CleanEnergy States Alliance

Solar Adopter Income and Demographic Trends:
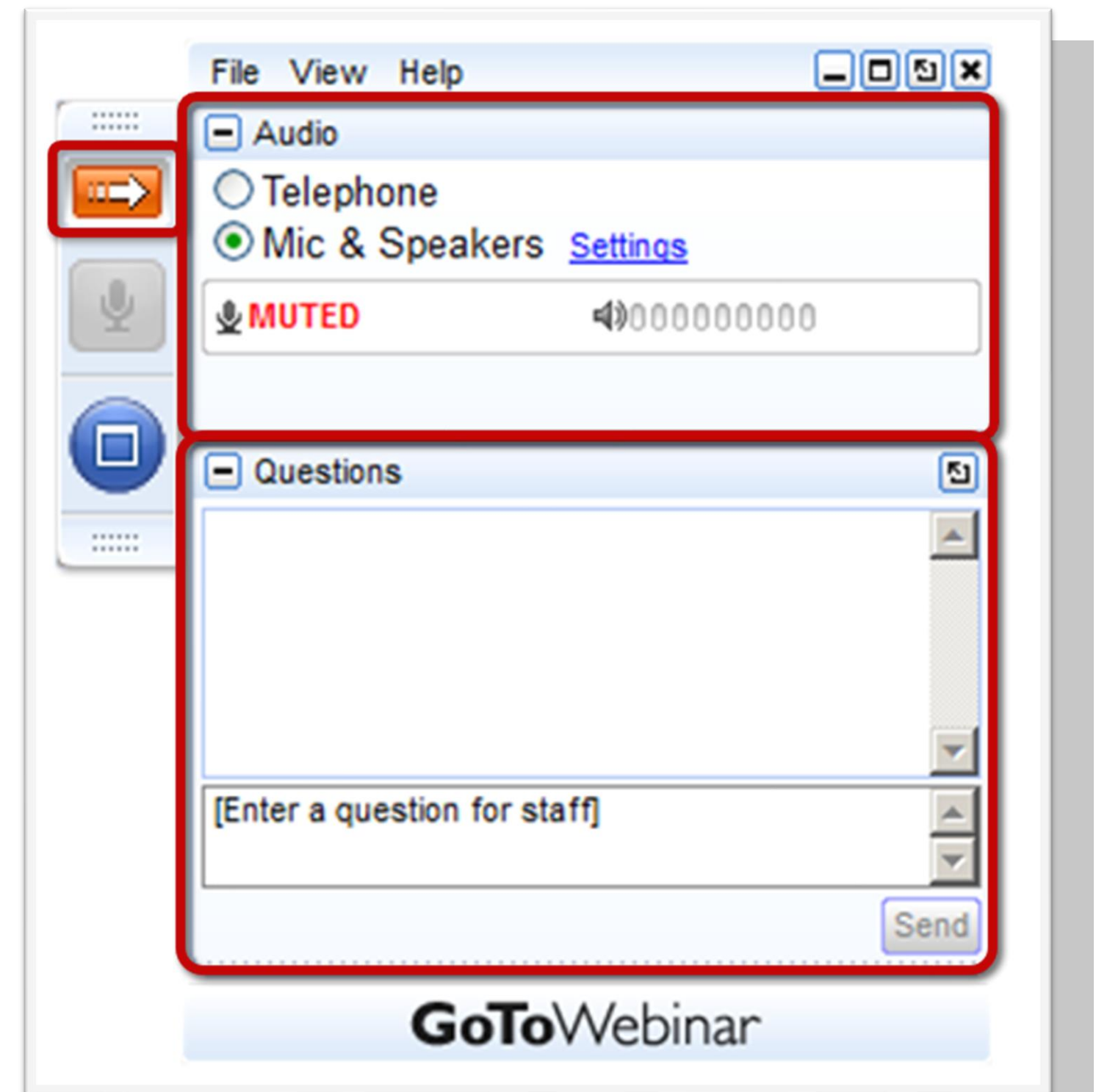## An Update from Berkeley Lab

February 15, 2024

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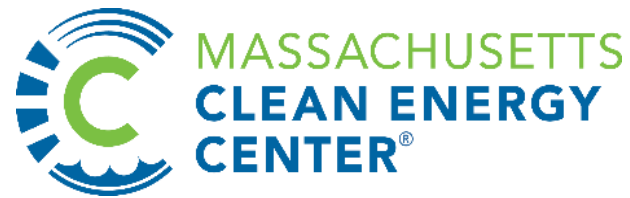
CESA members—mostly state agencies—include many of the most innovative, successful, and influential public funders of clean energy initiatives in the country.

www.cesa.org

Webinar Speakers

Warren Leon
Clean Energy States Alliance

Galen Barbose
Berkeley Lab

Sydney Forrester
Berkeley Lab

Eric O'Shaughnessy
Berkeley Lab

Solar Adopter Income and Demographic Trends: An Update from Berkeley Lab | February 15, 2024

Thank You

Warren Leon

Executive Director

Clean Energy States Alliance

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🌐 www.cesa.org

Upcoming Webinar

Peer Influence in Residential Solar Adoption: New Research from Berkeley Lab (March 6)

Read more and register at www.cesa.org/webinars

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Residential Solar-Adopter Income and Demographic Trends: 2023 Update

Sydney P. Forrester, Galen Barbose, Eric O'Shaughnessy, Naïm Darghouth, and Cristina Crespo Montañés

CESA Webinar

February 15, 2024

ENERGY TECHNOLOGIES AREA | ENERGY ANALYSIS AND ENVIRONMENTAL IMPACTS DIVISION

Outline of Full Report

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

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 2022
- ▣ More emphasis on comparing PV adopters specifically to owner-occupied households
- ▣ Additional trends on third-party ownership, race and ethnicity, and multifamily and renters

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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 ~2.4M systems, primarily from utilities & state agencies

- **BuildZoom** and **Ohm Analytics**: Purchased PV permit data; provides supplementary PV street addresses for an additional 1.0M systems

Income & Other Socio-Economic Data

- **Experian ConsumerView**: Purchased dataset providing modeled household-level income estimates and other socio-economic attributes

- **WRU:** Open source software used to estimate race and ethnicity

- **U.S. Census** and **Bureau of Labor Statistics**: Used for comparison purposes to characterize demographics of total U.S. population

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

Sample Coverage

2022 Systems

Market Coverage
- <20%
- 20% – 40%
- 40% – 60%
- 60% – 80%
- 80% – 100%
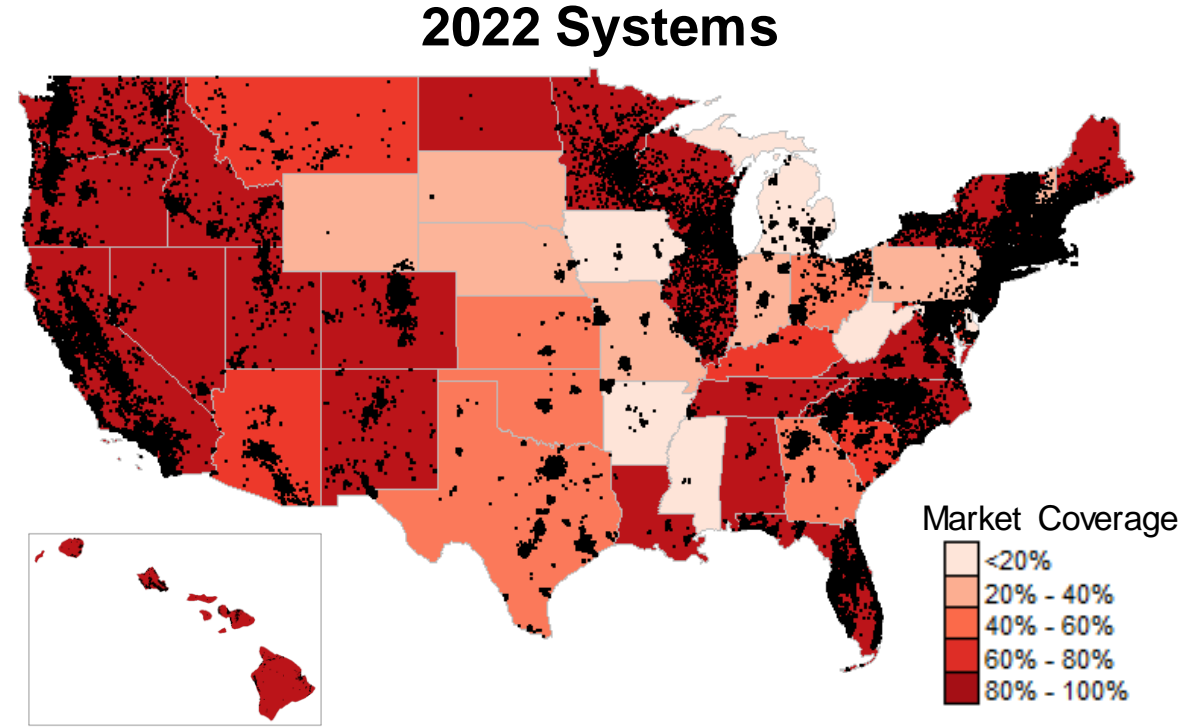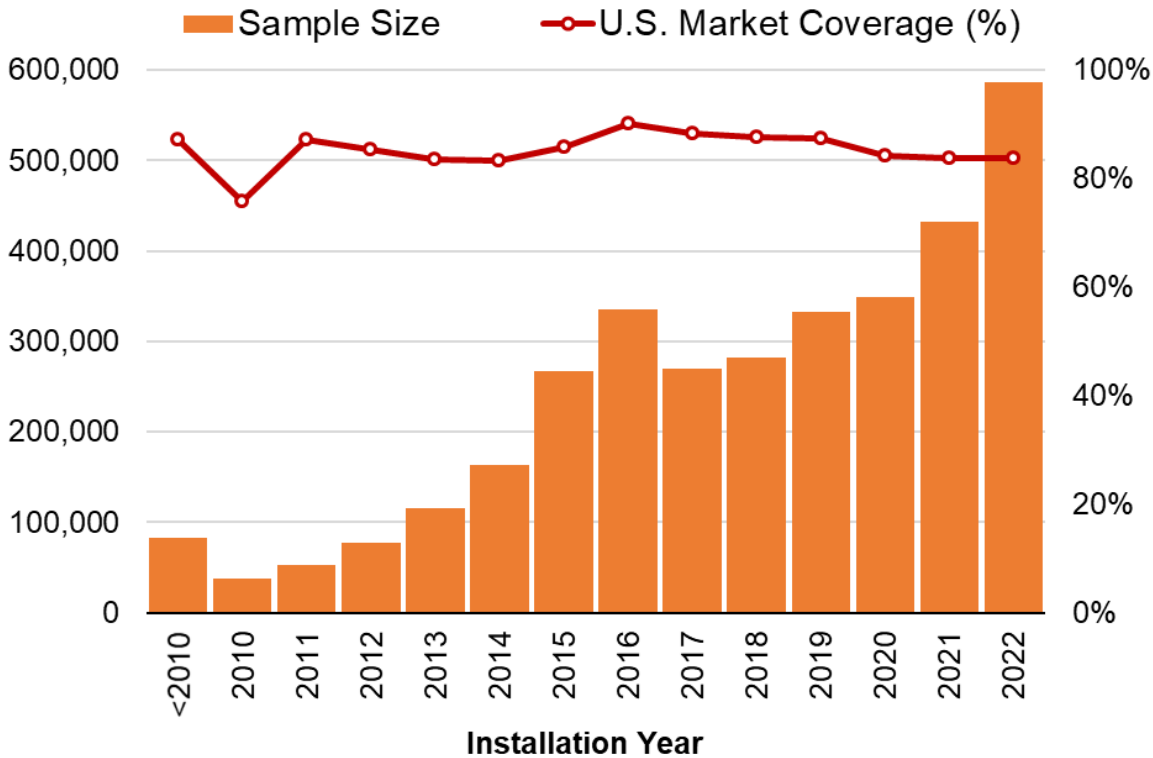
- Our sample consists of **3.4M systems**, covering roughly **86%** of all U.S. residential systems through 2022 and **84%** of systems installed in 2022

- State-level market coverage varies widely, but is over 40% in most states for 2022

Sample Distribution over Time

Percent of Solar-Adopter Sample
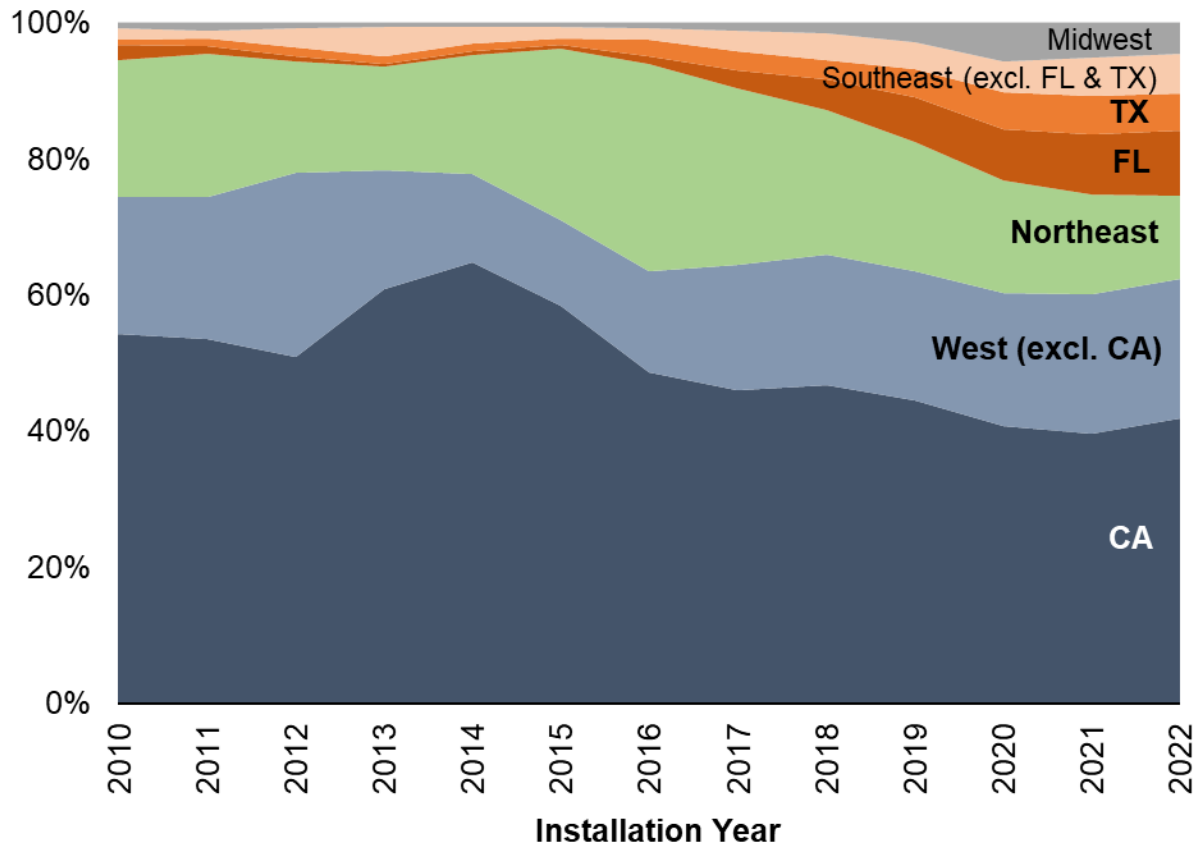
Notes: The figure represents the distribution of the solar-adopter sample used in this analysis, which covers 86% of the total U.S. market, but as shown on the previous slide, coverage for midwestern and southeastern states is somewhat lower than for other regions.

- The geographical distribution of the sample and shifts over time provide important context for understanding demographic trends shown later
- California represents 42% of systems installed in 2022, but its share has declined over time
- Other Western states' share of the sample has grown over the past decade, comprising 21% of the 2022 sample
- Florida, Texas, and other Southeastern states have all grown in their sample share
- Northeastern states have correspondingly declined in their share over time
- Midwestern states have grown but remain a small share of the sample

Key Points on the Data and Methods

☐ We focus here on **national and state-level trends**, with an emphasis on PV systems installed from 2010-2022; data at the county and Census tract-levels 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 Q3 2023, rather than at the time of adoption

☐ See full report for further details

Solar-Adopter Income Trends

Solar-Adopter Income Distribution

Percent of 2022 Solar Adopters

Current Household Income (thousand $)
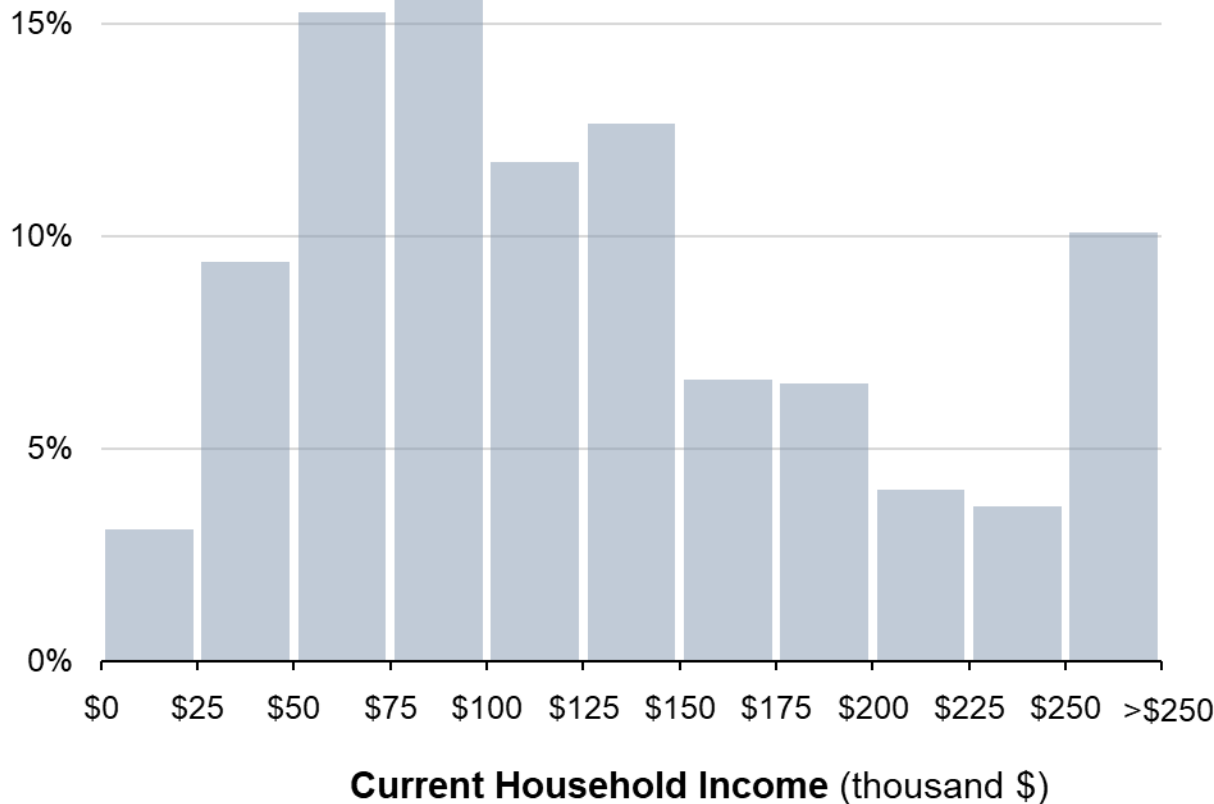
- ☐ Solar adopters span all household (HH) income levels

- ☐ A large fraction of solar adopters in 2022 could be considered "middle income": for example, one-third (31%) have HH incomes in the $50-100k range

  - ◻ 12% of adopters are below that range, while 55% are above it

- ☐ The distribution has a long upper tail, with 18% of adopters above $200k and 10% above $250k

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

Household Income (Thousand $)
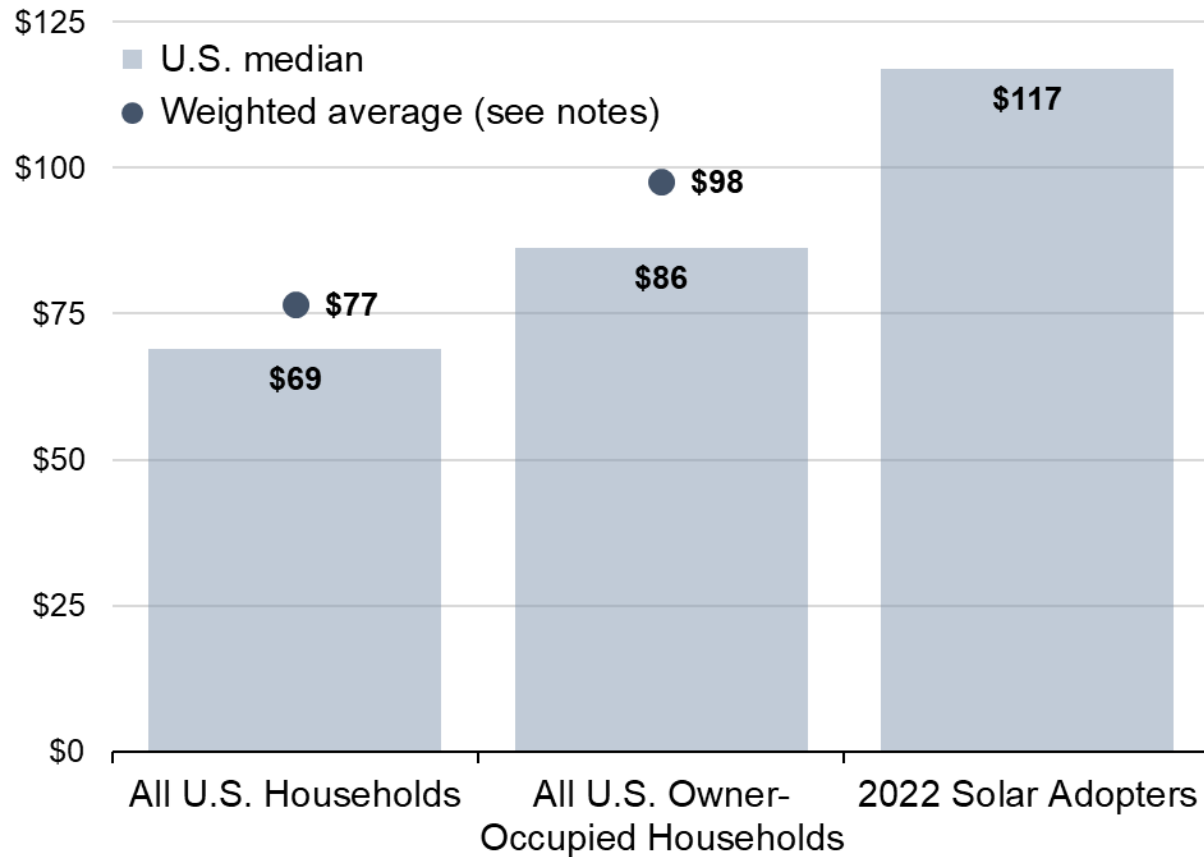
Notes: The weighted averages are based on the median income of all HHs or all OO-HHs in each state, weighted by the number of 2022 solar adopters in each state.

- Solar-adopter incomes skew high, but the degree of skew is highly dependent on how the comparison population is defined

- The median income of 2022 solar adopters ($117k) was **70%** higher than for all U.S. households ($69k)

- Onsite solar adopters are almost all owner-occupied households (OO-HHs); the percent difference is only half as large (**36%**) if comparing to only OO-HHs ($86k)

- Solar adopters are disproportionately located in high-income states (e.g., CA); median adopter incomes were **20%** higher if comparing to a solar-adopter weighted-average of state median incomes for OO-HHs (see figure notes)

Solar-Adopter "Relative Income"

Median Solar-Adopter Relative Income (2022 Adopters)
Percent of Comparison-Population Current Median Income

Legend:
- ■ Relative to All HHs
- ● Relative to OO-HHs

Data shown:
- U.S.: 170% (All HHs), 136% (OO-HHs)
- State: 149% (All HHs), 119% (OO-HHs)
- County: 150% (All HHs), 117% (OO-HHs)
- Tract: 128% (All HHs), 112% (OO-HHs)
- Block Group: 125% (All HHs)

Values above 100% indicate that solar adopter incomes skew high, relative to the comparison population

X-axis: **Comparison Population**
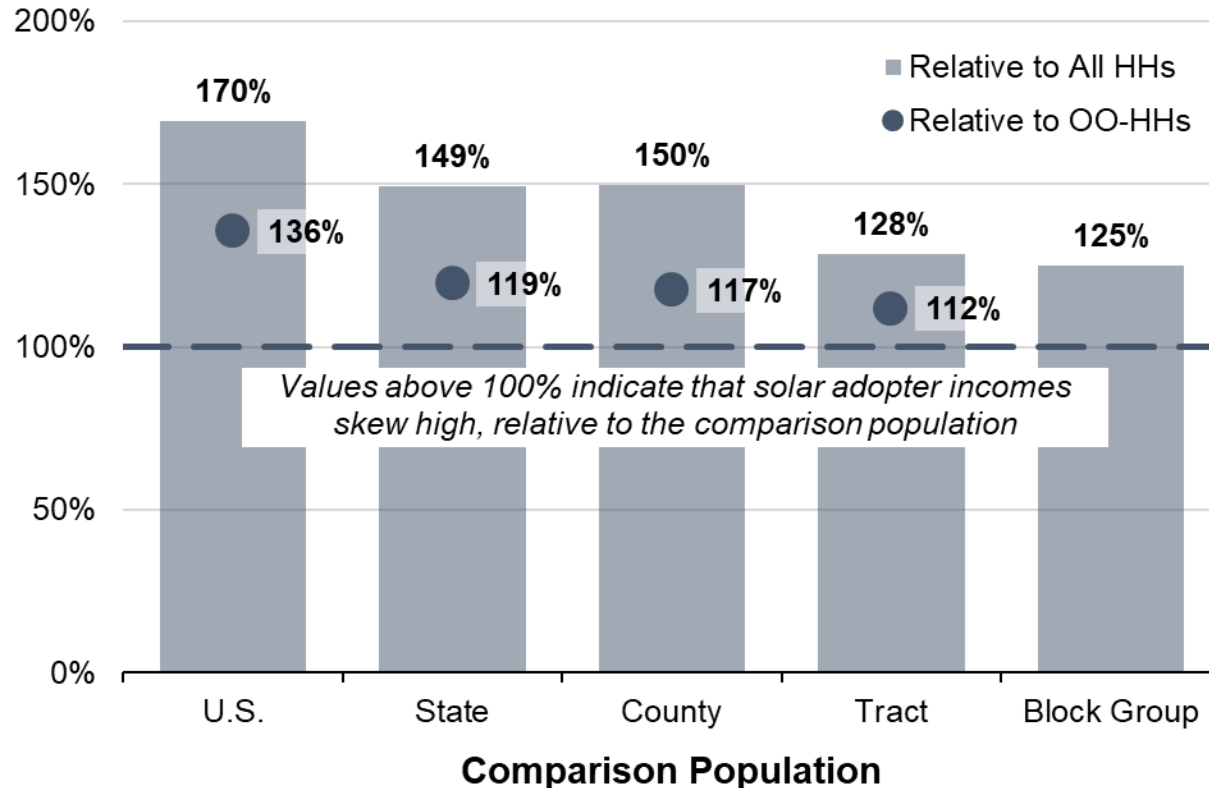
Notes: To calculate these values, we first calculate each solar adopter's household income as a percentage of the median household income for the given comparison population, and then take the median of those percentage values across all solar adopters. At the block group level, median incomes are available only for all HHs, but not for OO-HHs.

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. down to block group) and for either 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

Solar-Adopter Income Trends across States

Median Solar-Adopter Relative Income
(2022 Adopters, % of State Current Median Income)

Legend:
- Relative to All HH
- Relative to OO-HH
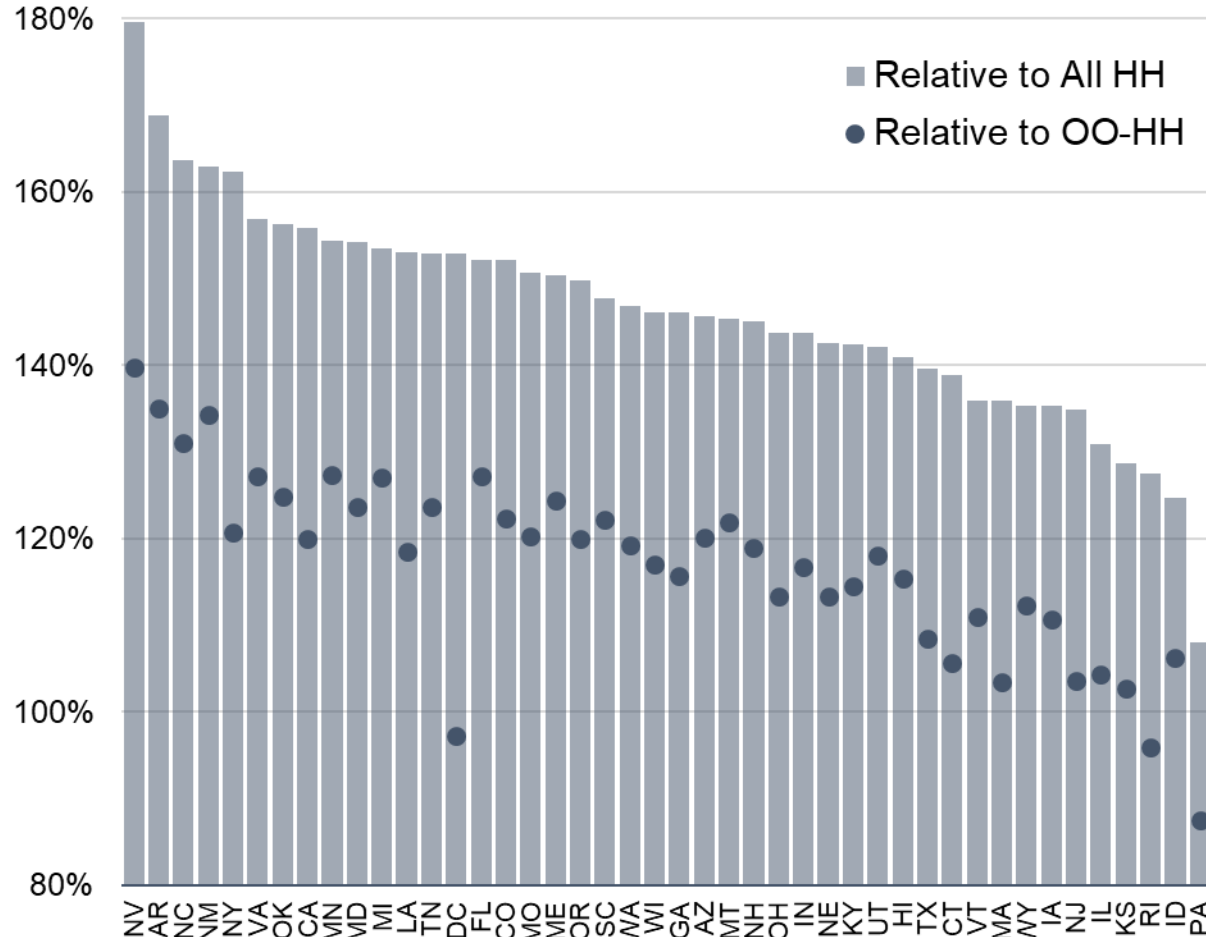
- Solar adopter incomes in all states skew high with median relative incomes ranging from 108-180% of the state median income for all households

- A number of states (DC, MA, NJ, IL, KS, PA) are at or near income parity when compared to just owner-occupied households (OO-HHs)

- Varying degrees of income skew across states reflects differences in:
  - Solar market maturity
  - Solar policies and programs
  - Broader socio-economic factors (overall income inequality, cost of living, educational levels, etc.)

Solar-Adopter Income Trends over Time

Median Solar-Adopter Current Income*
Thousand $

Percent of Solar Adopters

Chart showing stacked area of solar adopters by income bracket (HH income ≥$200k, $150-200k, $100-150k, $50-100k, <$50k) from 2010 to 2022, with a "Median Income" line declining over time. Y-axis left $0-$250, Y-axis right 0%-100%.*

Notes: Incomes are based on the year 2023, regardless of when the PV system was installed, with no inflation adjustments.

□ Solar adoption has gradually shifted over time toward progressively less affluent HHs, though trends since 2015 have slowed

□ Median solar adopter incomes correspondingly fell from $140k for HHs that installed PV in 2010 to $117k for HHs installing PV in 2022

□ Long-term trends driven by falling PV prices, expanded financing options, LMI-focused programs, and general market maturation, among other factors

□ As shown on the next two slides, these factors reflect both a "broadening" of solar markets into less affluent regions, as well as a "deepening" of solar markets as adoption increasingly reaches less affluent households in each region

Solar Market Broadening Trends

Percent of Solar Adopters

Notes: States are grouped based on whether they fall into the lower, middle, or upper third of all U.S. states, in terms of state median income of all households. States are sorted into the three groups so that each group represents roughly one-third of the U.S. population.
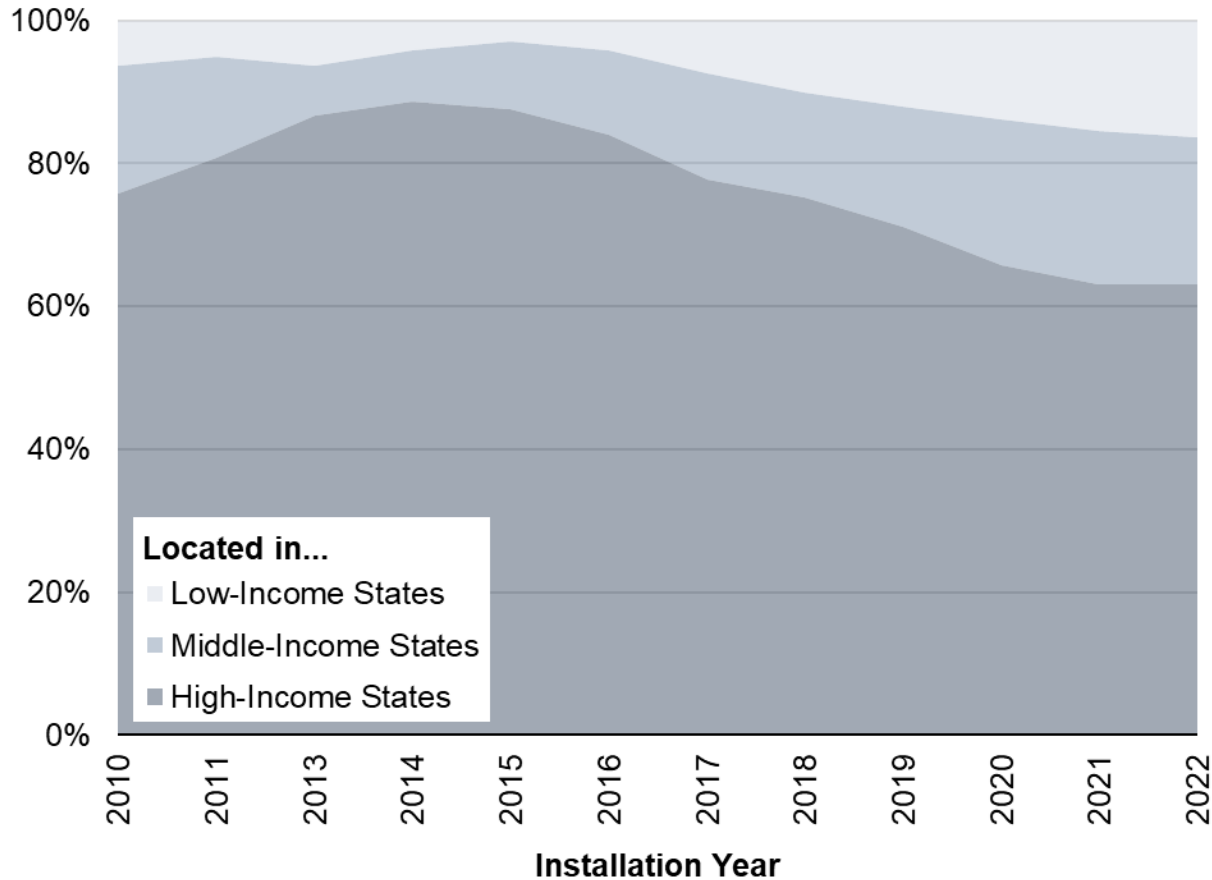
- The U.S. market has been steadily broadening into low- and middle-income states* since 2015, reaching 16% and 21% of 2022 installs, respectively

- The vast majority (~80%) of growth in market share among low- and middle-income states is associated with FL (low-income) and TX (middle-income)

- Regardless, high-income states still comprise a disproportionate share of the market (63% in 2022); for comparison, these states represent roughly one-third of the U.S. population

Solar Market Deepening Trends

Median Solar-Adopter Relative Income Income
Percent of Comparison-Population Current Median Income

Legend:
- Relative to National OO-HHs
- Relative to State OO-HHs
- Relative to County OO-HHs
- Relative to Tract OO-HHs

X-axis: Installation Year (2010–2022)
Y-axis: 100% to 160%
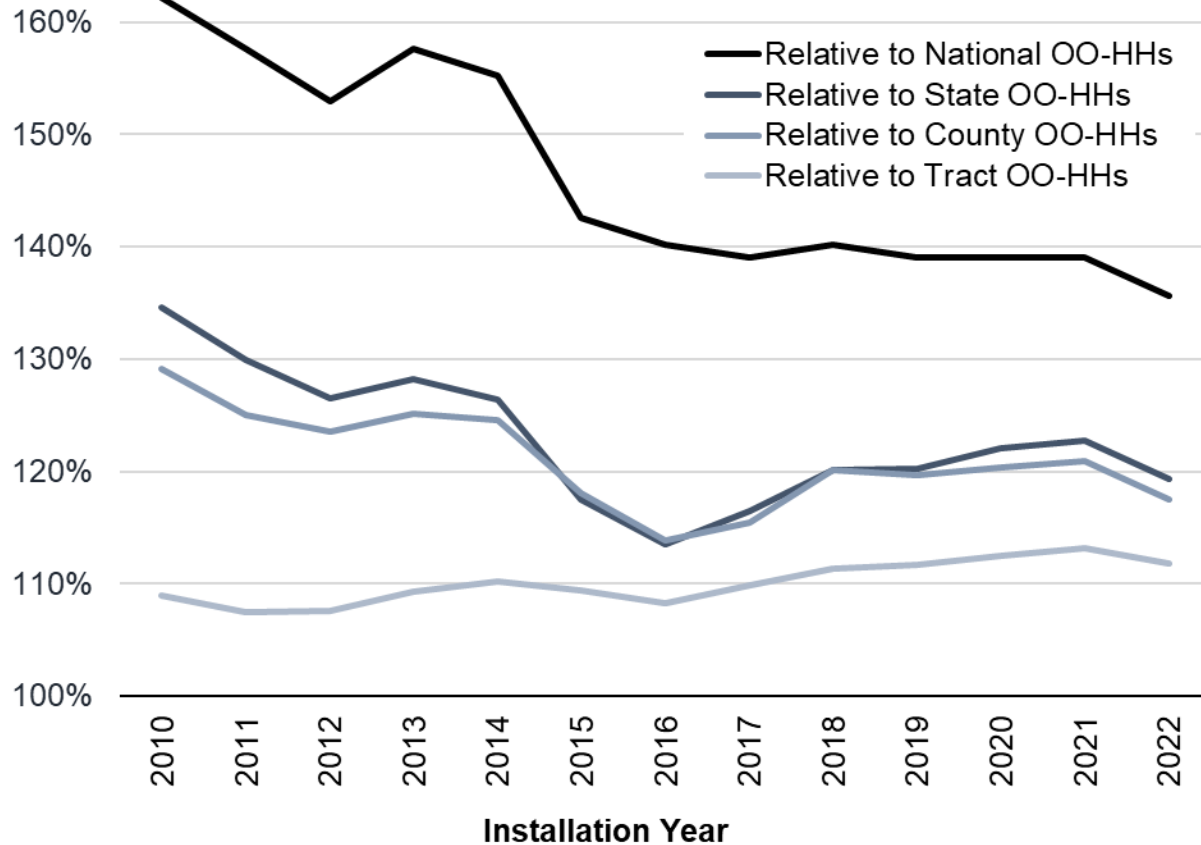
- Solar market deepening refers to a shift in adoption toward progressively less affluent households within a given region

- We can measure deepening (albeit imprecisely) by trends in solar-adopter relative incomes

- Over the long term, relative incomes have fallen at the national, state, and county levels; those trends stalled out in recent years, but picked up again in 2022

- Relative incomes at the tract level, however, have steadily risen: as adoption shifts into new neighborhoods, early adopters tend to be relatively affluent compared to immediate neighbors, even if they are less affluent compared to others in the broader market

LMI Share of U.S. Solar Adopters over Time

Percent of Solar Adopters
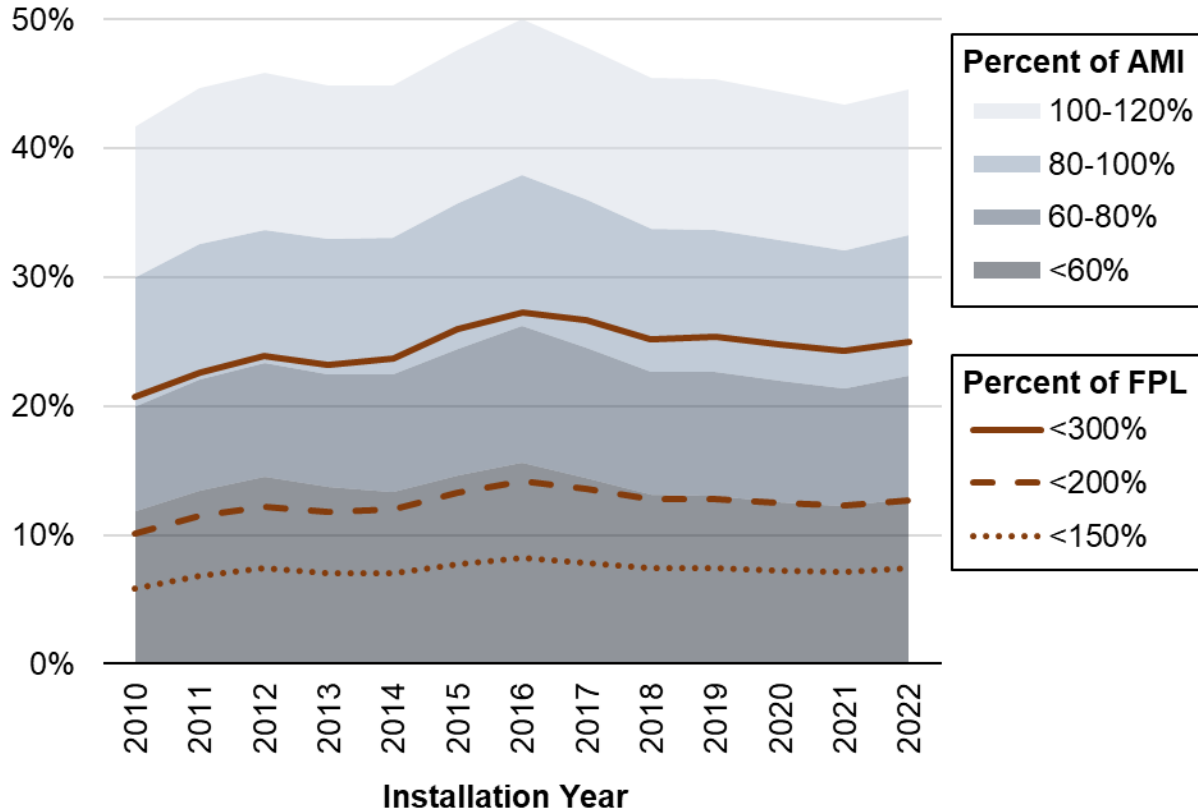
Notes: "Area" refers to the applicable U.S. Census Core-Based Statistical Area or county (for rural areas). Both AMI and FPL vary by household size. For a family of three, the FPL for the contiguous 48 states was $23,030 in 2022.

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 trending up over time

- Across all U.S. solar adopters in 2022:
  - **AMI:** 23% were <80% of AMI, 45% were <120% of AMI
  - **FPL:** 7% were <150% of FPL, 25% were <300% of FPL

- State-level data accessible online via Berkeley Lab's solar demographics tool

Solar Installation Attributes by Adopter Income Level

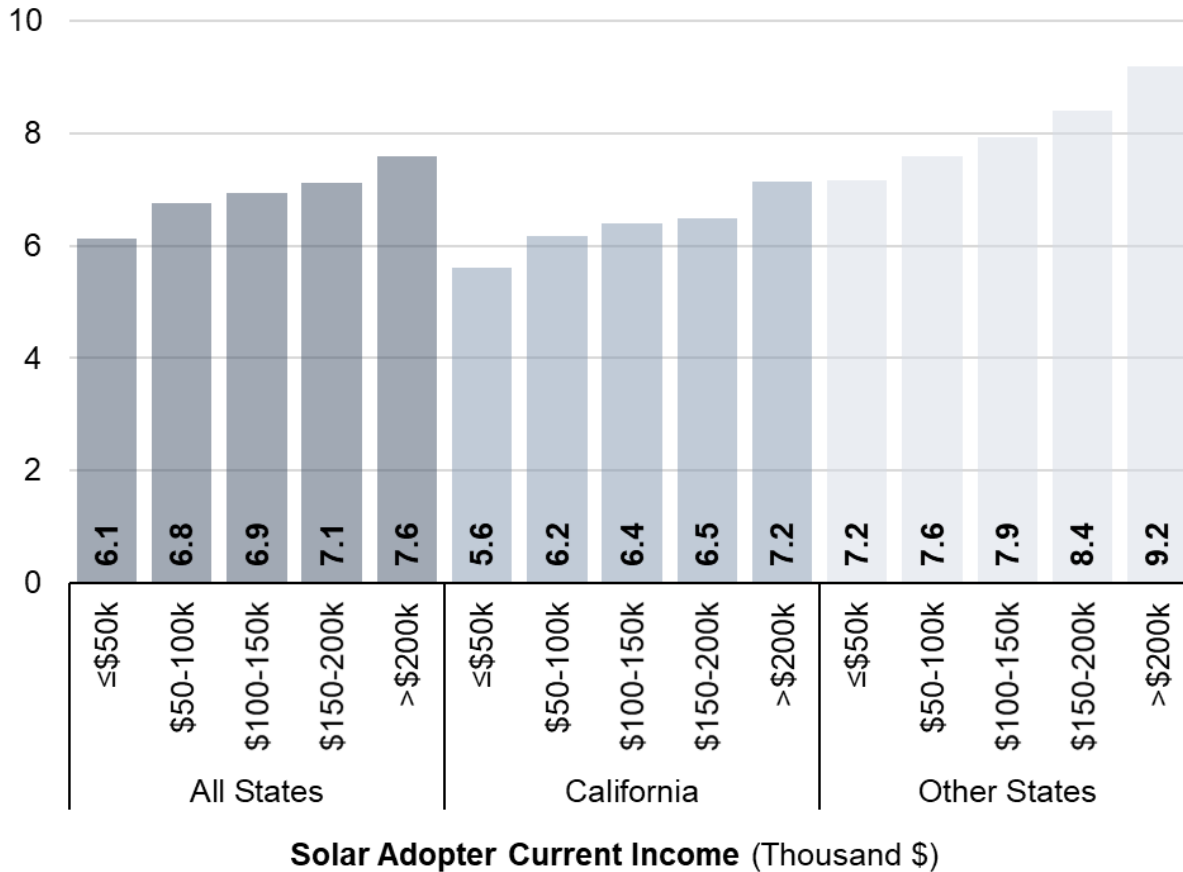# Solar Installation Attributes by Adopter Income Level

□ Beyond looking at how solar-adopter incomes vary over time and geography, we can also evaluate how PV system characteristics vary based on household income

- ◘ System size
- ◘ Third-party vs. host-owned
- ◘ Battery attachment rates
- ◘ Size of solar installer firm

□ Based primarily on the subset of the dataset originating from *Tracking the Sun*

System Size by Income Level

Median System Size (kW$_{DC}$) for Systems Installed in 2022

Bar chart values by Solar Adopter Current Income (Thousand $):

All States: ≤$50k: 6.1, $50-100k: 6.8, $100-150k: 6.9, $150-200k: 7.1, >$200k: 7.6

California: ≤$50k: 5.6, $50-100k: 6.2, $100-150k: 6.4, $150-200k: 6.5, >$200k: 7.2

Other States: ≤$50k: 7.2, $50-100k: 7.6, $100-150k: 7.9, $150-200k: 8.4, >$200k: 9.2

- Higher income households install larger systems
  - Larger systems cost more
  - Higher-income households may have larger homes with larger roof area, higher electricity demand
- Those with incomes >$200k have median systems 24% larger than those earning <$50k (7.6 kW vs. 6.1 kW)
- System size differences across income levels are slightly more pronounced when separating California from other states
  - California systems are small compared to other states, while incomes are relatively high

Third-Party Ownership Rates by Income Level

Third-Party Ownership Share
Percent of PV systems installed in 2022

Solar Adopter Current Income (Thousand $)
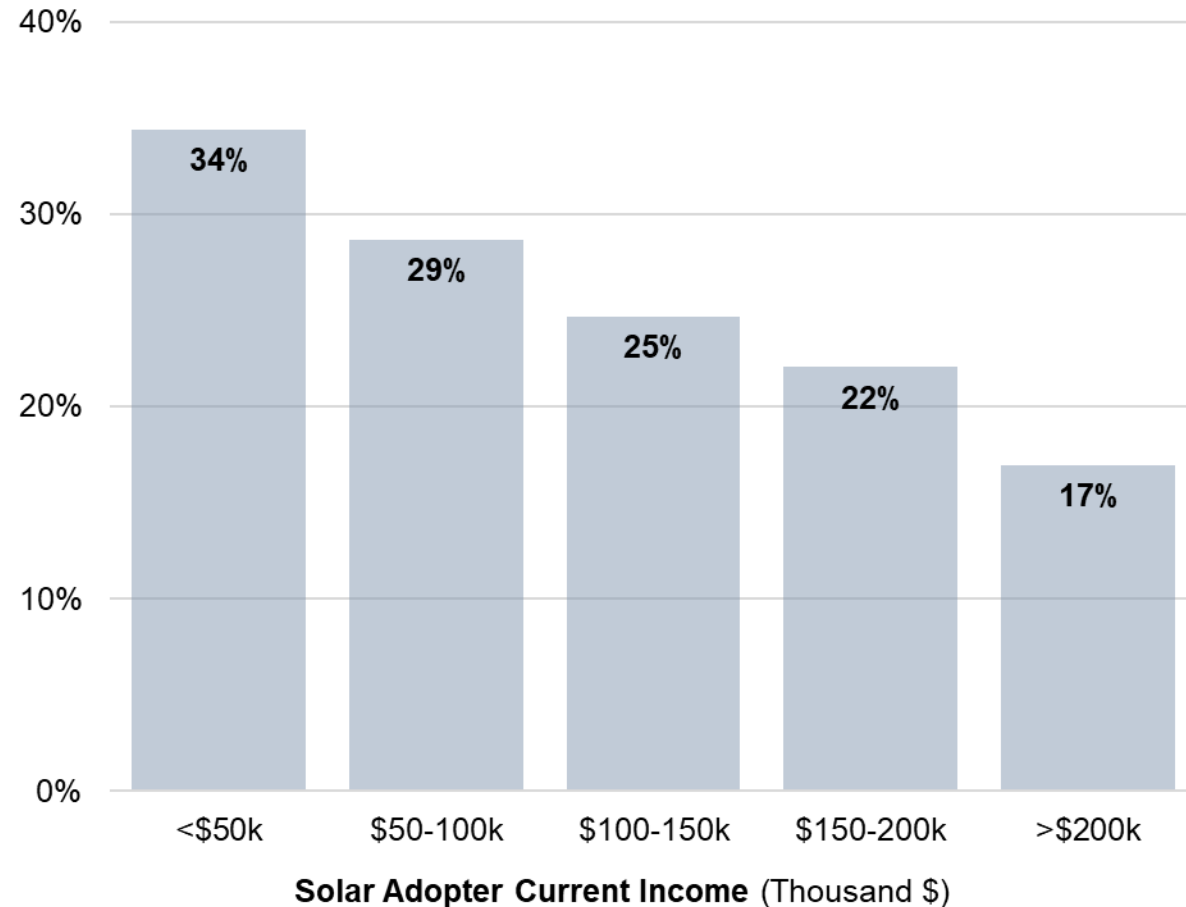
- Third party ownership (TPO) shares are consistently higher for lower-income households: roughly 2x for households in the lowest vs. the highest income group in 2022

- O'Shaughnessy et al. (2021) found that TPO has driven adoption by lower income HHs (as opposed to simply attracting LMI HHs that would otherwise install host-owned PV)

- That said, the market has steadily shifted away from TPO since its peak in 2015

- Solar loans have taken its place as the dominant form of solar financing, but unclear at present how the uptake of loans vary across household incomes

Storage Attachment Rates

Battery Storage Attachment Rates for Systems Installed in 2022
Percent of PV systems co-installed with storage

(Bar chart showing attachment rates by Solar Adopter Current Income (Thousand $), grouped by All States, California, and Other States)

All States: ≤$50k: 5%, $50-100k: 7%, $100-150k: 8%, $150-200k: 10%, >$200k: 15%

California: ≤$50k: 6%, $50-100k: 8%, $100-150k: 10%, $150-200k: 13%, >$200k: 19%

Other States: ≤$50k: 5%, $50-100k: 6%, $100-150k: 7%, $150-200k: 8%, >$200k: 9%

Solar Adopter Current Income (Thousand $)
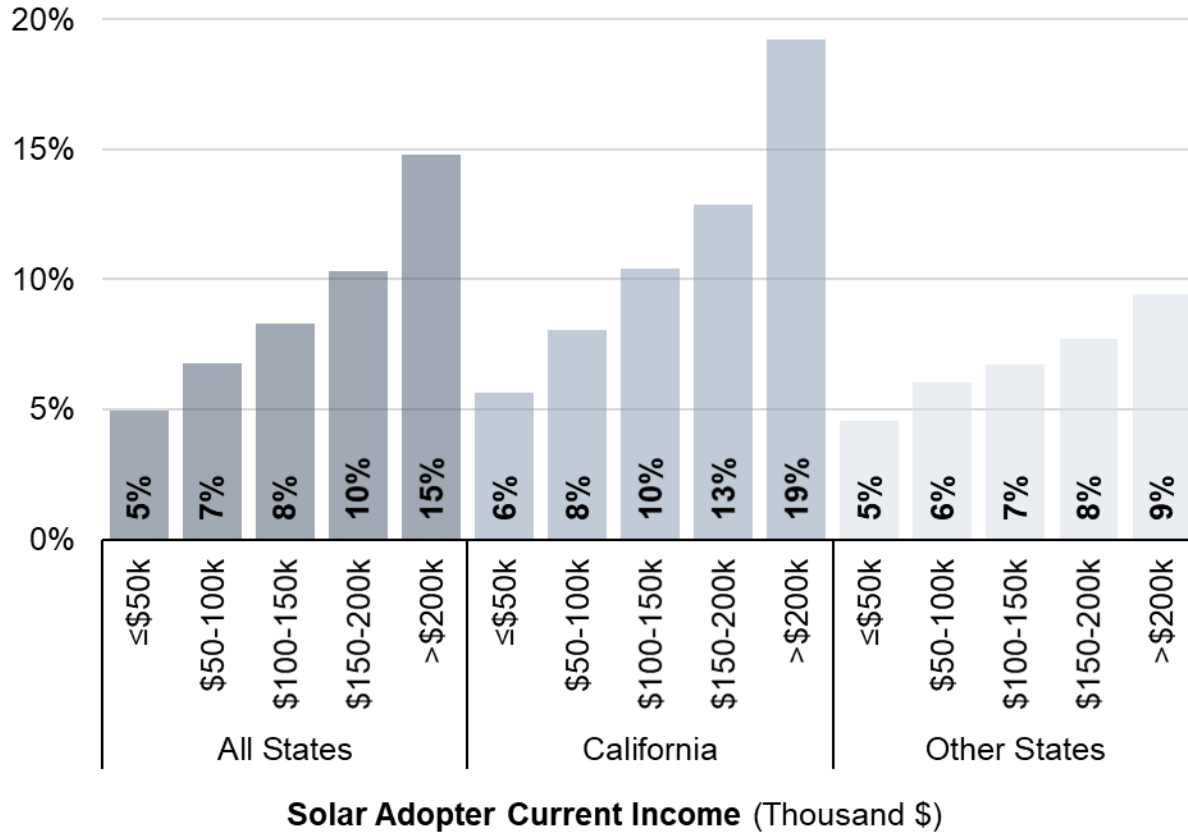
- ☐ Storage attachment rates are consistently higher for higher income households
  - ◻ Storage equipment adds cost, but also provides additional benefits (bill savings, resiliency)
- ☐ The difference in attachment rates between the highest and lowest income groups are especially pronounced in California compared to other states (a 13 point spread, compared to a 4 point spread in other states)
  - ◻ CA comprises more than half of all paired solar+storage systems in 2022, and has generally higher attachment rates

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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*:
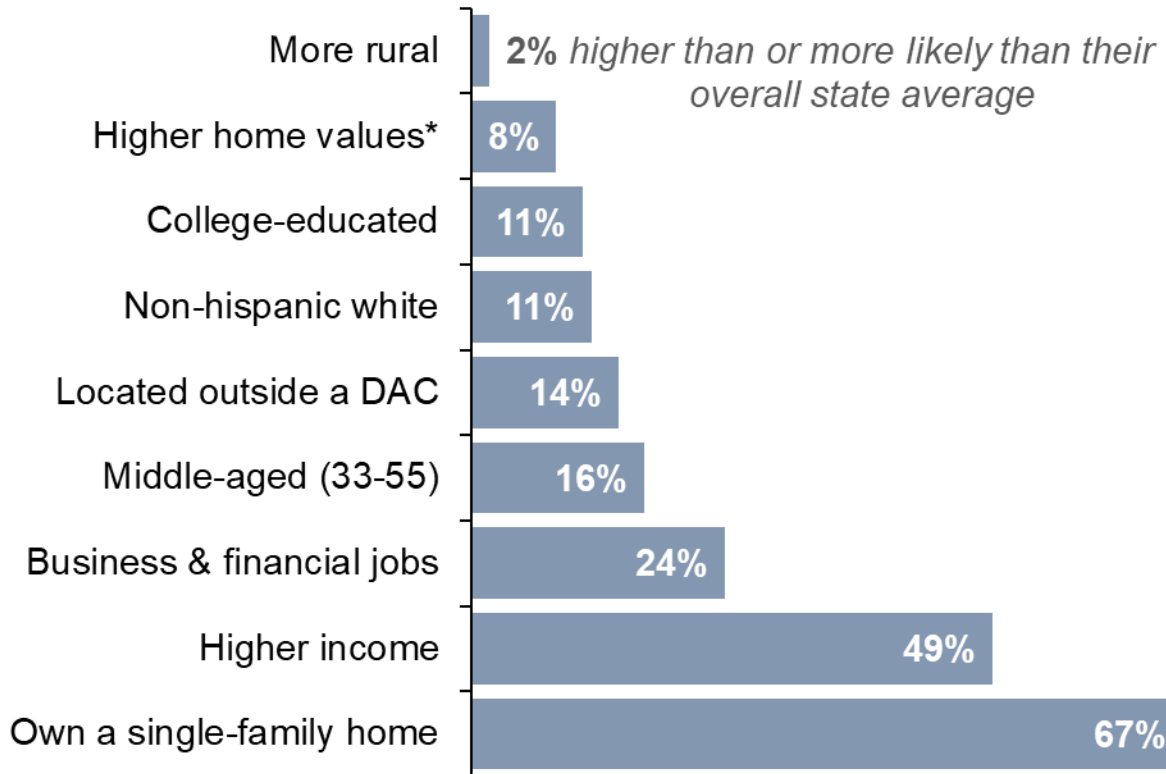
- Location in a Disadvantaged Community (DAC)
- Race and Ethnicity

- 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 equity, we can compare to the broader U.S. population on both an absolute and also a *weighted-average* basis across states

Summary of Solar-Adopter Socio-Economic Attributes

Compared to all households in their respective state, 2022 solar adopters tend to be or have...

| Attribute	%
More rural	2% *higher than or more likely than their overall state average*
Higher home values*	8%
College-educated	11%
Non-hispanic white	11%
Located outside a DAC	14%
Middle-aged (33-55)	16%
Business & financial jobs	24%
Higher income	49%
Own a single-family home	67%

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

- The figure shows how 2022 solar adopters compare to all HHs in their respective state (further details provided on the following slides)

- Skew is greatest for housing type/tenure (single family, owner-occupied homes) and income

- In contrast, rurality of PV adopters, on average, is quite similar to their respective state

- As shown elsewhere, the skew for some attributes can differ significantly if comparing to only OO-HHs (particularly notable for race and ethnicity, where the directionality flips)

DAC Share of U.S. Solar Adoption over Time

Percent of Households in DACs

Legend:
- Solar Adopters (bars)
- All U.S. Households (dashed line)

X-axis: Installation Year (2010–2022)
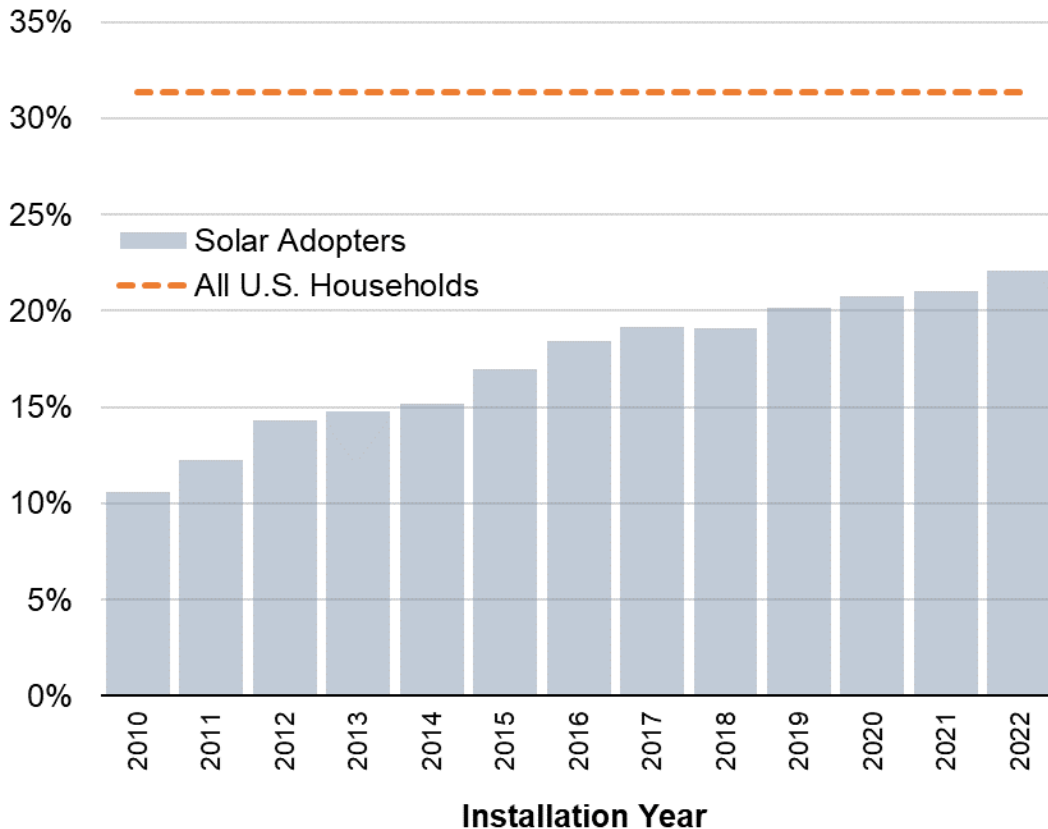
Notes: Each Census tract's DAC determination was made using the CEJST version 1.0 released November 2022. The percentage of all households in DACs was determined by summing the number of occupied dwelling units in DAC tracts versus those outside of DAC tracts using the ACS 2021 5-year survey.

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 2022

☐ 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)

DAC Share of Solar Adoption by State

Percent of Households in DACs

Legend: 2022 PV Adopters, All Households
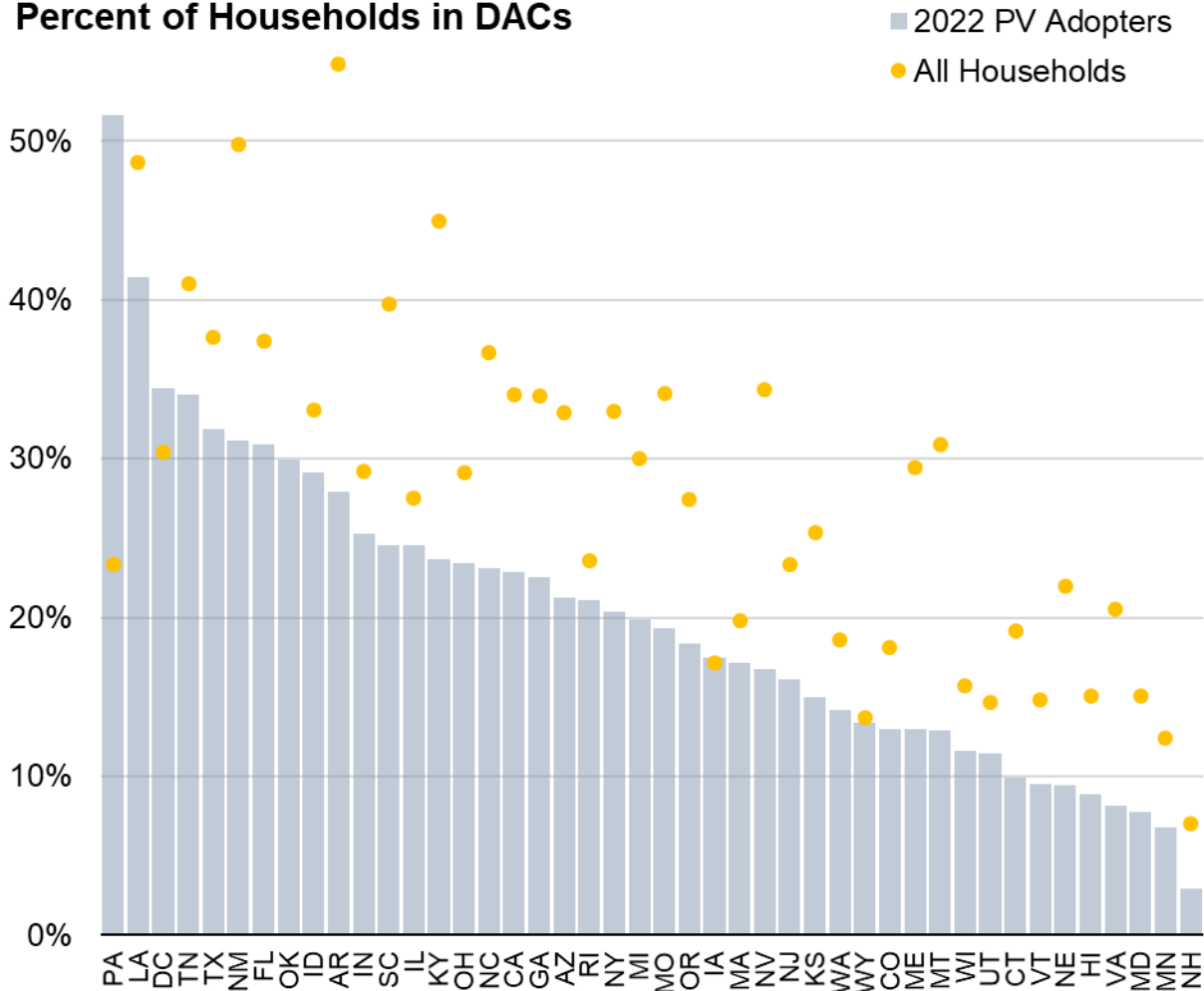
- At the state level, the share of PV adoption in DACs varies widely, reflecting underlying differences in the share of the overall population located in DACs

- In almost all states, DACs are under-represented among PV adopters in 2022
  - On average, 10 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 large share of population in DACs

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 tract and the name of the primary householder (Khanna et al. 2022)[1]

- ▫ 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 distinction between "Non-Hispanic White" vs. "Minority" (i.e., Hispanic and/or non-white), which provides greater accuracy*
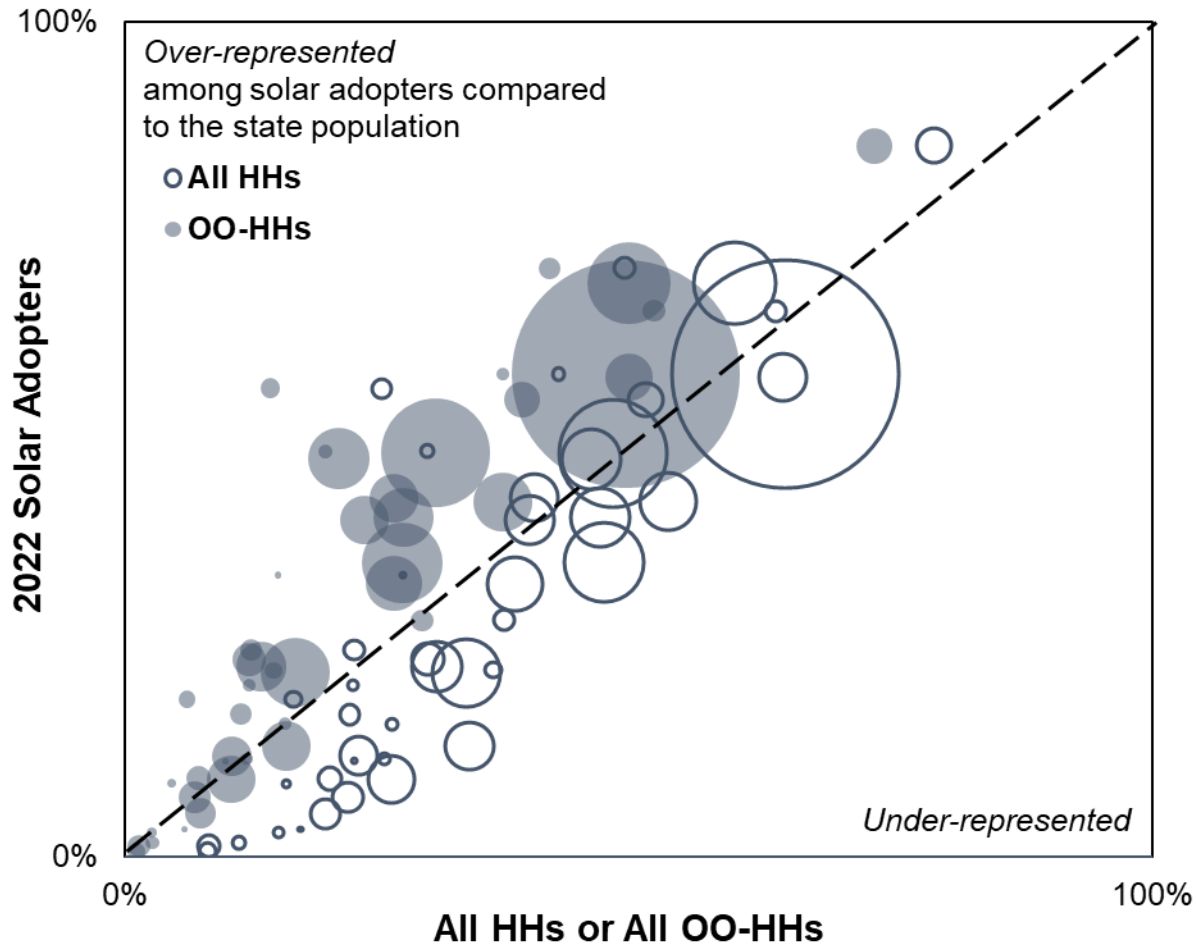
[1] *Khanna K, Bertelsen B, Olivella S, Rosenman E, Imai K (2022). "_wru: Who are You? Bayesian Prediction of Racial Category Using Surname, First Name, Middle Name, and Geolocation_". R package version 1.0.1, <https://CRAN.R-project.org/package=wru>.*
[2] *Yozwiak et al. (forthcoming), "Residential Solar's Effect on Household Energy Insecurity among Low-to-Moderate Income Households"*

Race and Ethnicity
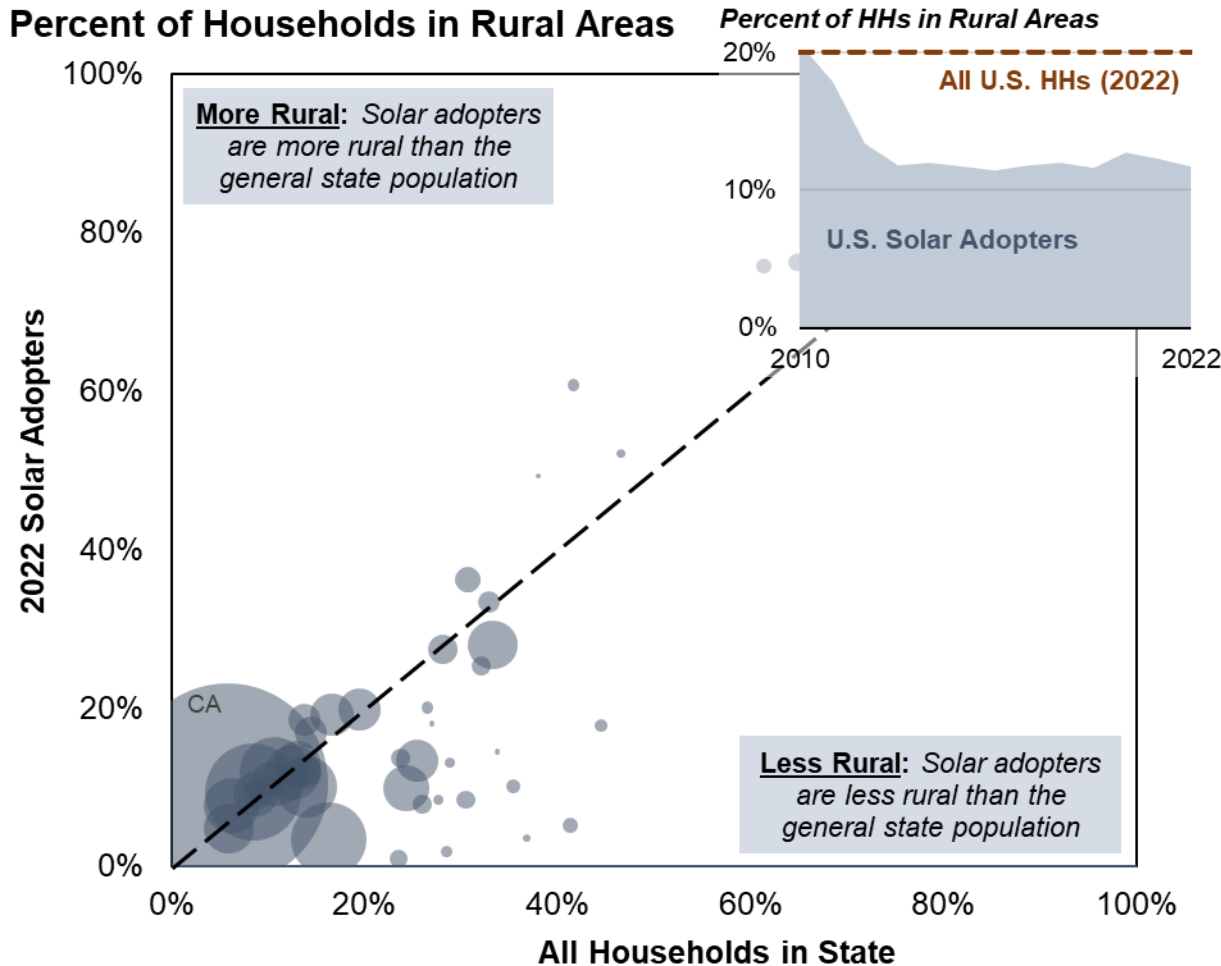## State-level comparisons: 2022 PV adopters vs. all HHs and all OO-HHs

Percent Minority Households by State

- Over-represented among solar adopters compared to the state population
  - ○ All HHs
  - ● OO-HHs
- Under-represented

2022 Solar Adopters (y-axis, 0% to 100%)

All HHs or All OO-HHs (x-axis, 0% to 100%)

- ☐ 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

Rural vs. Urban
State comparisons and national trends over time

Percent of Households in Rural Areas

More Rural: *Solar adopters are more rural than the general state population*

Percent of HHs in Rural Areas

All U.S. HHs (2022)

U.S. Solar Adopters

2010   2022

2022 Solar Adopters

CA

Less Rural: *Solar adopters are less rural than the general state population*

All Households in State

Notes: Urban/rural classification is based on the 2020 US Census definitions, which rely on population density and land use, among other factors.
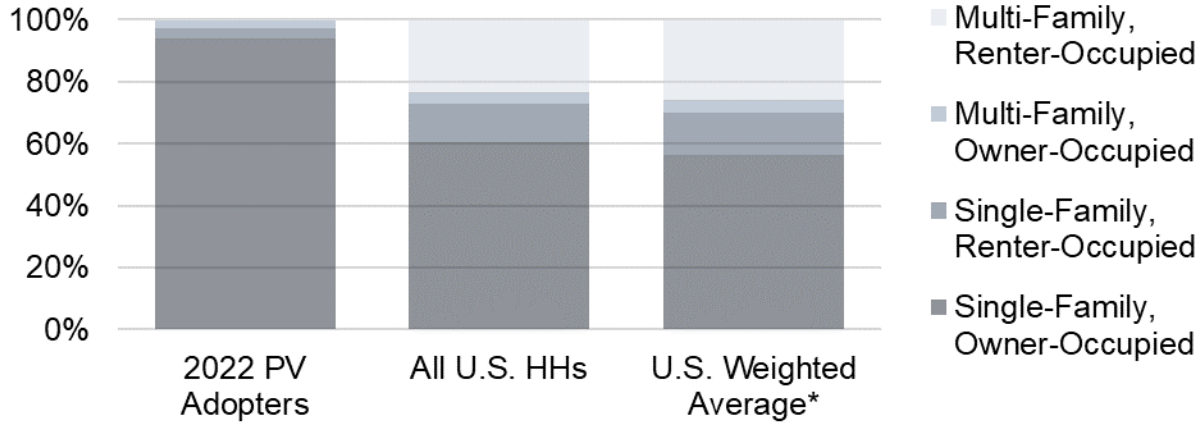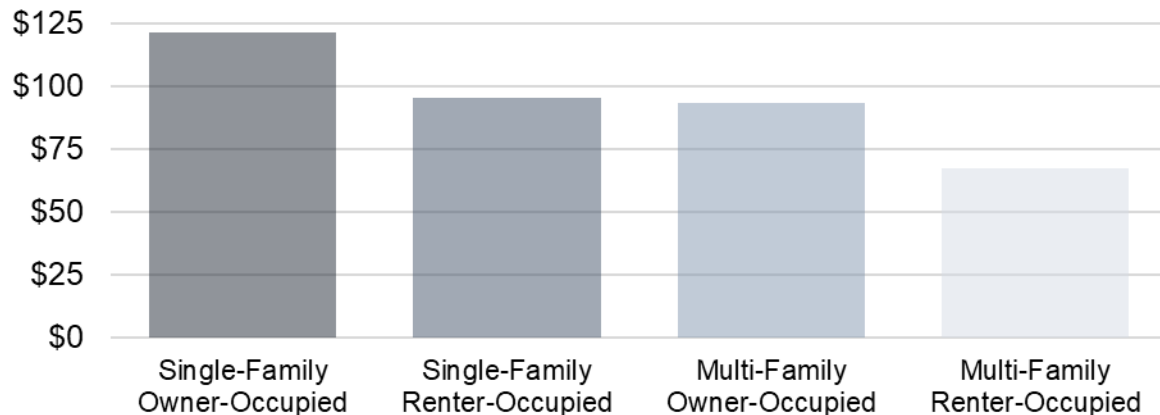
- Nationally, solar adoption is concentrated in less rural states, most notably California

- As a result, U.S. solar adopters are less rural overall (12% of 2022 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 mirrors the distribution of households between rural and urban areas at the state level

Housing Type and Tenure

Percent of Households

Legend:
- Multi-Family, Renter-Occupied
- Multi-Family, Owner-Occupied
- Single-Family, Renter-Occupied
- Single-Family, Owner-Occupied

Categories: 2022 PV Adopters, All U.S. HHs, U.S. Weighted Average*

Median Solar-Adopter Current Income (2022 Systems, Thousand $)

Categories: Single-Family Owner-Occupied, Single-Family Renter-Occupied, Multi-Family Owner-Occupied, Multi-Family Renter-Occupied

- The vast majority (94%) of 2022 PV systems were installed on single-family, owner-occupied homes
  - The remainder is split evenly between single-family renter-occupied and multi-family owner-occupied (primarily condos)
  - 2022 PV adopters include a negligible share of multi-family renter-occupied systems

- 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

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

- Data for 2022 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 vary considerably across states, in some cases suggestive of policy-related factors

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