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Starting with Solar: A Preliminary Assessment of Solar Energy Systems in Residential New Construction

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## Authors

Brittan, Grace

Hoen, Ben


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## Starting with Solar: A Preliminary Assessment of Solar Energy Systems in Residential New Construction

Grace Brittan and Ben Hoen, Lawrence Berkeley National Laboratory  
February 8, 2023



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*Cover Photo Source: Jeff Gritchen, Orange County Register/SCNG*



# Starting with Solar: contents

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- New home solar penetration levels inside and outside of California over time, by state, and by California county

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- Also includes logistic regression to tease out relationships

## ○ Conclusions

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Photo Source: Shutterstock

# Summary of key findings from this preliminary assessment

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**Data:** We assembled a dataset of all new homes and most existing homes through 2020 in areas with solar where address data were available: 13,460,000 existing homes, 527,000 new homes, and a total of 707,000 solar homes, of which almost 20,000 were new. Most new solar homes are in California but 18 other states and DC are represented.

## Key Findings Include:

- ❑ **California is different:** Even before the California Solar Home Mandate, the state had new solar home penetrations of ~ 40%; outside of California the average was just ~ 0.6% (AZ, NV, UT had relatively higher penetrations)
- ❑ **Drivers of new home solar penetrations:** The strongest correlates appear to be whether the home was located in an area that qualified for the New Solar Home Partnership incentive, and, in California, if the builder was among the largest in terms of market share
  - Average retail electricity rate, home value, median income levels, and population density show no, low and/or mixed correlations
  - Outside of California, larger builders are not associated with greater new solar home construction
- ❑ **Characteristics of the new home solar market are different from solar on existing homes:** Solar systems installed on new homes tend to:
  - Be smaller in size but associated with larger homes
  - Have lower battery attachment rates
  - Be more likely third-party owned
- ❑ **Solar system cost differences are modest:** The cost of solar systems on new homes is comparable to that of solar on existing homes on a \$/W basis; solar on new homes tend to be smaller so benefit less from economies of scale







## Introduction

*Photo Source: Sunrun*

# Policy and literature background

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## Policy Background

- The California Solar Mandate (Building Energy Efficiency Standards, Title 24, Part 6) became law recently
  - Enacted December 5, 2018 and went into effect January 1, 2020
  - The new code requires all new homes to have solar energy systems, with few exemptions
- Previously there was an incentive program entitled the California New Solar Home Partnership (NSHP)
  - This program, which targeted new homes, was enacted in 2007 and ran through 2018, but paid incentives into 2021
  - The program provided an incentive in the form of a cash rebate for building new solar homes in the three investor-owned utility (IOU) service areas (Pacific Gas & Electric Company (PG&E); San Diego Gas & Electric Company (SDG&E); Southern California Edison (SCE))
  - Incentives ranged from \$0.50-\$1.25/watt over the period and were not additional to other incentives available at the time in California
- Outside of NSHP, few policies existed in the U.S. that specifically targeted solar on new homes: solar on new homes in states other than California were mostly incentivized with policies that existed for any solar homes, new or existing
  - Those policies might include net metering, rebates, and performance incentives
  - One recent exception, though not pertinent to our study period, is a 2021 enacted adder for solar on new homes in New Jersey

## Literature Background

- Barbose et al. (2006) examined new solar home incentive programs and, more recently, Ardani et al. (2018) and Cook et al. (2022) outlined opportunities for cost savings in new solar home construction
- Although these studies provide useful background and insight, we are not aware of literature exploring the new solar home housing market through the lens of rates of deployment and characteristics of these homes
- This scoping study seeks to fill that gap

# Motivation and scope

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## Additional motivation for this analysis

- Between 2011 and 2021, approximately 1.1 million new homes initiated construction in the United States each year, and recently those rates have been increasing, to an average of 1.4 million from 2019-2021.<sup>1</sup> These add to the roughly 140 million single-family homes already built.
- Although a relatively small percentage of all homes, new homes provide an attractive avenue to reduce GHG emissions via reduced energy use, as evidenced by the steady increase in new home code energy efficiency requirements (Berg et al., 2020) and the California Solar Mandate mentioned on the previous slide. Installing solar on new homes may be less expensive than solar retrofits on existing homes.
- As efforts scale to reduce energy use and emissions, providing a baseline understanding of current market conditions for new solar homes and what conditions seem to spur higher adoption rates of solar on new home construction is useful.
- Further, the lead up to the California mandate is interesting because it allows an examination of new solar home buildout under a targeted long-term incentive policy, where builders voluntarily could adjust their practices to take advantage of market and policy conditions.

## Scope of this preliminary assessment

- To better understand the new solar home market, we examine the characteristics of new and existing solar homes both inside and outside of California. Specifically, we examine: solar system size, home size, third-party ownership, and installation costs as well as neighborhood characteristics to better understand if and by how much they differed.
- We also study the penetration of solar on new homes inside and outside of California, and the trends in deployment in the period leading up to 2020. Specifically, we examine new solar home deployment correlations with: new solar home incentives, builder market size, home assessed value, average electricity rates, population density, disadvantaged community designations, and neighborhood income levels.
- Finally, via regression we test which factors seem to be most correlated with adoption of solar on new home construction both inside and outside of California.
- This study represents a preliminary, scoping analysis of market characteristics and drivers.

<sup>1</sup> Data obtained from [ipropertymanagement.com/research/housing-starts](https://www.ipropertymanagement.com/research/housing-starts)





# Data, geographical coverage, and sample period

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- **Data:** We combined the following data sources for this analysis:
  - LBNL's Tracking the Sun (TTS) residential solar dataset (with data through 2020)
  - CoreLogic's dataset of single family and duplex home characteristics and transaction information
  - Multiple other datasets to fill in home characteristics, including rural/urban designations, utility service areas, DAC & Cal Enviro Screen designations, area median income, election results, rankings of builder market shares, etc.
  - Details about the sources of each of these datasets, and what are contained in the datasets are provided in the Appendix
- **Geographical Coverage**
  - We limited the geography to any zip code with a TTS solar system in it (12,369 out of 41,683 total zip codes in the U.S.)
  - The geography was further limited to zip codes with up-to-date and address specific data in TTS. This brought the total to 7,306 zip codes in 18 states and DC: AZ, CA, CT, DC, FL, MA, MN, NC, NJ, NM, NV, NY, OH, OR, RI, TX, UT, WA, WI
  - Note that some states have very limited coverage (e.g., FL is limited to 21 zip codes of 961 total), and other solar intensive states are not included at all (e.g., HI) due to limits of data availability
- **Sample Period**
  - CoreLogic data are available through Sept. 2021; TTS through Dec. 2020 for most areas, with some installations in 2021
  - Further, there is a lag in solar permission to operate of ~6 months after a new home transaction, so we could only accurately identify new solar homes using CoreLogic data through roughly June of 2020
  - Therefore, to ensure we are accurately representing when homes were built with solar, our analysis period is 2007-2019 with some transactions in 2020



# Methodology

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The analysis methodology for this preliminary assessment involves 1) comparing solar system and home characteristics across time, geography and different home types; 2) calculating “solar penetration” levels and comparing those levels across different subsets, time and geography; and 3) estimating a logistic regression to examine potentially competing correlates to higher and lower new solar home penetration levels. Each is discussed below.

## **Solar System and Home Characteristics**

We examine various solar system and home characteristics, including: solar system size, home square feet, if batteries were installed, if the solar system was owned by a third-party (i.e., not the homeowner), the system installation cost, the home value, and if the home was located in a disadvantaged community. We compare these characteristics across new and existing homes with solar installed, within and outside of California, and over time.

## **New Solar Home Penetration**

Solar penetration is calculated as the count of new solar home transactions divided by total new home transactions in that same data subset. Common subsets include states, California counties, and years of sale. We also examine penetrations across: different population densities, homes built by builders with different market shares, varying local median income levels, home values and retail electricity rates, and where targeted new solar home incentives existed (such as for California investor owned utilities) and where they did not.

## **Logistic Regression**

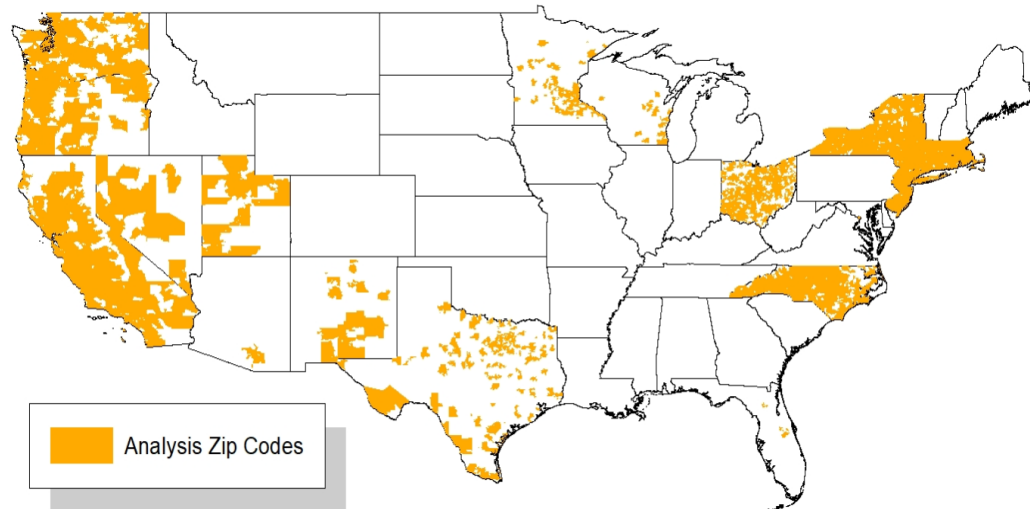
We examine differences in new solar home penetrations via a multinomial logistic regression to examine the potentially competing influences of some of the key variables described above. The formula for this regression is described in detail later.



# Analysis data summary: our new and existing home solar data, restricted to zip codes with at least one solar home with a valid address, covers many key markets in the U.S. across 18 states and DC

## Analysis Dataset: Solar Home Counts

### Analysis Data Geographic Coverage



Year	California		Other States	
	Existing Solar Homes	New Solar Homes	Existing Solar Homes	New Solar Homes
Pre-2016	167,769	5,343	54,739	133
2016	67,199	2,151	33,163	46
2017	53,522	2,196	27,064	87
2018	56,509	3,138	33,539	130
2019	62,915	2,894	36,557	226
2020*	60,517	2,789	34,252	172
<b>Total</b>	<b>468,431</b>	<b>18,511</b>	<b>219,314</b>	<b>794</b>

Notes: Coverage is drawn from TTS data through 2020 where addresses are available. \* New solar home transactions in 2020 are underestimated due to a lag in the permission to operate date after the home sale date.



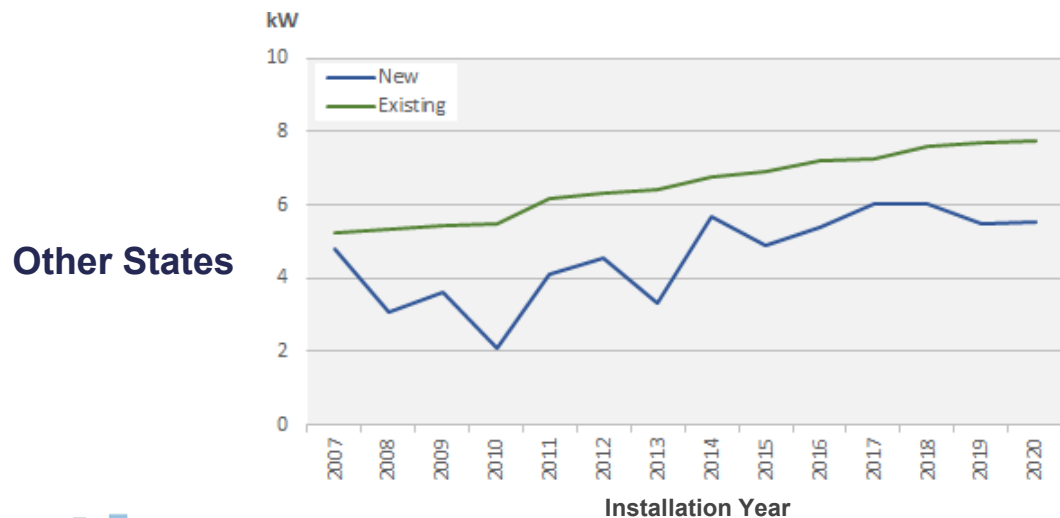
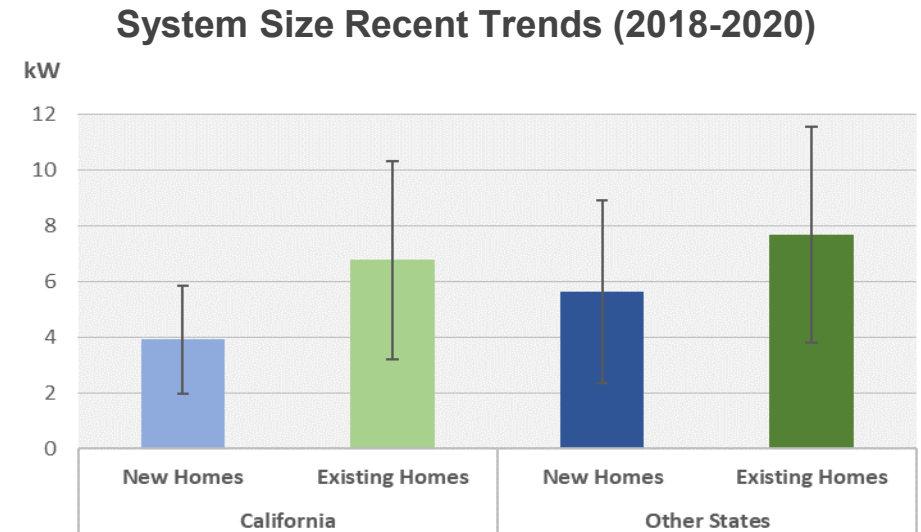
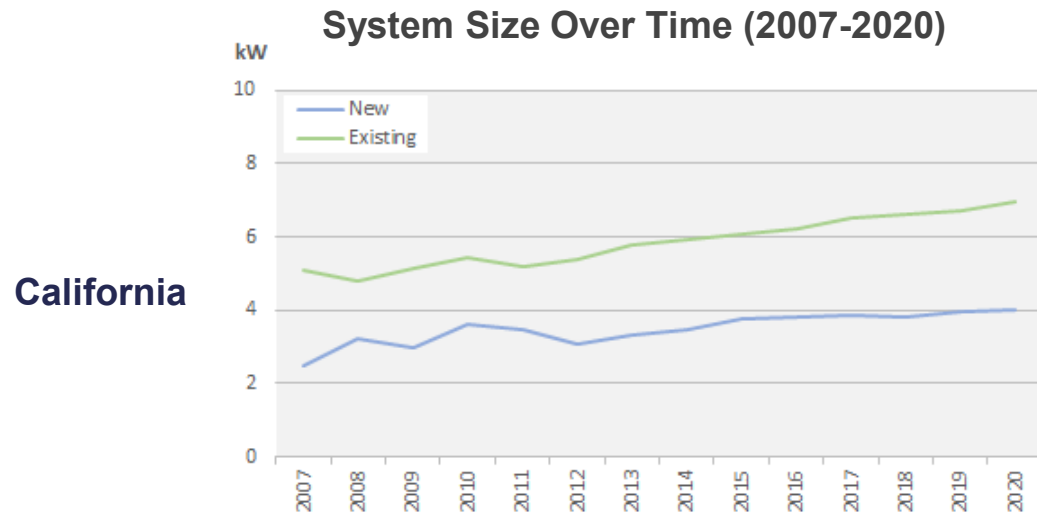
## Solar System and New Home Characteristics

**An examination of new and existing\* solar home characteristics  
inside and outside of California and over time**

*\* Existing solar homes are homes that had solar installed after they were built, in contrast to new solar homes that had solar installed at (or around) the time they were built. Years shown for existing homes apply to the year of solar installation not the year the home was built. This differs from that of new solar homes, where both dates are (roughly) the same.*



# Over the same time periods, new solar homes had smaller PV system sizes installed than existing solar homes, particularly in California



## Key Points

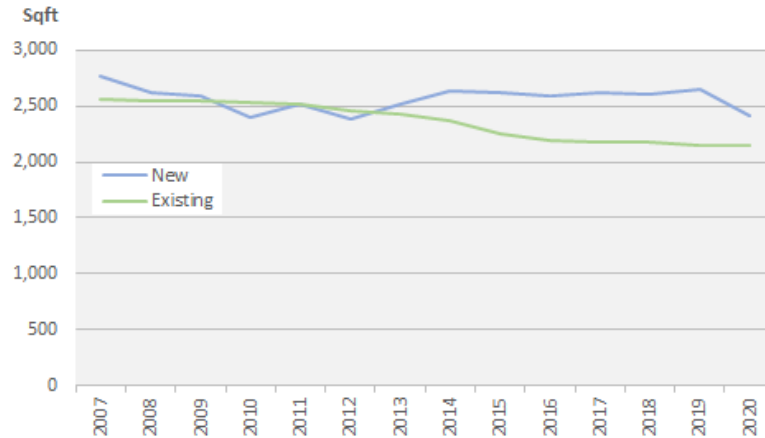
- System size is increasing over time, but has been largely constant for new homes in California over the last 5 years
- While new homes generally have smaller system sizes than existing homes, this may be due to having more energy efficiency measures (less load)
- New home system sizes have a smaller range, indicating more consistency in their sizes across the sample

*Figures show cohort means. Error bars represent 90% confidence intervals. Medians show similar results including p5 and p95 error bars.*

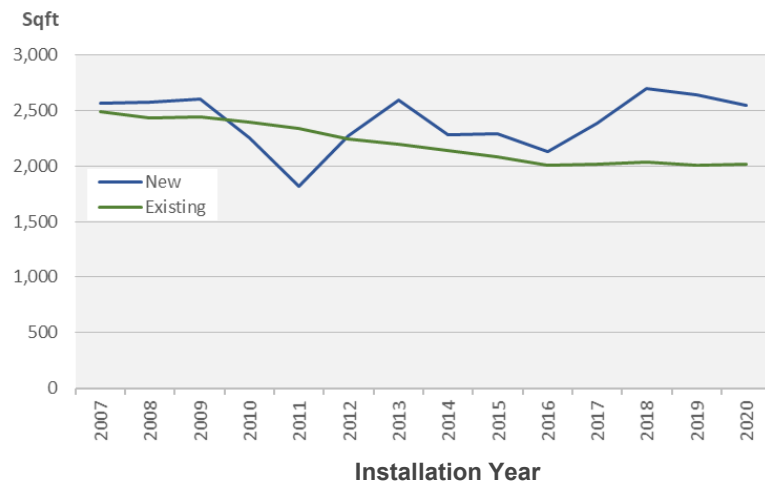
# New solar homes have trended slightly larger (in square feet) than existing homes with solar installed over the same time period

Home Size Over Time (2007-2020)

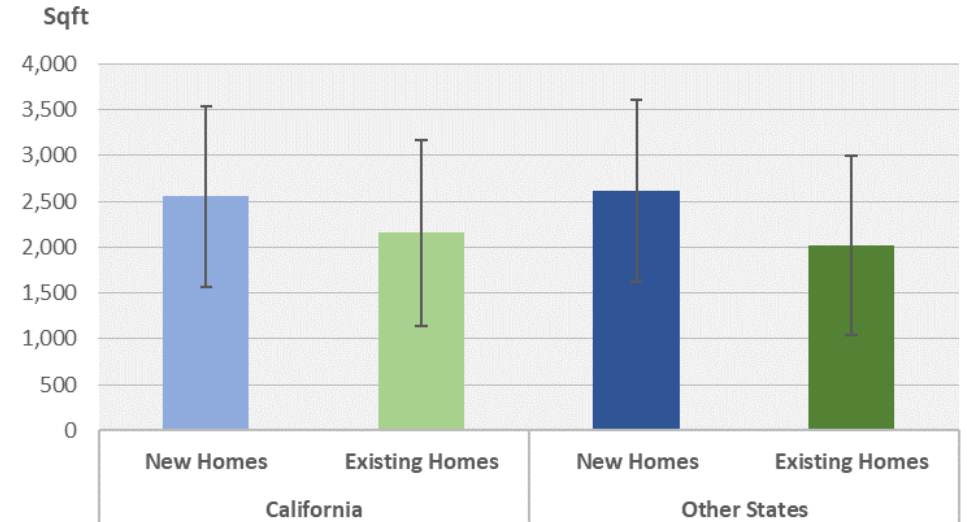
California



Other States



Home Size Recent Trends (2018-2020)



## Key Points

- Average solar home size for existing homes has declined over time; new solar home sizes have not changed much
- Sizes of new home and existing home solar installations are similar both in and outside of California
- New homes are generally more efficient and likely require less electricity, which might partially explain the smaller solar systems (previous slide) despite slightly larger home sizes.

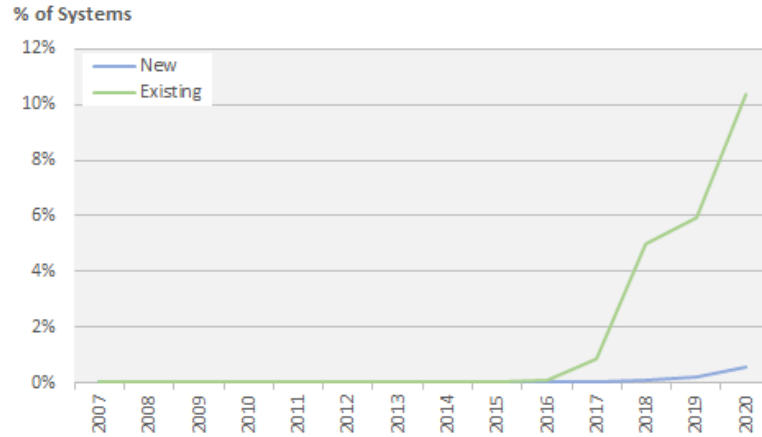
Figures show cohort means. Error bars represent 90% confidence intervals. Medians show similar results including p5 and p95 error bars.



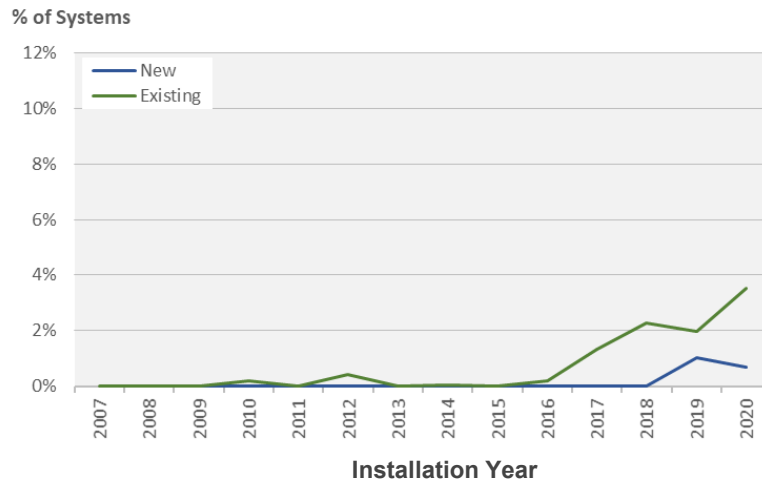


# New solar homes appear much less likely to have batteries installed contemporaneously than existing homes installing solar

**% Batteries Over Time (2007-2020)**

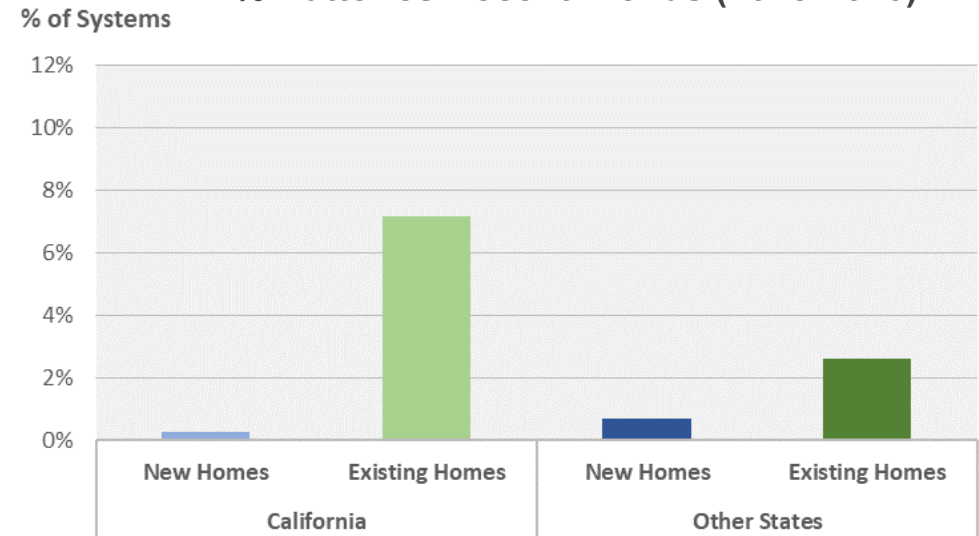


California



Other States

**% Batteries Recent Trends (2018-2020)**



## Key Points

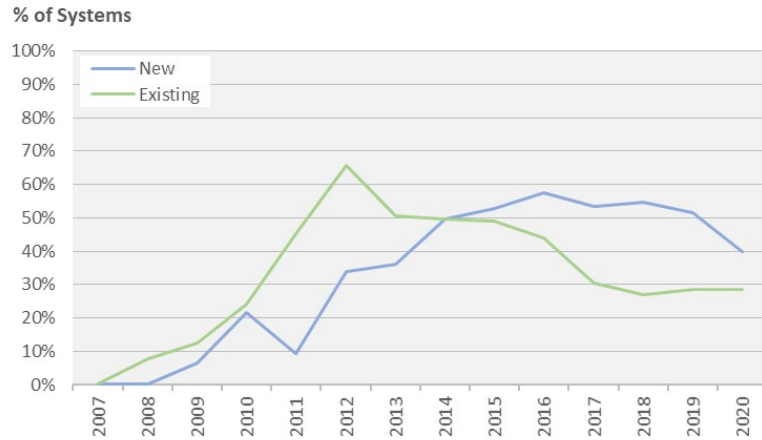
- Batteries have become more common in existing solar homes over the past five years; less so for new homes
- Recently, batteries in existing solar homes are installed almost three times more frequently in CA than outside CA
- Battery installation drivers not controlled for include safety shut-offs and base electricity rates, which might differ between new and existing homes

Note: Figures show percentages. To avoid including battery retrofits in our new home data analysis, systems were excluded if the battery was installed more than 30 days after the original solar system.

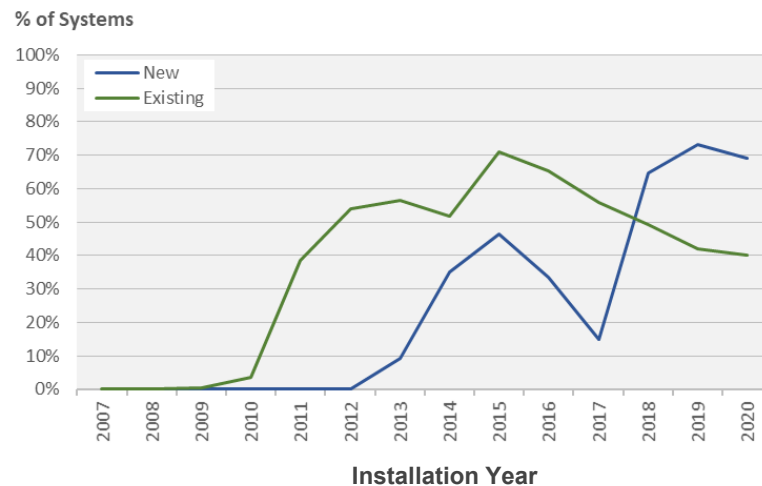
# New solar homes are more likely to have third-party owned systems, at least over the last few years

TPO Over Time (2007-2020)

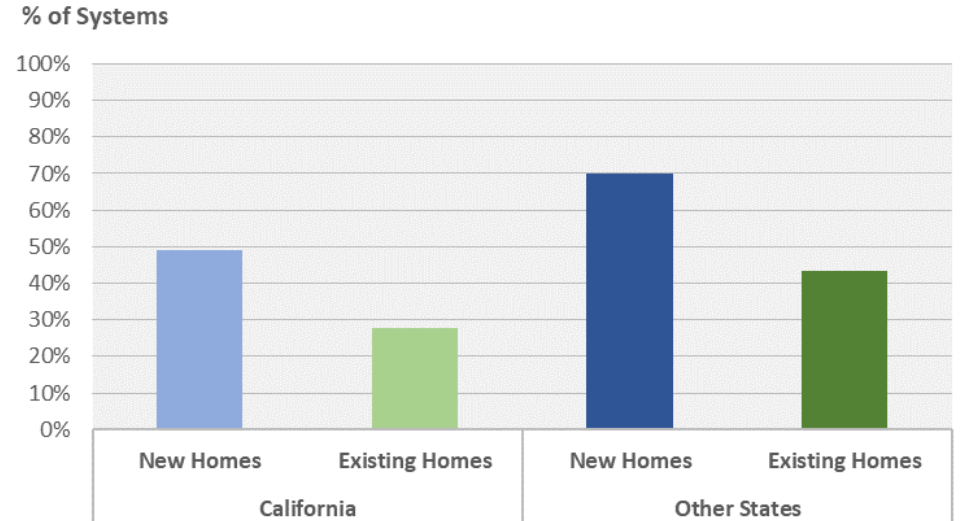
California



Other States



TPO Recent Trends (2018-2020)



## Key Points

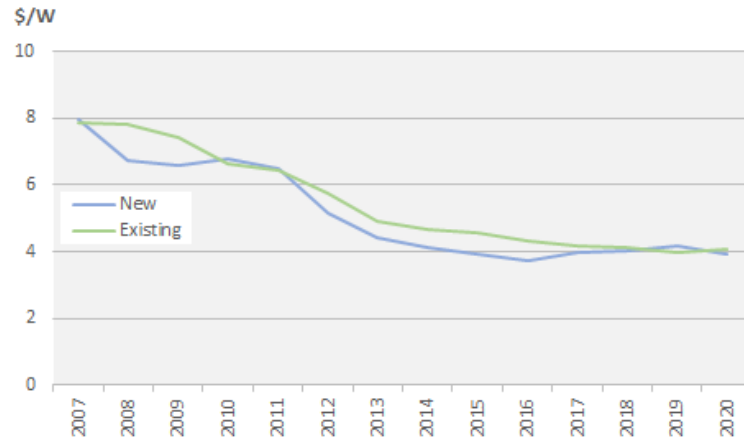
- Over the last several years, third-party ownership (TPO) has been more common for new solar homes
- Third-party ownership (TPO) has flattened or decreased over time in California as other financing options have emerged for owned systems
- New home TPO is a choice largely driven by builders, where for existing homes it is the homeowner's

Figures show cohort percentages.

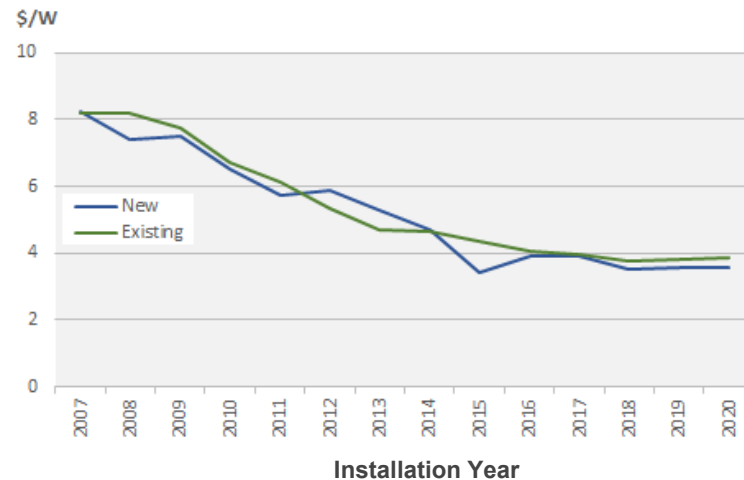
# Installed solar cost (\$/W) for new homes is similar to that of existing homes both inside and outside of California

Installation Cost Over Time (2007-2020)

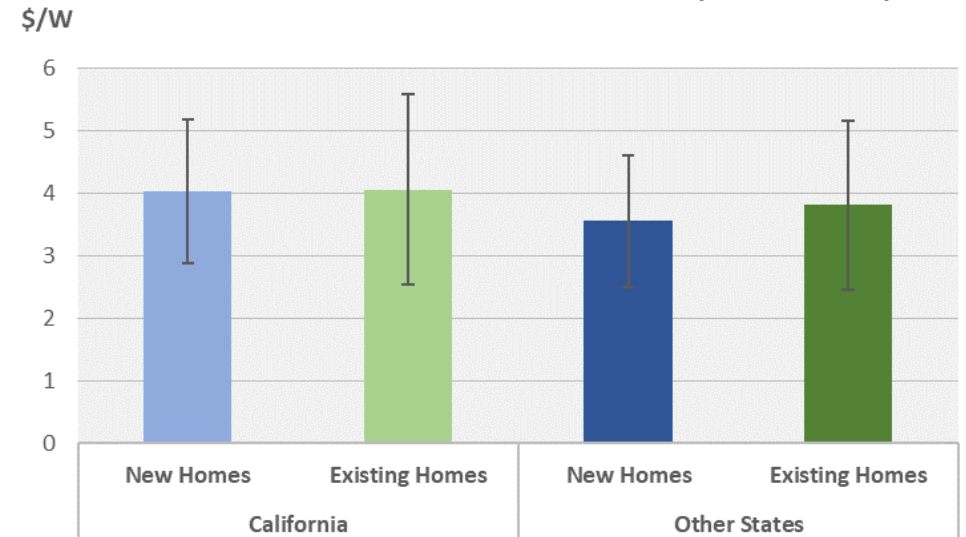
California



Other States



Installation Cost Recent Trends (2018-2020)



## Key Points

- Installation costs trended down over this period in response to lower equipment costs, especially module costs
- Note that solar systems on new homes have generally been smaller than solar on existing homes, and so have not benefitted from economies of scale to the same degree

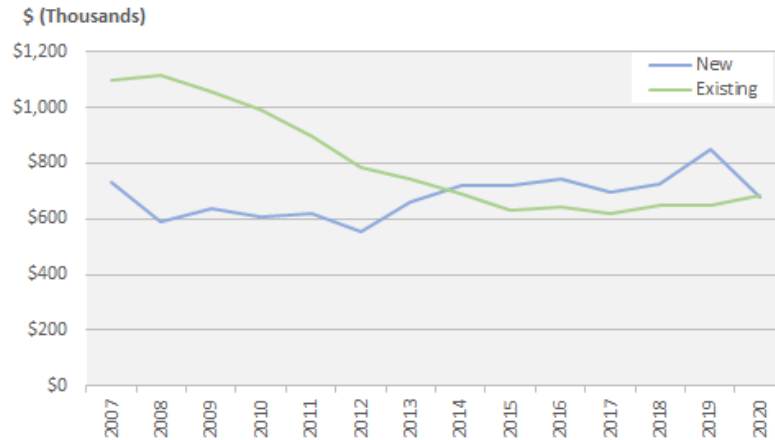
*Note: Figures show cohort means. Error bars represent 90% confidence intervals. Medians show similar results including p5 and p95 error bars. We did not take into account module or inverter type or other cost drivers that could impact results. Others have found lower installed prices for new homes when accounting for those other features (Barbose et al., 2022, Tracking the Sun)*



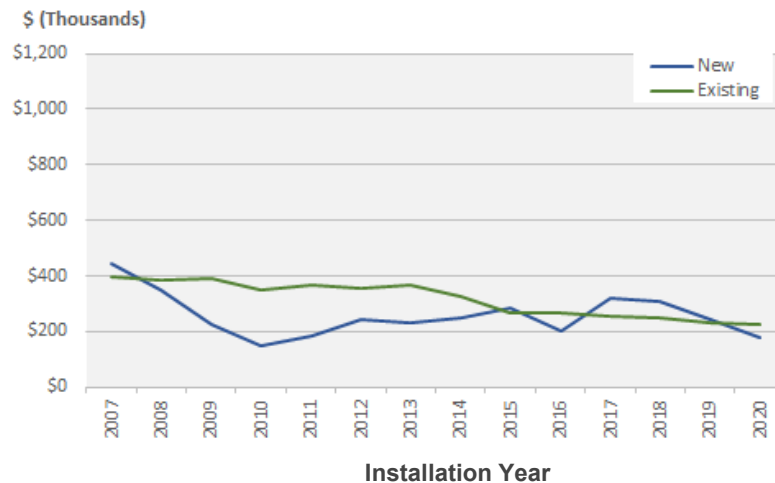
# In recent years, new solar homes have largely matched the assessed value of existing solar homes, both inside and outside of California

Assessed Value Over Time (2007-2020)

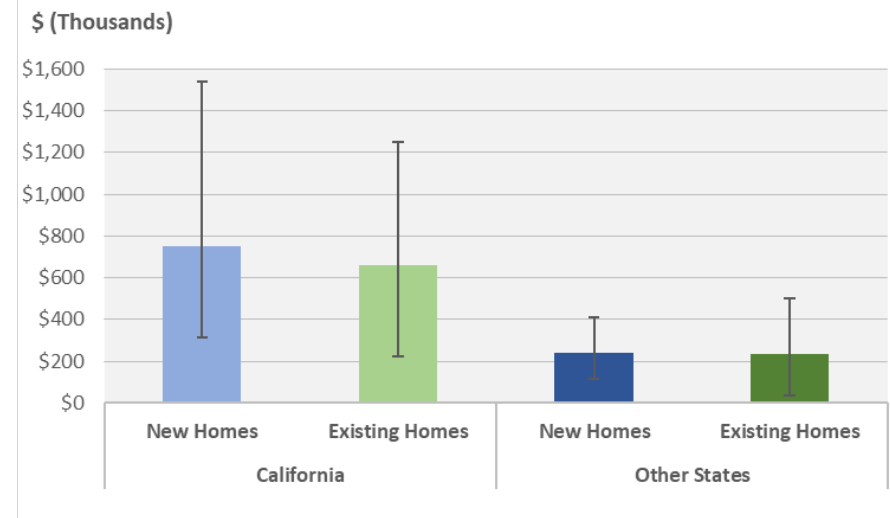
California



Other States



Assessed Value Recent Trends (2018-2020)



## Key Points

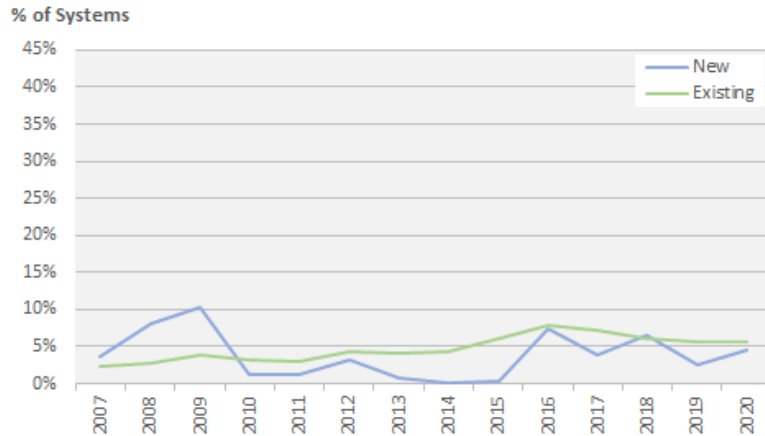
- The assessed value of solar homes, a key indicator of their value if they were to sell, has largely remained flat over the last 6 years—and relatively similar among new and existing homes
- Not surprisingly, Californian solar homes, both new and existing, have higher assessed values than non-Californian homes

Figures show cohort means. Error bars represent 90% confidence intervals. Medians show similar results including p5 and p95 error bars.

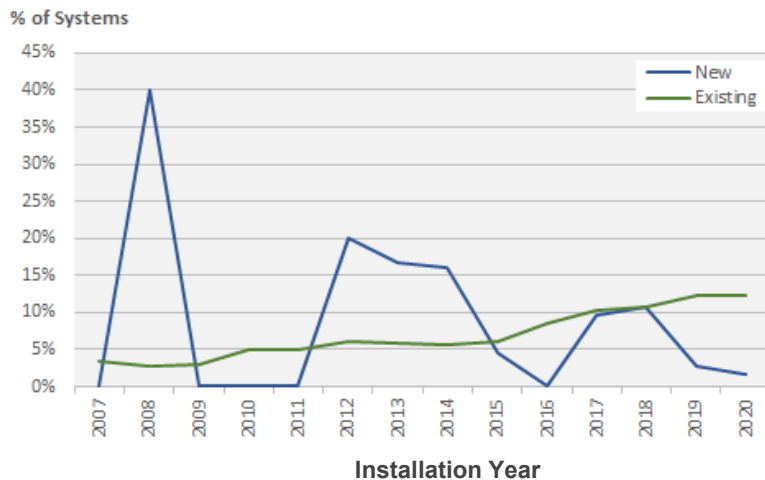
# Solar deployment in disadvantaged communities (DACs) is slightly higher for existing homes, particularly outside of California, but data are sparse

% DAC Over Time (2007-2020)

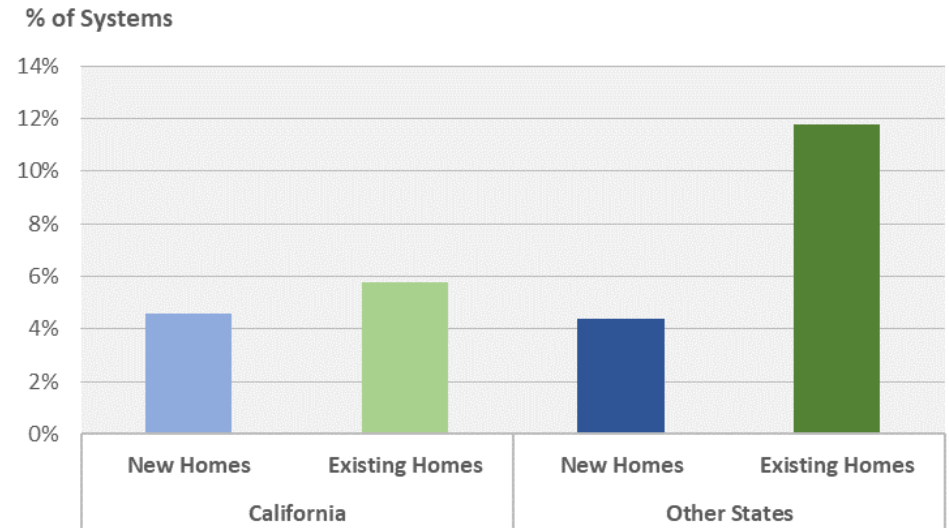
California



Other States



% DAC Recent Trends (2018-2020)



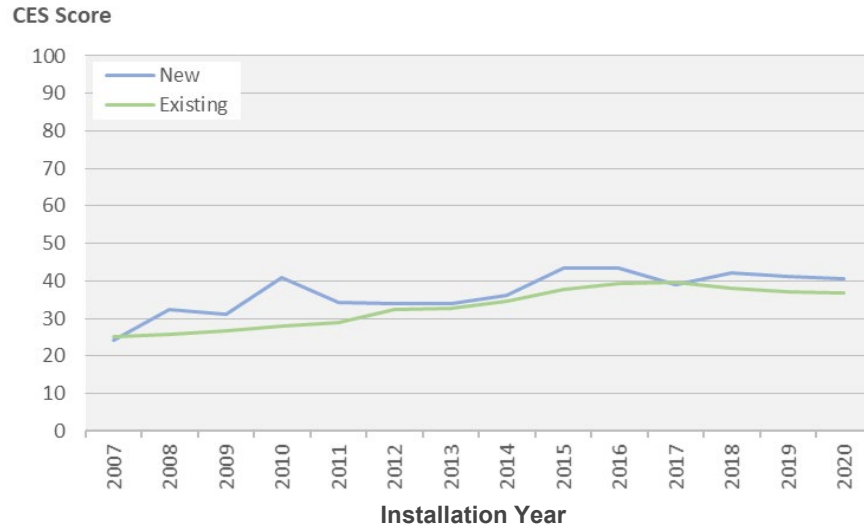
## Key Points

- Solar systems installed on existing homes are slightly more likely to occur in DACs than solar installed on new homes
- Relatively few solar systems are installed in DACs in general

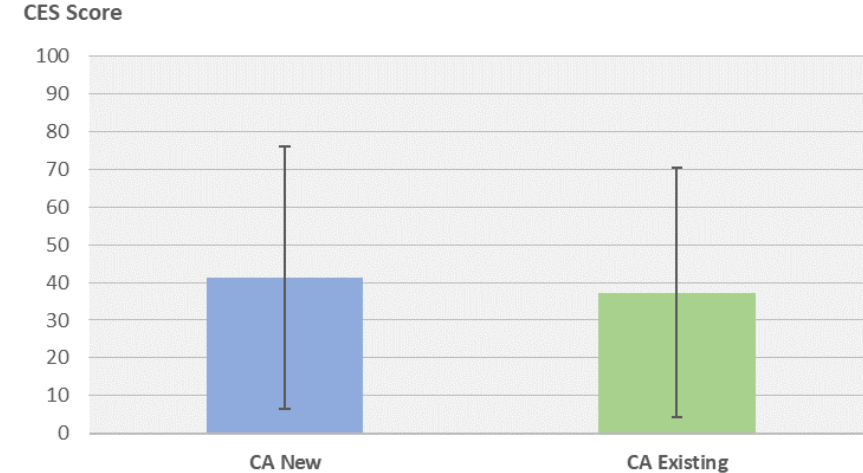
Note: Figures show percentages. Disadvantaged communities (DAC) are based on Justice 40 initiative classifications

# New solar homes are located in areas with similar CalEnviroScreen levels as existing homes with solar installations

### CalEnviroScreen Level Over Time (2007-2020)



### CalEnviroScreen Recent Trends (2018-2020)



## Key Points

- Using a different metric for “disadvantaged community”, the CalEnviroScreen, we find similar levels of penetration as when the Justice40 Initiative criteria were used (previous slide)
- We see a slow increase over time indicating solar installations are occurring in areas with higher CalEnviroScreen Scores, and therefore higher pollution burdens, over time

*Note: Figures show cohort means. Error bars represent 90% confidence intervals. Medians show similar results including p5 and p95 error bars. CalEnviroScreen ranks census tracts in California based on potential exposures to pollutants, adverse environmental conditions, socioeconomic factors and prevalence of certain health conditions. Higher levels (e.g., 75-99%) on CalEnviroScreen indicate higher burdens from pollution.*



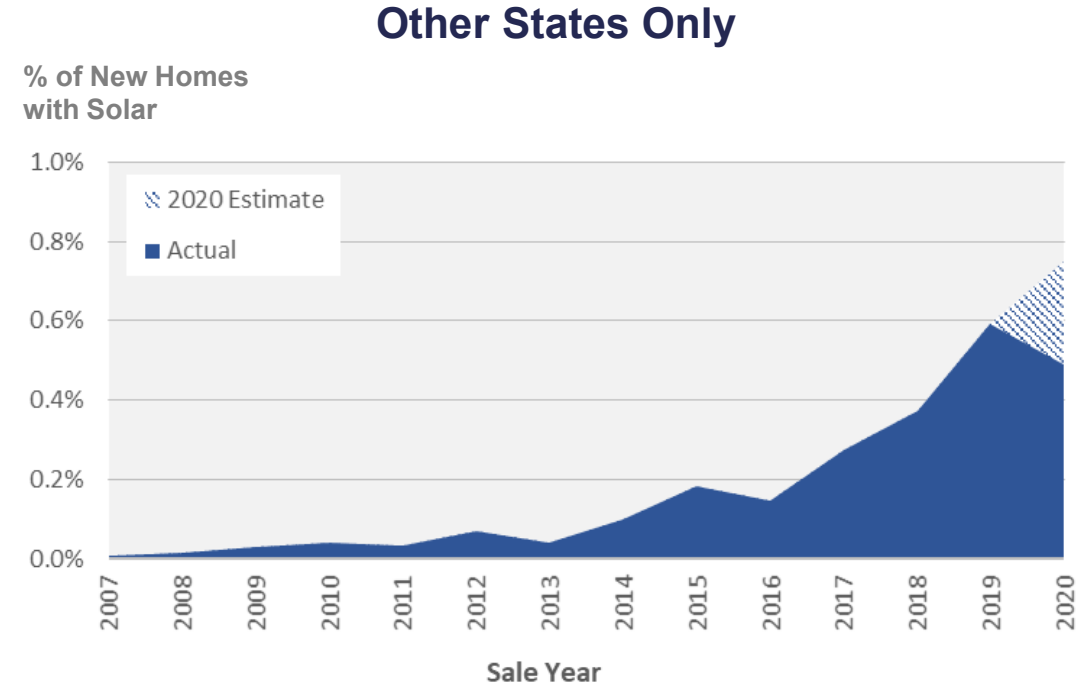
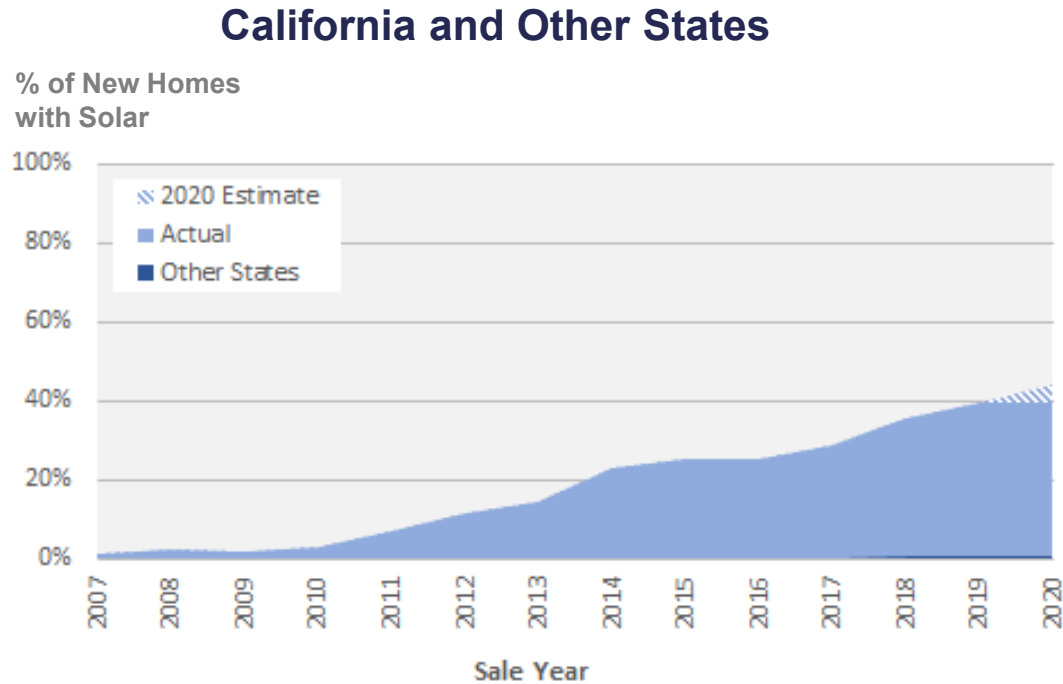
## New Solar Home Penetration Levels

A examination of solar penetrations\* into new homes inside and outside of California

*\* A reminder: “penetration” refers to the % of the new home sample cohort that contains solar*



# California new solar home penetrations reached 40% by 2020, whereas the average outside of California was less than 1%



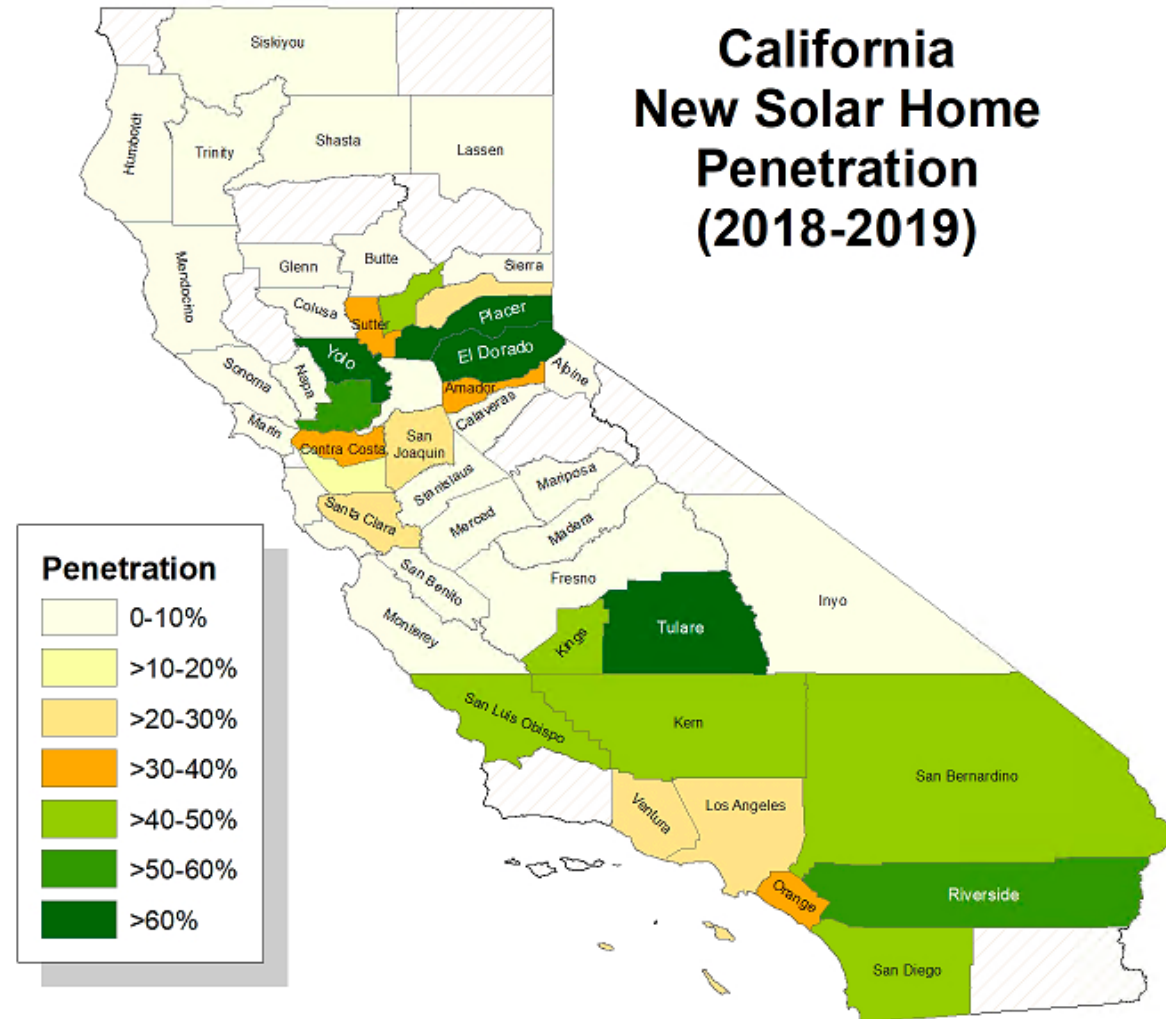
## Key Points:

- In 2018, when the California Solar Mandate was enacted, the state was already at ~ 35% penetration and has moved to ~ 40% through 2020
- Outside of California, new solar home penetrations are very low on average, showing that California is unique in the strength of the new solar home market

*Note: Actual data were not available for all of 2020. Estimated penetration levels through 2020 (shown in hash marks) are based on historical trends.*



Although CA had a 40% new solar home penetration on average through 2019, some counties had a 70% penetration while others were closer to 0%

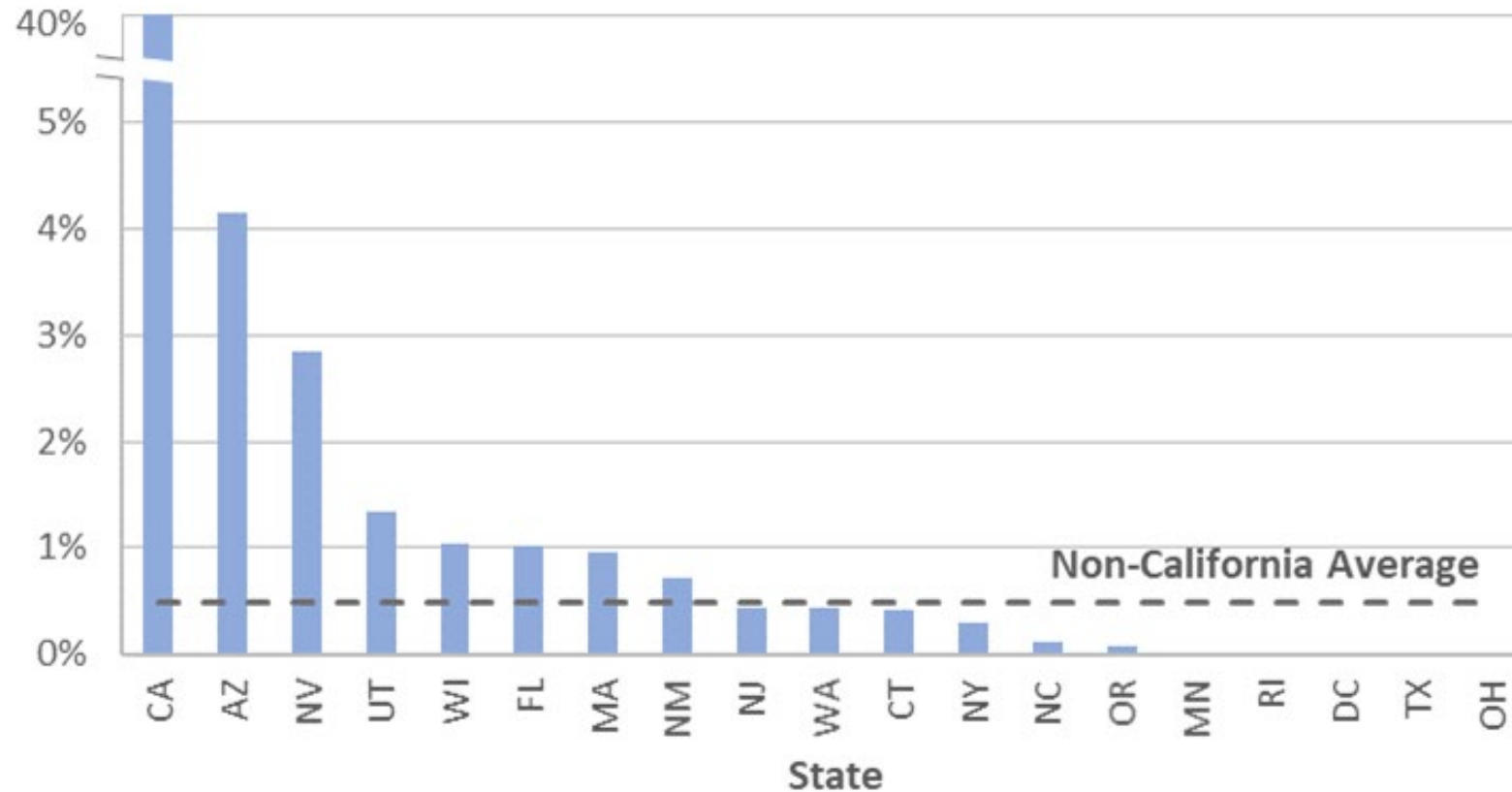


*Hashed areas contain less than 10 new homes sales in study period  
or represent areas where data were not available*



# Although nationwide the average non-CA penetration is less than 1%, some states have relatively higher penetrations (e.g., AZ, NV, UT)

% of New Homes with Solar within State



*Note: Penetrations are calculated using cumulative installations through 2019, therefore, the CA total and the "Non-California Average" correspond to the 2019 levels shown on Slide 21.*





## Characteristics of New Home Solar Penetration Inside and Outside of California

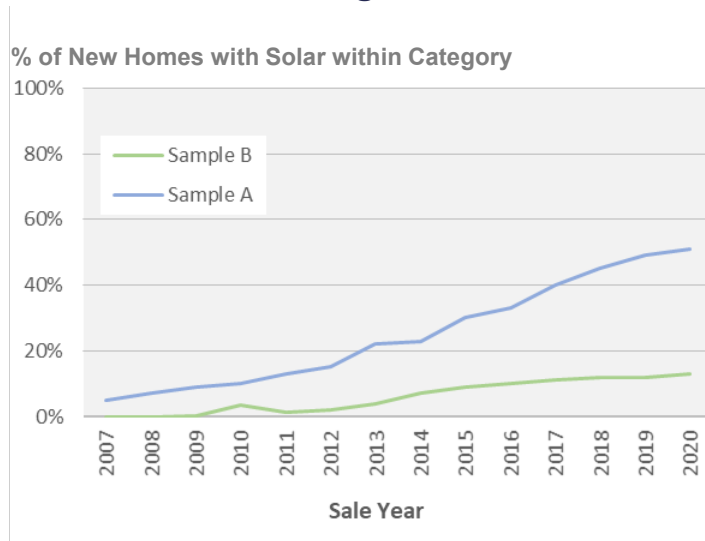
**An examination of differences in solar penetrations in new homes across characteristics, and inside and outside of California**

*Many of the slides in this section show a trio of figures.  
See descriptions of each of the figure types on the following slide.*



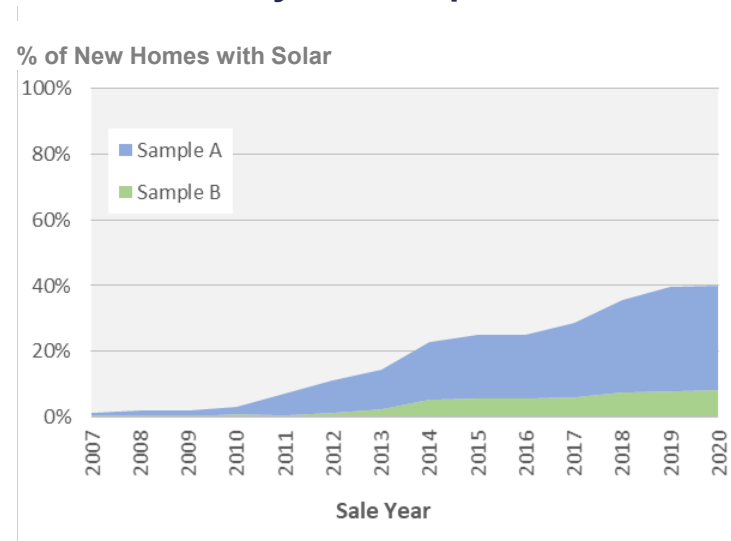
# Three figure types are used to describe California penetrations and possible drivers in the next series of slides

## Penetrations Within Categories



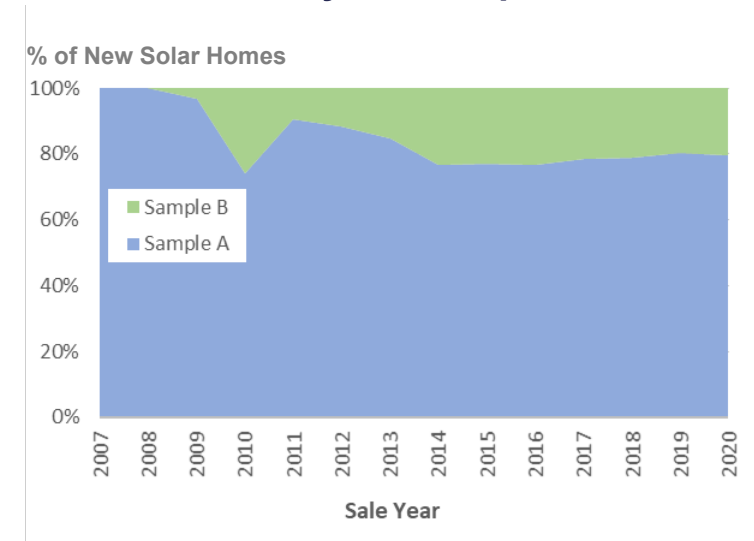
**Figure description:** Penetration Within a Category (sample A and sample B in this case) means the number of new solar homes sold in that subsample in that year as a portion of all new homes sold in that subsample in the same year

## Breakdown of Total Penetration By Subsample



**Figure description:** Breakdown of Total Penetration by Subsample (sample A and sample B in this case) means what portion of the total % penetration of new homes in any particular year are made up of the subsamples

## New Solar Home Percentages By Subsample

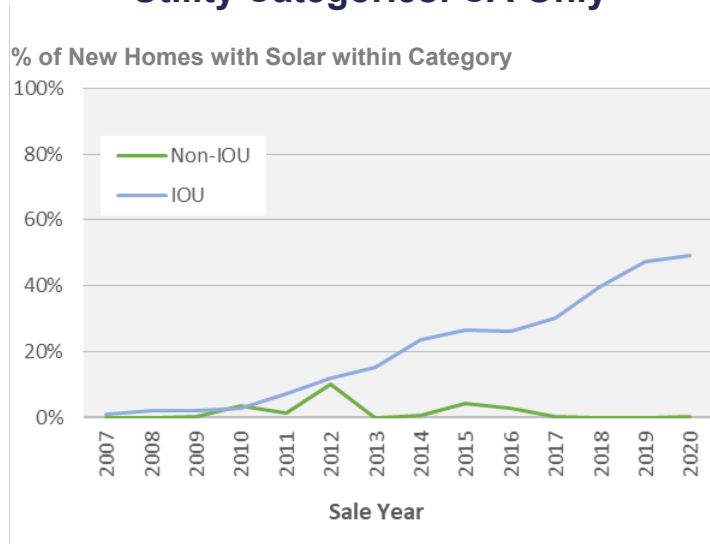


**Figure description:** New Solar Home Percentages by Subsample redistributes the levels in the figure to the left as a portion of 100% and therefore only focuses on new solar homes

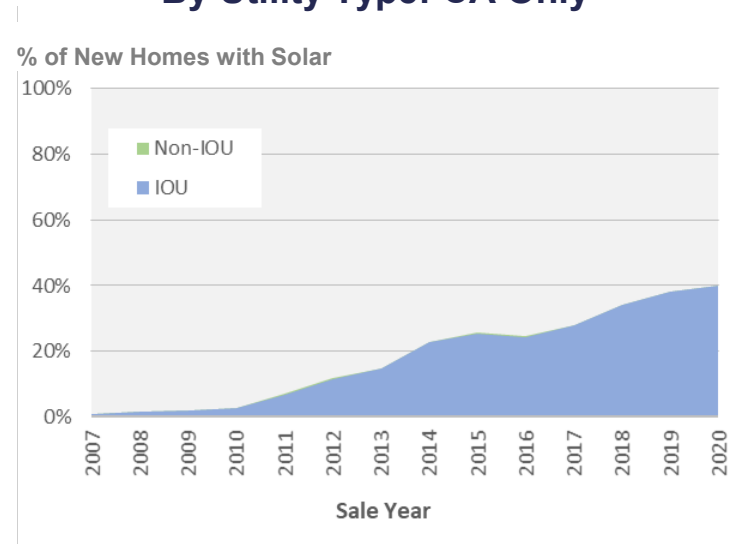


# Investor-owned utility (IOUs) service territories accounted for almost all new solar home installations in California, though data are sparse in non-IOU areas

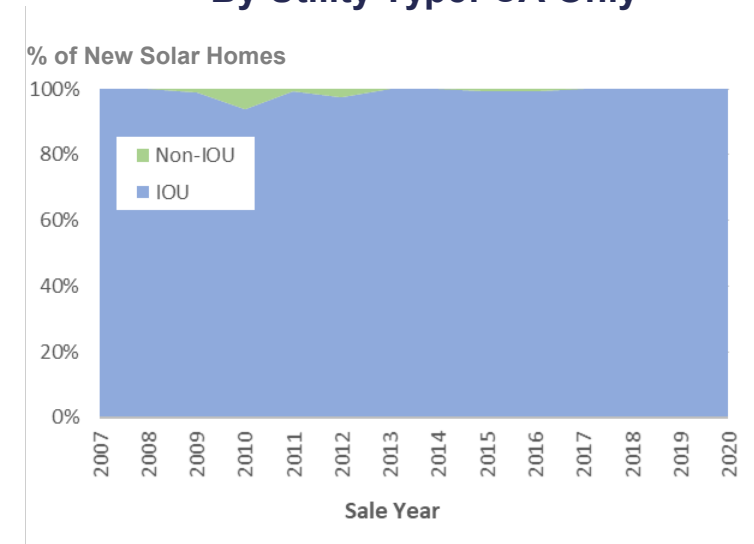
**Penetrations Within Utility Categories: CA Only**



**Breakdown of Total Penetration By Utility Type: CA Only**



**New Solar Home Percentages By Utility Type: CA Only**



## Key Points

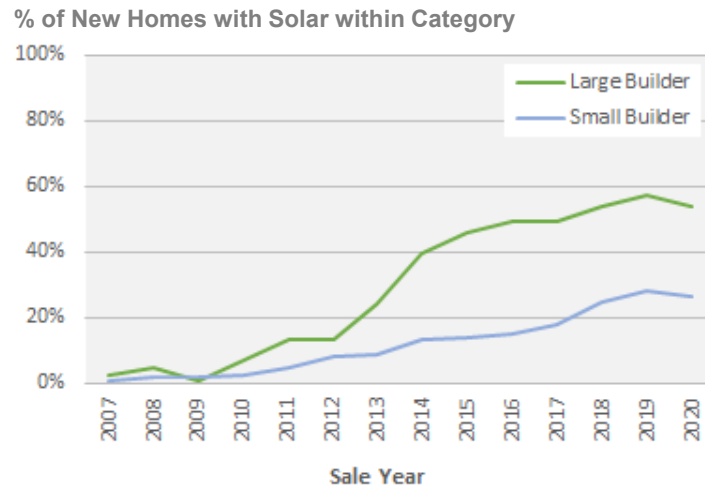
- Solar penetrations in IOUs were much higher, though data are sparse in non-IOU areas, especially in recent years, so there is likely more error in that estimate
- As discussed earlier, new solar home incentives were offered in IOU areas in California, which might explain differences: these relationships are further examined in the logistic regression later in this presentation

*Note: Zip codes where the utility service areas were either mixed or overlapping are not shown in these figures. In 2019 these zip codes represented ~5% of all installations.*

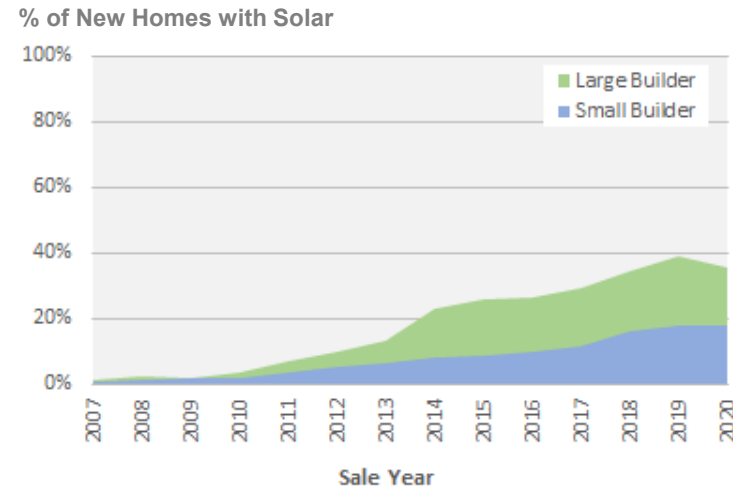


# Large California builders, based on market share, are much more likely to add solar to the homes they build, though small builders make up for it in volume despite lower penetrations

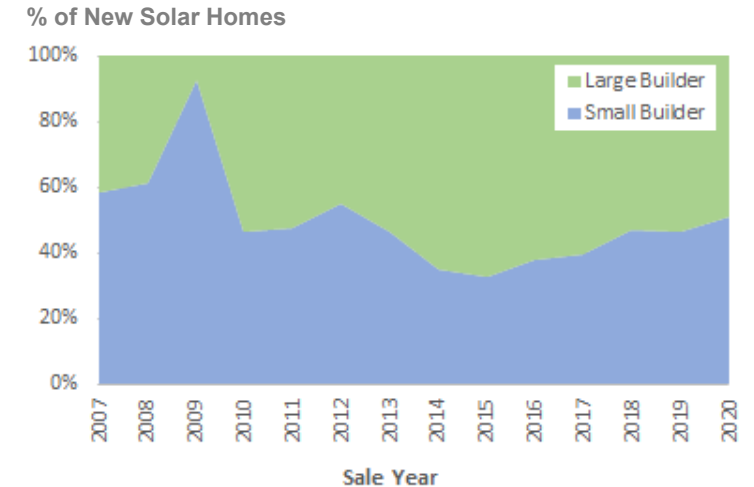
### Penetrations Within Market Share Categories: CA Only



### Breakdown of Total Penetration By Market Share: CA Only



### New Solar Home Percentages By Market Share: CA Only



## Key Points

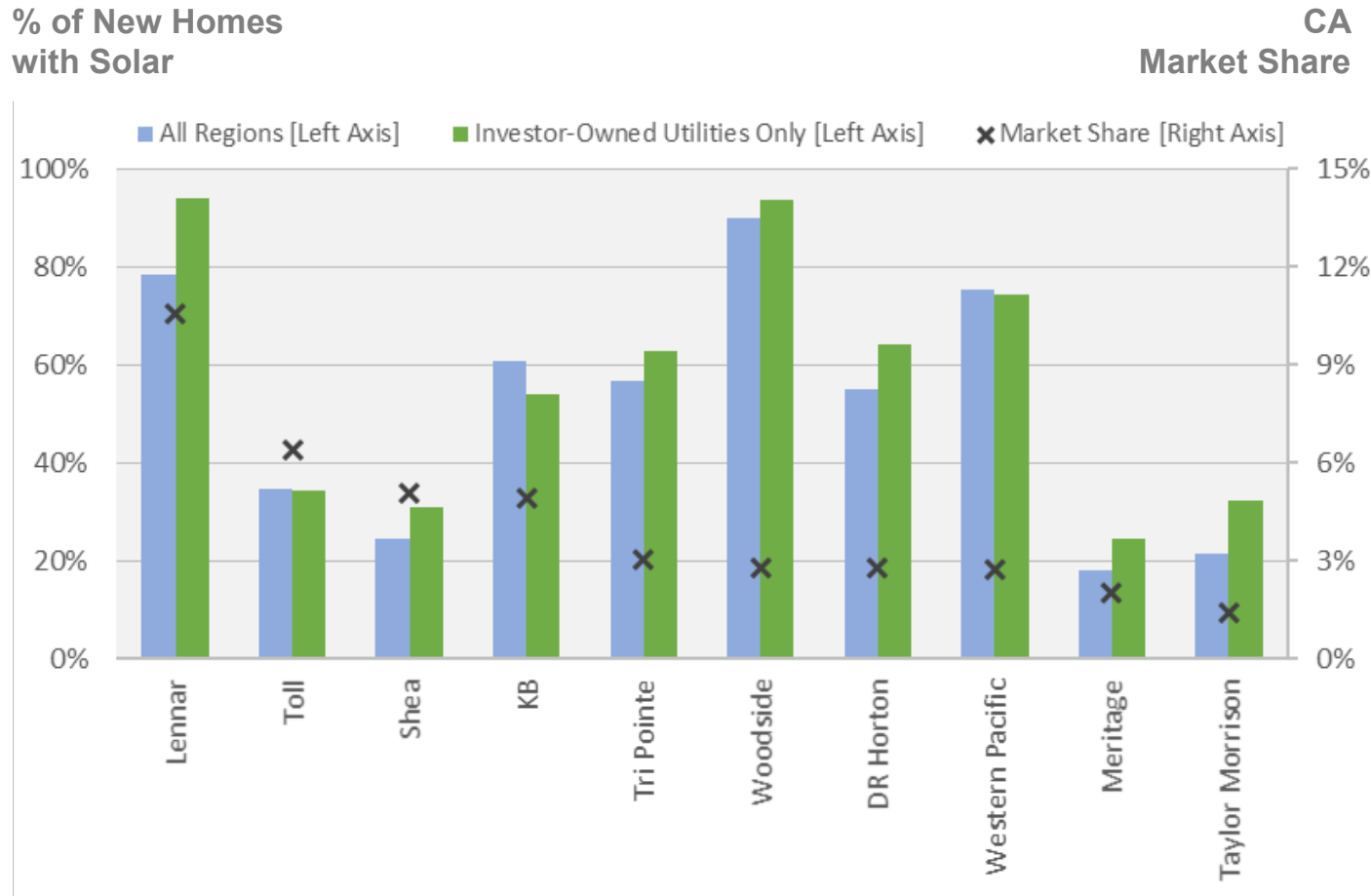
- Large builders, defined as the top-10 builders in California based on market share as of 2019, are more likely to install solar on the homes they build than all other builders (see left)
- But the smaller-market-share-builders combined to install as much solar as large builders (see middle and right)
- One reason for differences in penetrations (left) might be the size of new home development: larger builders are more likely to build larger developments, which might be more conducive to adding unique characteristics such as solar because of economies of scale
- Another reason might be the ability to organize accounting systems to take advantage of the incentives
- These relationships are further examined in the logistic regression later in this presentation





# But, there is variation among the large builders, with some installing solar on a much larger fraction of their new homes

Top Solar Builders in Recent Years (2018-2019)  
Ordered by California Market Share



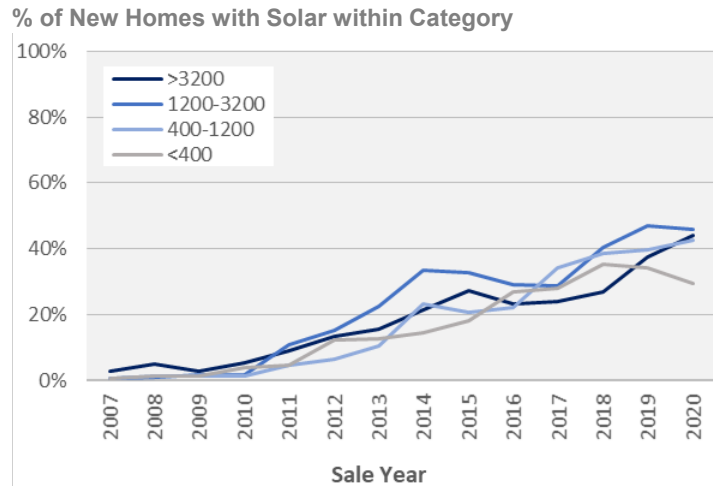
## Key Points

- Not all of the Top-10 new home builders have high solar penetrations, but many do
- Lennar was vertically integrated, installing the solar themselves, while the next three largest builders subcontracted solar installation to other companies
- Although not included in these results, we also examined the top-25 new home builders and found 18 out of 25 had higher than average solar penetrations

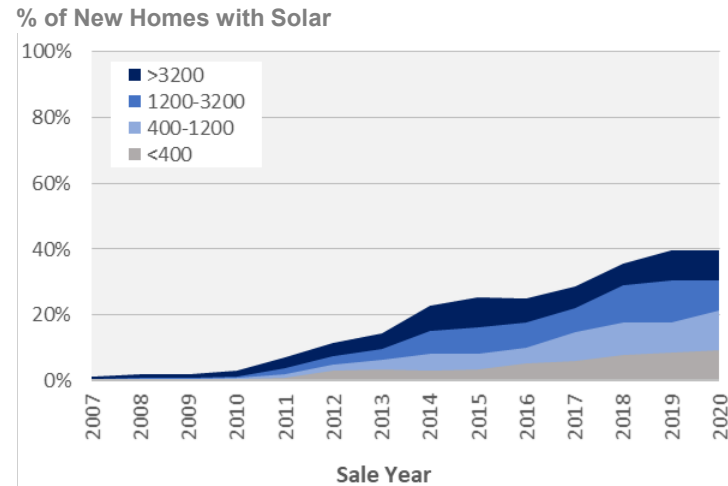
*Note: The California market share numbers include all new homes (solar and non-solar).*

# California's new solar home penetrations are roughly equal across population densities, implying density is likely not a strong driver of solar on new homes

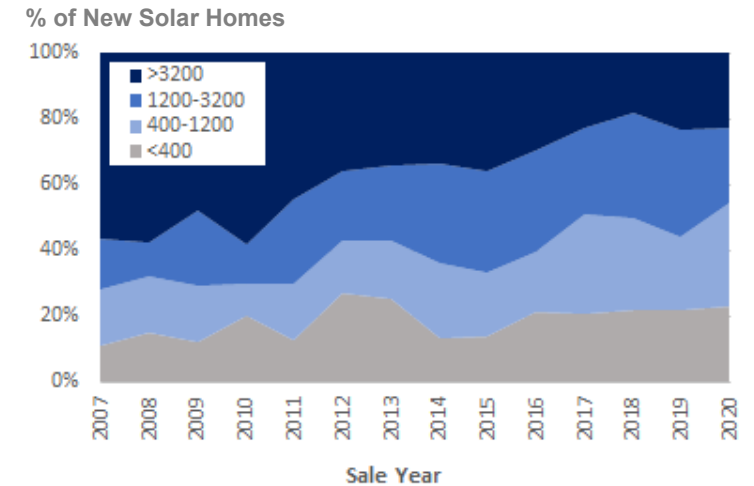
**Penetrations Within Population Density Categories: CA Only**



**Breakdown of Total Penetration By Population Density: CA Only**



**New Solar Home Percentages By Population Density: CA Only**



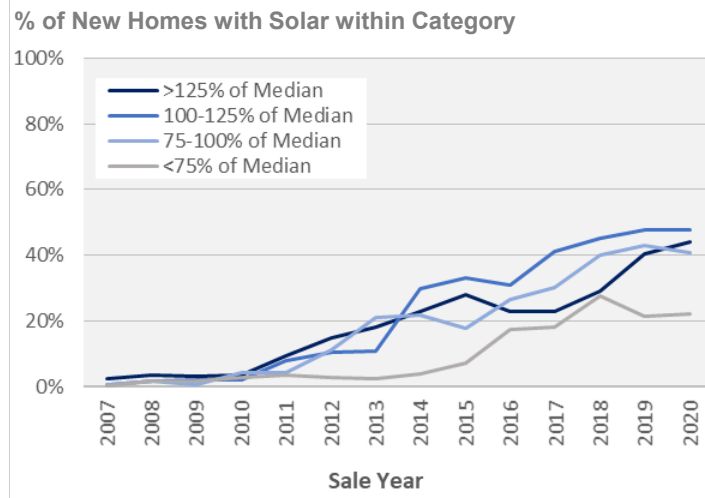
## Key Points

- New solar home penetrations are roughly equal across population densities (left)
- And the new homes that did have solar installed are fairly equally distributed across population density bins (middle and right)

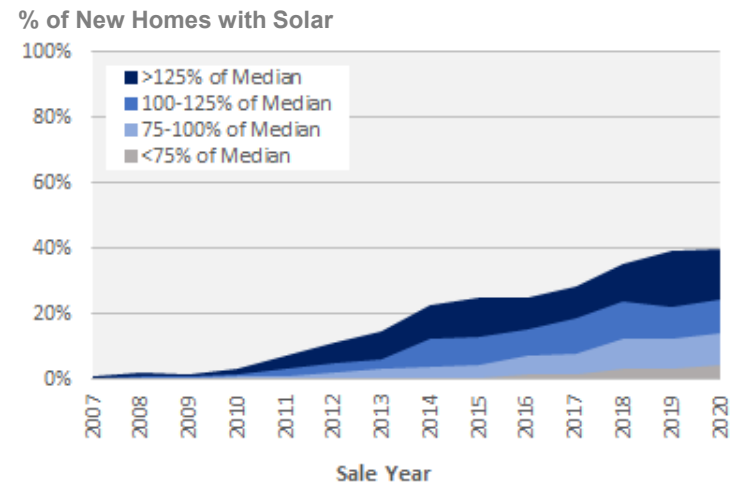
*Note: Population density is measured in people per square mile for each zip code. The cut offs for the four groups is based on the quartiles of population density for California zip codes.*

# California's lowest income areas appear to have lower penetrations, though they make up a smaller, but slowly growing, percentage of all new solar homes

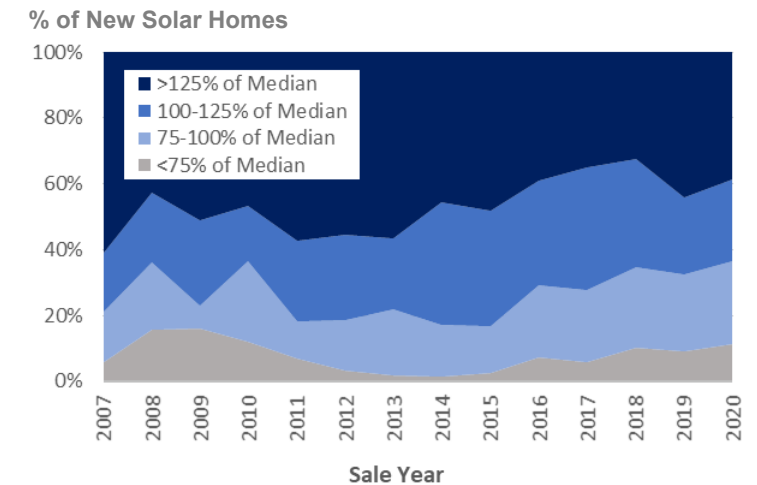
**Penetrations Within Income Categories: CA Only**



**Breakdown of Total Penetration By Income: CA Only**



**New Solar Home Percentages By Income: CA Only**



## Key Points

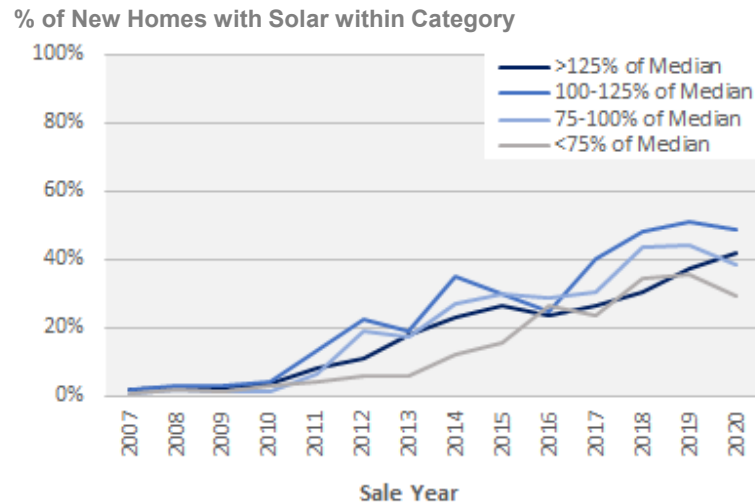
- Solar penetration into new home construction has lagged in the lowest income areas (left)
- Further, most new solar homes are installed in relatively higher-income areas (middle and right)

*Note: Categories are based on a comparison between zip code level 2019 income and statewide CA median income in 2019.*

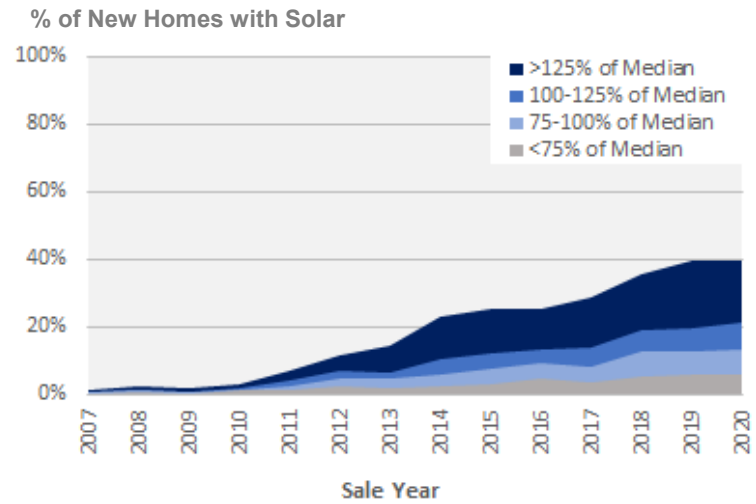


# Penetrations are relatively similar across California new home assessed value amounts

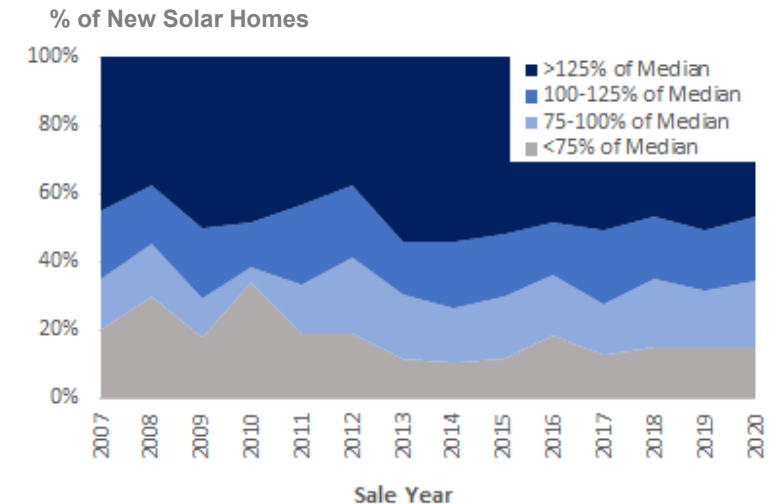
**Penetrations Within Assessed Amount Categories: CA Only**



**Breakdown of Total Penetration By Assessed Amount: CA Only**



**New Solar Home Percentages By Assessed Amount: CA Only**



## Key Points

- There is no clear distinction in penetration levels among different assessed values in California, though the lowest-value category has a lower solar new home penetration on average across time (left)
- This appears to indicate that higher assessed values do not strongly correlate with higher solar penetrations
- Despite that, these high-assessed value homes make up the largest percentage of all California solar homes (middle and right)
- A similar comparison (and similar results) is made with home sale prices in the Appendix

*Note: Categories are based on a comparison between home assessed value and the median assessed value statewide in California, by year.*

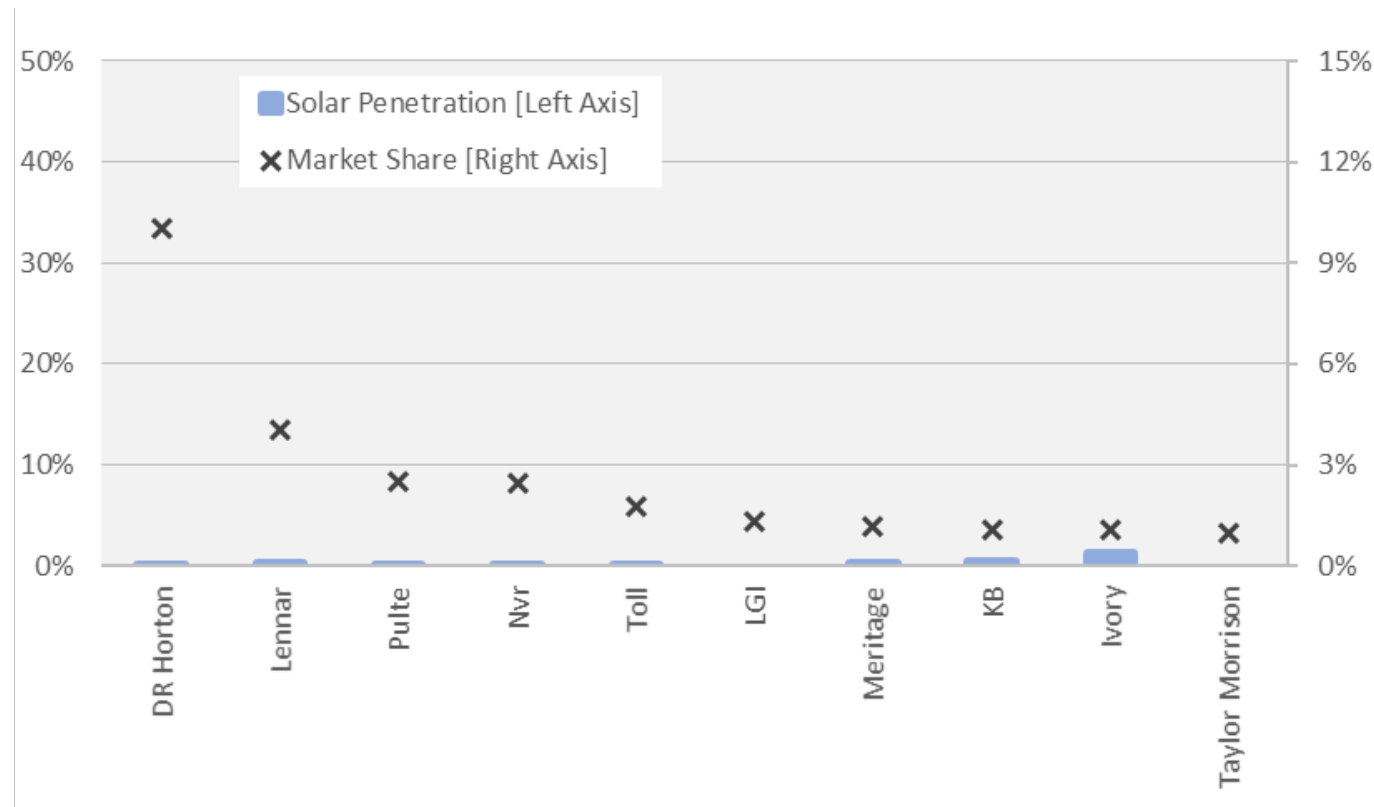


# Turning back to builders, but looking outside California: solar is much less frequent for the top US builders (many of which are top CA builders)

Top Builders in Recent Years (2018-2019)  
Ordered by Outside CA Market Share

% of New Homes  
with Solar

Other States  
Market Share



## Key Points

- Solar penetration is very small for the largest new home builders outside of CA, some of which are also top-builders in CA (see previous slide)
- In other words, the large builders that are installing lots of solar in CA do not appear to be repeating that outside of CA
- This may indicate that the CA NSHP incentives are a key driver for encouraging solar penetration, but could also be due to other unique attributes of the CA market
- These relationships are further examined in the logistic regression later in this presentation

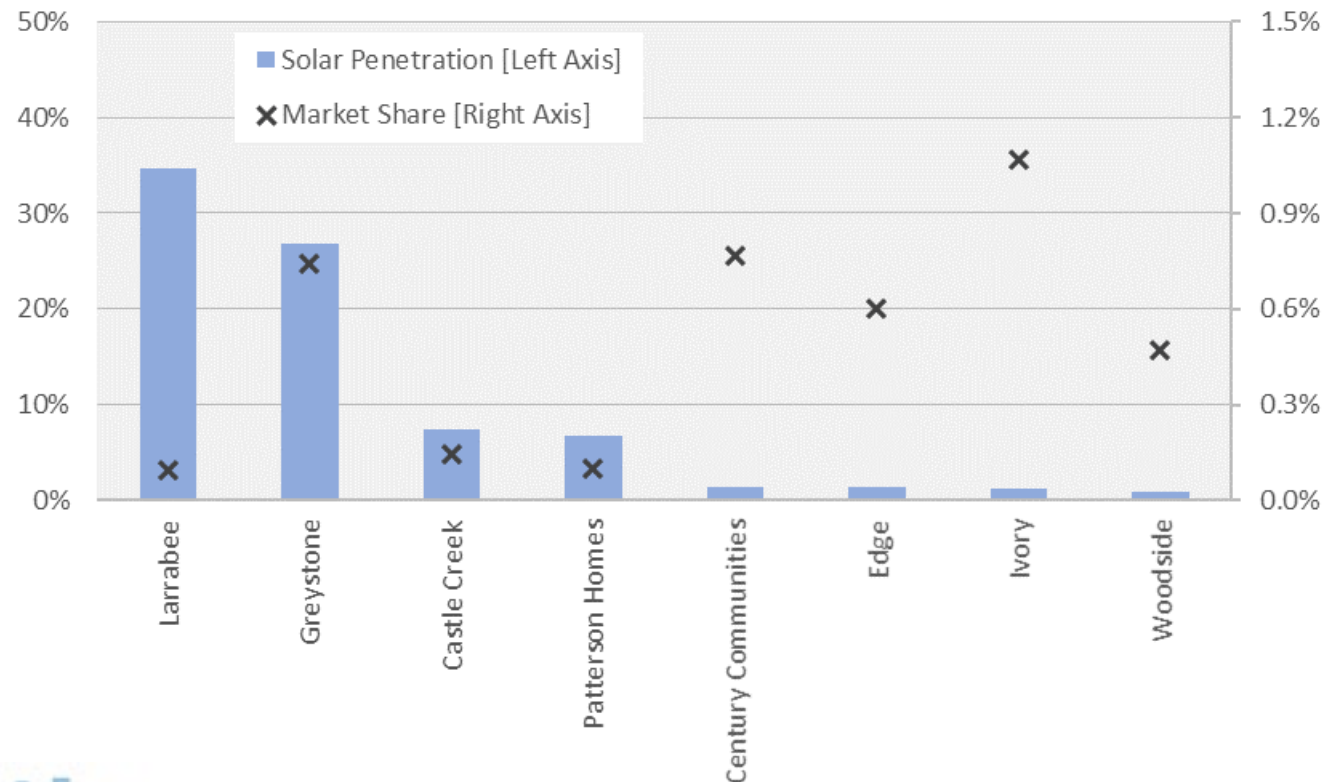
Note: Primary y-axis rescaled from previous slide

# Some very small market-share builders are installing a relatively large amount of solar outside of California

Highest Non-California Solar Penetration in Recent Years (2018-2019)  
Ordered By Highest Solar Penetration

% of New Homes  
with Solar

Other States  
Market Share

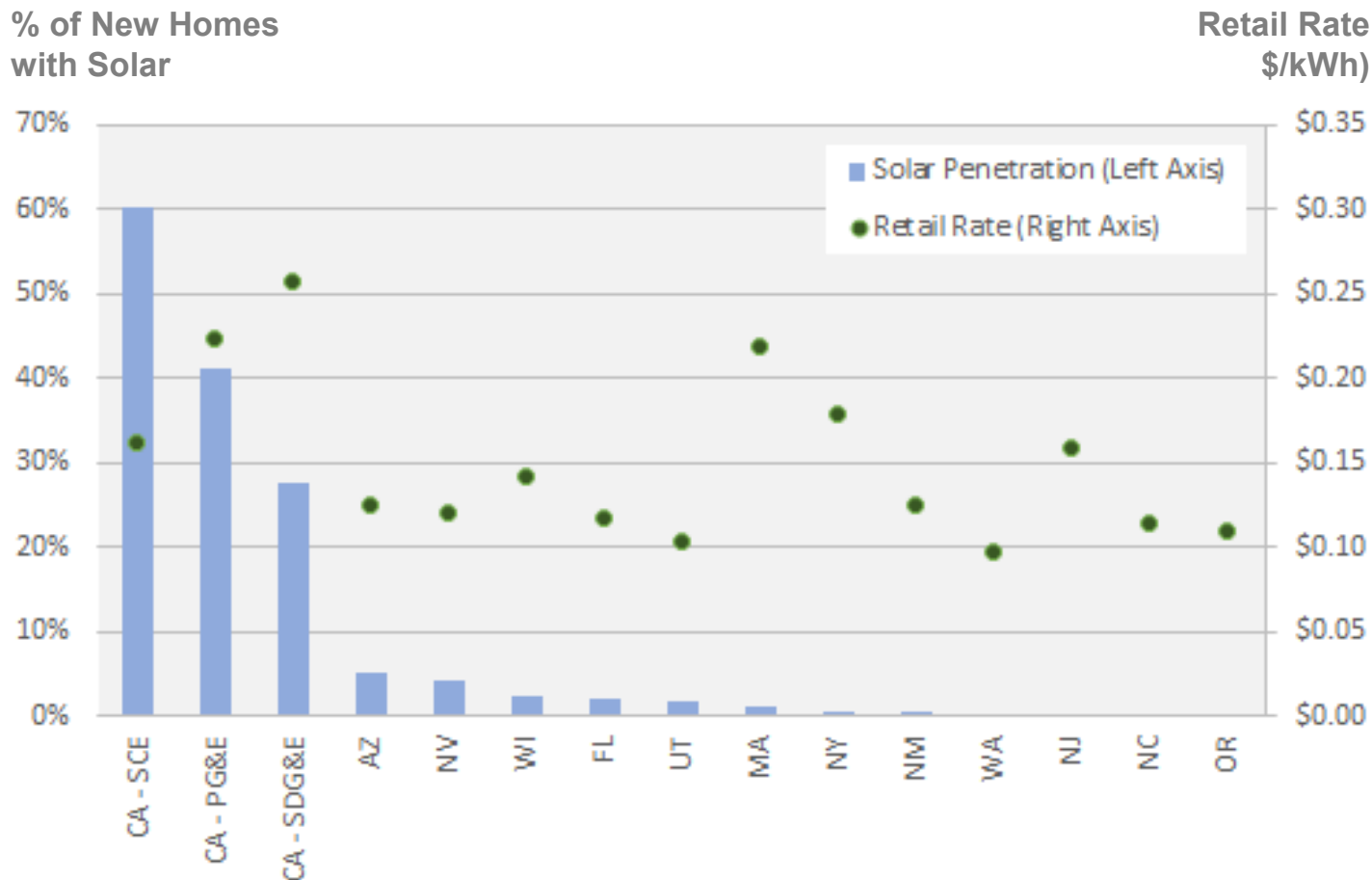


## Key Points

- A few builders outside of California seem to have specialized in building solar homes (e.g., Larrabee & Greystone), but they have very low market share, respectively 0.05% and 0.75%
- These relationships are further examined in the logistic regression later in this presentation
- Some of these builders are likely regional, and therefore their market share, which is based on all states in our data, might be biased regionally

# Finally, new home solar penetrations are seemingly not correlated with electricity rates, across non-California states and within California utilities

Solar Penetrations in Recent Years (2018-2019) Within States and CA Utilities (Left)  
Average Utility or State Retail Electricity Rates (Right)



## Key Points

- There are a wide variety of average rates among the highest penetration locations and vice versa: i.e., high rates do not obviously correlate with high penetrations
- Of course, average utility rates, as shown on this slide, might mask individual home rates that might be tiered and/or time-of-use and therefore differ significantly from the average
- These relationships are further examined in the logistic regression later in this presentation

*Note: Retail rates are as of 2019.*

## Logistic Regression





# Logistic regression to examine competing effects on new home solar penetration

To examine the potentially competing influences of some of these key variables, we estimated a multivariate logistic regression as follows:

$$PS_i = \alpha + \beta_1(N_i) + \beta_2(TB_i) + \beta_3(E_i) + \beta_4(I_i) + \beta_5(V_i) + \beta_6(D_i) + \varepsilon_i$$

- where
  - $PS_i$  represents the probability that new home  $i$  has a solar system installed at the time of sale,
  - $\alpha$  is the constant or intercept across the full sample,
  - $N_i$  is a vector of fixed effects if the home  $i$  is located in one of three investor-owned utility (IOU) service areas in California, where the New Solar Home Partnership Incentive Program (NSHP) was available,
  - $TB_i$  is a vector of fixed effects if home  $i$  was built by one of the top-10 builders in either California or all of the United States, or both (depending on the sample),
  - $E_i$  is a continuous variable indicating the 2019 average retail utility rate (\$/kilowatt-hour) for the particular California utility or state (outside of California) in which home  $i$  is located,
  - $I_i$  is a continuous variable for the median income as of 2019 (in \$100,000s) of the zip-code in which home  $i$  is located,
  - $V_i$  is a continuous variable for the assessed value (in \$100,000s) of home  $i$ ,
  - $D_i$  is a continuous variable for the population density (1000 persons/square mile) in the zip code in which home  $i$  is located, and
  - $\varepsilon_i$  is a random disturbance term for home  $i$ .
- We present these results as odds ratios, which represent the percent increase in probability that the new home has solar: 1) if the condition is true for fixed effect variables; and, 2) for a one-unit increase above the mean for continuous variables
- We estimate three models: 1) only California new homes (Model 1); 2) only new homes outside of California (Model 2); and 3) all new homes in our sample (Model 3).



# The California new solar home incentive, if the home is built by one of the top-10 builders, and area income appear strongly correlated with the presence of solar

		Model 1	Model 2	Model 3
		California	Non-California	All of US
$N_i$	CA IOU (NSHP Incentive)	>1000%		>1000%
$TBi$	Top-10 Builder in CA	250%		157%
	Top-10 Builder in US		-56%	53%
$E_i$	Average Electricity Rate (\$)	0%	-4%	0%
$I_i$	Zip Code Median Income (\$100K)	-0.3%	-0.7%	-0.4%
$V_i$	Home Assessed Value (\$100K)	-1.0%	1%	-1.1%
$D_i$	Population Density (1000/mile <sup>2</sup> )	-10%	4%	-10%
$n$		29,588	100,607	130,199
McFadden's R <sup>2</sup>		0.14	0.01	0.48

## Key Points

- All coefficients shown **bolded in green** are highly statistically significant ( $p$ -value <0.00). Those shown un-bolded in black are either not or are only weakly significant ( $p$ -value >0.05).
- A home's assessed value, area median income and population density are sometimes correlated with whether the new home has solar, but results are low or mixed inside and outside of California.
- Average retail electricity rates in California utilities or for the whole state outside of California, were not significantly correlated with the presence of solar on new homes.
- When builders could apply for the NSHP incentive or were one of the top-10 builders in California or the U.S. had a much stronger correlation with new solar homes.
- The top-10 builders outside of California, many of which are also top builders in California, have lower odds of building new solar homes than smaller builders; the opposite is true in California.
- The relatively high pseudo R<sup>2</sup> for Model 1 and 3 indicate the included variables do a relatively good job of predicting new solar home probability in California.

Note: These results are similar if a Top-25 builder designation is used and if either income or assessed value are omitted.

Notes: Results represent odds ratios. Positive numbers indicate increased odds of the new home having solar if the condition is true (for fixed effects) or for a unit increase in level (for continuous effects). The McFadden's pseudo R<sup>2</sup> in the range of 0.1-0.5 represents a strong fit for logistic regressions.



## Conclusions



# Summary conclusions from this preliminary analysis

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**Data:** We assembled a dataset of all new homes and most existing homes through 2020 in areas with solar where address data were available: 13,460,000 existing homes, 527,000 new homes, and a total of 707,000 solar homes, of which almost 20,000 were new. Most new solar homes are in California but 18 other states and DC are represented.

## Key Findings Include:

- ❑ **California is different:** Even before the California Solar Home Mandate, the state had new solar home penetrations of ~ 40%; outside of California the average was just ~ 0.6% (AZ, NV, UT had relatively higher penetrations)
- ❑ **Drivers of new home solar penetrations:** The strongest correlates appear to be whether the home was located in an area that qualified for the New Solar Home Partnership incentive, and, in California, if the builder was among the largest in terms of market share
  - Average retail electricity rate, home value, median income levels, and population density show no, low and/or mixed correlations
  - Outside of California, larger builders are not associated with greater new solar home construction
- ❑ **Characteristics of the new home solar market are different from solar on existing homes:** Solar systems installed on new homes tend to:
  - Be smaller in size but associated with larger homes
  - Have lower battery attachment rates
  - Be more likely third-party owned
- ❑ **Solar system cost differences are modest:** The cost of solar systems on new homes is comparable to that of solar on existing homes on a \$/W basis; solar on new homes tend to be smaller so benefit less from economies of scale



## To provide some context for these results we discussed them with a few large builders and found they concurred with the findings

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*“The use of the NSHP incentive funding and PV compliance credit (2017-2019) played a significant role in several large builders deciding to go solar prior to the mandate taking effect on 1/1/2000. Many small and medium-size builders waited until the state mandate took effect to go solar as opposed to the much larger companies who added solar as a standard feature prior to the mandate taking effect.”*

- Building Industry Association  
Representative

*“[We] take advantage of the regulatory environment in each state. Net metering and other incentives are central to new solar homes penciling out.”*

- Large Builder 1

*“Solar adds an additional \$10-15k cost per house. [We] build starter homes, so they have not been able to make that pencil in other parts of the country. In CA, the market can bear that cost because homes sell for over a million in CA. We can't pass that cost on in other states.”*

- Large Builder 2





## Contact

**Ben Hoen:** [bhoen@lbl.gov](mailto:bhoen@lbl.gov), 845-758-1896

## For more information

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The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or The Regents of the University of California.

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## Appendix: Additional Data Details



# Data sources

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- **LBNL’s Tracking the Sun (TTS):** Residential solar dataset that includes, for example, data on home address, operation date, system size and azimuth, third-party ownership, and if batteries are included. <https://emp.lbl.gov/tracking-the-sun>
- **CoreLogic:** Property and Data Solutions dataset of home characteristics and transaction information over time. Characteristics include, for example, address, home size, year built, and if home has air conditioning. Transaction details include if home was “new” at time of sale, sale price, sale date, and assessed value. <https://www.corelogic.com/find/property-data-solutions/>
- **Builder market share:** Manually categorized based on the “seller1fullname” variable for new homes in CoreLogic data (see above)
- **Investor-owned utility areas:** Derived from a GIS layer entitled “Retail Service Territories” sourced through ArcGIS Online that was produced via a collaboration between: Oak Ridge National Laboratory (ORNL), Los Alamos National Laboratory (LANL), Idaho National Laboratory (INL), National Geospatial-Intelligence Agency (NGA) Homeland Security Infrastructure Program (HSIP) Team
- **CA utility service areas:** For solar homes, used the “utility service area” variable in the TTS dataset. For non-solar homes, assumed that the utility service area is the same as that of the nearest solar home.
- **Population Density:** U.S. Census Bureau, 2020 Census, <https://www2.census.gov/geo/tiger/TIGER2021/UAC/>
- **Disadvantaged community designations:**
  - Justice40: Council on Environmental Quality, Climate and Economic Justice Screening Tool, <https://screeningtool.geoplatform.gov/en/downloads>
  - Cal Enviro Screen: California Office of Environmental Health Hazard Assessment, CalEnviroScreen 4.0 Data, <https://oehha.ca.gov/calenviroscreen/maps-data/download-data>
- **Area median income:** U.S. Census Bureau, Income and Poverty in the United States: 2020, <https://www.census.gov/library/publications/2021/demo/p60-273.html>
- **Election results:** MIT Election Data and Science Lab, U.S. President 1976–2020, <https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/42MVDX>
- **State electricity rates:** U.S. Energy Information Administration, Annual Retail Sales of Electricity to Ultimate Customers by State and Utility, <https://www.eia.gov/electricity/data.php>
- **CA utility electricity rates:** Utility Rate Database, Electric Utility Rates, [https://openei.org/wiki/Utility\\_Rate\\_Database](https://openei.org/wiki/Utility_Rate_Database)



# Data screening criteria

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## **To be included in our data, the new home transaction must have the following characteristics:**

- Single family residence or duplex
- Sale date, sale amount, and acreage are not missing
- Arm's length transaction and not a foreclosure
- Home address is not taken from the transaction mailing address
- Sale amount, sqft, sale amount per sqft, and acres are not the bottom or top 1% of the distribution
- Acres is greater than the home square footage, sale amount is greater than mortgage amount

## **To be classified as a “New Home”, the transaction must have the following characteristics:**

- Be classified as a new home transaction in the CoreLogic dataset
- Have build date between two years before or one year after the sale date (e.g., pre-sold homes)

## **To be classified as a “New Solar Home”, the transaction must have the following characteristics:**

- Match with the TTS solar dataset
- Permission to operate date is between one year before and one year after the sale date
- Further details on how we used the new solar home variable in the TTS dataset to classify the data are shown in the table on the next slide





# New solar home definition criteria

New Solar Home Variable in TTS	Permission to Operate Date Compared to the Sale Date for New Homes				
	>1 year before	1 year before to 90 days after	90 days to 6 months after	6 months to 1 year after	>1 year after
Yes	Excluded	Yes	Yes	Yes	Excluded
No	Excluded	Yes	Excluded	Excluded	Excluded
Missing	Excluded	Yes	Yes	Excluded	Excluded

*Note: Our criteria are based on discussions with Sunpower, which indicated that permission to operate (PTO) typically occurs 8-10 weeks after a homeowner moves in. They believe that 6 months after the sale date is an appropriate cut off.*



# Analysis dataset: new home coverage by state over 2007-2020

State	Zip Codes Included	Total Zip Codes In State	# of Transactions	# of Solar Transactions	# of New Transactions	# of New Solar Transactions
AZ	35	567	141,983	1,187	2,034	33
CA	1,435	2,653	3,574,298	142,078	102,959	18,511
CT	264	438	333,766	2,390	2,312	4
DC	20	53	34,301	363	94	0
FL	21	1,490	65,115	147	1,487	8
MA	489	703	624,660	7,888	2,878	12
MN	198	1,031	463,190	63	13,505	1
NC	596	1,090	1,239,498	1,029	109,775	61
NJ	568	731	908,796	11,003	7421	12
NM	77	426	131,713	1,486	4,142	26

*The total number of zip codes by state may change over the analysis period (2007-2020). The zip codes included in the analysis may include P.O. Box zip codes.*



## Analysis dataset: new home coverage by state over 2007-2020 (continued)

State	Zip Codes Included	Total Zip Codes In State	# of Transactions	# of Solar Transactions	# of New Transactions	# of New Solar Transactions
NV	115	254	564,937	6,730	27,399	370
NY	1,480	2,208	1,284,496	4,725	11,566	18
OH	570	1,447	1,151,129	192	10,870	1
OR	310	486	584,531	2,686	11,485	39
RI	74	91	105,130	315	804	0
TX	362	2,655	1,194,962	203	131,106	0
UT	179	347	375,264	946	26,171	141
WA	397	733	987,017	276	56,826	60
WI	111	898	222,162	58	4,243	8

*The total number of zip codes by state may change over the analysis period (2007-2020). The zip codes included in the analysis may include P.O. Box zip codes.*



## Appendix: Additional Figures and Results

**None of these figures and results appeared important enough to include in the main slide deck but some are interesting so we append them here for reader interest**



# Although CA had a 40% new solar home penetration in recent years, some CA counties had a 70% penetration, while others were at 0%

*Includes the five highest and lowest penetration counties over 2018-2019. Counties outside investor-owned utility territories (e.g., Shasta and Stanislaus) are excluded.*

	County	Total	Solar	Solar Penetration
<b>Top 5 Counties</b>	Placer	785	552	70%
	Yolo	306	215	70%
	El Dorado	289	203	70%
	Fresno	830	552	66%
	Tulare	1,043	632	61%
<b>Bottom 5 Counties</b>	San Mateo	26	1	4%
	Monterey	102	0	0%
	Marin	11	0	0%
	Santa Cruz	14	0	0%
	Napa	31	0	0%



## Similarly, some zip codes outside of California had a relatively high new solar home penetration in recent years (2018-2019)

State	Zip Code	Metro Area	Total	Solar	Solar Penetration
UT	84101	Salt Lake City	3	3	100%
NV	89014	Las Vegas	29	23	79%
NV	89179	Las Vegas	40	20	50%
WI	53151	Milwaukee	8	4	50%
NV	89002	Las Vegas	45	11	24%
WA	98226	Bellingham	114	25	22%
UT	84106	Salt Lake City	27	3	11%
UT	84404	Ogden	74	5	7%
AZ	85742	Tucson	94	5	5%
AZ	85653	Tucson	66	3	5%

*Note: The top ten penetration zip codes are included. Zip codes selected have at least three new solar homes over 2018-2019. A maximum of three zip codes per state are included.*





# Outside of California, high new solar home penetration seems to come from subdivisions (a few examples shown below)

**Las Vegas, NV (89179)**  
**Builder: Greystone**  
**Solar Penetration: 50%**



**Bellingham, WA (98226)**  
**Builder: Larrabee Springs**  
**Solar Penetration: 22%**



**Milwaukee Metro Area, WI (53151)**  
**Builder: Tim O'Brien Homes**  
**Solar Penetration: 50%**

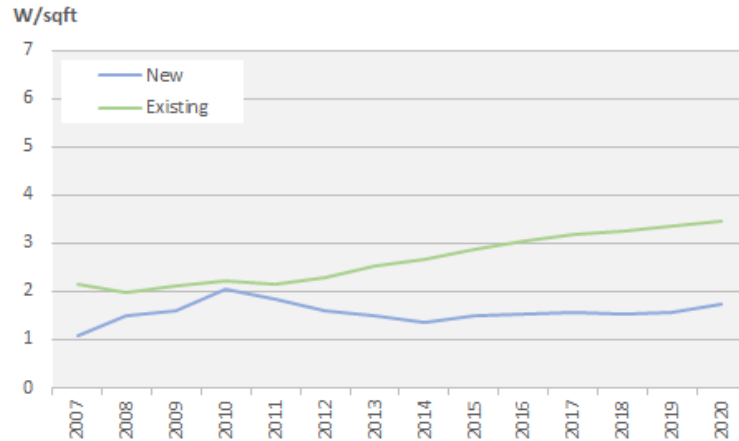


**Tucson, AZ (85742)**  
**Builder: KB Homes**  
**Solar Penetration: 5%**



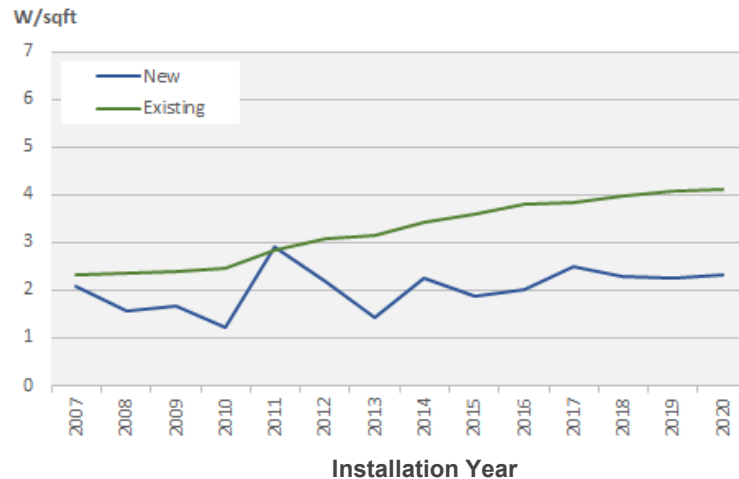
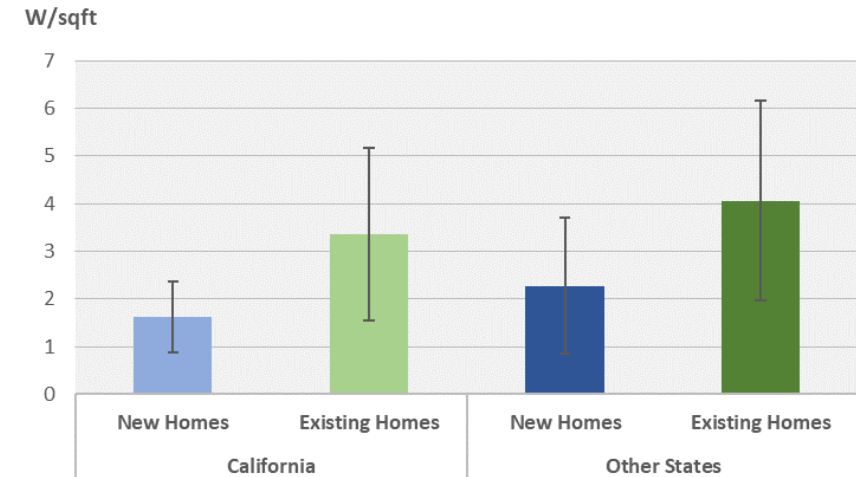
# The difference in system size between new and existing homes is fairly large when measured on a per square foot level

System Size/Sqft Over Time (2007-2020)



California

System Size/Sqft Recent Trends (2018-2020)



Other States

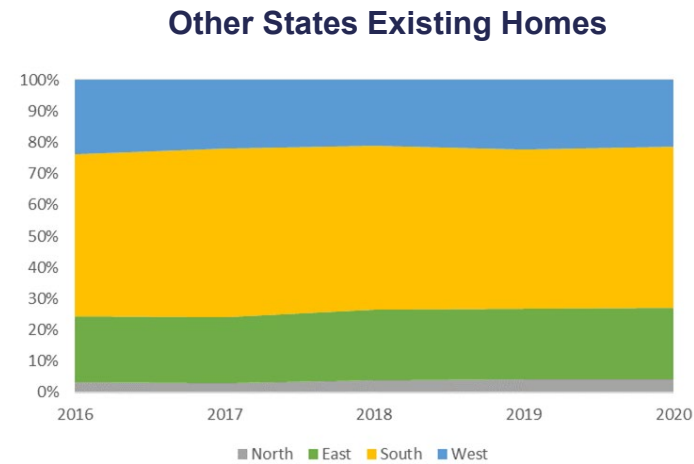
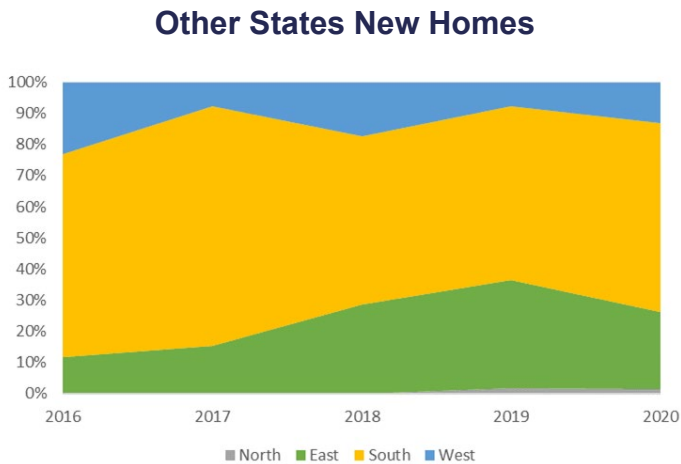
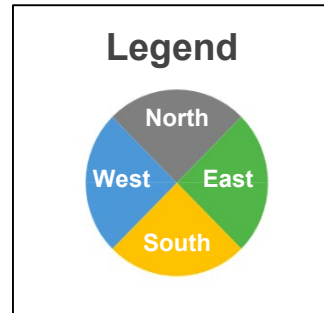
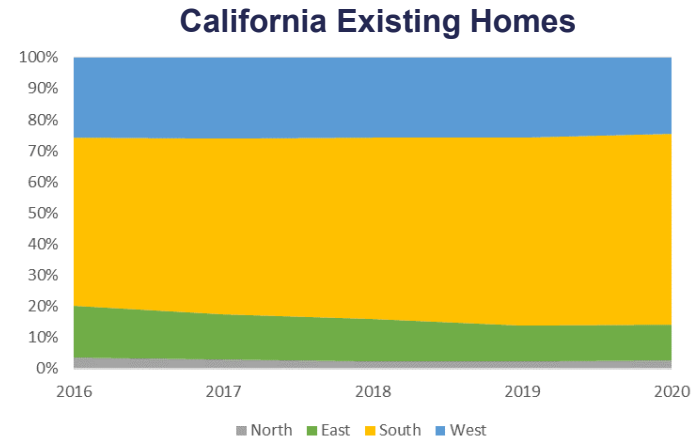
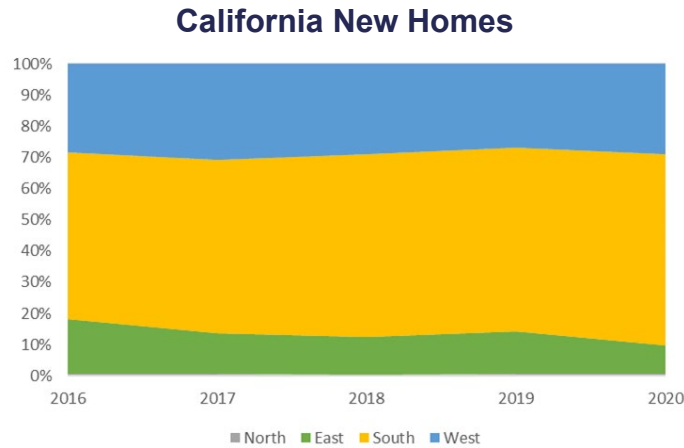
## Key Points

- System size per square foot has been increasing for existing homes but has remained flat for new homes
- New homes are likely more efficient and likely require less electricity, which might equate to smaller solar systems despite slightly larger home sizes (see earlier slides)

Figures show cohort means. Error bars represent 90% confidence intervals. Medians show similar results including p5 and p95 error bars.

# There are no major differences in azimuth for new and existing solar homes though California is slightly more West facing

## Azimuth Over Time (2016-2020)

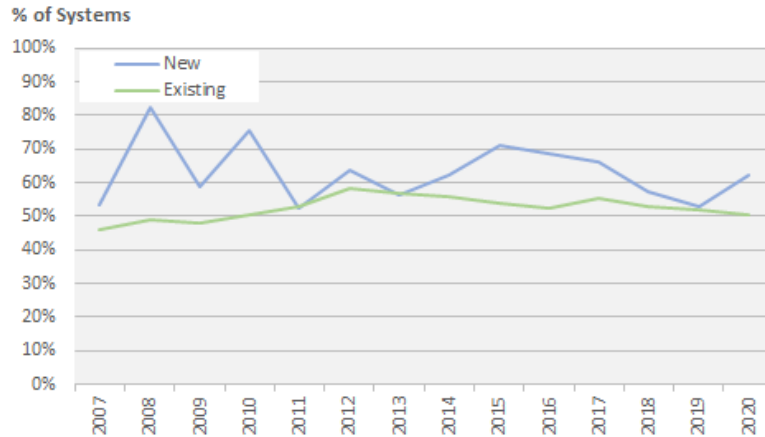


*Note: For homes with panels facing multiple directions, the azimuth with the most modules is used. Prior to 2016, data are too spotty to be used.*

# Air conditioning is more prevalent in new solar homes, particularly outside of California

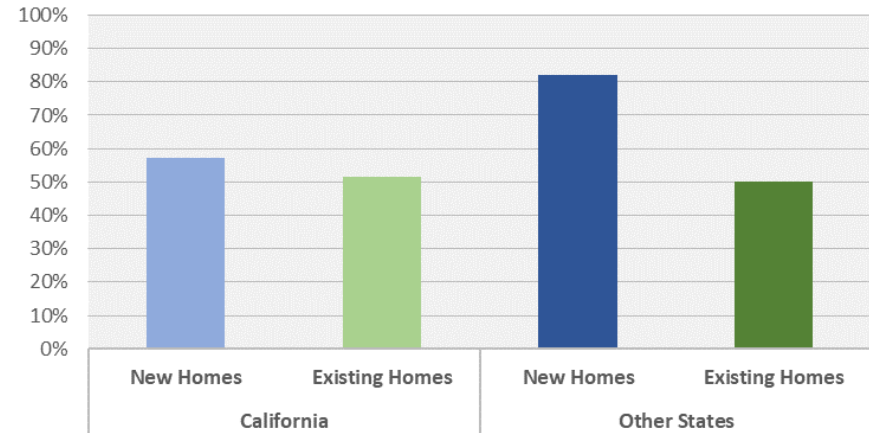
A/C Over Time (2007-2020)

California

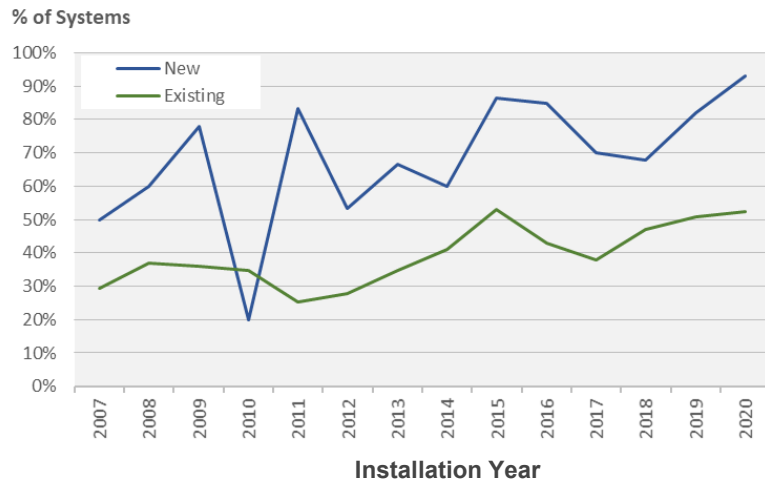


A/C Recent Trends (2018-2020)

% of Systems



Other States

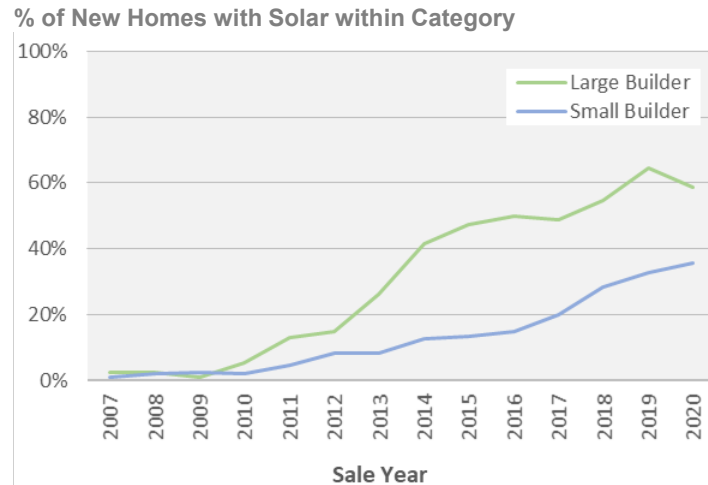


## Key Points

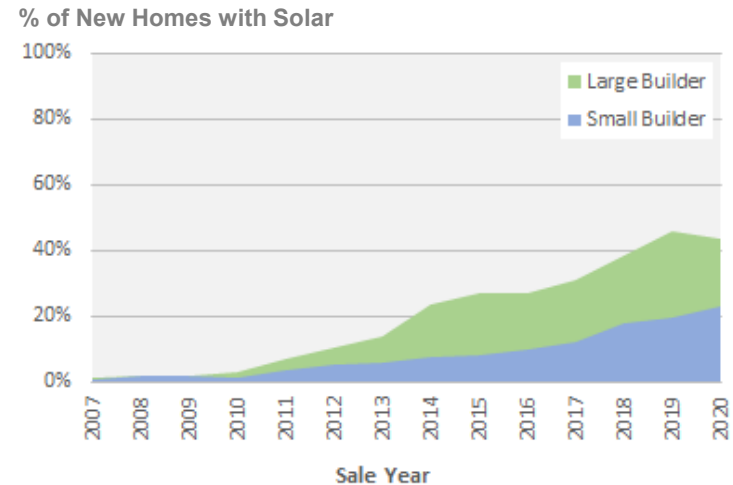
- Outside of California, new solar homes have considerably more AC than existing solar homes
- Both new and existing solar homes outside of California show growing AC percentages over time

# The large-small builder market share patterns persists even when only looking within investor-owned utilities in California

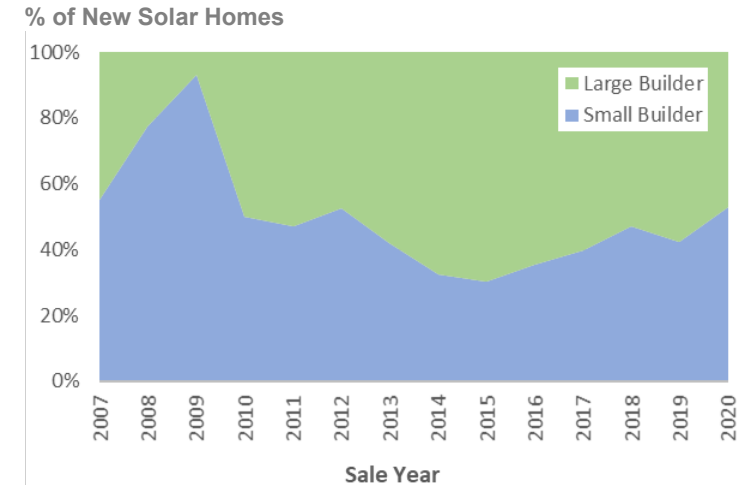
## IOU Penetrations Within Market Share Categories



## Breakdown of Total IOU Penetration By Market Share



## New Solar Home IOU Percentages By Market Share



## Key Points

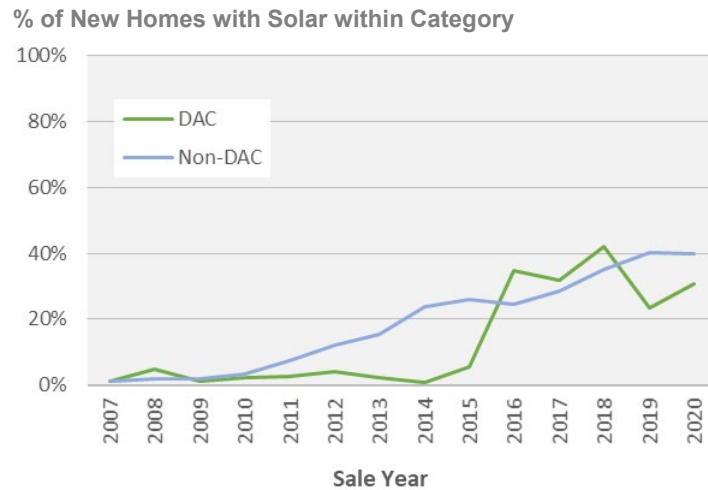
- The large/small builder effect exists within California IOU territories where NSHP incentives were offered (left)
- As noted on earlier slides, non-IOU CA data are sparse so it is not surprising that this slide is similar to the one shown in main body



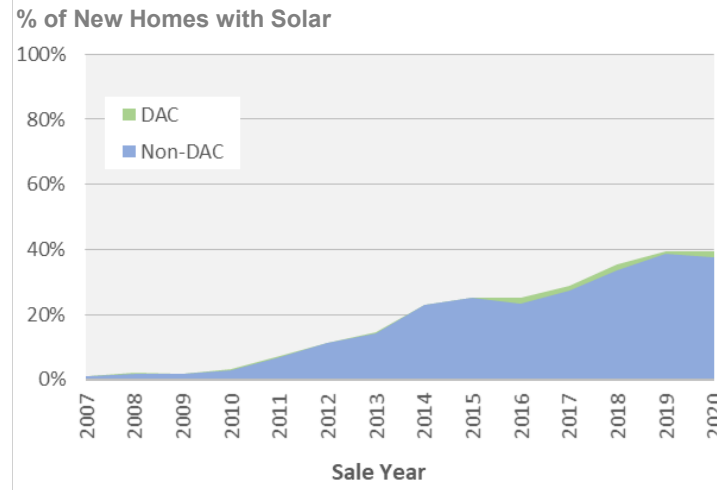


# California solar penetrations are slightly lower in disadvantaged communities (left) but non-DACs account for almost all new solar homes (middle and right)

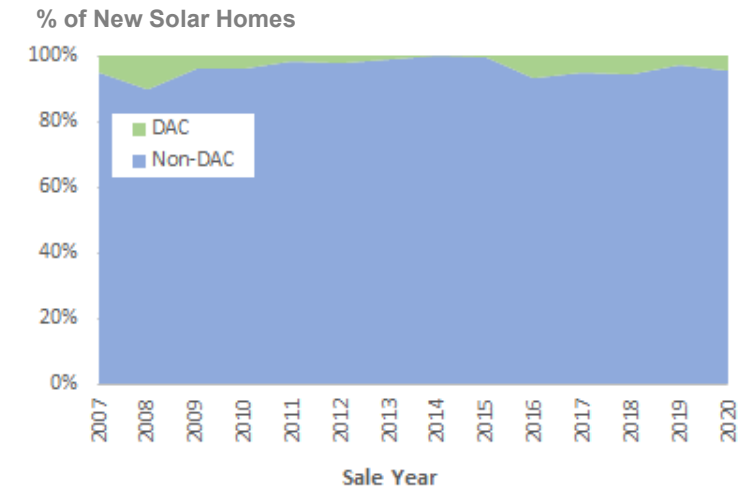
### Penetrations Within DAC Categories



### Breakdown of Total Penetration By DAC Designation



### New Solar Home Percentages By DAC Designation



## Key Points

- Here DACs are defined by DOE, not CEQ
- Solar penetrations in DACs appear lower (left) but data are sparse because DAC new solar home installations represent a small percentage of all California new solar homes (middle and right)
- This slide compliments an earlier one, which used CEQ DAC definitions

*Note: The Department of Energy's definition of disadvantaged communities (DAC) was used to categorize these data.*

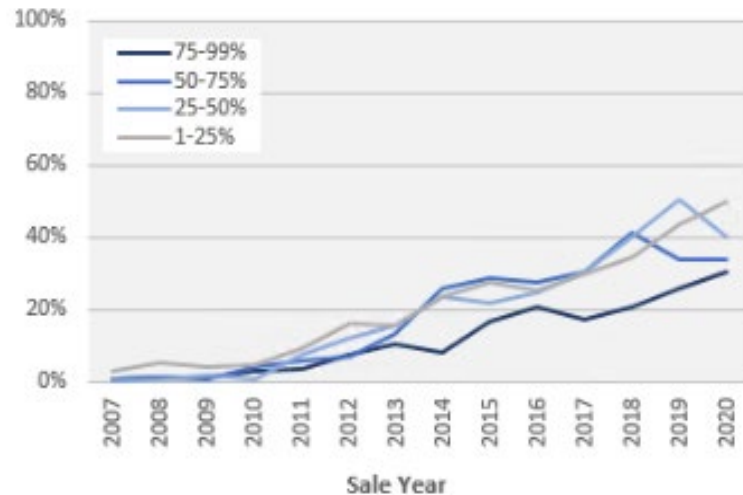




# Solar penetrations are slightly lower in communities heavily burdened by pollution based on CalEnviroScreen

## Penetrations Within CalEnviroScreen Categories

% of New Homes with Solar within Category



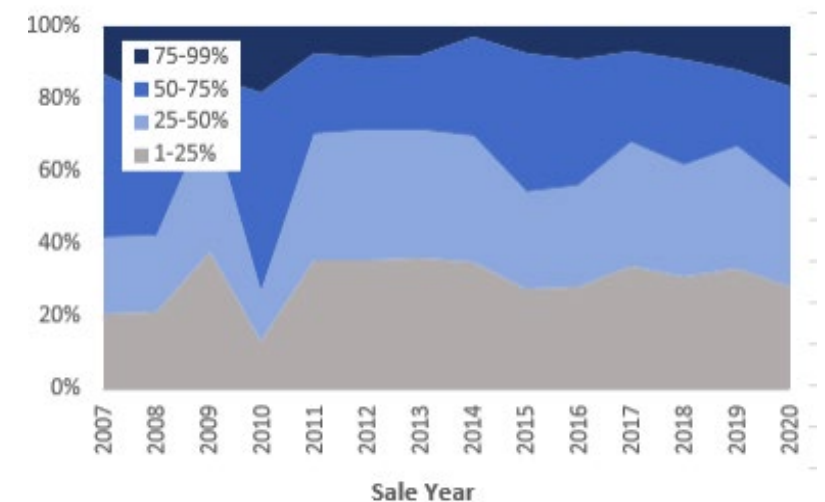
## Breakdown of Total Penetration By CalEnviroScreen Levels

% of New Homes with Solar



## New Solar Home Percentages By CalEnviroScreen Levels

% of New Solar Homes



### Key Points

- The lower penetration of new solar homes in more heavily burdened communities has been present since 2014, indicating a fairly consistent lack of solar installations on the few new homes that have been built in those areas (left)
- Though more recently this difference in penetration has begun to disappear (left), new solar homes in heavily burdened areas still represent a small portion of all new solar homes (middle and right)

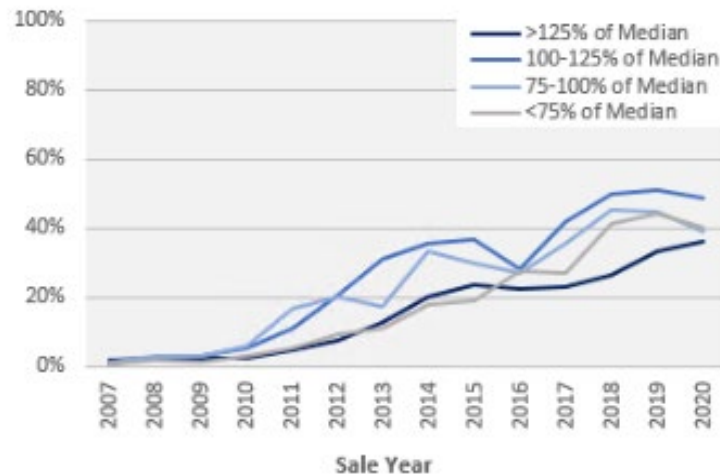
*Note: CalEnviroScreen ranks census tracts in California based on potential exposures to pollutants, adverse environmental conditions, socioeconomic factors and prevalence of certain health conditions. Higher levels (e.g., 75-99%) on CalEnviroScreen indicate as higher burden from pollution.*



# Penetrations are relatively similar across California new home sale price amounts, but are lowest among the highest value homes recently

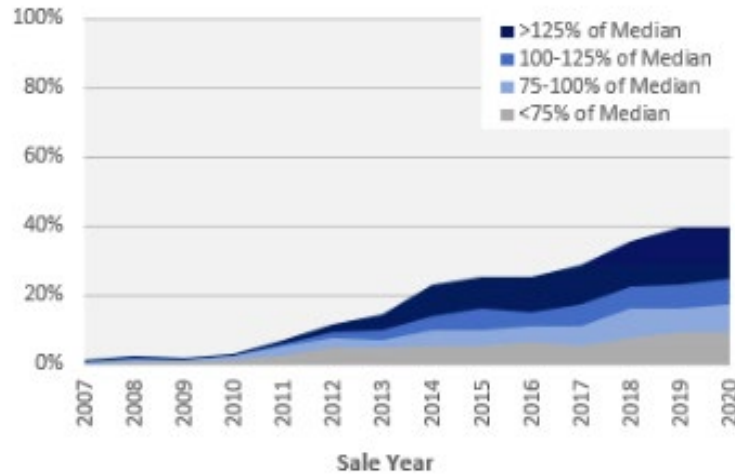
**Penetrations Within Sale Amount Categories**

% of New Homes with Solar within Category



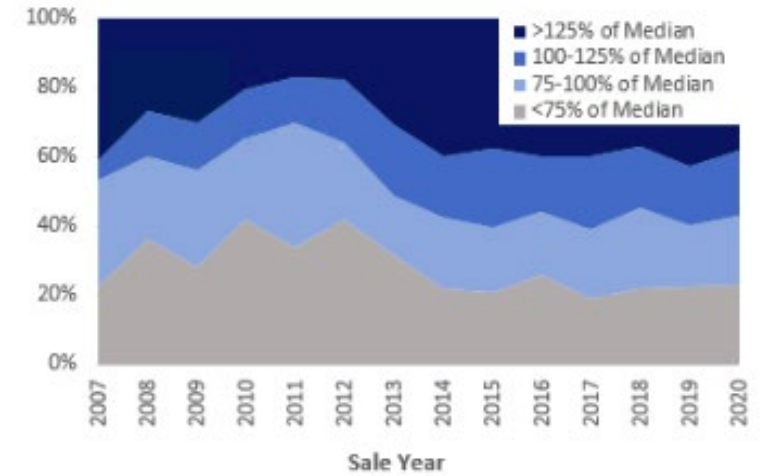
**Breakdown of Total Penetration By Sale Amount**

% of New Homes with Solar



**New Solar Home Percentages By Sale Amount**

% of New Solar Homes



## Key Points

- Since 2016, penetrations in new California homes have been lower for the highest priced homes (>125% of median home price, left)
- This seems to indicate that higher home values do not correlate with higher solar penetrations
- Despite that, these high-priced homes make up the largest percentage of all California solar homes (middle and right)

*Note: Categories are based on the comparison between home sale amount vs. median sale amount in California, by year.*

