Residential Solar-Adopter Income and Demographic Trends: November 2022 Update

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

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.

BERKELEY LAB

U.S. DEPARTMENT OF ENERGY

November 2022

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

Disclaimer

Copyright Notice

Report Outline

1. Introduction

- Overview and key findings
- Data sources and geographic coverage

2. Solar-Adopter Income Trends

- Temporal and geographic trends
- Solar-adopter incomes compared to the broader population
- Low-to-moderate income shares of adopters
- Adoption in “disadvantaged communities”
- Income trends based on:
  - Third-party ownership (TPO)
  - System size
  - Installer
  - Battery-storage pairing
  - Multi- vs. single-family housing

3. Other Socio-Economic Trends for Solar Adopters

- Race and ethnicity
- Language
- Rural vs. urban
- Education
- Occupation
- Age
- Home value
- Credit score

4. Conclusions and Open Questions

5. 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 2021
- Income trends for rural vs. urban adopters
- PV adoption trends among Disadvantaged Communities (DOE definition of DAC used)

Related Berkeley Lab Resources

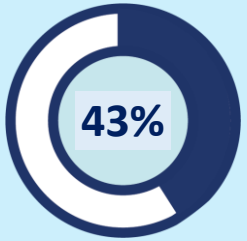
- Online data visualization tool allowing users to further explore the underlying dataset
- In depth topical studies on issues related to solar energy access and equity
- Analytical support to external organizations

BERKELEY LAB

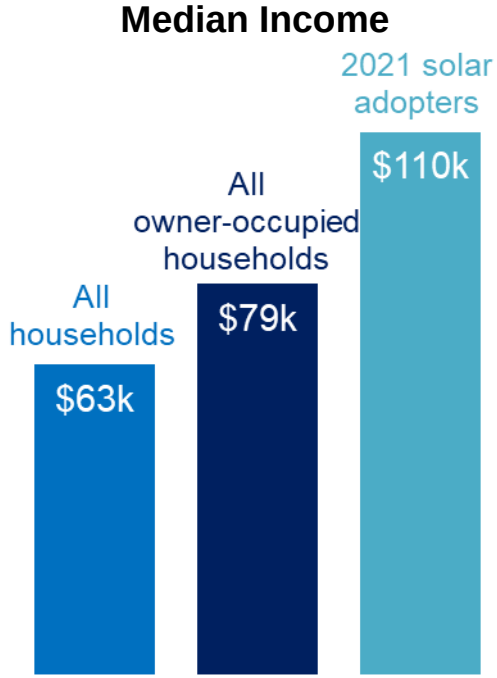
High-Level Findings

Solar adopter incomes vary considerably, but are generally higher than population averages

- The median solar adopter income was about $110k/year in 2021, compared to a U.S. median of about $63k/year
- The skew is smaller when comparing to only owner-occupied households or to other households in the same state—but all states exhibit some skew



Low- and Moderate-Income Adoption
While solar adoption skews toward high-income households, low- and moderate-income households are also adopting. In 2021, about 43% 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)



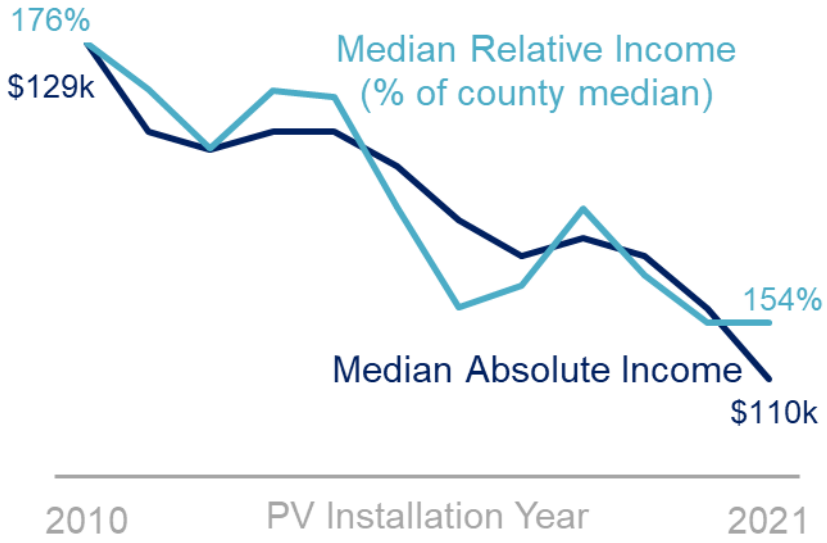
Solar adopters vary along other demographics

Compared to the broader population, solar adopters tend to:

- Identify as Non-Hispanic White
- Be primarily English-speaking
- Live in rural areas
- Have higher education levels
- Be middle-aged
- Work in business and finance-related occupations
- Live in higher-value homes
- Live in neighborhoods with higher average credit scores

The rooftop solar market is becoming more equitable over time

*Solar-Adopter Household Income**



* *Based on household incomes in the year 2021, regardless of PV installation date*

- Rooftop solar is **broadening** by expanding geographically into states with generally lower income levels
- Rooftop solar is also **deepening** by reaching lower-income households in existing markets.
- These trends reflect the effects of falling solar prices and the emergence of policies and business models that support broader adoption, among other factors

Data Sources

PV Street Addresses & System Data

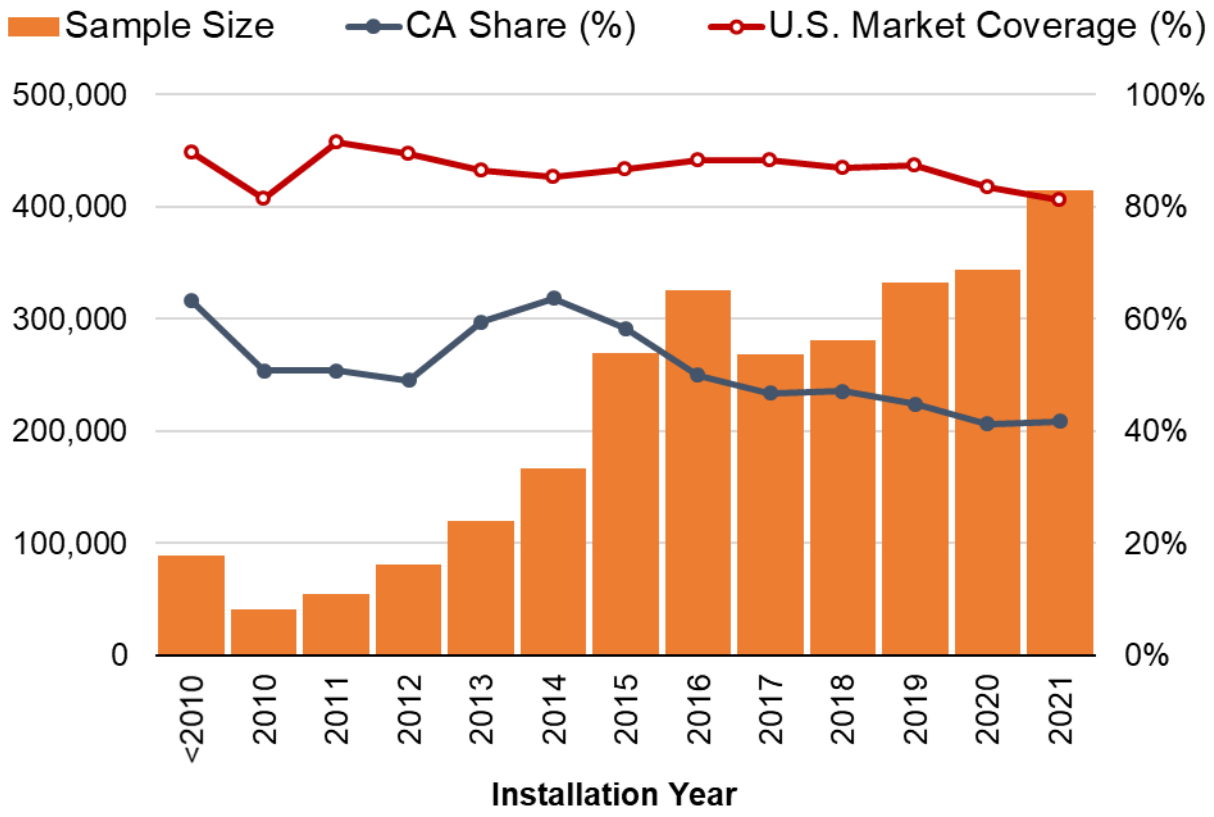
- Berkeley Lab's ***Tracking the Sun*** dataset: Primary data source; includes addresses and other data for roughly 1.9 million systems, obtained primarily from utilities and state agencies
- **BuildZoom** and **Ohm Analytics**: Purchased PV permit datasets; provide a supplementary source of PV street addresses for roughly an additional 900,000 systems

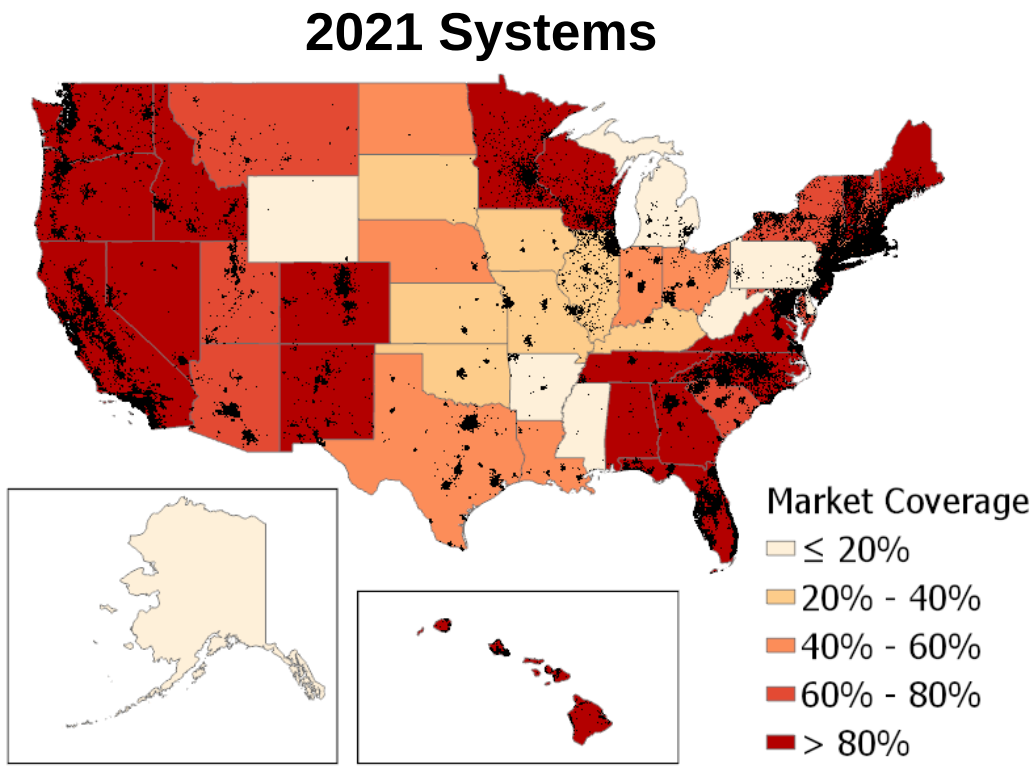
Income & Other Socio-Economic Data

- **Experian ConsumerView**: Purchased dataset providing modeled household-level income estimates for solar adopters and for population as a whole; as well as household data on other socio-economic attributes
- **U.S. Census** and **Bureau of Labor Statistics**: Used for comparison purposes to characterize demographics of total U.S. population

See appendix slides 44 - 45 for further details on income and other socio-economic data sources

Sample Coverage





- Sample consists of **2.8 million systems**, covering roughly **86%** of all U.S. residential systems through 2021 and **81%** of systems installed in 2021; market coverage by state varies widely, but >40% in most states
- California represents more than half of the total sample and 42% of systems installed in 2021

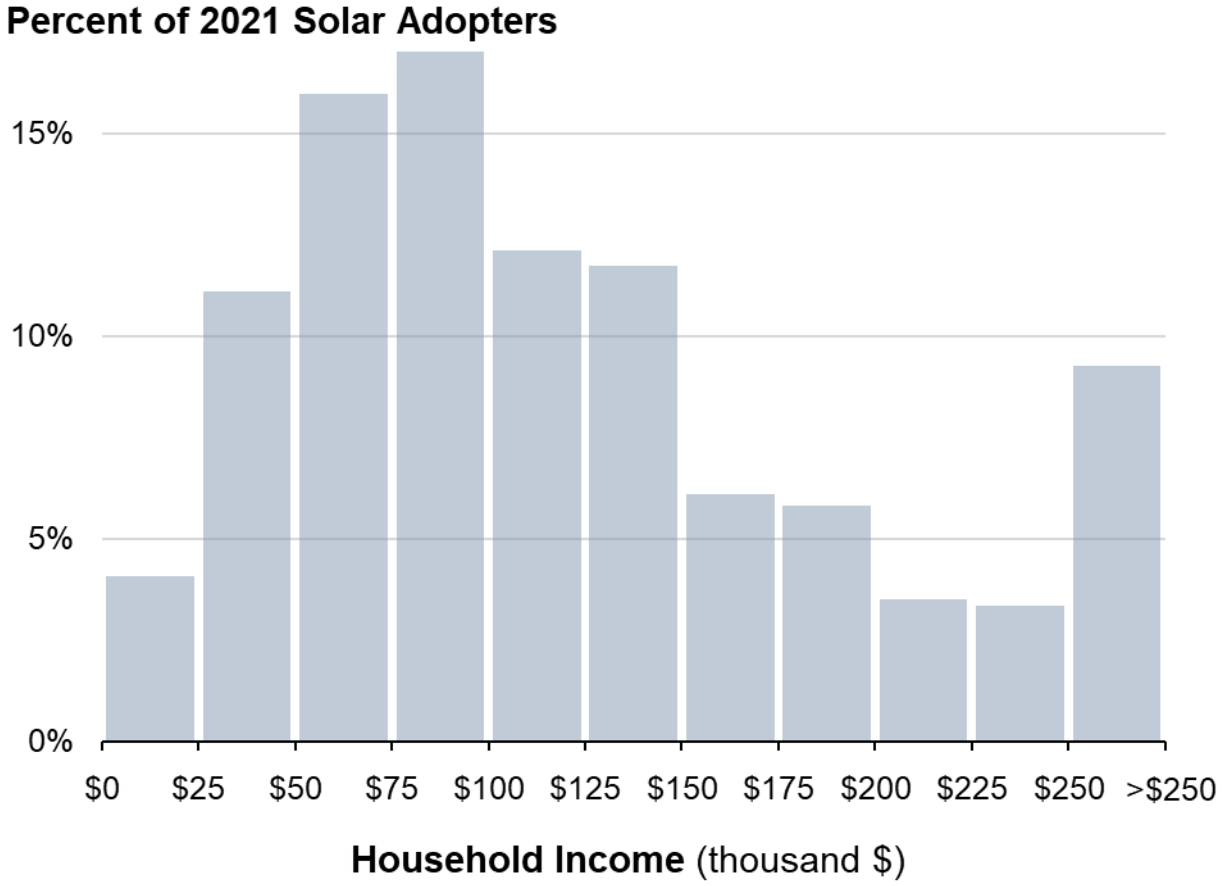
See appendix slides 46 - 47 for further details on sample sizes

General Points on the Data and Descriptive Approach

- We focus here on national and state-level trends, with an emphasis on PV systems installed from 2010-2021; additional data, including county- and Census tract-level trends, as well as data for earlier years, are available through Berkeley Lab's online data visualization tool
- PV adopter income and demographic data reflect *current* values based on Experian ConsumerView data obtained in Q3 2022, rather than at time of adoption; consequently, the data may not be representative of the household at the time of adoption (especially if the home since sold)
- Income estimates refer to total household income, while most of the other demographic attributes (race, language, occupation, education) are based on the primary householder; regardless, we describe trends in terms of "households" as the relevant unit for PV adoption
- All national trends are heavily impacted by California, given its large share of the market
- 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 sources and completeness of the associated data fields; see appendix slide 47 for details

Solar-Adopter Income Trends

Solar-Adopter Income Distribution

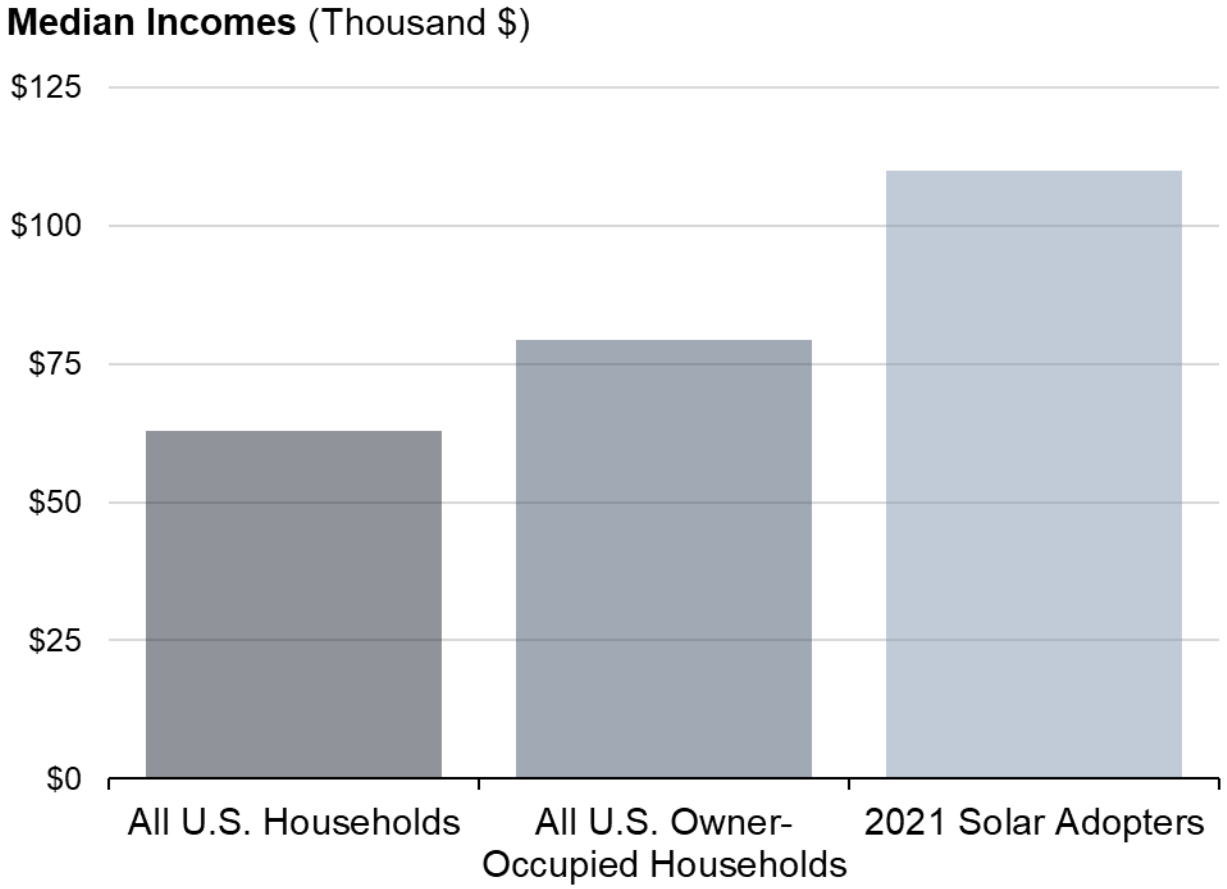


* *Notes: Experian does not differentiate income estimates >$250k, thus all households above that level are aggregated, leading to the spike on the right-hand side of the distribution*

- Solar adopters span all household (HH) income levels, from less than $25k to more than $250k
- A large fraction of solar adopters in 2021 could be considered “middle income”: for example, one-third (33%) have HH incomes in the $50-100k range
- 15% of adopters are below that range, while 52% are above it
- The distribution has a long upper tail, with 16% of adopters above $200k and 9% above $250k*

BERKELEY LAB

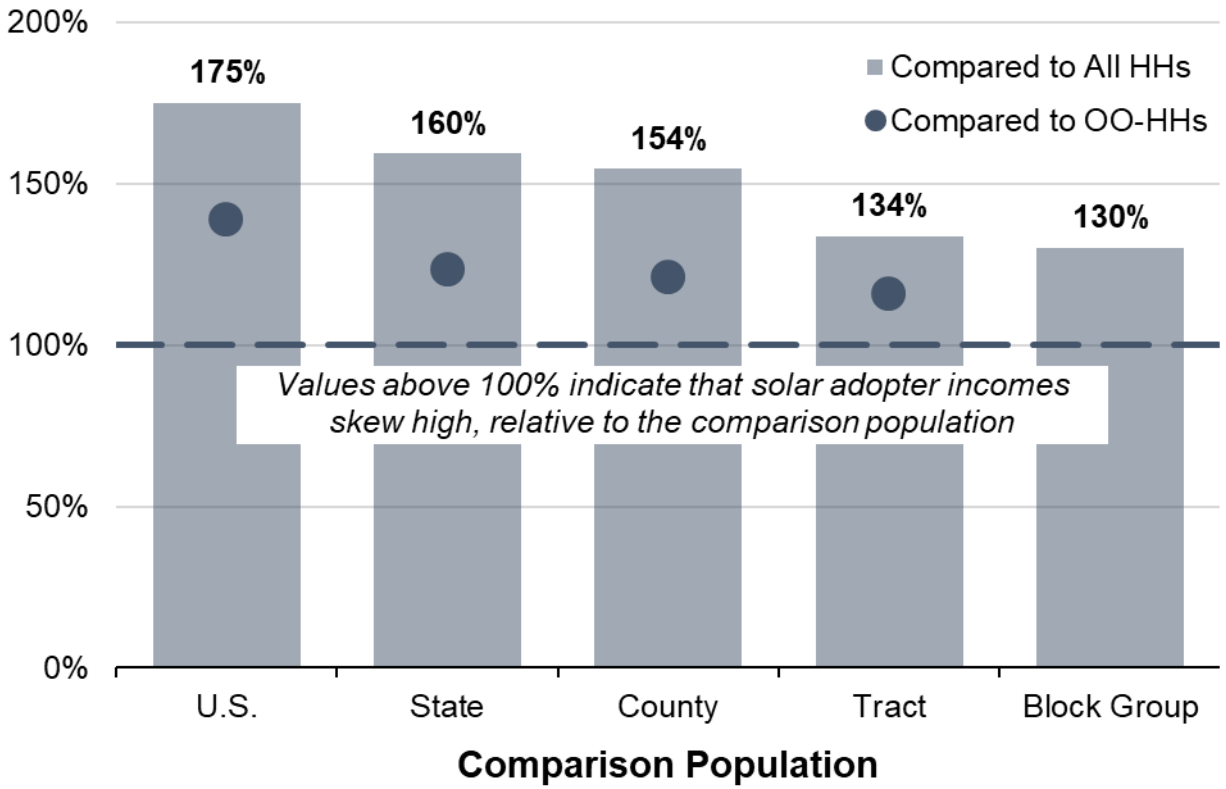
Solar-Adopter Incomes Compared to Total U.S. Population



- Solar-adopter incomes skew high relative to the population at large: median income of all U.S. HHs is $63k, compared to $110k for 2021 solar adopters
- Skew is less pronounced if comparing to only owner-occupied households (OO-HHs), who have a median income of $79k
  - Solar adopters in this study are almost entirely OO-HHs (due to owner-control of rooftop, owner/tenant split incentive)
- The skew relative to national median incomes is partly due to the fact that roughly half of solar adopters are in California, a relatively high-income state (though, as shown on later slides, all states exhibit some skew)

Solar-Adopter "Relative Income"

Median Solar-Adopter Relative Income (2021 Adopters)
% of Comparison-Population Median Income



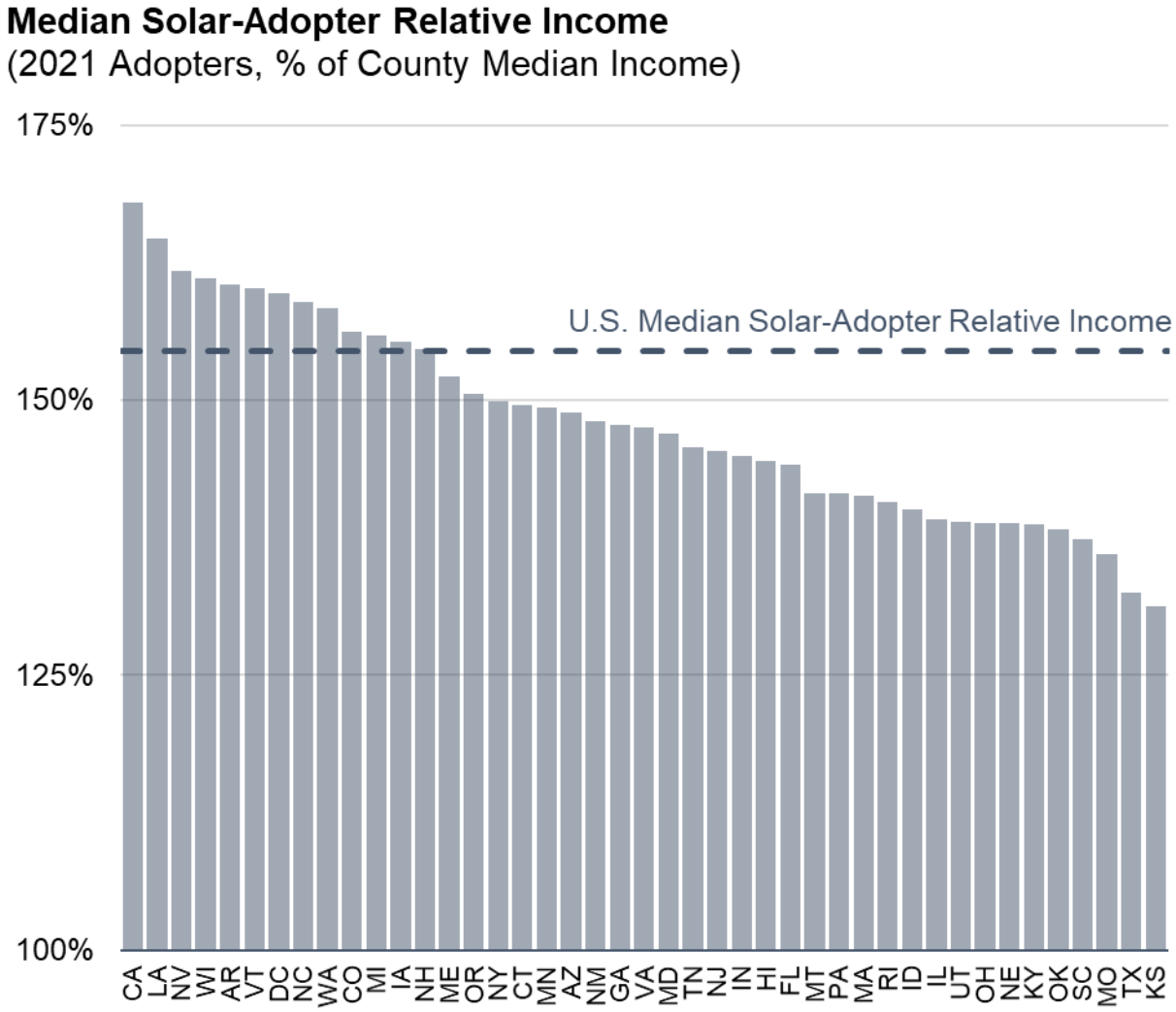
Notes: To calculate these values, we first calculate each solar adopter's household income as a percentage of the median household income for each comparison population, and then take the median of those percentage values across all solar adopters. At the block group level, median incomes are available 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

- Solar-adopter incomes skew high, regardless of how broadly defined the comparison region
- The skew is smaller the more localized the comparison, as households with similar incomes tend to cluster together
- Across all scales, skews are much smaller when comparing to only OO-HHs (e.g., 121% when comparing to OO-HHs in the same county vs. 154% if comparing to all HHs)

Going forward, we use County Median Income across all HHs for calculating relative incomes

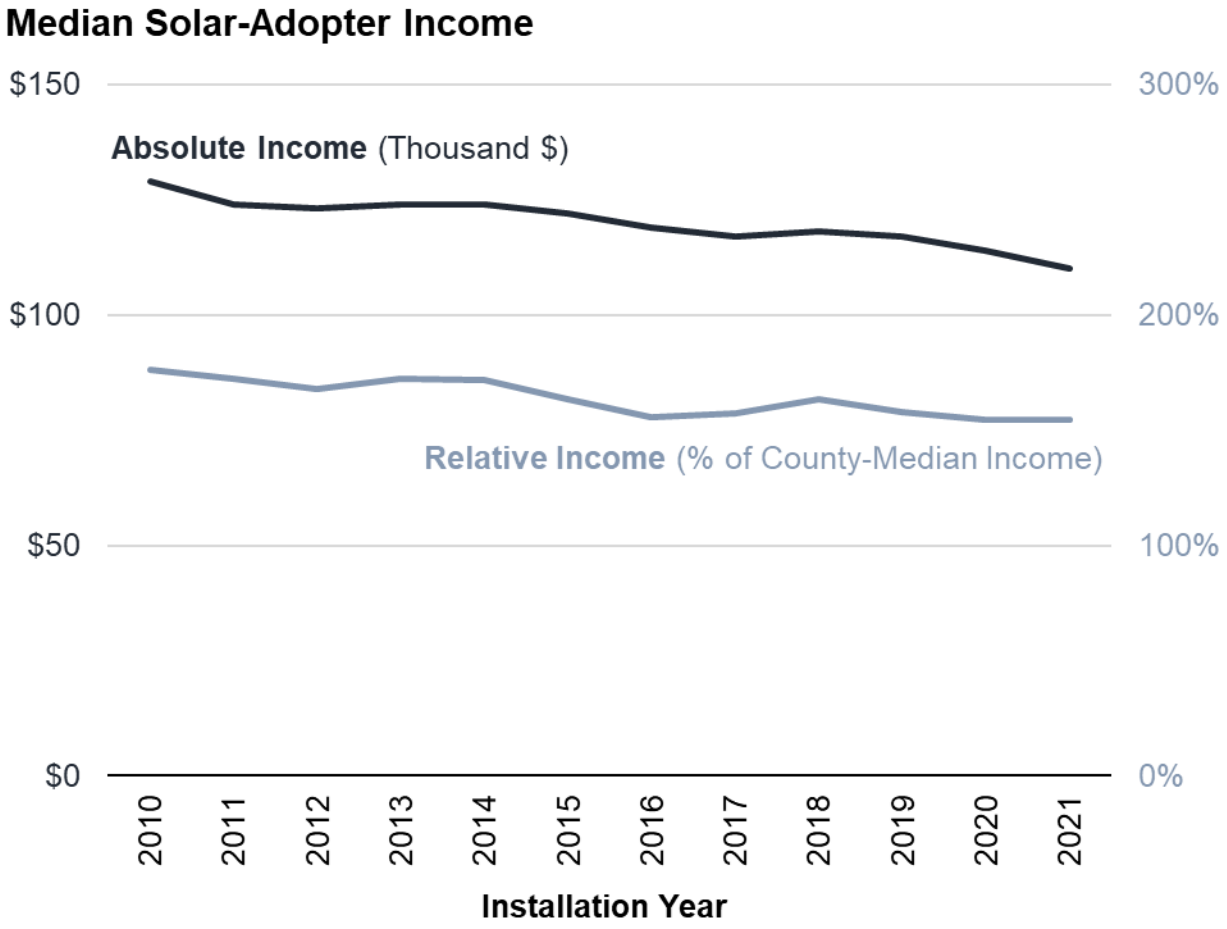
Solar-Adopter Income Trends across States



- Solar adopters in all states skew toward higher incomes, with median relative incomes ranging from 131-168% of the county median
- Skew in CA is highest among all states, pulling the national median up; most states are less skewed than the national median
- Varying degrees of income skew across states may reflect differences in:
  - Relative levels of solar market maturity
  - Solar policies, programs, financing availability
  - Broader socio-economic factors (income inequality, cost of living, educational levels, etc.)

See Darghouth et al. 2022 for analysis of local differences in income skew. See online data visualization tool for additional state-level data.

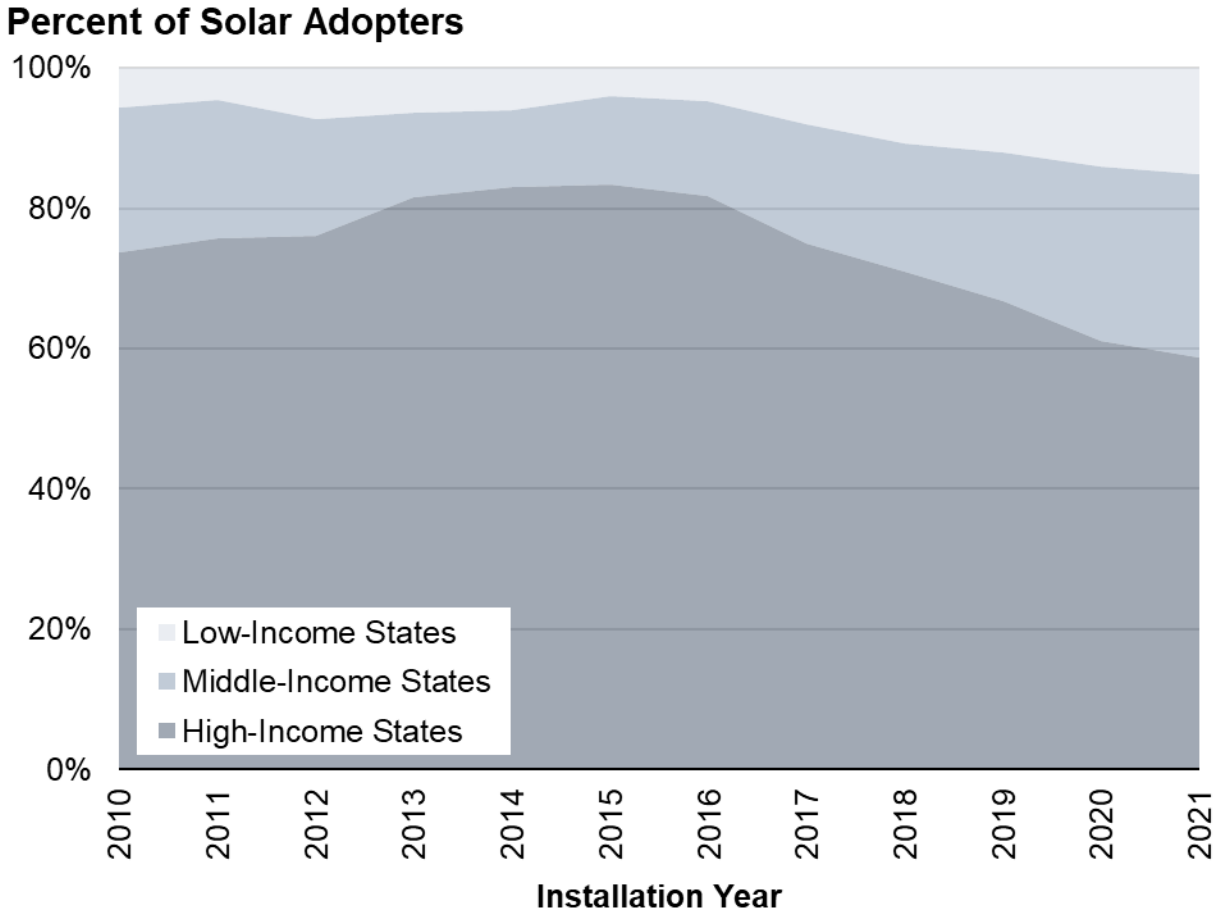
Solar-Adopter Income Trends over Time



** Notes: Incomes are based on the year 2022, regardless of when the PV system was installed, with no inflation adjustments.*

- Solar adoption has been slowly migrating toward less affluent households, on both an absolute (top line) and relative (bottom) basis
- Over the 2010-2021 period, median adopter incomes* fell from $129k to $110k, and from 176% to 154% of county-median income
- Long-term trends driven by falling PV prices, expanded financing options, LMI-focused programs, and general market maturation, among other factors
- Trends in relative income reflect a “deepening” of solar markets, as adoption increases among less affluent households in each market (defined here at the county level)
- Since 2016, trends in relative income are relatively flat, as solar markets have expanded into lower income states (see next slide)

Solar Market Broadening Trends

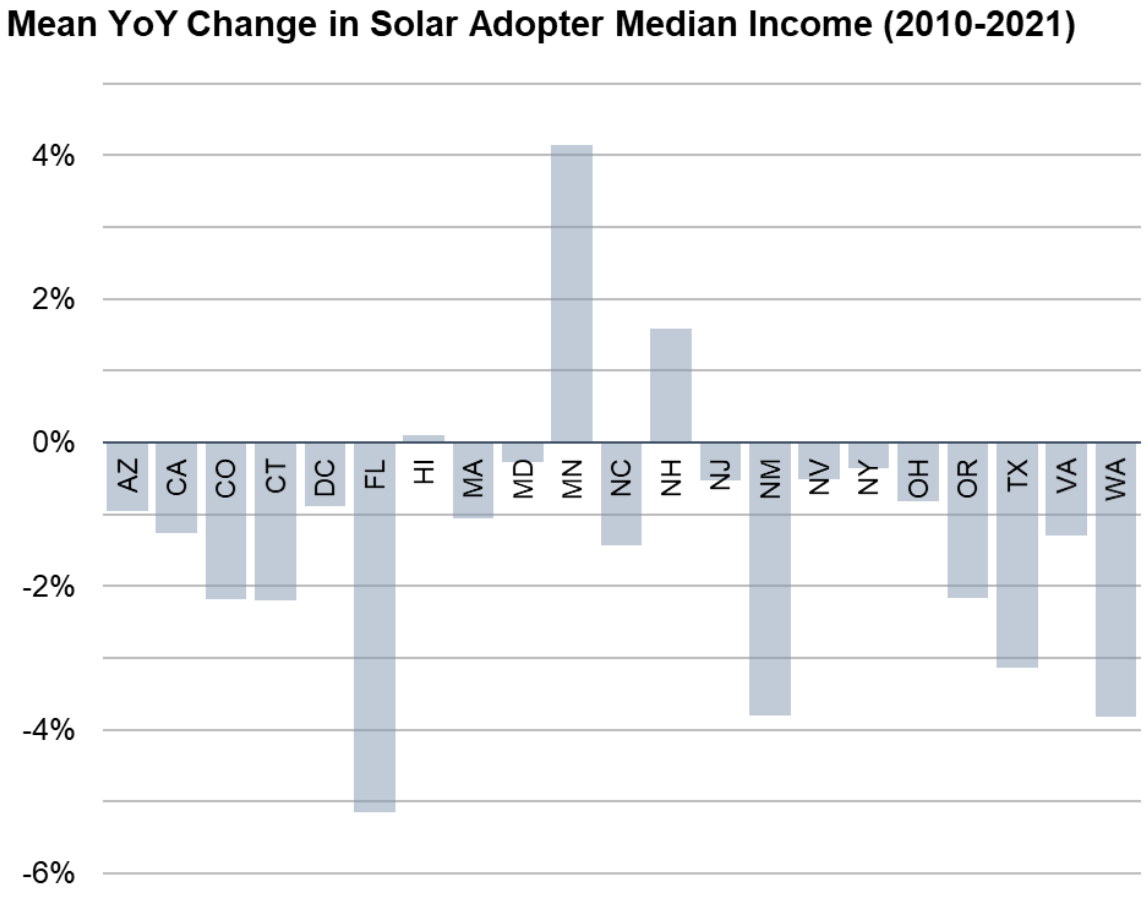


- The U.S. market has been steadily broadening into low- and middle-income states* since 2016, reaching 15% and 26% of 2021 installs, respectively
- Roughly half of that growth is associated with TX (middle-income) and FL (low-income)
- At the same time, annual installs in high-income states collectively dipped over this period
- To be sure, high-income states still comprise a disproportionate share of the market (59% in 2021); for comparison, these states represent roughly one-third of the U.S. population

** 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. Number of adopters by state is based on the estimated total market volume in each state.*

BERKELEY LAB

Solar-Adopter Income Trends over Time by State



Notes: The values plotted here are the weighted average of annual year-over-year (YoY) percentage change in median solar-adopter incomes in each state from 2010 to 2021, weighted by number of solar adopters in each year.

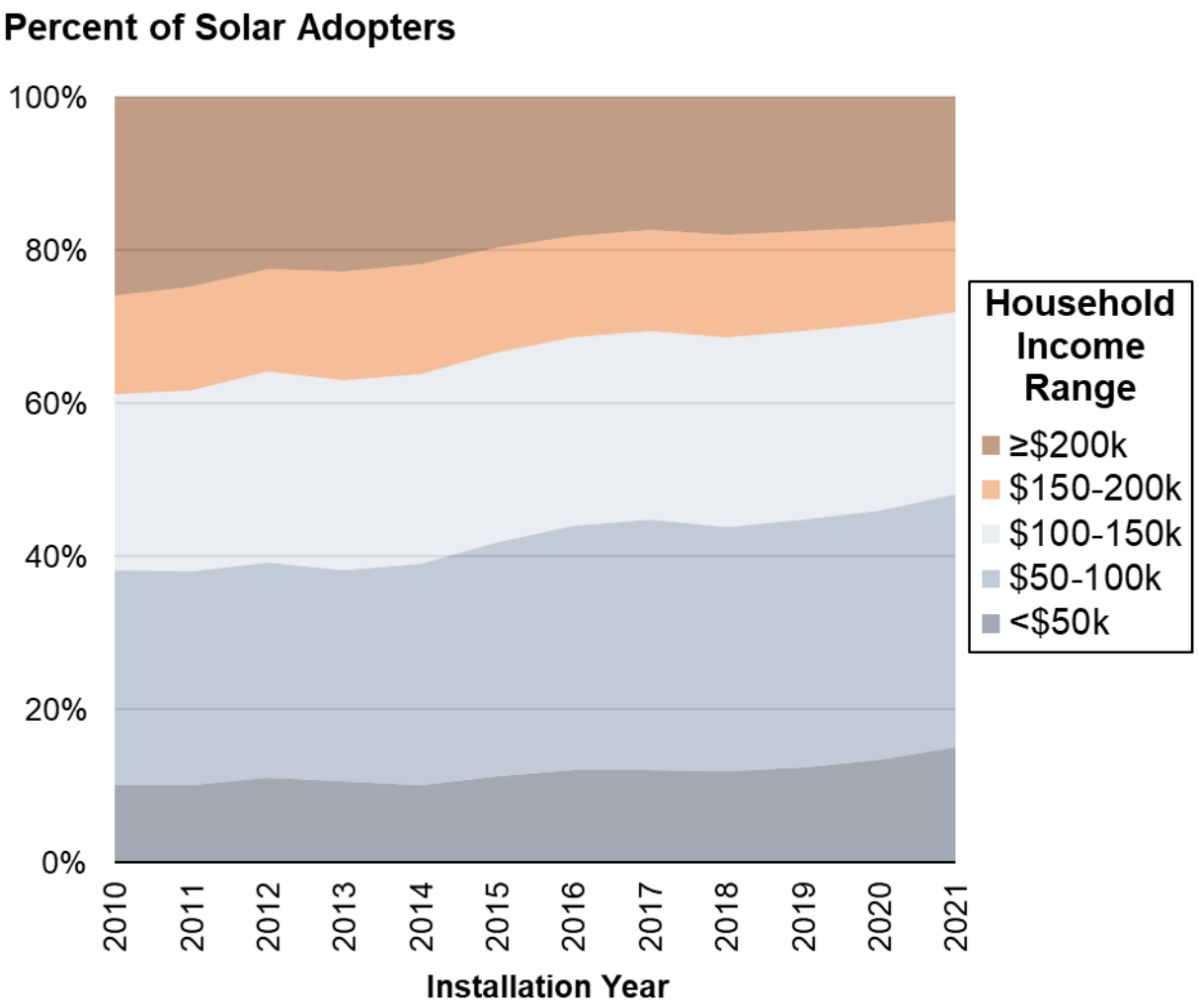
- Most states show declining solar-adopter incomes over time, with generally an average 1-2% drop per year over the 2010-2021 period
- Reflects some combination of both a broadening (i.e., a shift toward less affluent counties) and deepening of state solar markets
- A few states show the opposite trend, with solar-adopter incomes rising over time
- Increasing solar adopter incomes in MN are partly the result of especially low median adopter incomes in early years

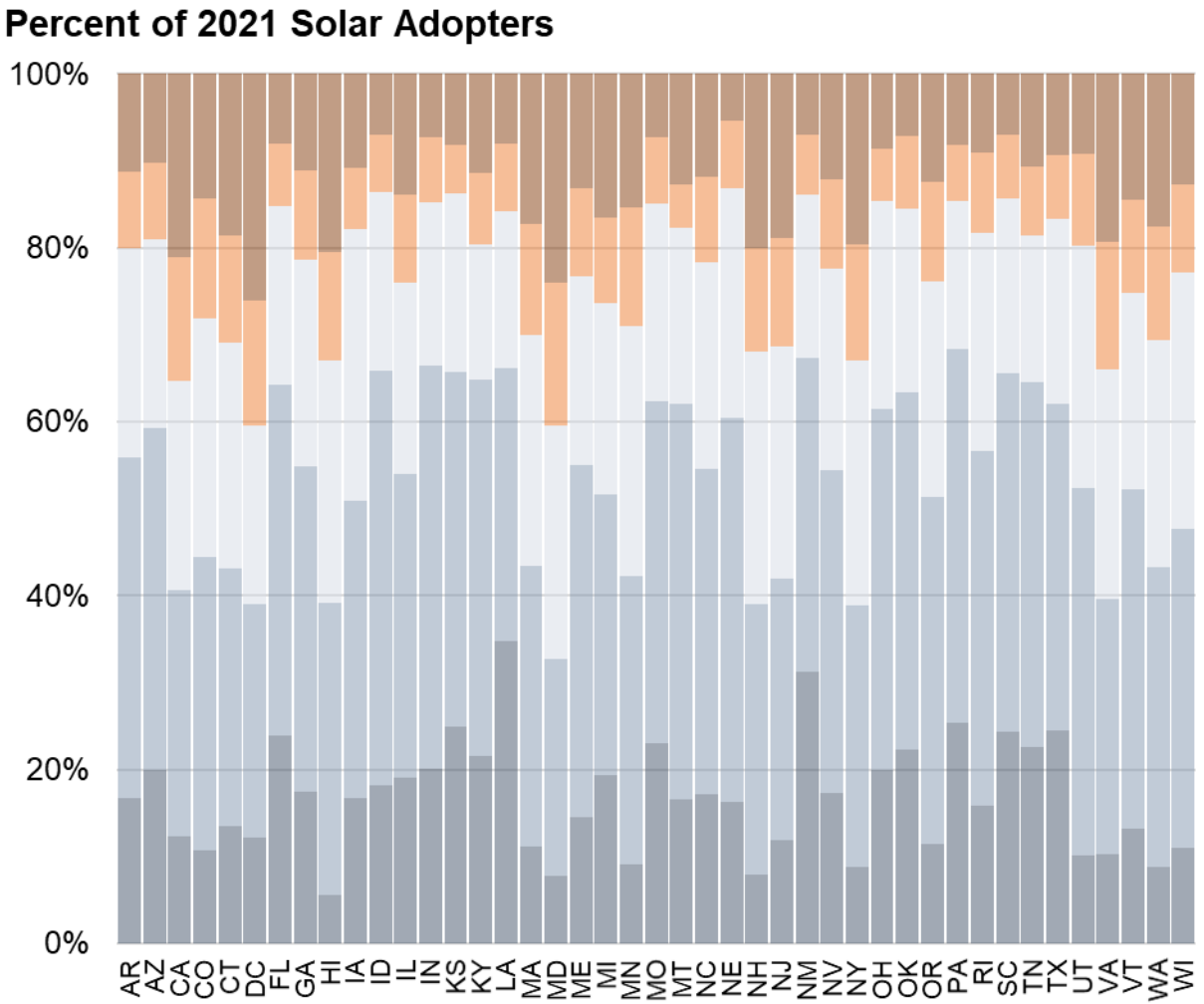
Time series data and other state-level details are available through the online data visualization tool

BERKELEY LAB

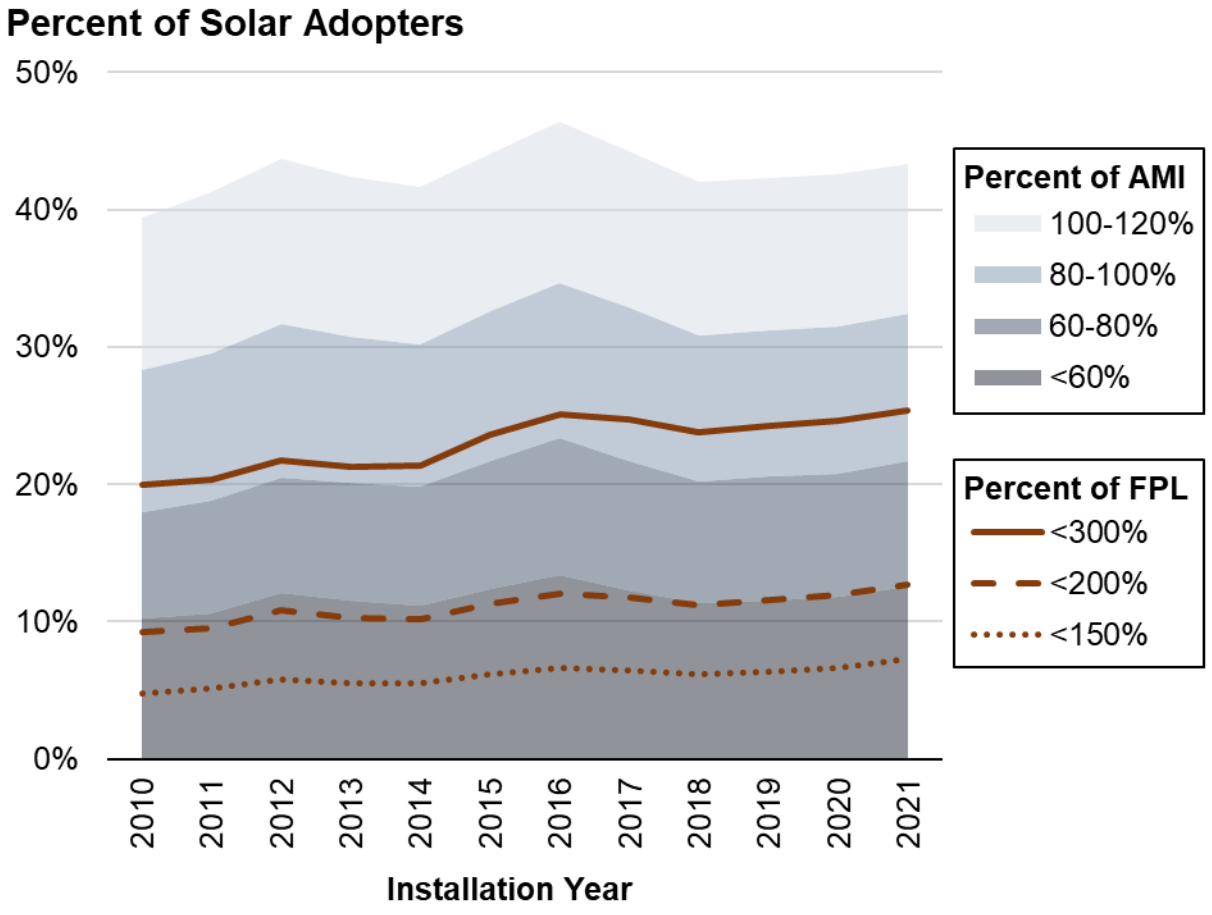
Solar-Adopter Income Distributions over Time and by State

Similar trends to median incomes, but highlighting the spread in adopter incomes





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 $21,960 in 2021.

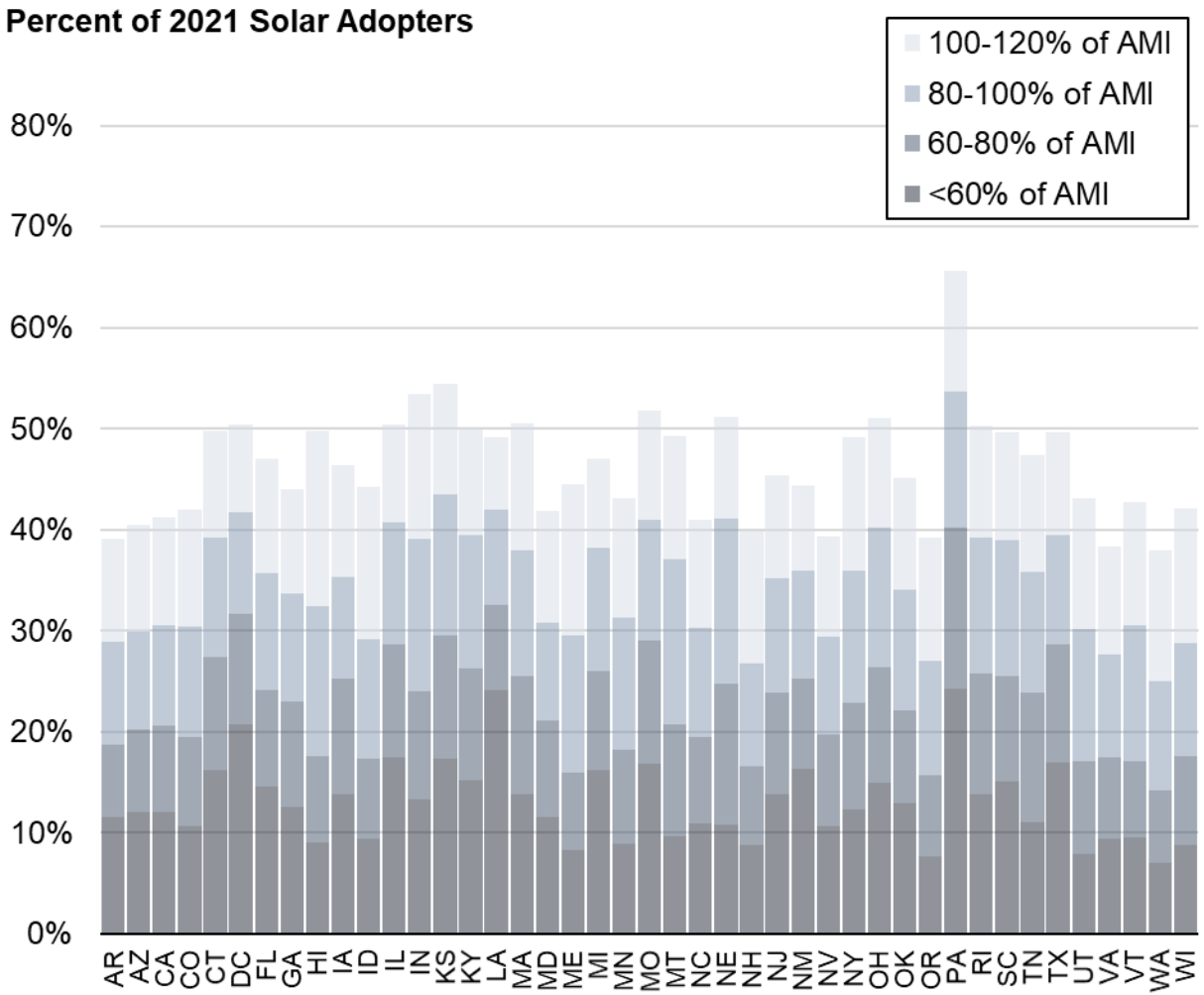
Various income metrics and thresholds can be used to define "low-to-moderate income" (LMI):

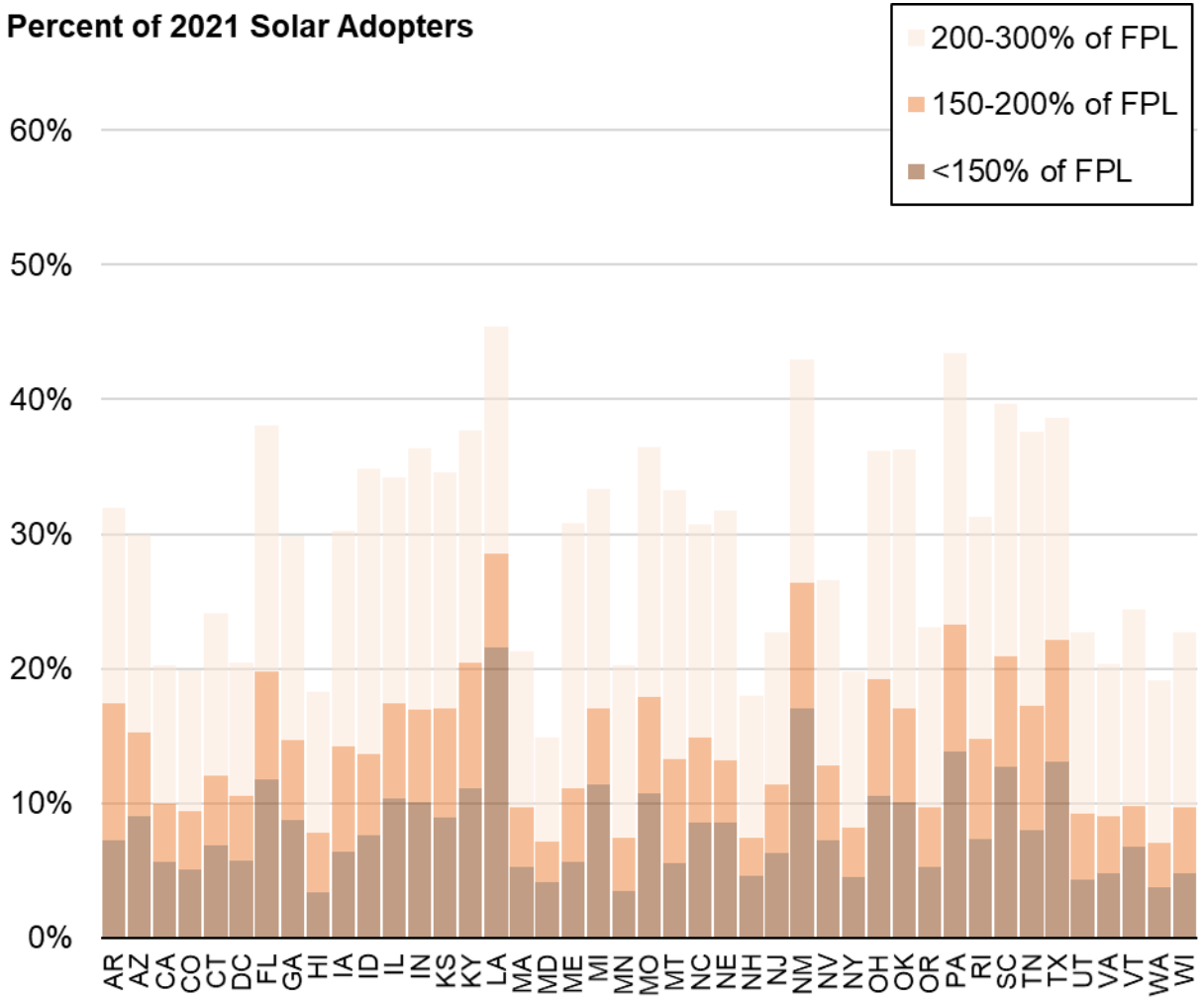
- 150-200% of Federal Poverty Level (FPL) is common, especially in low-income federal programs
- 80% of Area Median Income (AMI) is also often used
- Higher thresholds (e.g., 120% of AMI, 300% of FPL) are sometimes used to include "moderate" income

- 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 2021:
  - **AMI:** 22% were <80% of AMI, 43% were <120% of AMI
  - **FPL:** 7% were <150% of FPL, 25% were <300% of FPL
- AMI-based metrics account for the fact that adoption is concentrated in wealthier states

BERKELEY LAB

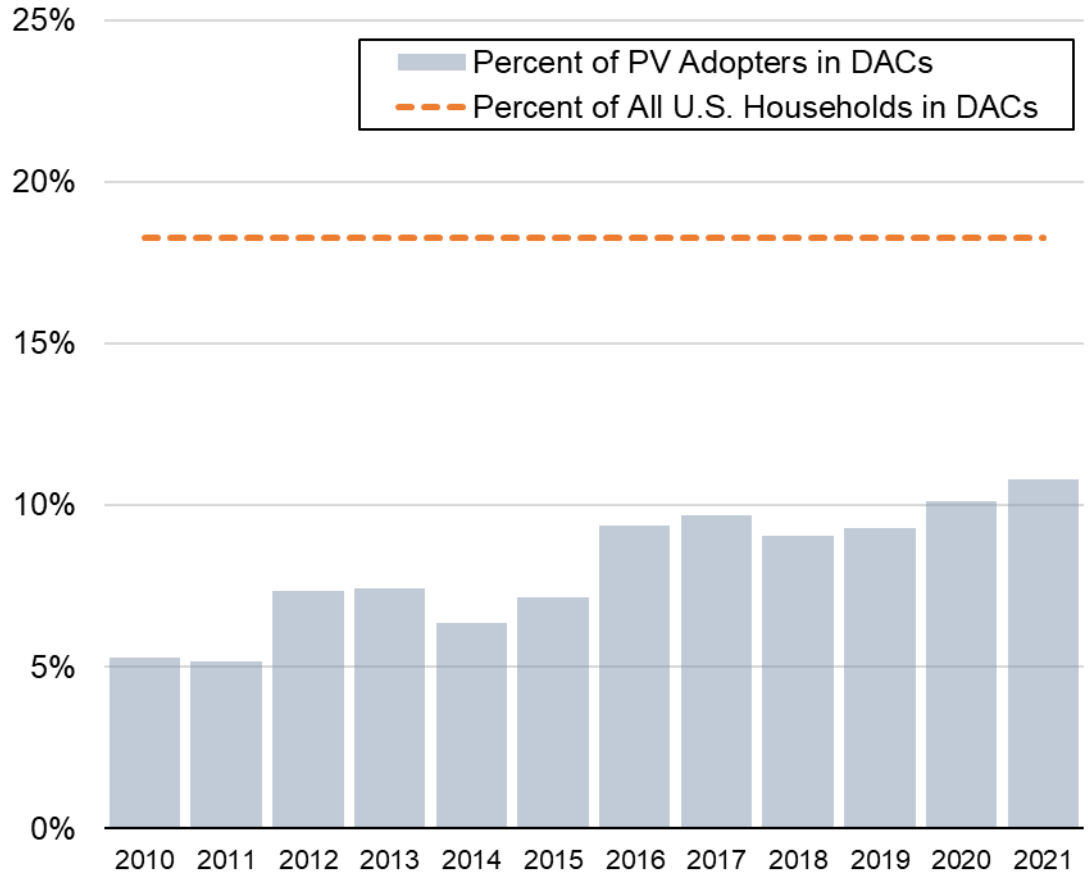
LMI Share of Solar Adopters by State





BERKELEY LAB

DAC Share of U.S. Solar Adoption over Time



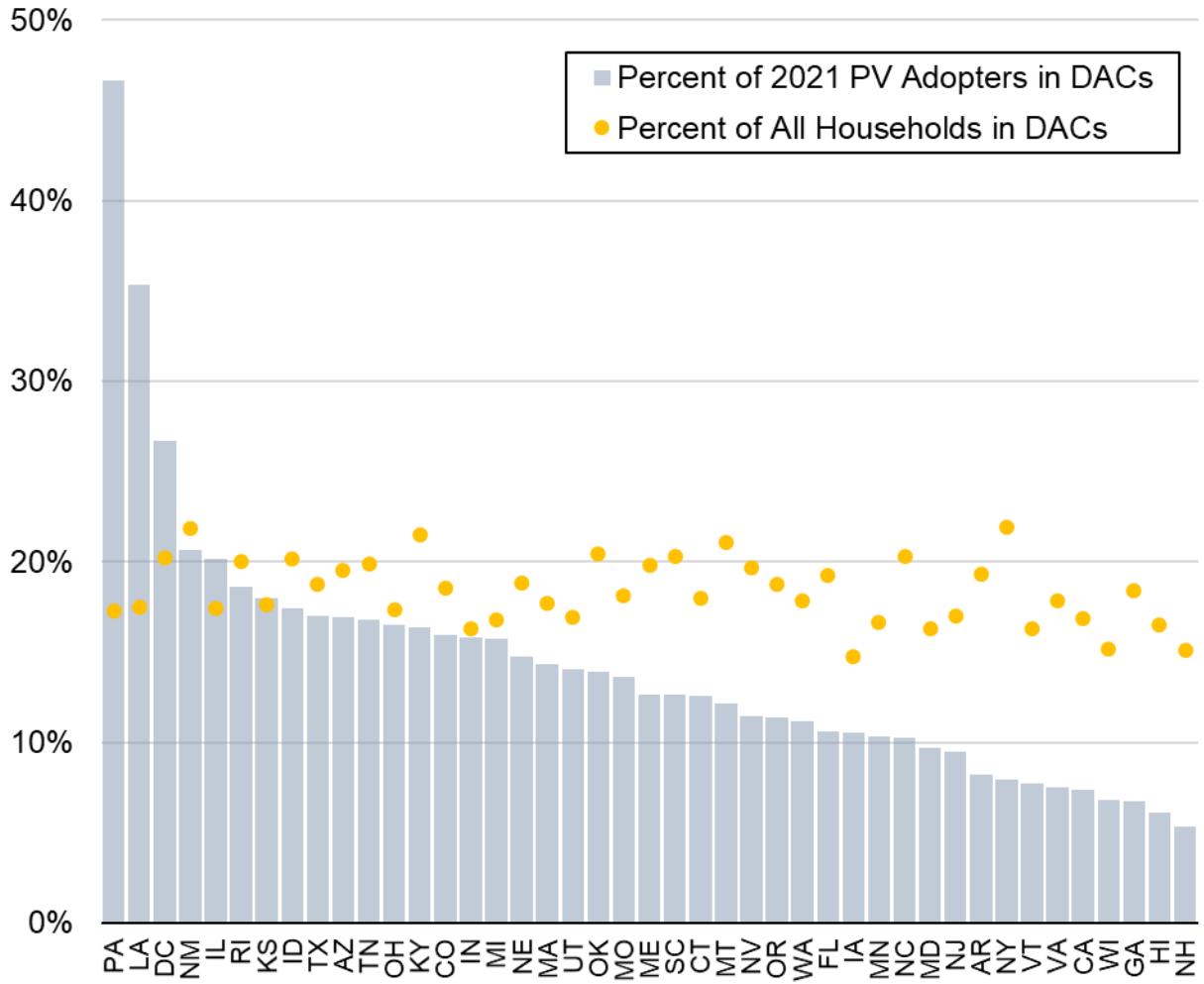
Notes: DACs are based on designations developed by the U.S. Department of Energy and are defined at the Census tract level.

DOE has developed a method for designating "disadvantaged communities" (DACs), based on 36 criteria related to energy burden, environmental and climate hazards, socio-economic vulnerabilities, and fossil dependence. Similar designations have been developed by others (e.g., the CEQ's Climate and Environmental Justice Screening Tool, EPA's EJScreen, CalEnviroScreen).

- Trends mirror those when looking solely at income
- Percent of PV adopters in DACs has been rising over time, from 5% in 2010 to 11% in 2021
- But DACs remain under-represented among solar adopters, relative to their overall share of all U.S. households (18%)

BERKELEY LAB

DAC Share of Solar Adoption by State



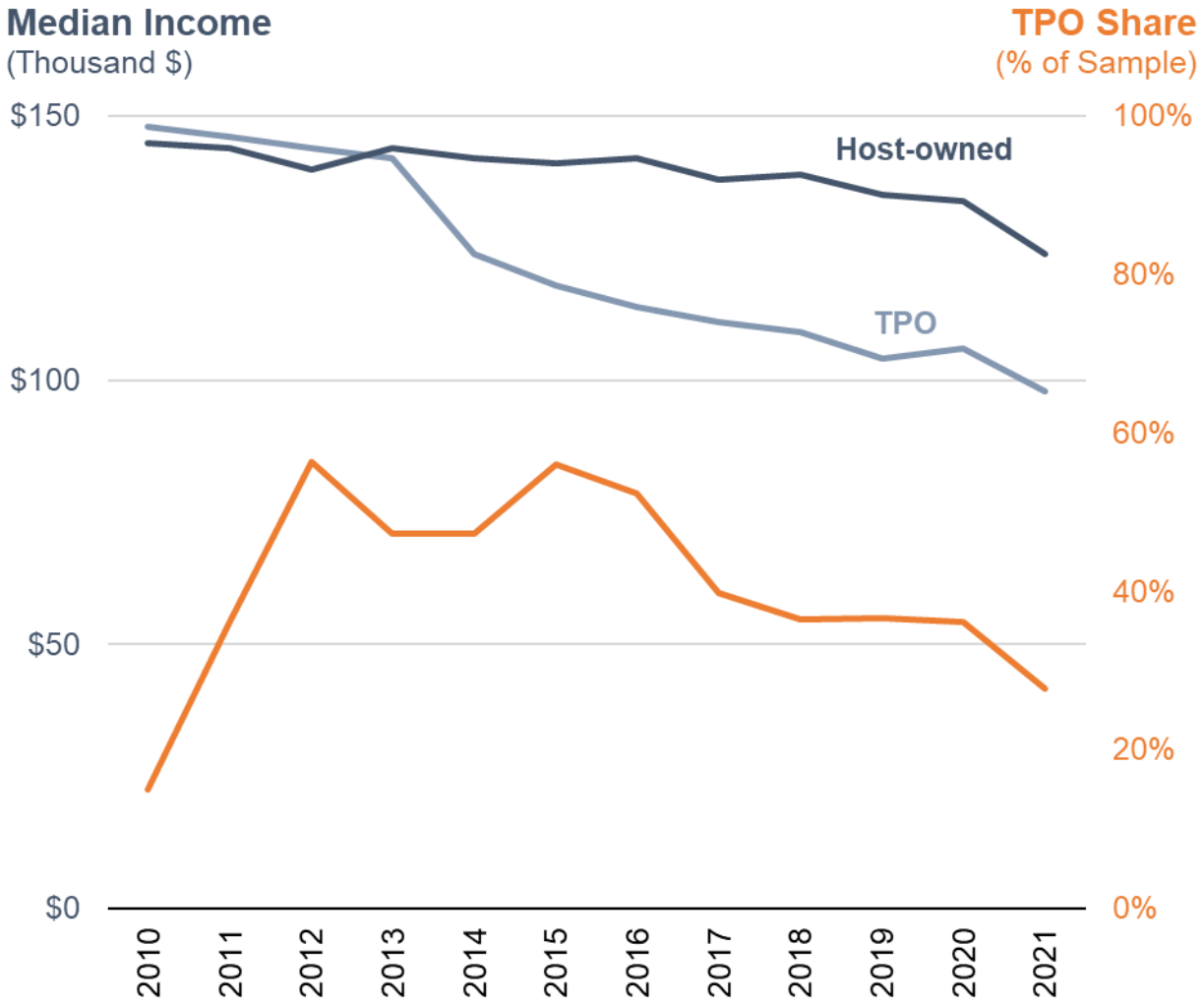
- Percent of all households in DACs is fairly uniform across states (typically 15-20%)
- But percent of PV adopters in DACs varies widely, from 6% (HI) to 46% (PA), though is typically less than 20%
- In the vast majority of states, DACs are under-represented among PV adopters, relative to their share of all HHs in the state
- The most notable exceptions are PA and LA, where most PV adopters are located in cities with large DAC populations
  - Diverges from income-specific trends, partly because DAC designations reflect more than just income

BERKELEY LAB

Solar-Adopter Income Trends by Segment

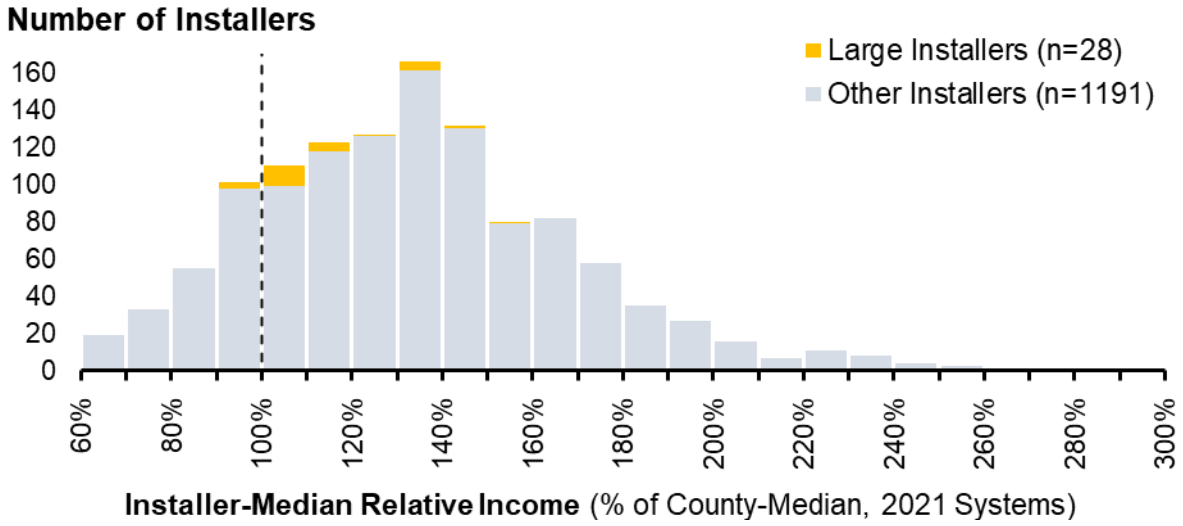
- Beyond looking at how solar-adopter incomes vary over time and geography, we can also evaluate differences based on other segmentations of the data
- Here, we focus on several segmentations:
  - Third-party vs. host-owned systems
  - System size by income level
  - Differences across solar installers
  - PV systems installed with battery storage vs. stand-alone PV systems
  - PV systems installed on multi-family vs. single-family homes
- Each comparison is based on the subset of the sample for which data on the relevant segmentation are available (see slide 47 for applicable sample sizes)
- Comparisons are made primarily in terms of relative incomes, though the same basic trends apply in terms of absolute income levels as well

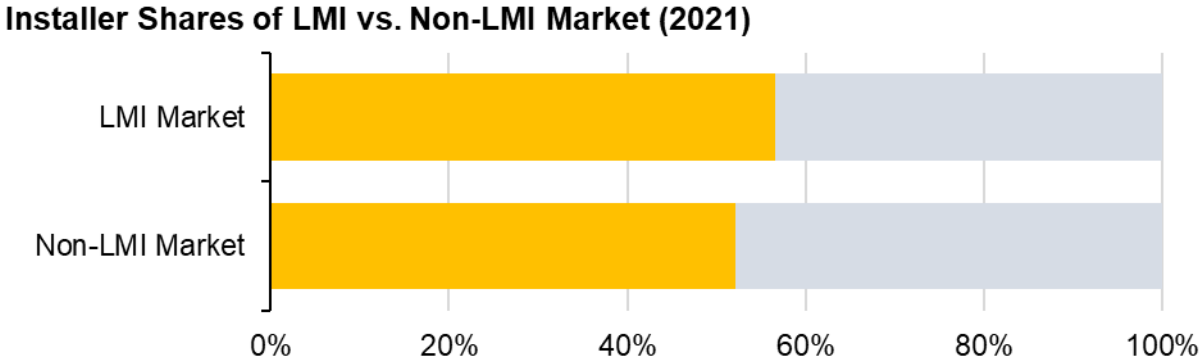
Third-Party vs. Host-Owned Systems



- Solar-adopter incomes for third-party owned (TPO) systems are presently lower, and have declined much more significantly over time, compared to host-owned systems
- 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 systems
- Two implications:
  - The general trend toward lower income solar adopters can be partially attributed to expanded access to TPO
  - The decline in TPO market share since 2016 has potentially dampened the trend toward lower incomes, depending on the relative efficacy of loan financing in reaching less affluent households

Installer-Level Trends

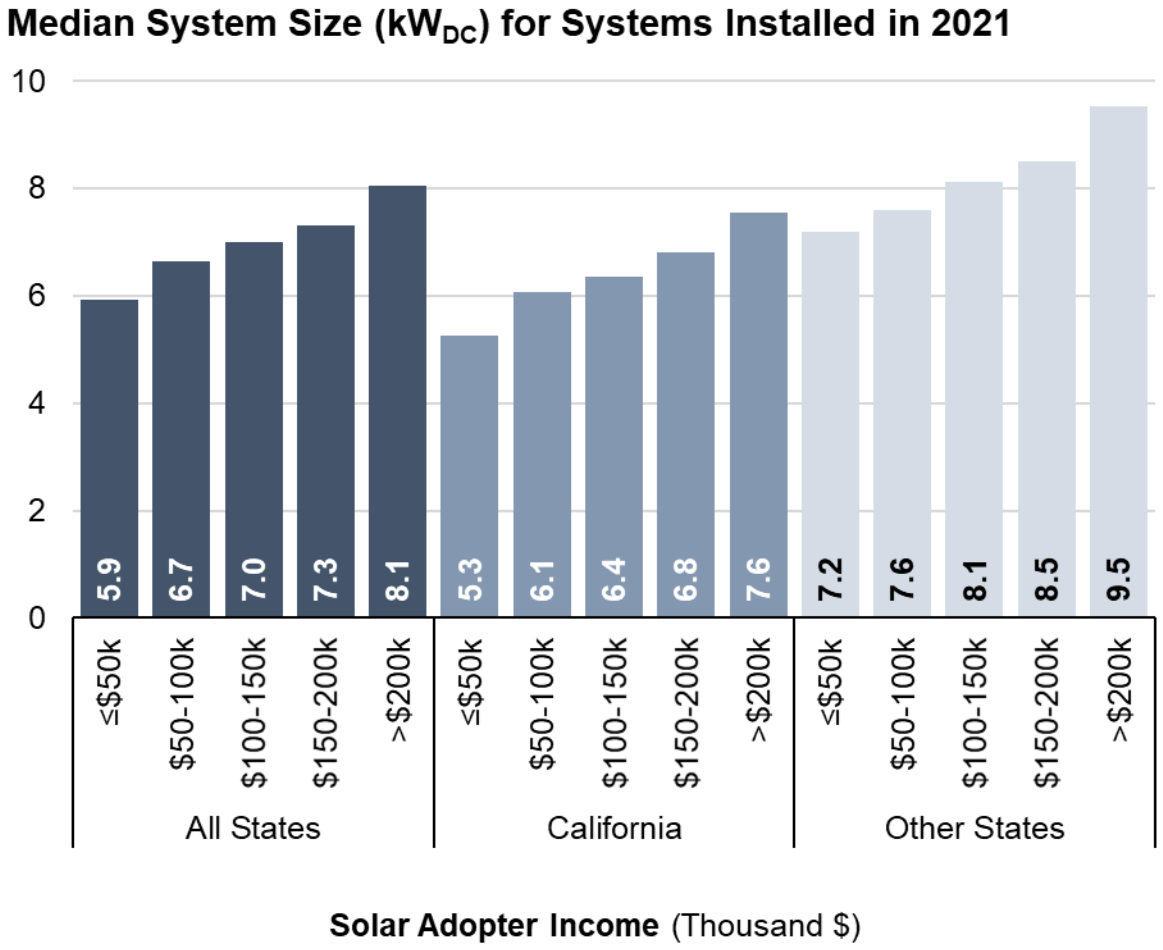




Notes: The histogram is based on installers with at least 10 systems installed in 2021. Large installers are those with more than 1,000 systems completed in 2021. LMI market is defined as PV adopters with household incomes less than 120% of AMI.

- Installers vary considerably in terms of their customers' income profile, though virtually all primarily serve customers with incomes higher than their county median (top figure)
  - A small subset of installers primarily serve customers with relatively low incomes (to the left of the dashed line), in some cases as a core part of their business model
- Large installers* account for over half (57%) of all LMI systems installed in 2021 (bottom figure)
  - Roughly in line with their share of the non-LMI market
  - Large installers are slightly more likely to serve LMI customers than other installers, potentially due to greater prevalence of TPO offerings

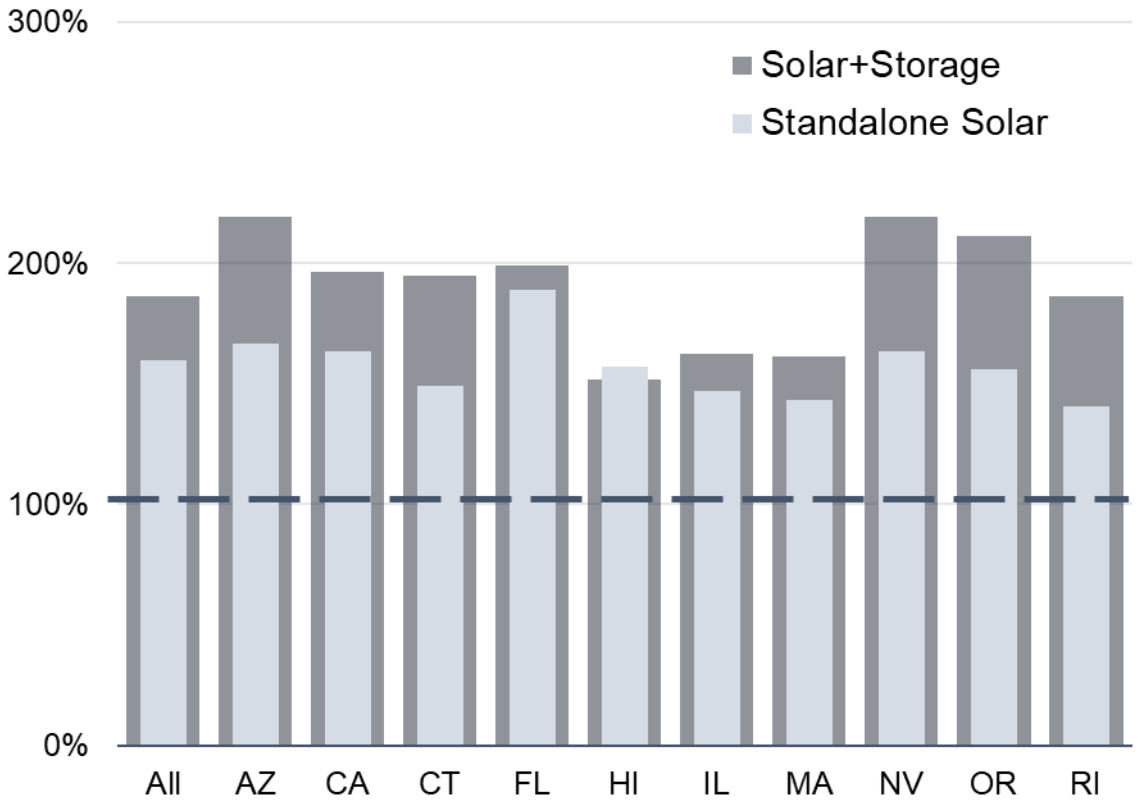
System Size by Income Level



- Higher income households install larger systems
- Across the sample, systems installed by the highest-income households were 37% larger than those of the lowest-income households, based on median system sizes
- California systems are relatively small overall, but differences in system size across income levels are similar to other states
- Aside from the fact that larger systems cost more, higher-income households may also tend to have larger homes with larger roof area and/or higher electricity consumption

Paired Solar+Storage vs. Stand-alone Solar

Median Solar-Adopter Relative Income
(2021 Systems, % of County Median Income)

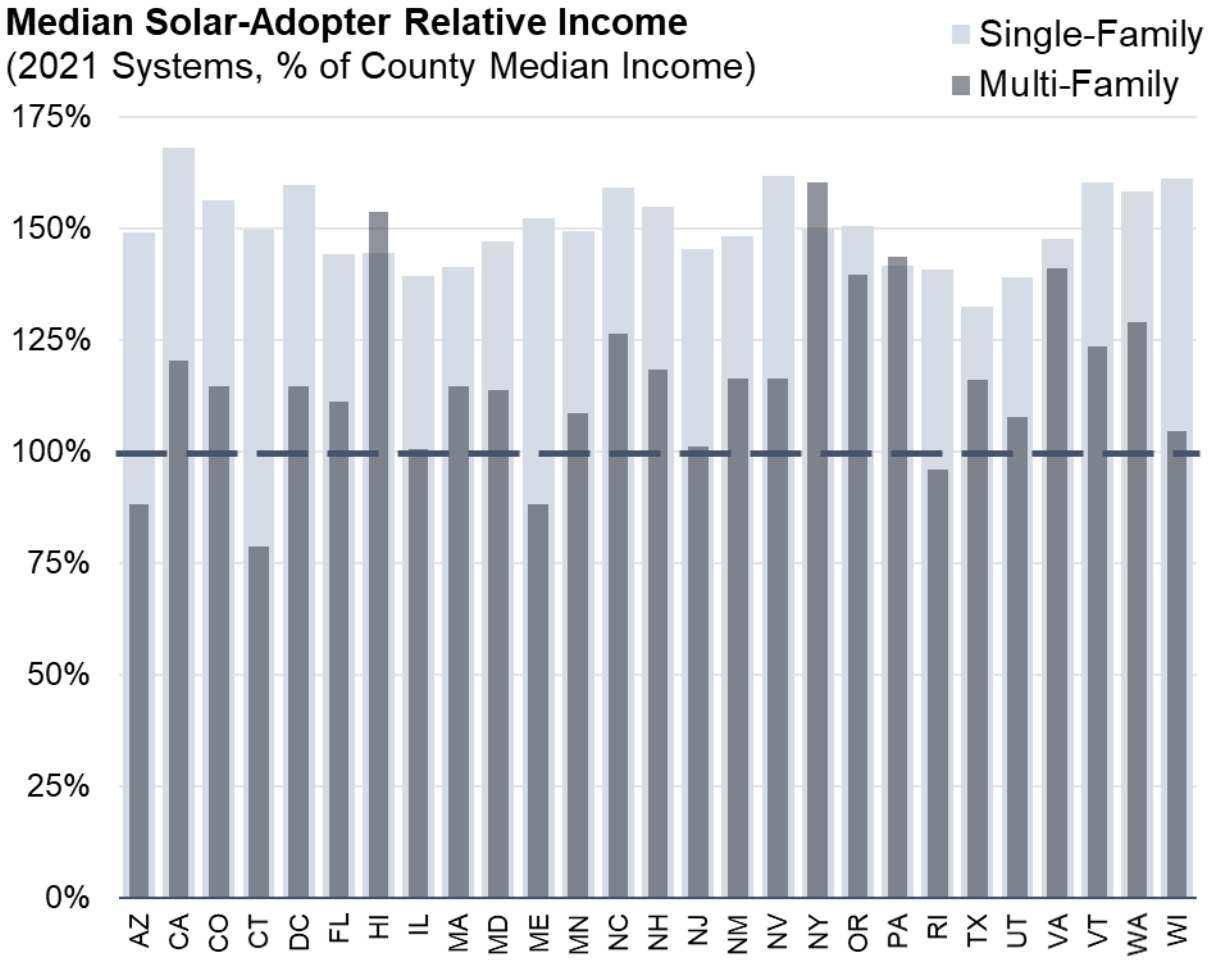


Notes: Figure includes states with at least 30 systems within each group. AZ and FL are included, but the data in this particular figure are based on a narrow subset of utilities and therefore may not be representative of the state as a whole.

- Roughly 12% of PV systems in the 2021 sample were paired with storage
- Paired solar+storage adopters generally have higher incomes than stand-alone solar adopters—as expected, given the additional cost of storage
- The one notable exception is Hawaii, where ~90% of all residential PV installed in 2021 was paired with storage, and solar+storage adopter incomes were roughly the same as those of stand-alone storage adopters
- By comparison, in CA, solar+storage adopter incomes were 20% higher than standalone solar adopters

BERKELEY LAB

Multi-Family vs. Single-Family



Notes: Figure includes states with at least 30 systems within each group.

- Roughly 3% of all solar systems in the 2021 sample were installed on multi-family buildings
  - Most are owner-occupied; includes condos
- Multi-family solar adopter incomes are generally well below those of single-family adopters
- Multi-family solar adopters still typically skew high compared to incomes of the general population, albeit with a few notable exceptions in 2021 (AZ, CT, ME, RI)
- Data on participation in income-qualifying solar programs is incomplete, but suggests higher participation by multi-family than single-family households (i.e., multi-family market may be more heavily driven by LMI-focused programs)

BERKELEY LAB

Other Socio-Economic Trends for Solar Adopters

Approach to Describing Other Socio-Economic Trends

Going beyond household income, we describe trends in other financial and socio-economic attributes of solar adopters*:

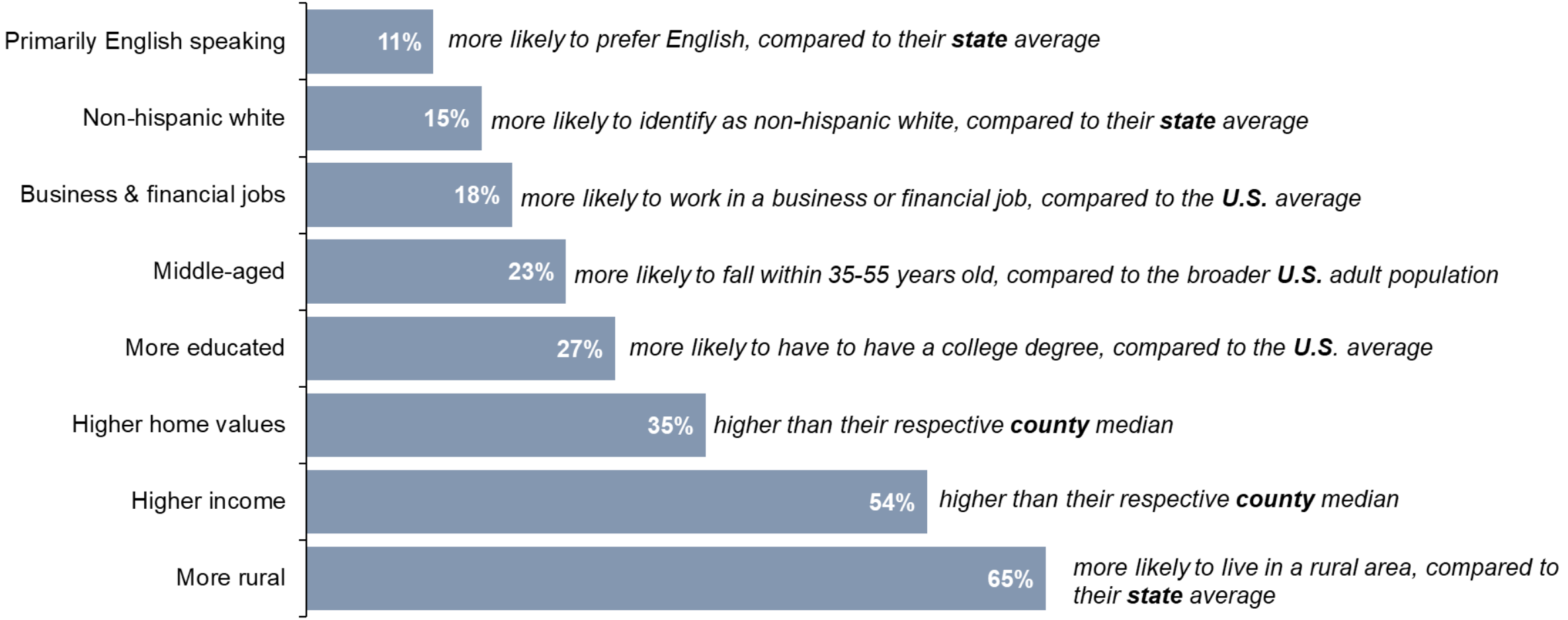
- Home Value
- Race and Ethnicity
- Language
- Rural vs. Urban
- Education Level
- Occupation
- Age

**Based in most cases on the primary householder; see slides 44 - 45 for definitions and sources*

- Some of the same basic trends emerge as with income:
  - Solar adopters differ from the broader US population, but those differences are diminishing over time
  - National trends reflect broad geographical patterns in solar adoption—most notably California's dominant share of the market
- Some of these attributes may correlate to income, contributing to parallel trends

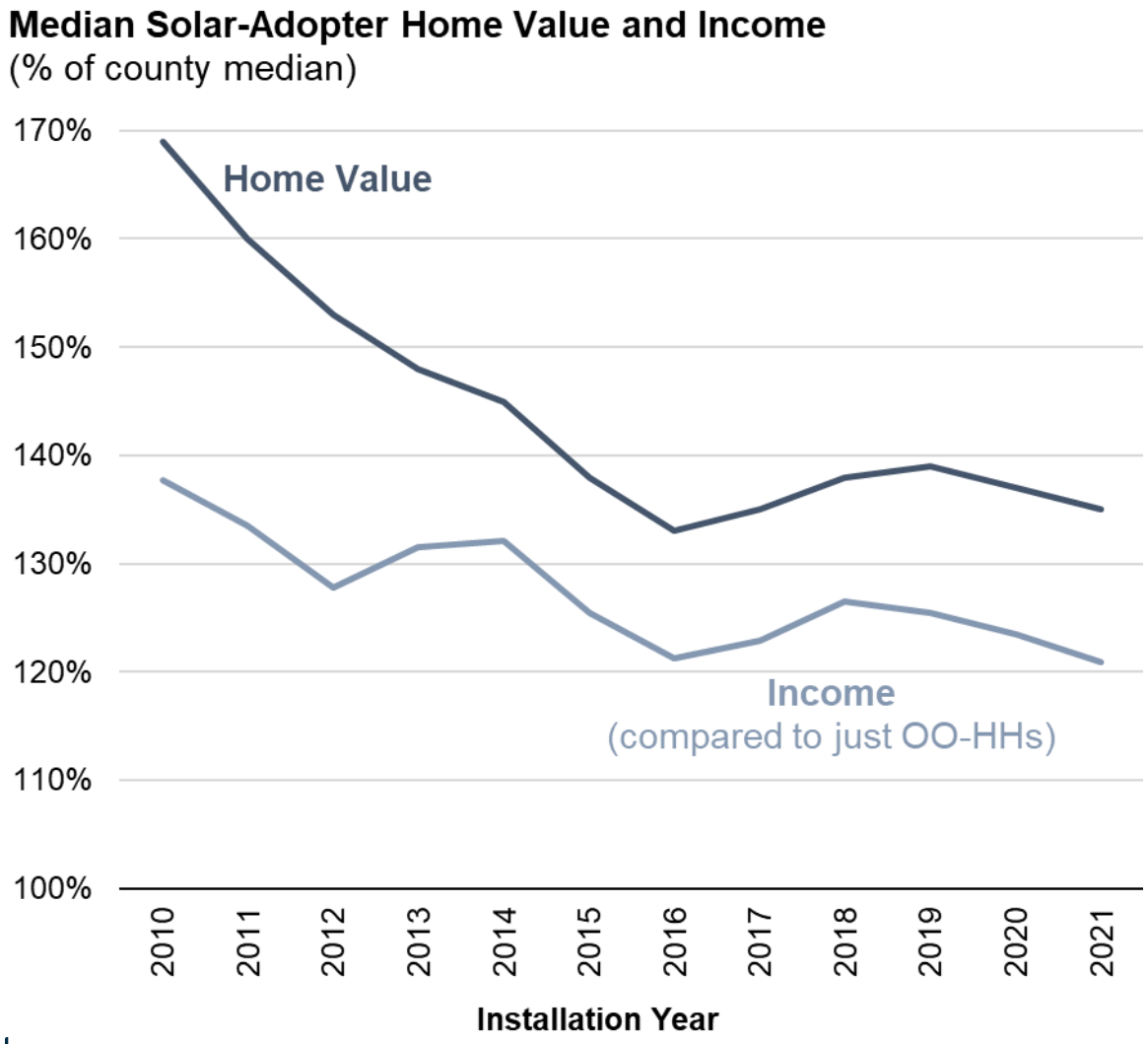
Summary of Solar-Adopter Socio-Economic Attributes

Compared to the General Population, 2021 Solar Adopters Tend to Have or Be...



Context and additional details provided on the following slides

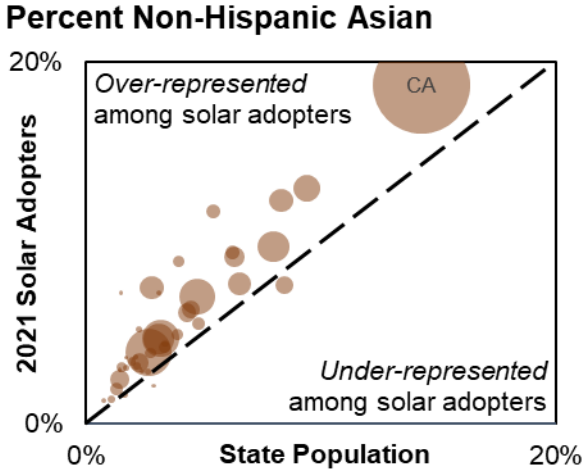
Home Value

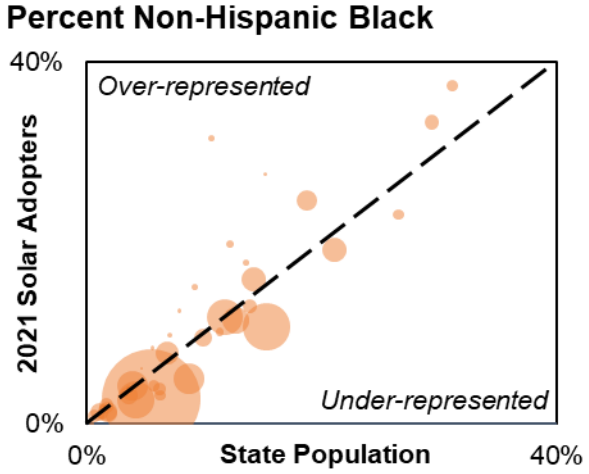


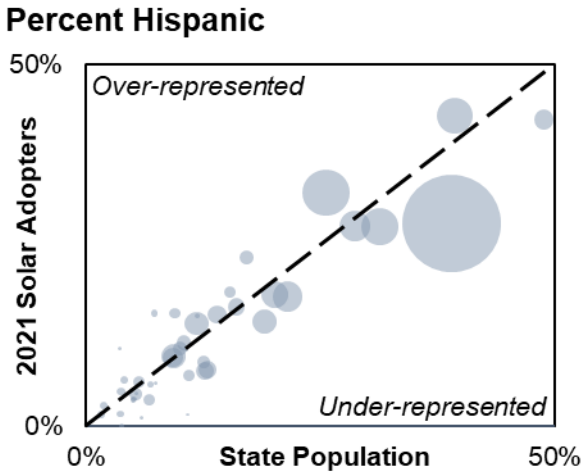
- Home value provides an indicator of household *wealth*, as distinct from income—albeit only for households that own their home
- Solar-adopter home value data are expressed as a percentage of the respective county median, in a similar vein to our relative income metric
- Solar-adopter home values are generally higher than others in the same county, but that skew has declined substantially over time (from 169% of county-median in 2010 to 135% in 2021)
- The skew is more pronounced than for income, even when limiting the comparison to only OO-HHs, suggesting that differences in wealth (above and beyond income) may also contribute to adoption inequities

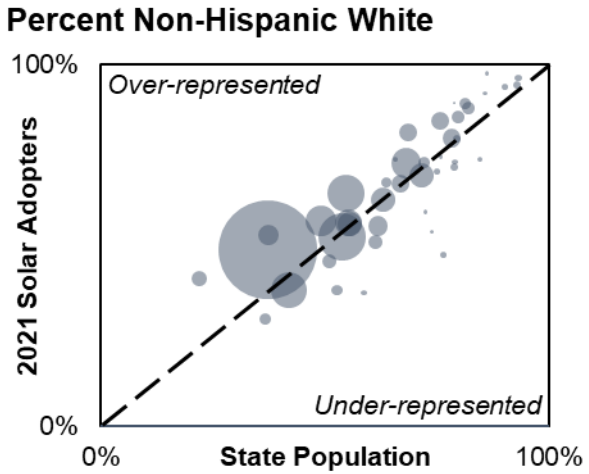
Race and Ethnicity

State-level comparisons: 2021 solar adopters vs. general population







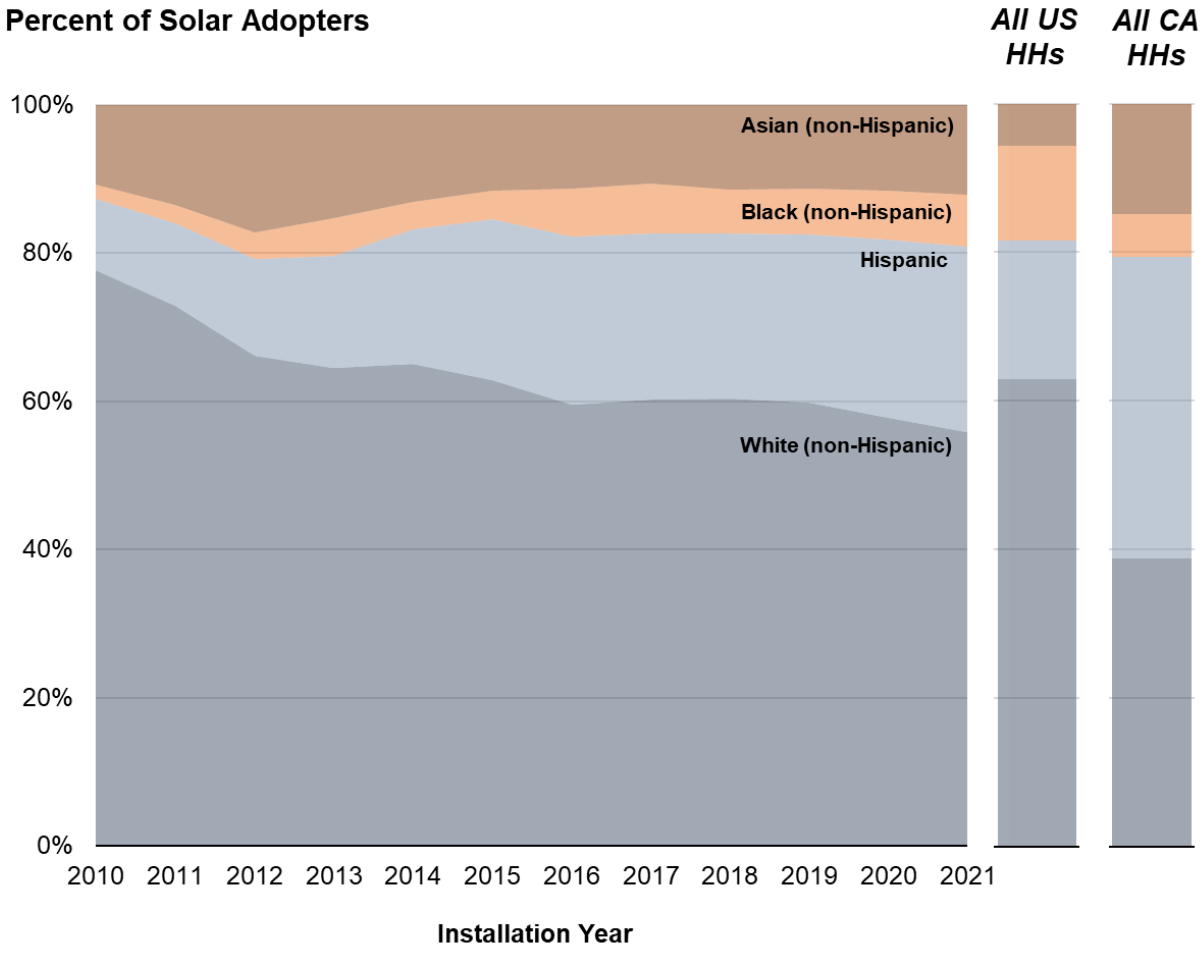


Notes: Distributions for solar adopters are based on the primary householder.

- White and Asian households are generally *over-represented* among solar adopters, while Hispanic and Black households are *under-represented* relative to the general population in each state
- Each group differs both in the *consistency* and *degree* to which their representation among solar adopters skews from the state population
- The trends are most consistent for Asian households, which are over-represented among solar adopters in almost every state, whereas the trends for other groups are more mixed
- The degree of skew is strongest for Asian (over-represented) and Black (under-represented) households

BERKELEY LAB

Race and Ethnicity:
National trends over time



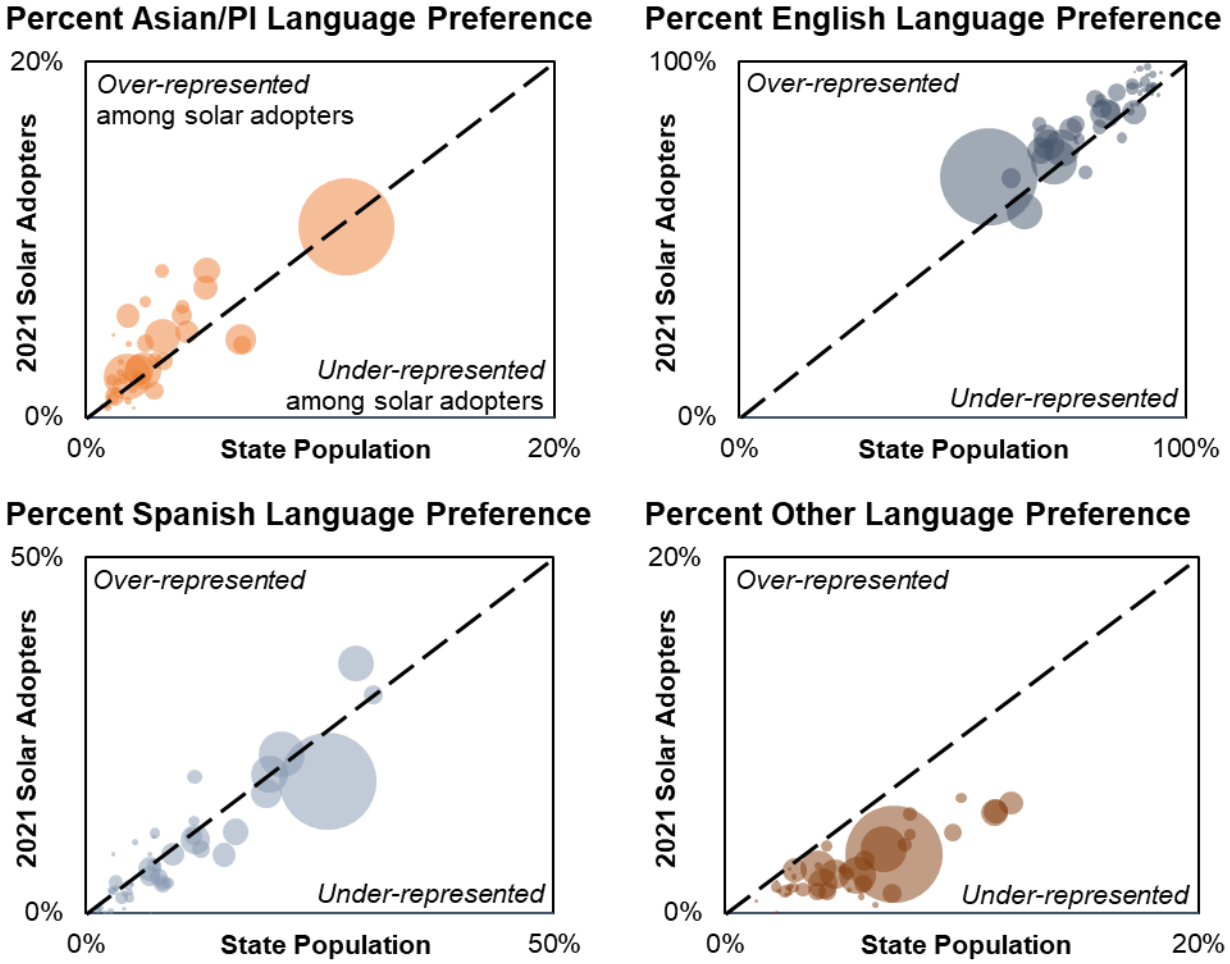
Notes: Distributions for solar adopters are based on the primary householder.

- Nationally, an increasing share of solar adopters consist of while Hispanic households, while the White household share has declined
- At the aggregate national level, solar adopters in 2021 were 12% Asian, 7% Black, 25% Hispanic, and 55% White
- Compared to the broader U.S. population, solar adopters have greater representation by Asian and Hispanic households, and lower representation among Black and White households
- Importantly, the national distribution of solar adopters is heavily impacted by California, which has relatively large Hispanic and Asian populations and lower Black populations

BERKELEY LAB

Language Preference

State-level comparisons: 2021 solar adopters vs. general population

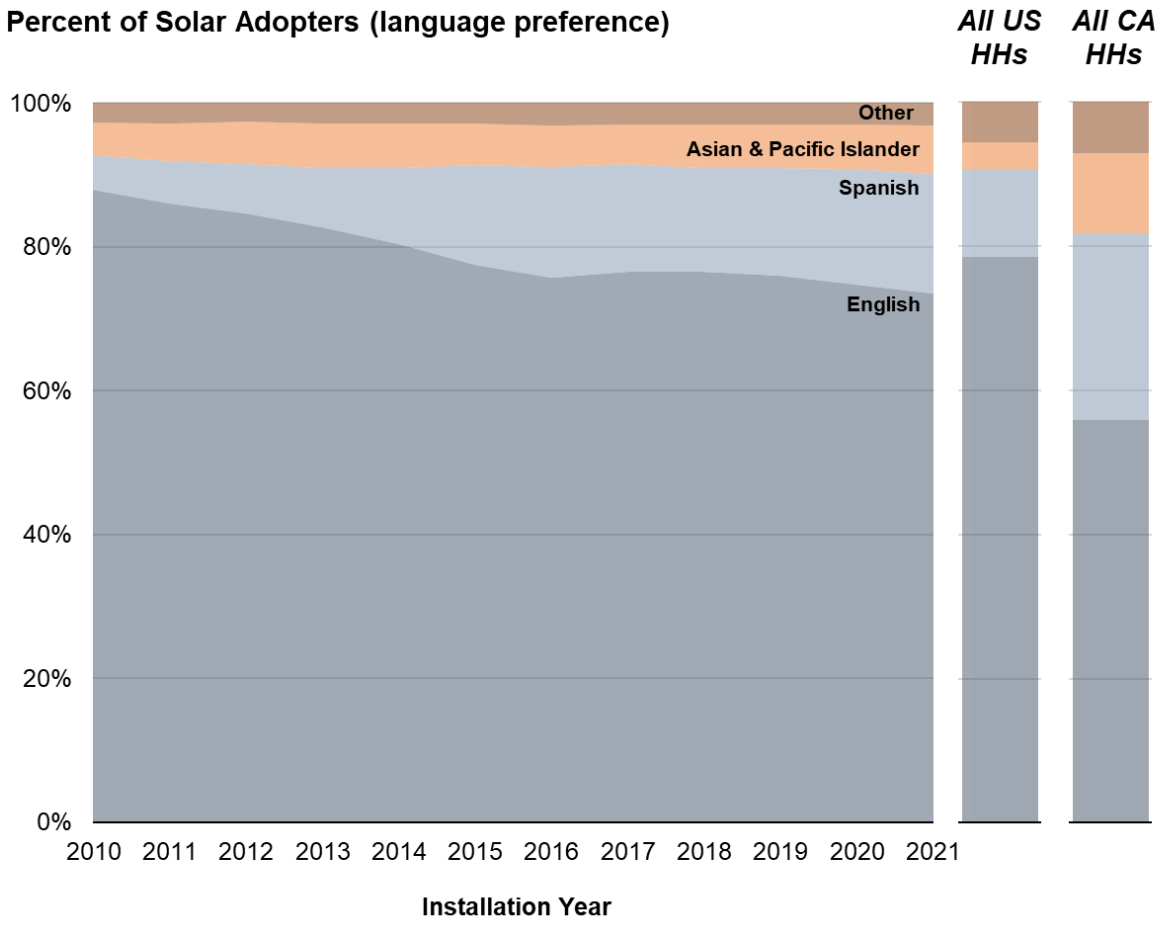


Notes: Households are classified by the language preference of the "primary" householder. Language groupings are based on the ACS. "Other" includes "Other Indo-European".

- Households with English-language preference are over-represented among solar adopters, while Spanish-speaking are under-represented and Asian or Pacific Islander (PI) language preference show no consistent trend
- Comparing to the race/ethnicity trends show the additive effects of language preference
  - In particular, under-representation by Spanish-language preference households is much stronger than it is for Hispanic households
  - Similarly, while Asian ethnicities are consistently over-represented, the same cannot be said for households that predominantly speak Asian/PI languages

BERKELEY LAB

Language Preference:
National trends over time

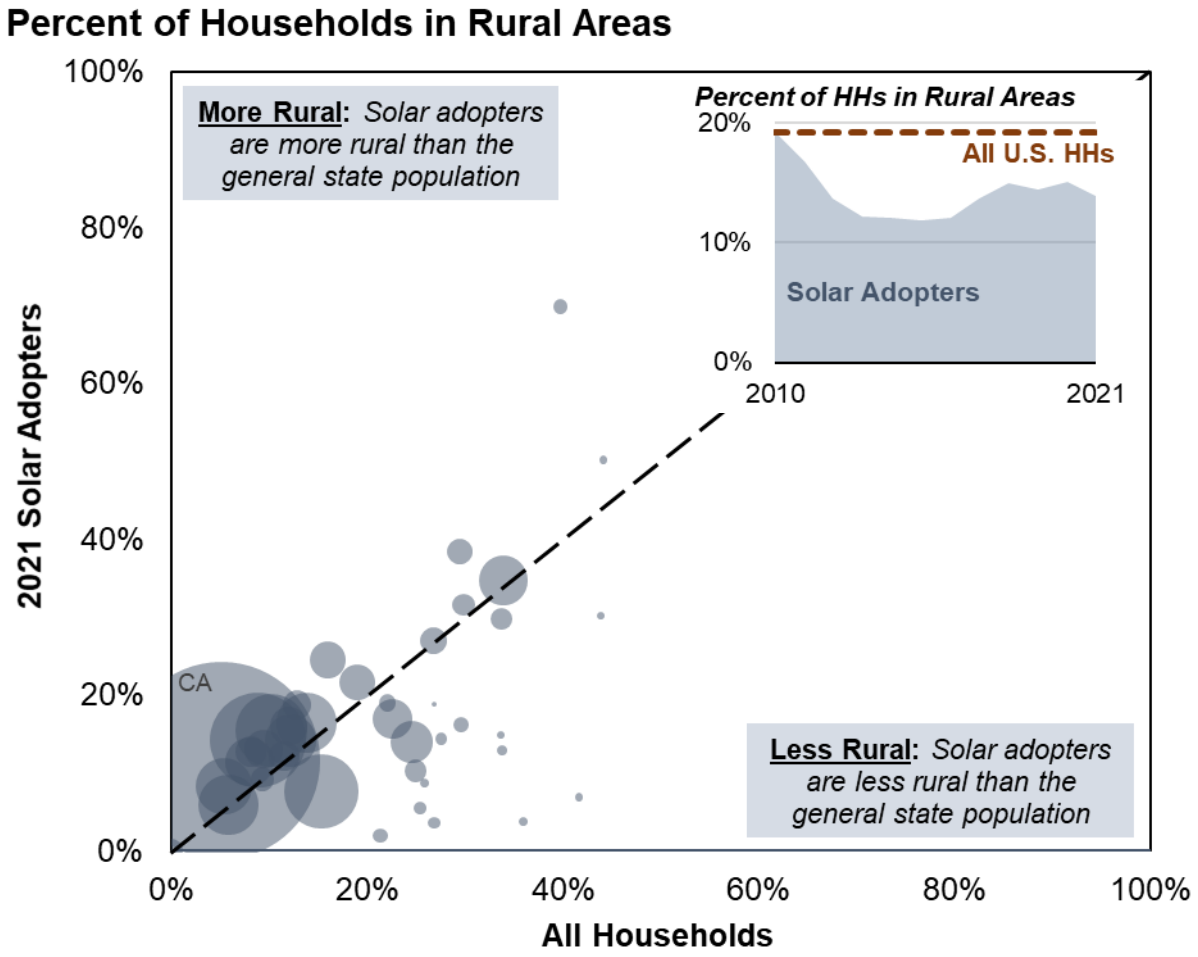


Notes: Households are classified by the language preference of the "primary" householder. Language groupings are based on the ACS. "Other" includes "Other Indo-European".

- Mirroring the national trend in race/ethnicity, the trends here show an increasing share of households with Spanish-language preference and declining share of English-preference
- At the national level, the language preference of solar adopters in 2021 was 74% English, 17% Spanish, 7% Asian/PI, and 2% Other
- Compared to the broader U.S. population, solar adopters have greater representation by Asian/PI and Spanish-language households
- As with the earlier national trends, the distribution is heavily impacted by California, which has relatively large Spanish and Asian/PI language populations

Rural vs. Urban

State comparisons and national trends over time

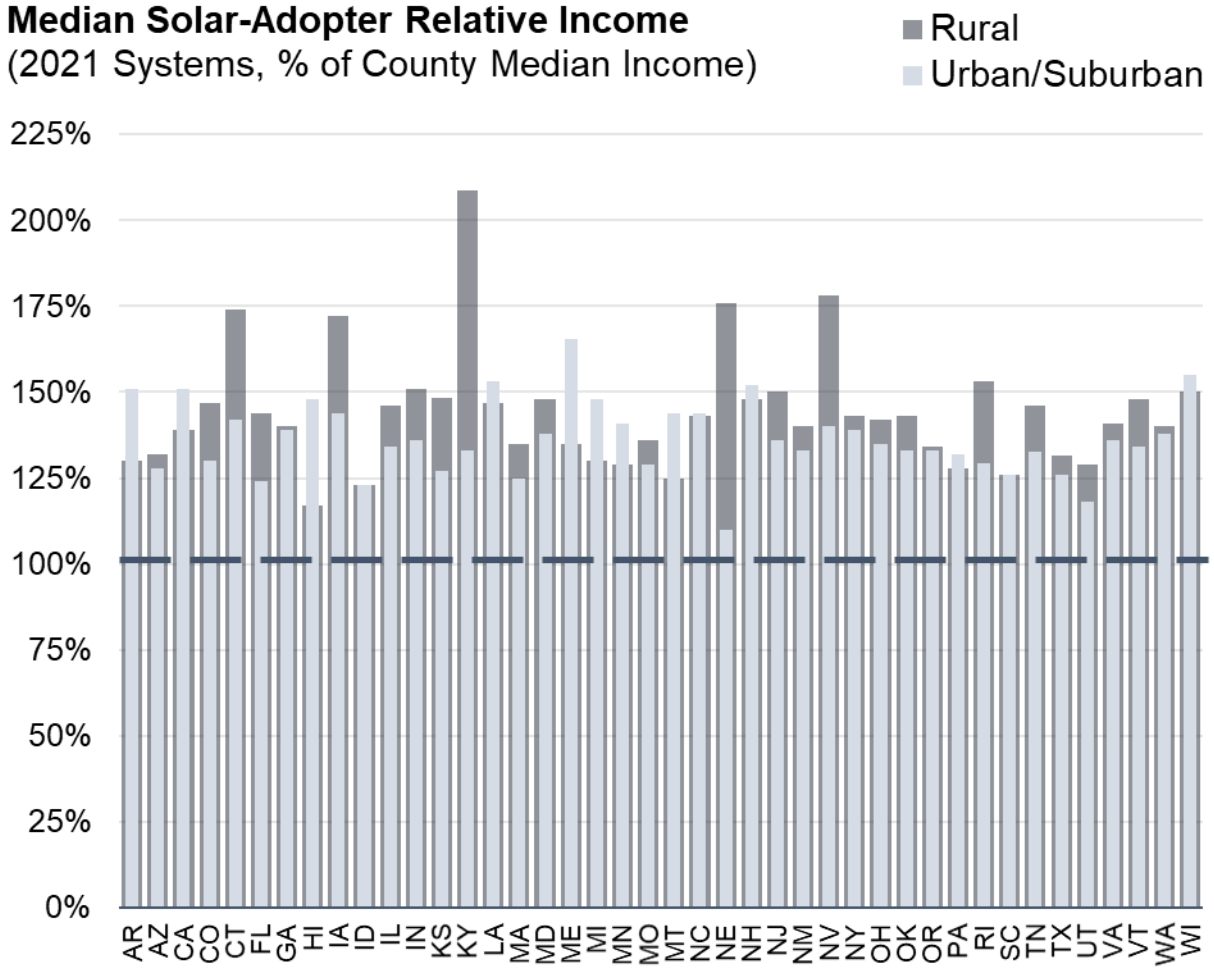


Notes: Urban/rural classification is based on the 2010 US Census definitions, which rely on population density and land use, among other factors.

- Nationally, solar adoption is concentrated in less rural states, most notably California
- As a result, U.S. solar adopters are less rural overall (15% of 2021 adopters) than the U.S. as a whole (19% of all households)—see insert
- That national trend has remained stable over the past five years or so
- However, at the individual state level (bubble plot), solar adopters may be either more rural (24 states) or less rural (19 states) than their respective state population
- In most of the larger state markets, adopters tend to skew rural (e.g., in CA, 12% of adopters are rural, compared to 5% of all HHs)

BERKELEY LAB

Solar-Adopter Income Trends by Rural/Urban Designation

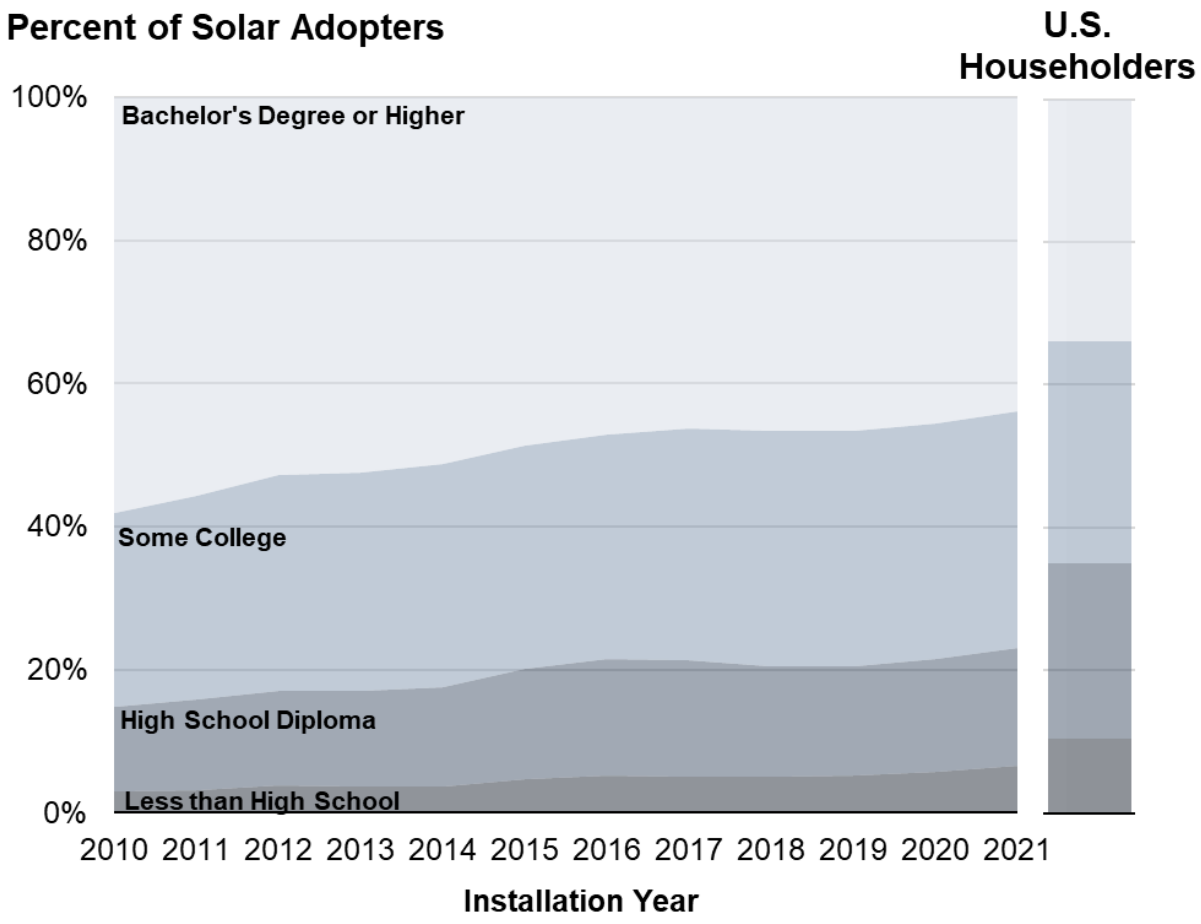


Notes: Urban/rural classification is based on the 2010 US Census definitions, which rely on population density and land use, among other factors.

- Solar adopters in both rural and urban/suburban areas skew toward higher income households (when comparing to median incomes for all HHs in the same county)
- On average, income skew is more pronounced in rural areas than in urban/suburban areas, though relative levels of skew vary by state
  - The most dramatic differences are in KY and NE, where solar adopters in rural areas skew much more heavily toward high income households than in other parts of the state
  - In contrast, HI and ME exhibit notably higher income skew in urban/suburban areas
  - In most states, the differences between rural vs. urban/suburban areas is small

BERKELEY LAB

Education Level

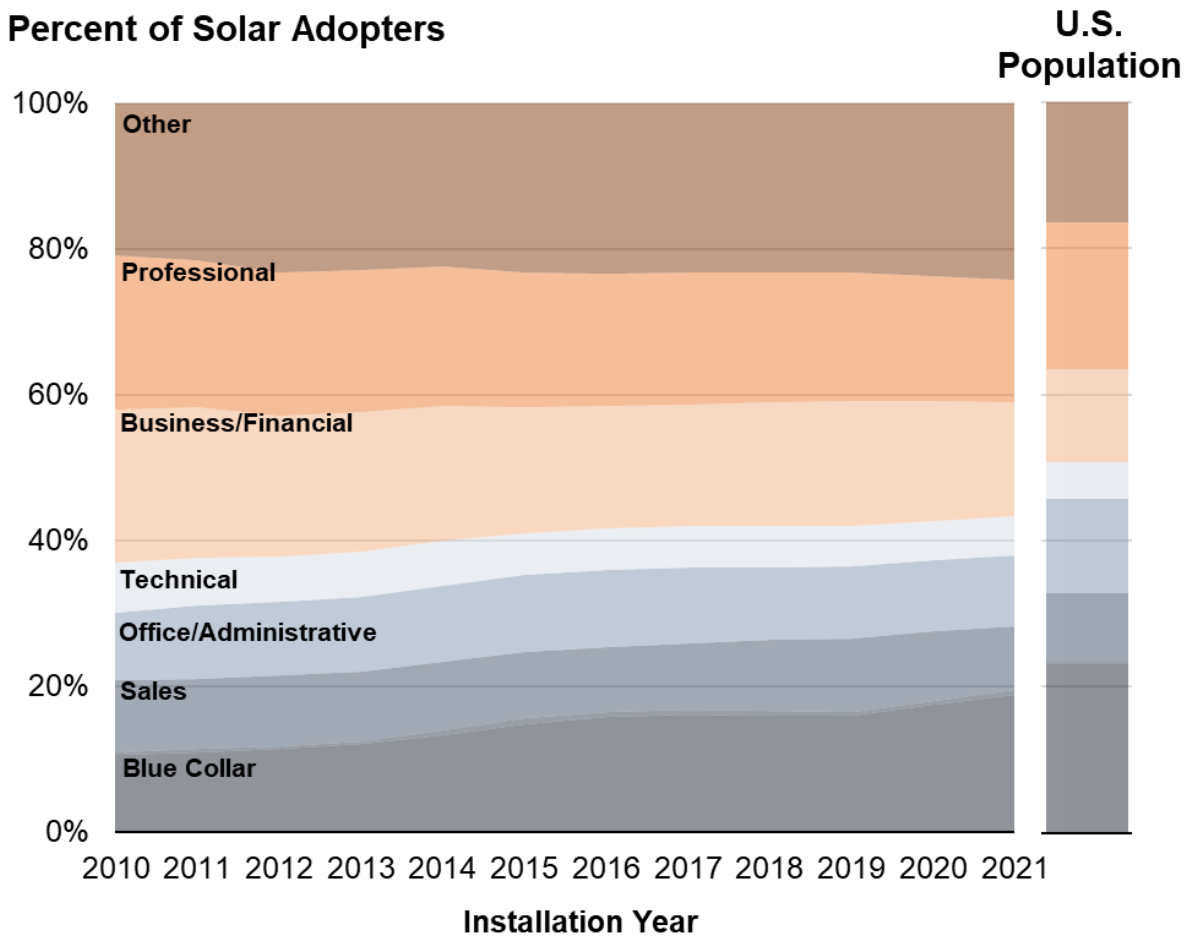


Notes: Education level for each solar adopter is based on the highest known education level among adult household members, and for the U.S. population is based on the education level of householders.

- Almost half (43%) of all solar adopters in 2021 had a bachelor's degree or higher, while 24% had a high school diploma or less, and the remainder in between
- Solar-adopter educational levels are generally higher than the population at large, where 34% have at least a bachelors degree and 35% have no more than a high school diploma
- That skew has diminished somewhat over time: in 2010, 57% of solar adopters had a bachelors degree, while 15% had no more than a high school diploma
- As with income, the trends in educational levels have flattened in recent years

BERKELEY LAB

Occupation

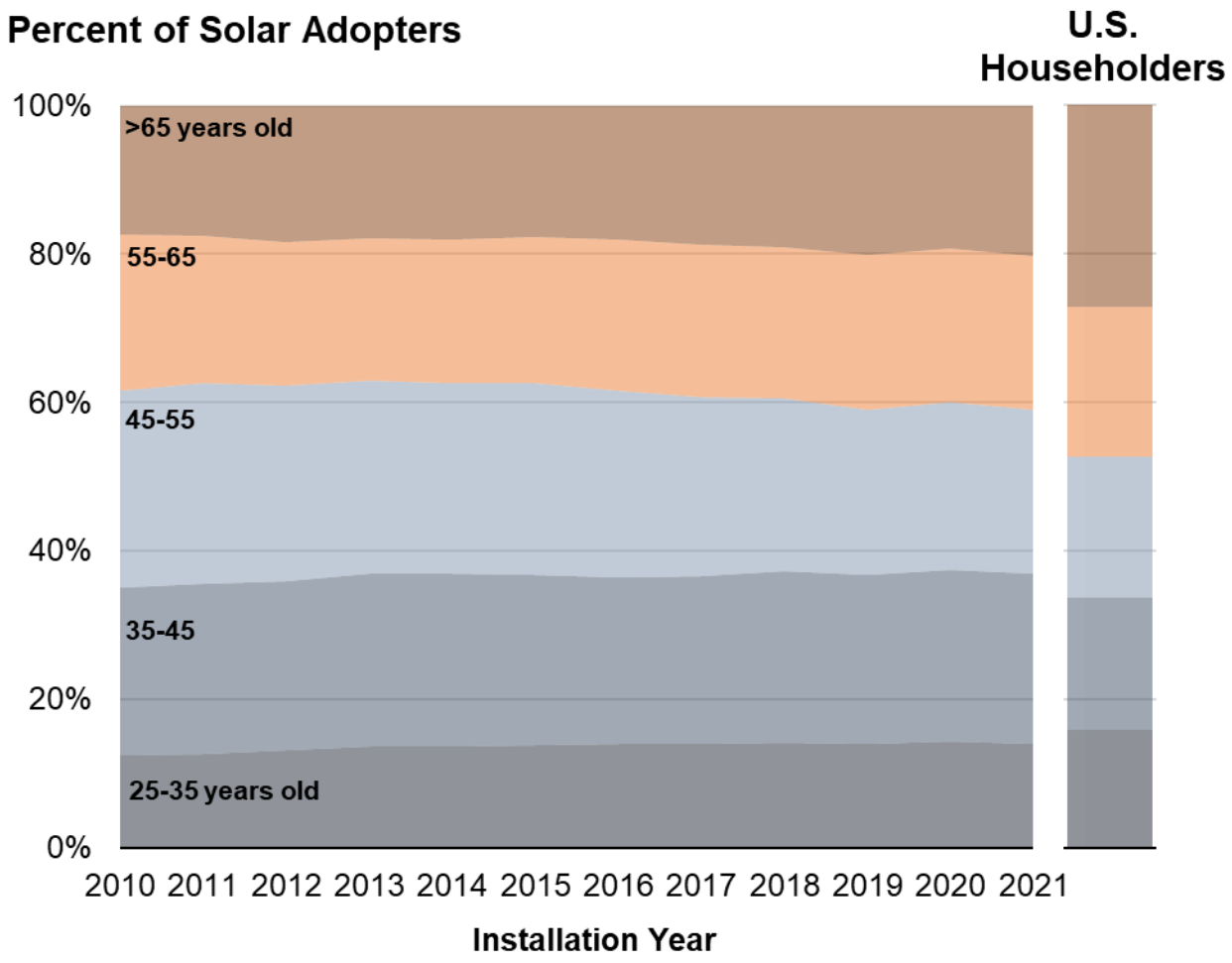


Notes: Occupation statistics for solar adopters are based on all adult household members. Statistics for U.S. population are based on data from the U.S. Bureau of Labor Statistics, consolidated and mapped on to Experian's occupational categories.

- Similar shares of 2021 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
- However, that skew has diminished greatly over time, as blue collar occupations comprise increasingly larger shares of new adopters (19% in 2021 vs. 11% in 2010)

BERKELEY LAB

Age



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.

- 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
- The most notable shift over time has been an increasing share of solar adopters within the oldest age group (65+), which remains under-represented, but less so than before
- The trend among the older group (mostly retirees) is consistent with growing technology acceptance (less perceived risk), and greater availability of financing (key for individuals on fixed-incomes)

BERKELEY LAB

Conclusions and Open Questions

Conclusions

- Solar adopters are heterogeneous in terms of their income and demographics
- Solar adopters diverge from the general U.S. population in many ways, skewing, for example, toward higher income and White, English-speaking households
- Solar adopters tend to concentrate in areas not defined as “disadvantaged communities”, which take into account socioeconomic and other indicators.
- Data for 2021 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

Open Questions

This report serves primarily to describe key trends, pointing to any number of questions that could be explored through more-targeted analysis; for example:

- *What impacts have LMI- and DAC-specific programs had on adoption patterns?*
- *How has the expansion of solar loan offerings impacted adoption by lower income households?*
- *Going beyond adoption levels, how do the broader set of benefits of rooftop solar adoption vary by income and demographic attributes?*
- *How do LMI solar adopters differ from LMI households more generally?*
- *Are solar costs (including those associated with permitting/interconnection delays) higher for households in disadvantaged communities?*
- *How do adoption patterns differ for community solar adopters?*
- *How do changes in solar compensation/rate design impact the demographics of solar adoption*

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.
- **Race/Ethnicity and Language:** Based on a comprehensive predictive name analysis process which identifies ethnic origin, probable religion, and the language preference of individuals.
- **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.

Key Public Data Elements Used in this Analysis

- **U.S. Census American Community Survey 5-Year Data (2015-2019):**
  - 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);
  - Household Language by Household Limited English Speaking Status (C16002);
  - Educational attainment by householder (Table B25013);
  - Age of householder (Table B25007)
- **U.S. Census 2010** Urban-rural classification: Rural, urban, and urban cluster populations by state; and definition by latitude/longitude for classification of solar adopters
- **Bureau of Labor and Statistics:** Occupational Employment Statistics Survey, March 2022
- **Department of Energy:** Disadvantaged Communities (DACs), March 2022

State Sample Sizes: *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					2021 Installations				
	TTS	Ohm	BZ	Total	Market Coverage	TTS	Ohm	BZ	Total	Market Coverage
AK	0	0	7	7	0%	0	0	0	0	0%
AL	0	52	26	78	47%	0	23	0	23	100%
AR	87	656	125	868	19%	0	286	18	304	16%
AZ	24,067	38,131	95,816	158,014	77%	4,927	13,174	7,074	25,175	77%
CA	1,262,265	385	98,978	1,361,628	96%	155,619	118	17,075	172,812	93%
CO	0	33,114	52,978	86,092	89%	0	10,837	5,340	16,177	100%
CT	45,516	651	2,514	48,681	80%	4,912	244	510	5,666	55%
DC	8,211	1,259	362	9,832	97%	1,389	871	151	2,411	100%
DE	0	41	1,803	1,844	24%	0	13	3	16	2%
FL	7,294	43,725	68,608	119,627	96%	2,162	21,401	15,618	39,181	100%
GA	0	1,981	1,092	3,073	78%	0	1,509	683	2,192	100%
HI	0	9,667	64,202	73,869	80%	0	1,983	1,996	3,979	83%
IA	0	807	346	1,153	22%	0	347	13	360	29%
ID	0	5,223	4,713	9,936	89%	0	2,192	738	2,930	98%
IL	24,371	2,781	441	27,593	74%	1,813	1,610	250	3,673	29%
IN	0	743	799	1,542	30%	0	354	353	707	46%
KS	0	419	631	1,050	49%	0	156	238	394	40%
KY	0	446	268	714	32%	0	226	116	342	35%
LA	0	2,515	12,460	14,975	63%	0	586	59	645	50%
MA	102,234	4,461	2,878	109,573	91%	7,191	2,126	631	9,948	85%
MD	0	41,881	20,409	62,290	79%	0	2,694	982	3,676	63%
ME	5,587	124	0	5,711	94%	868	42	0	910	100%
MI	0	935	2,513	3,448	26%	0	291	332	623	19%
MN	1,063	5,361	5,120	11,544	99%	0	2,216	760	2,976	100%
MO	0	2,767	2,557	5,324	34%	0	910	218	1,128	35%
MS	0	30	0	30	6%	0	8	0	8	7%

State	All Years					2021 Installations				
	TTS	BZ	Ohm	Total	Market Coverage	TTS	BZ	Ohm	Total	Market Coverage
MT	0	1,043	582	1,625	66%	0	317	44	361	80%
NC	24,026	7,276	3,074	34,376	98%	5,491	4,151	736	10,378	100%
ND	0	6	7	13	43%	0	3	1	4	57%
NE	0	30	277	307	42%	0	14	115	129	41%
NH	7,187	206	42	7,435	69%	829	36	1	866	68%
NJ	130,031	3,110	242	133,383	95%	11,417	1,582	3	13,002	94%
NM	25,086	9,066	5,432	39,584	97%	0	3,497	3,533	7,030	90%
NV	75,806	5,743	4,025	85,574	100%	13,669	3,070	343	17,082	100%
NY	83,035	9,675	2,748	95,458	63%	8,081	2,341	76	10,498	64%
OH	2,224	2,089	1,589	5,902	58%	55	870	254	1,179	45%
OK	0	835	192	1,027	35%	0	466	22	488	36%
OR	20,825	2,925	5,423	29,173	97%	2,662	1,942	1,265	5,869	100%
PA	5,719	1,646	3,083	10,448	26%	0	721	205	926	13%
RI	9,291	1,805	28	11,124	93%	1,330	996	25	2,351	81%
SC	0	13,343	3,799	17,142	67%	0	1,668	406	2,074	66%
SD	0	5	2	7	12%	0	4	0	4	25%
TN	0	513	428	941	48%	0	142	84	226	100%
TX	1,489	38,399	50,855	90,743	61%	0	14,689	8,638	23,327	52%
UT	21,454	7,533	5,668	34,655	62%	4,187	1,534	441	6,162	72%
VA	9,350	9,033	4,442	22,825	87%	0	5,278	2,141	7,419	83%
VT	3,119	6,841	14	9,974	75%	0	1,016	4	1,020	100%
WA	7,012	12,107	8,762	27,881	85%	0	4,954	780	5,734	100%
WI	6,559	314	499	7,372	82%	1,797	222	104	2,123	100%
WV	0	26	0	26	3%	0	10	0	10	2%
WY	0	6	101	107	7%	0	4	29	33	9%
U.S.	1,912,908	331,730	540,960	2,785,598	86%	228,399	113,744	72,408	414,551	81%

Sample Sizes by Analysis Element

Vary depending on data availability and unit of observation

Analysis Element	Unit of Observation	Sample Size	
		2021	All Years
Income	Household	414,541	2,785,521
TPO vs. host-owned	Household	217,625	1,734,215
Installer name	Household	244,619	n/a
With or without storage	Household	208,770	n/a
Multi- vs. single-family	Household	428,546	n/a
Home Value	Household	330,723	2,269,363
Education	Household	414,542	2,785,524
Occupation	Individuals	976,066	7,113,401
Urban vs. Rural	Individuals	1,222,917	8,941,943
Race/Ethnicity	Household	202,836	1,379,217
Language	Household	207,381	1,412,044
Age	Household	272,152	1,950,129

General Notes:

- With the exception of the multi- vs. single-family comparison, all other elements of the analysis are based only on single-family solar adopters
- 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 adopters 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
- Race/ethnicity and Language data were obtained for a random subset of the full sample, to economize data costs

BERKELEY LAB

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, Juan Botero, Michele Boyd, and Garrett Nilson for their support of this work.