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Solar PV on U.S. Houses of Worship

Overview of Market Activity and Trends

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- Data sources
- Market size and growth trends
- Community demographics
 - ▣ Income, race & ethnicity, education
- System characteristics
 - ▣ Size, price, financing, storage
- Installer network
- Key take-aways
- Appendix

Compare to the broader non-residential PV market, and to all houses of worship, as applicable

Data Sources and Approach

- The approximate “universe” of PV systems on U.S. houses of worship (HoW) determined by matching addresses from:
 - ▣ The U.S. Department of Homeland Security’s [All Places of Worship](#) dataset, and
 - ▣ LBNL’s PV Address Dataset, which includes 88% of all U.S. non-residential PV systems installed through 2021,
 - ▣ Supplemented by Interfaith Power & Light’s [Congregational Solar](#) directory
(see appendix for further details)
- U.S. Census data (American Community Survey, 2019 5-year) used to characterize demographic attributes of surrounding counties
- LBNL’s [Tracking the Sun](#) dataset used to characterize PV system attributes (size, cost, financing) for individual systems; current dataset extends through 2021
- Wood Mackenzie’s *Solar Market Insight* report used as the basis for the total size of the non-residential PV market in each state

Market Size: Top-Line Numbers

2,509 systems

Total number of PV systems on U.S. houses of worship (HoW) through 2021

1.9% penetration

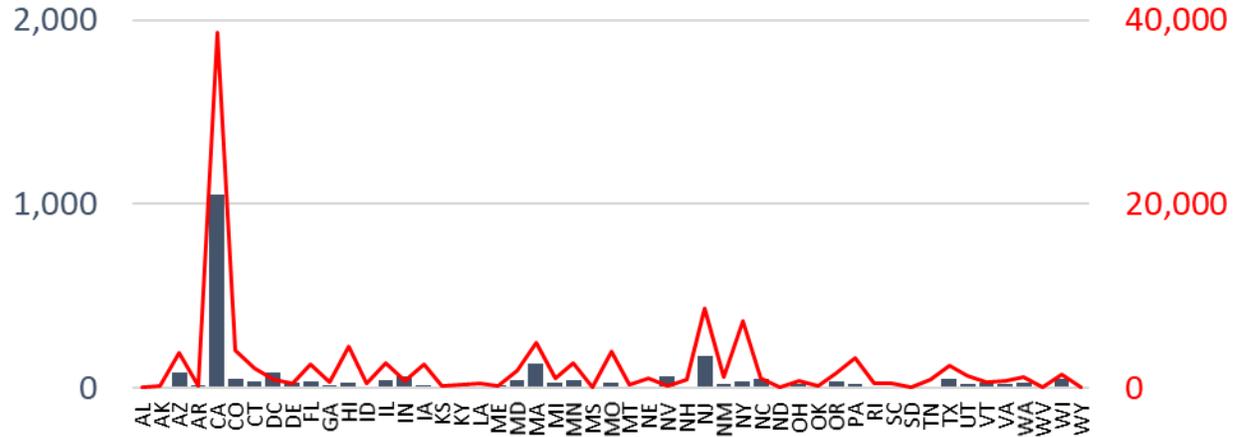
Percent of all U.S. HoW with PV

2.0% market share

HoW share of all non-residential PV systems
(by comparison, HoW represent **0.6%** of all non-residential buildings)

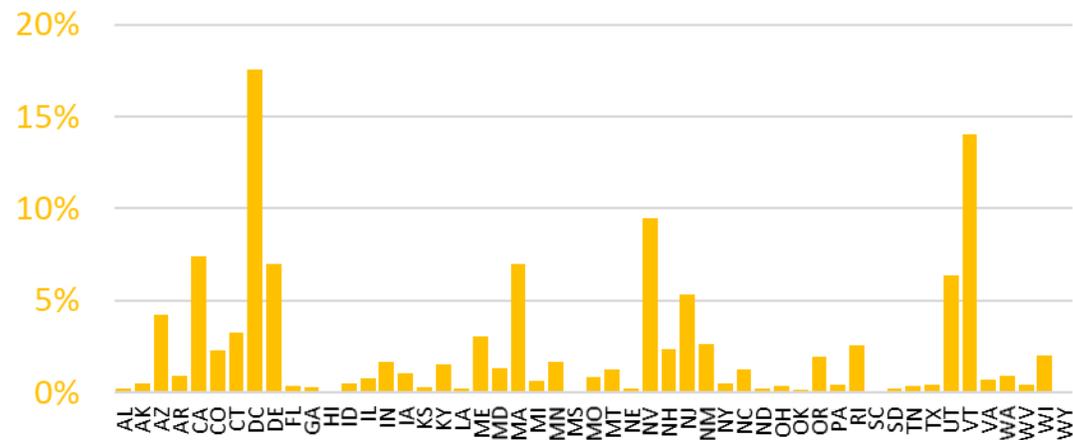
State-Level Market Activity

HoW PV Systems



All Non-Residential PV Systems

Percent of HoW with PV

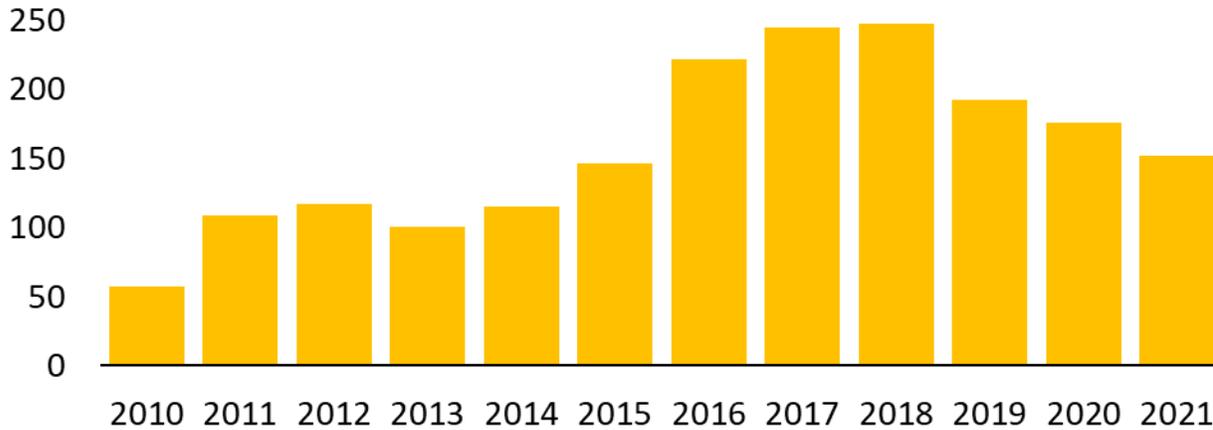


- HoW PV activity largely mirrors trends in the broader non-residential PV market
- Roughly half of all HoW PV systems are in California (compared to one-third of all non-residential systems that are in CA)
- The next 10 largest state markets have roughly 50-175 HoW PV systems each (though coverage in some states is incomplete; see appendix)
- On a relative basis, DC has the highest PV penetration on HoW, where 18% of HoW have PV, followed by VT at 14%
- Six other states (CA, DE, MA, NV, NJ, UT) have PV on 5-10% of HoW

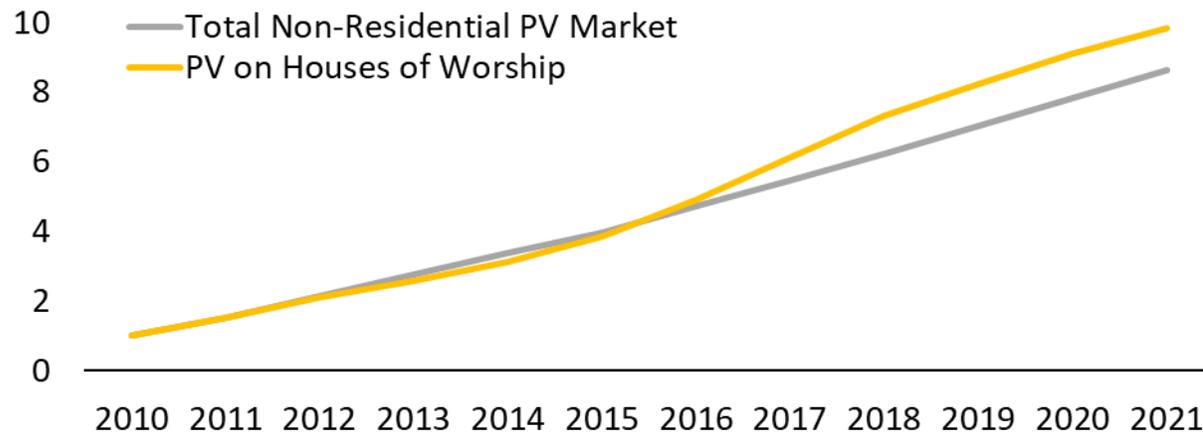
Data table included in appendix

U.S. Market Growth Trends

Annual PV Installs on Houses of Worship



Cumulative Growth in PV Installations (2010=1.0)



- New PV installs on HoW were at their peak in 2016-2018, but have been declining since
- In 2021, roughly 150 new PV systems were installed on HoW
- PV growth on HoW has generally followed in lock-step with the broader non-residential PV market (with the exception of the HoW “boom years” of 2016-2018)

Community Demographic Comparisons

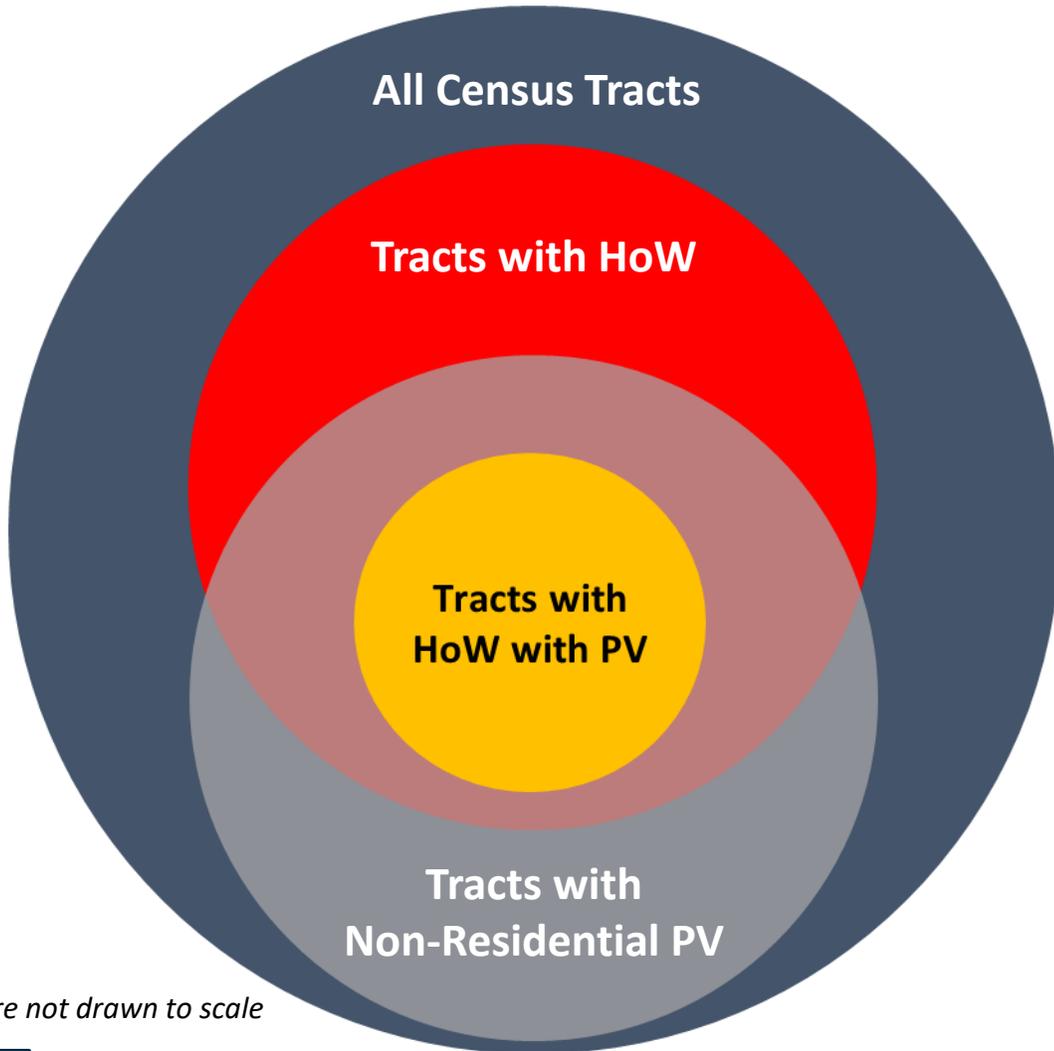


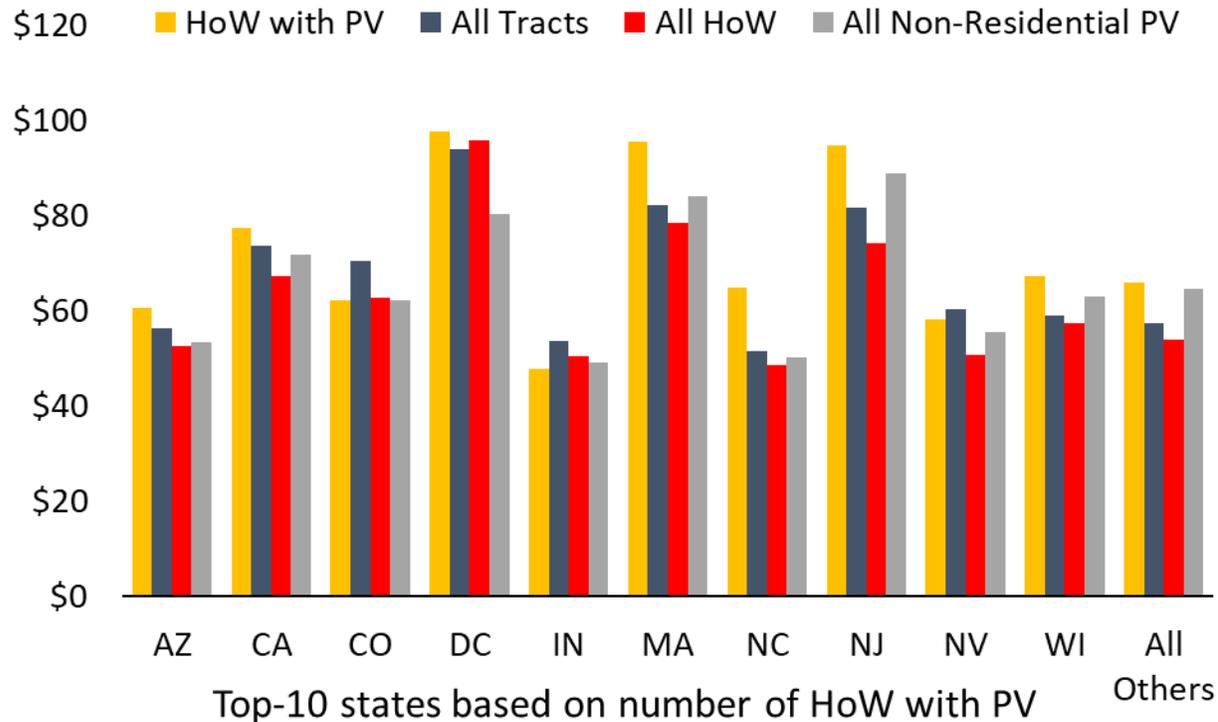
Figure not drawn to scale

- We can associate HoW PV systems with demographic characteristics of the census tracts where these systems are located
- We can then compare to tract-level characteristics of:
 1. **All Census Tracts** in the same state
 2. **All HoW** in the state
 3. **All Non-Residential PV** systems in the state
- The following slides present comparisons for income, race & ethnicity, and education levels
- Comparisons are based on median values, while acknowledging that wide variation may exist around those central tendencies

Household Income

Comparisons based on median household incomes in the surrounding census tracts

Median of Census-Tract Median Household Incomes (Thousand \$)

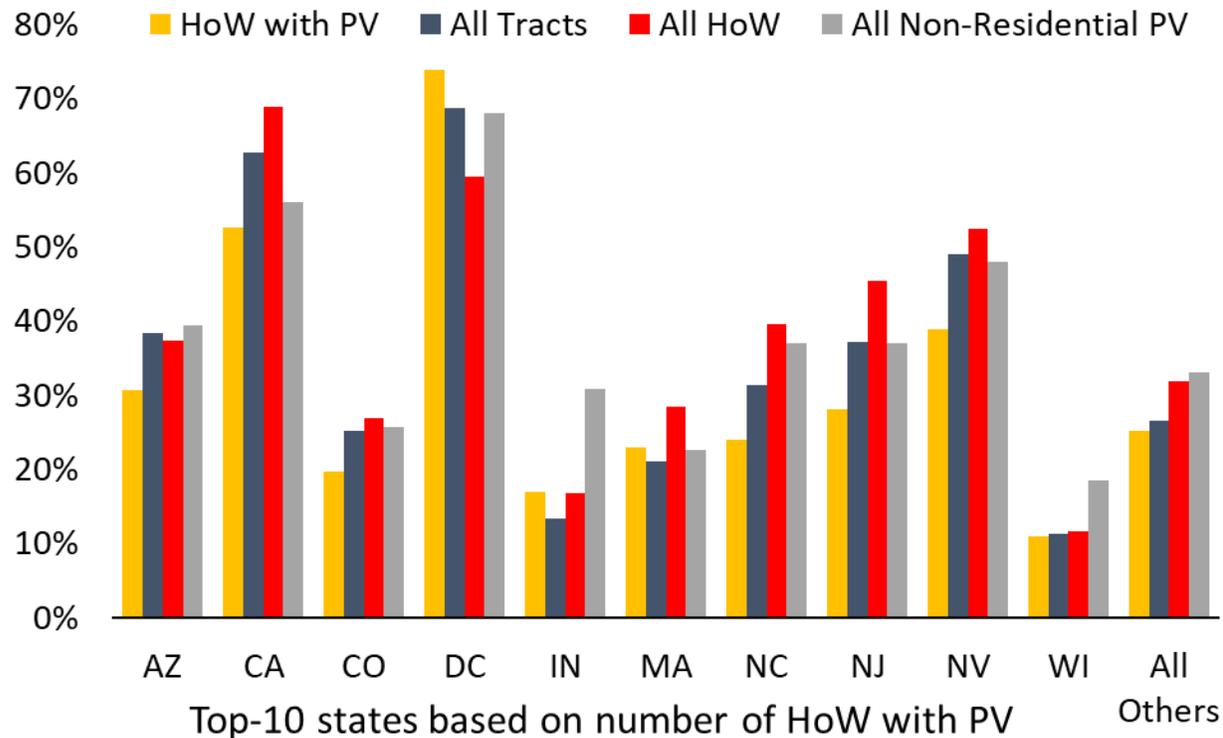


- HoW with PV tend to be located in relatively wealthy census tracts, relative to all tracts in each state, and also relative to just those tracts with HoW
- To some extent, these trends reflect the more general tendency of PV adoption to concentrate in higher income areas
- That said, HoW with PV are also often concentrated in wealthier tracts than the overall non-residential PV market
- Thus the HoW PV market seems to exhibit a *particularly strong skew* toward higher income neighborhoods

Race & Ethnicity

Comparisons based on percentage of the population that is non-White and/or Hispanic

Median Percent Non-White or Hispanic in the Surrounding Tract

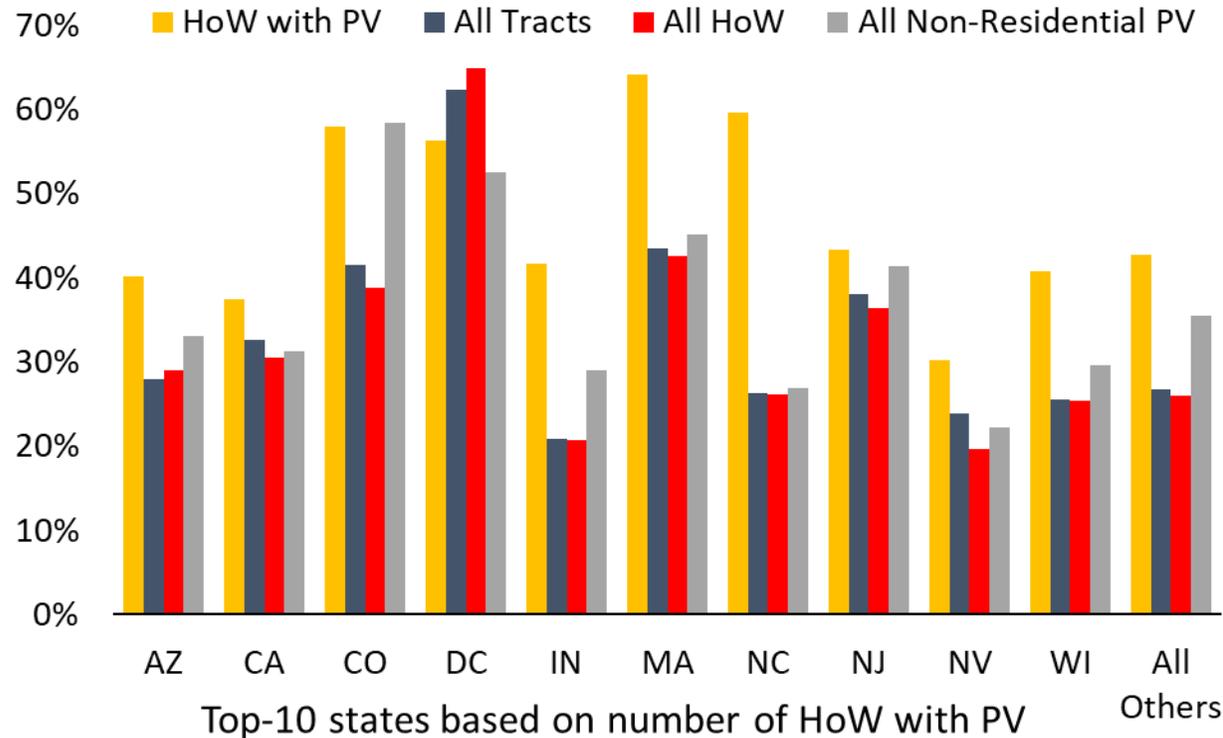


- HoW as a whole tend to be located in tracts with *relatively high* non-White or Hispanic populations, compared to the broader population in each state
- In contrast, HoW with PV tend to be located in census tracts with *relatively low* non-White or Hispanic populations
- HoW with PV also tend to be concentrated in tracts with relatively low non-White or Hispanic populations compared to other non-residential PV systems
- DC is an obvious exception to these trends

Education Levels

Comparisons based on the percentage of householders with at least a Bachelor's degree

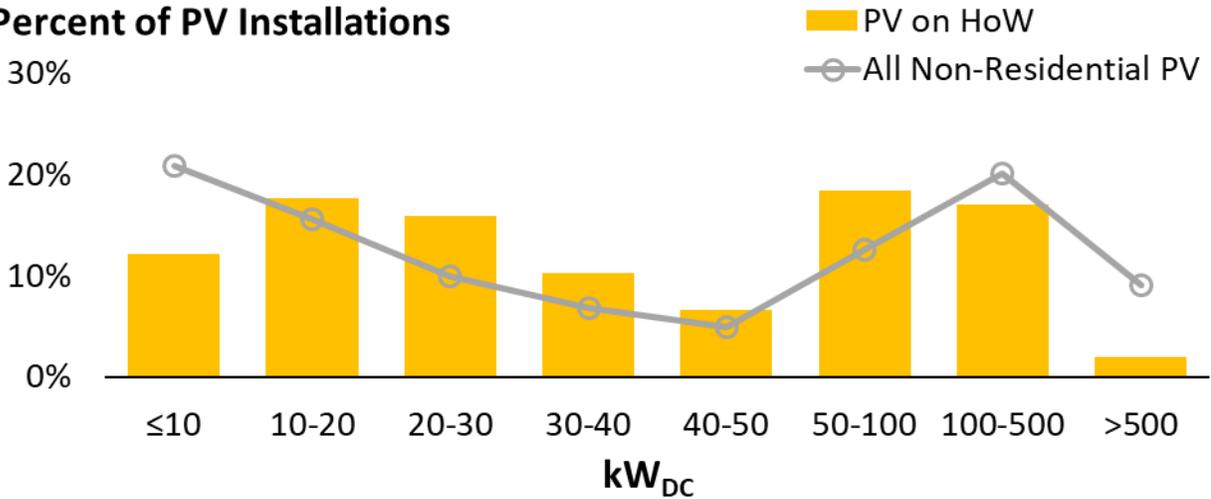
Median Percent with at least Bachelor's Degree in the Tract



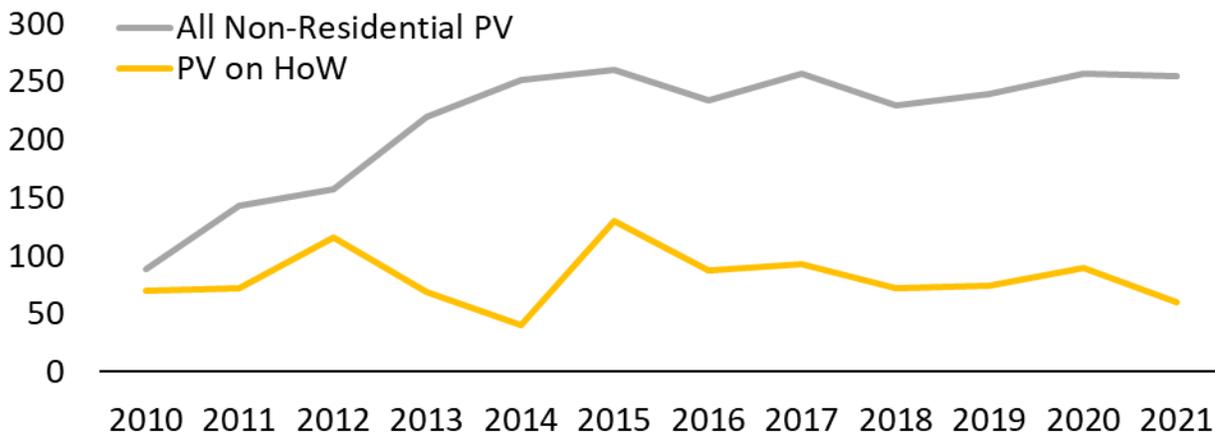
- HoW as a whole are distributed more or less proportionately across the population, in terms of education levels of the surrounding community
- In contrast, HoW with PV tend to be located in tracts with relatively highly educated populations
- This trend is even more pronounced than those related to income or race/ethnicity
 - ▣ Education levels in tracts with HoW PV are ~50% higher than in all HoW tracts
 - ▣ In comparison, income levels are ~15% higher, and non-White/Hispanic population shares are ~15% lower

System Sizing

Percent of PV Installations



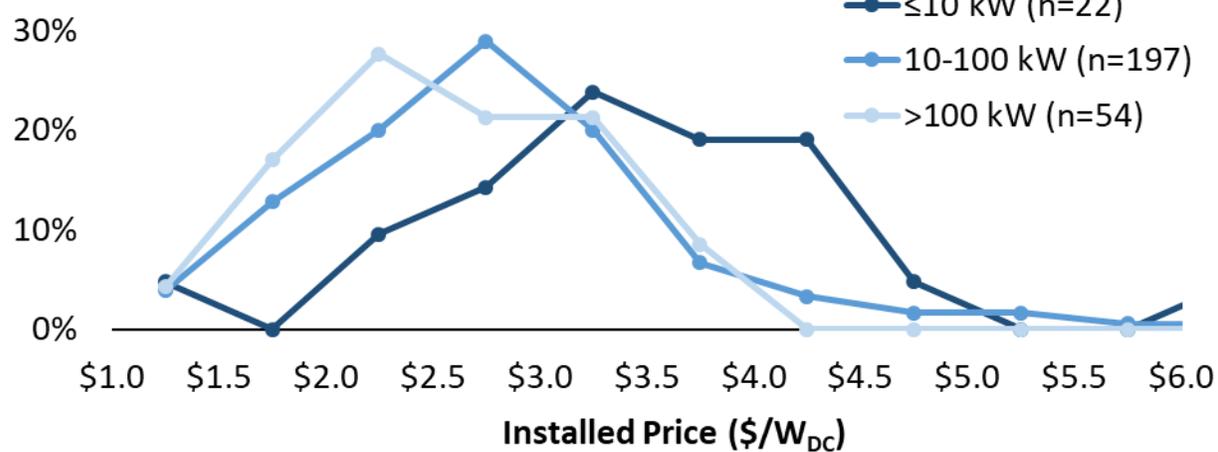
Average System Size (kW_{DC})



- PV systems on HoW average 80 kW, but vary widely in size
- Size distribution is generally similar to other non-residential PV systems, albeit with a notably smaller share of systems >500 kW
- Average non-residential PV sizes increased significantly during the early years of the last decade as the market evolved toward larger applications (schools, big box stores, warehouses)
- In contrast, sizing for PV on HoW has remained flat, partly reflecting sizing constraints inherent to HoW (e.g., roof area, onsite load)
- That said, it is notable that the market hasn't evolved toward larger HoW project sizes and sites (mega-churches, parking structures, etc.), given potential economies of scale

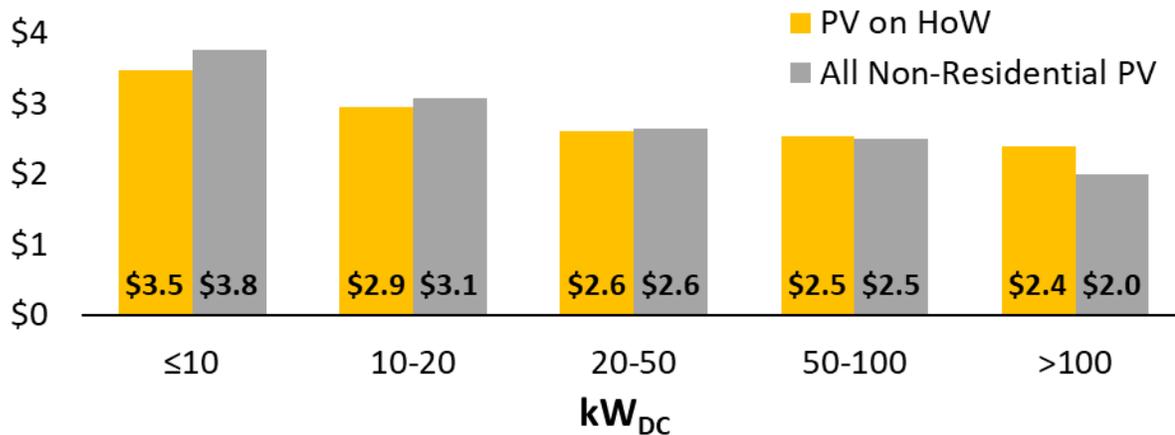
Installed Prices

Percent of HoW PV Systems (2019-2021)



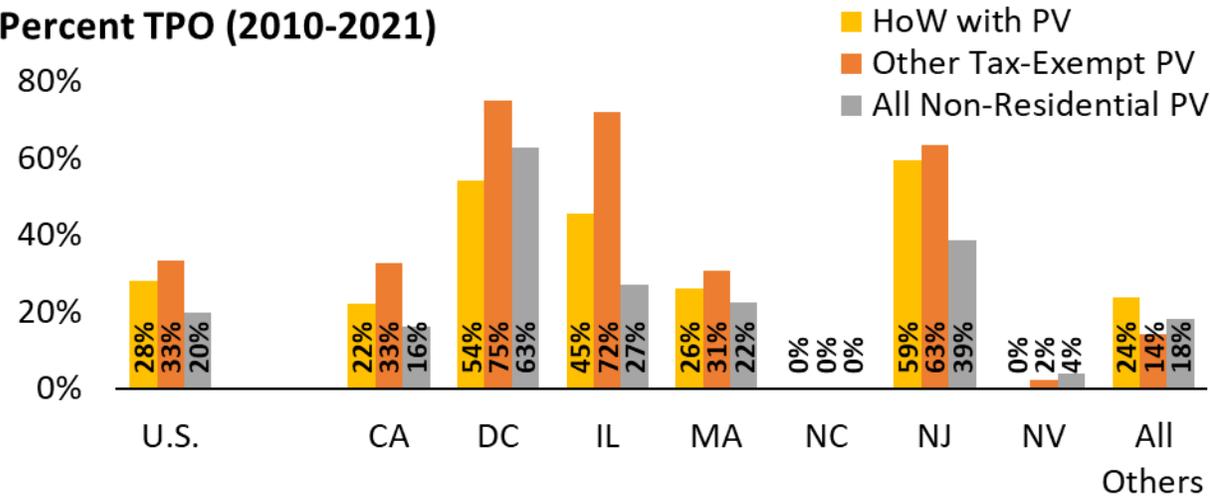
- PV pricing levels vary widely for HoW, even within a given size range
- For example, systems ≤10 kW had an inter-quartile (25th to 75th percentile) range from \$2.9/W to \$4.3/W, with a median of ~\$3.5/W
- As to be expected, prices are lower for larger systems
- Prices for PV systems on HoW are generally in-line with prices for other non-residential PV systems within the same size range

Median Installed Price, 2019-2021 (\$/W_{DC})

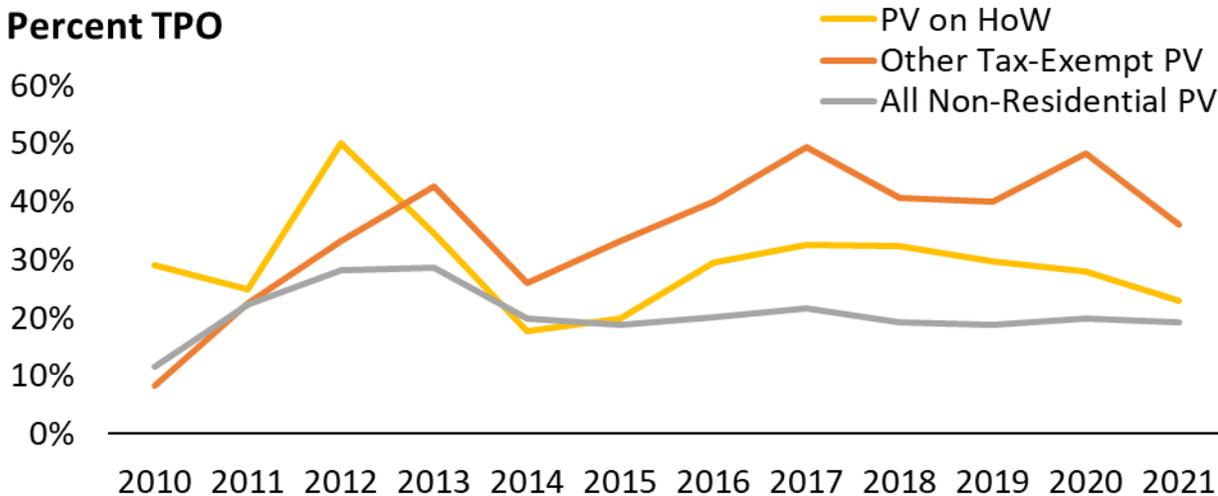


Third-Party Ownership

Percent TPO (2010-2021)



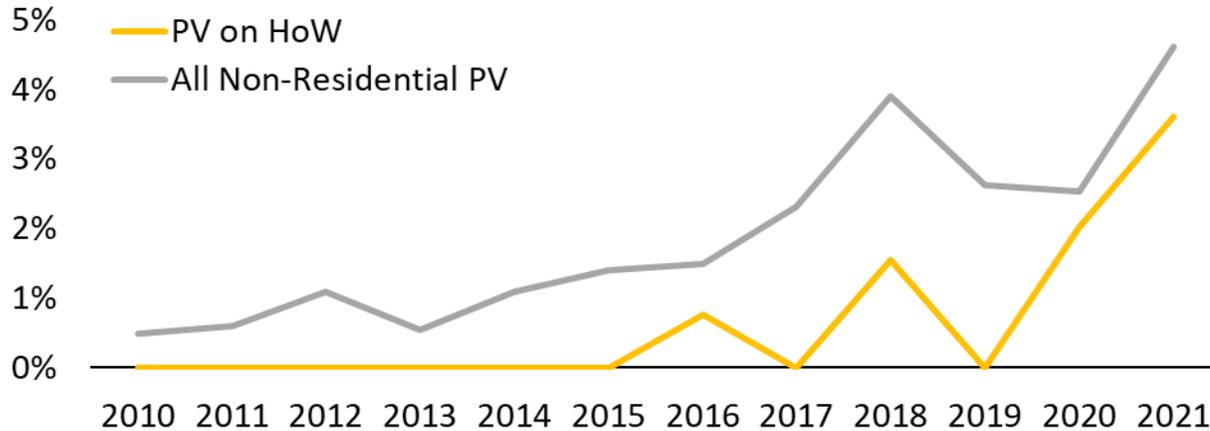
Percent TPO



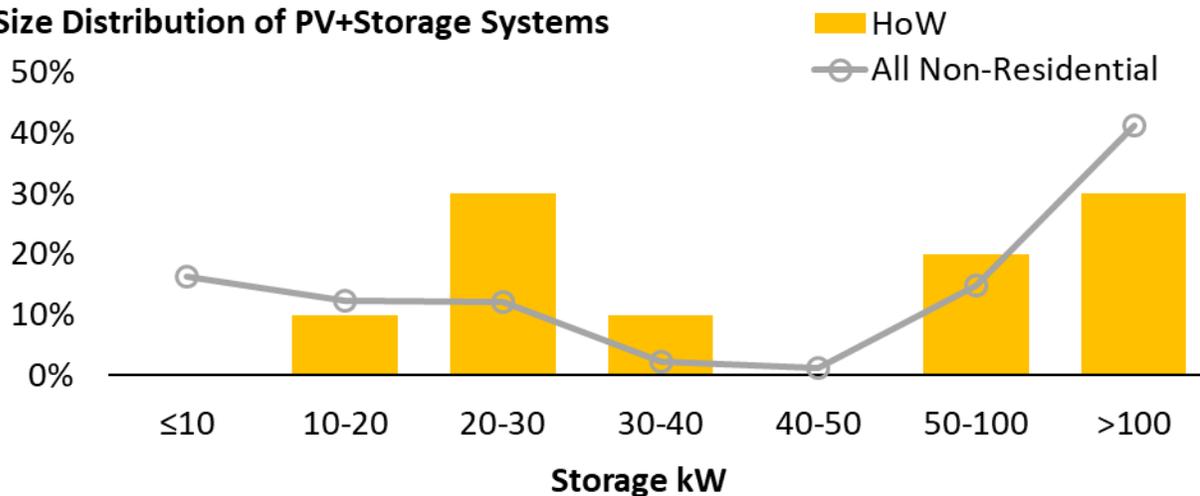
- TPO allows tax-exempt entities, such as HoW, to monetize the federal tax credit (though new “direct-pay” option under the IRA will eliminate that need)
- 28% of all PV systems on HoW are third-party owned (TPO)
- TPO shares are slightly higher for HoW than for the broader non-residential market (20%), though less than other tax-exempt PV systems (33%)
- TPO shares are higher in states such as DC, IL, and NJ that have lucrative incentives
- As in the broader non-residential PV market, TPO shares for HoW have declined somewhat from their peak a decade ago

Solar Paired with Storage

Percent of PV Installs with Storage



Size Distribution of PV+Storage Systems



- Adding battery storage to PV installations can enhance utility bill savings (depending on the rate structure) and may allow HoW to serve as community resiliency hubs during power outages
- Pairing solar with battery storage has become slightly more common in recent years, but is still a very small part of the market (~4% of HoW PV systems installed in 2021 included storage)
- Storage attachment rates are lower than in the broader non-residential PV market, potentially owing to the higher costs
- Virtually all of the paired PV+storage systems on HoW are in California, where incentives and wildfire issues have led to higher rates of adoption
- Storage system sizes for HoW vary widely, and about half are relatively large systems >50 kW, consistent with the broader non-residential market

Installer Network

Top-10 Installers by # of Systems

	Installer Name	Share	Avg. Size (kW)
1	Tesla Energy	3%	81
2	Sunbug Solar	2%	37
3	Sullivan Solar Power	2%	76
4	Geoscape Solar LLC	2%	43
5	RGS Energy	1%	71
6	Sunwork Renewable Energy	1%	20
7	Solarcraft Services	1%	75
8	Solar Technologies	1%	88
9	A-C Electric Company	1%	138
10	Baker Electric Solar	1%	156
	All others (557 installers)		

Top-10 Installers by Installed Capacity

	Installer Name	Share	Avg. Size (kW)
1	Heelstone Renewable Energy	6%	6500
2	Gehrlicher Solar America Corporation	4%	3580
3	Tesla Energy	3%	81
4	Renewable Energy Partners	3%	212
5	Baker Electric Solar	2%	156
6	Sel Construction	2%	197
7	A-C Electric Company	2%	138
8	Sullivan Solar Power	2%	76
9	Sunbelt Solar Corp	2%	813
10	Solar Renewable Energy Concepts	2%	1621
	All others (557 installers)	74%	70

- More than 550 installers have serviced the HoW PV market over the years
- The vast majority have completed just a few HoW installations, and most are local or regional firms
- In general, the market is fairly dispersed: Tesla comprises the largest market share in terms of the number of systems installed, at 3%
- The firms with the largest shares of installed capacity tend to focus on larger systems, including several firms that have installed large multi-MW project (ground-mounted, utility connected)

Key Take-Aways

- Houses of worship (HoW) are a small but outsized portion of the overall U.S. non-residential PV market, though its share of the market has been diminishing over time
- California dominates the HoW PV market in terms of sheer volume, but a number of other states have relatively high penetration rates (DC is the highest, where 18% of all HoW have PV)
- HoW with PV are disproportionately located in relatively wealthy, White, and educated census tracts, compared to the overall population, to all HoW, and to other non-residential PV systems in each state (with a particularly strong skew in education levels)
- PV systems installed on HoW vary widely in size, but have not been trending larger, as seen in the broader non-residential PV market
- PV pricing for HoW is similar to the broader non-residential PV market, for similarly sized systems
- Third-party ownership has been slightly more popular for PV systems installed on HoW, though not as common as for other tax-exempt PV site hosts
- A growing but still small share of HoW PV systems are paired with storage, almost all in CA
- PV installations on HoW have primarily been installed by relatively small local or regional firms



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Appendix



HoW PV Sample Construction and Market Size Estimate

DHS HoW Dataset		
(A)	Total Number of Records	254,742
(B)	Total Number of Unique Addresses	237,366
(C)	Unique Addresses Matched to LBNL PV Dataset	4,485
(D)	Matched Records with a Business Address	1,640
IPL Dataset		
(E)	Full IPL Dataset	1,278
(F)	Records with Addresses	780
(G)	Incremental to (D)	595
HoW PV Sample		
(H)	Full HoW PV Sample (D+G)	2,235
(I)	HoW PV Subsample with PV Attributes	1,396
HoW Market Size Estimates		
(J)	Total Number of HoW	132,812
(K)	Total Number of HoW with PV	2,509

Abbreviations: DHS = Department of Homeland Security, IPL = Interfaith Power & Light

Notes:

- (D) Each DHS record was sent to Melissa Data, which matched to official USPS addresses and also provided an “address type” (either business, residential, or unknown). LBNL conducted visual verification of a random sample of addresses, using photo imagery from Google maps and streetview. Based on that verification process, it was determined that virtually all records with business addresses are HoW, but virtually no records with residential addresses are HoW, and roughly 40% of records with unknown address types are HoW. On that basis, only those DHS records with a business address were used in the analysis.
- (E) The Full IPL Dataset includes state identifiers, but not street addresses.
- (H) The Full HoW PV Sample was used for the demographic comparisons.
- (I) The HoW PV Subsample with PV Attributes was used to characterize PV system attributes and the installer network
- (J) The Total Number of HoW was estimated from (A) and is equal to 100% of records with a business address + 40% of records with an Unknown address type + 60% of records without an address type returned. Those latter two percentages were based on visual spot checks for a random sample of addresses. For states where the count from the full IPL dataset (E) is larger, those values were used instead.
- (K) The Total Number of HoW with PV was estimated from (C), following the same procedure as described above for (J), by taking the sum of the records of business addresses plus a portion of those with Unknown address types or without an address type

State Totals

State	Total Non-Residential PV Market		Estimated HoW Market Size	
	Number of Systems through 2021 ^(a)	LBNL Market Coverage ^(b)	Number of HoW ^(c)	Number of HoW with PV ^(c)
AL	107	30%	1,729	3
AK	142	1%	415	2
AZ	5,478	100%	1,963	83
AR	221	13%	1,280	11
CA	38,691	91%	14,223	1,054
CO	5,181	100%	2,124	49
CT	2,073	93%	1,138	37
DC	836	89%	454	80
DE	469	100%	389	27
FL	2,490	83%	9,308	32
GA	635	27%	5,156	15
HI	4,559	28%	unavailable	26
ID	422	43%	595	3
IL	2,648	93%	5,672	45
IN	754	13%	3,626	60
IA	2,534	3%	1,578	16
KS	175	40%	1,754	5
KY	290	6%	1,615	24
LA	478	31%	1,770	4
ME	915	100%	362	11
MD	1,902	45%	2,878	38
MA	5,327	100%	1,841	128
MI	1,025	24%	4,566	27
MN	2,720	75%	2,630	44
MS	63	10%	1,024	0
MO	3,883	15%	3,021	25

State	Total Non-Residential PV Market		Estimated HoW Market Size	
	Number of Systems through 2021 ^(a)	LBNL Market Coverage ^(b)	Number of HoW ^(c)	Number of HoW with PV ^(c)
MT	342	53%	581	7
NE	1,022	4%	1,006	2
NV	1,146	100%	641	61
NH	866	82%	356	8
NJ	8,705	76%	3,299	175
NM	1,114	85%	916	24
NY	9,551	100%	8,332	38
NC	2,090	100%	3,996	50
ND	7	57%	428	1
OH	798	100%	5,599	20
OK	152	28%	1,958	2
OR	2,967	100%	1,765	34
PA	3,239	41%	5,310	22
RI	824	100%	352	9
SC	491	37%	3,277	1
SD	5	20%	533	1
TN	904	20%	2,360	8
TX	3,295	100%	10,713	46
UT	1,250	89%	345	22
VT	678	63%	214	30
VA	755	100%	3,423	23
WA	2,263	100%	2,791	25
WV	64	13%	780	3
WI	1,547	100%	2,484	50
WY	70	7%	242	0
Total	116,103	88%	132,812	2,509

Notes: (a) Based on the larger of either the total reported in WoodMackenzie's Solar Market Insights report or LBNL's PV Address Dataset. (b) Market coverage refers to the portion of all non-residential systems included in LBNL's PV Address Dataset. (c) Estimated based on the data sources and decision rules described on the previous slide.

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