Residential Solar-Adopter Income and Demographic Trends: 2021 Update

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- Income trends based on:
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Overview

Report describes income- and other 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 both its level of market coverage and granularity
- Updates and expands previous reports with data on adopters through 2019 and an expanded range of demographic trends, beyond the prior focus primarily on income
- Intends to be descriptive and data-oriented; complements and informs other ongoing work at Berkeley Lab surrounding issues of solar energy access and equity, including:
  - An online data visualization tool that allows users to further explore the underlying dataset in this report
  - In depth analyses around drivers and potential solutions to solar energy adoption inequities
  - Institutional support to organizations working on solar energy access and equity

For further information on related research at Berkeley Lab, see:
solardemographics.lbl.gov

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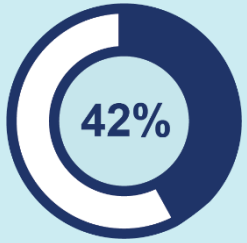
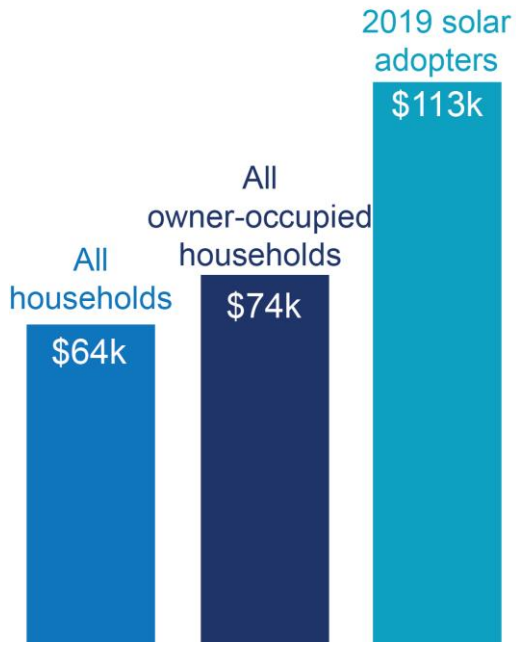
High-Level Findings

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

- The median solar adopter income was about $113k/year in 2019, compared to a U.S. median of about $64k/year
- The skew toward high incomes is particularly stark among adopters that own their systems and for those with paired solar-plus-storage systems



Low- and Moderate-Income Adoption
While solar adoption skews toward high-income households, low- and moderate-income households are also adopting. In 2019, about 42% 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)

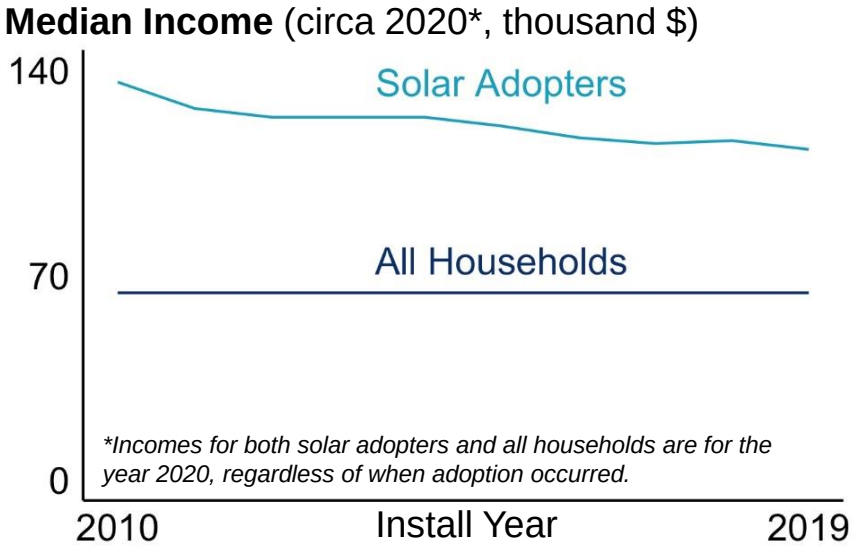


Solar adopters vary along other demographics

Compared to the broader population, solar adopters tend to:

- Live in higher-value homes
- Have higher credit scores
- Have more education
- Live in majority-white block groups
- Be older
- Work in business and finance-related occupations

Over time, solar adopters increasingly resemble the broader population



- The difference in income between solar adopters and the broader population fell from $72k/year in 2010 to $49k/year in 2019, at the median
- Solar adopters have become more reflective of the broader population in terms of education levels, race, and occupation
- These trends reflect the effects of falling solar prices and the emergence of policies and business models that support broader adoption, among other factors

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Data Sources

PV Street Addresses & System Data

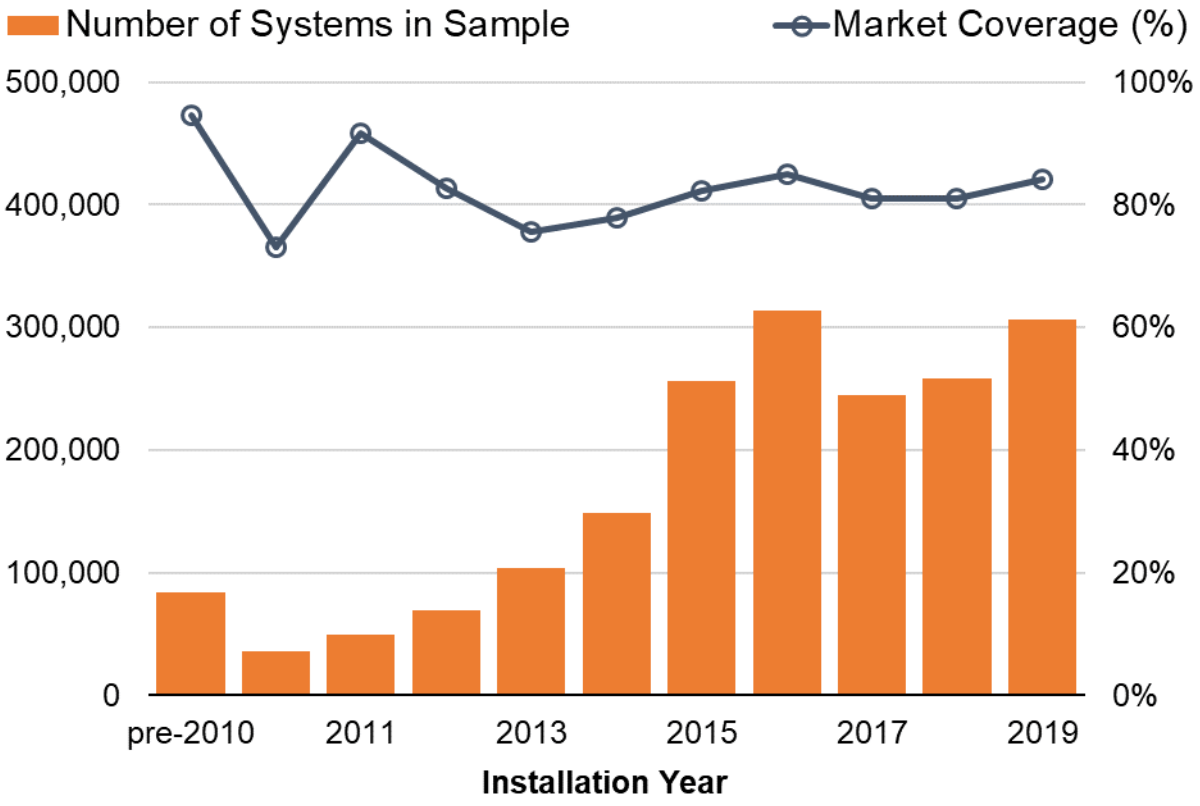
- Berkeley Lab's ***Tracking the Sun*** dataset: Primary data source; includes addresses and other data for roughly 1.5 million systems, obtained primarily from utilities and state agencies
- **BuildZoom** and **Ohm Analytics**: Purchased PV permit datasets; provide a supplementary source of PV street addresses for roughly an additional 400,000 systems

Income & Other Socio-Economic Data

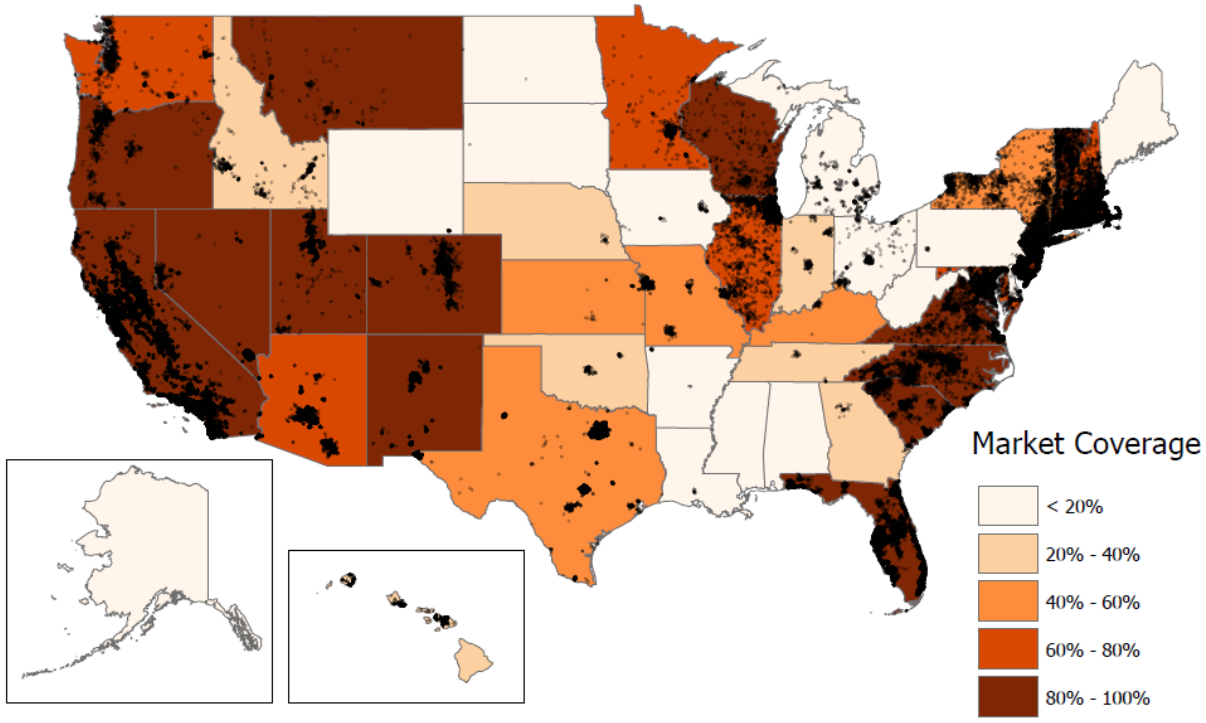
- **Experian ConsumerView**: Purchased dataset providing modeled household-level income estimates for solar adopters and for population as a whole; as well as household data on other socio-economic attributes
- **U.S. Census** and **Bureau of Labor Statistics**: Used for comparison purposes to characterize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

See appendix slides 38-39 for further details on income and other socio-economic data sources

Sample Coverage



2019 Systems



Sample consists of **1.9 million systems**, covering **82%** of all U.S. residential systems through 2019 and **84%** of systems installed in 2019

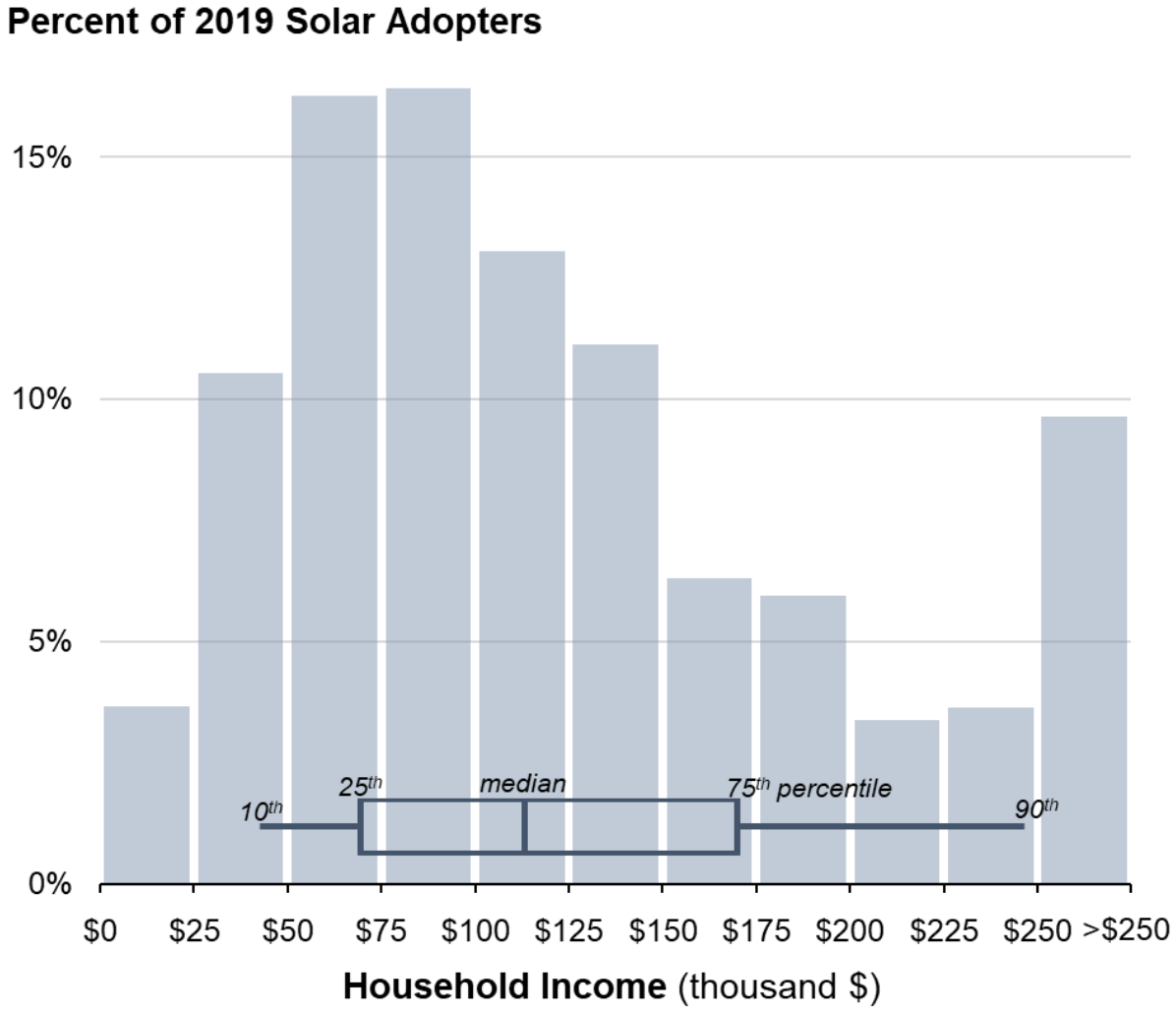
See appendix slides 40-41 for further details on sample sizes

General Points on the Data and Descriptive Approach

- We focus here on national and state-level trends, with an emphasis on PV systems installed in 2019; 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
- Temporal trends are shown starting from 2010; data are available for earlier years but tend to be noisy, due to small sample size, and are heavily dominated by California
- Income estimates from Experian are based on the first quarter of 2020, regardless of the date of installation, and thus represent current incomes, rather than incomes at the time of adoption
- For all state-level figures, we present trends only if the underlying sample consists of at least 100 systems and at least 10% market coverage for the applicable state and year; see appendix slide 40
- 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 41 for details
- All comparisons of solar adopter incomes to Area Median Incomes (AMI) are based on household size; as used throughout this report, "Area" refers to the applicable U.S. Census Core-Based Statistical Area or county (for rural areas)

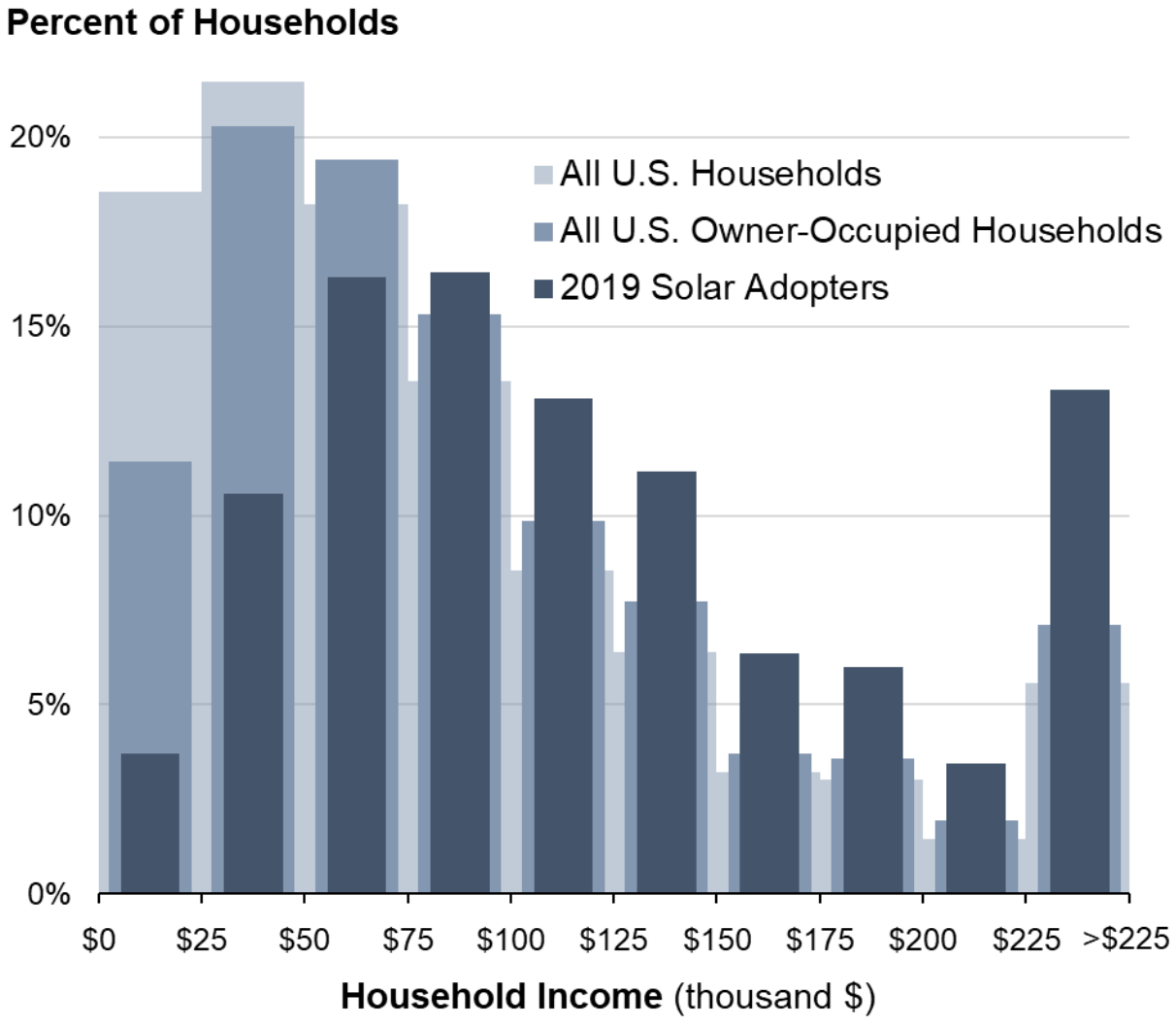
Solar-Adopter Income Trends

Solar-Adopter Income Distribution



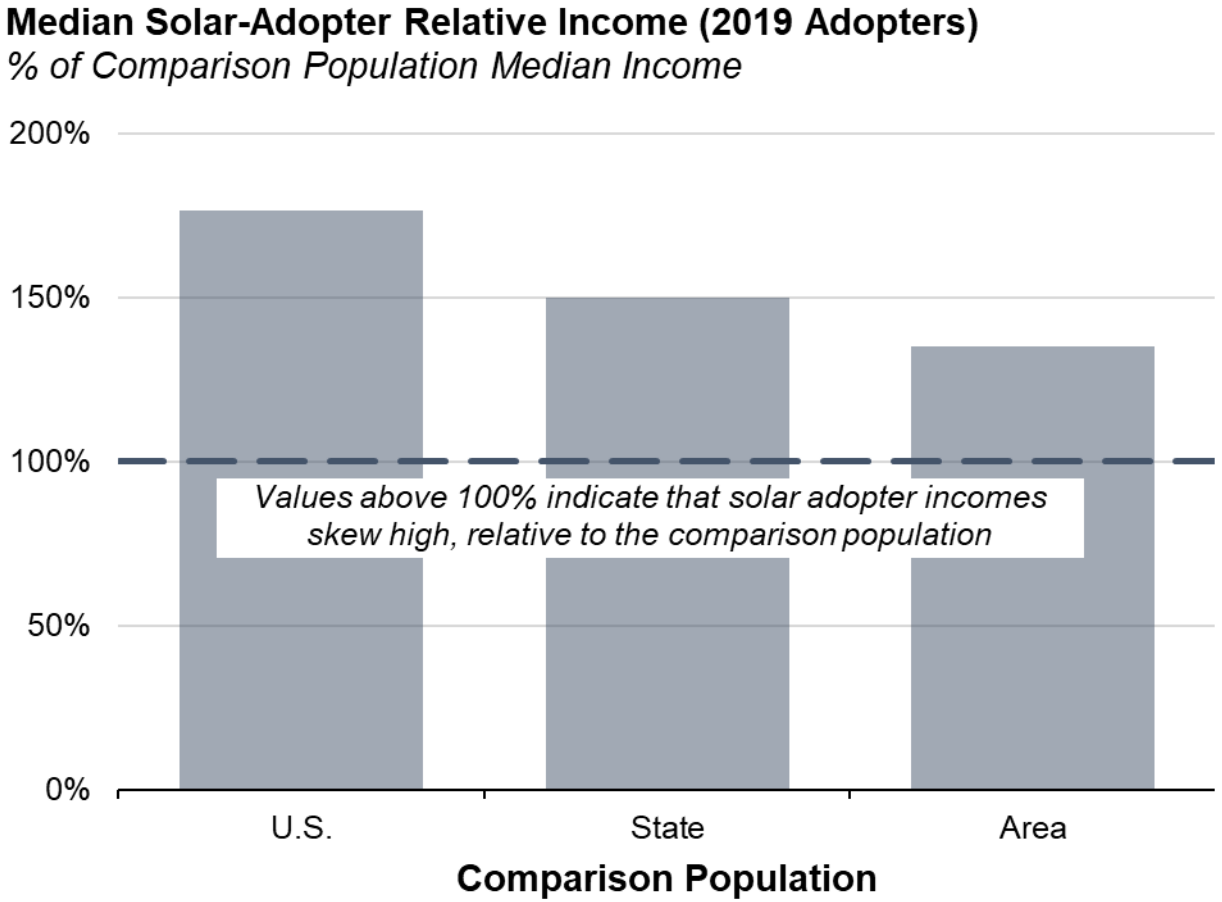
- Solar-adopter household (HH) incomes span all income ranges
  - Distribution peaks at $50-100k, but with a long upper tail
- Median solar-adopter HH income was $113k in 2019
  - Half of 2019 solar adopters (the 25-75th percentile range) had incomes of $69-170k
  - While the large majority (10-90th percentile range) fell between $42-247k

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 $64k, compared to $113k for 2019 solar adopters
  - Disparities are most pronounced at the low and high ends of the income spectrum
  - The next set of slides provide a more refined set of metrics to characterize the degree of skew
- Skew is less pronounced if comparing to only owner-occupied households (OO-HHs)
  - Median income of all OO-HHs is $74k
  - Solar adopters in this study are almost entirely OO-HHs (due to owner-control of rooftop, owner/tenant split incentive)

Solar-Adopter "Relative Income"



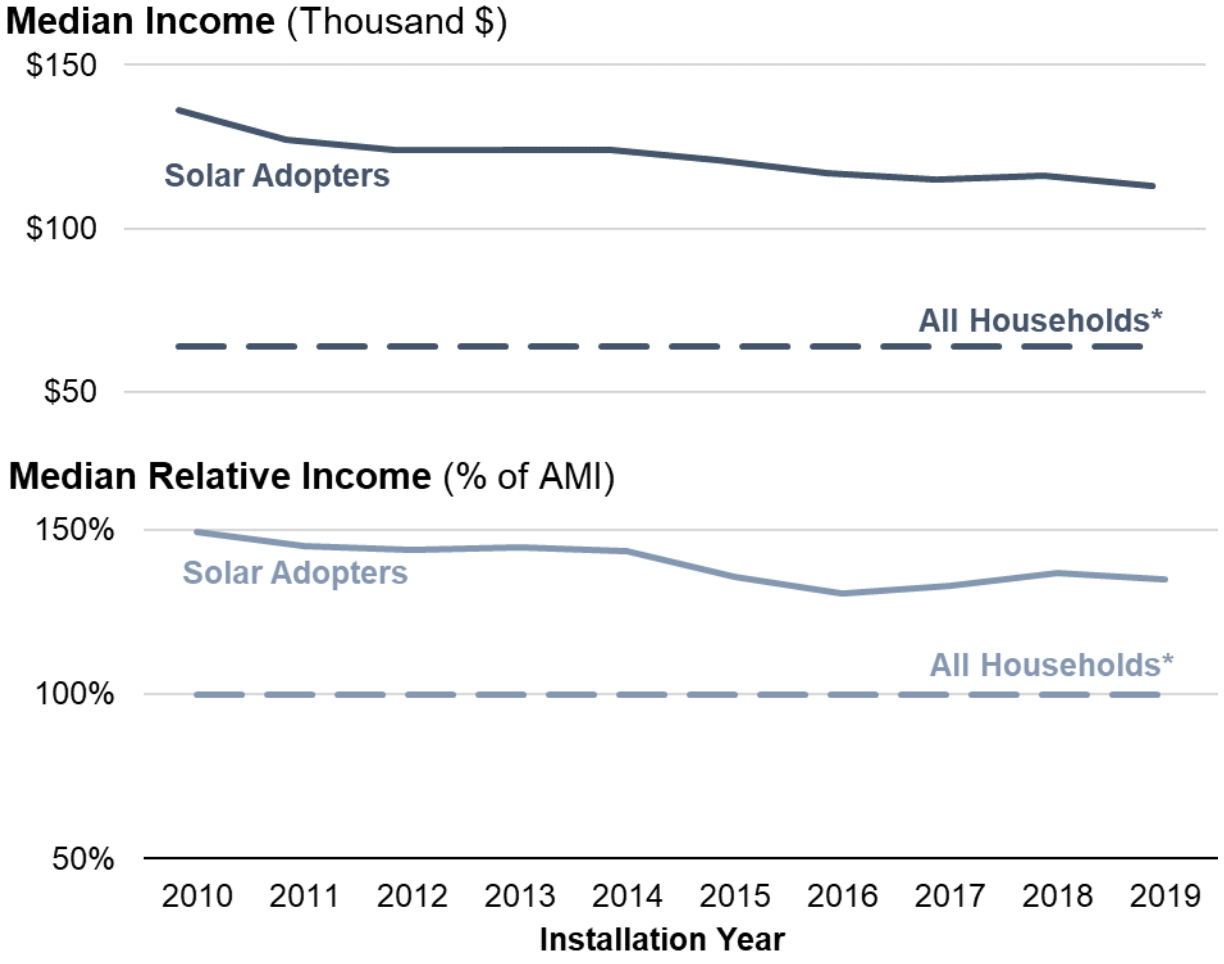
Note: To calculate these values, we first calculate each solar adopter's household income as a percentage of the median household income for each comparison population, and then take the median of those percentage values across all solar adopters.

Relative Income: Solar adopter HH income *as a percentage* of the median income of all HHs

- Provides a simple metric to characterize the degree to which solar adopter incomes differ from the rest of the population
- Can be based on comparison populations at different geographical scales: here we compare to national, state, and area medium incomes
- Solar-adopter incomes skew high, regardless of how broadly defined the comparison region, though the skew is smaller the more localized the comparison

Going forward, we default to Area Median Income (AMI) as the basis for calculating relative incomes

Solar-Adopter Income Trends over Time



**The flat lines for "All Households" reflect incomes in Q1 2020 and simply serve as a reference level for the solar-adopter incomes, which are based on the same timeframe.*

- Solar adoption has been slowly migrating toward lower incomes over time
- We see this in terms of both absolute and relative incomes, though the trend in relative incomes has flattened in recent years
- Long-term trends reflect some combination of:
  - Falling PV prices
  - Maturing PV markets
  - Expansion of PV financing options
  - Programs targeting LMI households
- Recent trends impacted by shifting market share of TPO, as shown later in slide 20

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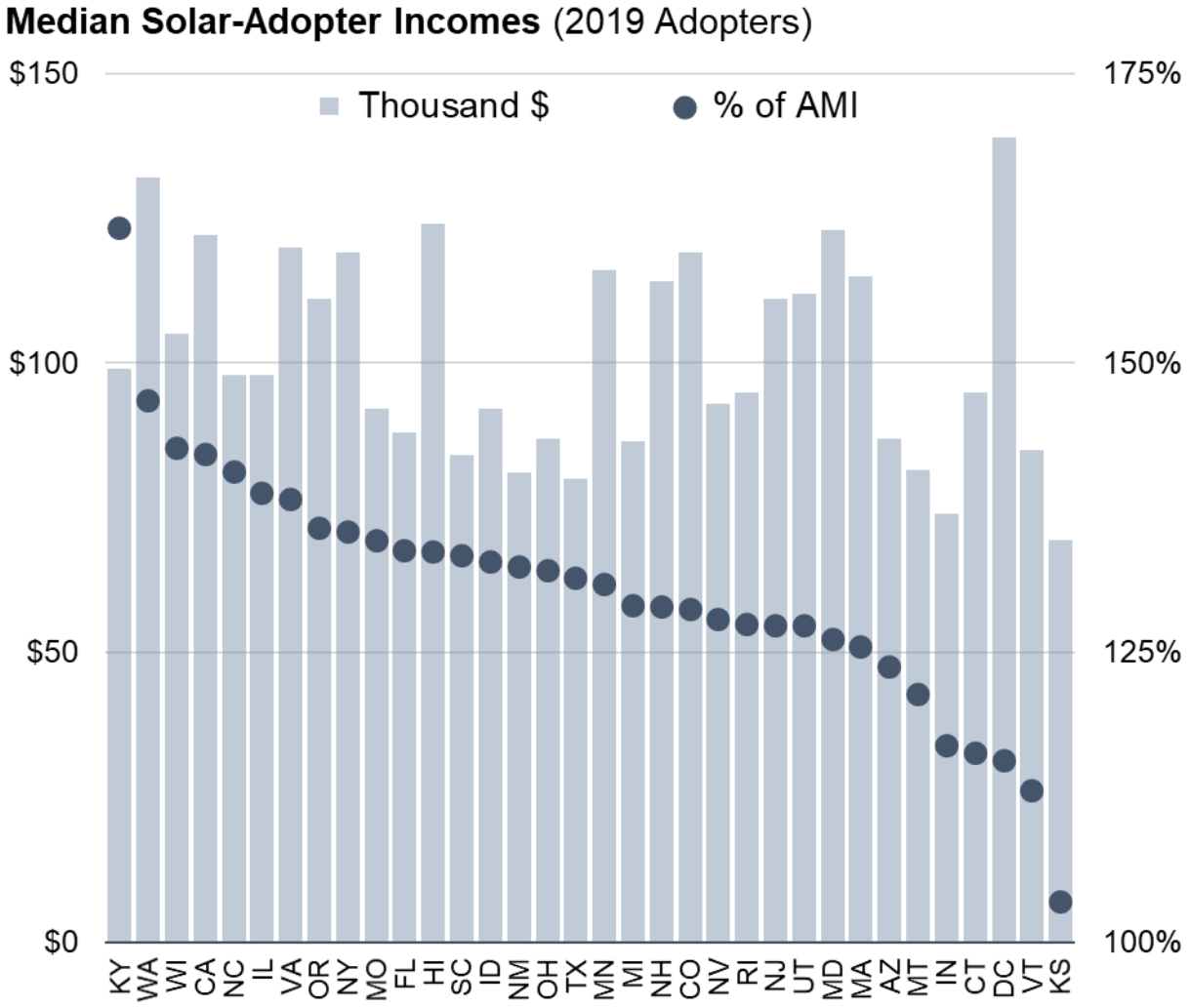
Solar-Adopter Income Trends across States



- Solar-adopter median incomes vary widely across states, as expected, given general differences in income levels across states
- All states exhibit some skew toward higher incomes, with median relative incomes typically ranging from 120-140% of AMI
- Some of that variation (especially at the extremes) may be idiosyncratic, though may also reflect fundamental drivers, such as:
  - Relative levels of solar market maturity
  - Solar policies and programs
  - Availability of financing
  - Income inequality within the broader population

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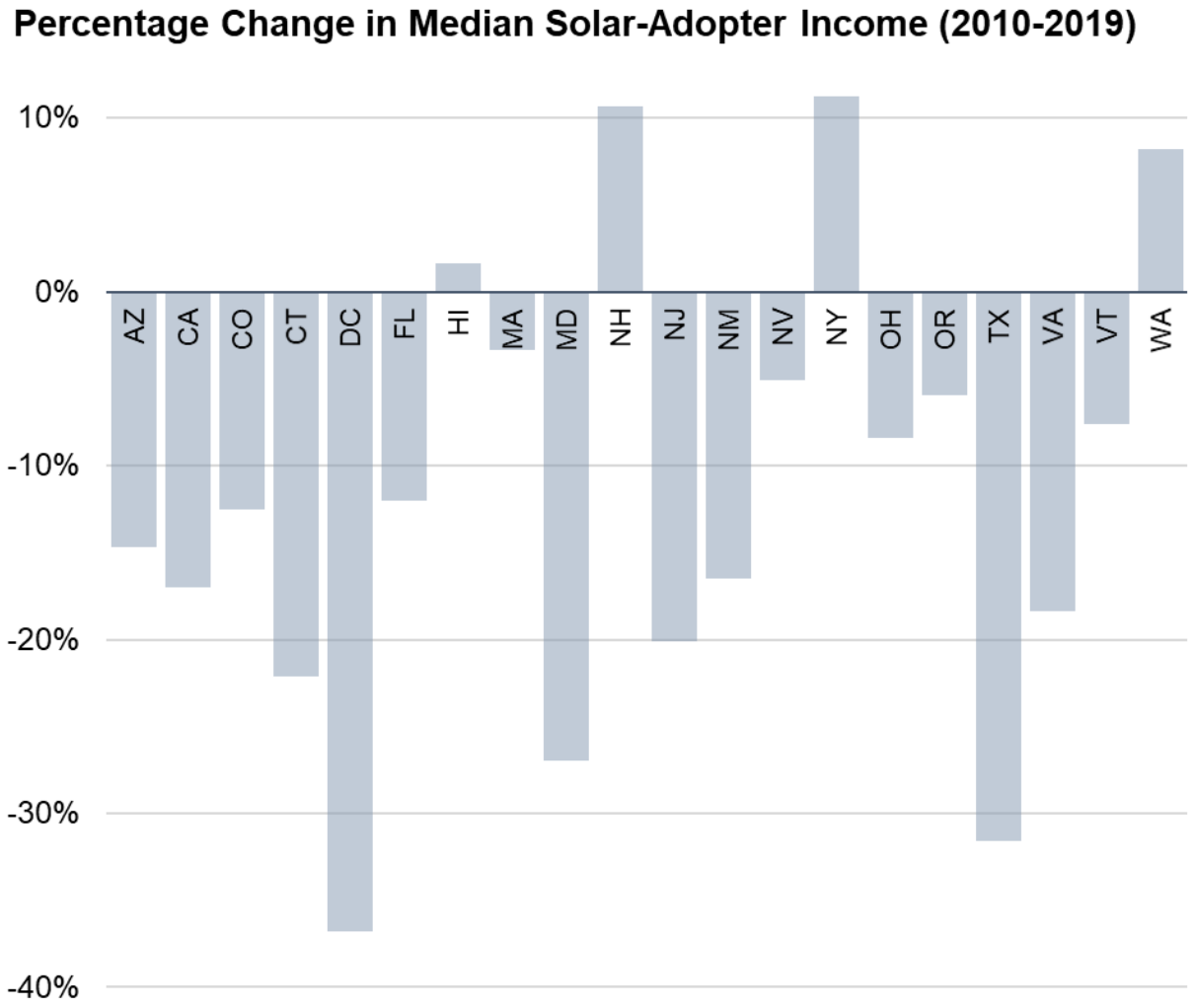
Solar-Adopter Income Trends over Time by State



- Virtually all states show a trend toward lower income adopters over time, with generally about a 5-20% drop in median adopter incomes over the 2010-2019 period
- Though not shown here, similar trends occur at the county-level as well
- Trends reflect both *deepening* and *broadening* of solar markets (O'Shaughnessy et al. 2021)
  - ***Deepening*:** Solar adoption within existing markets progressively moving toward lower incomes
  - ***Broadening*:** Solar adoption expanding into previously under-served, lower-income areas within each state

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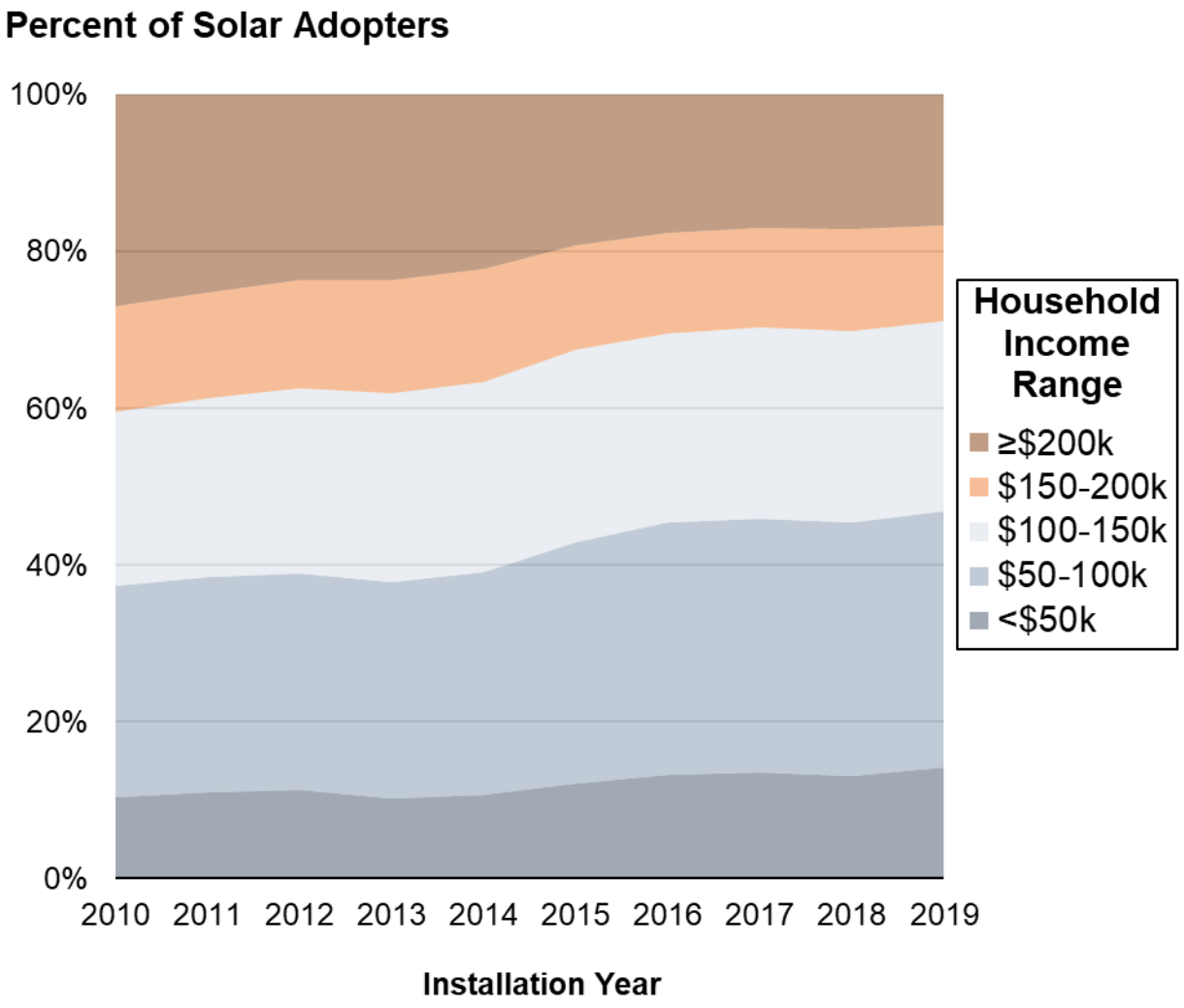
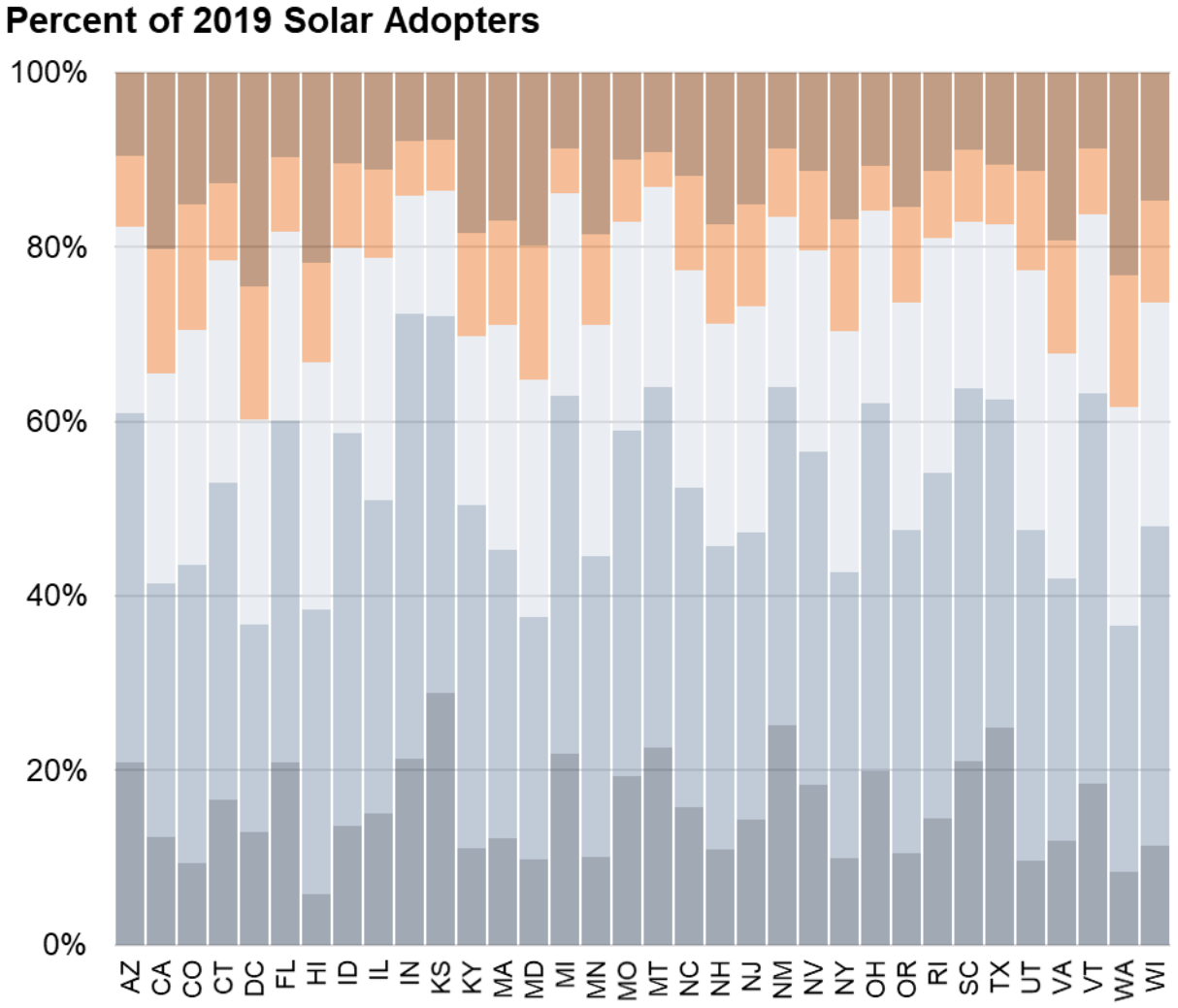
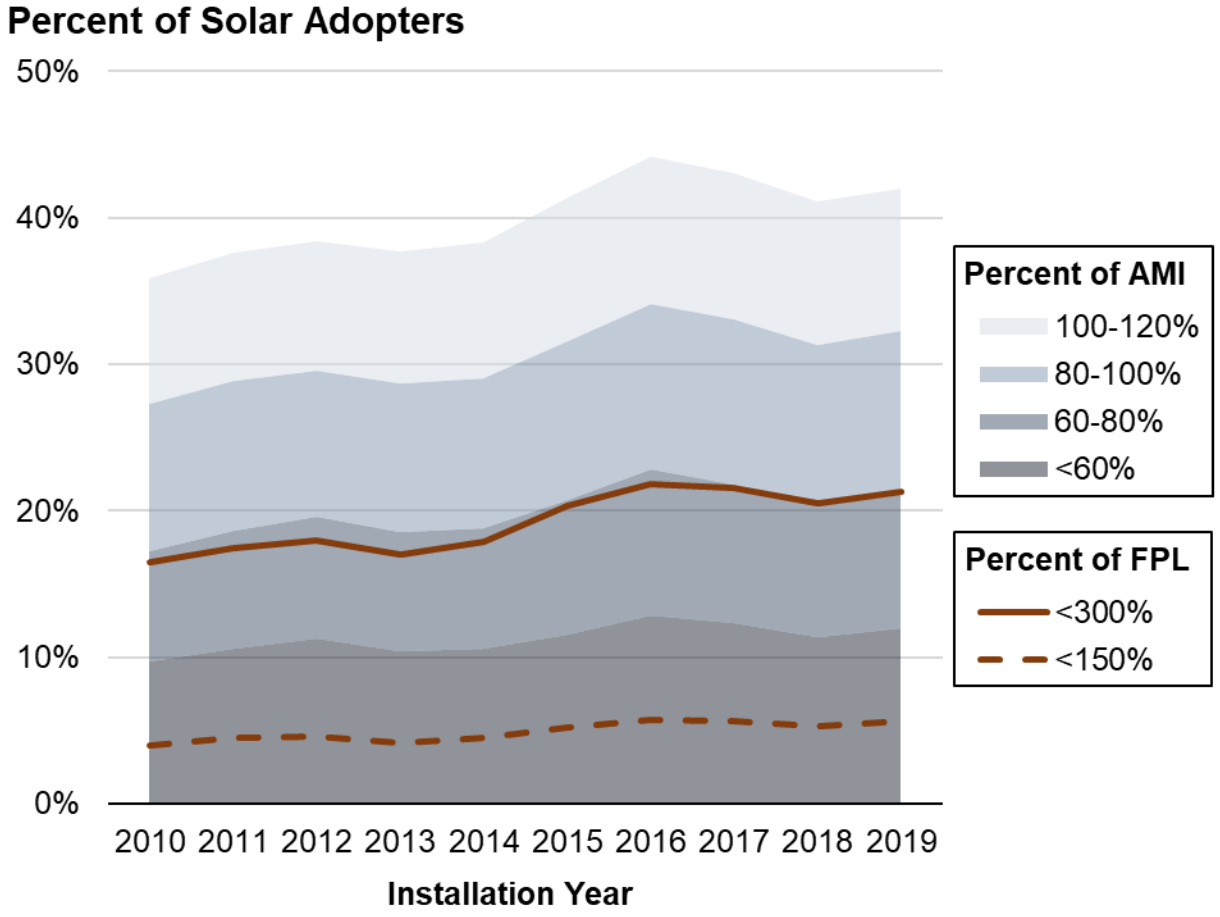
Solar-Adopter Income Distributions over Time and by State

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





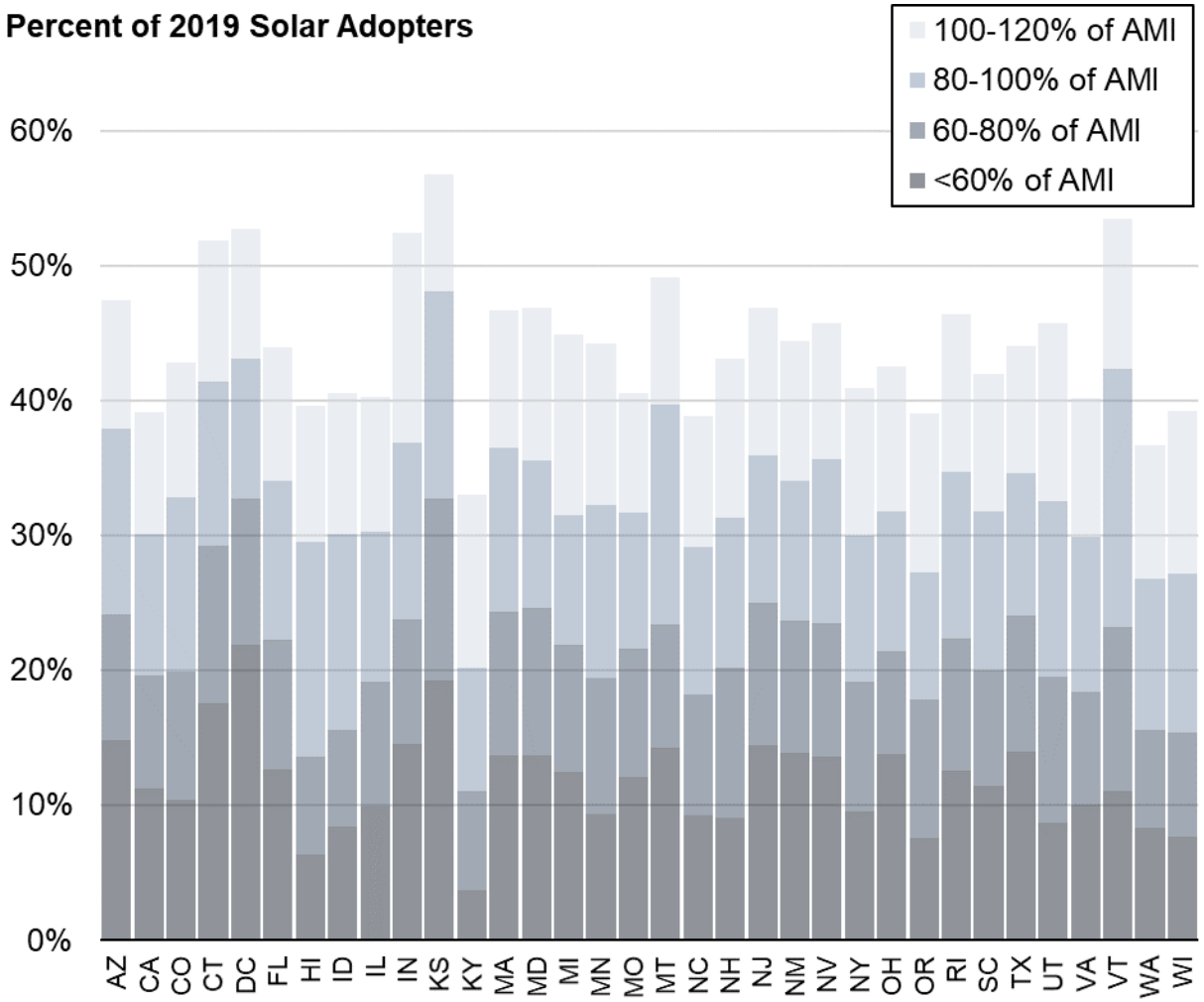
LMI Share of U.S. Solar Adopters over Time

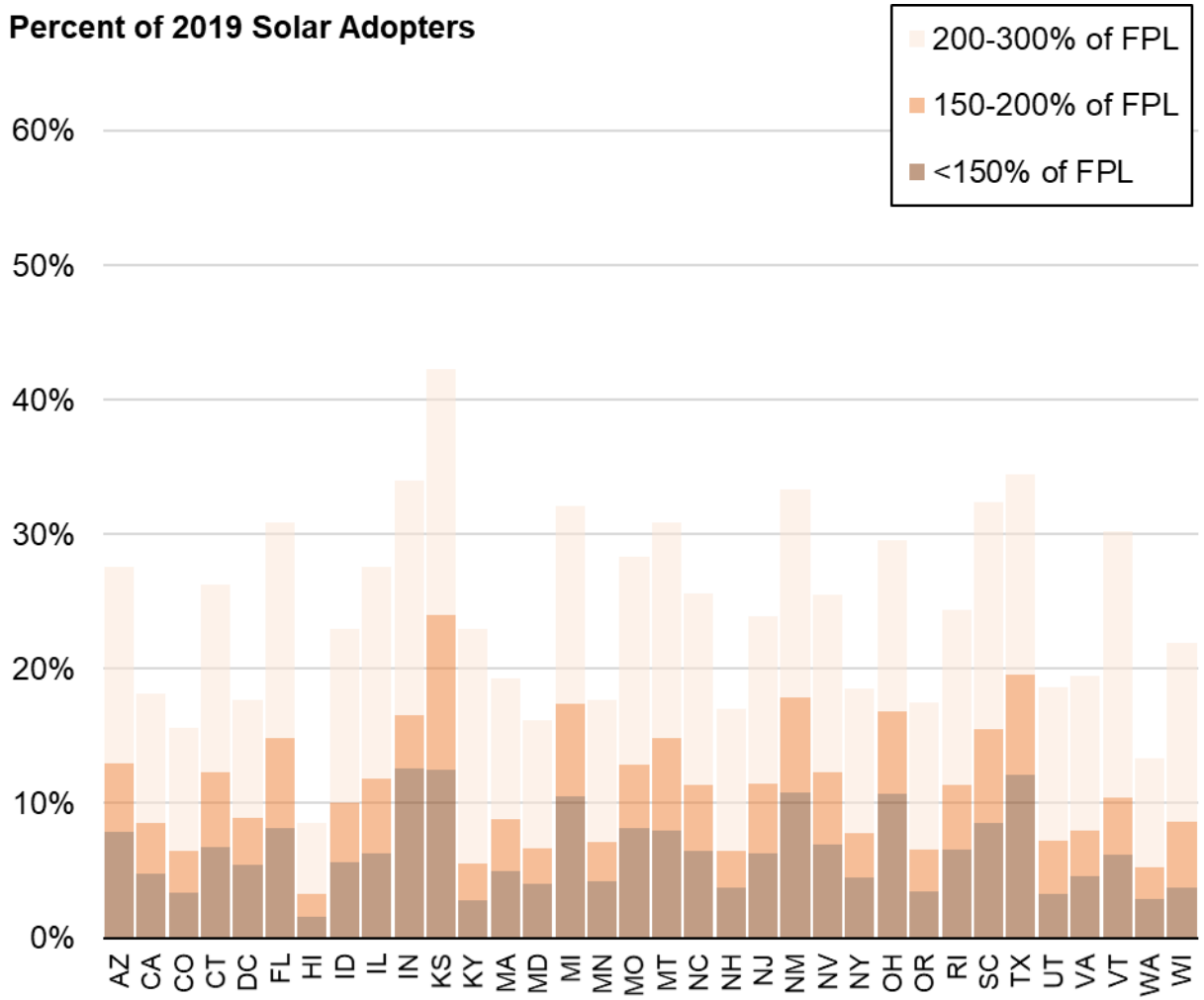


Notes: Both AMI and FPL vary by household size. For a family of three, the FPL for the contiguous 48 states was $21,330 in 2019.

- Various income metrics and thresholds can be used to define "low-to-moderate income" (LMI):
  - 150% of Federal Poverty Level (FPL) is common, especially in federal programs
  - 80% of AMI is also frequently used
  - Higher thresholds (e.g., 300% of FPL, 100-120% of AMI) are sometimes used to include "moderate" income
- Regardless of how its defined, LMI shares of U.S. solar adopters are trending up over time
  - Consistent with earlier trends in absolute income levels, and notwithstanding some variability in changes year-over-year
- Across all U.S. solar adopters in 2019:
  - **AMI:** 21% were <80% of AMI, 42% were <120% of AMI
  - **FPL:** 6% were <150% of FPL, 21% were <300% of FPL

LMI Share of Solar Adopters by State

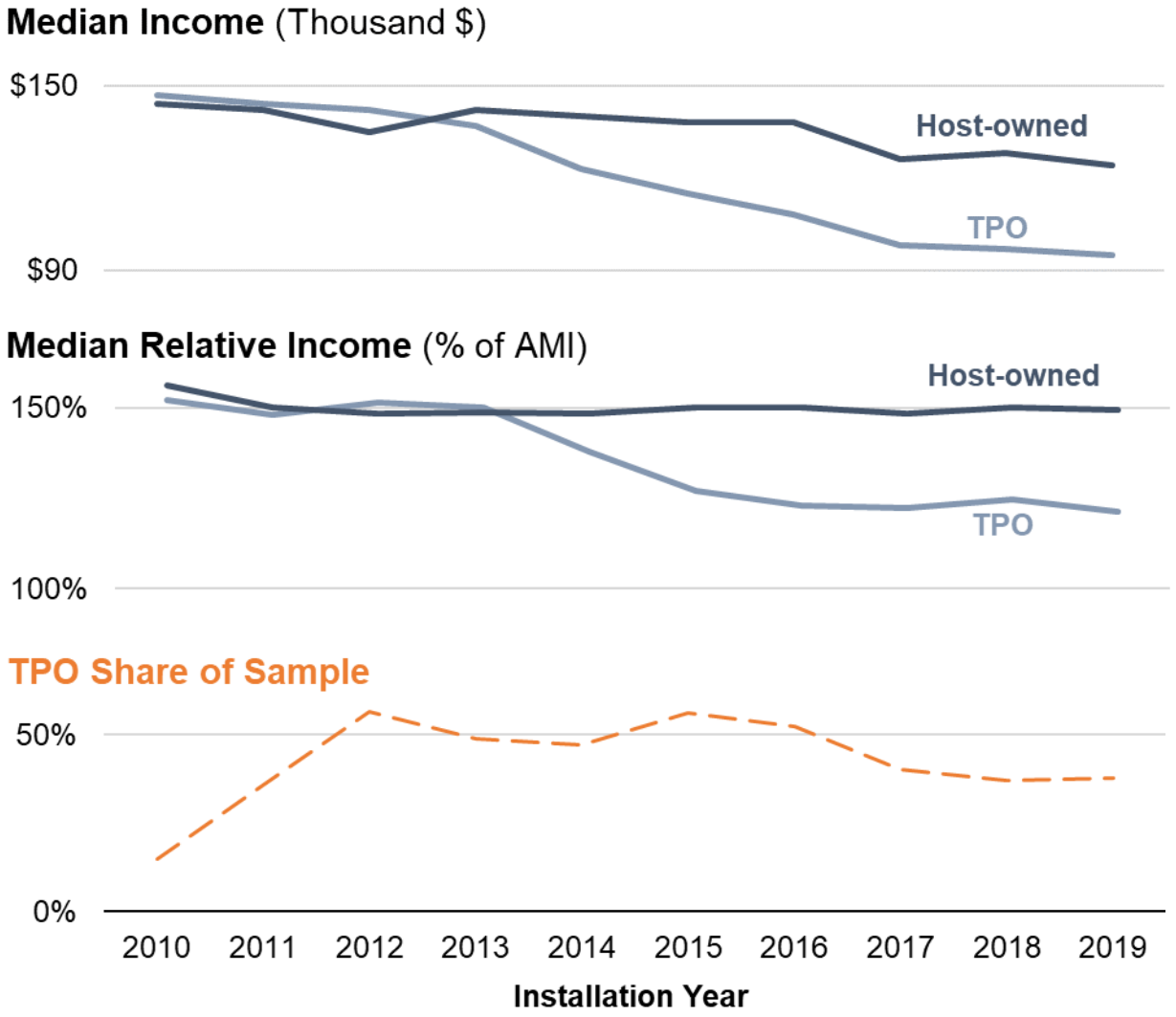




Solar-Adopter Income Trends by Segment

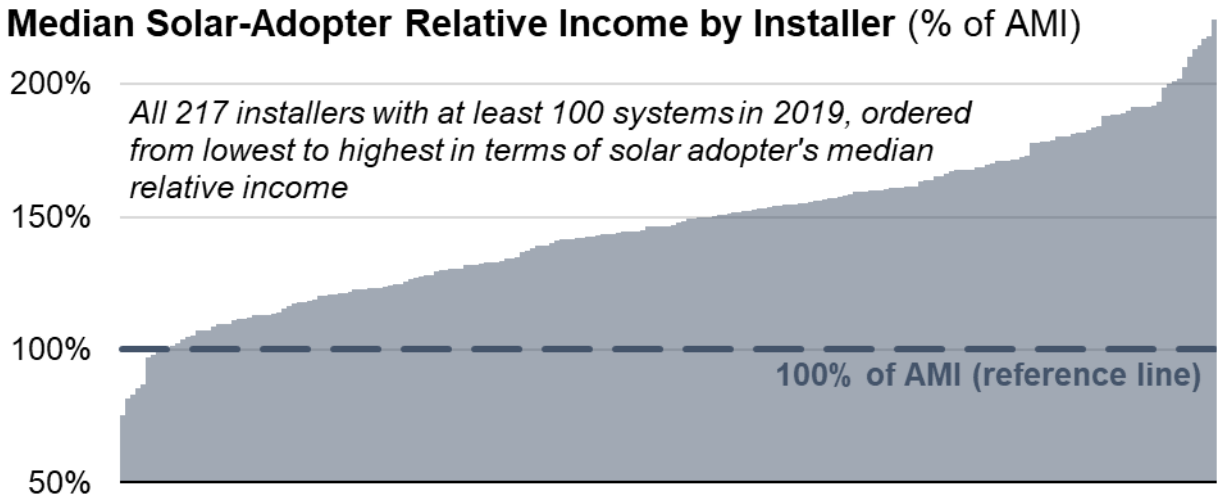
- Beyond looking at how solar-adopter incomes vary over time and geography, we can also evaluate differences by market segment
- Here, we focus on several segmentations:
  - Third-party vs. host-owned systems
  - Differences across solar installers
  - PV systems installed with battery storage vs. stand-alone 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 41 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

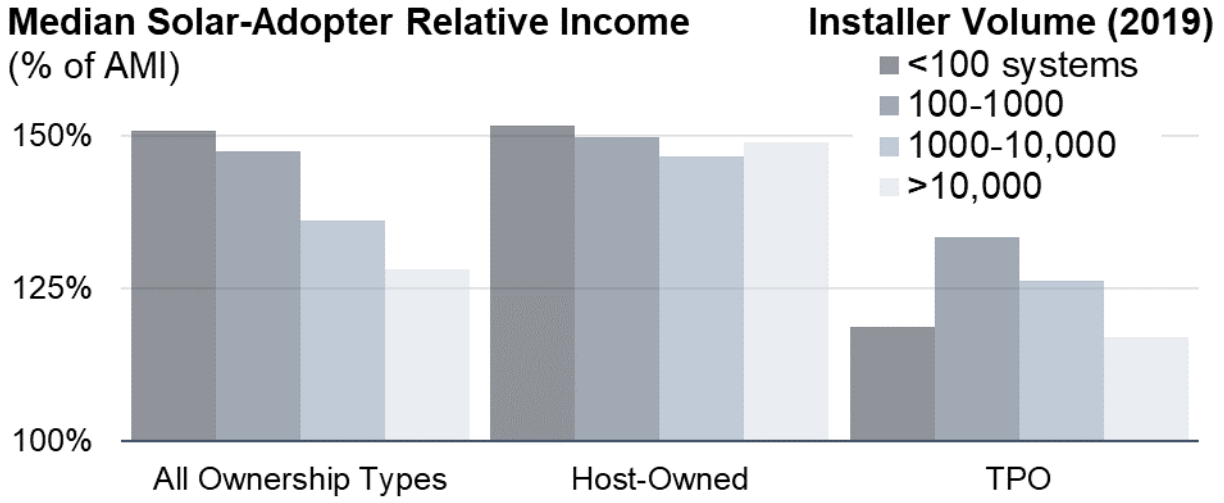
Third-Party vs. Host-Owned Systems



- 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
  - Though not shown here, state-level comparisons generally exhibit the same basic trends
- O'Shaughnessy et al. (2021) found that TPO has driven adoption by lower income HHs
- Implication is that the general trend toward lower income solar adopters, observed earlier, can be substantially attributed to TPO
- The recent decline in TPO market share has likely dampened the overall trend toward lower income solar adopters

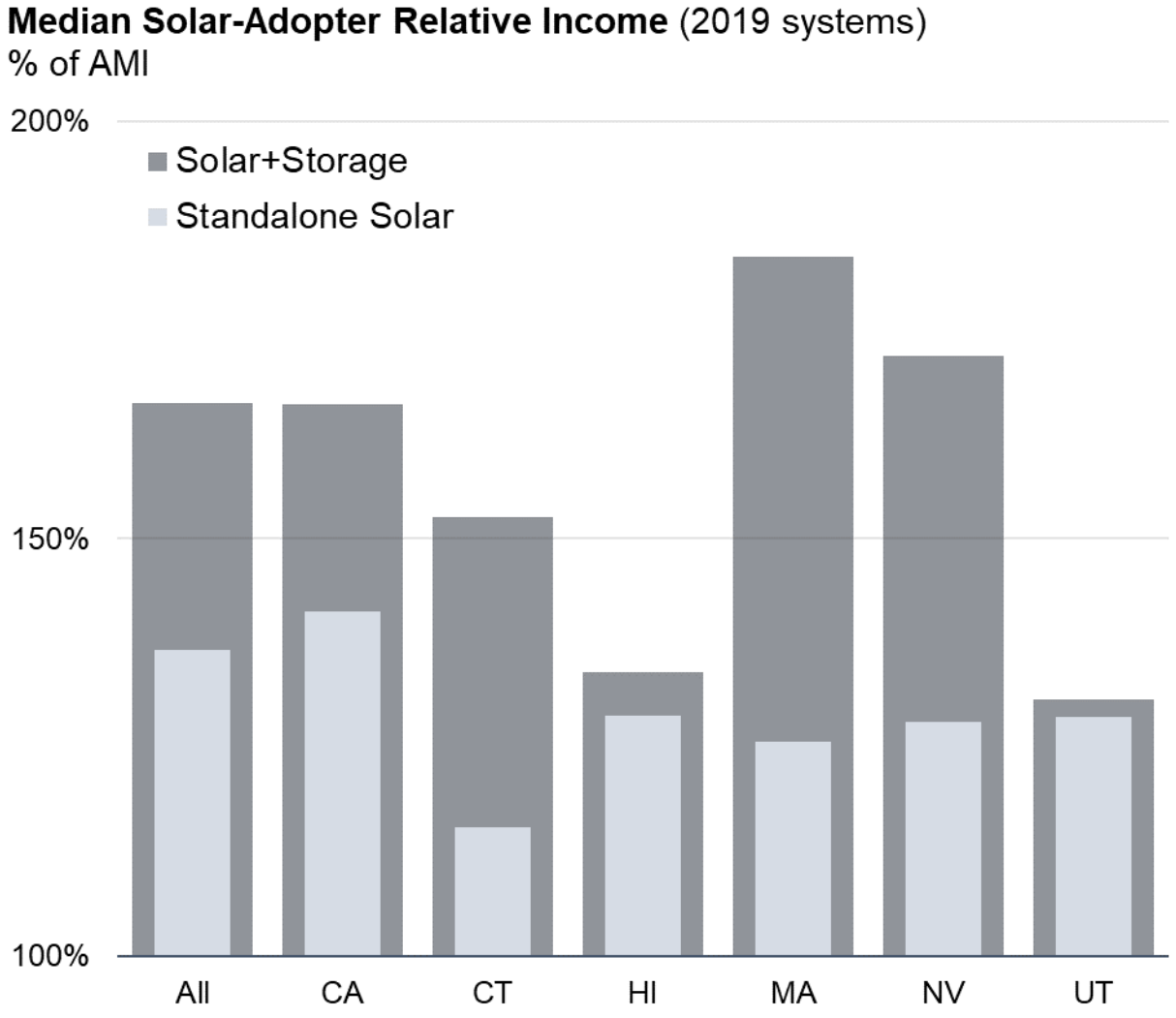
Installer-Level Trends





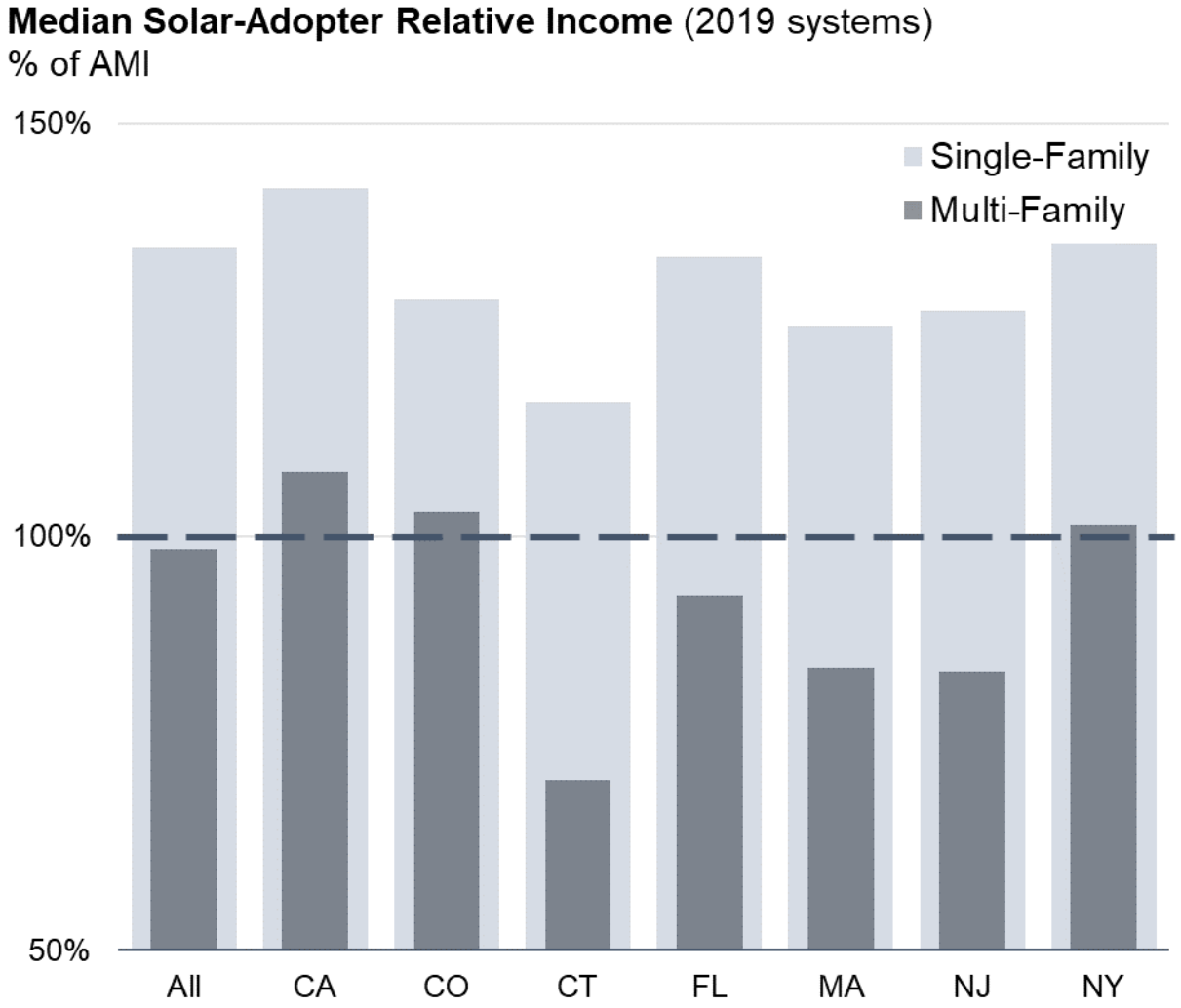
- Solar-adopter relative income varies considerably across installers, though virtually all skew higher than AMI
- Among the small set of installers (8 firms) with median incomes below AMI are several with business models focused specifically on LMI
- Larger volume installers exhibit lower relative income, primarily because they tend to more heavily favor TPO
- Among host-owned systems, installer size has no bearing on relative income; among TPO systems, the relationship is ambiguous (relative incomes are generally lower the larger the installer, except for the smallest installers)

Paired Solar+Storage vs. Stand-alone Solar



- Roughly 4% of the PV systems in the sample were paired with storage in 2019, but that rate is growing (Barbose et al. 2021)
- Paired solar+storage systems typically cost about 30% more than stand-alone PV systems, for standard system sizes
- Not surprisingly, given the price differential, solar+storage adopters tend to have higher incomes (roughly 22% higher) than stand-alone solar adopters
- The solar+storage sample is dominated by CA, but the general trend in income differences between paired vs. stand-alone systems is consistent across other states as well

Multi-Family vs. Single-Family



- Roughly 2% of all solar systems in the 2019 sample were installed on multi-family buildings
  - Most are owner-occupied; includes condos
- Multi-family solar adopter incomes are considerably and consistently below those of single-family adopters
- Across all multi-family systems in the dataset, incomes are roughly equivalent to AMI, but are well below AMI in several states
- Data on participation in income-qualifying solar programs is incomplete, but suggests higher participation by multi-family than single-family households, though still a minority overall
  - In CA, 20% of multi-family vs. 1% of single-family solar adopters participated in LMI programs

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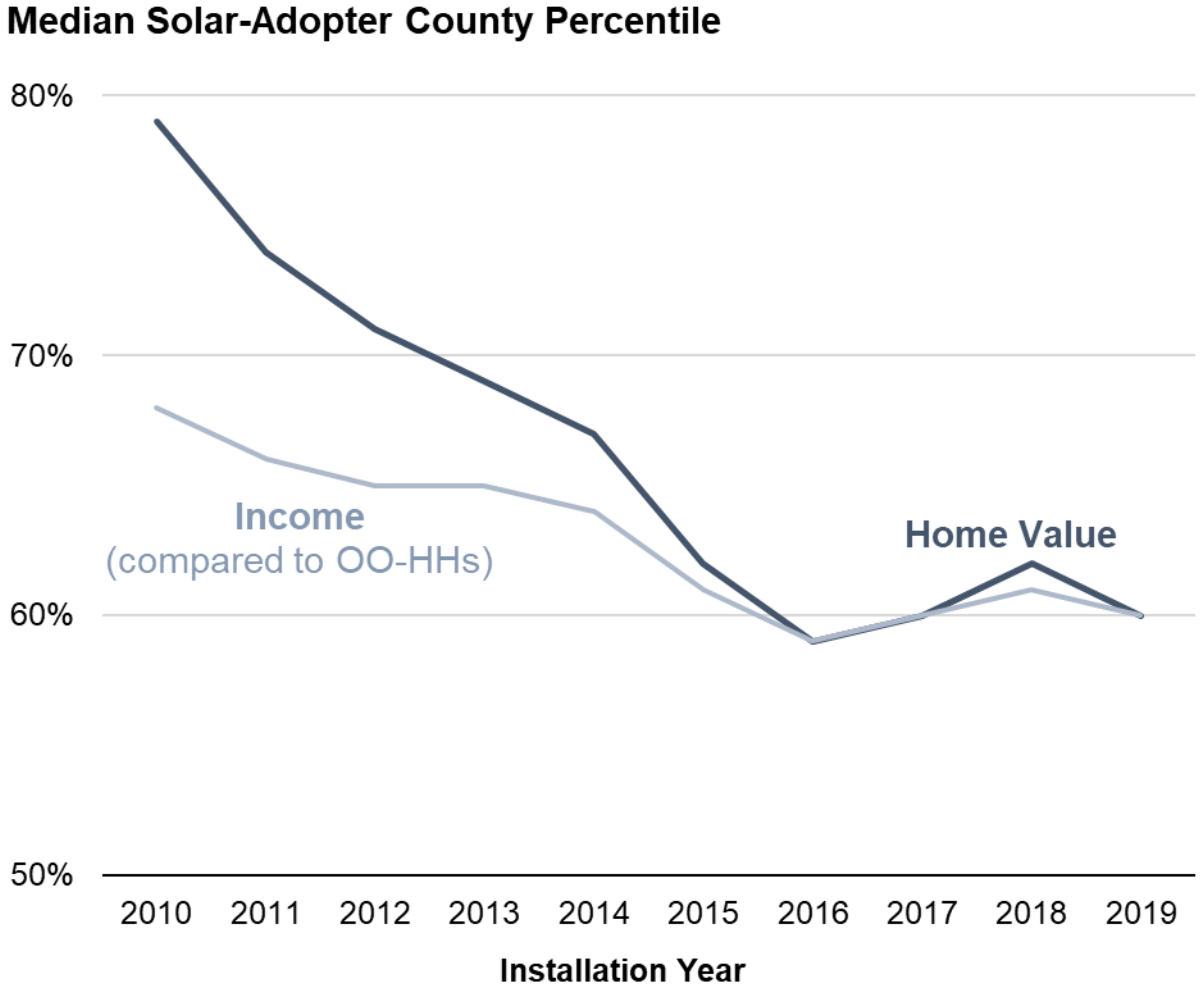
Other Socio-Economic Trends for Solar Adopters

Approach to Describing Other Socio-Economic Trends

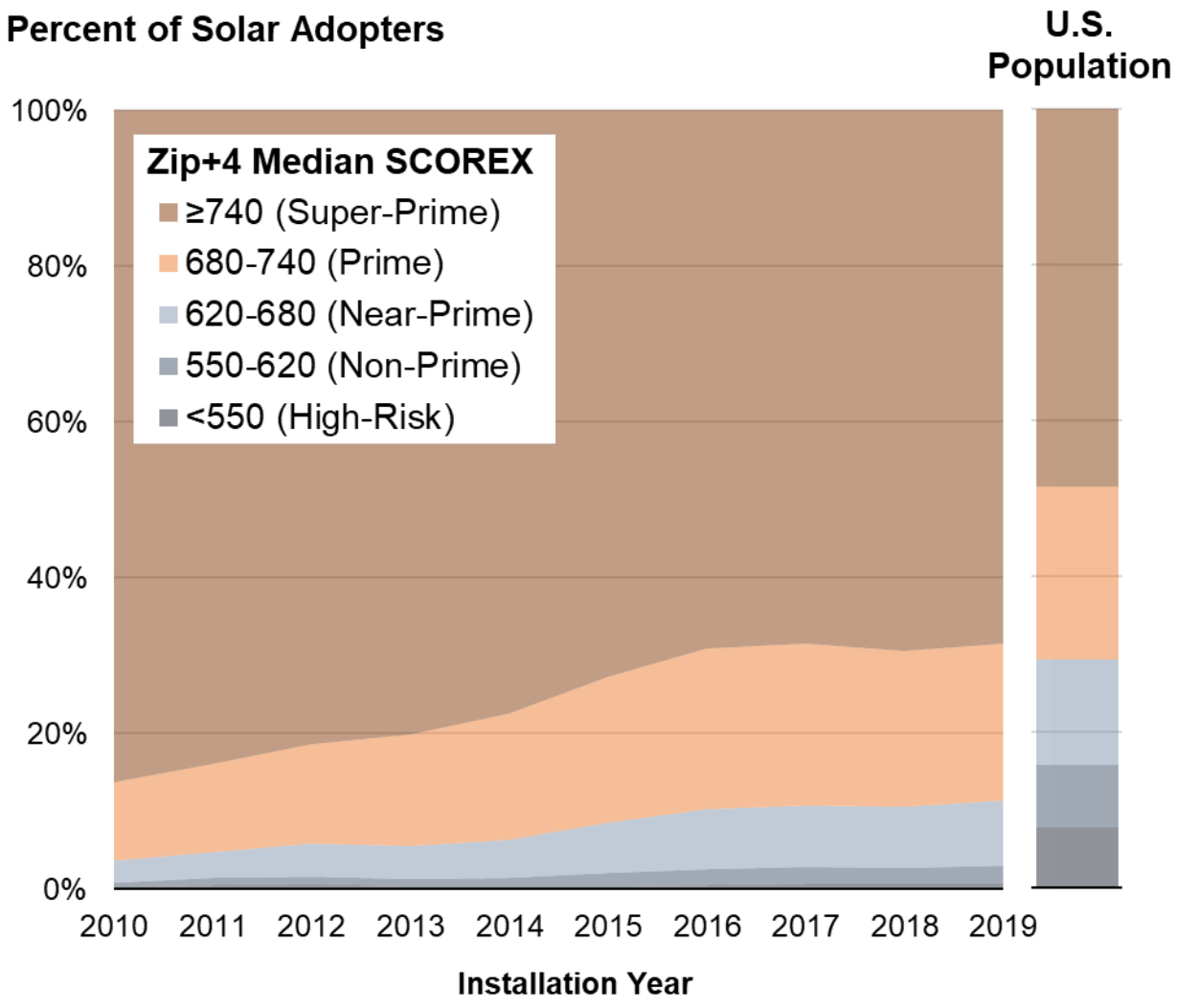
- Going beyond household income, we describe trends in other demographic and financial attributes of solar adopters (*see slides 38-39 for details on these variables*):
  - Home Value
  - Credit Scores
  - Education Level
  - Occupation
  - Rural vs. Urban
  - Race and Ethnicity
  - Age
- Trends describe the distribution of solar adopters nationally, changes over time, and comparison to the broader (in most cases, total U.S.) population
- Many of these trends illustrate a consistent theme: solar adopters more closely resembling the broader US population over time, but still exhibit some skew
- Some of these attributes may be correlated to income, leading to parallel trends

Home Value



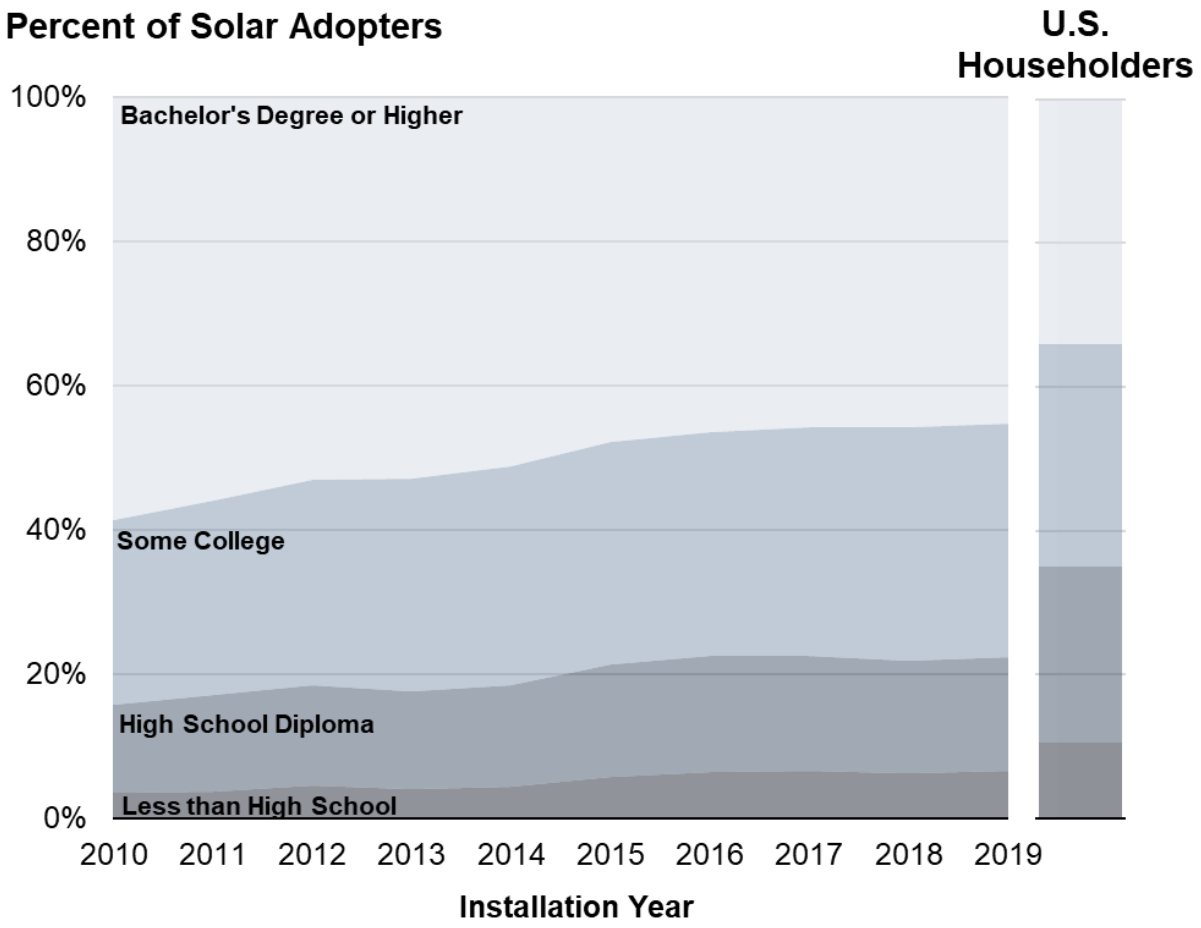
- Home value provides a measure of household *wealth*, as distinct from income—albeit only for households that own their home
- Solar-adopter home value data are expressed as a *percentile* of all homes in the same county (a different metric for expressing relative value)
- Solar-adopter home values are generally higher than others in the same county (above the 50th percentile), though that skew has declined substantially over time
- And has converged to resemble the skew in income among owner-occupied households (OO-HHs)
- A more comprehensive metric of wealth is needed to fully assess how solar adopters compare to the broader population, which includes renters

Credit Scores



- Due to privacy issues, credit score data consist of median values for all individuals in each solar adopter's zip+4, rather than individual or HH-level scores
- Solar adopters skew toward higher credit-score zip+4s, with a disproportionately large share of Super-Prime and virtually none with credit scores in the lower two groups—no doubt highly related to home ownership
- The skew has diminished over time as solar adopters within the middle tiers (Prime and Near-Prime) have comprised a larger share, though that trend has flattened in recent years

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 (45%) of all solar adopters in 2019 had a bachelor's degree or higher, while 22% 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, 59% of solar adopters had a bachelors degree, while 16% had no more than a high school diploma
- As with income, the trends in educational levels have flattened in recent years

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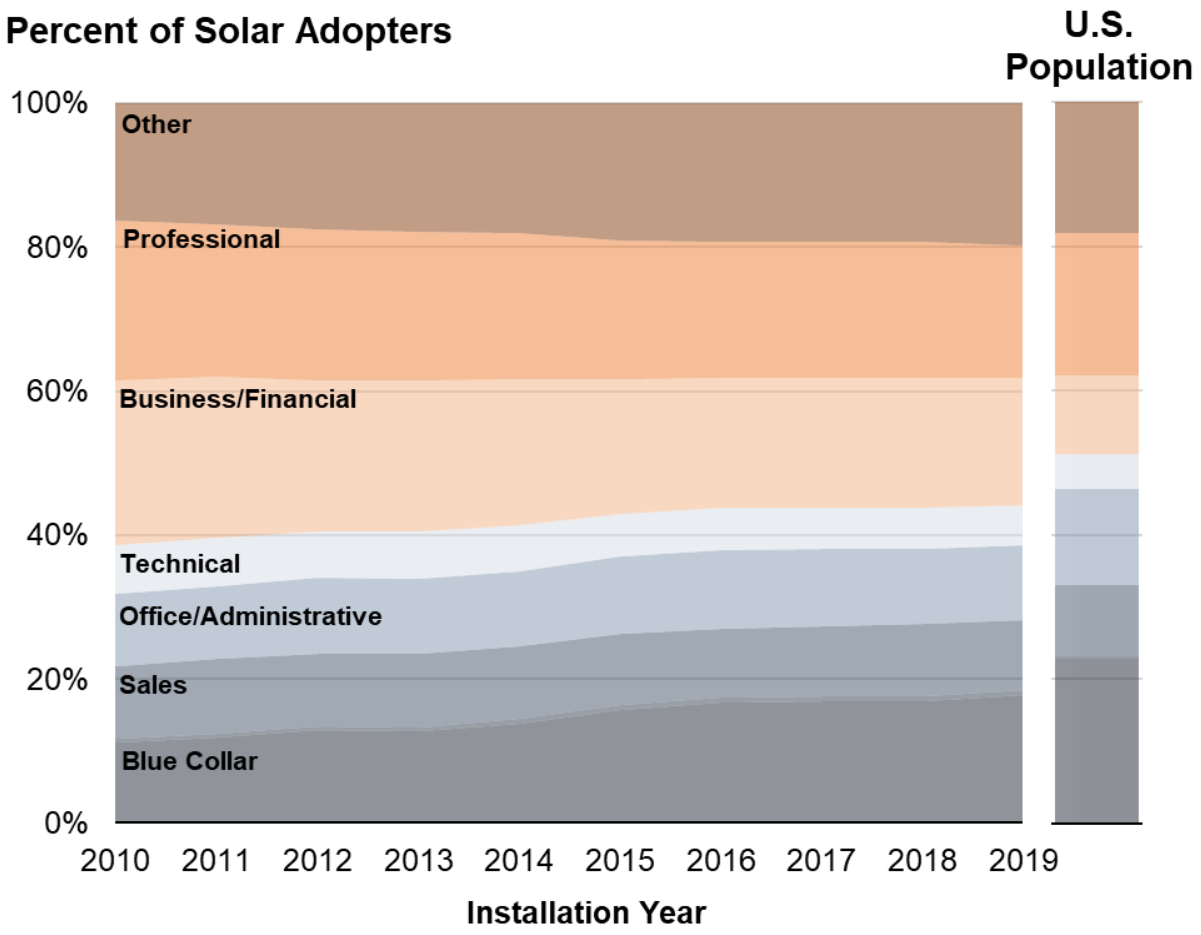
Occupation



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 the Experian's occupational categories.

- Similar shares of 2019 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

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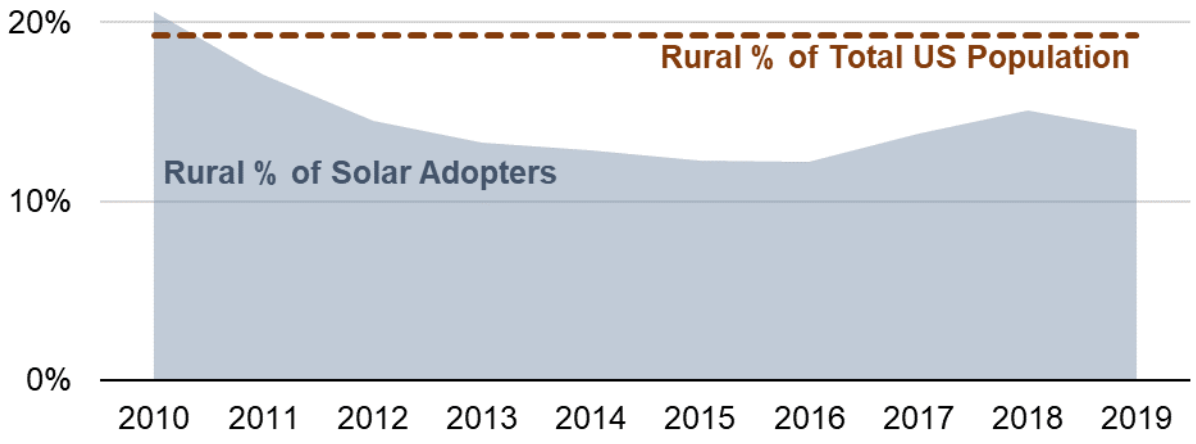
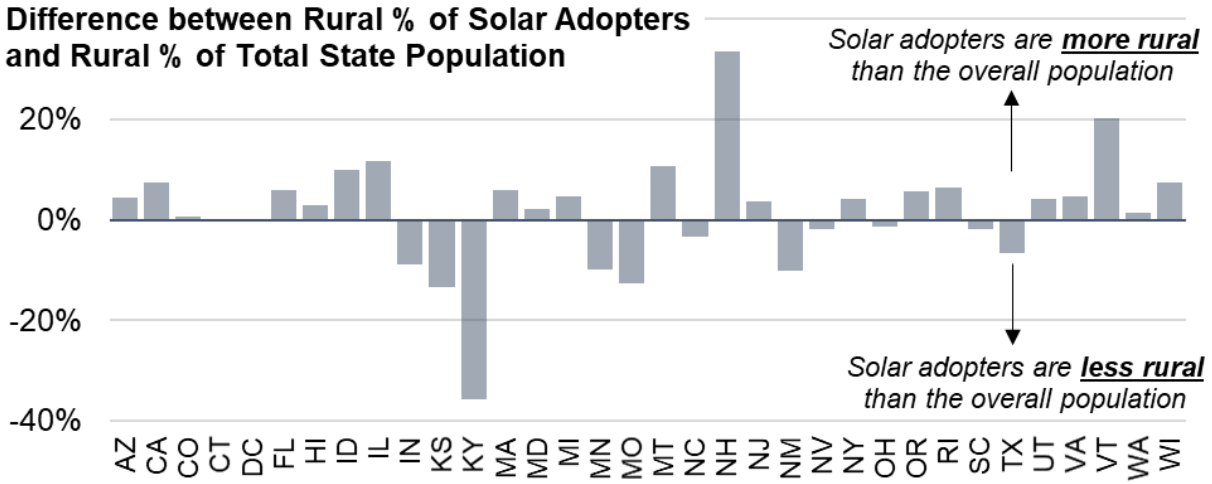
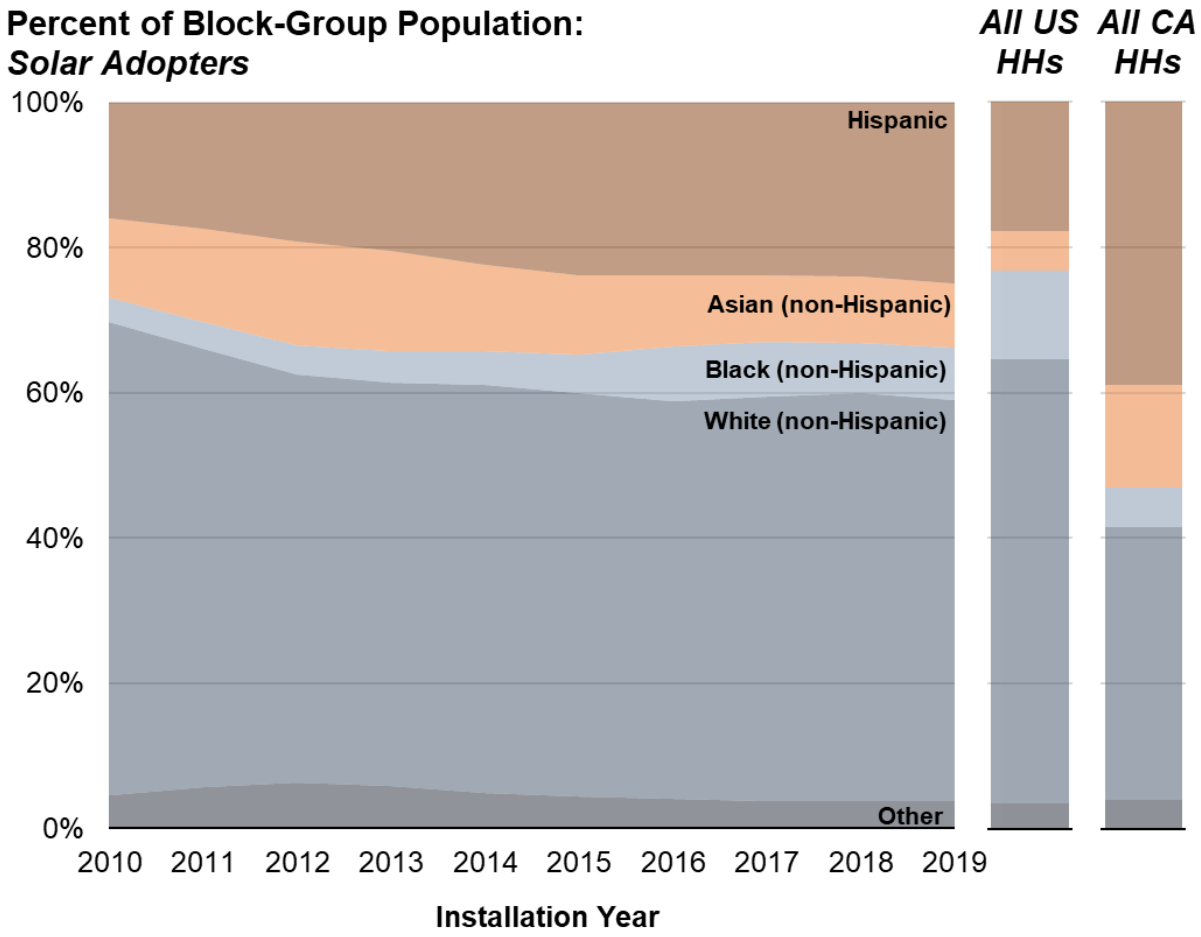
Urban vs. Rural





- U.S. Census defines “rural” vs. “urban” areas based on population density; urban areas often include surrounding suburbs/exurbs
- Solar adopters are slightly less rural than the U.S. as a whole: 14% of solar adopters in 2019 vs. 19% of the total U.S. population
- Temporal trend is mixed: solar adopters were less rural in 2019 than in 2010, but trends have shifted over the intervening years
- National trends reflect the fact that solar adoption skews towards less rural states
- At the individual state level, solar adopters may be more or less rural than the state as a whole (if anything, they tend to skew rural)

Race and Ethnicity:
National Trends

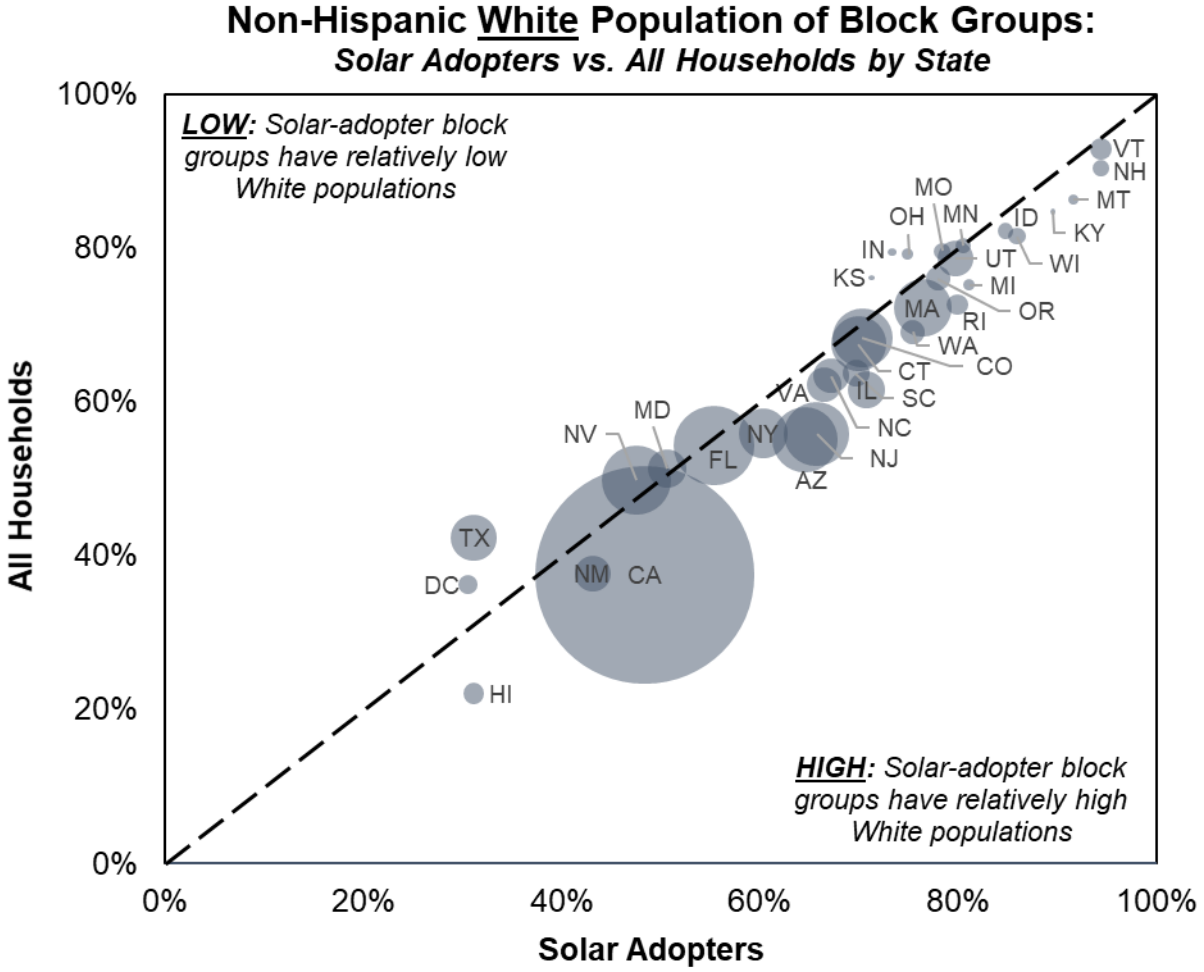


Notes: To construct the figure, each household (solar adopter or otherwise) is assigned the racial/ethnic composition of its block group, and the values plotted are the averages across all applicable set of households.

- Data on race and ethnicity of individual solar adopters were unavailable for this study; we instead characterize solar adopters based on the composition of their block group
- Compared to all U.S. households, solar adopters live in block groups with larger Hispanic and Asian populations, and with correspondingly smaller White or Black populations
- To a significant degree, this reflects broad geographical trends in solar adoption: specifically, roughly half are in CA, which has relatively large Hispanic and Asian populations

Race and Ethnicity:

State-Level Differences in Non-Hispanic White Population

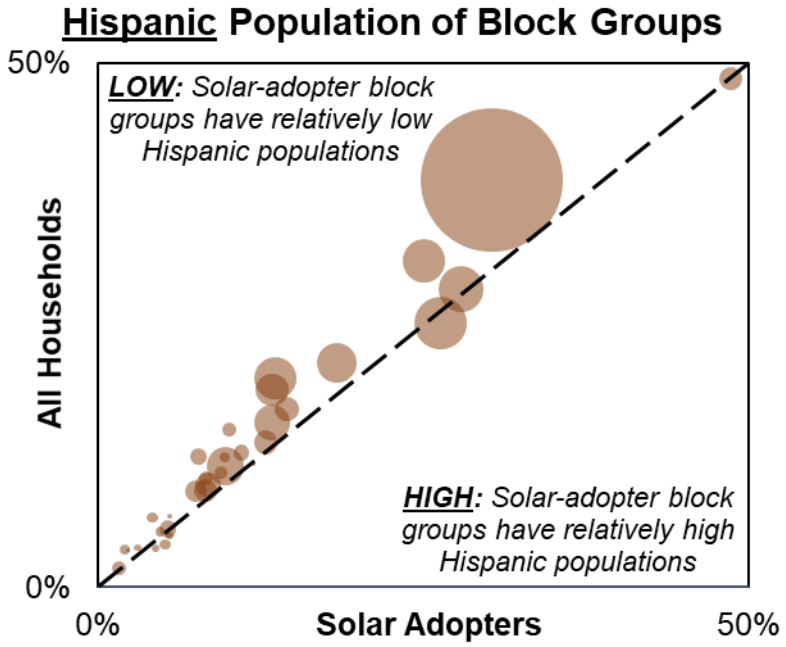


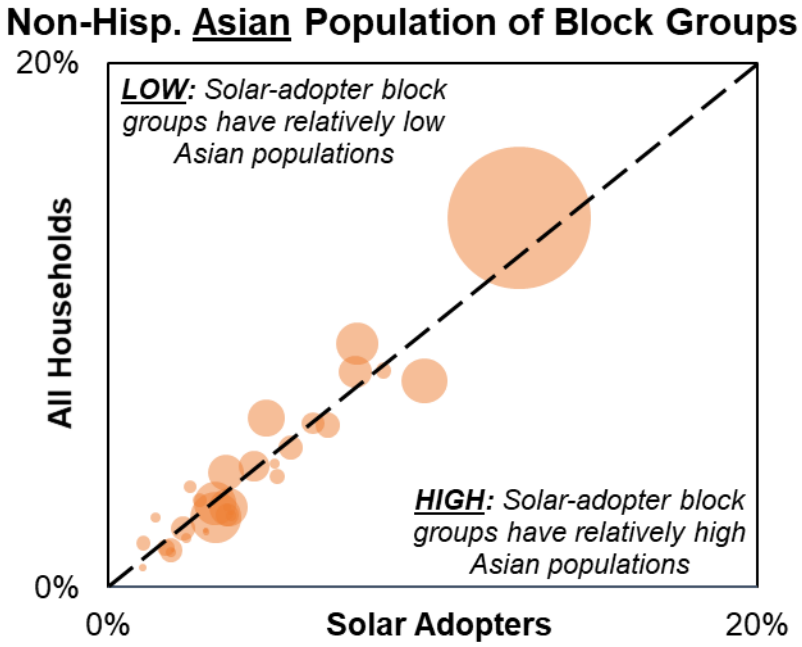
Notes: The size of the bubbles represents the solar-adopter sample size. See the previous slide for a description of how the plotted values were calculated.

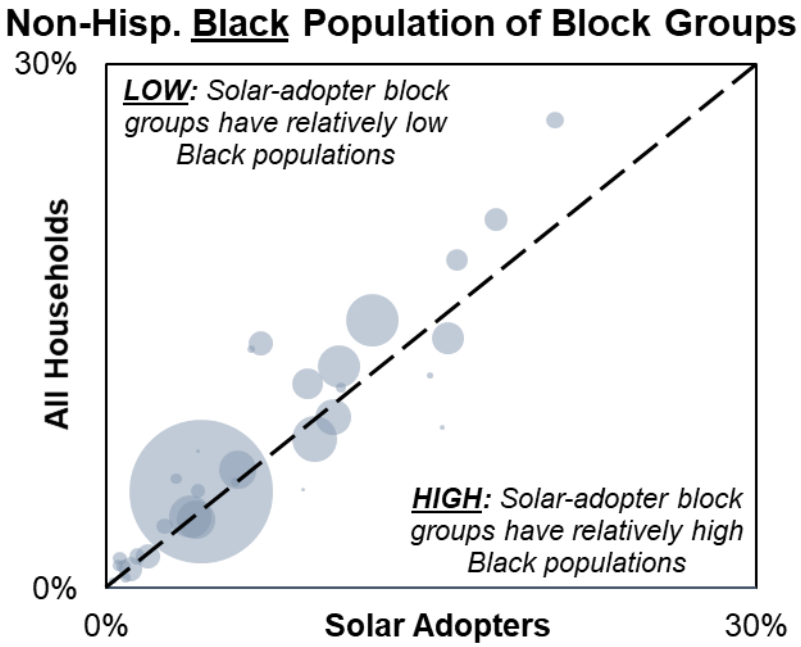
- State-level comparisons show that solar adopters generally skew towards block groups with relatively high White population
- The figure compares the percentage of the block group population that is White (non-Hispanic) for solar adopters vs. all households in each state
- As shown, in most states, solar adopters skew toward block groups with larger White populations (i.e., are below the diagonal line)
- In CA, the disparity is relatively high: solar adopters live in block groups where, on average, 48% of the population is White, compared to 38% for all HHs in the state

Race and Ethnicity:

State-Level Differences in Hispanic, Black, and Asian Populations

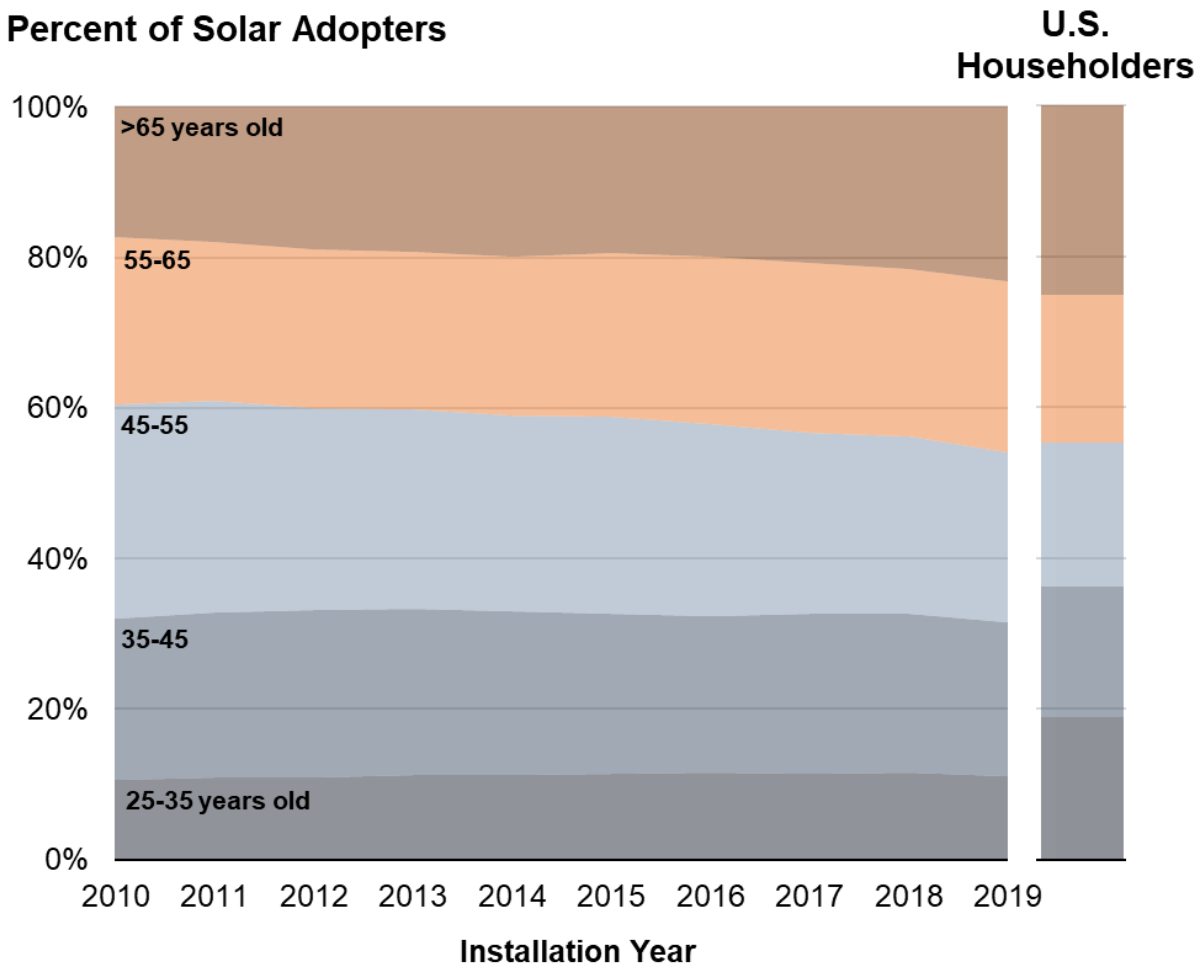






- Solar adoption generally skews toward block groups with relatively low Hispanic and Black populations, with somewhat larger and more consistent disparities for Hispanic populations
- In contrast, solar adoption skews toward block groups with relatively high Asian populations in most states (roughly two-thirds), though not in California, and the skew is much smaller than that observed for non-Hispanic White populations on the previous slide

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.

- As a general matter, solar adopters skew slightly older than the broader population (comparing among adults 25+)
- This is largely due to under-representation among the youngest group (25-35), which is not surprising, given 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 had previously been under-represented
- That trend is consistent with growing technology acceptance (less perceived risk), and likely fueled by greater availability of financing (key for individuals on fixed-incomes)

Conclusions

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, more urban, and more educated households
- Those differences are diminishing over time, albeit slowly
- The degree of disparity between solar adopters and the broader population varies significantly across states, and also tends to be smaller the more localized the comparison
- We highlight the role of third-party ownership in driving some of these trends, and speculate about other potential drivers, but further analysis would help to better understand the underlying dynamics—especially around the effects of policy interventions aimed at addressing adoption inequities

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.
- **SCOREX PLUS** : Predicts the likelihood of future serious delinquencies on any type of account. Due to limitations related to the Federal Fair Credit Reporting Act, data provided for each address represent the corresponding Census block medians, rather than the credit score of the specific individual or household.
- **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.
- **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.
- **Occupation Group:** Compiled from self-reported surveys, derived from state licensing agencies, or calculated through the application of predictive models.
- **Individual Education:** Compiled from self-reported surveys, derived based on occupational information, or calculated through the application of predictive models.

Key Public Data Elements Used in this Analysis

- **U.S. Census American Community Survey 5-Year Data (2014-2018):** Educational attainment by householder (Table B25013); Hispanic or Latino origin by race – population (Table B03002); 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, May 2019

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					2019 Installations				
	TTS	BZ	Ohm	Total	Market Coverage	TTS	BZ	Ohm	Total	Market Coverage
AK	0	1	0	1	0%	0	0	0	0	0%
AL	0	2	0	2	2%	0	0	0	0	0%
AR	88	39	0	127	10%	0	27	0	27	5%
AZ	0	26,616	52,873	79,489	53%	0	1,252	12,512	13,764	70%
CA	981,359	47,200	0	1,028,559	96%	141,764	11,762	0	153,526	97%
CO	0	23,063	28,845	51,908	84%	0	1,034	10,461	11,495	100%
CT	37,651	1,247	0	38,898	94%	9,247	293	0	9,540	100%
DC	4,445	500	0	4,945	88%	889	301	0	1,190	70%
DE	0	966	0	966	15%	0	66	0	66	12%
FL	3,760	13,368	31,120	48,248	94%	894	4,377	15,231	20,502	100%
GA	0	124	0	124	13%	0	35	0	35	27%
HI	0	46,428	0	46,428	57%	0	1,398	0	1,398	38%
IA	0	273	0	273	9%	0	81	0	81	10%
ID	0	3,290	0	3,290	55%	0	848	0	848	32%
IL	7,092	173	0	7,265	74%	4,315	103	0	4,418	67%
IN	0	61	350	411	17%	0	4	202	206	30%
KS	0	69	301	370	77%	0	11	93	104	46%
KY	0	41	203	244	33%	0	18	91	109	40%
LA	0	1,888	0	1,888	12%	0	12	0	12	1%
MA	88,661	2,775	0	91,436	90%	9,660	883	0	10,543	77%
MD	0	9,577	38,613	48,190	73%	0	849	3,815	4,664	79%
ME	0	0	0	0	0%	0	0	0	0	0%
MI	0	1,292	1	1,293	19%	0	448	0	448	16%
MN	1,070	2,797	0	3,867	82%	0	746	0	746	65%
MO	0	399	1,812	2,211	26%	0	41	826	867	48%
MS	0	0	0	0	0%	0	0	0	0	0%
MT	0	253	675	928	61%	0	11	339	350	80%
NC	12,212	1,022	0	13,234	99%	3,472	421	0	3,893	90%
ND	0	8	0	8	47%	0	1	0	1	13%
NE	0	122	0	122	56%	0	29	0	29	31%
NH	6,258	14	0	6,272	83%	847	9	0	856	77%
NJ	107,726	244	1	107,971	99%	13,293	26	0	13,319	88%
NM	20,381	1,086	0	21,467	99%	3,671	623	0	4,294	100%
NV	49,337	2,506	1	51,844	100%	14,708	609	0	15,317	100%
NY	71,619	2,743	0	74,362	61%	7,762	135	0	7,897	51%
OH	2,042	694	0	2,736	56%	59	334	0	393	19%
OK	0	18	110	128	17%	0	2	94	96	35%
OR	16,444	2,674	0	19,118	100%	1,158	833	0	1,991	100%
PA	5,980	1,908	0	7,888	30%	0	402	0	402	8%
RI	6,813	0	0	6,813	100%	1,487	0	0	1,487	88%
SC	0	819	11,735	12,554	64%	0	125	2,104	2,229	80%
SD	0	2	0	2	9%	0	1	0	1	6%
TN	0	224	0	224	15%	0	30	0	30	21%
TX	1,362	26,388	1	27,751	45%	49	6,885	0	6,934	44%
UT	13,031	4,516	0	17,547	48%	3,977	304	0	4,281	92%
VA	9,323	387	0	9,710	100%	3,599	158	0	3,757	98%
VT	12,326	3	0	12,329	100%	1,527	0	0	1,527	100%
WA	7,018	4,866	1,928	13,812	70%	1,144	113	777	2,034	70%
WI	3,284	207	0	3,491	81%	852	83	0	935	100%
WV	0	0	0	0	0%	0	0	0	0	0%
WY	0	25	0	25	4%	0	19	0	19	7%
US	1,469,282	232,918	168,569	**1,870,769**	**82%**	224,374	35,742	46,545	**306,661**	**84%**

Sample Sizes by Analysis Element

Vary depending on data availability and unit of observation

Analysis Element	Unit of Observation	Sample Size	
		2019	All Years
Income (single-family)	Household	306,658	1,870,718
TPO vs. host-owned	Household	207,670	1,318,524
Installer name	Household	170,391	n/a
With or without storage	Household	186,839	n/a
Multi- vs. single-family	Household	312,836	n/a
Home Value	Household	258,079	1,555,724
Credit Score	Household	306,660	1,870,745
Education	Household	306,658	1,870,718
Occupation	Individuals	708,984	4,601,798
Urban vs. Rural	Individuals	902,298	5,860,654
Race/Ethnicity	Household	299,700	1,822,326
Age	Household	192,824	1,240,172

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

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