Residential Solar-Adopter Income and Demographic Trends: 2024 Update

Sydney Forrester, Galen Barbose, Eric O'Shaughnessy, and Naïm Darghouth

BERKELEY LAB

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number 388444 and Contract No. DE-AC02-05CH11231.

U.S. DEPARTMENT OF ENERGY

December 2024

LAWRENCE BERKELEY NATIONAL LABORATORY | ENERGY TECHNOLOGIES AREA | ENERGY ANALYSIS AND ENVIRONMENTAL IMPACTS DIVISION

Disclaimer

Copyright Notice

Report Outline

1. **Introduction, Data, and Methods**
   - Overview and key findings
   - Data sources and geographic coverage
2. **Solar-Adopter Income Trends**
   - Overall distribution and comparisons to the broader population
   - Temporal and geographic trends
   - Low-to-moderate income shares of adopters
3. **Solar Installation Attributes by Income**
   - System size
   - Third-party ownership (TPO)
   - Battery-storage pairing
   - Installer size
4. **Other Socio-Economic Trends for Solar Adopters**
   - Race and ethnicity
   - Rural vs. urban
   - Location in disadvantaged community
   - Home value
   - Housing type and tenure
   - Education
   - Occupation
   - Age
5. **Conclusions**
6. **Appendix**

BERKELEY LAB

Overview

Describes income and demographic trends among U.S. residential solar photovoltaic (PV) adopters

- Pairs Berkeley Lab's *Tracking the Sun* dataset and other sources of PV addresses with *household-level* income and demographic data
- Unique in its market coverage and granularity
- Descriptive and data-oriented; complements and informs other related work at Berkeley Lab

For related research at Berkeley Lab:
solardemographics.lbl.gov

What's New?

- Data on systems installed through 2023
- More detailed data on multi-family property type and tenure

Related Berkeley Lab Resources

- Online data visualization tool allowing users to further explore the underlying dataset
- In-depth topical studies on issues related to solar energy access and equity
- Analytical support to external organizations, by request

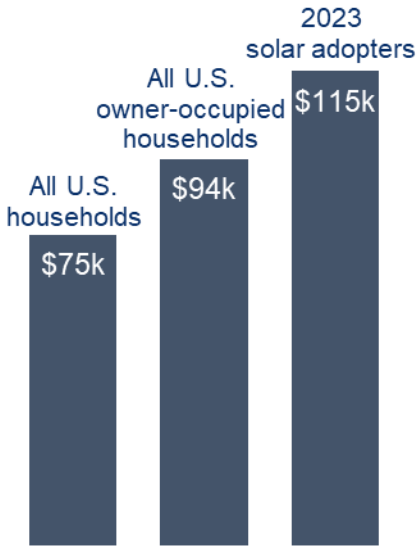
BERKELEY LAB

High-Level Findings

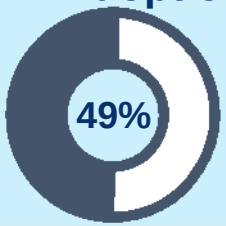
Solar-adopter incomes vary considerably, but are generally higher than the broader population

- Differences are considerably smaller when comparing to only owner-occupied households (HHs)
- The disparities at a national level are partly driven by the concentration of the U.S. market in states with higher HH incomes

Median Incomes



LMI Adoption

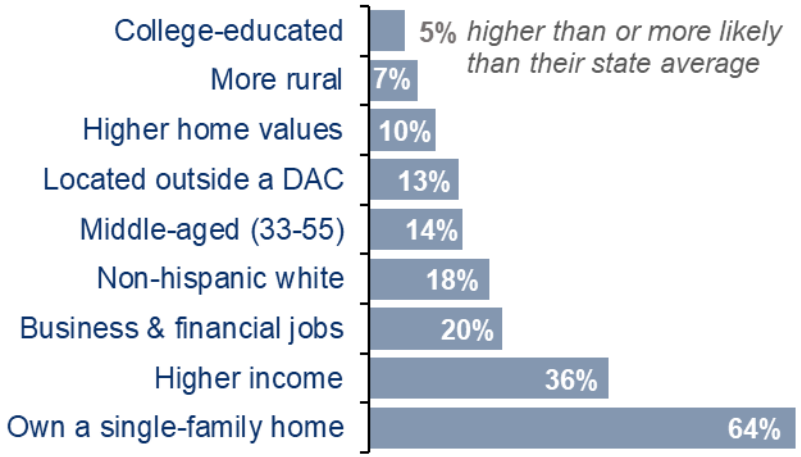


While solar adoption skews toward high-income households, low- and moderate-income (LMI) households are also adopting. In 2023, roughly half of adopters earned less than 120% of their area's median income. (120% is a threshold sometimes used to include both low and moderate income)

Solar adopters vary along other socio-economic dimensions

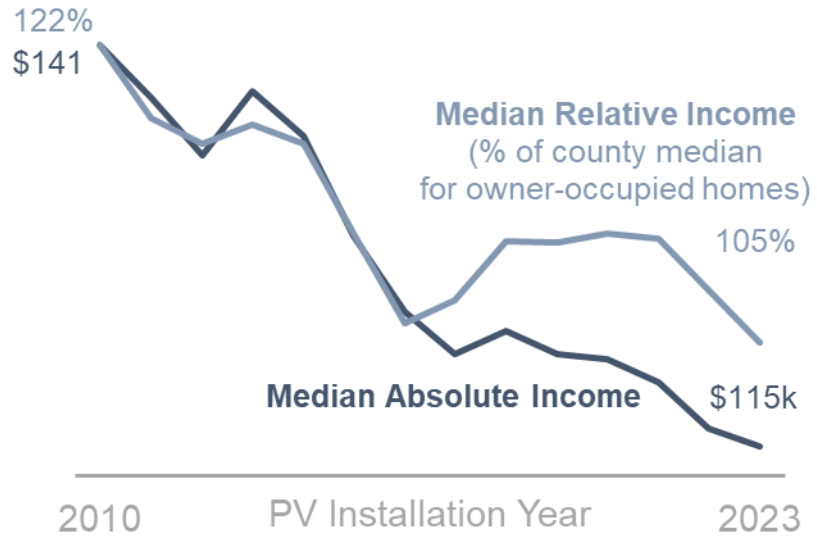
- Solar adopters are diverse, but tend to differ from the broader population in many respects
- The largest differences relate to housing type and tenure, but differences also exist with respect to occupation, race, and other factors
- As with income, these differences are generally diminishing over time

Compared all households in their respective state, 2023 solar adopters tend to be or have...



The rooftop solar market is *gradually* becoming more equitable over time

*Solar-Adopter Current Household Income**



* *Based on estimated household incomes for the year 2024, regardless of the PV installation year*

- Rooftop solar is **broadening** into states with generally lower income levels
- Rooftop solar is also **deepening** by reaching less-affluent households and disadvantaged communities in established markets
- Reflects falling solar prices, policies and business models that support broader adoption, and other factors

Data Sources

PV Street Addresses & System Data

- Berkeley Lab's ***Tracking the Sun*** is the primary data source; addresses and other data for ~2.7M systems, primarily from utilities & state agencies
- **BuildZoom*** and **Ohm Analytics**: Purchased PV permit data; provides supplementary PV street addresses for an additional 1.4M systems as well as battery attachment flags

*Additional information on building permit data provided by BuildZoom available here: https://www.buildzoom.com/data

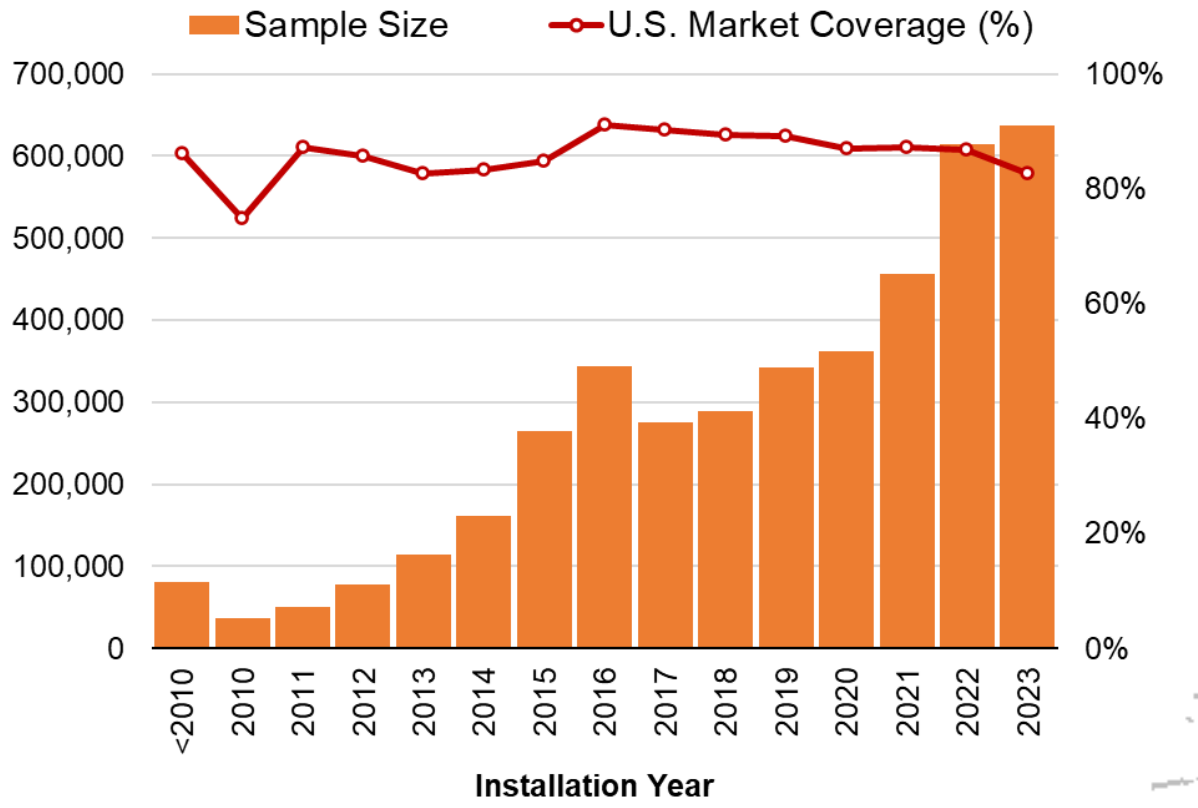
Socio-Economic and Property Data

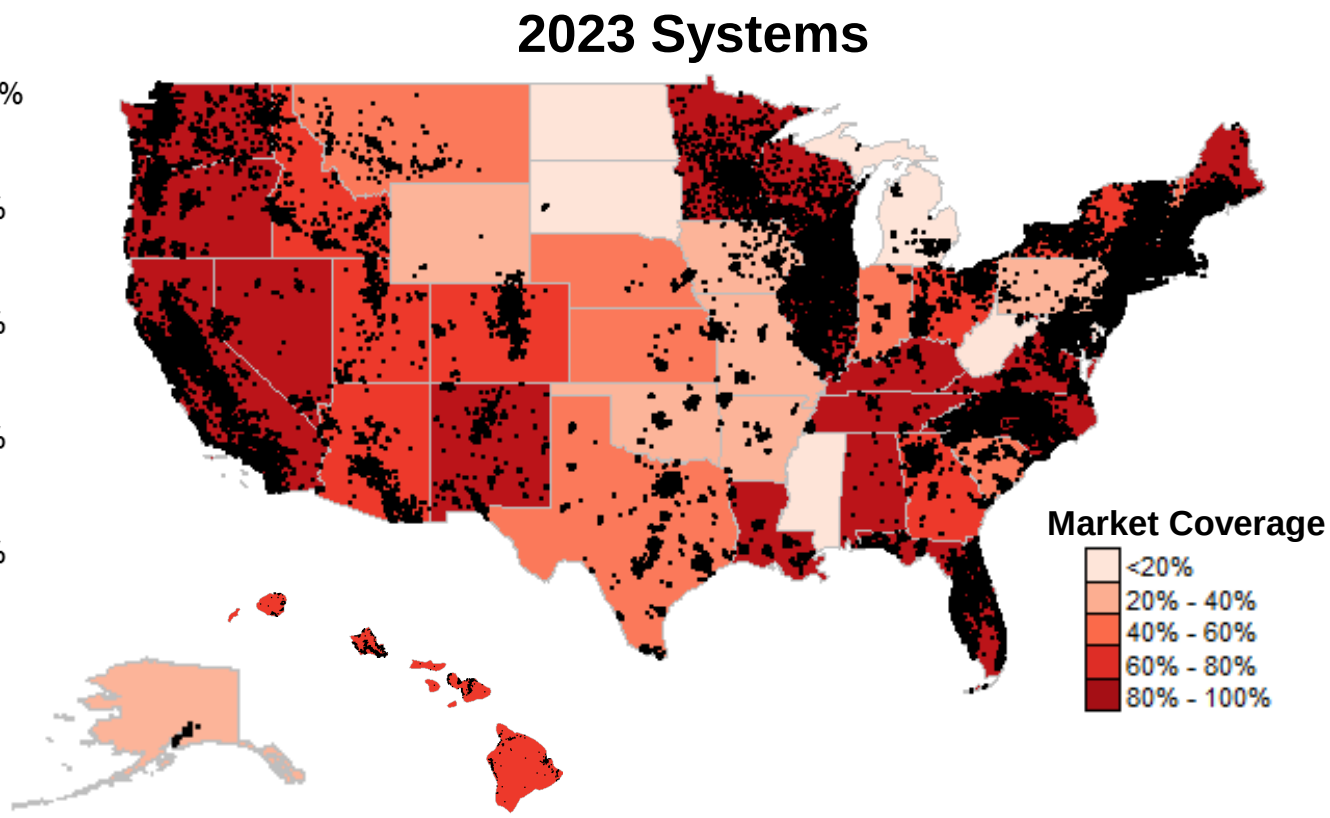
- **Experian ConsumerView**: Purchased dataset with estimated household-level income and other socio-economic attributes of solar adopters
- **U.S. Census** and **Bureau of Labor Statistics**: Used for comparison purposes to characterize demographics of total U.S. population
- **WRU**: Open-source algorithm used to estimate race and ethnicity of household members
- **CoreLogic**: Purchased data on building attributes used to identify building type, tenure

See appendix for further details on income and other socio-economic data sources

BERKELEY LAB

Sample Coverage

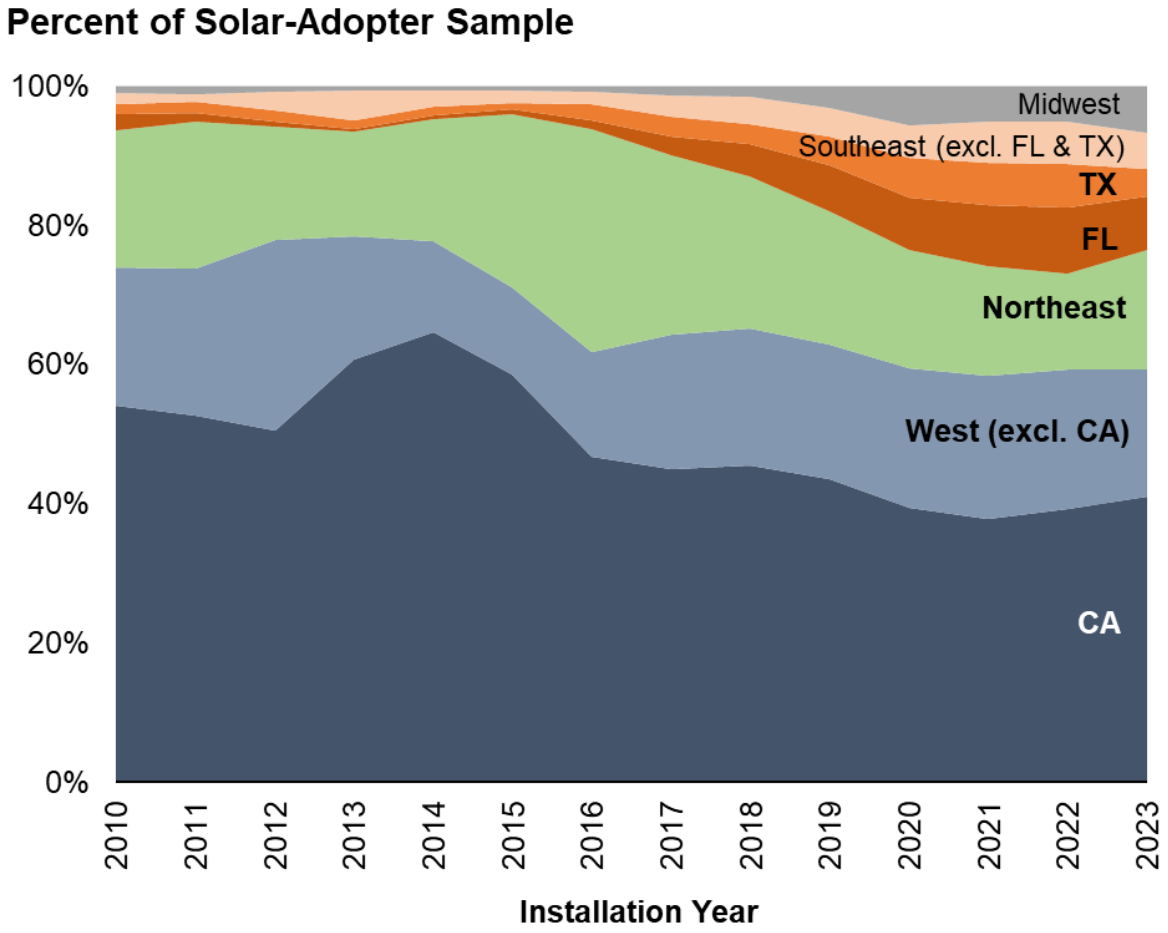




- Our sample consists of over **4.1M systems**, covering roughly **87%** of all U.S. residential systems through 2023 and **83%** of systems installed in 2023
- State-level market coverage varies widely, but is over 40% in most states for 2023

*****See appendix slide 49 for tabular details on sample sizes*****

Sample Distribution over Time



Notes: The figure represents the distribution of the solar-adopter sample used in this analysis, which covers 87% of the total U.S. market, but as shown on the previous slide, coverage for the Midwest and Southeast is somewhat lower than for other regions.

- Shifts in the sample distribution over time reflect changes in the broader PV market, as well as changes in state-level sample coverage
- These geographic shifts contribute to the some of the broader demographic trends shown later
- CA and Northeastern states' shares of the sample have generally declined over time, though both ticked upward in 2023 (to 41% and 17%, respectively)
- FL, TX, and other Southeastern states have all correspondingly grown in their sample share over time, though shrunk slightly in 2023 to 17%
- Western states other than CA have maintained a fairly steady share (18% in 2023), while Midwestern states' share is small but growing (7% in 2023)

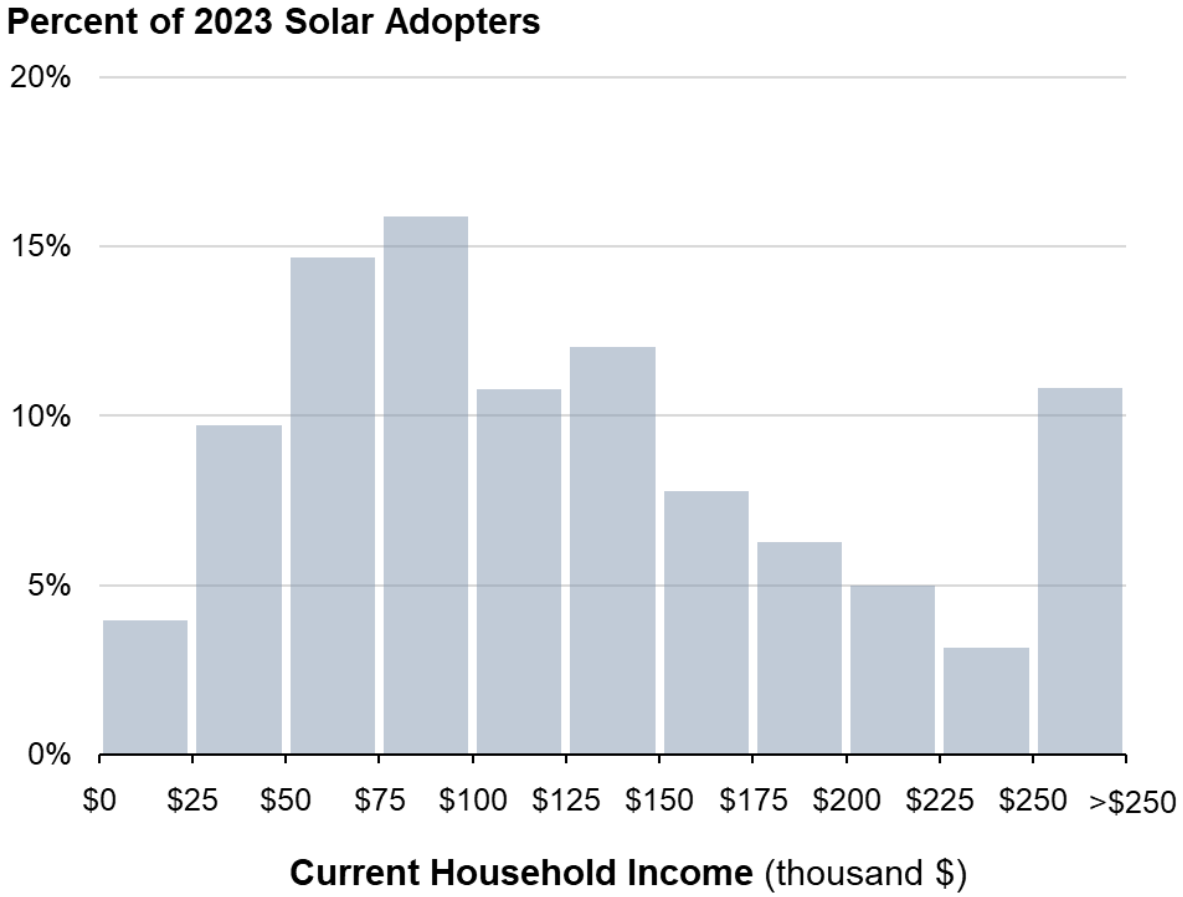
BERKELEY LAB

Key Points on Data and Methods

- We focus here on national and state-level trends, with an emphasis on PV systems installed from 2010-2023; additional data, including county- and Census tract-level trends, as well as data for earlier years, are available through Berkeley Lab's online solar demographics tool
- Income estimates refer to total household income, while most of the other demographic attributes (race, occupation, education) are based on the primary householder; regardless, we describe trends in terms of "households" as the relevant unit for PV adoption
- PV adopter income and demographic data reflect *current* values based on Experian ConsumerView data obtained in Q2 2024; the data therefore may not be reflective of household characteristics at the time of adoption (if the home since sold)
- PV adopter income is calibrated to align Experian and Census data; see slide 47 for details
- Unless otherwise noted, we present state-level data only if the underlying sample consists of at least 100 systems and at least 10% market coverage for the applicable state and year
- Sample sizes vary across different elements of the analysis, depending on the underlying data source and completeness of the associated data fields; see appendix slide 50 for details

Solar-Adopter Income Trends

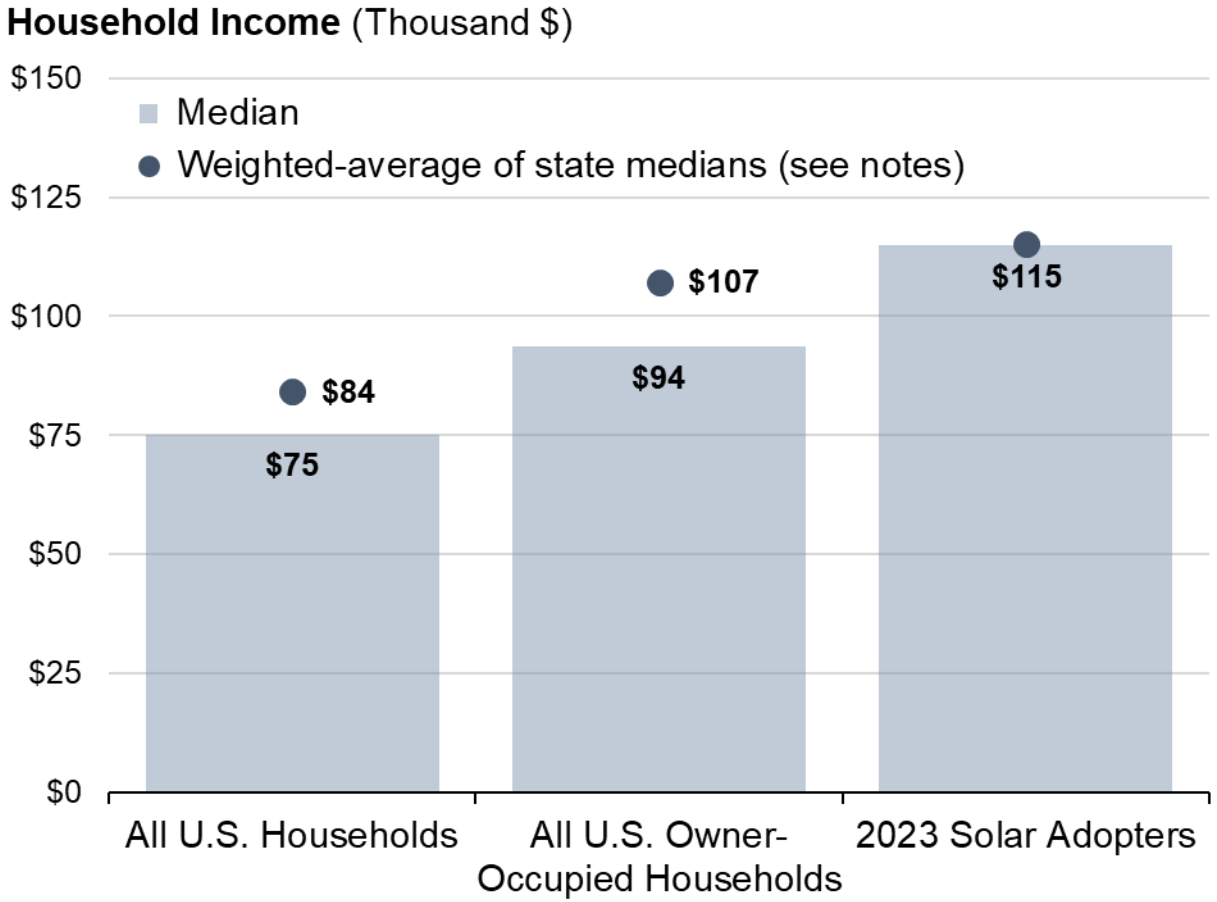
Solar-Adopter Household Income Distribution



** Notes: Experian does not differentiate income estimates >$250k, thus all households above that level are aggregated, leading to the spike on the right-hand side of the distribution*

- Solar adopters span all household (HH) income levels, from less than $25k to more than $250k, with many in the “middle income” range
- Roughly 44% of adopters have HH incomes <$100k, while 37% are from $100-200k, and the remaining 19% are above $200k
- The distribution has a long upper tail, collapsed in the figure for all incomes >$250k (see figure notes)

Solar-Adopter Incomes Compared to Total U.S. Population

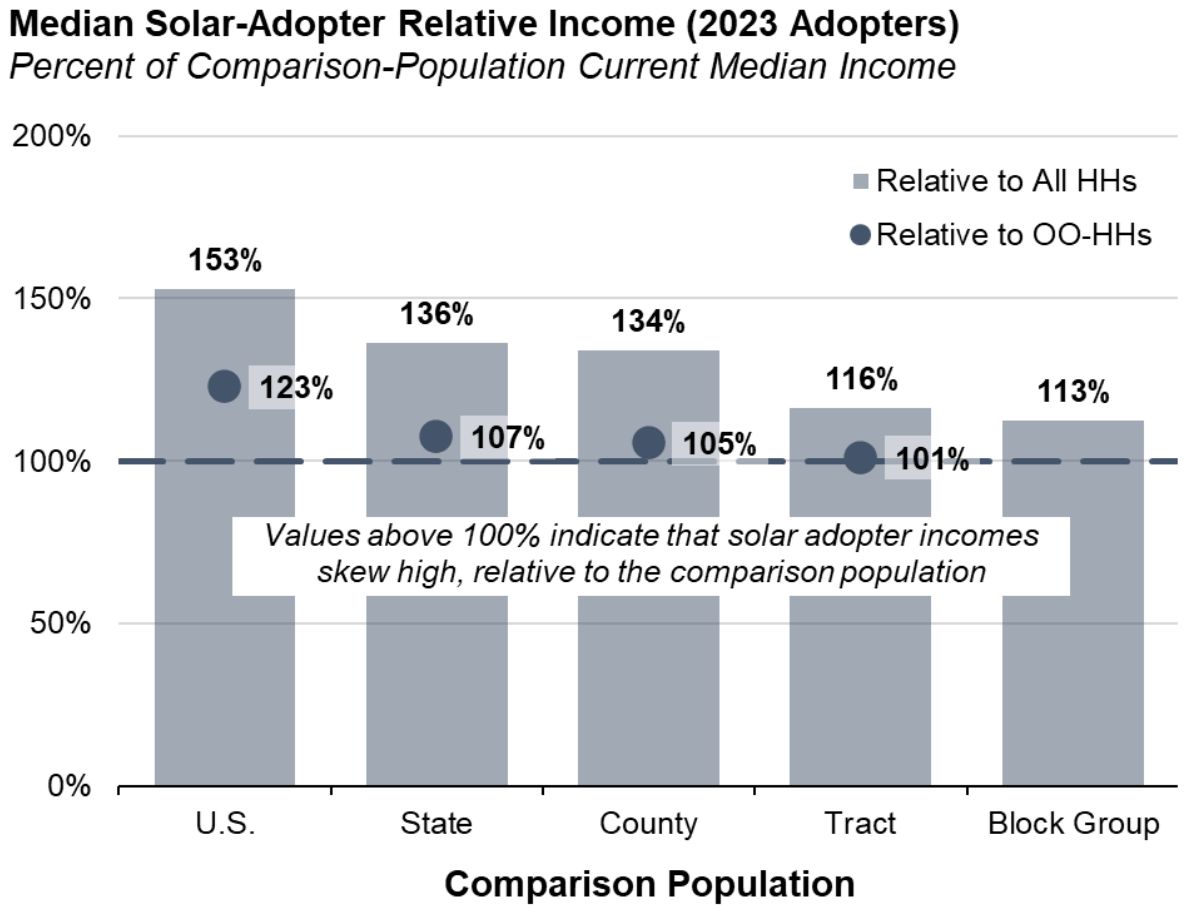


Notes: The weighted averages are averages of state-level median incomes for each group, weighted by the number of 2023 solar adopters in each state. The purpose of those weighted averages is to provide a basis for comparison that controls for the concentration of solar adopters within particular states.

- Solar-adopter incomes skew high, but the degree of skew is highly dependent on how the comparison population is defined
- The median income of 2023 solar adopters ($115k) is **53%** higher than for all U.S. households ($75k)
- Onsite solar adopters are almost all owner-occupied households (OO-HHs); solar adopter incomes are only **23%** higher if comparing to only OO-HHs ($94k)
- Solar adopters are disproportionately located in high-income states (e.g., CA); the skew narrows drastically to **7%** ($115k vs. $107k) when also controlling for the state-level distribution of solar adopters (see figure notes)

BERKELEY LAB

Solar-Adopter "Relative Income"



Notes: To calculate these values, we first calculate each solar adopter's "relative income" compared to the comparison population (a percentage value) and then take the median of those percentage values across all solar adopters. At the block group level, median incomes for OO-HHs are not available, thus no data point is shown.

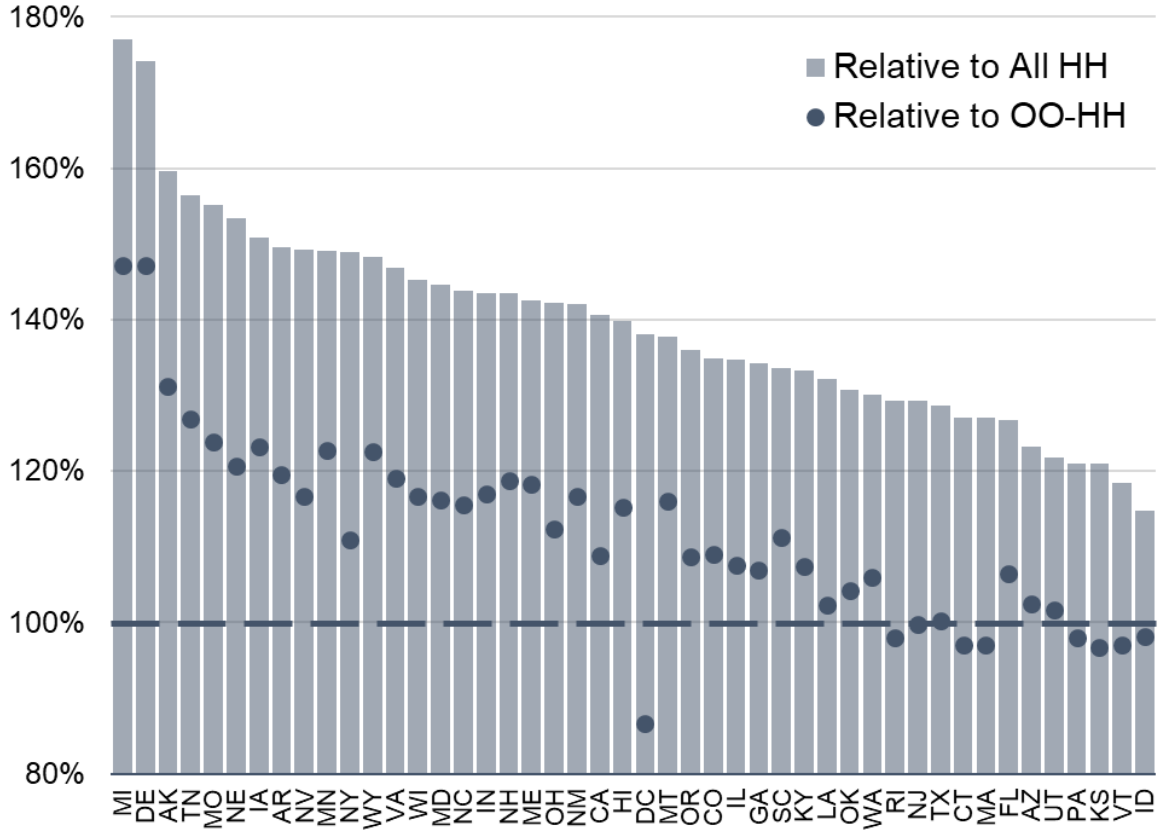
Relative Income: Solar-adopter HH income *as a percentage* of the median income across all HHs in the comparison population

- This is the metric used throughout the report to describe the skew in solar-adopter incomes
- Comparison population can be defined at different geographical scales (from U.S. to block group) and for all HHs or only OO-HHs
- As shown, solar-adopter income skew is smaller the more localized the comparison and when comparing to only OO-HHs
- Overall, U.S. solar-adopter incomes are near parity with other OO-HHs in the same Census tract, county, and state

BERKELEY LAB

Solar-Adopter Income Trends across States

Median Solar-Adopter Relative Income
(2023 Adopters, % of State Current Median Income)

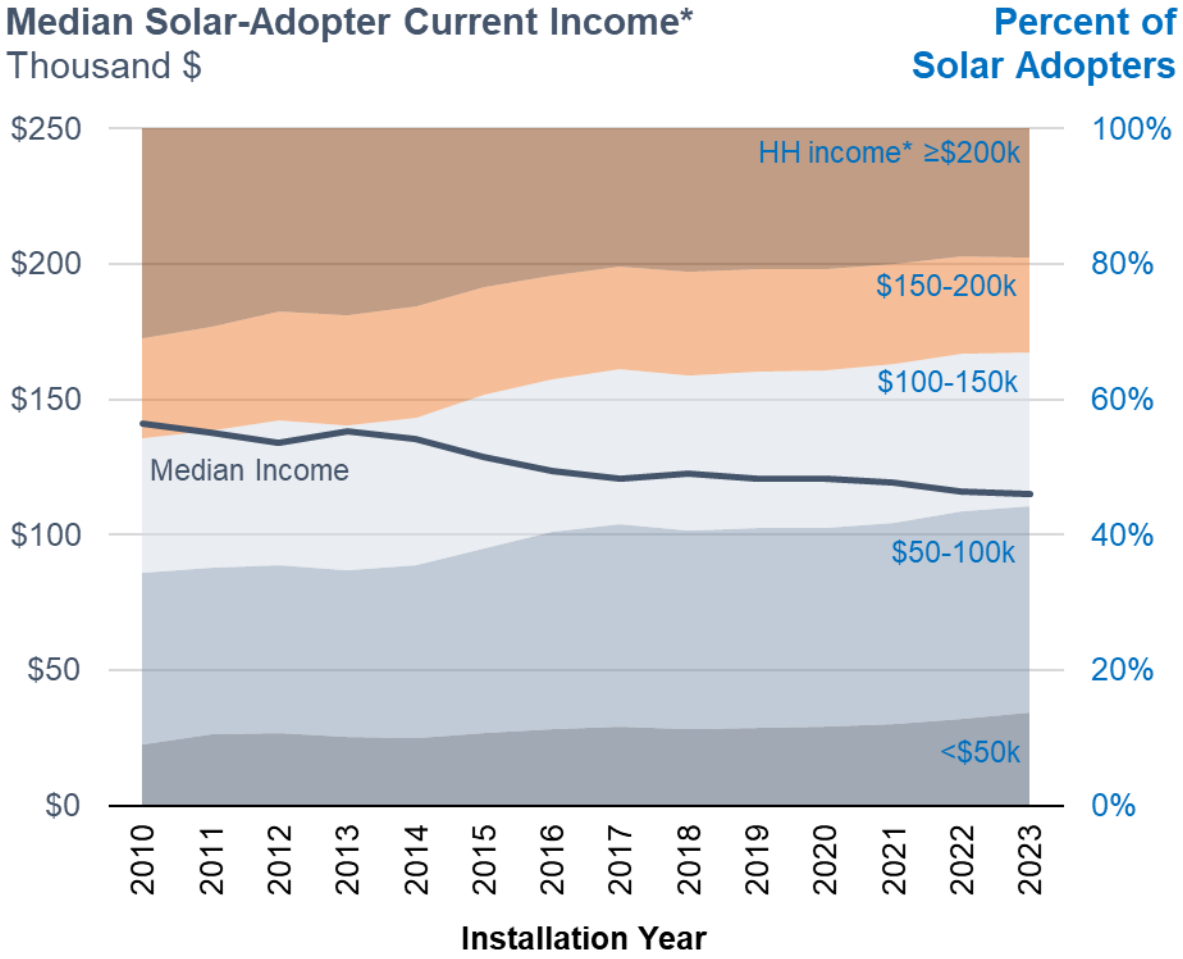


Notes: The large divergence between the two relative income metrics for DC are due to the fact that the median income of OO-HH in DC is substantially higher than that of All HH.

- Solar adopter incomes in all states skew high compared to the *general population* (All HH), with median relative incomes ranging from 115-177% of the state median income
- But when comparing to only OO-HHs, 10 states are at (or beyond) income parity (i.e., median relative income = 100%)
- Over all states, solar adopter incomes relative other OO-HHs ranged from 87%-147%
- Varying degrees of income skew across states can reflect differences in solar market maturity; solar policies and programs; and broader socio-economic factors (income inequality, cost of living, etc.)

BERKELEY LAB

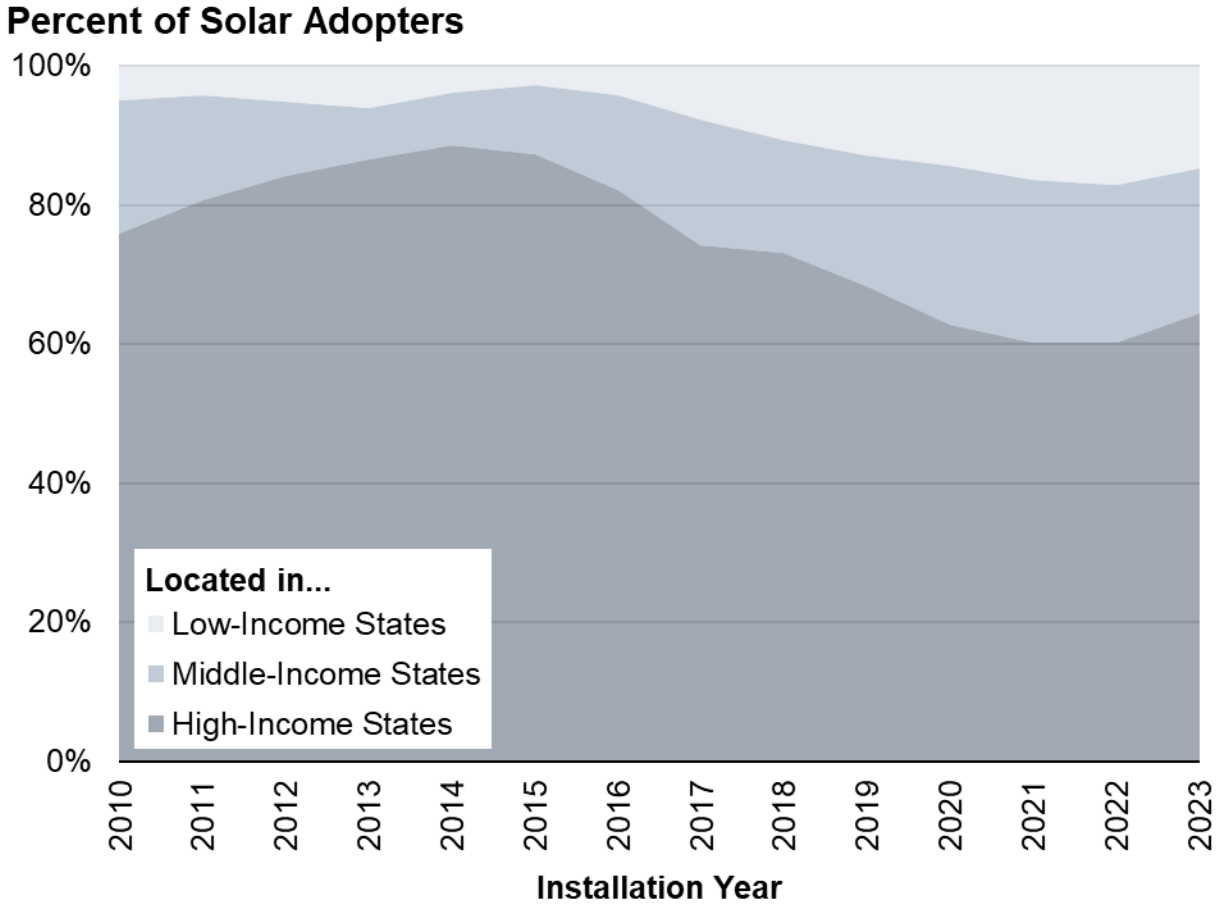
Solar-Adopter Income Trends over Time



** Notes: Incomes are based on the year 2024, regardless of when the PV system was installed, with no inflation adjustments.*

- Solar adoption has gradually shifted over time toward progressively less affluent HHs, and a smaller fraction of adopters coming from the highest income tier (>$200k)
- Median solar adopter incomes correspondingly fell from $141k for HHs that installed PV in 2010 to $115k for HHs installing PV in 2023 (recall: income estimates based on *current* HH income)
- Long-term trends driven by falling PV prices, expanded financing options, LMI programs, general market maturation, and other factors
- These factors manifest in both a "broadening" and “deepening” of solar markets, as described on the following slides

Solar Market Broadening Trends

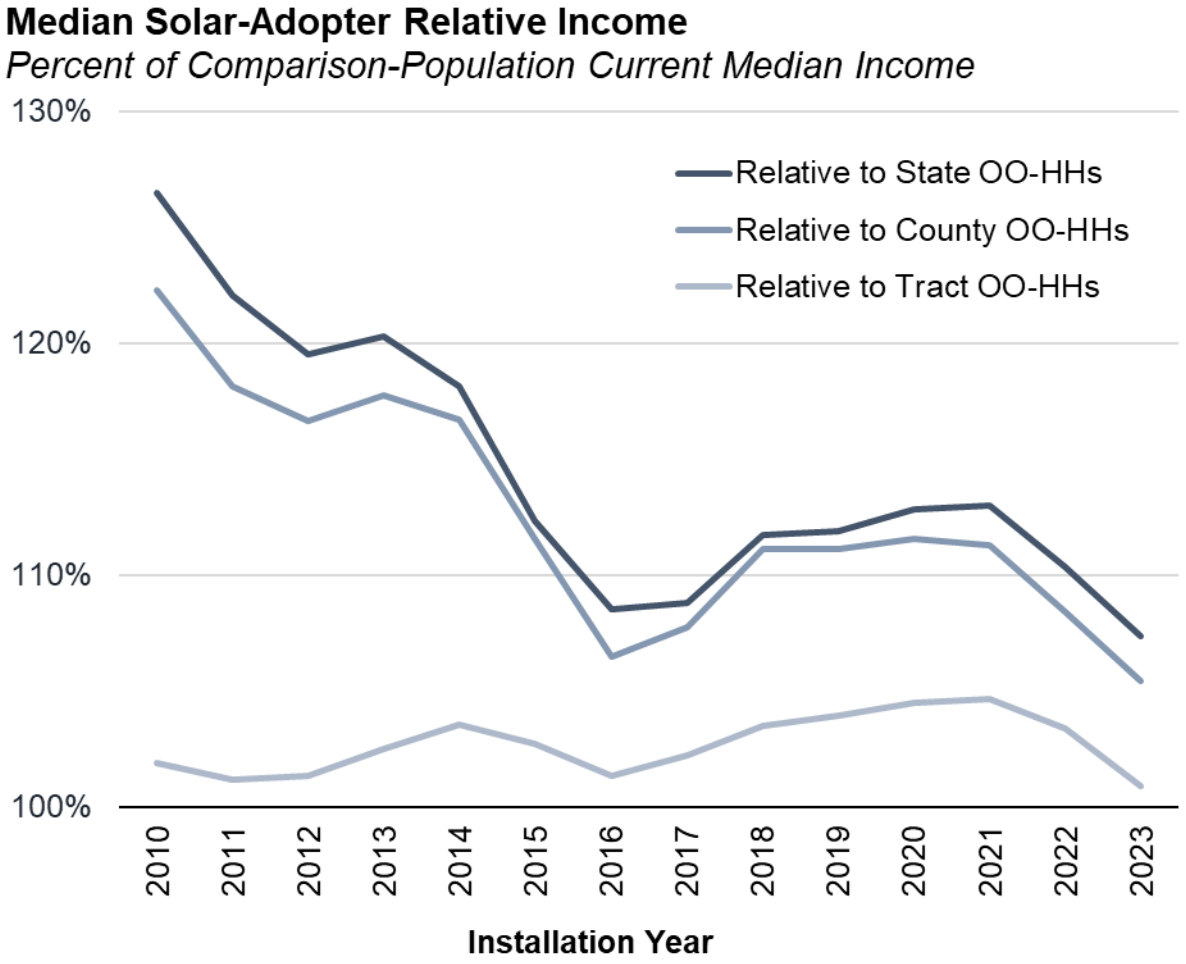


Notes: States are grouped based on their median household income, with roughly an equal number of households in each group. The distribution is based on the solar-adopter sample, which slightly over-represents high-income states compared to the total U.S. solar market.

- Solar adoption has been generally broadening into low- and middle-income states over time, reaching 15% and 21% of 2023 installs, respectively (based on the study sample)
- High-income states still make up a disproportionate share (64%), compared to their share of all U.S. households (33%)
- Trends are driven by a relatively small set of states within each grouping: CA (high-income); FL (low); and TX, IL, AZ, NV (middle)
- Sample share for high-income states ticked up in 2023, due to drop in install volumes in many of the low and middle-income states (esp. TX), along with modest growth in CA

BERKELEY LAB

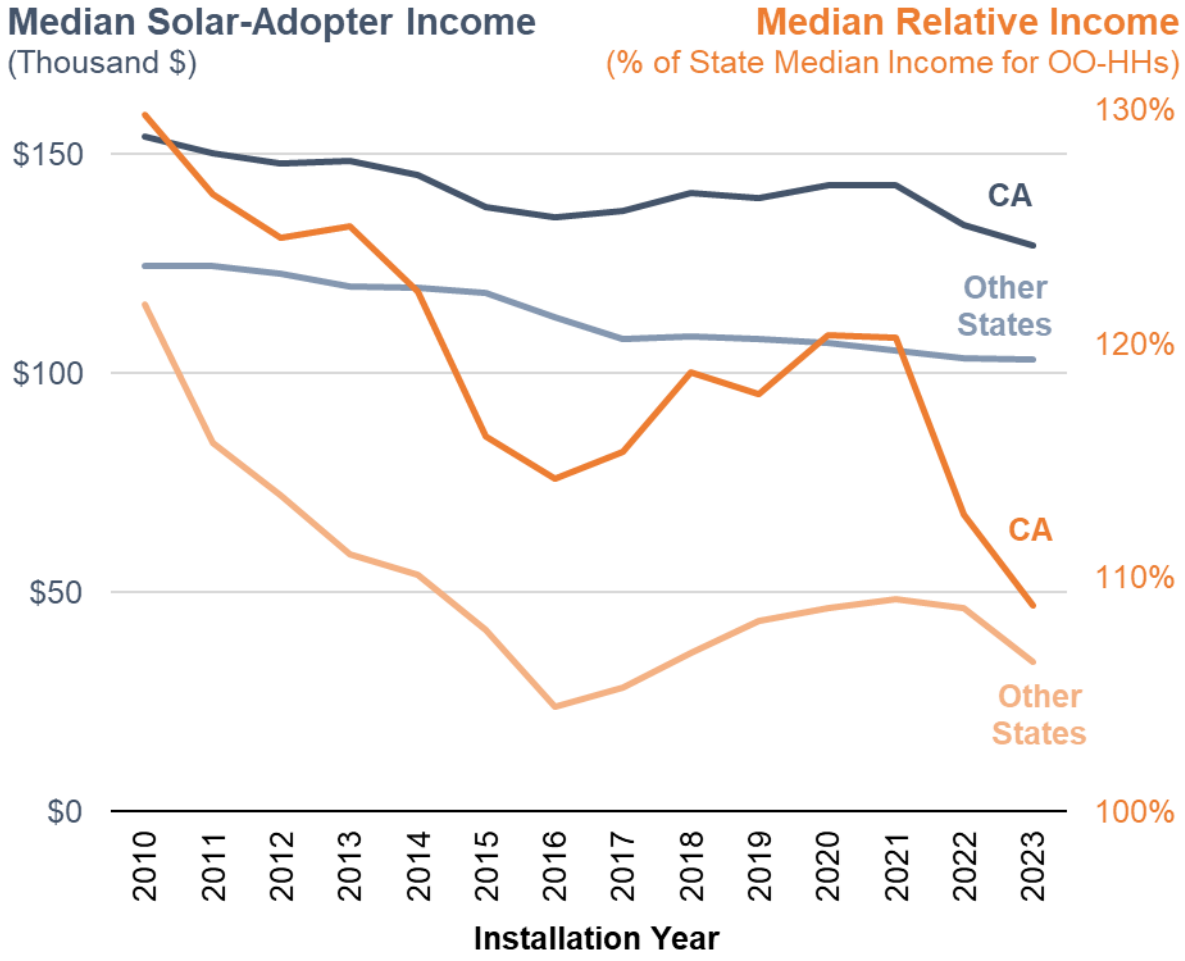
Solar Market Deepening Trends



- Solar market deepening refers to a shift in adoption toward progressively less affluent households within a given region
- Relative income trends provide some measure of solar market deepening (albeit imprecisely*)
- Relative incomes at the **state** and **county** levels have also fallen over the long term, but have fluctuated since 2016, with fairly steep drops the past couple years
- Relative incomes at the **tract** level have remained more or less static and are close to parity, compared to all OO-HHs

** The imprecision stems from the fact that solar markets are simultaneously broadening, and adoption in new markets often begins with relatively affluent households, which tends to mask the deepening occurring in more-established markets.*

Solar-Adopter Income Trends: California vs. Other States

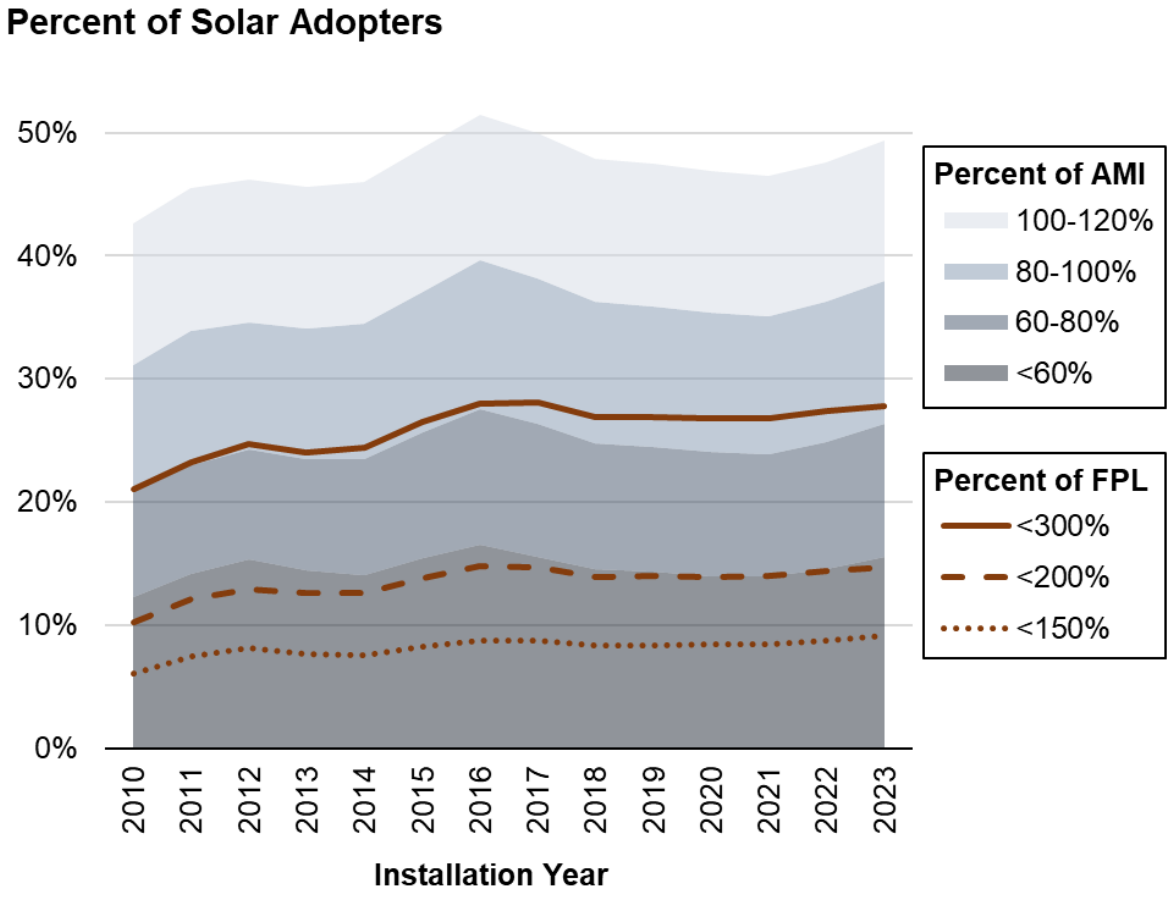


** Notes: Incomes are based on the year 2024, regardless of when the PV system was installed, with no inflation adjustments.*

- Given its outsized share of the market, solar-adopter income trends in CA have a large effect on overall U.S. trends
- Absolute solar-adopter incomes have been declining in CA and other states at a similar pace over the long run
- Relative income trends are also broadly similar between CA and other states
- However, California stands out over the past few years, since 2021, when absolute and relative solar-adopter incomes have shifted downward more rapidly than in other states
- Likely due in part to new CA building codes requiring PV on all new homes

BERKELEY LAB

LMI Share of U.S. Solar Adopters over Time



Notes: "Area" refers to the applicable U.S. Census Core-Based Statistical Area or county (for rural areas). Both AMI and FPL vary by household size. For a family of three, the FPL for the contiguous 48 states was $24,860 in 2023.

Various income metrics and thresholds can be used to define "low-to-moderate income" (LMI):

- 150-200% of Federal Poverty Level (FPL) is common, especially in low-income federal energy programs
- 80% of Area Median Income (AMI) is also often used
- Higher thresholds (e.g., 120% of AMI, 300% of FPL) are sometimes used to include "moderate" income

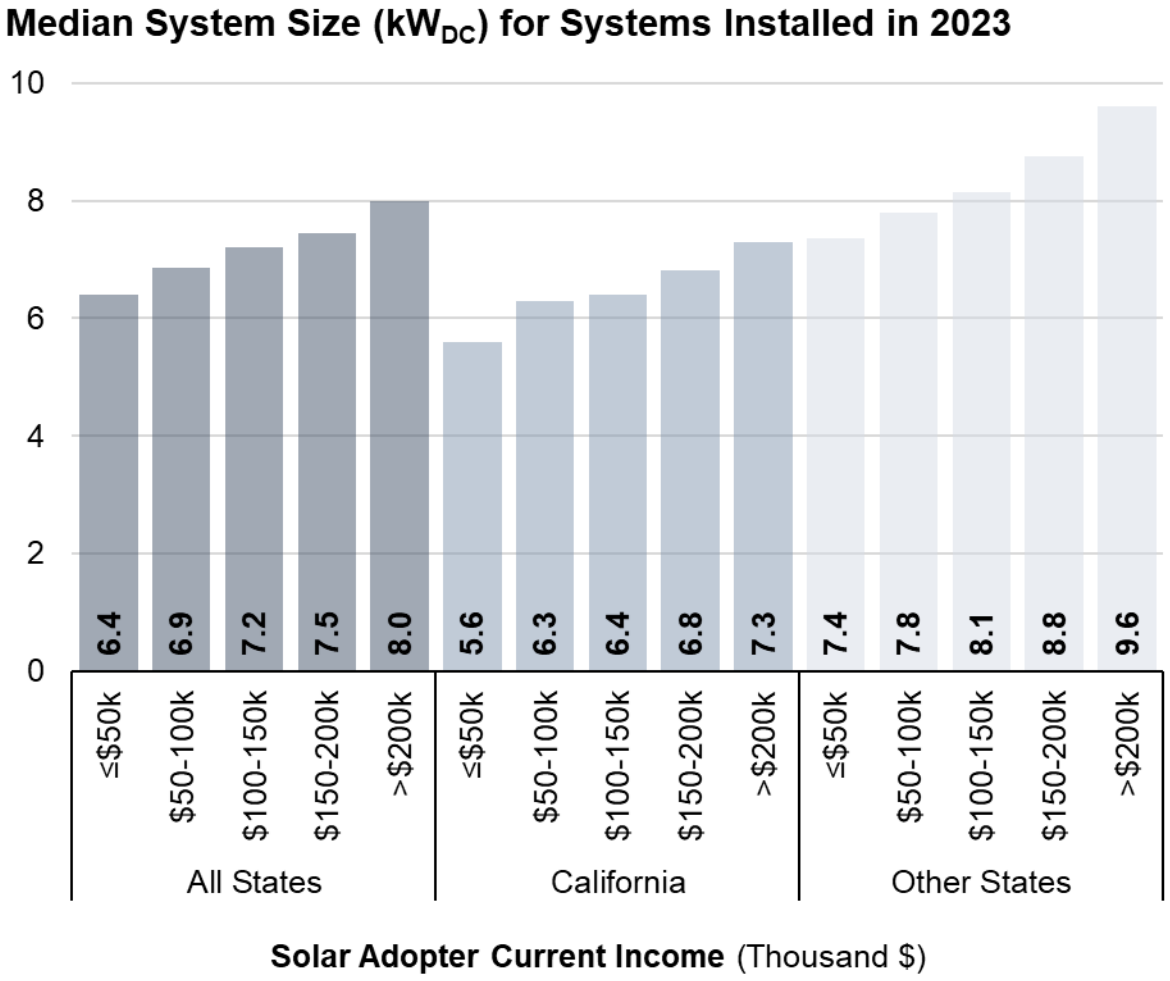
- Regardless of how it is defined, LMI shares of U.S. solar adopters are slowly trending up
- Across all U.S. solar adopters in 2023:
  - **AMI:** 26% were <80% of AMI, 49% were <120% of AMI
  - **FPL:** 9% were <150% of FPL, 28% were <300% of FPL
- State-level data accessible online via Berkeley Lab's solar demographics tool

Solar Installation Attributes by Adopter Income Level

Solar Installation Attributes by Adopter Income Level

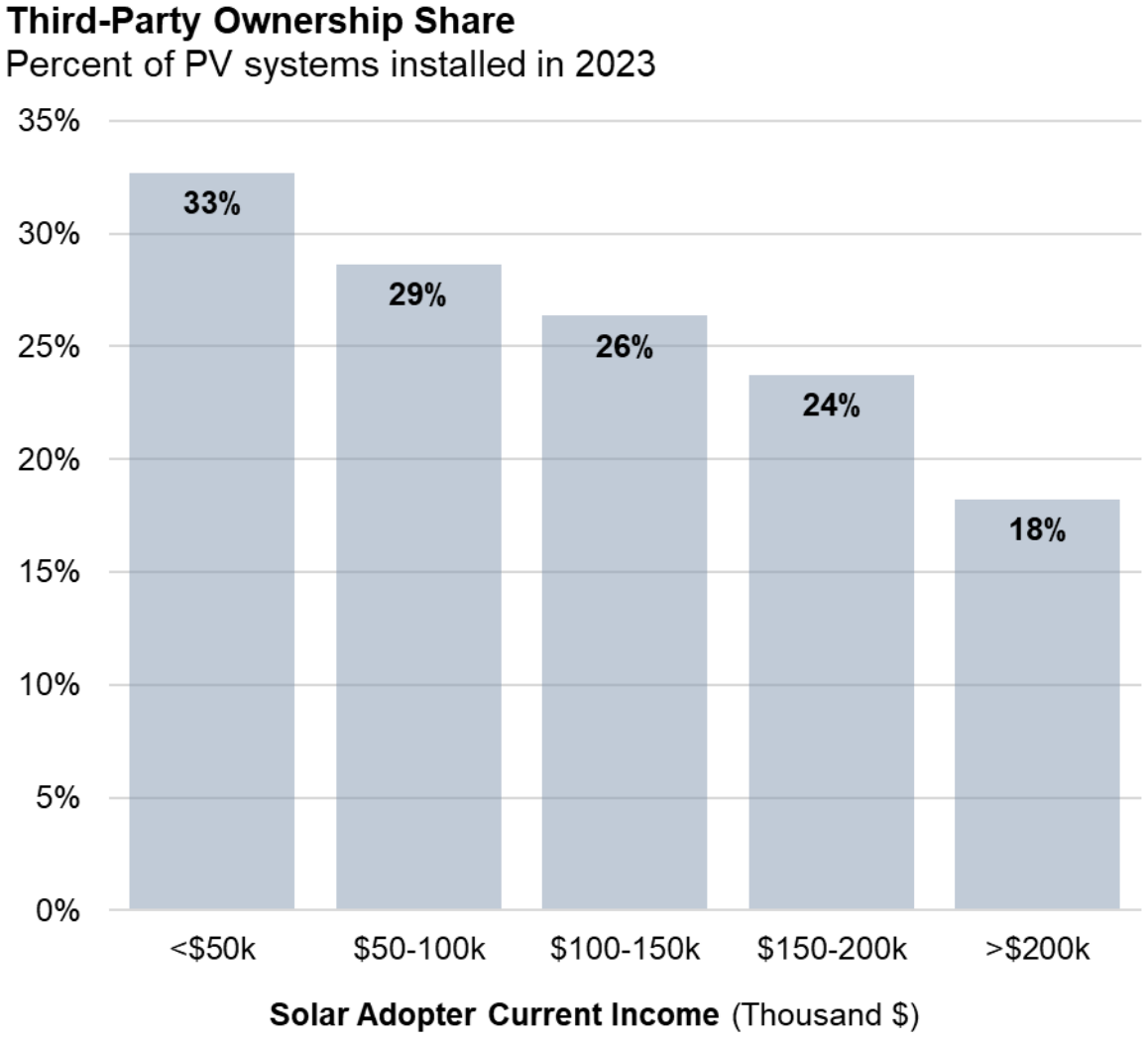
- Solar PV system characteristics may vary based on household income level; here we focus on several:
  - System size
  - Third-party owned (TPO) vs. host-owned systems
  - Paired PV+storage vs. stand-alone PV systems
- Related, we also explore differences in the income profile of solar adopters across individual installers, and whether there are any differences based on installer size
- These comparisons are based primarily on the subset of the PV adopter dataset originating from *Tracking the Sun*, which provides PV system attributes (see slides 50 for applicable sample sizes)

System Size by Income Level



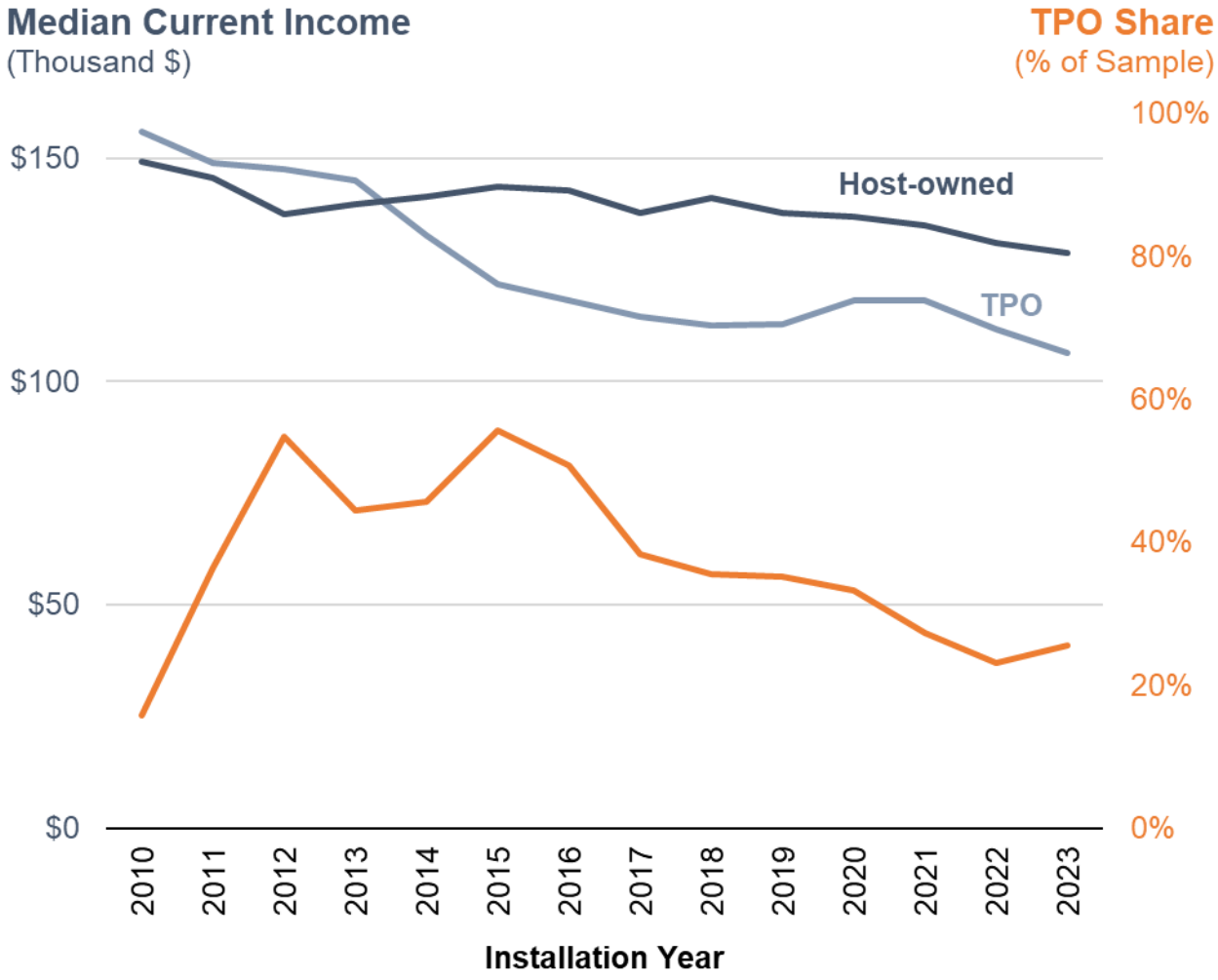
- Higher income households install larger systems
- Trends explained by the fact that larger systems cost more, and that higher-income households tend to have larger homes with larger roof area and to have higher electricity consumption
- Across the sample, systems installed by the highest-income households were 25% larger than those of the lowest-income households, based on median system sizes (8.0 vs. 6.4 kW)
- California systems are relatively small overall, pulling median system sizes down for the sample, but the same trends in system size across income levels are evident in CA and in other states as well

Third-Party Ownership Rates by Income Level



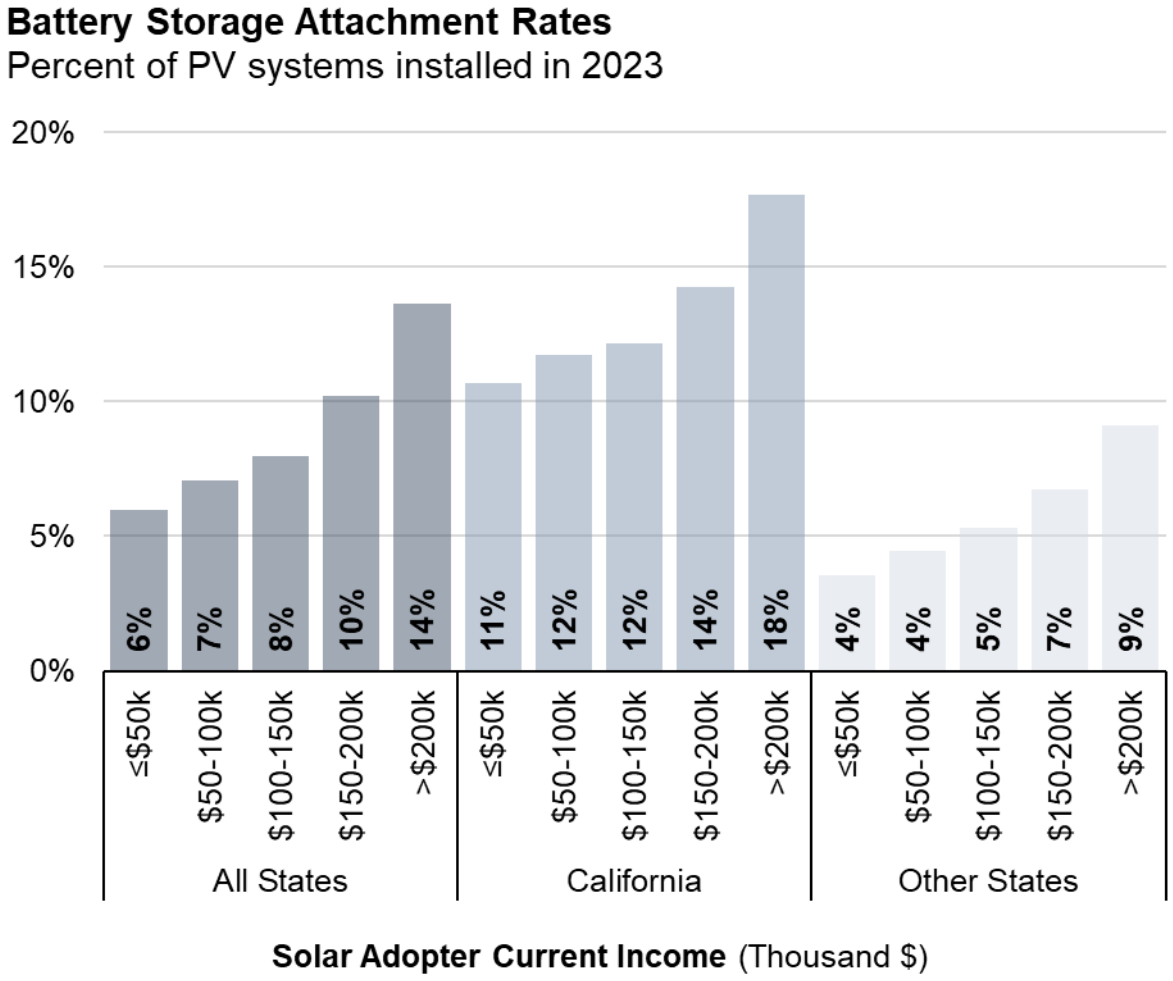
- Third-party ownership (TPO) through leases or power purchase agreements is one way to address up-front cost barriers to PV adoption
- TPO shares are higher for less affluent households: almost 2x for households in the lowest vs. the highest income group in 2023
- O'Shaughnessy et al. (2021) found that TPO has driven *additional* adoption by lower income HHs, and has been a key driver in shifting solar adoption toward less affluent households
- The Inflation Reduction Act (IRA) included bonus tax credit adders for low-income TPO systems, though those bonus credits were not available until late 2023; future impacts TBD

Third-Party vs. Host-Owned Systems



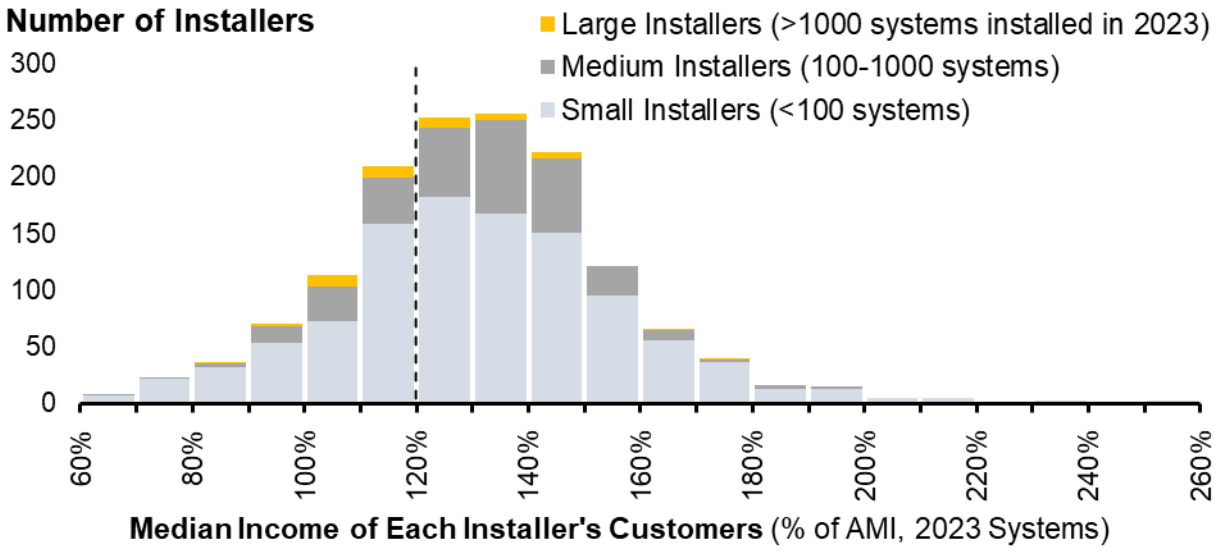
- Median TPO adopter incomes dropped below host-owned adopter incomes from 2013-2015, reflecting geographical shifts in the TPO market, but the two have moved in parallel since then
- The TPO share of the sample has fallen substantially since 2016, as loan financing has become progressively more common
- LBNL is separately exploring income trends within the solar-loan market, which will show how the shift from TPO to loans has impacted adoption equity
- The slight uptick in TPO share from 2022-2023, coupled with a relatively steep drop in TPO-adopter incomes, helped to drive increasing adoption equity over the last year

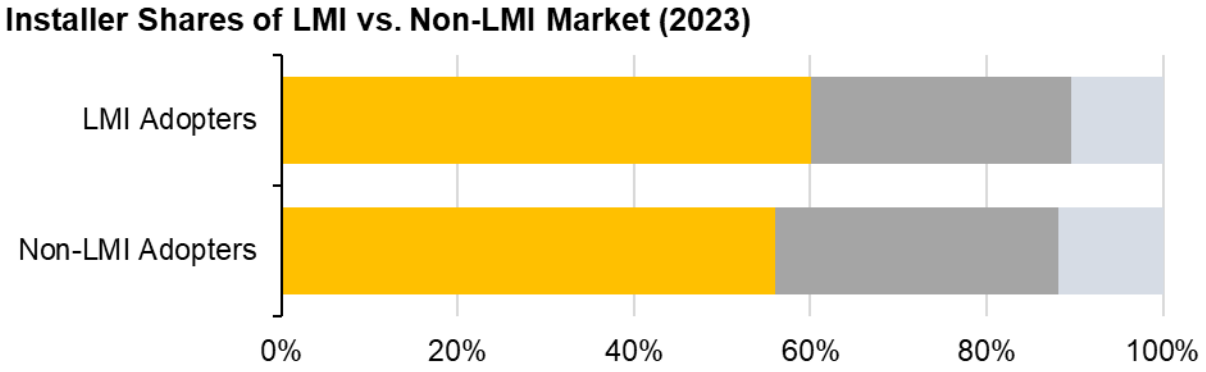
Storage Attachment Rates



- Including storage with solar PV entails additional costs, but also provides added benefits (bill savings, resiliency)
- Storage attachment rates are higher for more affluent households: across all states, roughly double for the highest income group compared to the lowest income group
- The same general trends apply in California (which comprises 63% of all paired solar+storage systems in 2023) and other states
- Trends in CA may shift over time, as the market completes its transition to the new net billing (aka NEM 3.0) structure, which incentivizes pairing of storage with solar

Installer-Level Trends





Notes: LMI defined here as having a household income less than 120% of AMI.

- We can characterize installers by the median income of their customers
  - An installer whose customers have a median income <120% of AMI is described here as "primarily serving LMI households"
- Installers vary considerably in terms of the income profile of their customer base
  - Across roughly 1500 installers, 32% primarily serve LMI customers
- Large installers (>1000 systems per year) are slightly more likely to serve LMI households
  - 50% of large installers primarily serve LMI customers, and large installers account for a slightly larger share of LMI than non-LMI systems
  - Differences likely driven in part by TPO, which is mostly limited to large installers

Other Socio-Economic Trends for Solar Adopters

Approach to Describing Other Socio-Economic Trends

We describe trends in other socio-economic attributes of solar adopters*:

- Location in a Disadvantaged Community (DAC)
- Race and Ethnicity
- Rural vs. Urban
- Home Value
- Housing Type and Tenure
- Education Level
- Occupation
- Age

In some cases, also describing how those trends align with income

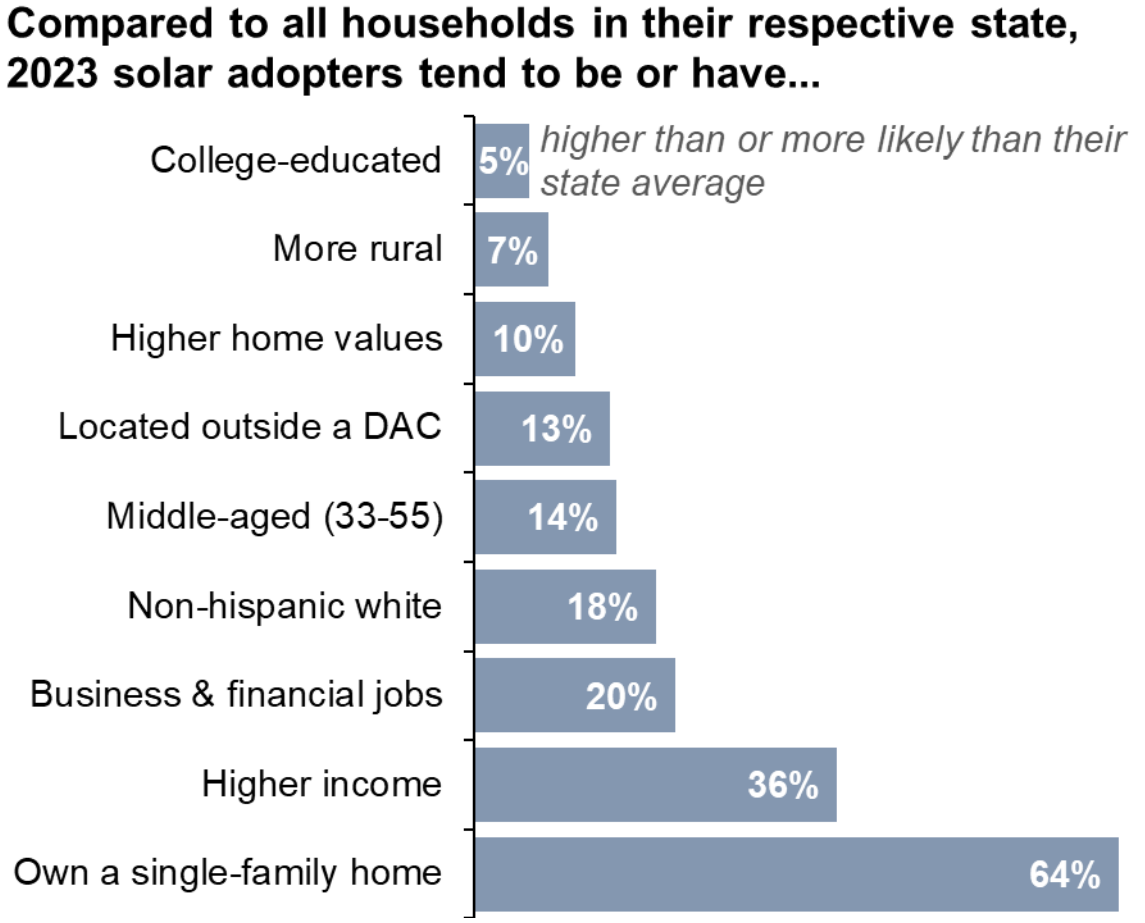
To characterize adoption equity, we can compare solar adopters to the broader U.S. population on both an absolute and a *weighted-average* basis

***Weighted averages*:** For any given attribute (e.g., race and ethnicity), take the average across all states, weighted by the number of PV adopters in each state; provides a benchmark that controls for broad geographical patterns in the U.S. PV market

** Based in most cases on the primary householder; see slide 45 for definitions and sources*

BERKELEY LAB

Summary of Solar-Adopter Socio-Economic Attributes

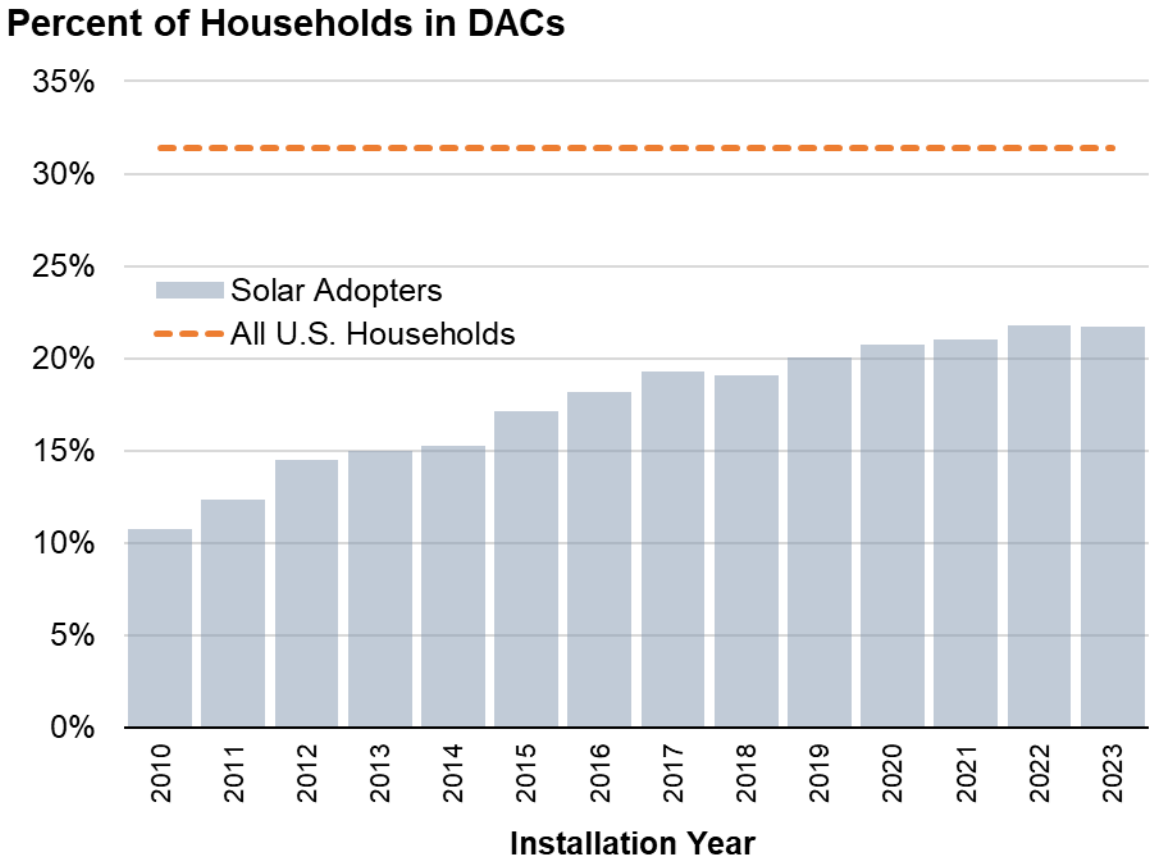


Notes: The percentages were calculated by comparing PV adopters to all households in their respective state. The only exception is home value, where, for reasons of data availability, the comparison is to all households in the same county.

- The figure shows how 2023 solar adopters compare to all HHs in their respective state
  - E.g., solar adopters are 5% more likely to be college-educated and 7% more likely to live in a rural area, compared to all households in the same state
- Though differences between solar adopters and the broader population exist across all of the attributes, in most cases they are smaller than the income skew (the one notable exception being home-ownership)
- As shown elsewhere, the skew for some attributes can differ significantly if comparing instead to only OO-HHs (particularly notable for race and ethnicity, where the directionality flips)

BERKELEY LAB

DAC Share of U.S. Solar Adoption over Time



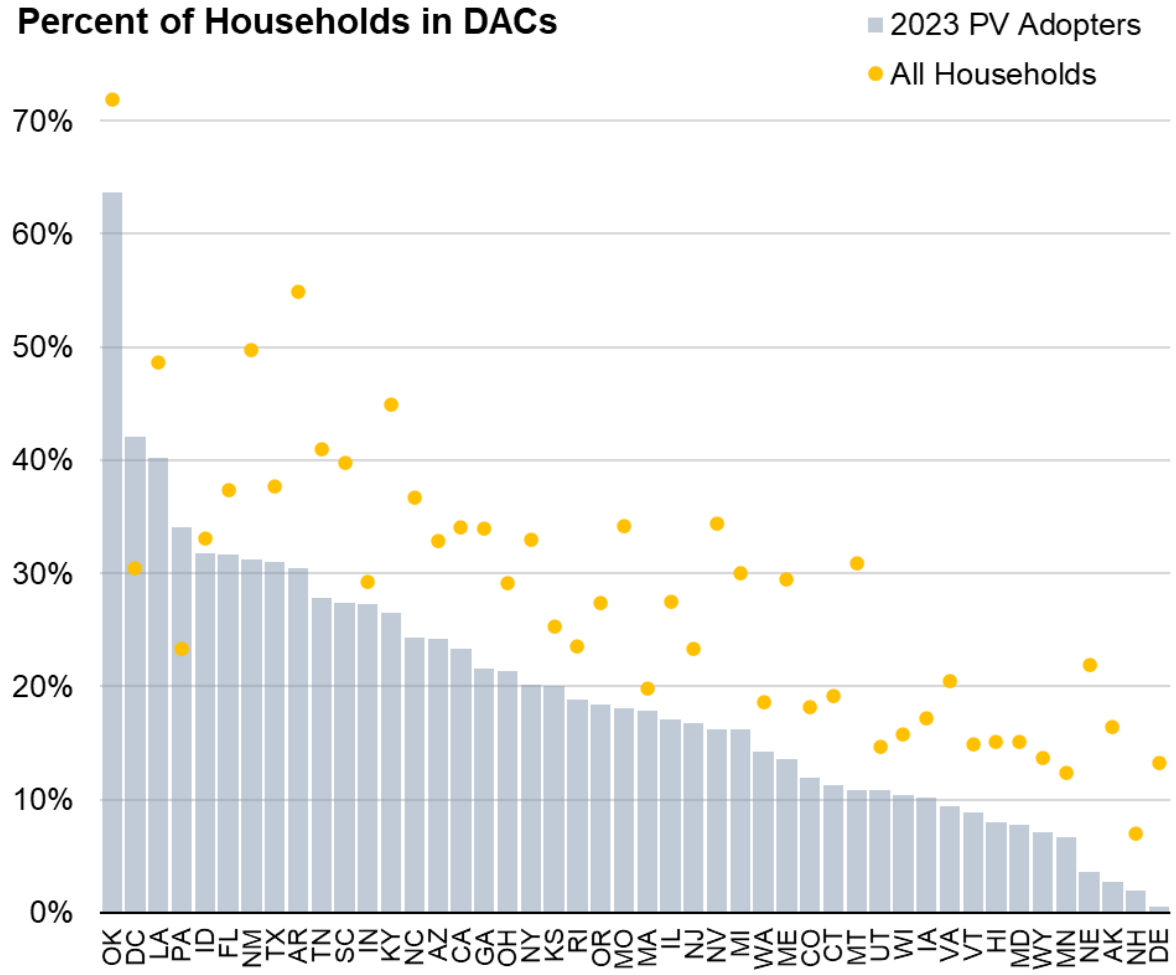
Notes: Each Census tract's DAC determination was made using the CEJST version 1.0 released November 2022. The percentage of all households in DACs was determined by summing the number of occupied dwelling units in DAC tracts versus those outside of DAC tracts using the ACS 2021 5-year survey.

The U.S. Council on Environmental Quality's Climate and Economic Justice Screening Tool (CEJST) designates "disadvantaged communities" (DACs) based on a broad set of criteria related to climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, workforce development, income, and tribes.

- Percent of PV adopters in DACs has been rising over time, from 11% in 2010 to 22% in 2023
- But DACs remain under-represented among solar adopters, relative to their overall share of all U.S. households (31% on absolute basis, or 32% if calculated as a weighted average based on PV adopter distribution across states)

BERKELEY LAB

DAC Share of Solar Adoption by State



- At the state level, the share of PV adoption in DACs varies widely, reflecting underlying differences in the share of the overall population located in DACs
- In almost all states, DACs are under-represented among PV adopters in 2023
  - On average, 9 percentage points lower than their share of the overall population
- There are exceptions where PV adopters are equally or even more-concentrated in DACs than the population at large
  - Most notably, PA and DC, where most PV adopters are located in metro areas with a large share of the population living in DACs

Notes: See previous slide for DAC definition and data source.

BERKELEY LAB

Race and Ethnicity: Notes on Data and Methodology

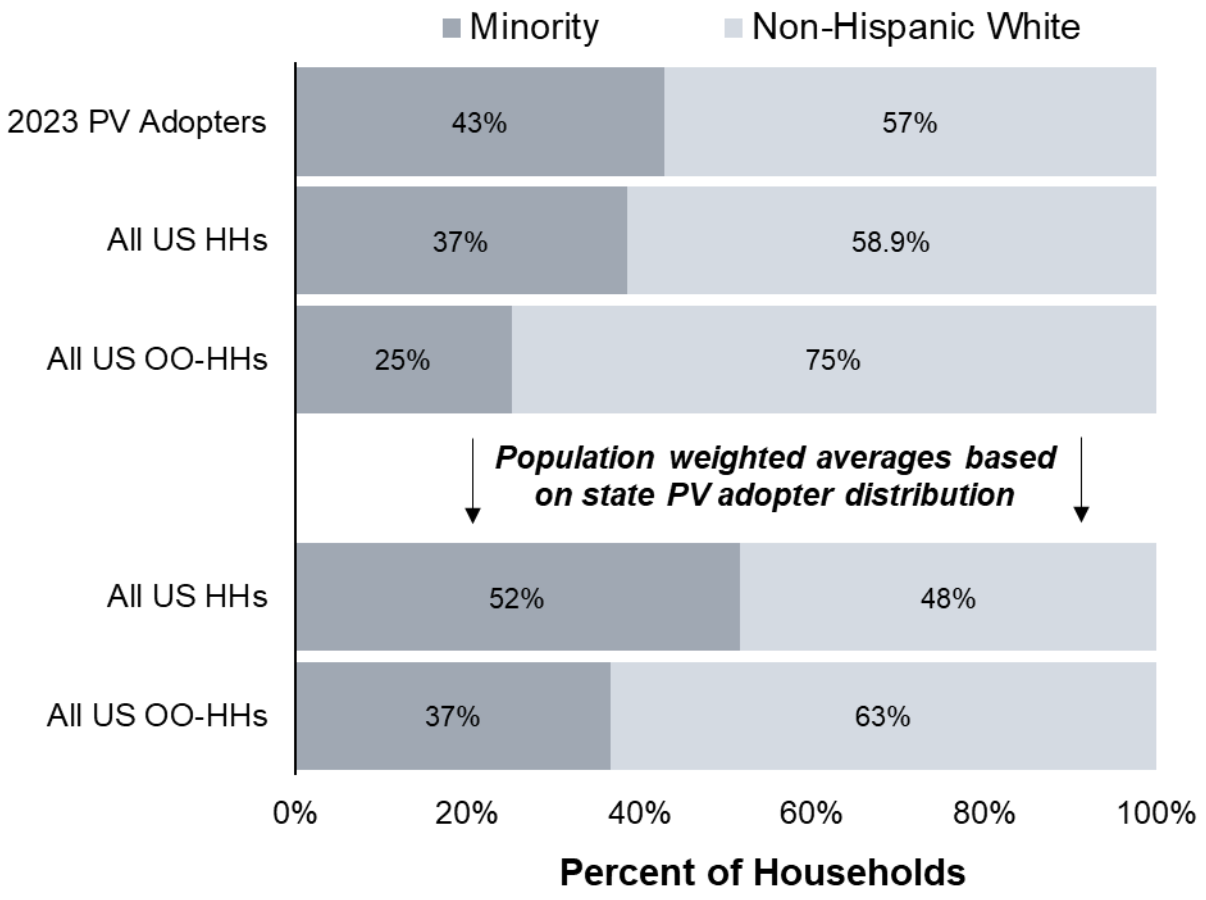
- **Race and ethnicity of PV adopters is inferred**
  - Using an open-source algorithm that predicts household race based on the household's Census block group and the name of the primary householder (Khanna et al. 2022)[1]
  - Output consists of probabilities for Hispanic and non-Hispanic White, Asian, Black, and Other; results used only if probability >50%
  - Predictions tested for ~1500 surveyed LMI PV adopters[2] and found to accurately predict reported race/ethnicity 79% of the time, but overpredicted Hispanic and underpredicted Asian and Other households
  - ***For that reason, the results focus on the binary distinction between "Non-Hispanic White" vs. "Minority"*** *(i.e., Hispanic and/or non-white)*
- Race and ethnicity of comparison populations:
  - All OO-HHs: estimated by applying the same predictive algorithm to property data obtained from CoreLogic; used this approach for consistency with PV adopters, but distribution closely resembles Census data
  - All HHs: based on US Census Data (ACS), as CoreLogic data provides surnames only for property owners, thus can't be used to infer race/ethnicity for rental property

[1] *Khanna K, Bertelsen B, Olivella S, Rosenman E, Imai K (2022). "_wru: Who are You? Bayesian Prediction of Racial Category Using Surname, First Name, Middle Name, and Geolocation_". R package version 1.0.1, <https://CRAN.R-project.org/package=wru>.*

[2] *Yozwiak et al. (forthcoming), "Residential Solar's Effect on Household Energy Insecurity among Low-to-Moderate Income Households"*

Race and Ethnicity

National comparison of PV adopters to all HHs and all OO-HHs



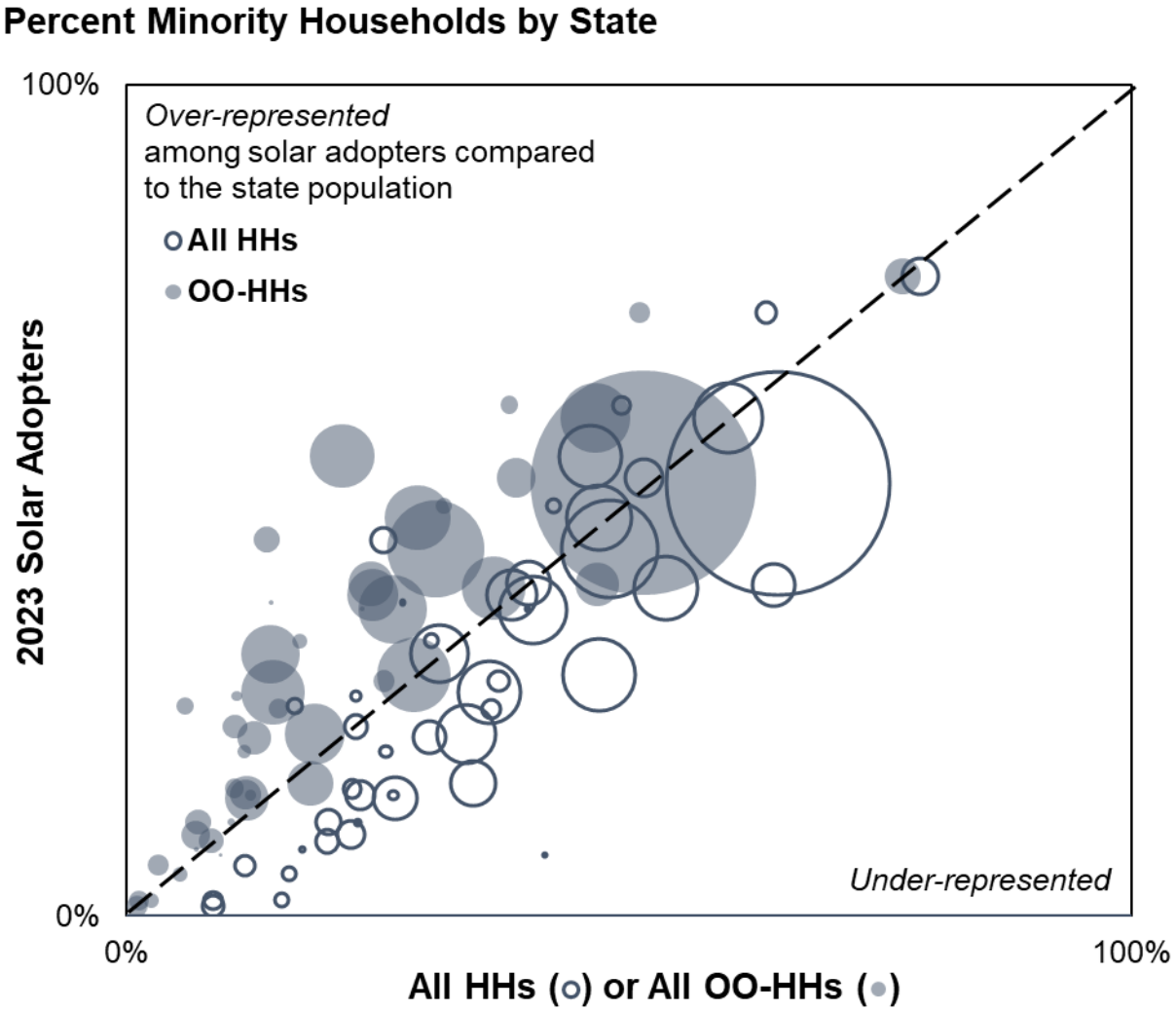
Notes: Weighted averages are calculated by taking the race/ethnicity breakdown of all HHs or all OO-HHs in each state and calculating the weighted average based on the number of PV adopters in each state (within our PV adopter dataset).

- PV adopters in 2023 had a larger Minority HH share (43%) than the general population of all U.S. HHs (37%) and OO-HHs (25%)
- Reflects broad geographical patterns where PV markets have taken hold (e.g., CA and sunbelt states with high Hispanic populations)
- When we "control" for this by comparing to a weighted average of U.S. households based on the distribution of PV adopters, adopters have a lower minority share compared to all HHs (43% vs. 52%), but still a higher Minority share when comparing to OO-HHs (43% vs. 37%)
- Results show how racial disparities in PV adoption mirror (and may partly derive from) disparities in home ownership

BERKELEY LAB

Race and Ethnicity

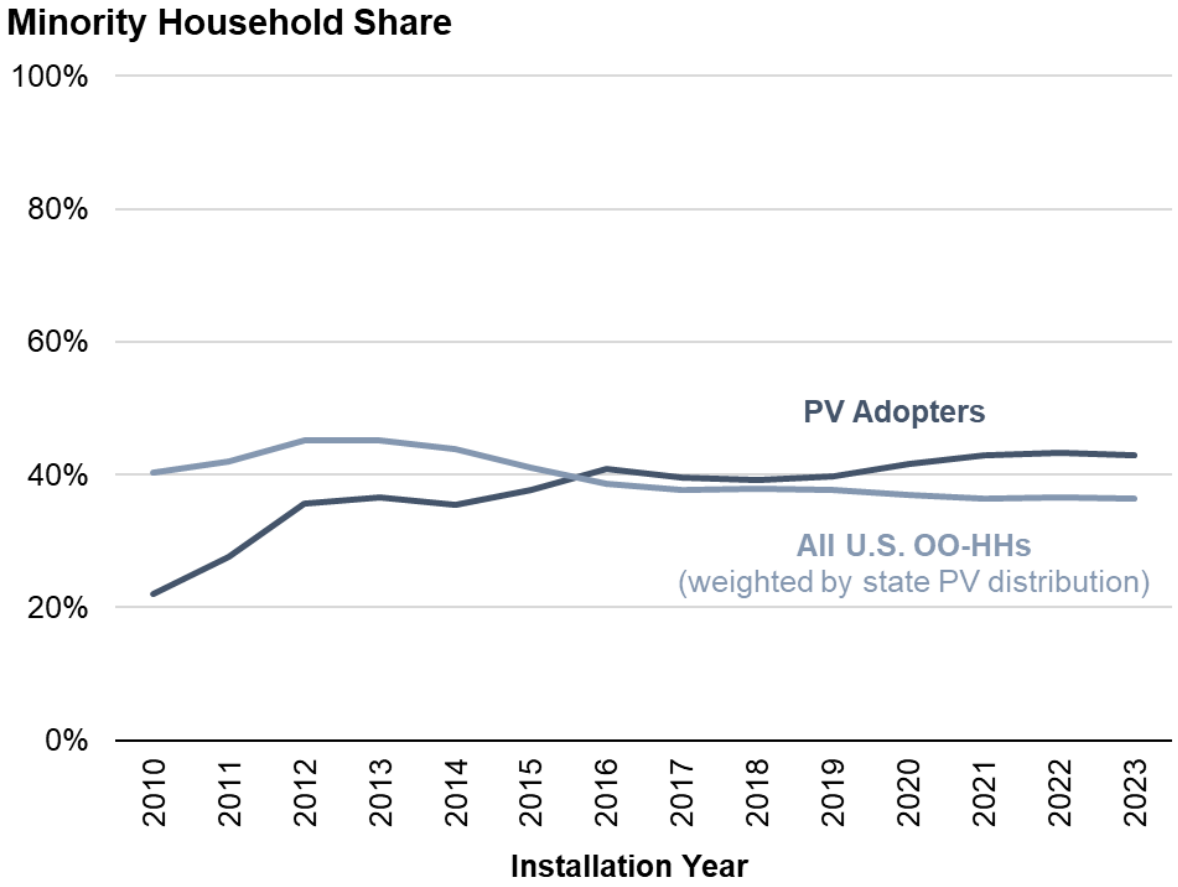
State-level comparisons: 2023 PV adopters vs. all HHs and all OO-HHs



- State level trends mirror the national trends
- Minority households are under-represented among solar adopters when comparing to all HHs in most states (the open circles)
- But the trends reverse if comparing to only OO-HHs (bubbles shift to the left), where solar adopters have *higher* minority representation than the broader population of OO-HHs in most states (solid circles)
- Results suggest that, among OO-HHs, minority households collectively have a greater propensity to adopt than non-Hispanic White households; further research would be needed to understand the specific drivers

BERKELEY LAB

Race and Ethnicity:
National trends over time

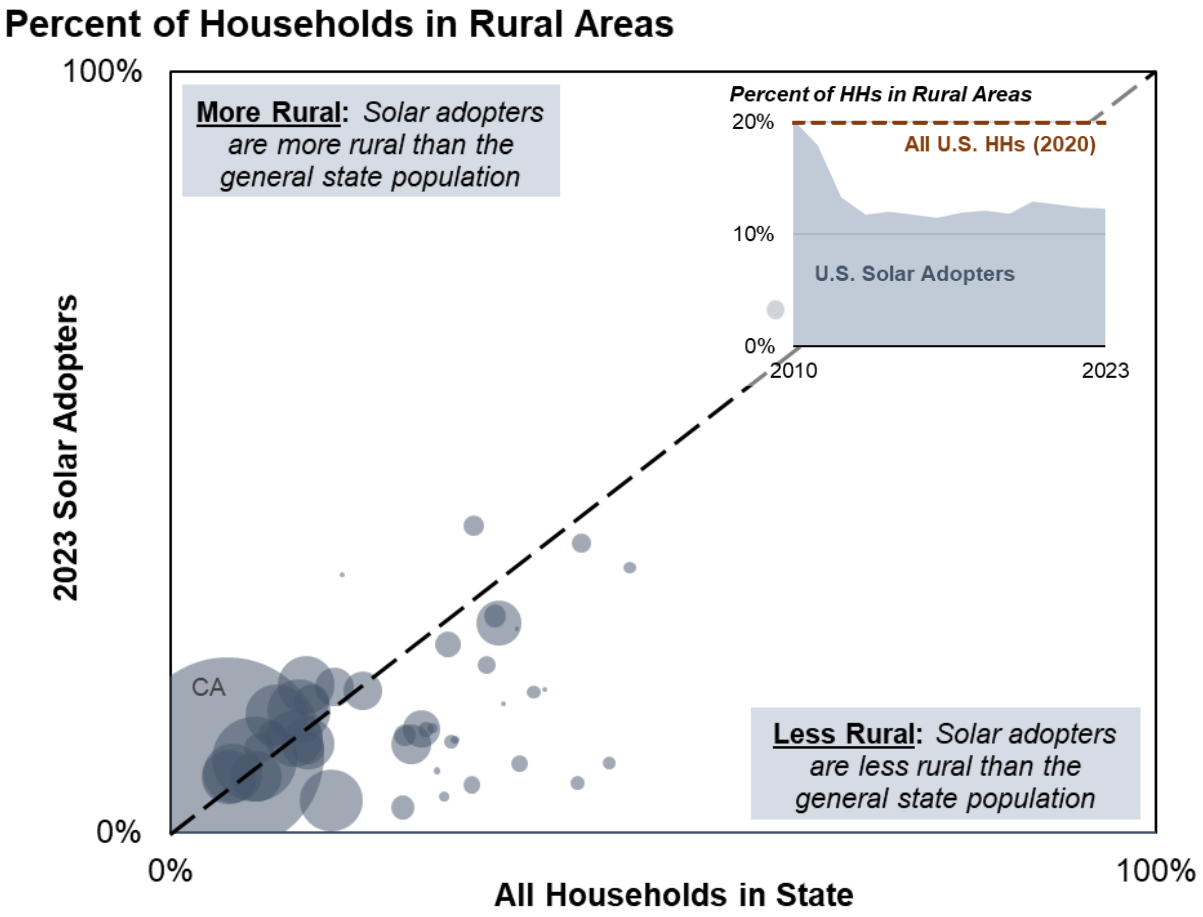


Notes: The line for All U.S. OO-HHs is calculated by taking the race/ethnicity breakdown of all OO-HHs in each state and calculating the weighted average based on the number of PV adopters in each state in each year.

- Nationally, PV adoption has been shifting toward greater representation among minority households over time
  - A rather dramatic uptick from 2010-2012, followed by a slow but steady upward trend
- In contrast, the benchmark weighted average minority share of all U.S. OO-HHs has been relatively flat since 2016
  - In other words, PV markets have *not* been shifting systematically towards states with either higher or lower minority shares of OO-HHs
  - The steady growth in the minority share of PV adopters therefore is not obviously the result of larger geographical shifts in PV markets; other factors are likely at play

Rural vs. Urban

State comparisons and national trends over time

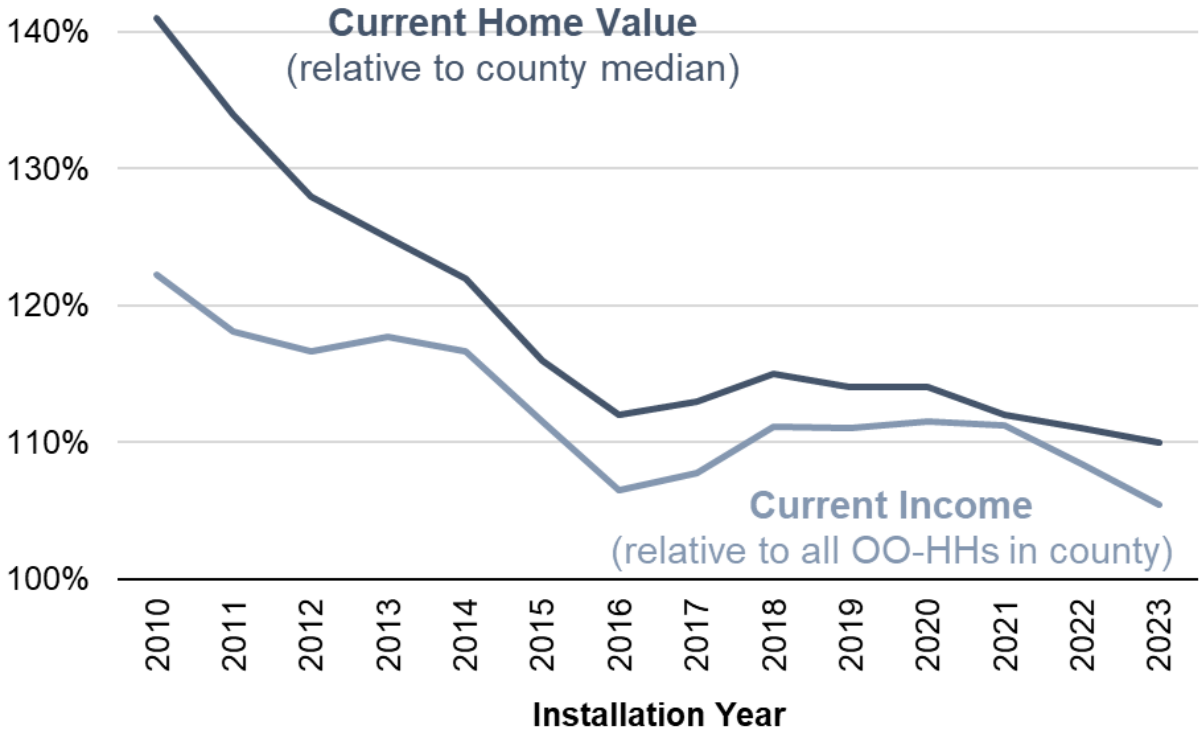


- Nationally, solar adoption is concentrated in less rural states, most notably California
- As a result, U.S. solar adopters are less rural overall (12% of 2023 adopters) than the U.S. as a whole (20% of all households)—see insert
- However, at the individual state level (bubble plot), solar adopters may be either *more* or *less* rural than their respective state population
- On a weighted average basis, PV adoption tends to be slightly more rural than the distribution of households at the state level

Notes: Urban/rural classification is based on the 2020 US Census definitions, which rely on population density and land use, among other factors.

Home Value

Median Solar-Adopter Current Home Value and Current Income
(% of current county median)

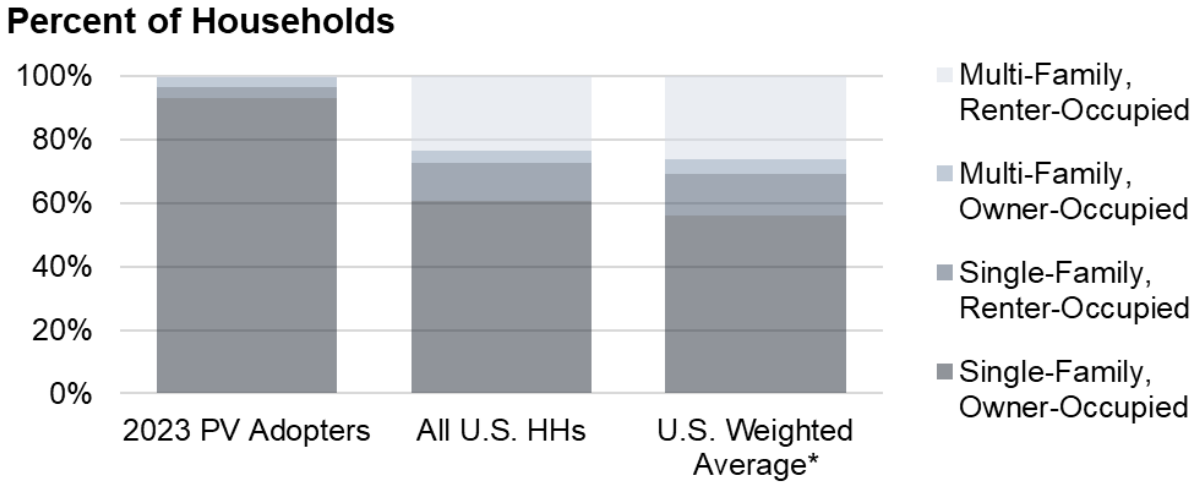


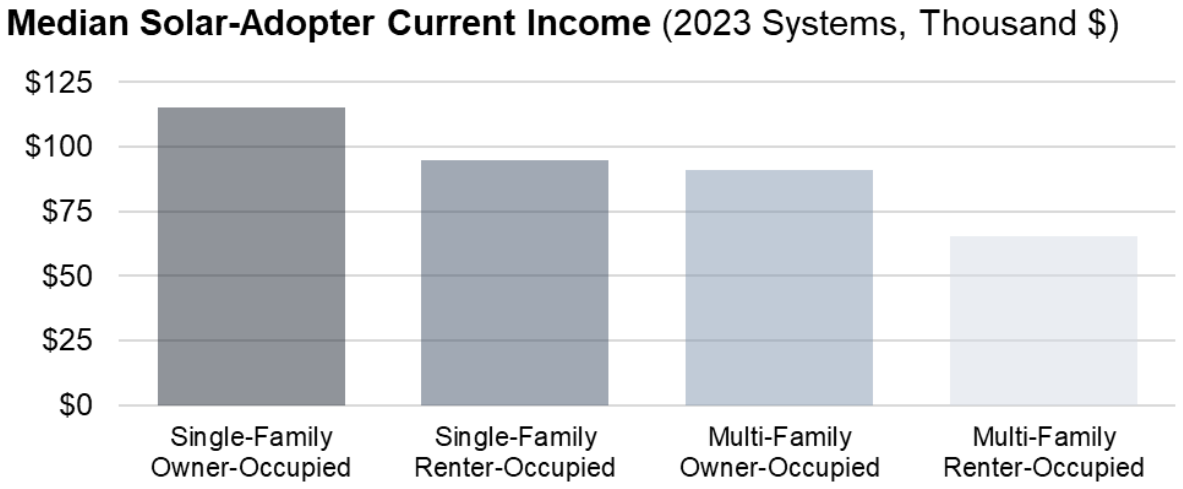
Notes: As with the income estimates, the home value estimates also refer to current values, not the value at the time of solar installation. As such, the skew in solar adopter home values may partly reflect the effect of solar installations on home value.

- Home value provides an indicator of household *wealth*, as distinct from income—albeit only for households that own their home (and only for the household's equity in the home)
- Solar-adopter home value data are expressed as a percentage of the respective county median, similar to our relative income metric
- Solar-adopter home values are generally higher than others in the same county, but that skew has declined substantially over time, largely tracking income trends
- The skew in solar-adopter home value is more pronounced than for income, suggesting that income could be a weaker contributor to adoption inequities than broader differences in household wealth (beyond the threshold factor of home ownership)

BERKELEY LAB

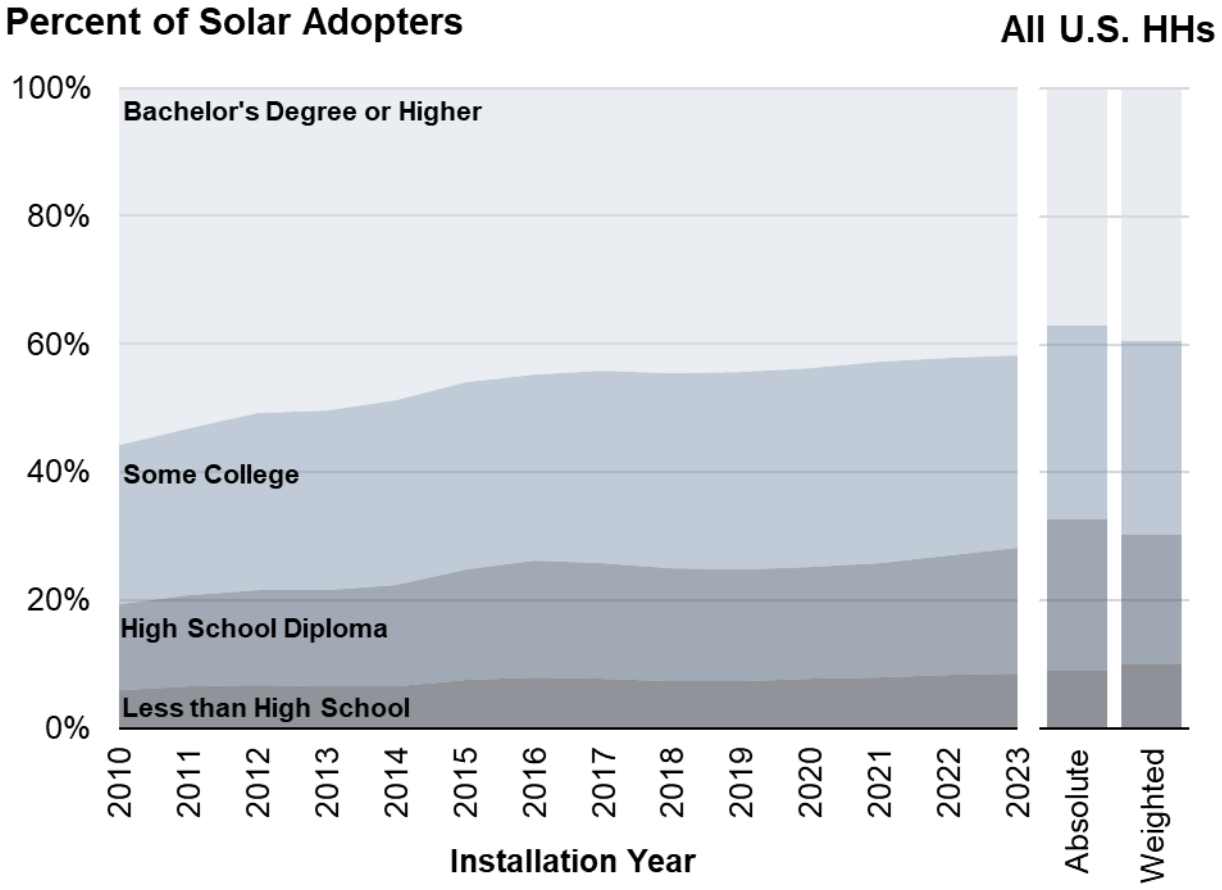
Housing Type and Tenure





- The vast majority (96%) of 2023 PV systems were installed on owner-occupied homes
  - Of this share, 97% are on single family, detached homes, and the remaining 3% are on multi-family homes
  - A large portion of those multi-family systems are on condos and small multi-family units (duplexes, triplexes, etc.)
- The remaining 4% of installations are on renter-occupied homes, of which the vast majority (89%) are on single-family homes
- As to be expected, incomes are lower for solar adopters (in this case referring to the occupants) who are renters and/or live in multi-family housing

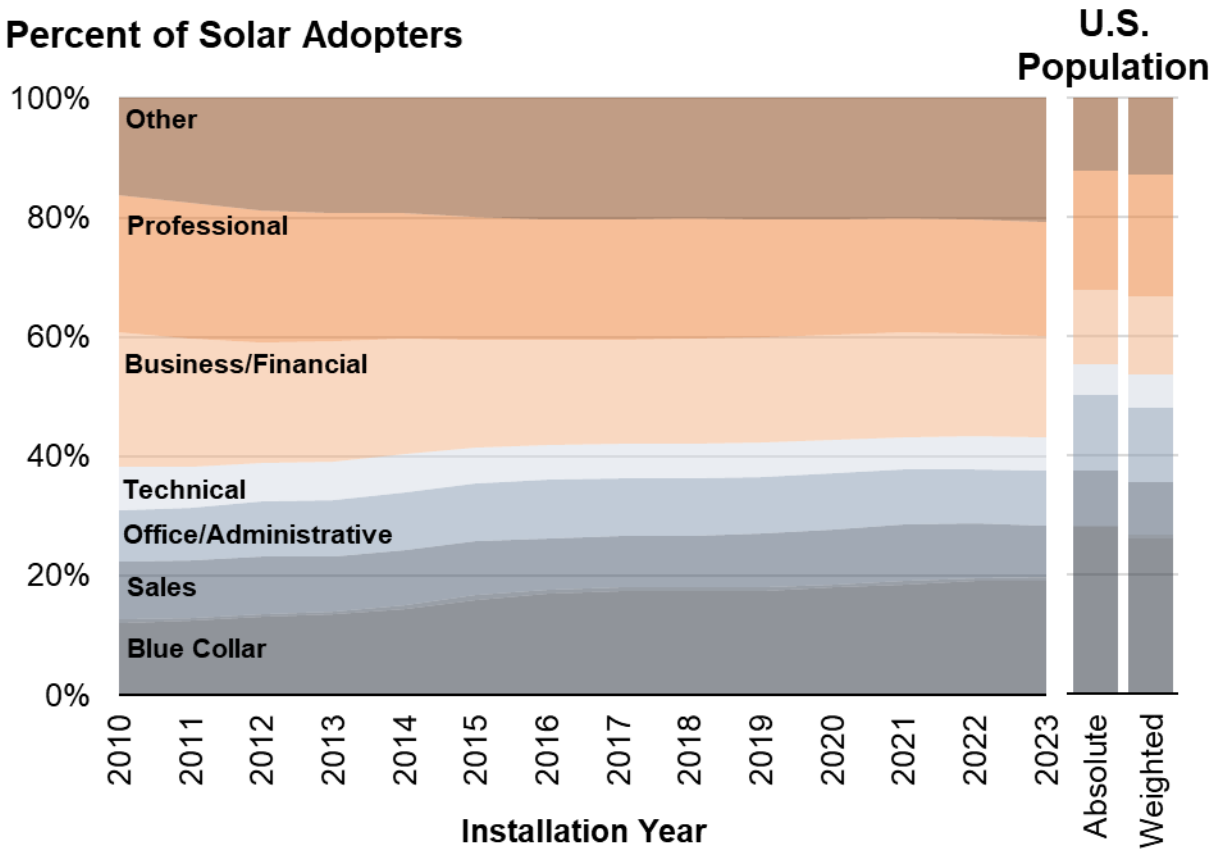
Education Level



Notes: Education level for each solar adopter is based on the highest current education level among adult household members. For the U.S., it is based on the householders' education level. See earlier notes for explanation of weighted average values.

- Solar adopters in 2023 had slightly higher educational levels than the broader population
  - 42% have a bachelor's degree or higher, compared to 37% of all U.S. HHs (or 40% on a weighted average basis)
- That skew has significantly diminished over time: e.g., 56% of 2010 solar adopters have a bachelors degree
- As with some of the other trends we've seen, much of that shift occurred in the early years of the period shown; the trend since 2015 has been more gradual

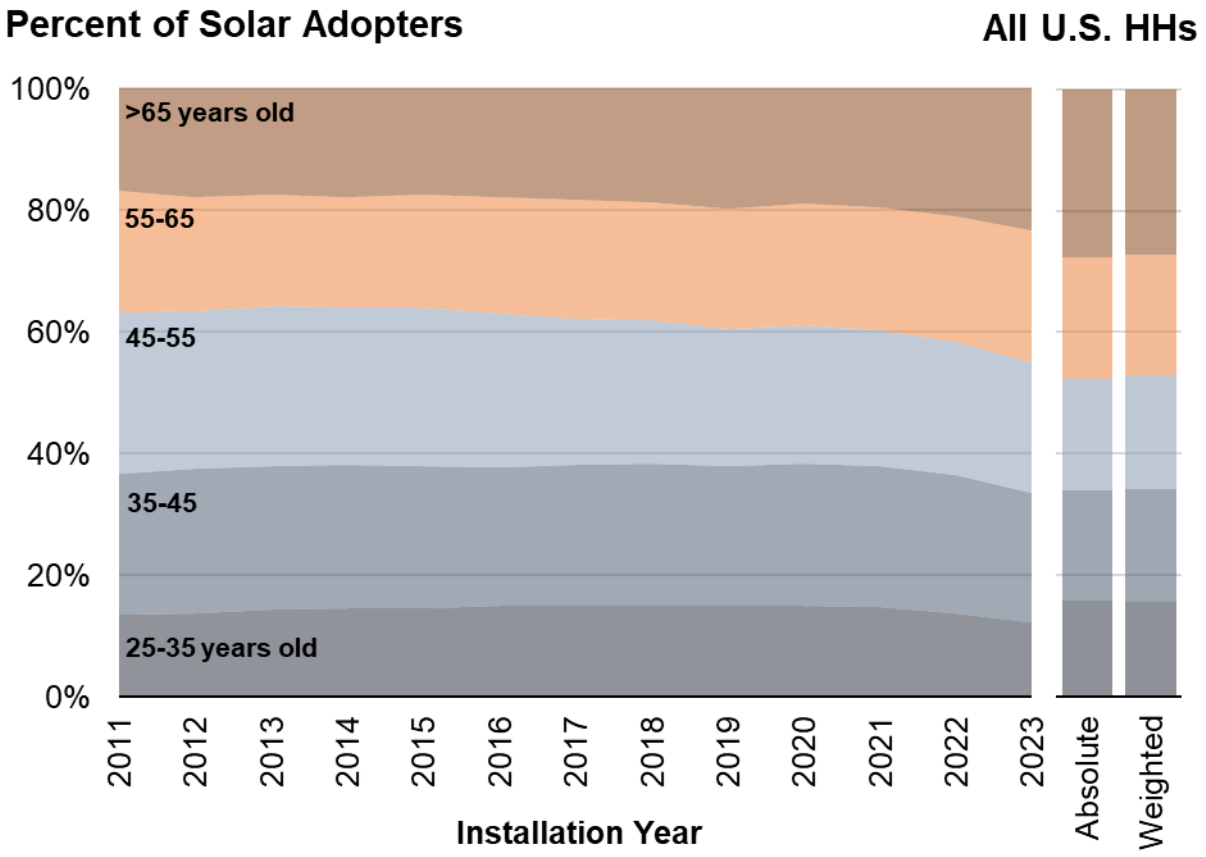
Occupation



- Similar shares of 2023 solar adopters came from professional, business & financial, and blue-collar occupational categories as well as the catch-all “other” category
- Compared to the broader U.S. population, solar adopters are over-represented by business/financial occupations and under-represented by blue collar occupations
- As with other trends, that skew has diminished greatly over time, as the blue-collar share of solar adopters has grown from 12% in 2010 to 19% in 2023

Notes: Occupation statistics for solar adopters are based on all adult household members and reflect current occupations. Statistics for U.S. population are based on data from the U.S. Bureau of Labor Statistics, mapped to Experian’s occupational categories. Comparison excludes retirees. See earlier notes for explanation of weighted average values.

Age at the Time of Adoption



Notes: Ages for solar adopters are based on the primary household member, adjusted to reflect age at the time of adoption, and for the U.S. population are based on the householder. See earlier notes for explanation of weighted average values.

- Solar adopters are under-represented among the youngest (25-35) and oldest (65+) age groups
- For the youngest group, this likely reflects lower home ownership rates and incomes
- Trends are fairly stable over time, though the share of adopters within the oldest age group (65+) has risen, especially since 2021
- Increasing adoption by the oldest group (mostly retirees) is consistent with growing technology acceptance (less perceived risk), and greater availability of financing (key for individuals on fixed-incomes), though may also increase risks of predatory marketing

Conclusions

Conclusions

- Solar adopters are heterogeneous in terms of their income and demographics
- Solar adopters diverge from the general U.S. population, skewing, for example, toward higher income, Non-Hispanic White, and more educated households
- Those differences are considerably smaller (and in some cases reverse direction) if comparing to only owner-occupied households, which may be the more relevant point of comparison in some contexts
- Data through 2023 generally show that these differences are continuing to diminish over time, as a result of both a broadening and deepening of the U.S. residential solar market
- Differences between solar adopters and the general population also vary considerably across states, in some cases suggestive of policy-related factors

Appendix

Key Experian Data Elements Used in this Analysis

- **Estimated Household Income**: The total estimated income for a living unit, incorporating several highly predictive individual and household level variables. The income estimation is determined using multiple statistical methodologies to predict the income estimate for the living unit.
- **Dwelling Type:** Each household is assigned a dwelling type code based on United States Postal Service (USPS) information; could be either Single Family Dwelling Units, Multi-Family, Marginal Multi Family, P.O. Boxes, or Unknown.
- **Household Size:** The total number of people on the record, includes count for children, adults.
- **Individual Education:** Compiled from self-reported surveys, derived based on occupational information, or calculated through the application of predictive models.
- **Occupation Group:** Compiled from self-reported surveys, derived from state licensing agencies, or calculated through the application of predictive models.
- **Date of Birth/Combined Adult Age:** Date of Birth is acquired from public and proprietary files. These sources provide, at a minimum, the year of birth. The birth month is provided where available. Estimated ages are acquired from proprietary data sources and Experian models which estimate the adult age.
- **Estimated Current Home Value:** Predicts the current home value. Integrates market-specific data sources that include the most current, complete and relevant home value information available. In addition to public record data, such as deed data, the model will consider all available market information including recent sales and property listings.

Further Details on Experian Income Estimation

The estimated household income model incorporates several highly predictive individual and household level variables to provide accurate estimates for each living unit. Using multiple statistical techniques, the models predicts total estimated household income and assigns each living unit to one of twelve income ranges and income in thousands.

Estimated Income Model Development

To create an optimal solution the income model is based on the most up to date multivariate modeling techniques. For validation, in addition, to utilizing hold out samples from the model target universe, other internal resources were tested to ensure the models accuracy on a variety of populations. Resources include but are not limited to de-identified financial data, syndicated research panels and census data. Significant predictors of the Income include ConsumerView household and individual demographics, housing attributes, transactional purchase data, self-reported and geo level data such as census and IRS salary bands.

The percentage of households that the model predicts accurately was determined overall and at various income cut points. Multiple statistical tests were performed to assess the overall fit of the model.

1. Comparing the income estimates to the income provided by syndicated research
2. Comparing the distribution of ConsumerView households across the estimated income categories to the income distributions reported by the Census at various geo-levels.

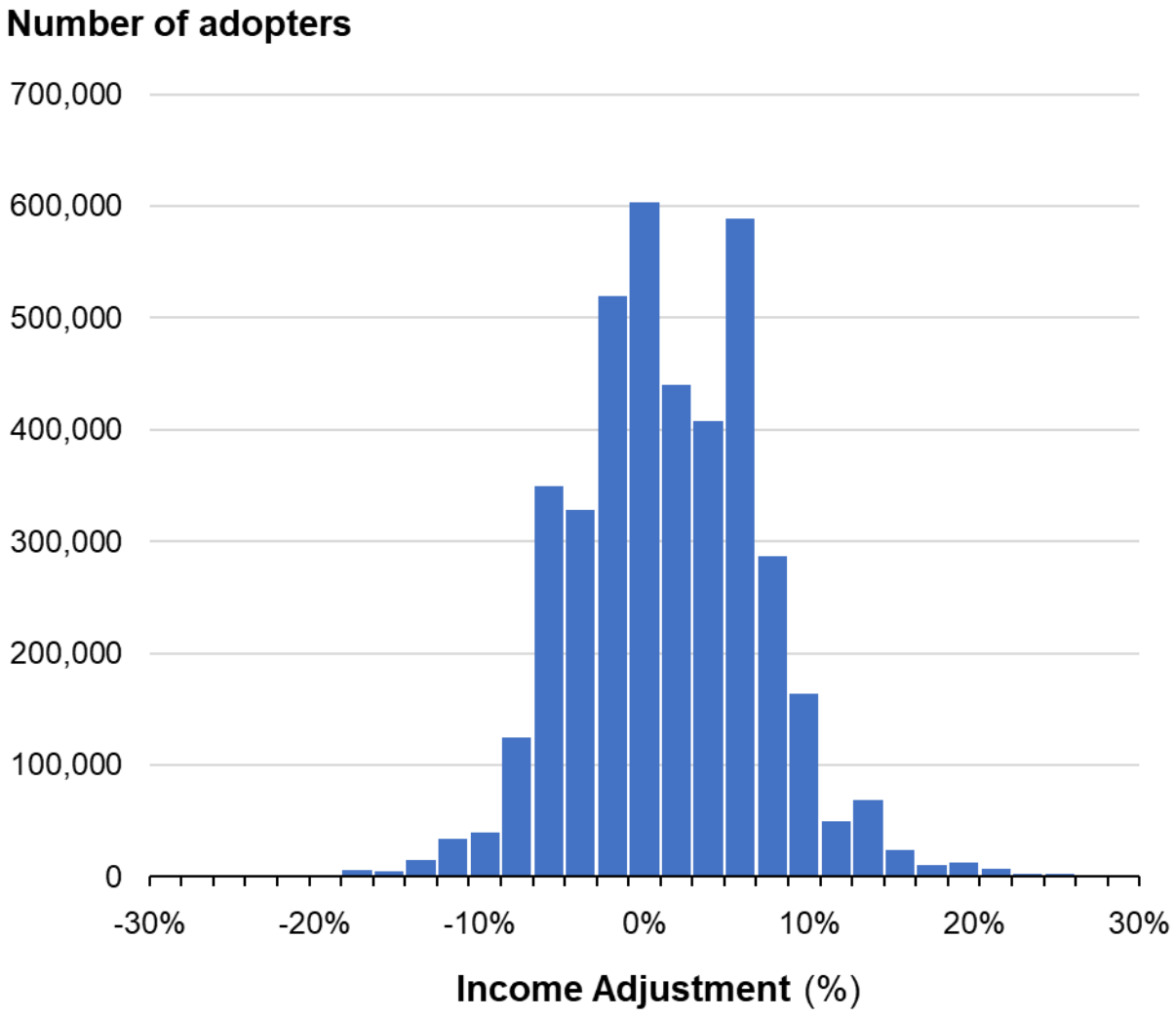
ConsumerView Income distributions closely align with national Census distributions, though adjustments are made (see next slide)

Calibration of Experian Income Estimates

- Throughout the analysis, we compare solar-adopter income estimates from Experian to population-level income data from the Census
- In order to improve the internal consistency in those comparisons, we re-calibrate the Experian income estimates
- We perform this calibration using Experian's modeled income estimates for all households within each county, where the adjustment for solar adopter (i) in county (C) equals:

$$Adjustment_{i,C} = \frac{CensusMedianIncome_C}{ExperianMedianIncome_C} - 1$$

- This percentage adjustments is then applied to the Experian income estimate for adopter (i)



Key Public Data Elements Used in this Analysis

- **U.S. Census American Community Survey 5-Year Data (2018-2022):**
  - Median household income in the past 12 months (Table B25119);
  - Median household income (B19013);
  - Tenure by household income (Table B25118);
  - Hispanic or Latino origin by race – population (Table B03002);
  - Educational attainment by householder (Table B25013);
  - Age of householder (Table B25007)
- **U.S. Census 2020** Urban-rural classification: Rural and urban populations by state; and definition by latitude/longitude for classification of solar adopters
- **Bureau of Labor and Statistics:** Occupational Employment Statistics Survey, March 2024
- **U.S. Climate and Economic Justice Screening Tool (CEJST):** Disadvantaged Communities (DACs), November 2022

State Sample Sizes (filtered): *TTS=Tracking the Sun, BZ=BuildZoom, Ohm=Ohm Analytics; Market Coverage based on comparison to Wood Mackenzie's Solar Market Insight report*

State	All Years				2023 Installations			
	TTS	Ohm & BZ	Total	Market Coverage	TTS	Ohm & BZ	Total	Market Coverage
AK	1,017	0	1,017	43%	112	0	112	25%
AL	0	55	55	36%	0	17	17	100%
AR	89	4,633	4,722	35%	0	1,141	1,141	29%
AZ	44,388	157,564	201,952	71%	8,018	20,715	28,733	74%
CA	1,730,523	122,600	1,853,123	95%	237,140	24,649	261,789	93%
CO	0	120,802	120,802	82%	0	18,989	18,989	62%
CT	71,563	16,207	87,770	92%	17,566	4,056	21,622	100%
DC	12,123	2,940	15,063	100%	1,135	1,254	2,389	100%
DE	597	1,629	2,226	21%	166	9	175	12%
FL	11,596	217,983	229,579	97%	1,888	47,383	49,271	95%
GA	0	9,210	9,210	74%	0	1,733	1,733	68%
HI	21,838	71,622	93,460	85%	945	6,057	7,002	71%
IA	0	5,240	5,240	43%	0	1,150	1,150	31%
ID	0	18,527	18,527	88%	0	3,190	3,190	69%
IL	50,998	11,962	62,960	83%	18,378	6,002	24,380	94%
IN	0	3,088	3,088	36%	0	561	561	45%
KS	0	3,153	3,153	55%	0	938	938	45%
KY	0	4,057	4,057	69%	0	1,439	1,439	84%
LA	0	16,952	16,952	65%	0	1,305	1,305	100%
MA	129,821	35,025	164,846	99%	4,132	13,461	17,593	100%
MD	0	91,081	91,081	87%	0	7,961	7,961	87%
ME	10,518	469	10,987	99%	2,254	261	2,515	100%
MI	0	6,054	6,054	29%	0	625	625	19%
MN	1,102	19,385	20,487	98%	0	4,290	4,290	95%
MO	0	9,993	9,993	29%	0	2,000	2,000	21%
MS	0	0	0	0%	0	0	0	0%

State	All Years				2023 Installations			
	TTS	Ohm & BZ	Total	Market Coverage	TTS	Ohm & BZ	Total	Market Coverage
MT	0	3,642	3,642	68%	0	1,176	1,176	59%
NC	46,457	14,706	61,163	99%	9,100	4,791	13,891	100%
ND	0	24	24	51%	0	0	0	0%
NE	0	1,383	1,383	61%	0	302	302	48%
NH	8,986	3,828	12,814	69%	643	1,783	2,426	47%
NJ	175,772	5,264	181,036	98%	19,656	2,450	22,106	99%
NM	42,453	13,953	56,406	96%	7,205	2,535	9,740	100%
NV	107,174	6,304	113,478	95%	19,707	1,503	21,210	98%
NY	125,676	26,556	152,232	78%	16,633	4,523	21,156	77%
OH	2,930	9,891	12,821	68%	217	2,811	3,028	63%
OK	0	5,179	5,179	48%	0	2,038	2,038	37%
OR	30,114	19,594	49,708	93%	4,490	5,712	10,202	87%
PA	5,920	17,442	23,362	36%	0	3,515	3,515	23%
RI	21,009	2,612	23,621	99%	5,214	762	5,976	100%
SC	0	25,234	25,234	76%	0	2,413	2,413	56%
SD	0	39	39	25%	0	6	6	10%
TN	0	1,741	1,741	64%	0	158	158	100%
TX	1,504	158,840	160,344	59%	0	25,680	25,680	48%
UT	30,495	22,581	53,076	74%	3,073	1,671	4,744	68%
VA	9,529	37,849	47,378	92%	0	10,330	10,330	91%
VT	20,502	3,308	23,810	99%	1,450	446	1,896	100%
WA	7,114	40,007	47,121	88%	0	10,948	10,948	100%
WI	11,942	2,302	14,244	91%	2,292	1,213	3,505	100%
WV	0	1	1	0%	0	0	0	0%
WY	0	892	892	39%	0	154	154	37%
Total	**2,733,750**	**1,373,403**	**4,107,153**	**87%**	**381,414**	**256,106**	**637,520**	**83%**

BERKELEY LAB

Sample Sizes (filtered) by Analysis Element

Vary depending on data availability and unit of observation

Analysis Element	Unit of Observation	Sample Size	
		2023	All Years
Income	Household	637,506	4,106,682
TPO vs. host-owned	Household	956,443	2,385,345
Installer name	Household	244,619	n/a
With or without storage	Household	581,211	n/a
Multi- vs. single-family	Household	661,326	n/a
Home Value	Household	631,657	4,074,348
Education	Household	637,506	4,106,682
Occupation	Individuals	1,524,141	10,371,778
Urban vs. Rural	Individuals	1,913,647	13,093,301
Race/Ethnicity	Household	504,832	2,910,036
Age	Household	388,182	2,645,889

General Notes:

- All elements of the study *combine* single and multifamily households
- The unit of observation for most analysis elements is the household, but for several elements (occupation and urban vs. rural), data for the overall U.S. population are available only at the individual level. In those cases, solar-adopter summary statistics are based on all individuals in each household in order to allow for comparison to the U.S. population.
- Analysis elements related to TPO, installer name, and battery storage are based almost entirely on solar adopter addresses from Tracking the Sun

Contacts

Sydney Forrester: spforrester@lbl.gov, (510) 486-4123
Galen Barbose: glbarbose@lbl.gov, (510) 495-2593
Eric O'Shaughnessy: eoshaughnessy@lbl.gov, (720) 381-4889
Naïm Darghouth: ndarghouth@lbl.gov, (510) 486-4570

For more information

Download publications from the Electricity Markets & Policy Group: https://emp.lbl.gov/publications
Sign up for our email list: https://emp.lbl.gov/mailing-list
Follow the Electricity Markets & Policy Group on Twitter: @BerkeleyLabEMP

Acknowledgements

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number 38444 and Contract No. DE-AC02-05CH11231. We would like to especially thank Ammar Qusaibaty, Kimberly Shields, Juan Botero, Michele Boyd, and Garrett Nilson for their support of this work.