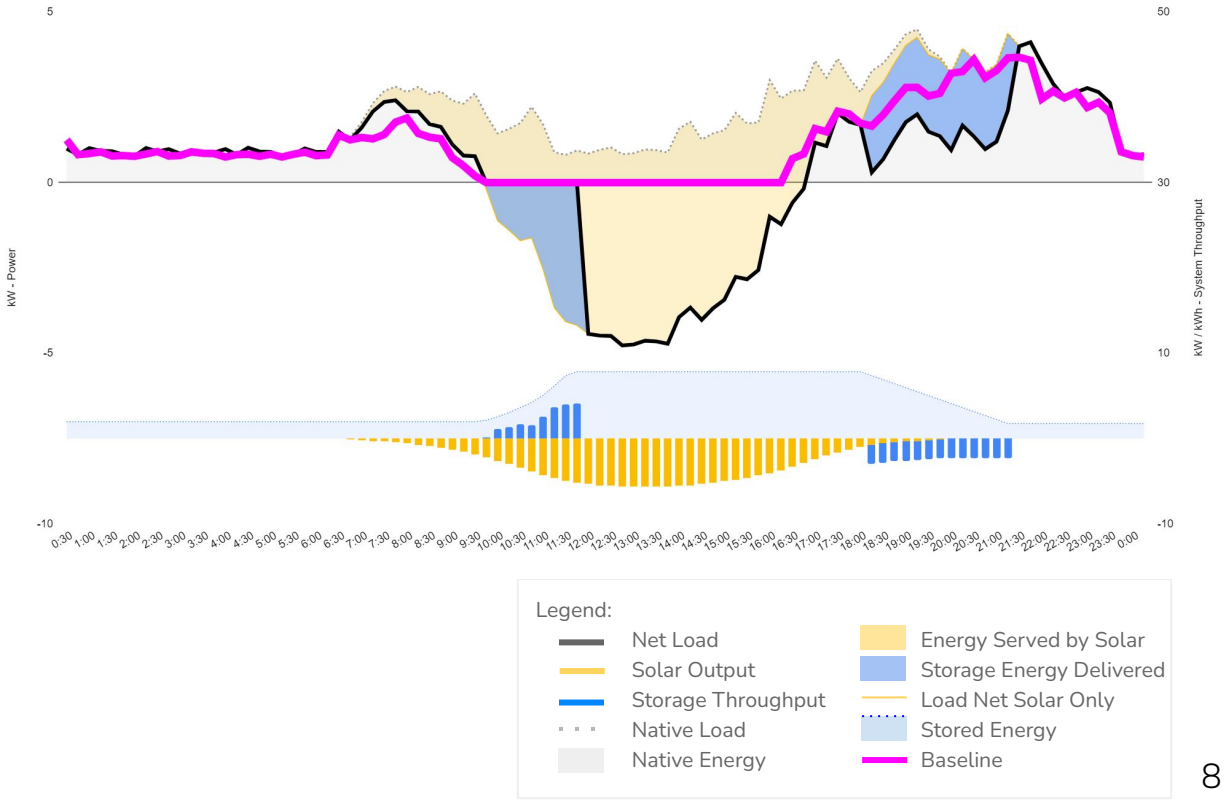
Brightbox Activities Factored

In our modeling methodology, Sunrun makes the following assumptions relative to battery activity:

- **TOU bill management:** Sunrun models batteries participate in TOU activity on *non-event days only*.
  - This activity is factored into baseline calculations.
  - Sunrun does not assume battery system operation changes on non-event days to optimize baselines
- **Minimizing solar export** by charging exclusively from solar.
  - This activity is factored into baseline calculations and the modeled reference load available
- **Backup power** capacity reserved exclusively for grid outage
  - This back-up power is treated as unusable for providing RA capacity
- **Distribution system capacity, voltage controls and other grid services** by responding to utility / market signals
  - Sunrun simulates consecutive daily dispatch activity to model system's ability to recharge on a daily basis.
- **System export is not counted towards RA**

Paradigm Shift: Direct Metering

- Battery energy discharge serves customer load and reduces grid demand by commensurate amount
- Combining metered BTM storage with metered customer load provides **complete**, **comprehensive** and **empirical** views of customer energy consumption, unambiguous records of load impact on the event day itself.
- Calculating DR performance for storage-backed resources using reference load baselines and not valuing net energy export is therefore demonstrably not recognizing the full capacity value being provided



Recommendations

Clear and consistent guidance is needed for applicability of LIP to BTM batteries and hybrid systems, as well as greater recognition of the capabilities of said systems. Sunrun recommendations include the following:

Regarding the Calculation of Load Impact:

- Sunrun recommends that behind-the-meter storage assets be permitted to use directly metered output data post-event for ex-post reporting in combination with site level metering.
- For future evaluation, Sunrun recommends using a combination of metered output data with engineering models/forecasts for ex-ante evaluations, to be submitted following initial events.

Thank you.

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sunrun

Appendix

Description of study methodology:

The results of this study are based on a combination of Ex Post Day Matching analysis and Ex Ante IOU-specific engineering models.

Under Day-matching methods, ex post load impact is calculated as the difference between the reference load and the observed load. Sunrun customers are residential only and so the 5 in 10 baseline methodology has been selected to estimate reference load which also includes same day adjustments on top of simple averaged unadjusted baseline. For each CAISO market dispatch event between the hours of 5:00 PM and 9:00 PM in 2021, Sunrun analyzed five scenarios to evaluate ex-post behind the meter battery performance and commensurate load impacts:

The IOU-specific engineering models of a typical Sunrun single family home customer with behind-the-meter energy storage systems that are participating in event-based demand response between the hours of 5:00 PM and 9:00 PM on event days, and on non-event days discharging for other customer value. These customers are modeled with system characteristics typical to these kinds of solar and storage deployments, such as PV size, inverter efficiency losses, maximum usable energy, hardware specifications and operational capabilities. Solar and battery sizes are also based on typical characteristics seen in Sunrun's typical solar and battery installations.

The modeled system operational characteristics include being both non-grid charging and only charged by solar; Sunrun has modeled the systems as maintaining a portion of the stored energy in the battery at all times for customer resiliency in the event of a grid outage; Sunrun has also included as a modeled behavior regular retail energy arbitrage that discharges the battery during peak pricing periods on every non-event day. All of this typical usage is baselined at the site level meter so that it is accounted for in the site 10-in-10 baseline that measures load impact.

Appendix

The following scenarios have been analyzed for ex post evaluation using empirical market dispatch performance data from 2021

- **Scenario 1: Sunrun Day Matching Actual (Estimated Load Impact)**
  - Actual load reduction is measured as the difference between the the 5-in-10 Day-Matching adjusted load baseline and actual customer utility meter data
- **Scenario 2: Max Sunrun Day Matching Possible (Theoretical Load Impact)**
  - As a point of comparison to scenario 1, the maximum theoretical load reduction is measured using the same 5-in-10 Day-Matching adjusted load baseline, but also assuming the initial state of useable energy (kWh) at the beginning of each market dispatch - energy available for dispatch - was fully discharged by the energy storage systems
- **Scenario 2.5: Max Sunrun Day Matching Maximum Possible (Maximum Theoretical Load Impact)**
  - Identical to scenario 2 but assumes the initial state of charge at the beginning of each market dispatch is 100% which implies the battery would be fully charged before CAISO dispatch.
- **Scenario 3: Sunrun Sub-Metered Actual (Average Battery Output)**
  - Actual (empirical) battery discharge in terms of average kWDC power output
- **Scenario 4: Max Sunrun Sub-Metered Possible (Theoretical Battery Output)**
  - As a point of comparison to scenario 3: the maximum theoretical battery discharge (kWAC) is based on initial state of energy (kWh) at the time of dispatch at the beginning of each market dispatch - energy available for dispatch - was fully discharged by the energy storage systems

Appendix

The following methods, assumptions and data sources were used to model customer load in Sunrun Engineering Models: *(cont'd next page)*

- Creation of a detailed, physics based engineering model based on average Sunrun system characteristics, efficiency losses, TMY data, and OpenEI load curves for single family homes. Load curves and solar production values are scaled to typical Sunrun fleet load characteristics and solar production values.
  - Residential solar system characteristics based on Sunrun's average DC system size, on a per-IOU territory basis. Inclusive of:
    - Observed kWh/kW based on historical data of currently installed systems
    - Typical weather pattern variance including low insolation periods
  - Residential energy storage system characteristics based on average specifications of LG Chem RESU10H systems paired with SolarEdge Storedge 7.6kW inverters. The model conservatively estimates only a single battery system per home, inclusive of:
    - Weighted inverter efficiency characteristics for DC-DC and DC-AC conversions and inclusive of all efficiency losses
    - Power and inverter output limitations for the system
    - Usable energy characteristics and conservative system sizing using the smallest system configuration Sunrun offers
- Weather files allow for realistic overall performance variation due to insolation differences and typical usage patterns for the highest number of customers within a utility's service territory. TMY3 weather data for modeled PV system output based on:
  - San Jose International Airport (PG&E)
  - Riverside Municipal Airport (SCE)
  - San Diego Montgomery Field (SDG&E)

Appendix

The following methods, assumptions and data sources were used to model customer load: *(cont'd)*

- Reference load curves for residential systems based on the Department of Energy's modeled residential load dataset using the same TMY3 information from above. These curves were then scaled so that total annualized energy usage was equivalent to typical Sunrun single family home customer electricity usage on a per-IOU basis. This accounts for realistic customer usage expectations and averages usage across utilities instead of indexing to only one location. Specifically, the load curve shapes used were from:
  - BASE load for San Jose (PG&E)
  - BASE load for Riverside (SCE)
  - BASE load for San Diego (SCE)
- Simulation of system output for a typical meteorological year and specifically the output of systems during four hours of the Must Offer Obligation window (MOO).
  - Assumes specified efficiency losses per asset manufacturer information.
  - Assumes provision of resource adequacy from energy storage system only via event based DR with an event window between 5:00 pm and 9:00 pm, called on a daily basis. This assumption is to ensure a solar backed energy storage system must recharge each day.
  - Assumes that resource adequacy values are the average monthly available during such hours based on the typical solar resource month for a particular IOU territory.
  - Assumes reserving a margin of useable energy (20%) in the storage system for customer resiliency and backup.
  - Assumes use of the system for regular customer retail energy arbitrage only on non-event days and when there is sufficient energy arbitrage value. Sunrun did not alter the model of system output so it would change operational behavior to try to optimize baselines and improve baselined performance. Moreover, the model only values performance as the difference between the 10-in-10 site level baseline for non-event days and the event day. Only site load drop is credited; systems are not credited for export. This results in a more conservative performance result than what might be expected in actual operations, which Sunrun accepts as necessary in order to simplify the model.

Appendix

The following methods, assumptions and data sources were used to estimate QC for 2023:

- Estimation of load impact per customer based on a combination of Ex Post Day Matching analysis and Ex Ante IOU-specific engineering models.
- Forecast of customer enrollment based on signed contracts for RA delivery in 2023.
- Estimation of QC values for the 2023 RA year based on, 1) estimation of load impact per customer, 2) forecasted customer enrollment for resource adequacy within each IOU territory.