Residential Solar-Adopter Income and Demographic Trends: 2024 Update

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   - Low-to-moderate income shares of adopters
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Overview

Describes income and demographic trends among U.S. residential "onsite" 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

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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

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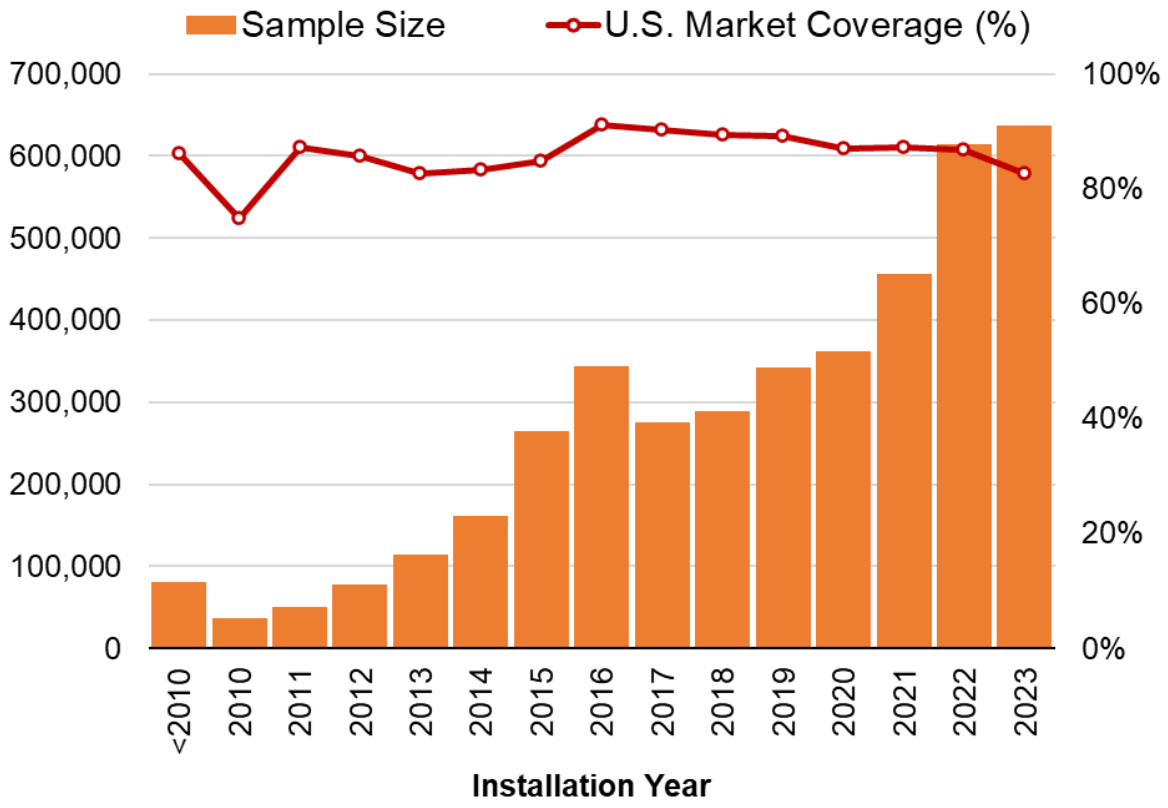
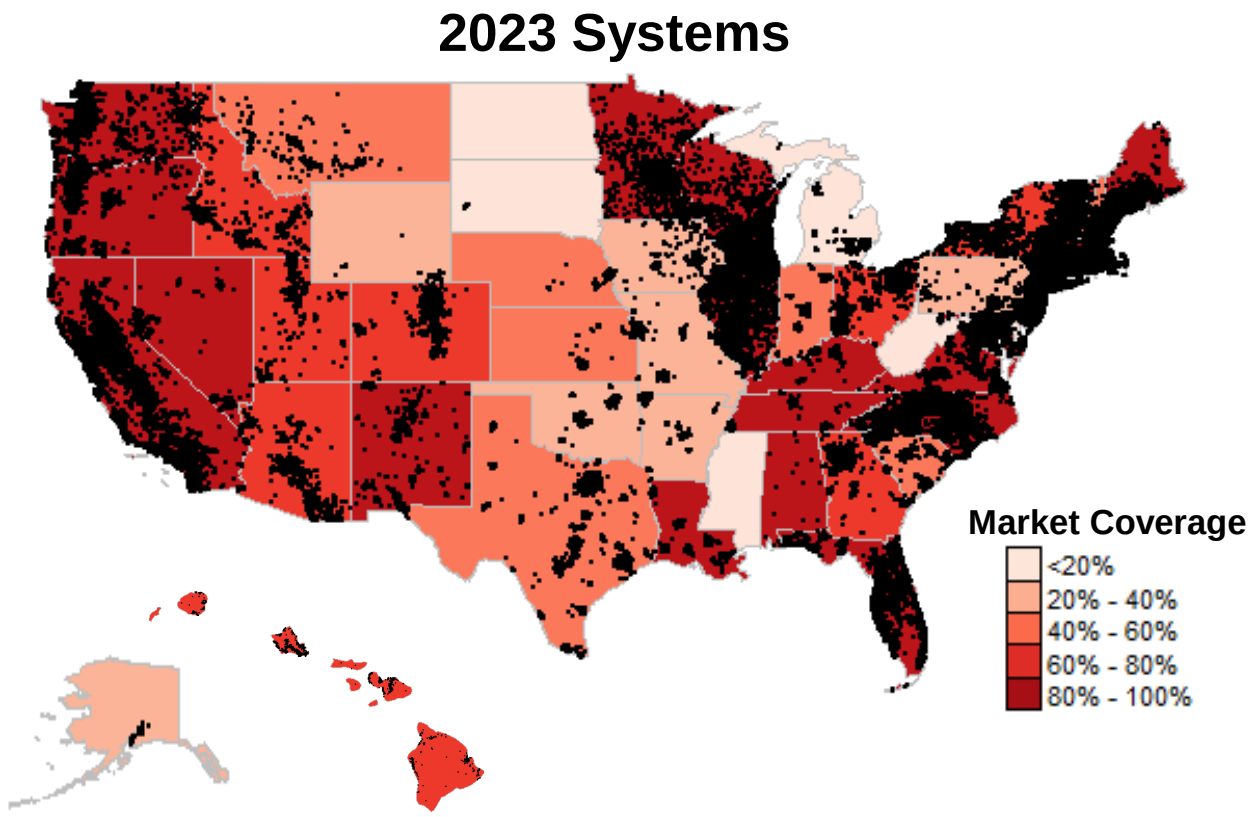
Sample Coverage

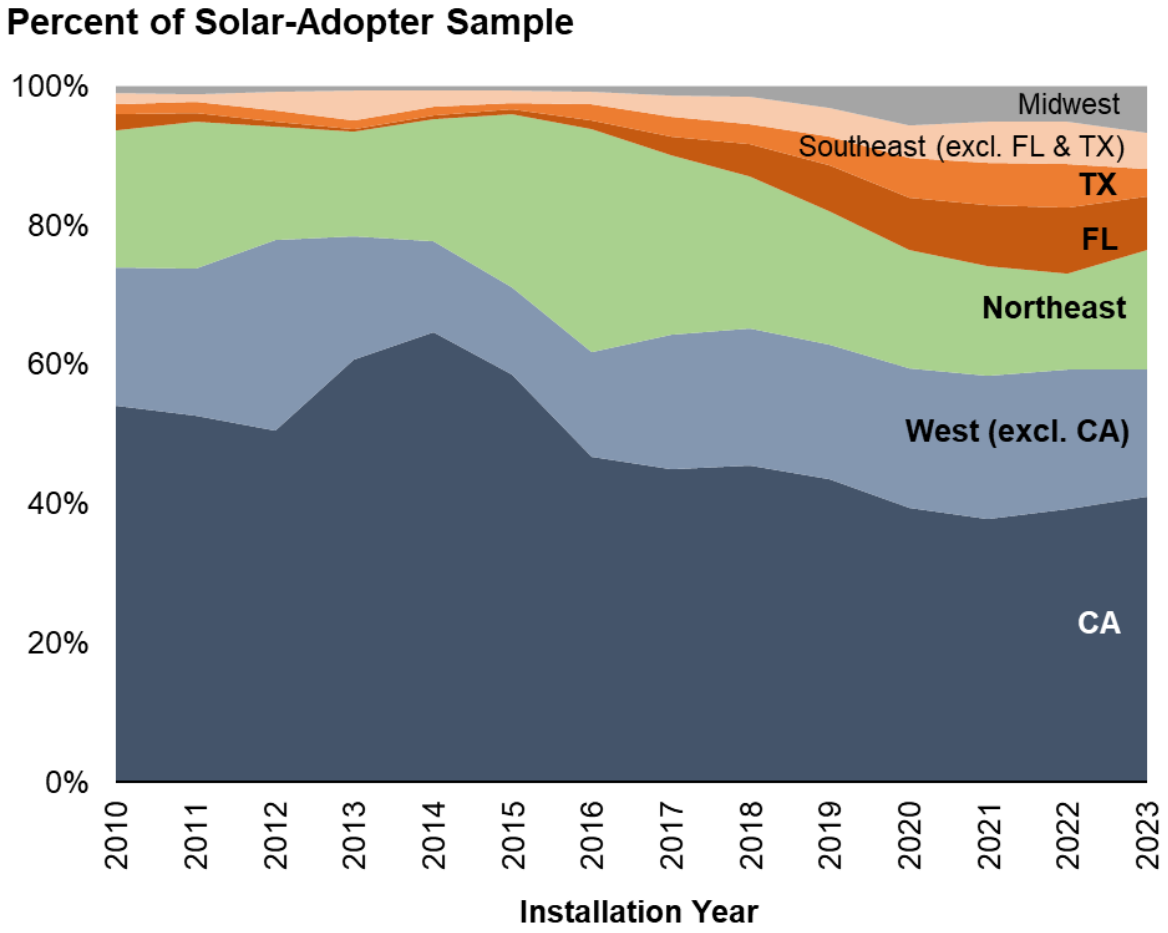




- Our sample consists of over **4.1M systems**, covering roughly **87%** of all U.S. residential systems through 2023 and **83%** of systems installed in 2023
- State-level market coverage varies widely, but is over 40% in most states for 2023

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 over time reflect changes in the broader PV market, as well as changes in state-level sample coverage
- CA and Northeastern states' shares of the sample have generally declined over time, though both ticked upward in 2023
- FL, TX, and other SE states have all grown in their sample share over time, though shrunk slightly in 2023

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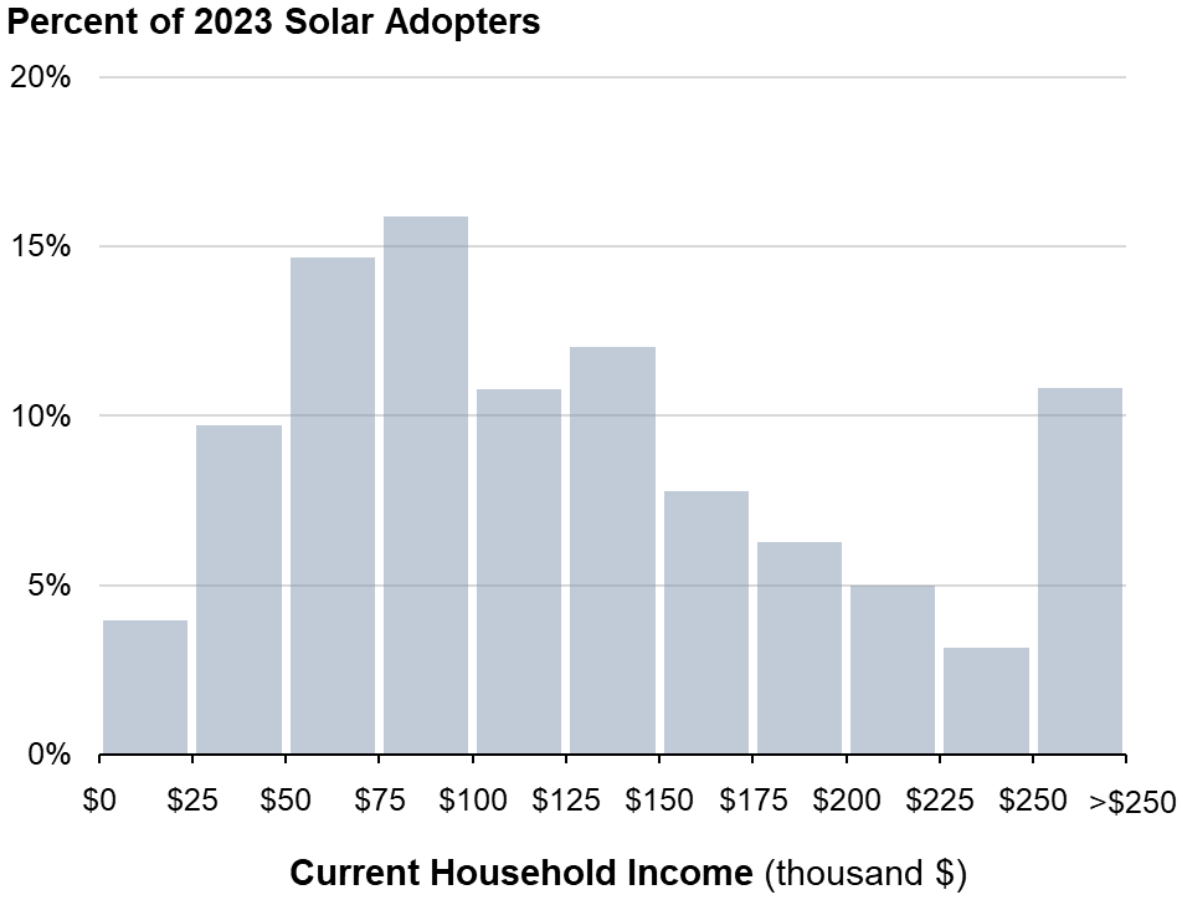
Key Points on Data and Methods

- We focus here on **national and state-level trends**, with an emphasis on PV systems installed from 2010-2023
- Data at the county- and Census tract-level trends, as well as data for earlier years, are available through Berkeley Lab's online solar demographics tool
- **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 report for details
- See full report for further details

Solar-Adopter Income Trends

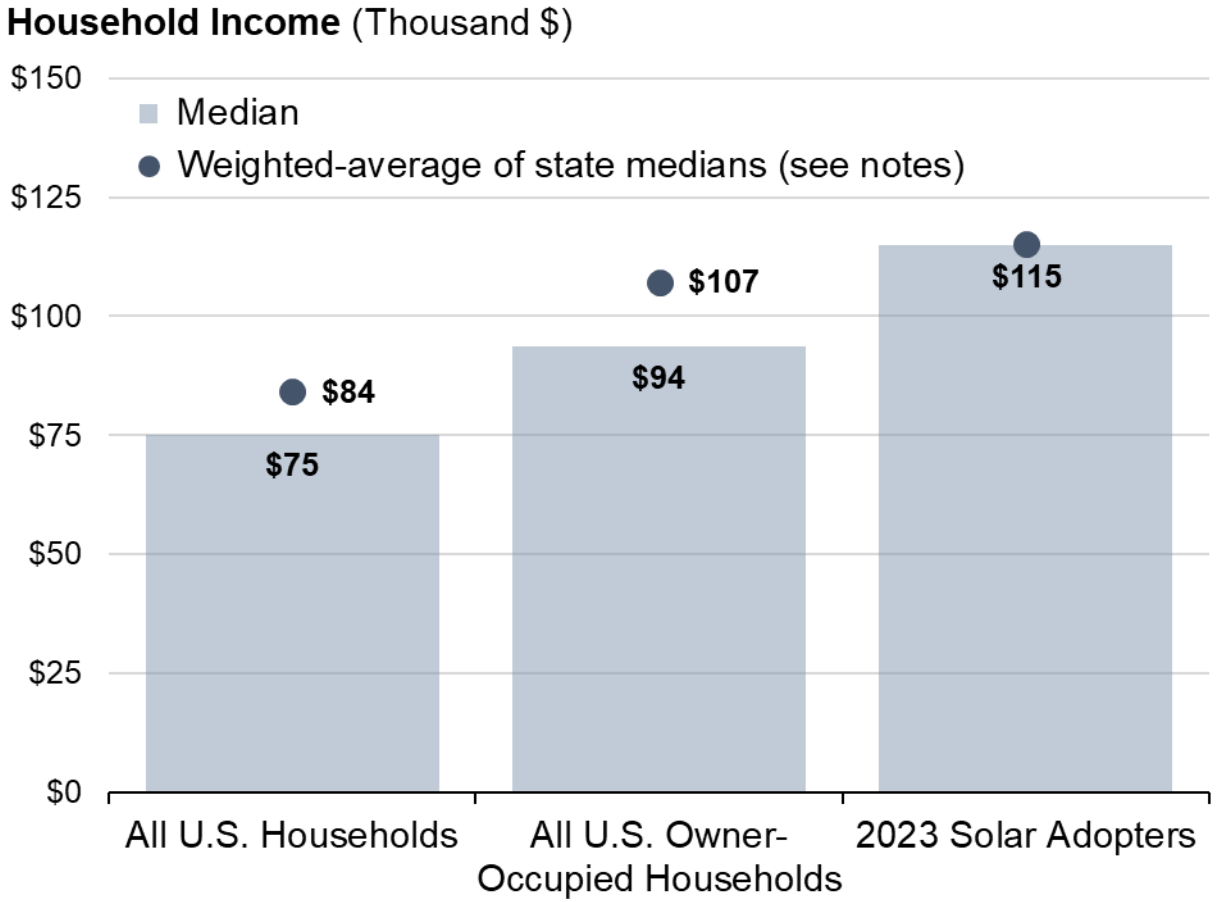
Solar-Adopter Household Income Distribution



** 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, with many in the “middle income” range
- Roughly 44% of adopters have HH incomes <$100k
  - 37% are from $100-200k,
  - Remaining 19% are above $200k with a long upper tail

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)

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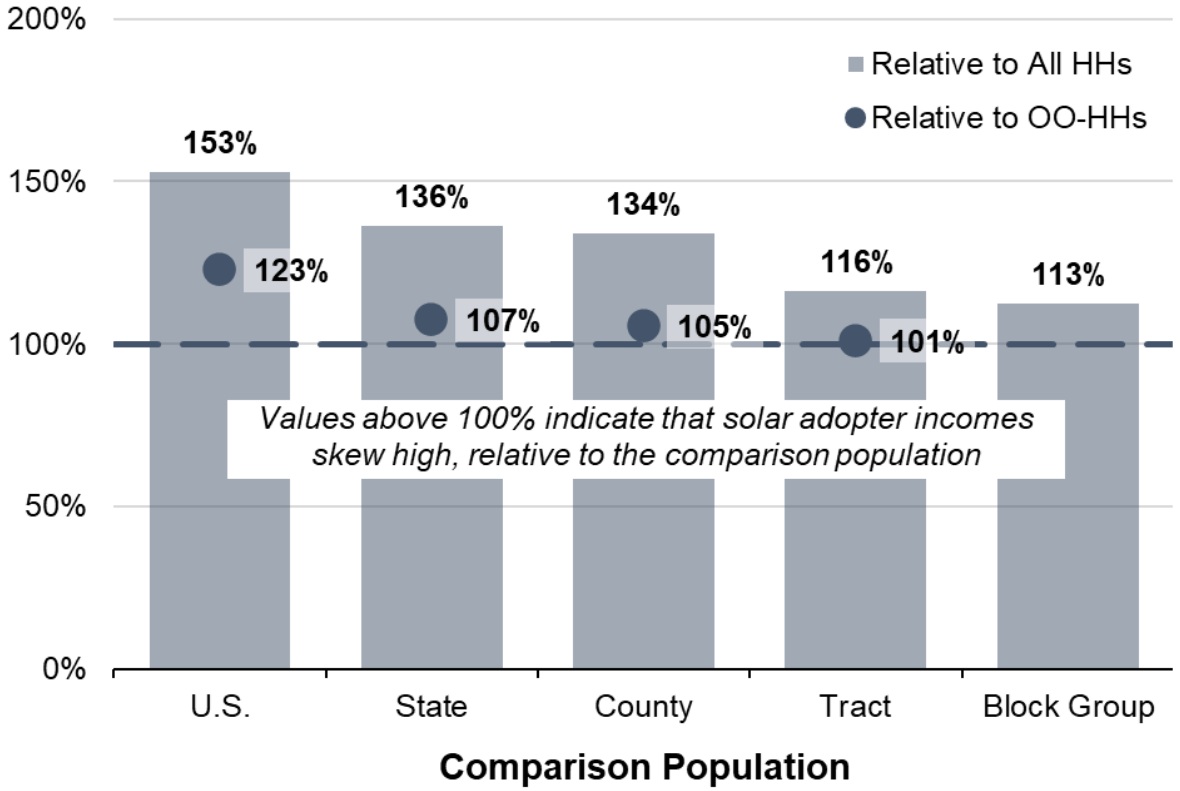
Solar-Adopter "Relative Income"

Median Solar-Adopter Relative Income (2023 Adopters)
Percent of Comparison-Population Current Median 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

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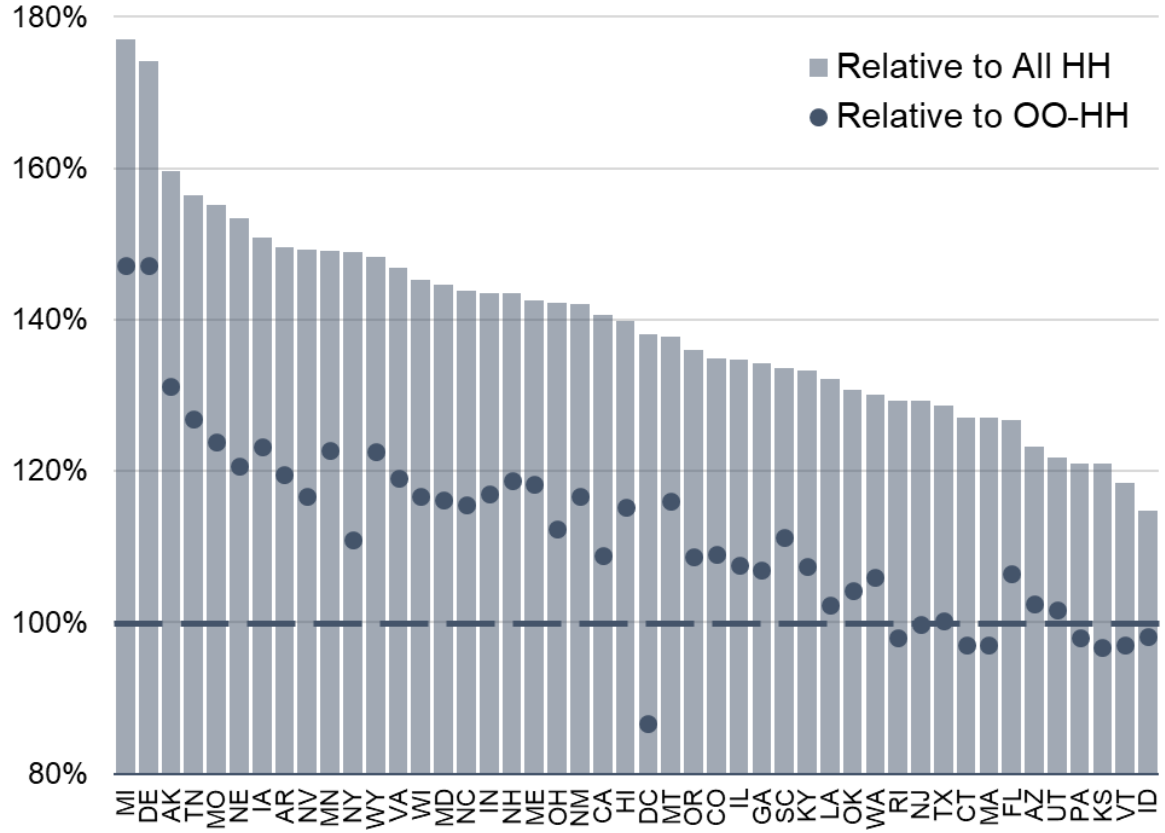
Solar-Adopter Income Trends across States

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 to other OO-HHs ranged 87-147%
- Varying degrees of income skew across states can reflect differences in:
  - Solar market maturity
  - Solar policies and programs
  - Broader socio-economic factors (income inequality, cost of living, etc.)

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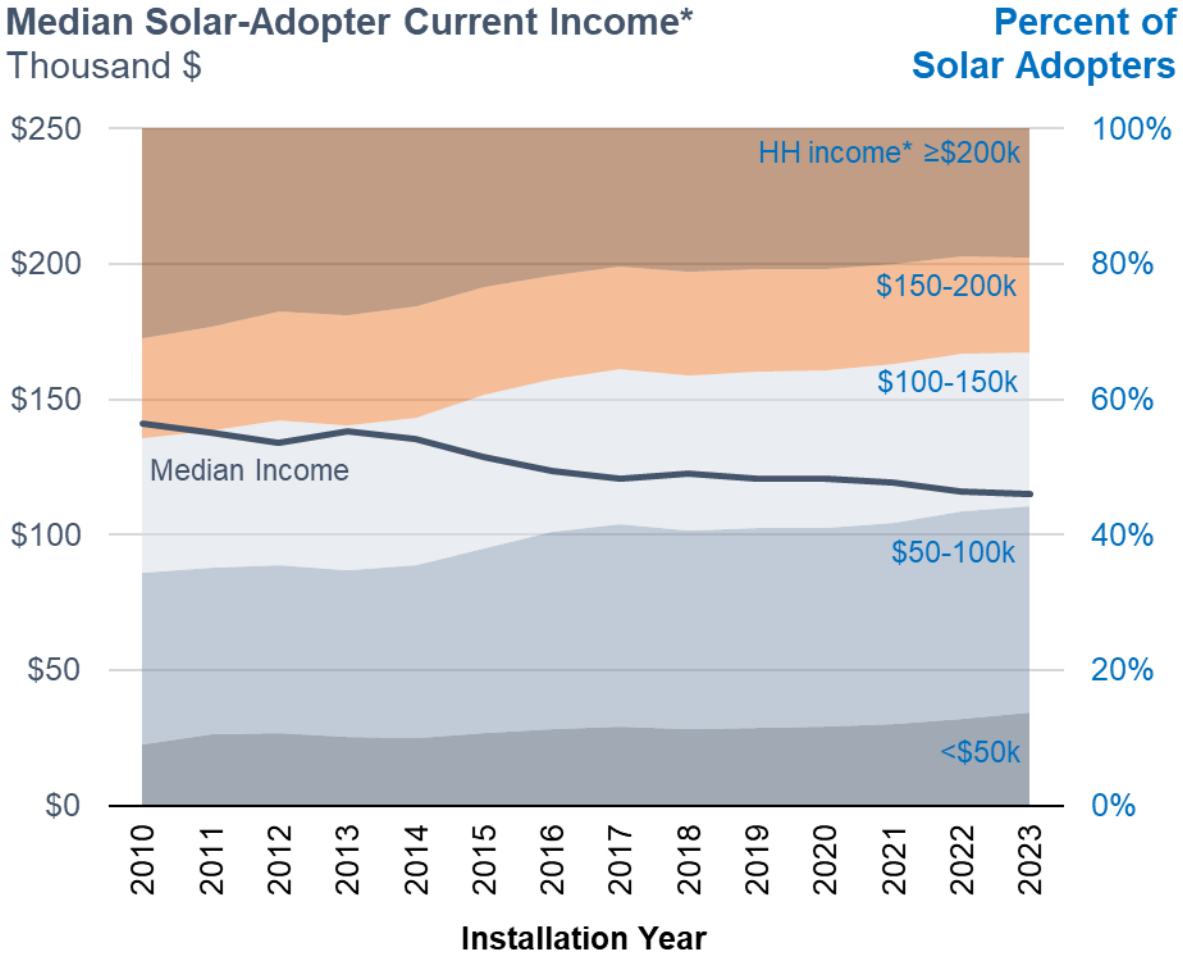
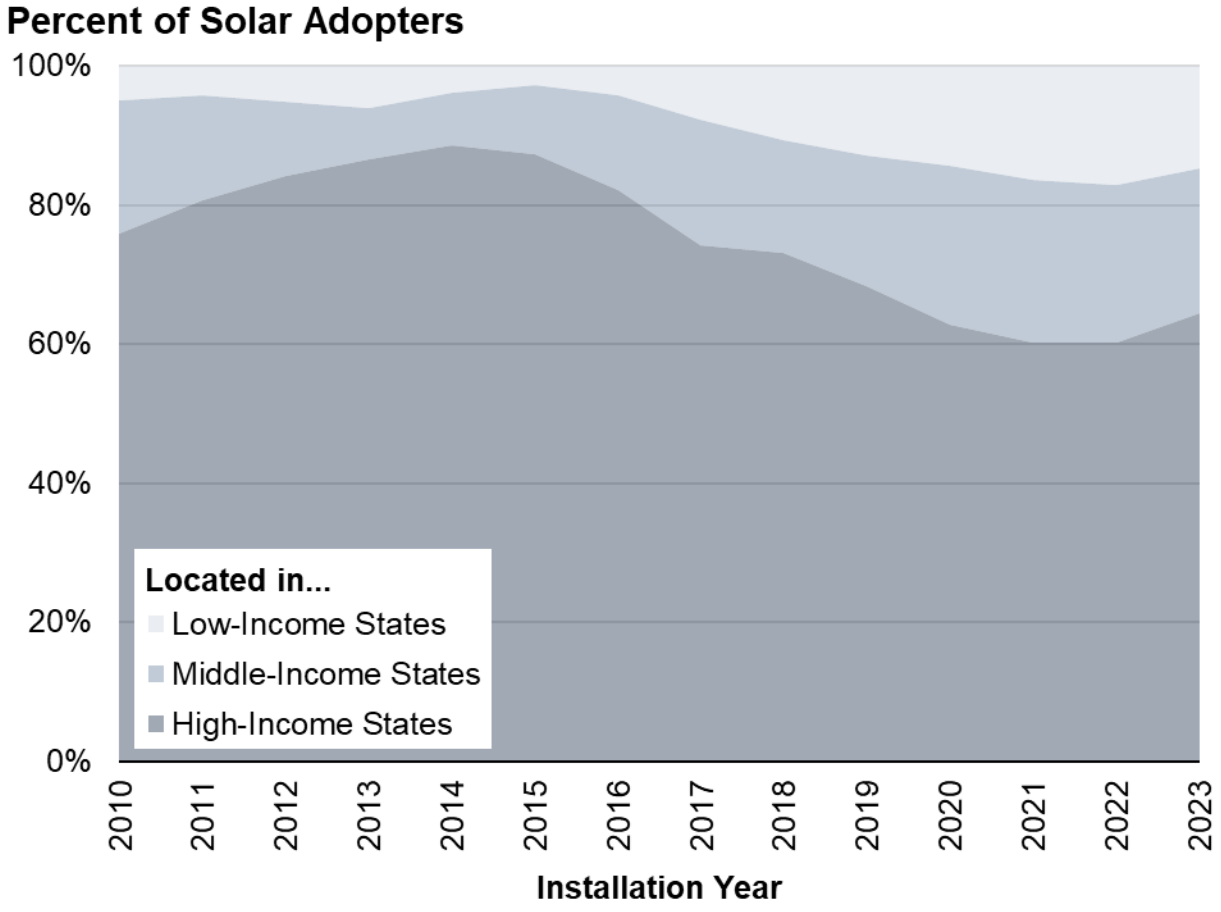
Solar-Adopter Income Trends over Time



** 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

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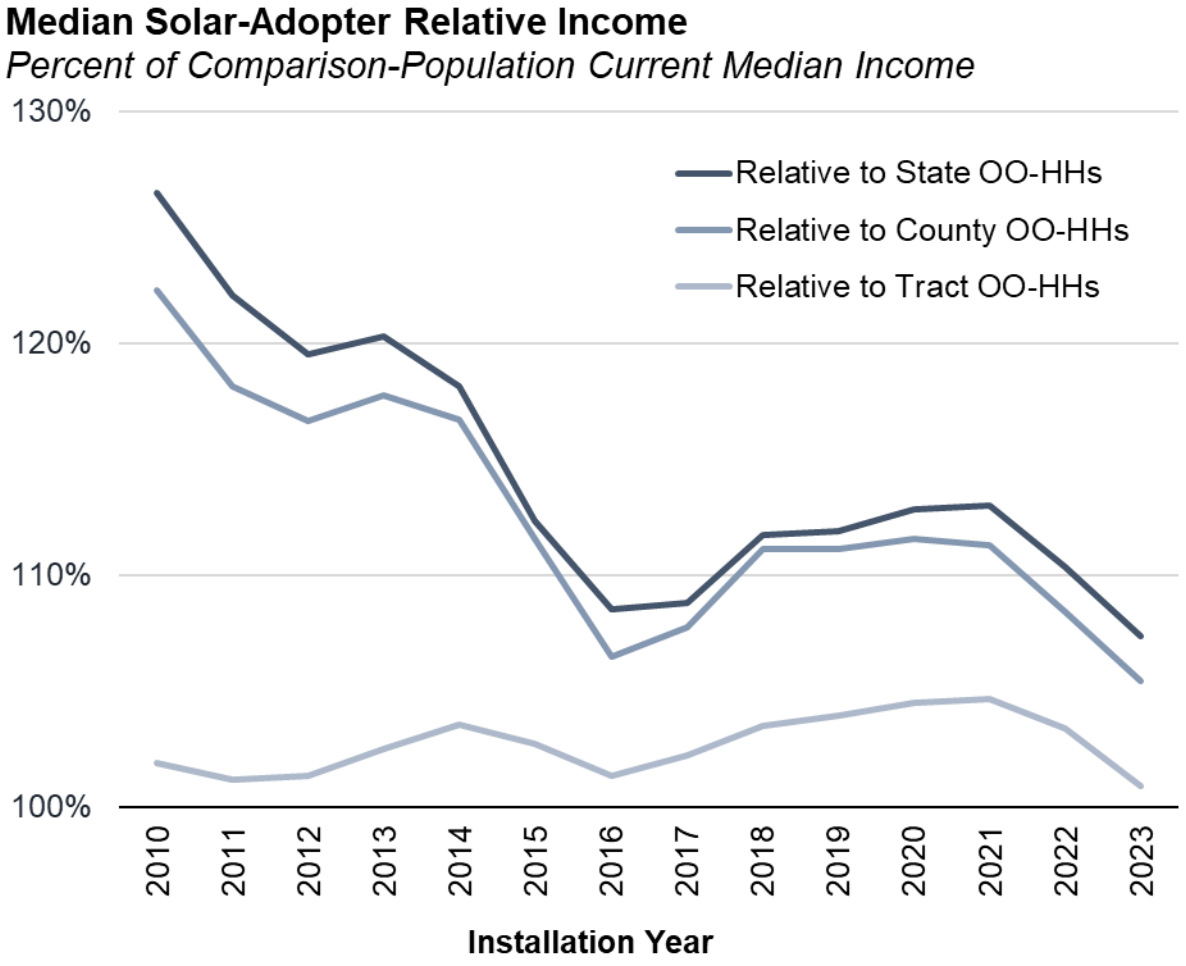
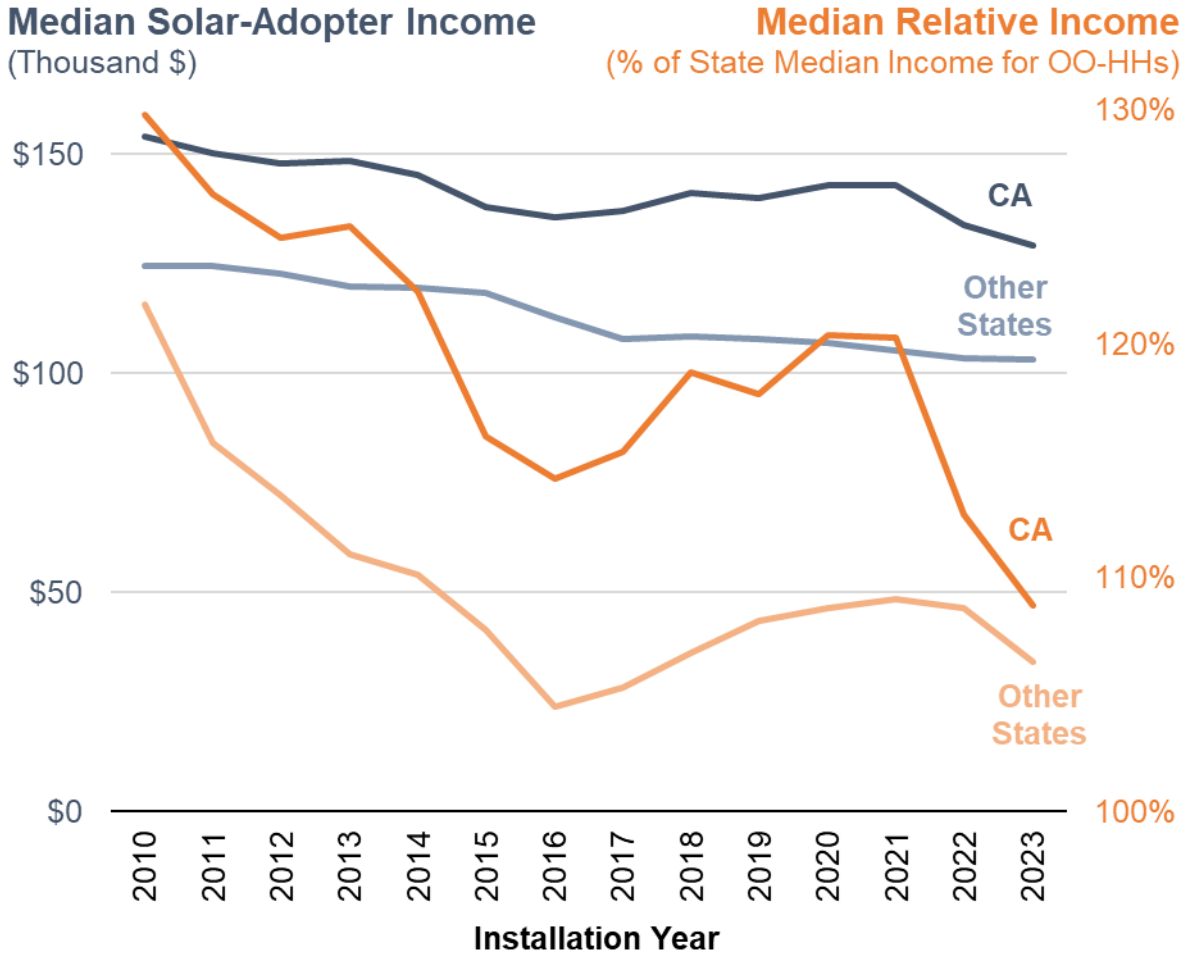
Solar Market Deepening Trends



- 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

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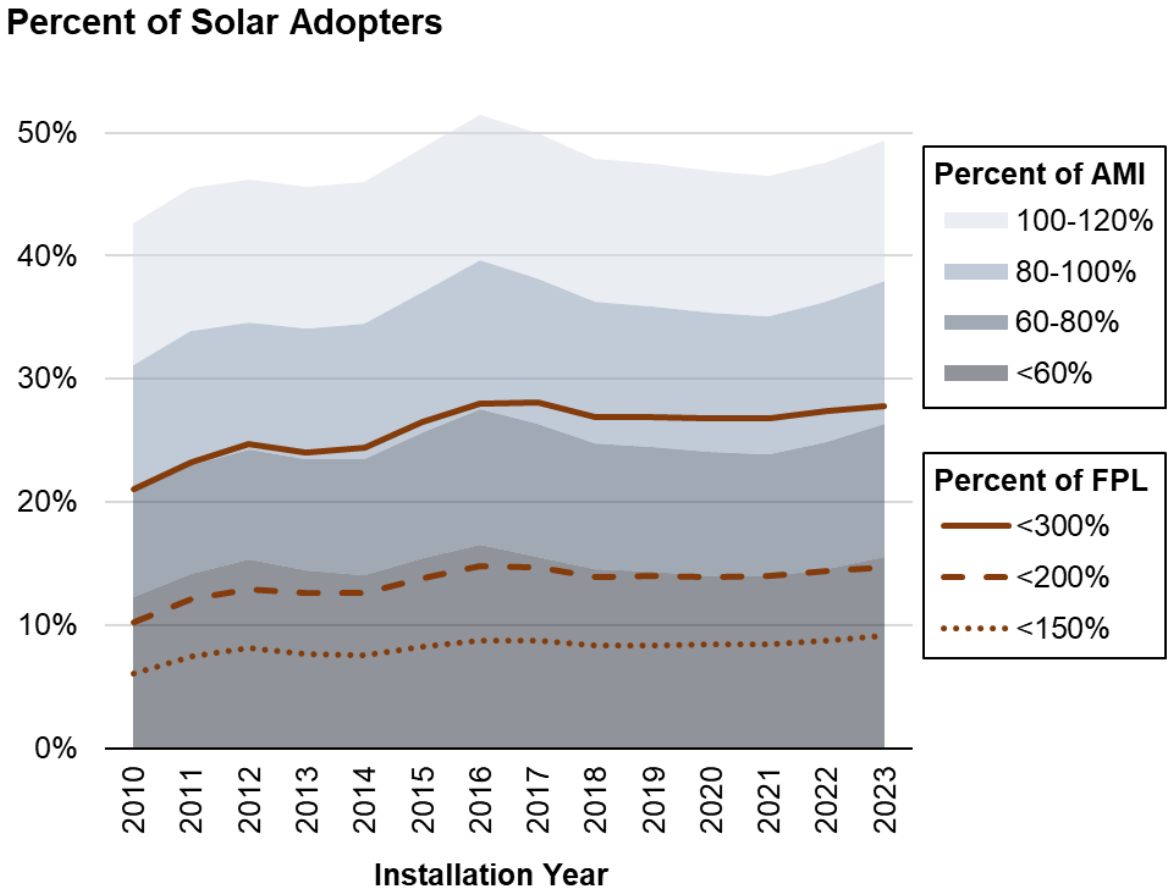
LMI Share of U.S. Solar Adopters over Time



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

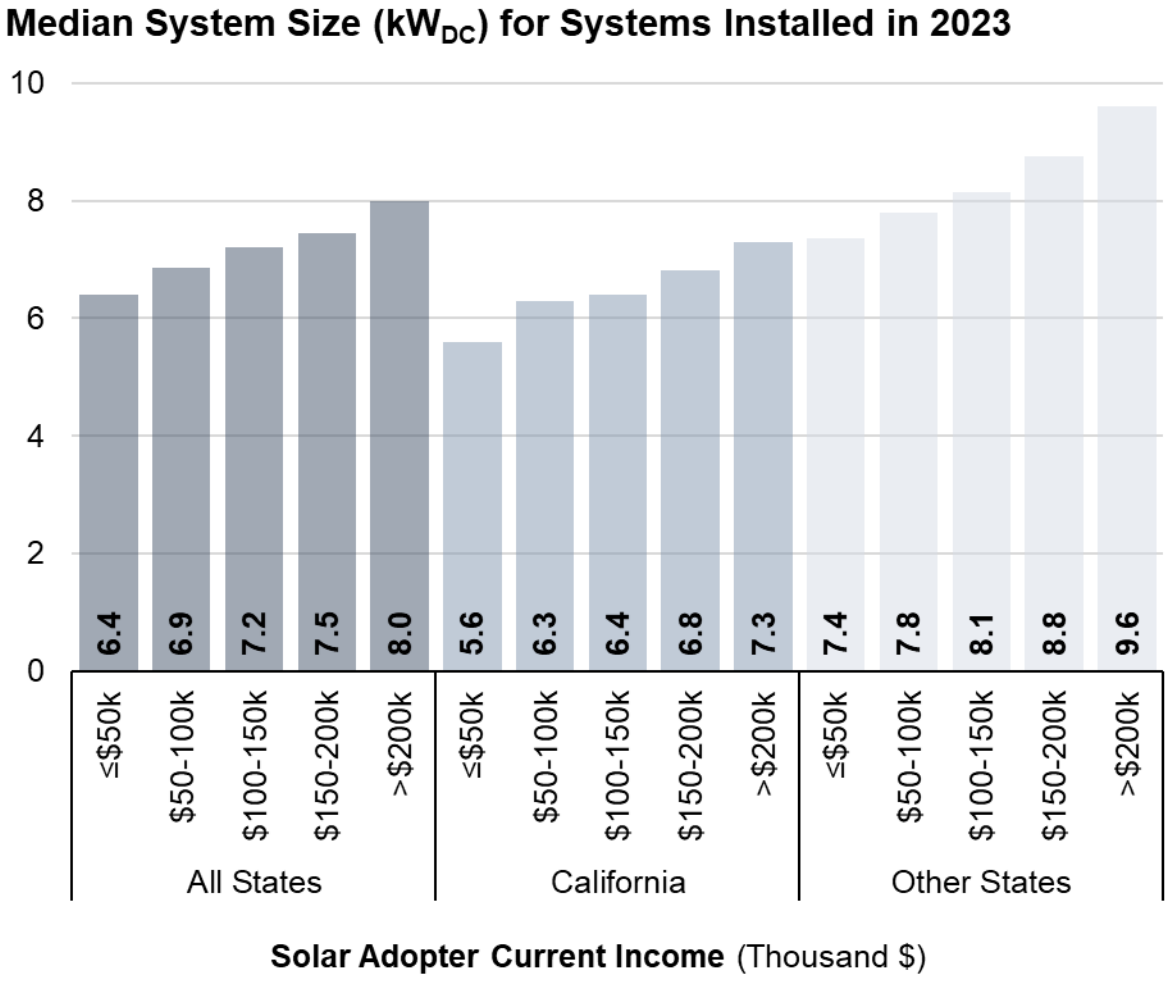
Solar Installation Attributes by Adopter Income Level

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

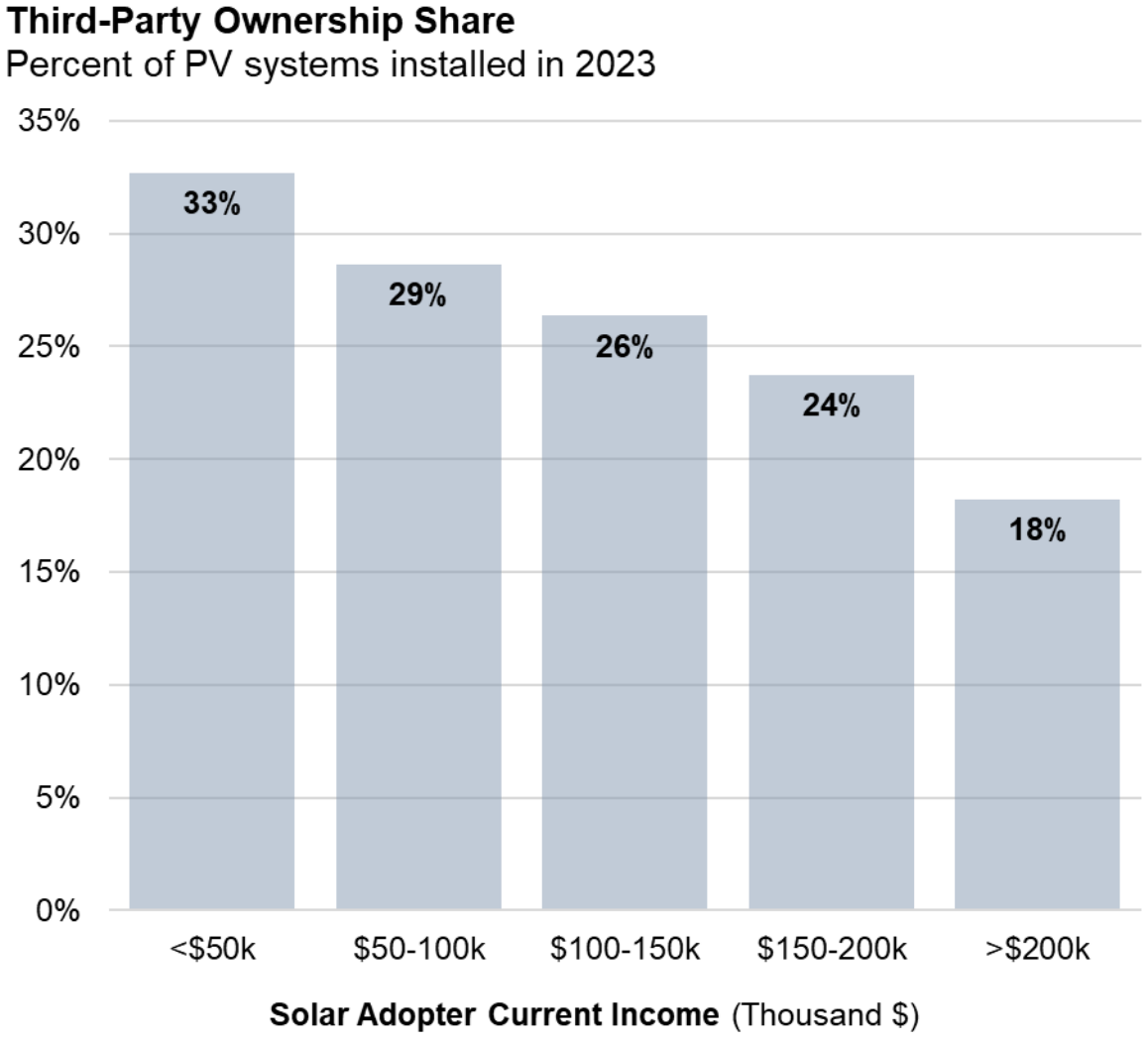
- Based primarily on the subset of the data originating from *Tracking the Sun*

System Size by Income Level



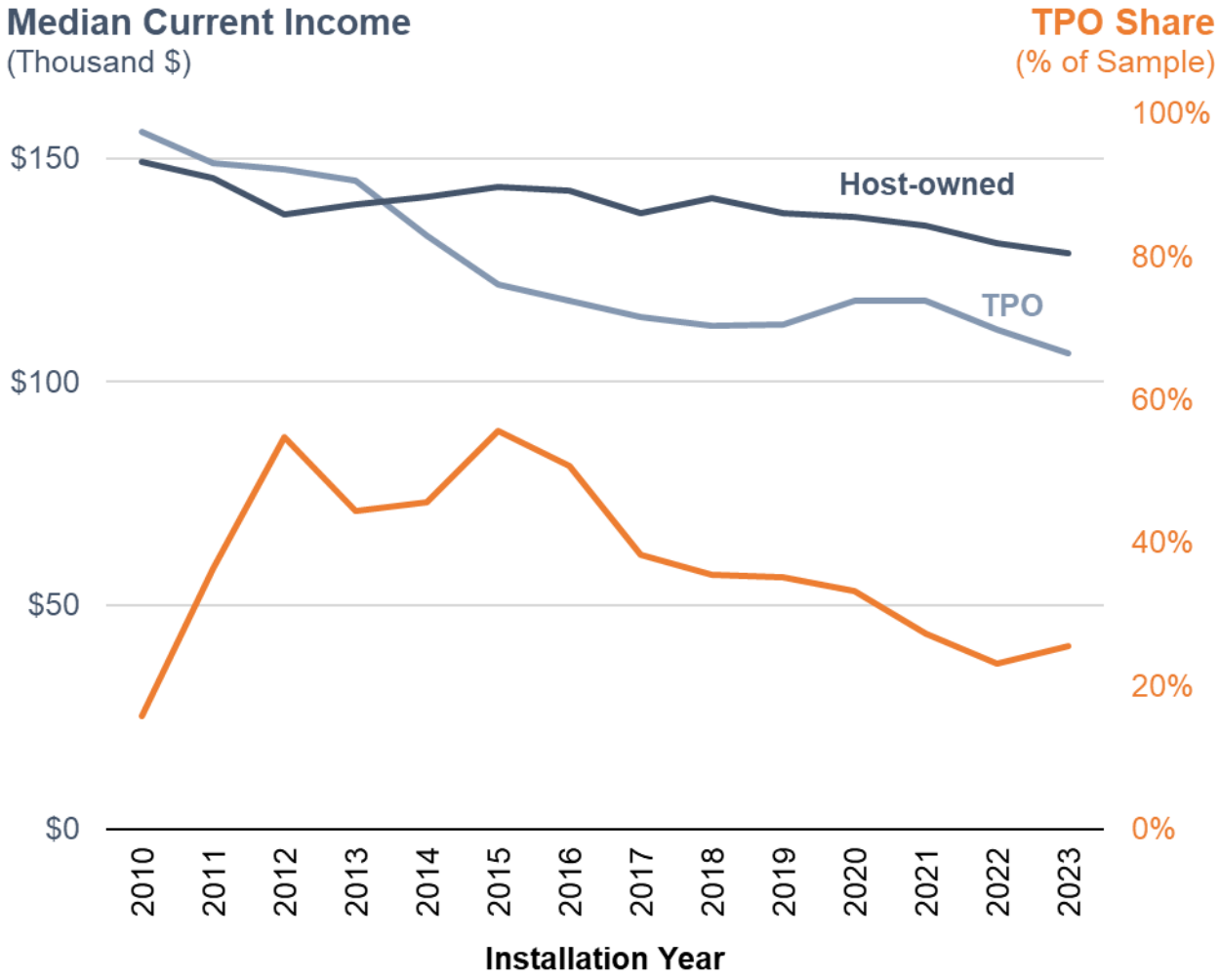
- Higher income households install larger systems
  - Larger systems cost more
  - Higher-income households tend to have larger homes with larger roof area, higher electricity consumption
- Systems installed by the highest-income households were 25% larger than those of the lowest-income households (8.0 vs. 6.4 kW)
- CA systems are relatively small overall, pulling median system sizes down for the sample

Third-Party Ownership Rates by Income Level



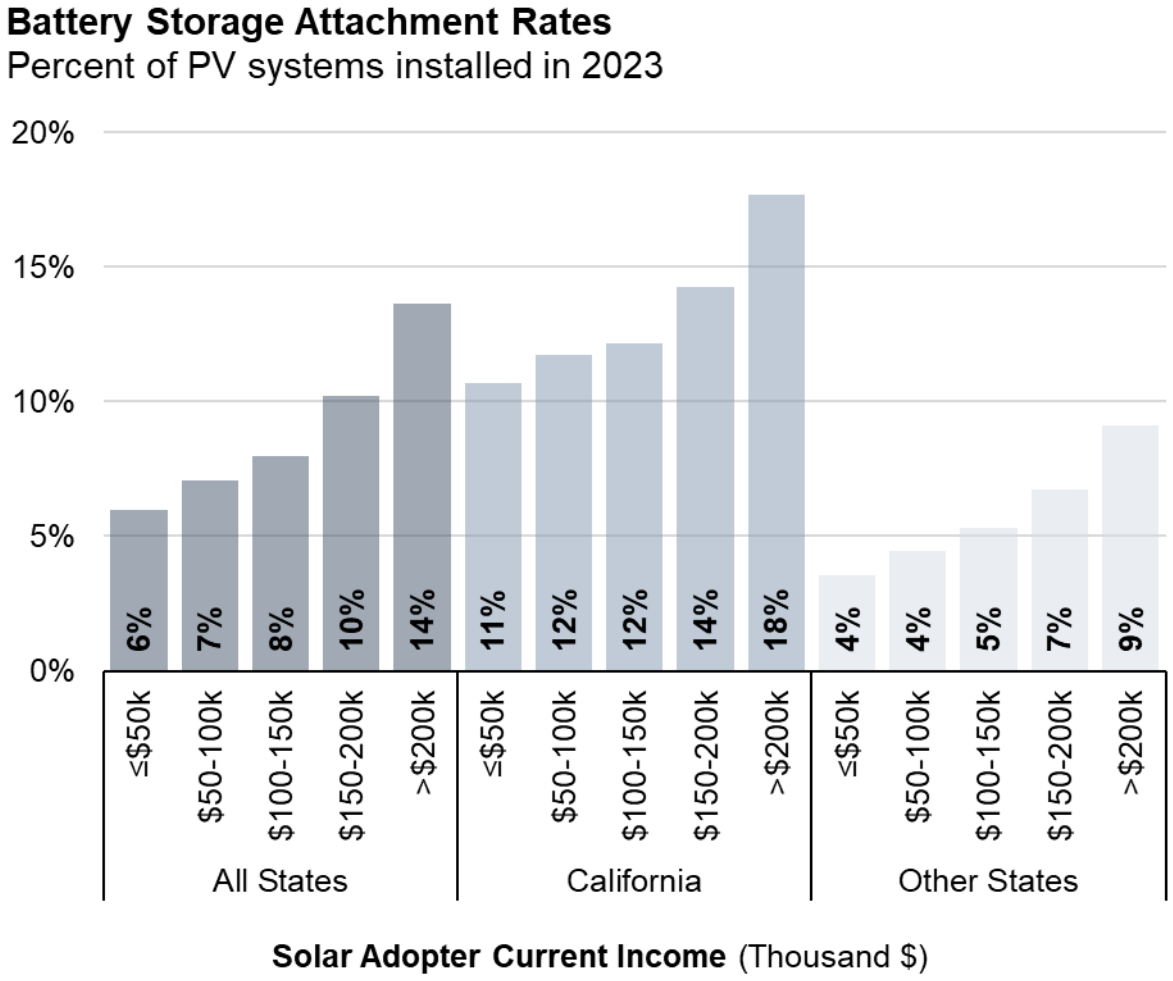
- Third-party ownership (TPO) through leases or power purchase agreements is one way to address up-front cost barriers to PV adoption
- TPO shares are higher for less affluent households: almost 2x for households in the lowest vs. the highest income group in 2023
- O'Shaughnessy et al. (2021) found that 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



- 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



- Storage attachment rates are consistently higher for more affluent households: across all states, roughly double for the highest income group compared to the lowest income group
  - Including storage with solar PV entails additional costs, but also provides added benefits (bill savings, resiliency)
- Similar trends apply in California (63% of all paired solar+storage systems in 2023) and other states
  - CA trends 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

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*:

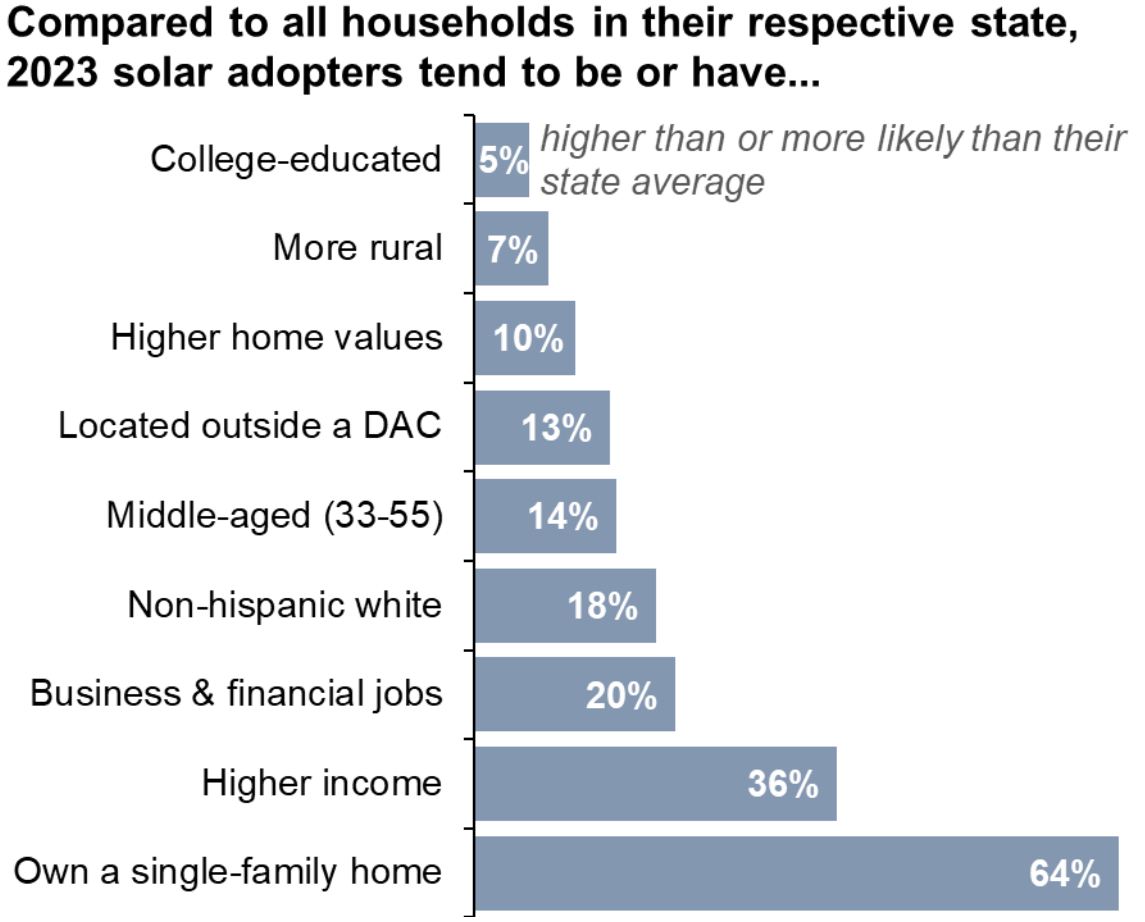
- Location in a Disadvantaged Community (DAC)
- Race and Ethnicity
- Rural vs. Urban
- Home Value
- Housing Type and Tenure
- Education Level
- Occupation
- Age

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 that accounts for the number of PV adopters in each state

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

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
- Income and home ownership are the two largest differences between adopters and non-adopters
- 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)

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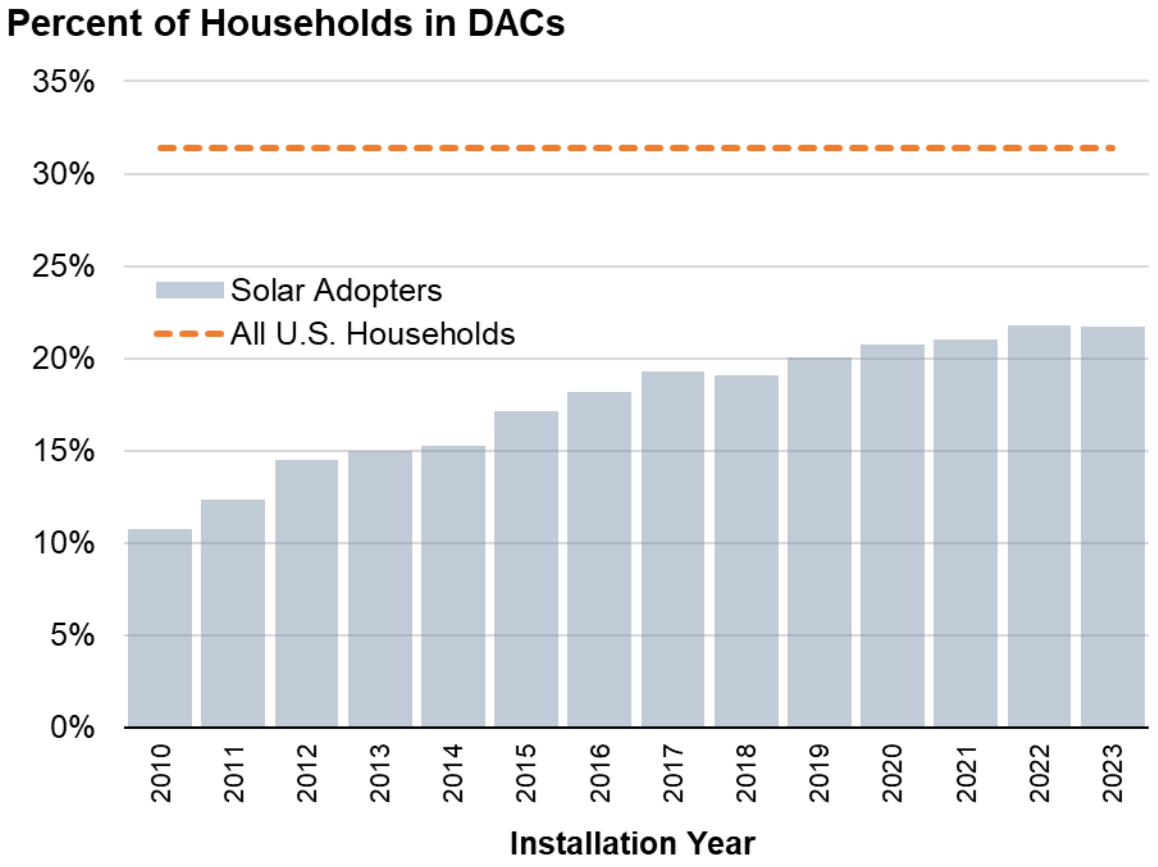
DAC Share of U.S. Solar Adoption over Time



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)

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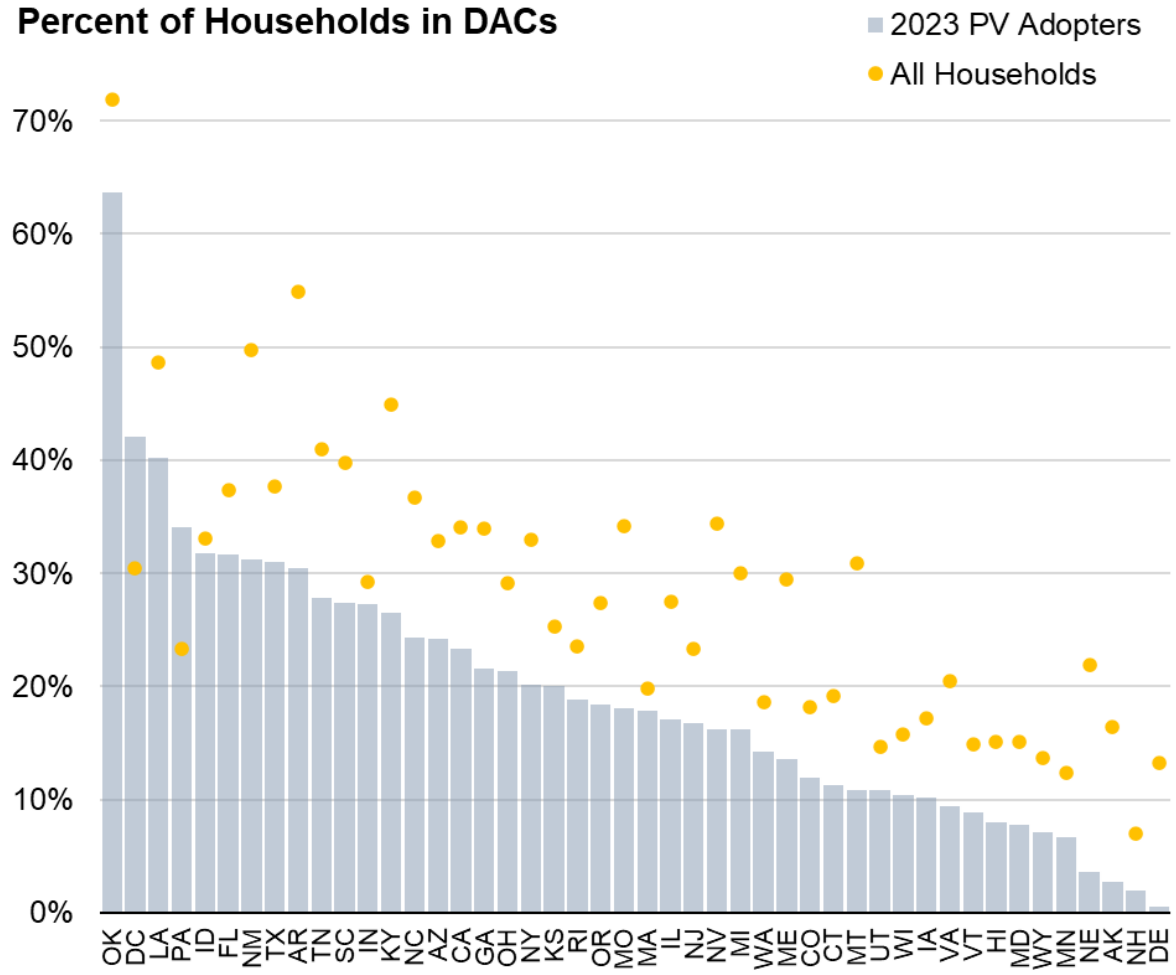
DAC Share of Solar Adoption by State



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

- At the state level, the share of PV adoption in DACs varies widely
- 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
  - Exceptions in PA and DC, where most PV adopters are located in metro areas with a large share of the population living in DACs

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Race and Ethnicity: Notes on Data and Methodology

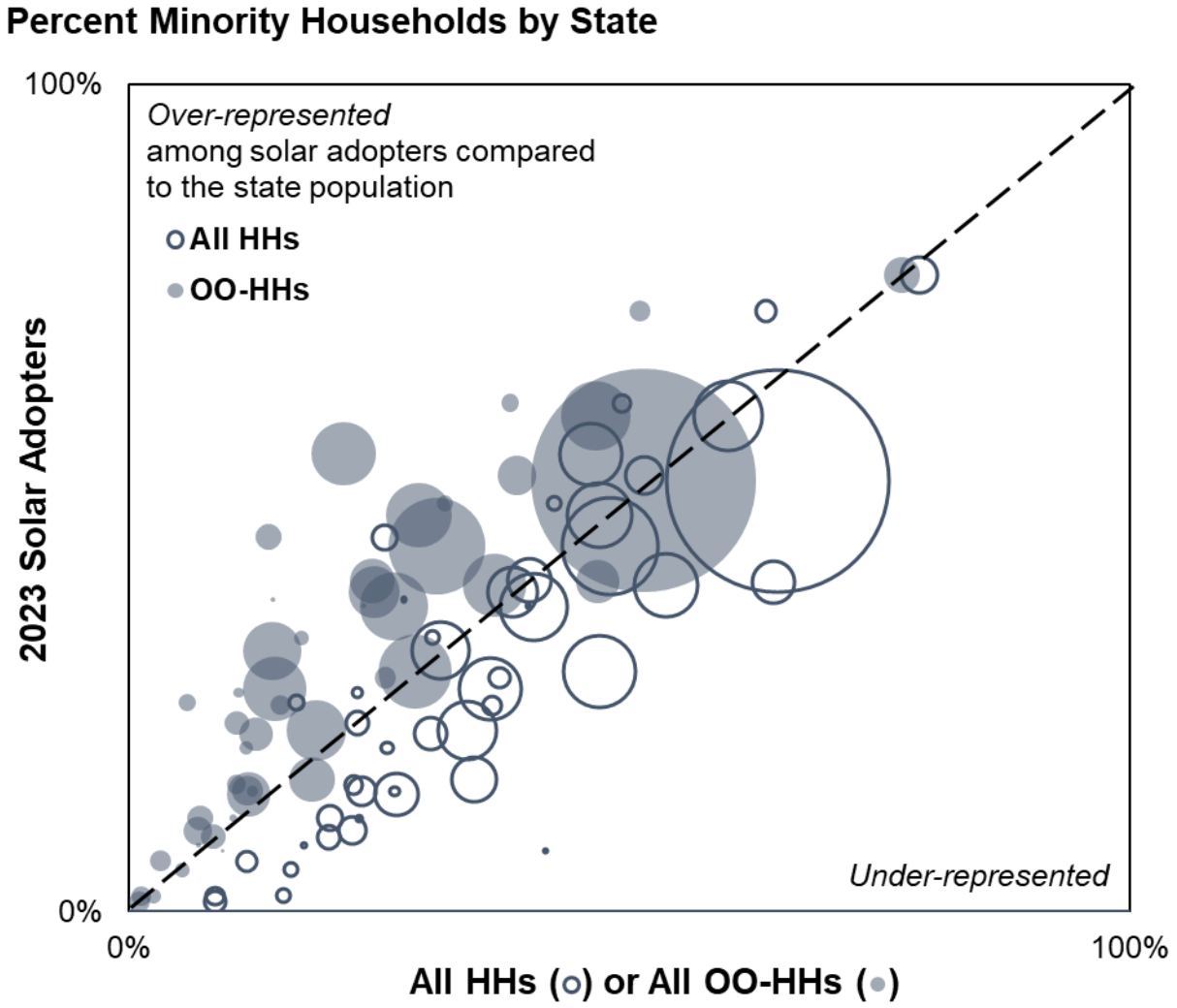
- **Race and ethnicity of PV adopters is inferred**
  - Using an open-source algorithm that predicts household race based on the household's Census block group and the name of the primary householder (Khanna et al. 2022)[1]
  - Output consists of probabilities for Hispanic and non-Hispanic White, Asian, 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"*

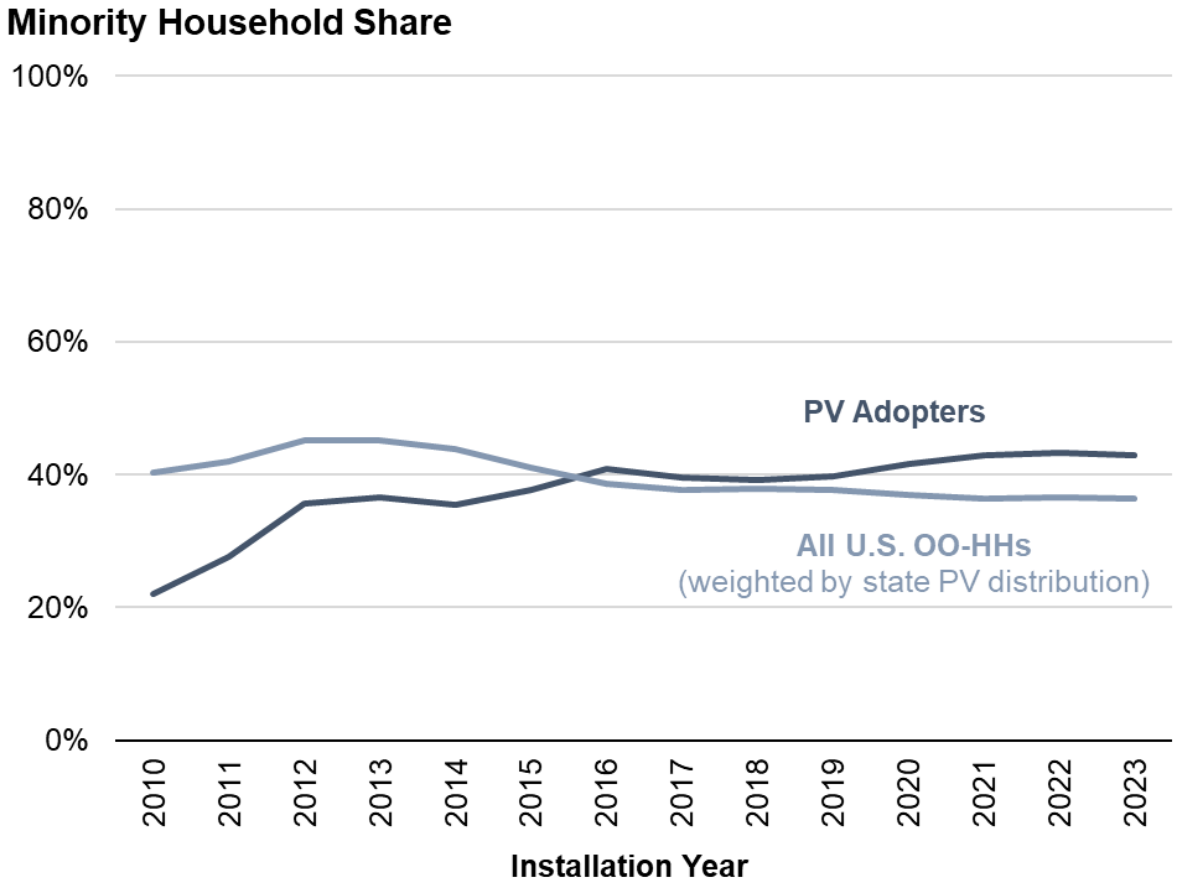
Race and Ethnicity

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



- State level trends mirror national trends and show how racial disparities in PV adoption mirror (and may partly derive from) disparities in home ownership
- Minority households are under-represented among solar adopters when comparing to all HHs in most states (the open circles)
- But trends reverse if comparing to only OO-HHs (bubbles shift to the left), where solar adopters have *higher* minority representation than the broader population 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

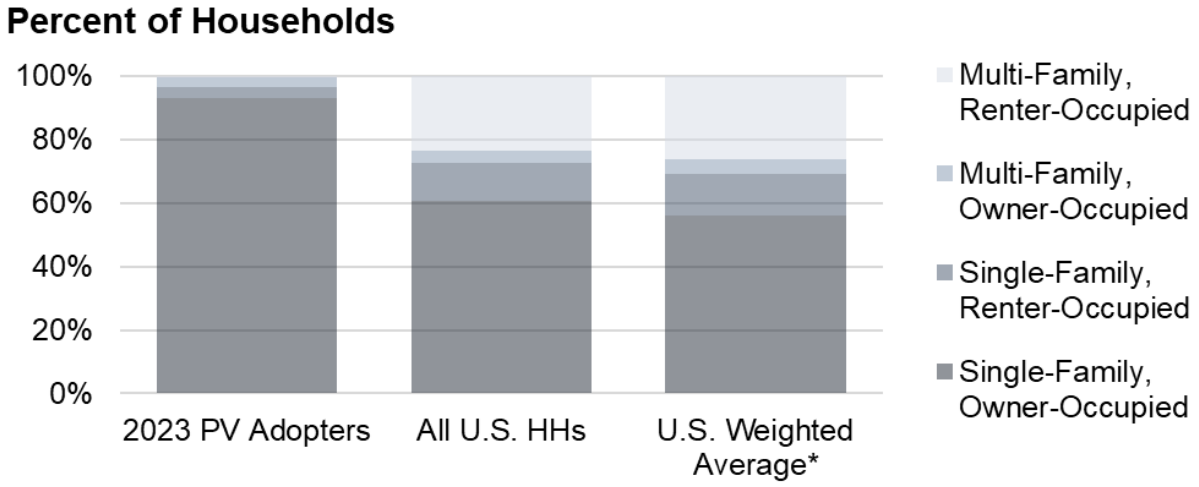
Race and Ethnicity:
National trends over time

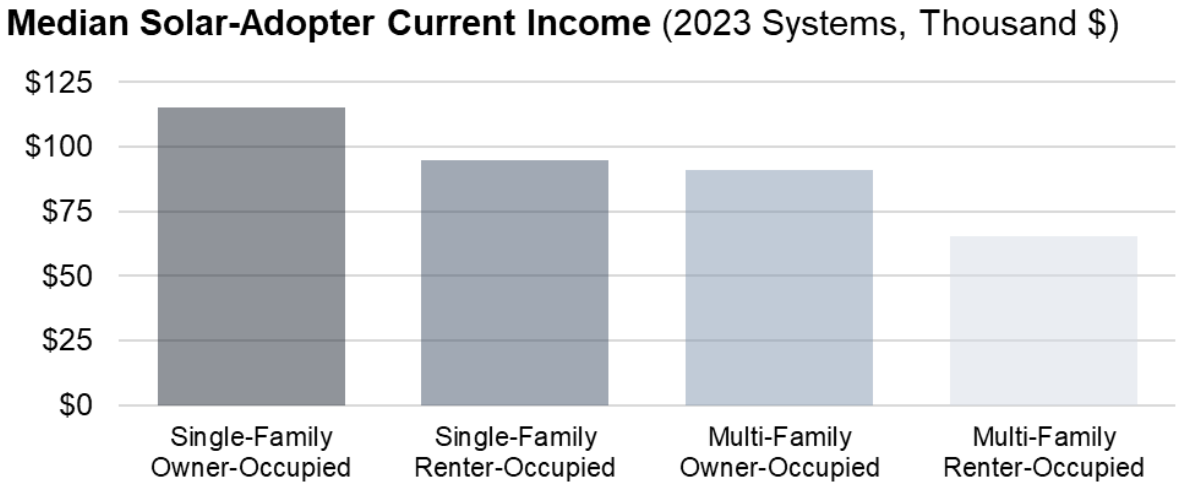


Notes: The line for All U.S. OO-HHs is calculated by taking the race/ethnicity breakdown of all OO-HHs in each state and calculating the weighted average based on the number of PV adopters in each state in each year.

- 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 higher/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

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

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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

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