Supplemental information

Private vs. public value of U.S. residential battery storage operated for solar self-consumption

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Supplementary Figures and Tables

Figure S1. Schematic Comparison of Net Metering vs. Net Billing, Related to Introduction and Figure 1. The total amount of solar generation is A+B. NEM and net billing both treat area B in the same manner: it directly offsets contemporaneous consumption. The difference between the two billing approaches is in how they treat area A. Under NEM, that portion of solar generation offsets consumption at other times (area C). Under net billing, that portion of solar generation is instead compensated at some designated solar export price, generally less than the price paid for consumption.

Figure S2. Solar PV Grid Exports under Hourly and 1-Minute Netting Intervals, Related to STAR Methods. The figures compare annual PV grid exports when netted against load on either an hourly or 1-minute basis. Each line represents the median value across a sample of customers for each state, with the underlying sample size denoted in the title above each panel. Analysis is based on 1-minute interval load and PV data for a sample of residential customers, collected by Pecan Street, Inc.
Figure S3. PV Export Levels across Individual Households, Related to Figure 1. The two figures show the distribution of PV export levels across individual households for each utility, under our standard system configuration (PV sized to meet 100% of annual customer consumption) without storage (Panel a) and with storage (Panel b) sized at 50% of average daily PV generation.

Figure S4. Customer Bill Savings from Operating Storage for Solar Self-Consumption: Sensitivity to PV System Size, Related to Figure 2. The figure shows annual bill savings across a range of PV system sizes, assuming a storage system sized at 50% of average daily PV generation. The solid lines represent median values across all customers of each utility, while the percentile band represents the 5th to 95th percentile range across all customers of all utilities.
**Figure S5.** Energy Market Value of Storage Operated to Maximize Solar Self-Consumption: Sensitivity to PV System Size, Related to Figure 4. The figure shows the energy market value of storage dispatched to maximize solar self-consumption under time-invariant net billing rates, across a range of PV system sizes, assuming a storage system sized at 50% of average daily PV generation. The solid lines represent median values across all customers of each utility, while the percentile band represents the 5th to 95th percentile range across all customers of all utilities.

**Figure S6.** Peak Value of Storage Operated for Solar Self-Consumption: Sensitivities to PV and Storage System Size, Related to Figures 2 and 5. Panel a shows sensitivity to PV system size, assuming storage system sizes equal to 50% of average daily PV generation, while panel b shows sensitivity to storage system size, assuming PV systems sized to generate 100% of annual customer consumption. The solid lines represent median values across all customers of each utility, while the percentile band represents the 5th to 95th percentile range across all customers of all utilities.
Table S1. TOU Periods Derived from Hourly Energy Prices, Related to Table 7

| Utility                      | Summer peak period | Winter peak period |
|------------------------------|--------------------|-------------------|
| Detroit Edison (DTE)         | 12pm-6pm           | 5pm-9pm           |
| Green Mountain Power (GMP)   | 12pm-5pm           | 4pm-8pm           |
| Lakeland Electric (LE)       | 1pm-5pm            | 2pm-8pm           |
| NV Energy (NVE)              | 4pm-8pm            | 5pm-9pm           |
| Sacramento Municipal (SMUD)  | 1pm-5pm            | 5pm-9pm           |
| Vermont Elect. Co-ops (VEC) | 12pm-5pm           | 4pm-8pm           |

Notes: Summer season is May-September. Peak period occurs only on weekdays.

Figure S7. Storage Dispatch Value with TOU-Based Export and Consumption Prices, Related to Table 7. The figure compares the energy plus peak value of storage dispatched to maximize solar self-consumption under net billing with three different pricing structures. Scenarios 1 (time-invariant pricing) and Scenario 2 (hourly varying pricing) are those presented in the main body of the report. The alternative scenario instead applies time-of-use (TOU) prices. Bar segments represent median values across all customers of each utility, and error bands represent the 5th and 95th percentiles.
Figure S8. Storage Dispatch Value with Alternate Sequencing of Grid Charging and Discharging Scenarios, Related to Table 7. The figure shows the energy plus peak value of storage dispatched under net billing tariffs with hourly pricing, with varying constraints related to grid charging and discharging.

Table S2. Electricity Market Indicators for the Cambium 2020 Low Renewables Cost Scenario, Related to Figure 8.

| Location            | Solar Penetration (% of Total Generation) | Shadow Capacity Price ($/kW-year) | Coefficient of Variation of Hourly Energy Prices |
|---------------------|------------------------------------------|----------------------------------|--------------------------------------------------|
|                     | 2020 | 2050 | 2020 | 2050 | 2020 | 2050 |
| Albuquerque, NM     | 7%   | 4%   | 41   | 93   | 0.1  | 0.9  |
| Atlanta, GA         | 6%   | 13%  | 36   | 111  | 0.2  | 0.4  |
| Baltimore, MD       | 33%  | 47%  | 36   | 115  | 0.3  | 0.4  |
| Colorado Springs, CO| 6%   | 17%  | 37   | 99   | 0.1  | 0.8  |
| Duluth, MN          | 5%   | 9%   | 41   | 96   | 0.4  | 1.2  |
| Helena, MT          | 0%   | 2%   | 39   | 97   | 0.1  | 0.7  |
| Houston, TX         | 1%   | 65%  | 28   | 82   | 0.3  | 1.0  |
| Los Angeles, CA     | 29%  | 60%  | 47   | 109  | 0.2  | 0.6  |
| Las Vegas, CA       | 17%  | 50%  | 46   | 102  | 0.2  | 0.7  |
| Miami, FL           | 2%   | 37%  | 36   | 89   | 0.2  | 0.6  |
| Minneapolis, MN     | 5%   | 9%   | 41   | 96   | 0.4  | 1.2  |
| Peoria, IL          | 11%  | 98%  | 36   | 102  | 0.3  | 0.7  |
| Phoenix, AZ         | 10%  | 17%  | 45   | 101  | 0.1  | 0.7  |
| Seattle, WA         | 1%   | 13%  | 40   | 101  | 0.1  | 0.7  |
| San Francisco, CA   | 14%  | 25%  | 45   | 109  | 0.2  | 0.6  |
| Average             | 10%  | 31%  | 30   | 25   | 40   | 100  |

Notes: All data in the table are based on the balancing authorities associated with each of the listed locations.
Table S3. Energy and capacity value of storage dispatch profiles, Related to Figure 8.

| Location                  | Maximize Solar Self-Consumption | Maximize Market Value |
|---------------------------|---------------------------------|-----------------------|
|                           | Energy Value   | Capacity Value | Energy Value   | Capacity Value |
|                           | 2020    | 2050    | 2020    | 2050    | 2020    | 2050    |
| Albuquerque, NM           | -0.2    | 1.9     | 3.8     | 9.2     | 1.5     | 4.0     | 11.6    | 32.0    |
| Atlanta, GA               | -0.8    | 3.3     | -0.7    | 12.7    | 4.0     | 5.7     | 7.8     | 43.9    |
| Baltimore, MD             | -0.5    | 3.6     | -0.1    | 15.6    | 5.0     | 6.2     | 7.9     | 45.2    |
| Colorado Springs, CO      | -0.7    | 1.2     | 2.6     | 8.3     | 1.4     | 3.5     | 11.2    | 28.8    |
| Duluth, MN                | -1.8    | 0.7     | -1.2    | 1.1     | 5.6     | 2.8     | 8.6     | 23.1    |
| Helena, MT                | -0.9    | 0.1     | 3.5     | 8.9     | 0.3     | 1.5     | 11.4    | 39.7    |
| Houston, TX               | -2.2    | 2.0     | -2.2    | 7.4     | 7.0     | 6.5     | 6.0     | 26.9    |
| Los Angeles, CA           | 0.4     | 3.0     | 6.6     | 16.4    | 1.7     | 4.5     | 13.1    | 37.1    |
| Las Vegas, CA             | 0.4     | 4.0     | 3.7     | 7.8     | 1.8     | 6.0     | 13.3    | 41.7    |
| Miami, FL                 | -0.7    | 8.0     | 0.8     | 8.2     | 5.2     | 12.5    | 9.7     | 37.8    |
| Minneapolis, MN           | -1.9    | 0.8     | -3.1    | 2.4     | 5.6     | 2.8     | 8.6     | 23.1    |
| Peoria, IL                | -1.4    | 2.6     | -2.2    | 12.8    | 4.7     | 5.3     | 5.3     | 31.8    |
| Phoenix, AZ               | 0.2     | 4.0     | 3.3     | 9.0     | 1.7     | 6.3     | 12.6    | 34.7    |
| Seattle, WA               | -0.8    | 0.0     | 0.9     | 3.5     | 0.3     | 1.1     | 11.6    | 29.9    |
| San Francisco, CA         | 0.1     | 2.7     | 4.6     | 11.5    | 1.4     | 4.1     | 12.5    | 37.0    |
| Average                   | -0.7    | 2.5     | 1.4     | 9.0     | 3.1     | 4.9     | 10.1    | 34.2    |

Notes: All units are $ per kWh of storage per year, and refer to averages across the 24 load profiles modeled for each location.

Table S4. Estimated generation capacity value for utilities analyzed in this study, Related to STAR Methods.

| [$/kW-year] | LE* | DTE | GMP | VEC | SMUD** | NVE** |
|-------------|-----|-----|-----|-----|--------|-------|
| 2012        | 78  | 0   | 39  | 39  | 57     | 57    |
| 2013        | 101 | 0   | 35  | 35  | 54     | 54    |
| 2014        | 137 | 4   | 37  | 37  | 54     | 54    |
| 2015        | 137 | 3   | 40  | 40  | 36     | 36    |
| 2016        | 118 | 16  | 39  | 39  | 36     | 36    |
| 2017        | 95  | 11  | 65  | 65  | 36     | 36    |
| 2018        | 128 | 2   | 102 | 102 | 43     | 43    |
| 2019        | 107 | 7   | 97  | 97  | 43     | 43    |

Notes: EIA-IDs used to define values for DTE, GMP, VEC. SMUD, and NVE were 60017, 60877, 62763, 56917, and 57373, respectively. *Since LE is not located in an organized wholesale market, we use annual estimated bilateral capacity prices for Florida. **CAISO nodes near NVE and SMUD were used as proxies, despite the two utilities being located outside of the CAISO market.