Title

Commercial PV Property Characterization: An Analysis of Solar Deployment Trends in Commercial Real Estate

Authors

Hoen, Ben

Rand, Joseph

Elmallah, Salma

Publication Date

2019-09-26

Peer reviewed

Energy Technologies Area Lawrence Berkeley National Laboratory

Commercial PV Property Characterization

An Analysis of Solar Deployment Trends in Commercial Real Estate

Ben Hoen, Joe Rand and Salma Elmallah

Lawrence Berkeley National Laboratory

September 2019

This analysis was funded by the U.S. Department of Energy Solar Energy Technologies Office under Contract No. DE-AC02-05CH11231

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

Acknowledgments

This analysis was funded by the U.S. Department of Energy Solar Energy Technologies Office under Contract No. DE-AC02-05CH11231. We thank Dave Rench-McCauley, Anna Ebers, Ammar Qusaibaty and Shubha Jaishankar of the U.S. Department of Energy's Solar Energy Technologies Office (SETO) for their support of this work.

We would also like to thank Ryan Wiser, Mark Bolinger, Naim Darghouth and Galen Barbose of Berkeley Lab for providing comments on the research and/or the draft results as well as the following: Rob Gauchat of Solar Liberty; Dave Riess of The Wunder Company; Drew Torbin of Black Bear Energy; Hugh Bromley of BloombergNEF; Erin Hiatt of the Retail Industries Leaders Association (RILA); and, Billy Grayson of Liberty Property Trust. We would also especially like to thank Richard Veith and Stuart Feldstein of SMR Research for the countless ways they supported this project including, but not limited to, draft results review.

Of course, the authors are solely responsible for any remaining omissions or errors.

Disclaimer

Copyright Notice

Outline

- **Overview and Background**
- Data
- Results
  - PV Penetration Overall, State and Property Type
  - What Property & Building Characteristics Are Correlated With Higher Penetrations?
  - How Have PV Property & Building Characteristics Changed Over Time?
  - How Have PV System Characteristics Changed Over Time, And By State and Property Type?
- Conclusions & Next Steps
- Appendix

Project Overview

Objective: *Describe commercial PV adopter trends as it relates to real estate, highlighting differences in PV vs. non-PV properties and potential opportunities for future deployment.*

Unique features of this analysis

- ***Nationwide commercial real estate database*****:** SMR Research address-level real estate database has nationwide coverage and contains a rich set of property and building descriptive fields. Almost 2.5 million properties are used for this analysis
- ***Relatively extensive coverage of the U.S. solar market*****:** Based on Berkeley Lab's *Tracking the Sun (TTS)* dataset, of roughly 1.3 million systems, covering ~81% of the total U.S. market (Barbose et al., 2018)
- ***Manual sample infilling:*** To accommodate for the difficulty of matching commercial property address records from multiple sources, manual infilling of a representative sample is conducted

Scope

- ***Rooftop installations on commercial (i.e., non-residential, non-community, non-utility-scale) properties*****:** Considerable effort was made (as will be discussed on following slides) to ensure the analysis focused on non-residential real estate while excluding community & utility-scale solar.
- ***Systems installed through 2017 in 20 states*****:** Focuses on states in TTS dataset with address data available for installs through 2017 encompassing ~32,000 installs; later work may evaluate more-recent adopters and additional states
- ***Basic descriptive trends*****:** Focus here is on establishing building and solar system characteristic trends over time, among states and property types and, where possible, describe PV and non-PV property differences

This work documents basic trends in the commercial PV real estate market, building on previous, yet mostly fee-based-access, literature

- Some prior analyses of commercial PV-adopter trends and potential exist:
  - Wood Mackenzie (formerly GTM) reports on commercial PV adopter trends, but they are only available for a fee (Davis, 2017). Some detail from reports are available via articles (e.g., Davis, 2018a; 2018b; 2018c; Davis & Smith, 2018; Merchant, 2018)
  - Gagnon et al. (2016) estimate a capacity potential of 154 GW in commercial buildings between 5,000 and 25,000 ft^2
  - Bird et al. (2016) estimate 44 GW of potential in office, hotel and warehouses, with ½ from just offices
- These reports are fairly limited with regard to real estate properties and their characteristics:
  - They focus only on broad set of PV property types (e.g., commercial vs. industrial vs. municipal etc.) but not the characteristics of those property types nor the solar systems installed on them
  - They do not contrast them with non-PV properties where a better understanding of trends might emerge, nor do they provide details about the PV systems across property types
- Yet some interesting topics from the work invite further inquiry:
  - Enormous potential exists for commercial PV (Gagnon et al., 2016; Bird et al,, 2016), but has that been realized?
  - Financing has been a major hurdle for the commercial market (Davis, 2018c), but that might be changing (Merchant, 2018; Davis, 2018a). Do we see property types that benefit from third-party financing showing signs of solar deployment acceleration?
  - There has reported to be significant upward change in the number of third-party owned systems in the commercial market (Davis, 2018b). Do we see that in our data?
  - Corporate solar interest has helped drive PPA procurement, but do we see a corresponding growth in installations on corporate-owned properties?

Outline

- Overview and Background
- **Data**
- Results
  - PV Penetration Overall, State and Property Type
  - What Property & Building Characteristics Are Correlated With Higher Penetrations?
  - How Have PV Property & Building Characteristics Changed Over Time?
  - How Have PV System Characteristics Changed Over Time, And By State and Property Type?
- Conclusions & Next Steps
- Appendix

Analysis builds off *Tracking the Sun (TTS) dataset*

- TTS 11 dataset (August 2018 release)
  - System-level PV data through 2017
  - 32,317 "commercial" systems with street addresses
- This analysis focuses on 20 states, 12 with relatively complete address-level coverage (listed in table to the right)
  - Analysis sample represents 60% of all commercial systems in the 20 states covered, and 67% in the 12 states with > 60% TTS coverage through 2017 (see *)
    - Note: Coverage %s (E) depend on the denominator, which may contain: residential, community or utility-scale installs; ground-mount systems; and, multiple systems at the same address. Each are excluded from the present analysis.
  - Missing from the analysis are a number of relatively large state commercial markets: AZ, CO, HI, and MD

See appendix for additional details on data sources and sample sizes by installation year.

	A	B	C	D	E
State	TTS Thru-2017 PV Addresses Matched to SMR Commercial Database	TTS Thru-2017 PV Addresses Matched to USPS "Business" (and Not SMR-Matching) (Estimated)	Total Commercial PV Addresses in CPVP Analysis (A+B)	US "Non-Residential" Thru-2017 PV Systems	TTS "Commercial" Addresses vs Non-Residential System Totals (C/D)
AR	4	7	11	39	28%
CA*	10,537	5,255	15,792	25,054	63%
CT	200	73	273	1,145	24%
DC*	212	76	288	285	>99%
FL	196	169	365	1,724	21%
IL	62	74	136	393	35%
MA*	2,138	844	2,982	3,765	79%
MN	159	32	191	1,233	15%
NC*	345	205	550	529	>99%
NH*	203	60	263	409	64%
NJ*	2,402	1,867	4,269	6,660	64%
NM*	176	307	483	619	78%
NV*	328	301	629	882	71%
NY*	2,095	1,038	3,133	4,960	63%
OH*	363	148	511	477	>99%
OR*	737	241	978	972	>99%
PA	736	153	889	2,754	32%
RI*	50	25	75	51	>99%
TX	101	95	196	1,561	13%
WI	213	90	303	748	41%
All	**21,257**	**11,060**	**32,317**	**54,260**	**60%**

*Notes: Market Size (D) is based on maximum value reported across three sources: EIA Form 861 data, GTM Solar Market Insight, and TTS "Non-Residential" 2018. Importantly, Market size is based on numbers of systems and the CPVP analysis is focused on unique addresses that match either SMR of USPS. Where there are multiple systems at a single address, or an adress does not match one of the two sources of commercial information, it would not be counted. Therefore, the % totals in Column E likely underestimate the actual coverage. *indicates >60% "coverage"*

BERKELEY LAB

SMR Research commercial real estate data

Matched to TTS data; contains a rich set of property and building characteristics

- All TTS PV addresses are sent to SMR for matching
  - SMR has both commercial and residential datasets so initial matching is done to one or the other
  - > 1 million addresses sent: 890k residential; >22k commercial; 114k unmatched
    - non-matches occur for various reasons but mostly differences in mailing address used often in TTS and parcel address used in SMR (such as P.O. boxes, and suite #s)
  - SMR also provided data on <u>all</u> unmatched commercial properties from which the non-PV segment used for this analysis is comprised (see slide 12 for more detail)
  - SMR data were updated through the end of 2018

SMR RESEARCH

- SMR provided a rich set of property, building and occupant data on matched records
  - Property data: overall property use type
  - Building characteristics: square feet; year built; stories; owner-occupied; and, market value
  - Occupant data: number of tenants; and corporate (vs. individual) ownership

United States Postal Service (USPS) data

Also matched to TTS; determine if address is considered "Business" by USPS

- All TTS PV addresses were also sent to Melissa Data - a service provider for matching to USPS data
  - USPS matching produces high match rates (94%) so allows us to determine "business" vs. "residential" for almost all of the TTS properties.
- USPS "Business" aligns well with both TTS customer segments and SMR property types so it serves as a useful proxy
  - >90% are identified as non-residential from TTS data sources
  - >94% are identified as "commercial" by SMR
- Those USPS "Business" addresses that did not match to SMR could be further investigated in order to "in-fill" data
  - This is discussed on the next slide

UNITED STATES POSTAL SERVICE®

melissa GLOBAL INTELLIGENCE

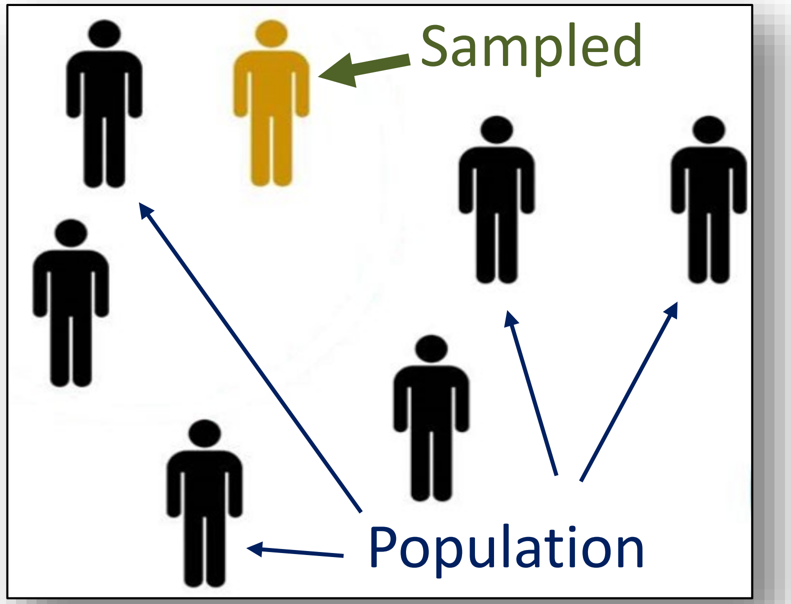
Non-SMR matching data are examined to fill in gaps in data

Publicly-available online data from multiple sources used to infill

- USPS "Business" addresses from TTS that did not match to SMR commercial were investigated
  - Online publicly available data such as Google Maps, Google Earth and other online sources allowed us to infill data to add to the SMR-matched dataset. Collecting these data was manual and therefore time consuming
- A randomly drawn sample of ~900 addresses were pulled from the what was originally ~12,000 non-SMR-matching set of USPS "Business" addresses
  - No less than 30 addresses were drawn for each state most were > 40
- While viewing the properties' roofs online, likely erroneous data were screened out, improving the quality of these non-SMR matching data
  - Because one of the reasons these addresses did not match to SMR was because they were wrongly inputted originally before TTS collected them, if erroneous data were discovered they were screened out of this non-SMR matching dataset.
  - Using imagery, it was determined if the building had solar (assuming imagery was available after the system was installed). If it did, then the number of panels was checked to ensure it conformed with the expected number calculated using the rated system capacity and annual state-level panel capacity averages.
  - If either solar was not found or the number of panels was outside the expected range then the property was excluded.
  - **This reduced the final weighted non-SMR matching dataset to 11,060 systems**.
- Key data were collected and in-filled when available
  - 1) Parcel property type categories based on occupant type and visual inspection; 2) building size estimated using Google Earth measurement tools; 3) numbers of stories based on visual inspection; and, 4) numbers of tenants using address records and Google search.

Data collected from both SMR-matching and non-SMR-matching datasets are combined using weights

- PV property data from SMR-matching and non-SMR-matching sources are combined, where possible
  - Data fields collected from both sources include: property type, number of stories, square feet, and numbers of tenants
  - Data fields collected from only SMR include: market value, owner-occupied, building age, and corporate owned
- Because only a sample of non-SMR-matching data were examined, weights were needed to apply findings to full non-SMR-matching data
  - For example, if we found that 17% of the 900 non-SMR-matching sample were education properties, we would assume that out of the full non-SMR-matching data of 11,060 properties, ~1,880 were education properties
  - Weights were similarly applied to other fields in the non-SMR-matching data



Defining the "Comparable" Non-PV Population

- Throughout the analysis, commercial PV properties are compared to a set of non-PV commercial properties
  - These non-PV properties are culled from any SMR commercial properties which did not match to TTS PV properties (~ 5.5 million properties)
    - In the figure to the right, this would be any part of the blue circle not contained in the Commercial PV Properties area
- Because many states did not have even coverage, a subset of the SMR commercial non-PV properties were used:
  - They include all non-PV commercial properties from any zip code where at least one commercial PV property exists (~2.5 million properties)
  - This was done to reduce differences that might exist for properties where PV is unlikely to be developed <u>and</u> therefore, to reduce spurious differences between the PV and non-PV cohorts

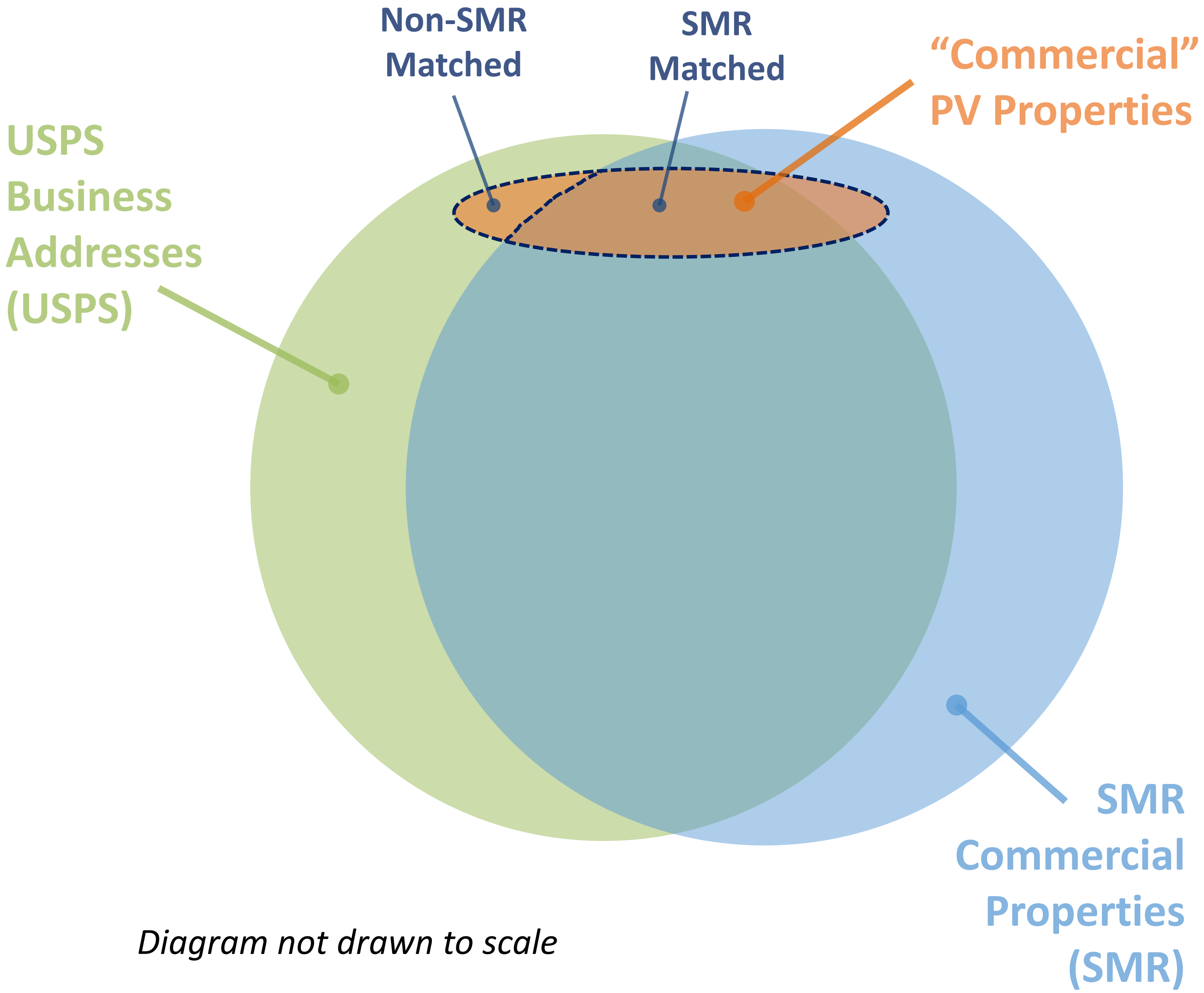


Diagram not drawn to scale

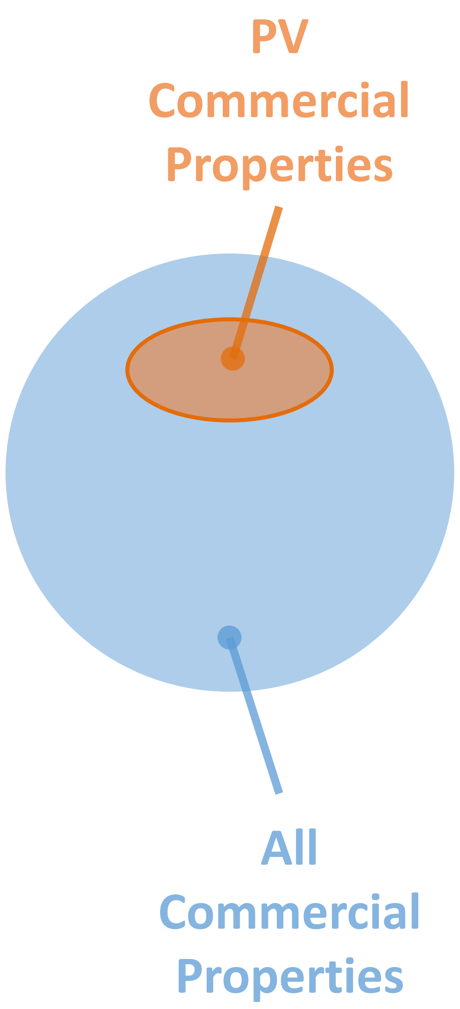
Final PV and Non-PV Dataset Screening and Cleaning

- To ensure a final dataset that was suitable for analysis and did not contain outliers a number of property- and solar system-level characteristic screens were used to cull data (resulting in the totals in the table to the right)
  - All properties needed to have either building size, year built, or an assessed improvement value populated, which would indicate there is a building on the property; and,
  - For PV properties, system size needed to be populated and be < 2,000 kW and not have ground-mount systems to, hopefully, exclude community and utility-scale systems
- Additionally, the following fields were considered "missing" if they were outside the 1 & 99 percentile range noted below (but the record was retained):
  - Building size: 1,000 to 200,000 ft^2
  - Building market value: $10 to $850/$ft^2$
  - PV system installed cost: $1 to $16.75/watt

State	Commercial PV			Commercial Non-PV
	SMR Match	Non-SMR Match	Total	
AR	4	7	11	3,269
CA	10,537	5,255	15,792	654,240
CT	200	73	273	50,637
DC	212	76	288	13,361
FL	196	169	365	63,198
IL	62	74	136	45,692
MA	2,138	844	2,982	162,608
MN	159	32	191	43,415
NC	345	205	550	136,813
NH	203	60	263	35,756
NJ	2,402	1,867	4,269	175,904
NM	176	307	483	24,186
NV	328	301	629	35,631
NY	2,095	1,038	3,133	356,210
OH	363	148	511	184,888
OR	737	241	978	108,102
PA	736	153	889	168,590
RI	50	25	75	17,448
TX	101	95	196	67,621
WI	213	90	303	75,879
Total	**21,257**	**11,060**	**32,317**	**2,423,448**

A note about “PV penetrations”

- In many of the following slides “PV penetrations” are presented. These represent the number of PV containing properties in any zip code as a percentage of all properties in those zip codes
  - E.g., 50 PV properties among 1,000 total properties = 5% PV penetration
- In this ratio, both the numerator (the number of PV properties) and the denominator (the number of all - PV and non-PV - properties) can affect its level. In deriving the two parts, we have tended to be conservative.
  - **Numerator:** We have screened out TTS addresses that could not be verified to have solar using satellite imagery from after the install date. With the hope of excluding community or utility-scale solar systems, all ground mount systems and large (>2,000 kW) systems are excluded, as well we apply select only properties that contain a building (see previous slide for those screens). Finally, even when multiple PV systems have been installed on a single property, we count that property as one. Each of these will cause the numerator to be smaller and thus the penetration to be lower[1]
  - **Denominator**: As with PV properties, we apply screening filters to non-PV records to ensure the property contains a building. Additionally, as discussed on slide 12, we limit the non-PV properties to those in zip codes where at least one PV property exists. Both would tend to increase penetration
- Despite these careful efforts, we recognize there is noise (i.e., error) in the penetrations. So for this analysis one might focus on differences in penetrations across cohorts rather than the absolute levels of those penetrations

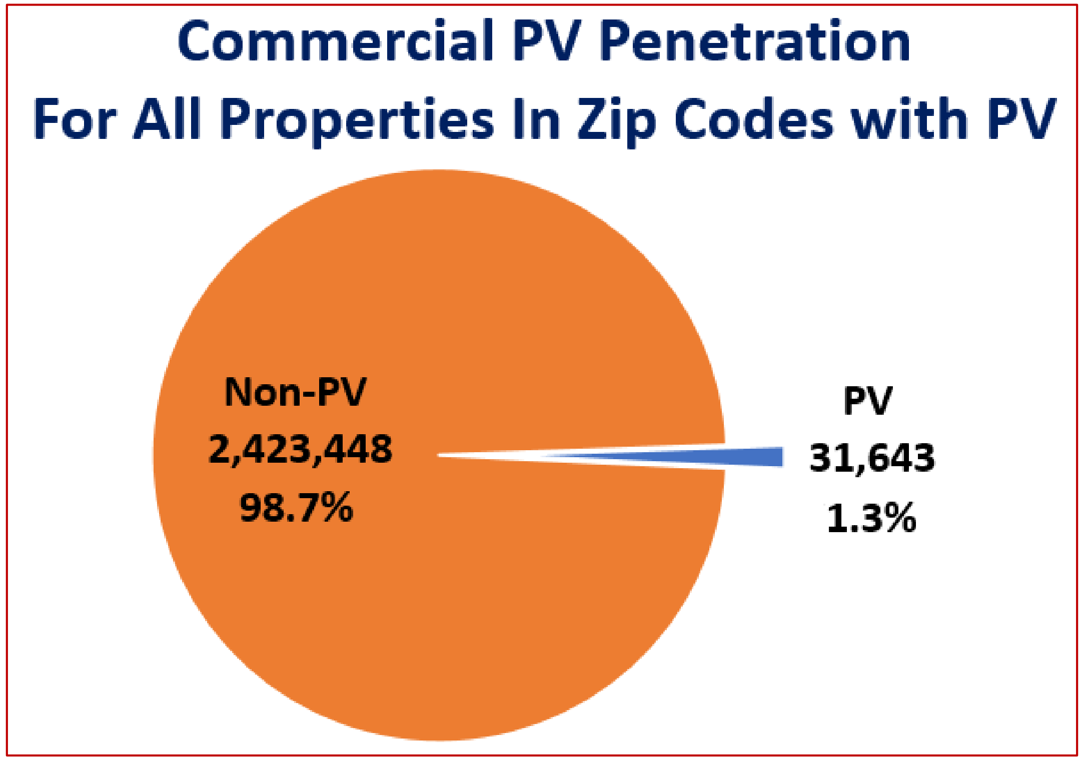


[1] *The U.S. Energy Information Administration (EIA) and the Solar Energy Industries Association (SEIA) also collect data on “commercial” solar system totals. But neither make these same exclusions for their totals or are opaque in what exclusions they make, and therefore, unfortunately, we are not able to compare the totals herein to theirs..*

Outline

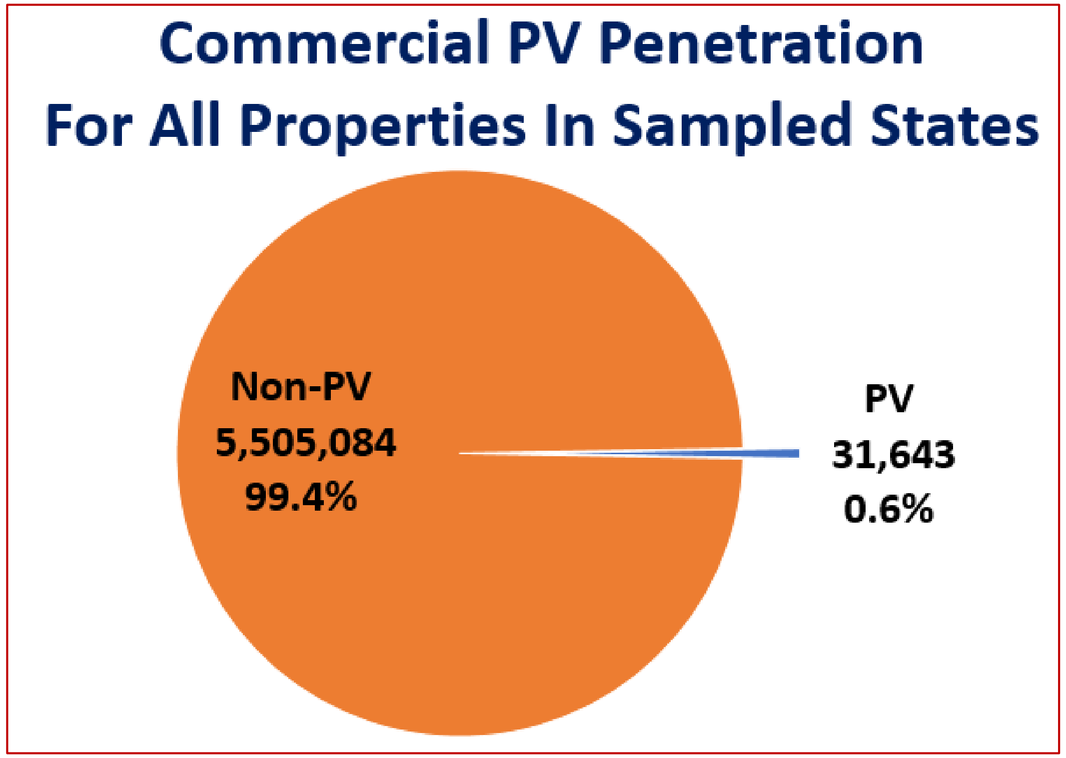
- Overview and Background
- Data
- **Results**
  - **PV Penetration Overall, State and Property Type**
  - What Property & Building Characteristics Are Correlated With Higher Penetrations?
  - How Have PV Property & Building Characteristics Changed Over Time?
  - How Have PV System Characteristics Changed Over Time, And By State and Property Type?
- Conclusions & Next Steps
- Appendix

Commercial PV penetration (based on the numbers of properties) using state- and zip code-based data ranges from 0.6% to 1.3%



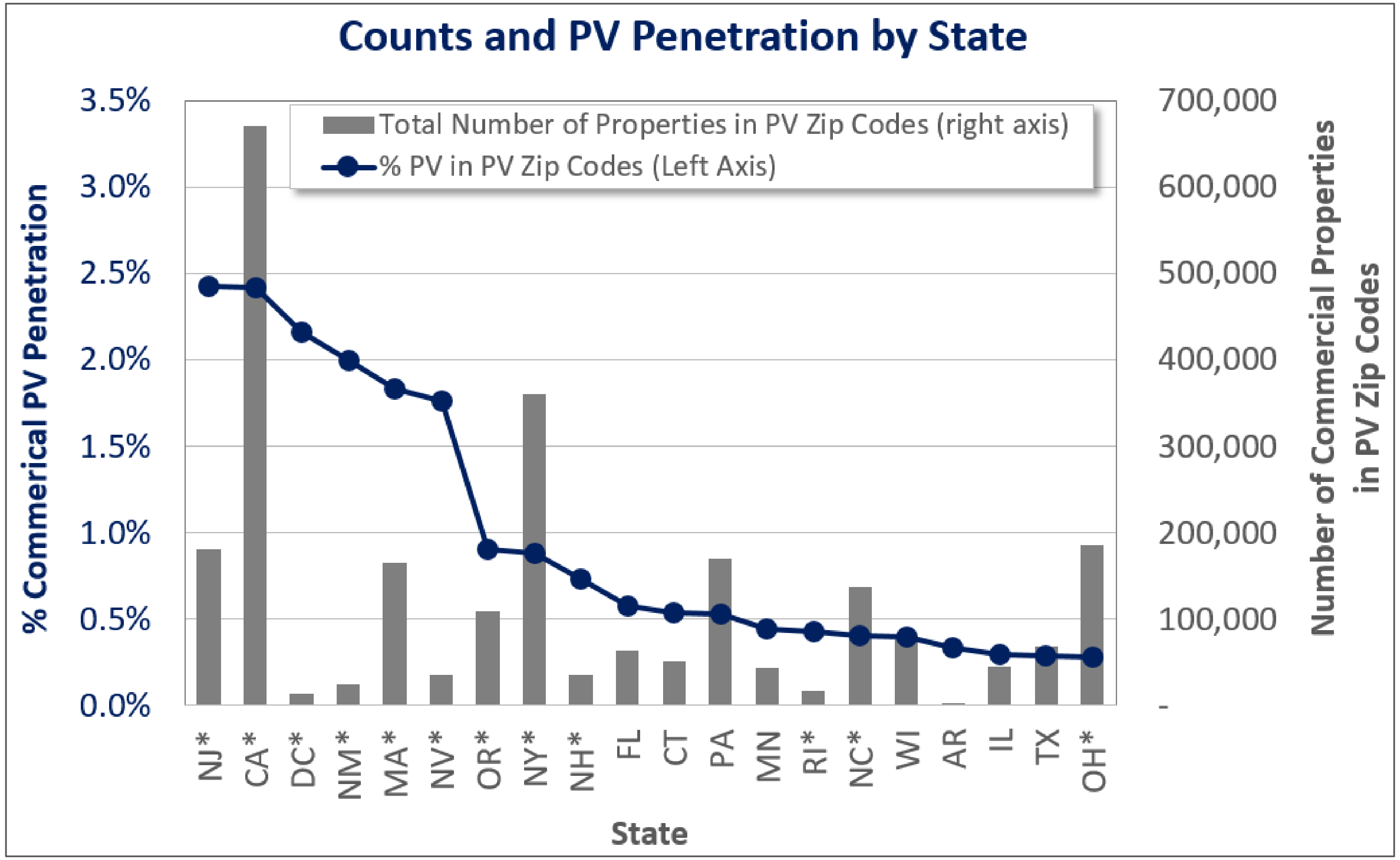
Zip Code level non-PV data are used for comparison throughout this analysis (left figure)

But state-level non-PV data are used here for reference (right figure)



Some states with high penetrations, such as AZ, CO, HI, and MD, are not included in the analysis. Similarly, all PV data might not be available in some zip codes or across the entire state. Both could drive up penetrations if included. Also, for reference, residential PV penetration, as calculated using TTS data, is roughly 2.1% through 2017.

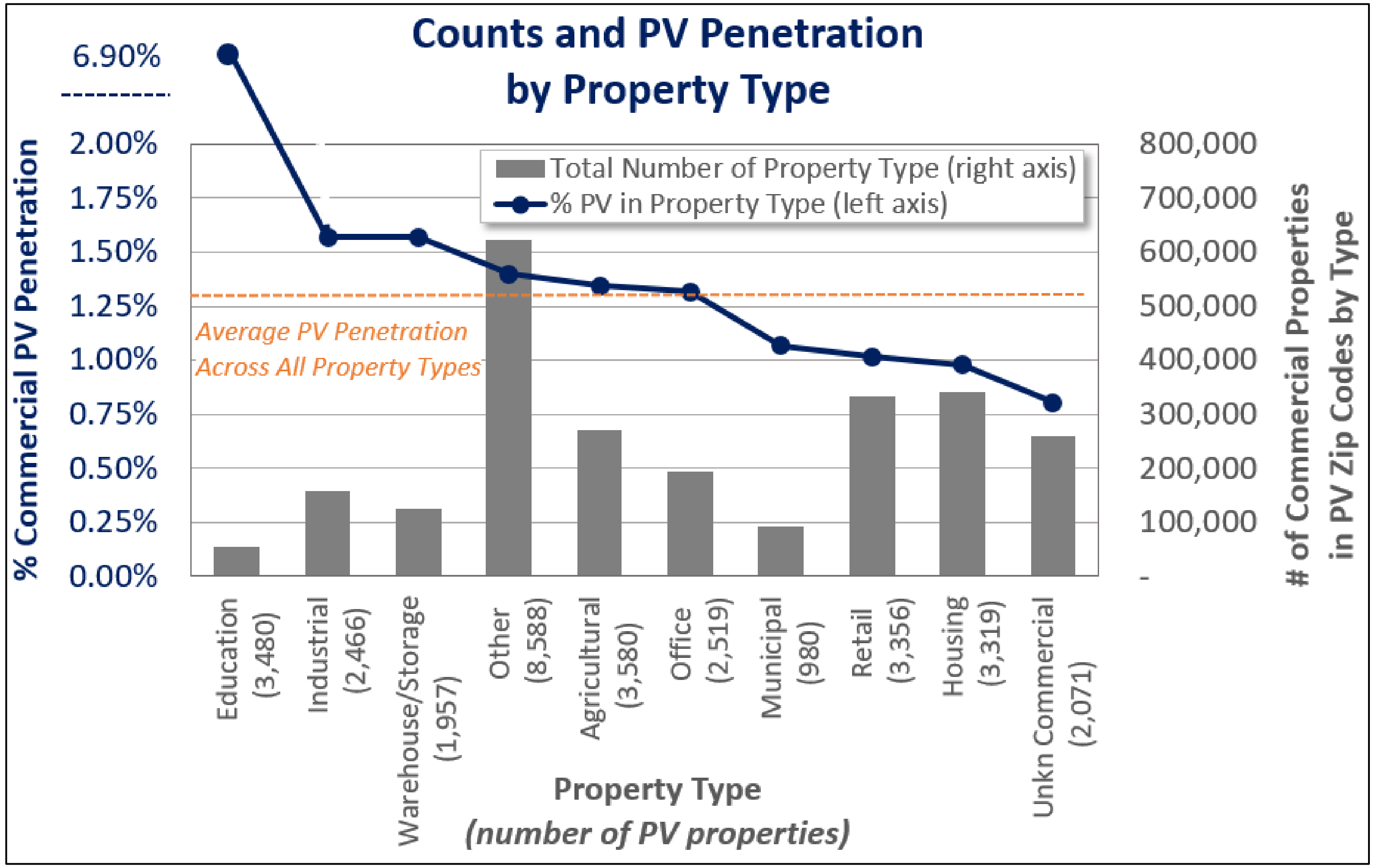
New Jersey and California enjoy the highest commercial property penetrations of nearly 2.5%, but more than half of states are around or below 0.5%



- Higher penetrations are seen in states with longer histories of aggressive deployment policies
  - NJ, CA, DC, NM and MA have each had strong PV policies for many years
- Enormous potential exists in the commercial PV market, though clearly barriers exist
  - With less than 2.5% penetration in the even the highest states, enormous potential exists for additional deployment
  - Conversely, the low penetrations indicate significant barriers to adoption and/or fewer policy drivers

Notes: *States with >60% estimated data coverage are marked with an *.*

Of the main PV property types, education property PV penetration, at 6.9%, far outpaces others; industrial, warehouses, and agricultural are also above average

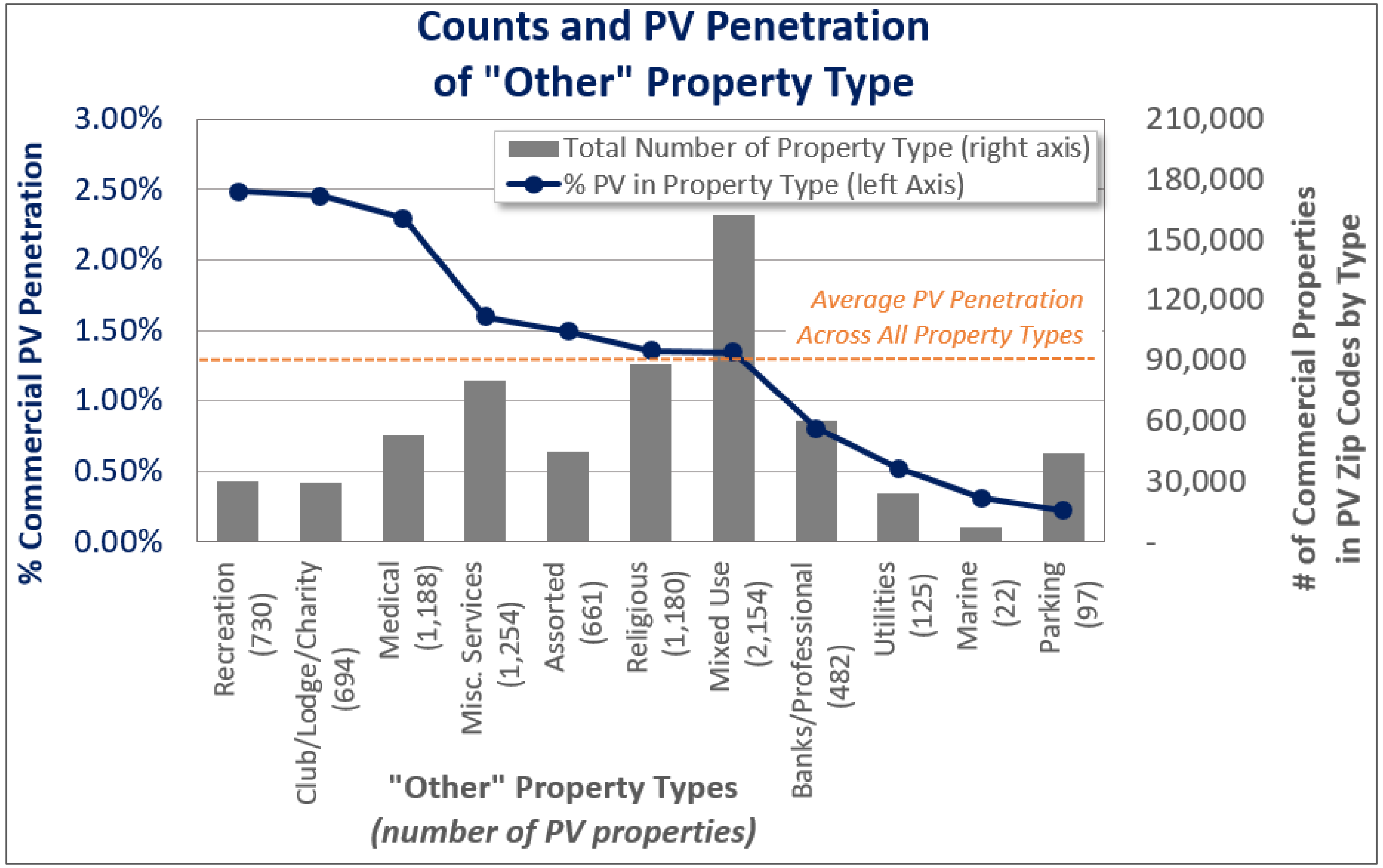


Notes: *"Other" property types are broken down further on the next slide. "Unkn Commercial" properties are properties that are commercial but have not been further categorized. "Housing" includes large multi-family residential buildings such as apartments, and also includes hotels and motels.*

- Education properties have more than 3-times the penetration as other property types
  - Possibly strong policies and a weaker need to see a fast return on investment leads schools, colleges and universities to see higher penetrations
  - School properties have the largest roofs in our data, potentially encouraging greater adoption
- Industrial, warehouses and agricultural properties are all above average
  - Industrial and warehouses have 2nd and 3rd largest roofs in our data, which might encourage greater adoption
  - USDA grants have driven development on agricultural property
- Relative development difficulties on municipal, retail, housing are apparent
  - municipal can't use ITC other than TPO (discussed in later slide) and each other types has relatively small roofs

Detailed breakdowns of each of the property types are provided in the Appendix

Among "other" property types (which were grouped together on the previous slide and which see lower numbers of PV installations in total) recreation, clubs/charities, and hospitals see higher penetrations, with parking and utilities being lowest



Notes: *"Assorted" category includes, e.g.: transportation, laboratories, RV parks, mining, cemeteries, museums, and libraries. "Recreation" includes, e.g., golf courses, country clubs, and indoor and outdoor recreations facilities.*

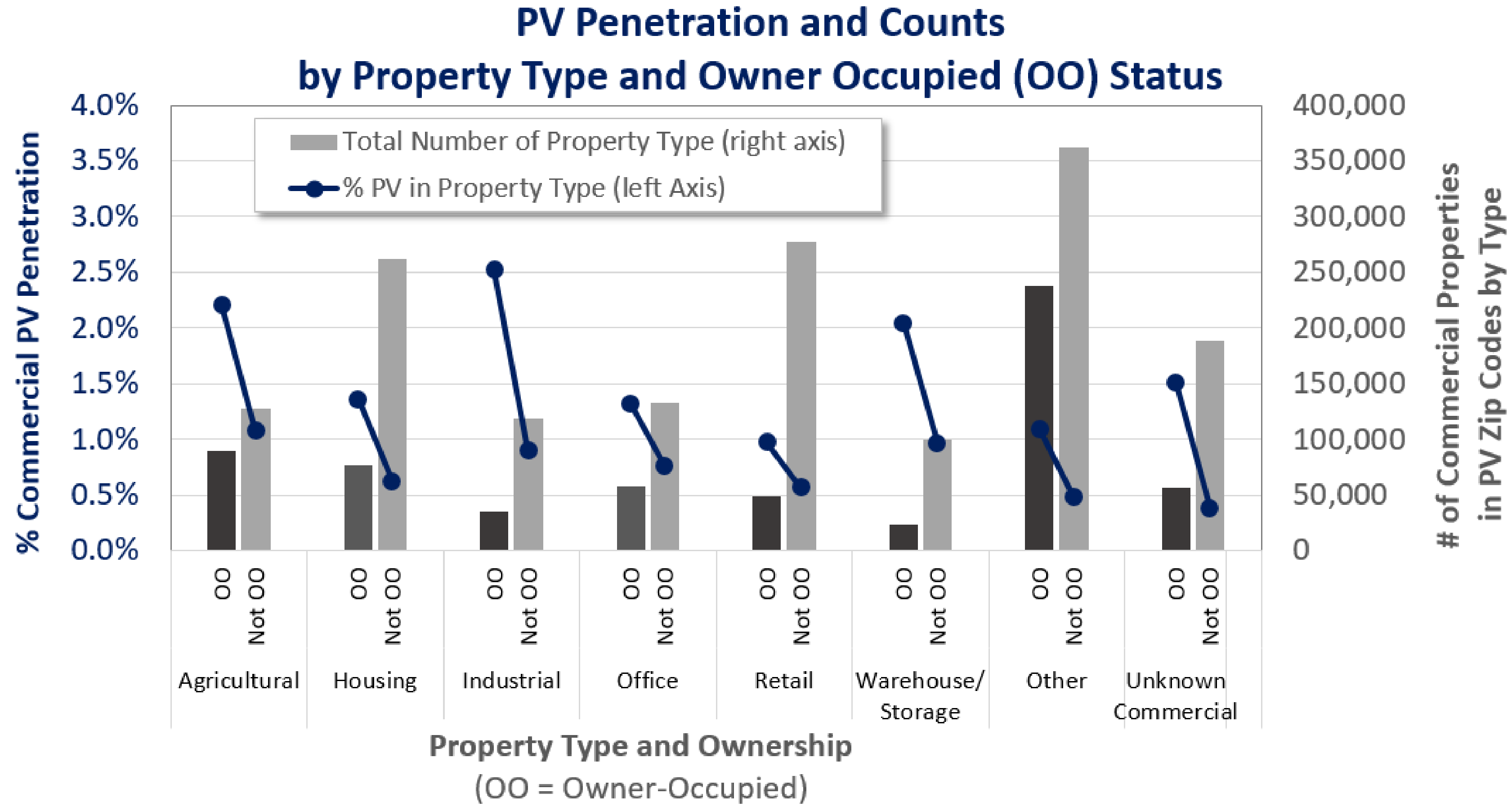
- At >2% penetration, recreation sites, clubs, and hospitals lead the "other" category of properties
  - Development success might be related to inherent advantages:
    - Recreation: relatively large roofs at country clubs?
    - Clubs/Charity: concentrated ownership, no tenants, perhaps environmental motivation
    - Hospitals: large roofs, corporate ownership
- Parking and utilities lag other properties in deployment
  - Parking facilities offer canopy opportunities, potentially, but have not been aggressively deployed, possibly related to low electricity use
- Potential exists in mixed use market

Detailed breakdowns of each of the property types are provided in the Appendix

Outline

- Overview and Background
- Data
- **Results**
  - PV Penetration Overall, State and Property Type
  - **What Property & Building Characteristics Are Correlated With Higher Penetrations?**
  - How Have PV Property & Building Characteristics Changed Over Time?
  - How Have PV System Characteristics Changed Over Time, And By State and Property Type?
- Conclusions & Next Steps
- Appendix

Buildings that are owner-occupied (OO) see much higher penetrations across all property types

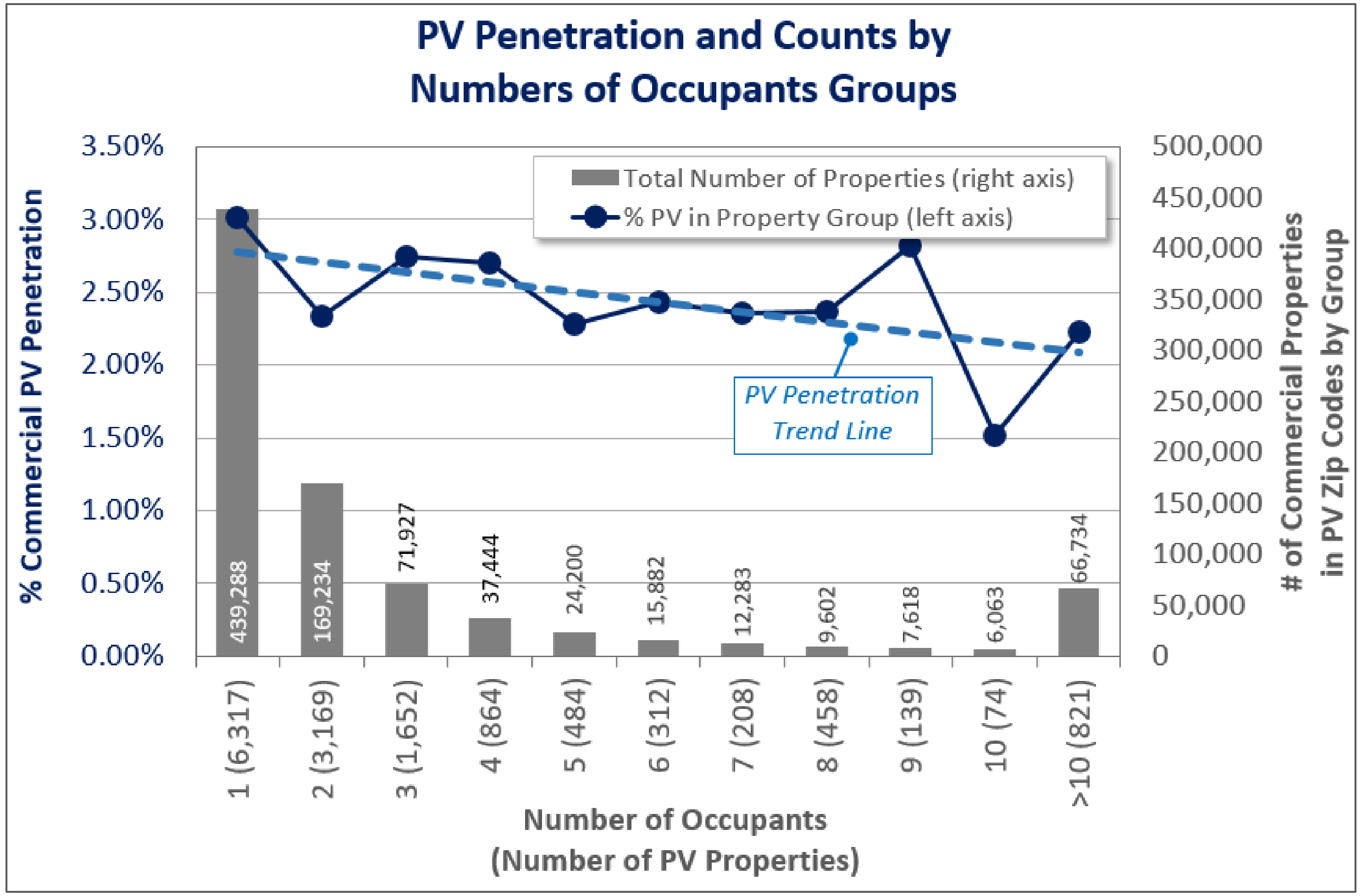


Note: PV penetration percentage for OO and Non-OO properties is significantly different ($p < 0.05$) all property types.
Education and Municipal are excluded because almost all were owner-occupied

Notes: *Approximately 95.7% of the full dataset had information on whether a building was owner-occupied or not. "Unkn Commercial" properties are properties that are commercial but have not been further categorized.*

- Being owner-occupied is correlated with higher levels of penetration
  - This pattern exists across all property types
- Where payee for and beneficiary of solar system are aligned, as with owner-occupied buildings, greater deployment opportunities might exist (i.e., there is no "split-incentive")
- Although non-owner-occupied properties are more numerous, penetrations are lower, showing potential

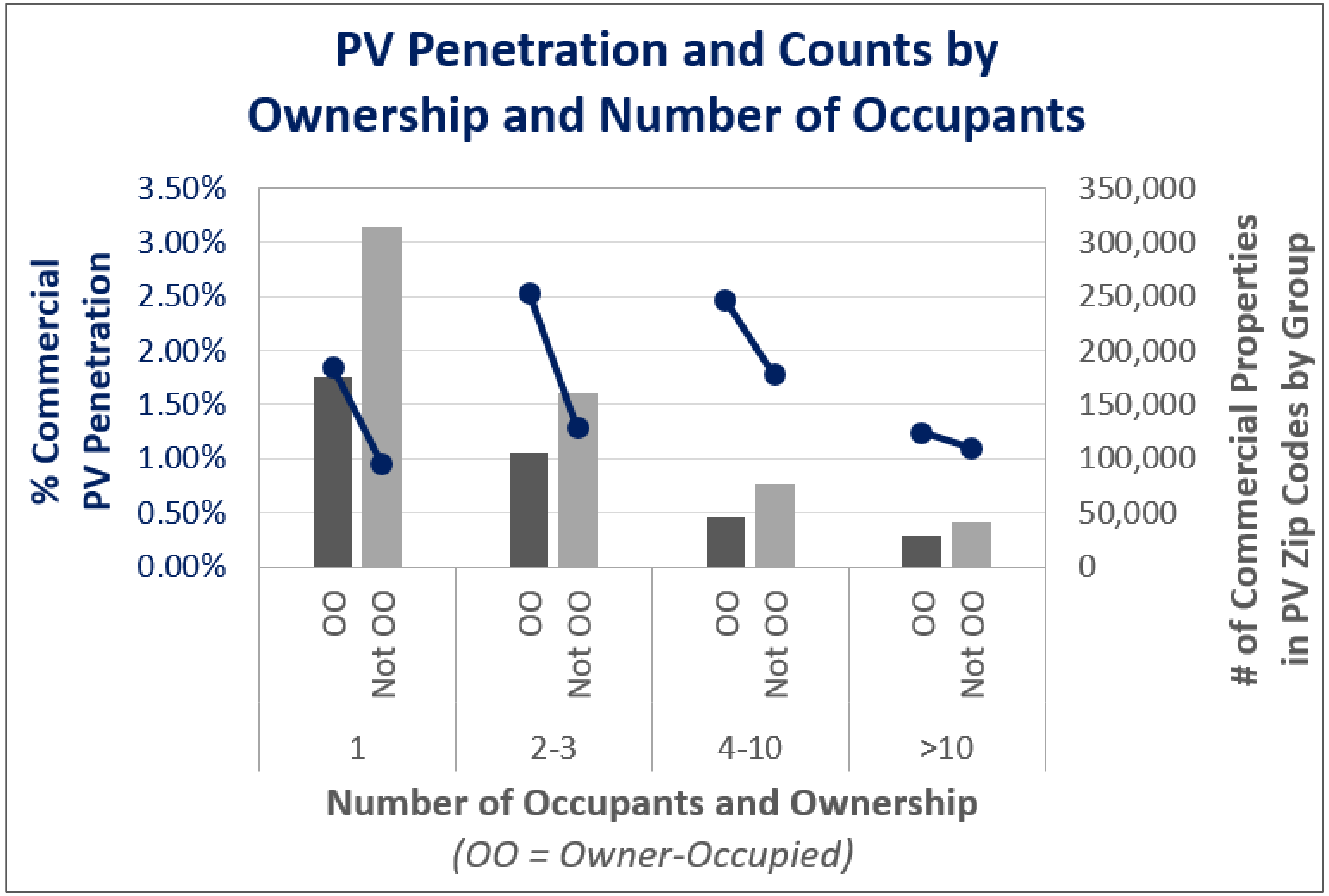
An increasing number of occupants is correlated with a lower solar penetration (note: multi-family apartments & condos are excluded)



- "Occupants" refers to the number of separate businesses at an address. This is similar to tenants, but can also include, potentially, the building owner
- Small numbers of occupants seems to be indicative of higher penetrations
  - The differences are not dramatic, though they are statistically significant
  - These patterns are robust if only offices and industrial properties are used, the two with consistent high numbers of occupants
- Potentially, this is an indication of the difficulty of recovering costs across multiple occupants
  - Occupants might have uncertain long-term plans and therefore might be less inclined to agree to cover a long-term property expense such as a solar system

Notes: *SMR does not make a distinction between not having occupant data and building with no additional occupants other than the owner, so all records with no occupants were excluded. Approximately 40% of the full dataset had information on the numbers of occupants. The above figure excludes residential multi-family properties, which had spotty data on the number of residents. Non-multi-family PV buildings* (mean = 4.0) have *significantly fewer occupants than similar non-PV non-multi-family buildings (mean = 4.4; p*-value <0.00).

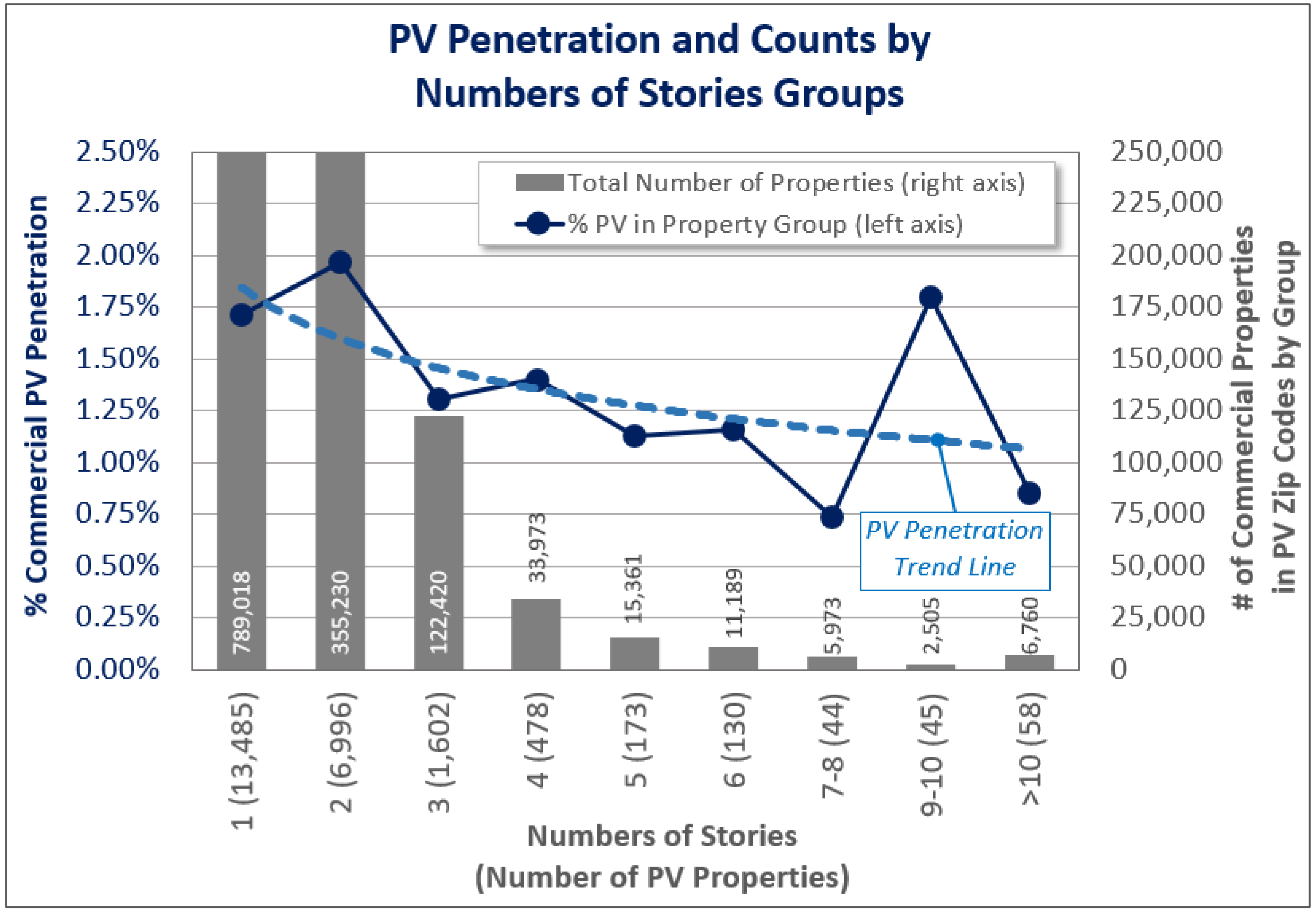
Some of the highest penetrations are seen in owner-occupied buildings with small numbers of occupants



- Regardless of the number of occupants, owner occupied properties see higher penetrations
  - The ownership effect appears stronger than the number of occupants effect
  - With more than 250,000 owner-occupied buildings with less than four occupants in the non-PV dataset there is a significant opportunity for deployment

Notes: *Approximately 39% of the full dataset had information on the numbers of occupants* <u>*and*</u> *whether the building was owner-occupied or not. The above figure excludes residential multi-family properties.*

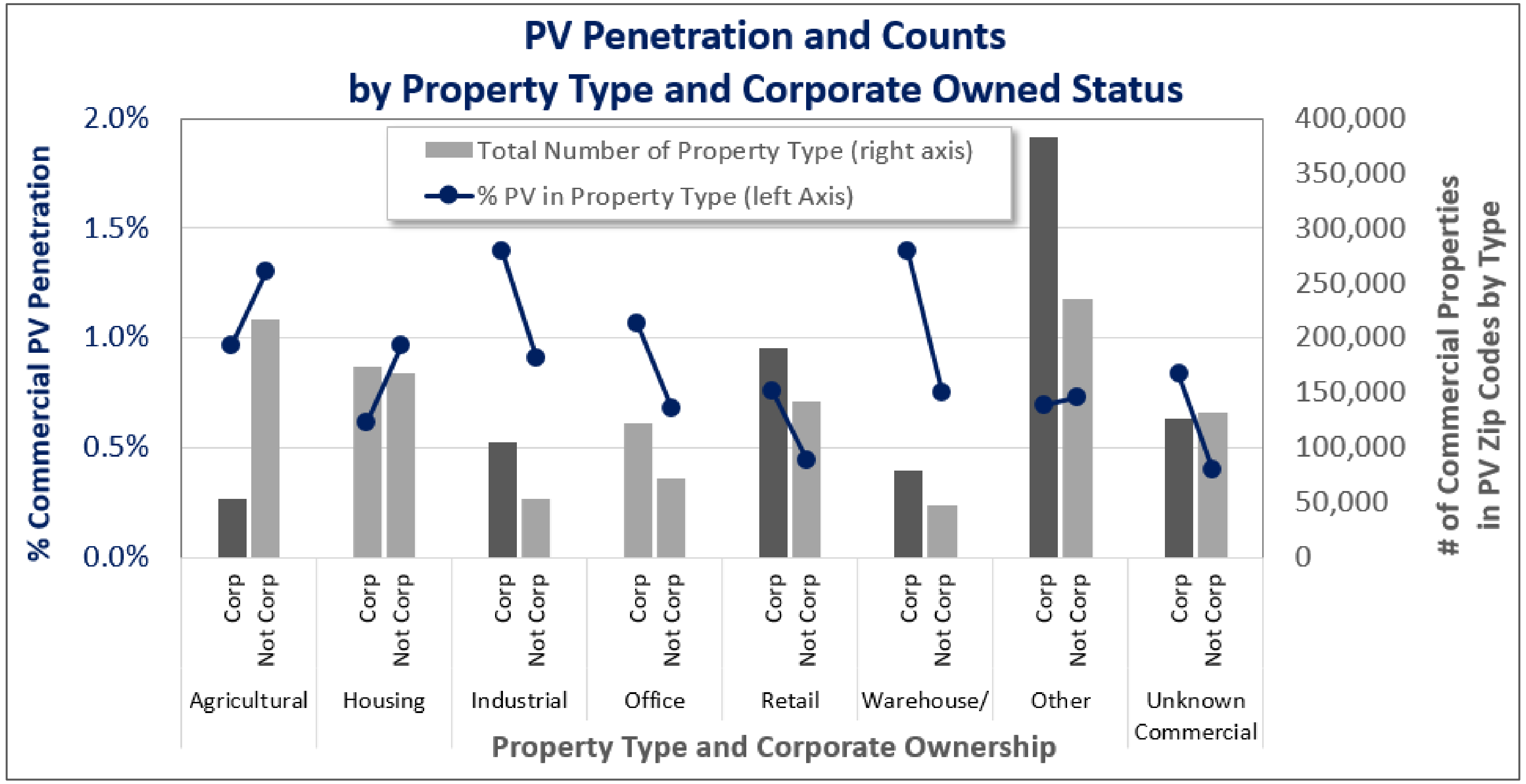
Lower solar penetrations are seen in taller buildings



Notes: *Approximately 56% of the full dataset had information on the numbers of stories. PV buildings* (mean = 1.61) have *significantly fewer stories than non-PV buildings (mean = 1.74; p*-value <0.00).

- Buildings with one story have penetrations twice as high as buildings with 7-8 stories
  - PV buildings have significantly fewer stories than non-PV buildings
  - Costs per watt for installing solar increase slightly (0.4 cents/watt) as buildings increase in height (*p*-value 0.04), which might drive the decreased penetration
  - Potentially, taller buildings are among other taller buildings which produce shade. Therefore, they might have decreased output potential and related ROI
  - Note: small numbers of many-storied buildings in the dataset, and an uneven distribution between building types, make definitive PV penetration calculations more challenging
  - Interestingly this effect is much stronger for owner-occupied buildings

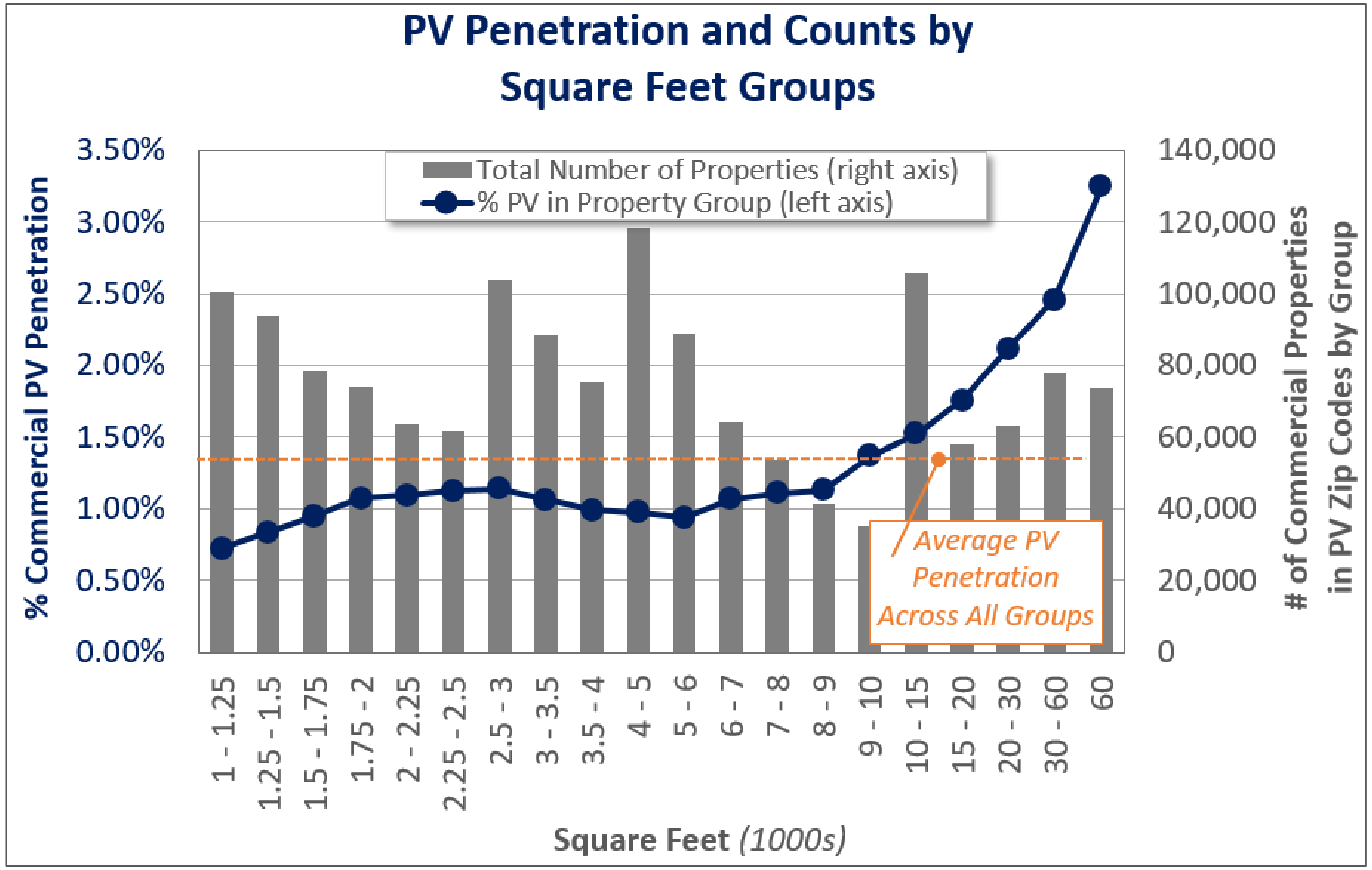
Whether a property is known to be owned by a corporation (vs. an individual) does not appear to influence deployment consistently



Notes: *100% of the full dataset had information on whether the property was owned by a corporation or an individual. "Unkn Commercial" properties are properties that are commercial but have not been further categorized. PV penetration percentage for corporate or non-corporate ownership properties is significantly different ($p < 0.05$) for all property types. Education and Municipal are excluded because almost all were not corporate owned.*

- SMR flags any property as "corporate" when it finds "corporation", "corp", "llc", "ltd", etc. in its name.
  - Therefore when this flag = 0, it might still have a corporate owner
  - Corp-owner properties are much larger (17k ft^2) and more valuable ($135/$ft^2$) than non-corp-owned (6k ft^2; $121/$ft^2$), so there is clearly a distinction
- With this caveat in mind, we find agricultural and housing & lodging properties that have corporate owners see lower penetrations than individually owned properties
  - Corporate owners of these properties might not prioritize solar
- Alternatively, industrial, office, retail, and warehouse properties see higher penetrations when the building owner is a corporation
  - This could be an indication of corporate sustainability goals

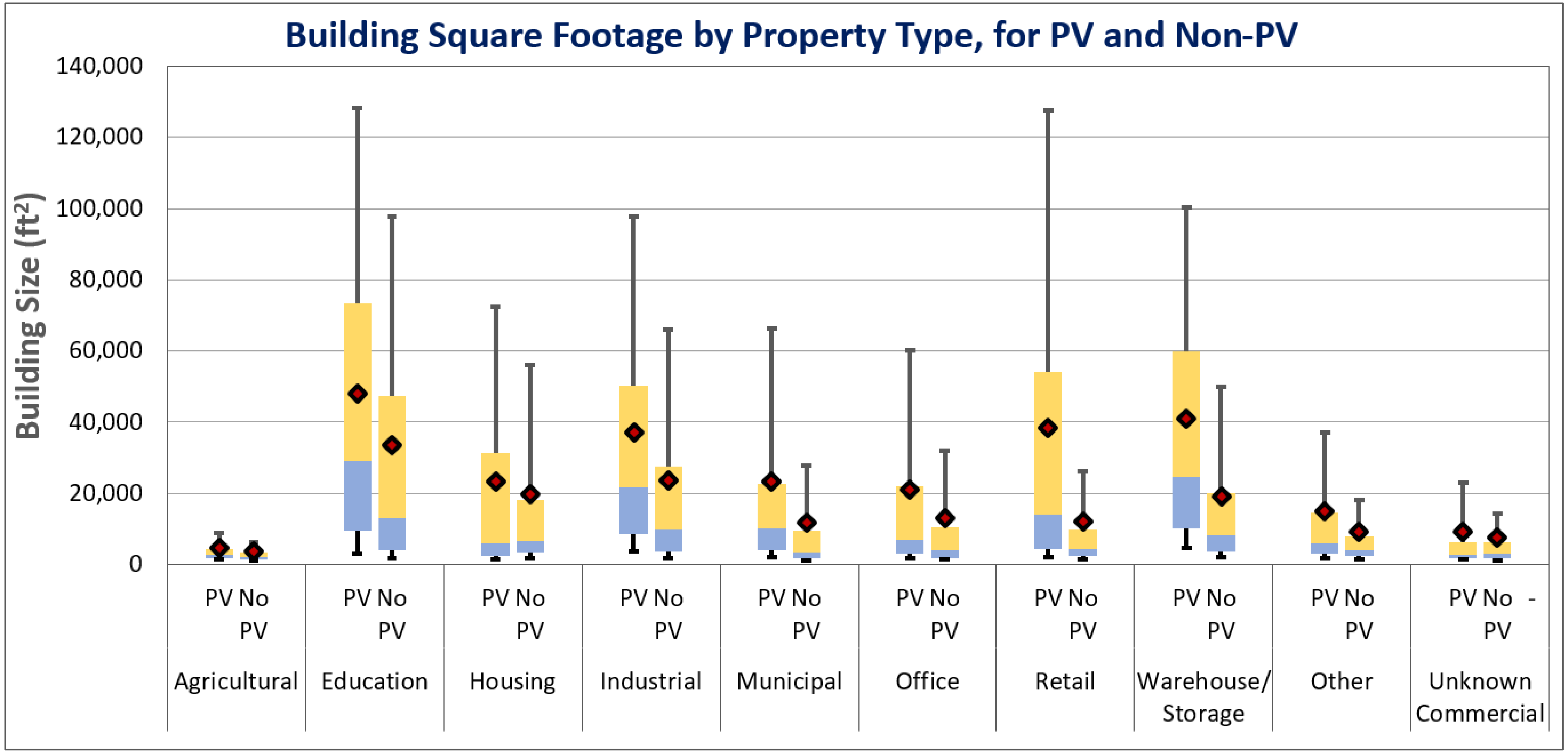
Penetrations are relatively flat through building sizes up to 9000 ft^2, but then increase dramatically through 60,000 ft^2



***Notes:** 100% of the full dataset had information on building size. Ranges are inclusive of the upper end, therefore "1.5 – 1.75" actually means ">1.5 - ≤1.75". PV buildings* (mean = 22,800 ft^2) *are significantly larger than non-PV buildings (mean = 12,500; p*-value <0.00)

- Some of the highest penetrations in our analysis are seen in very large buildings
  - Although, building size is strongly positively correlated with both system size and installed PV prices per watt (both *p*-value <0.00), the effect sizes for both of those relationships are very small (2 kW and $0.003/watt for each 1000 ft^2 increase in size)
  - Roof size, which is only available for a portion of the data, is strongly correlated building size. It also has a very similar penetration pattern, hovering around between 1-1.25% until roof sizes surpass 6000 ft^2, which align with ~ 9000 ft^2 building sizes
  - This implies that customer savings and building/roof sizes are not driving increased penetrations, but rather, something else
  - Potentially, below a certain threshold, an offsite PPA (or a high-RE ESCO energy purchase) is more economical

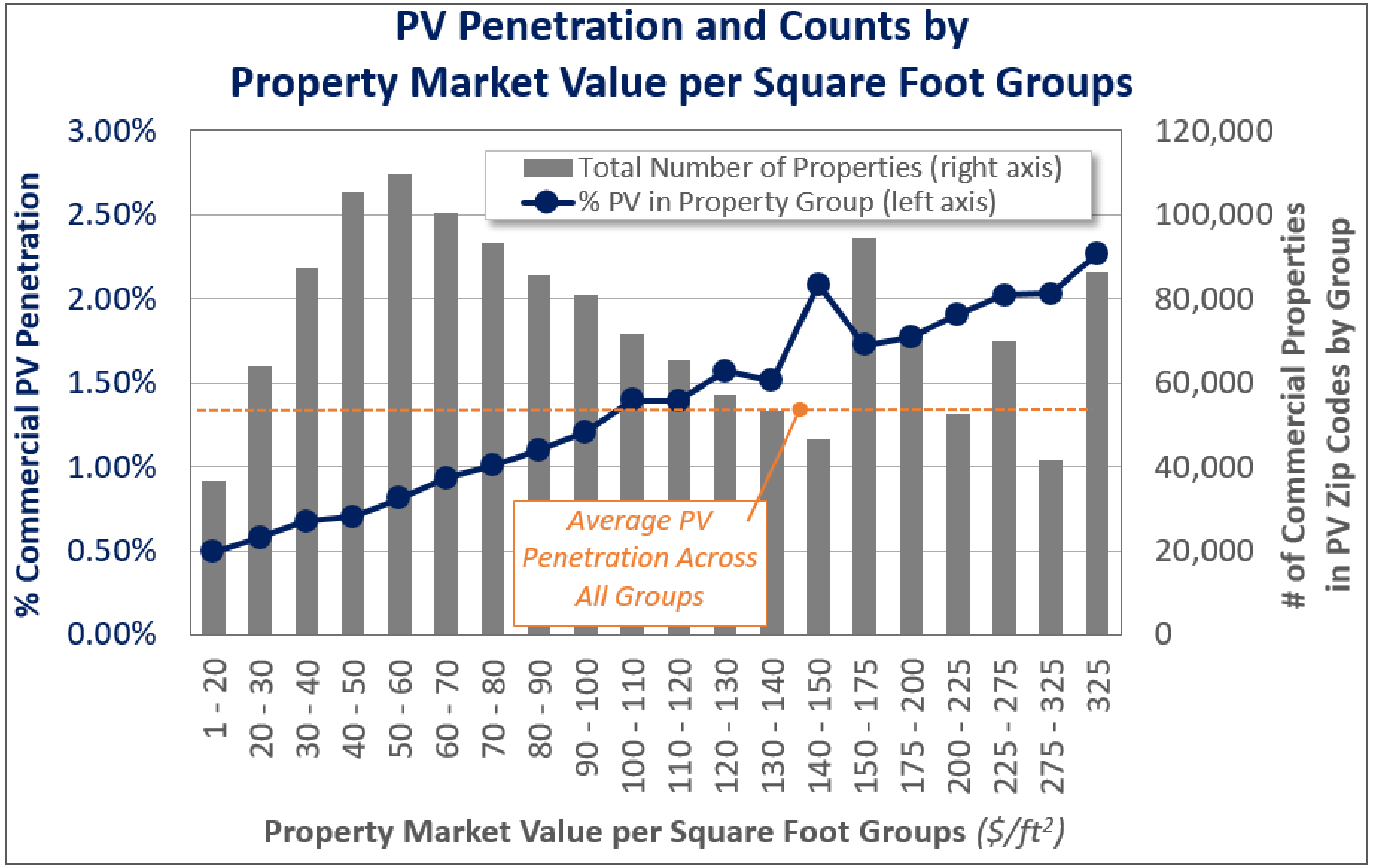
PV building sizes consistently exceed the sizes of non-PV buildings, regardless of property type



- The size of PV buildings, regardless of which building type it is, consistently exceeds that for non-PV buildings
- As discussed on the previous slide, marketing to customers with, and the economics of installing PV on, larger buildings (with larger roofs) might drive this difference
  - i.e., only larger buildings will have PV

Notes: *100% of the full dataset had information on building size. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. The large disparity in the mean and median, indicates that in all years, many very large PV buildings were developed, but they represent a small portion of the total.*

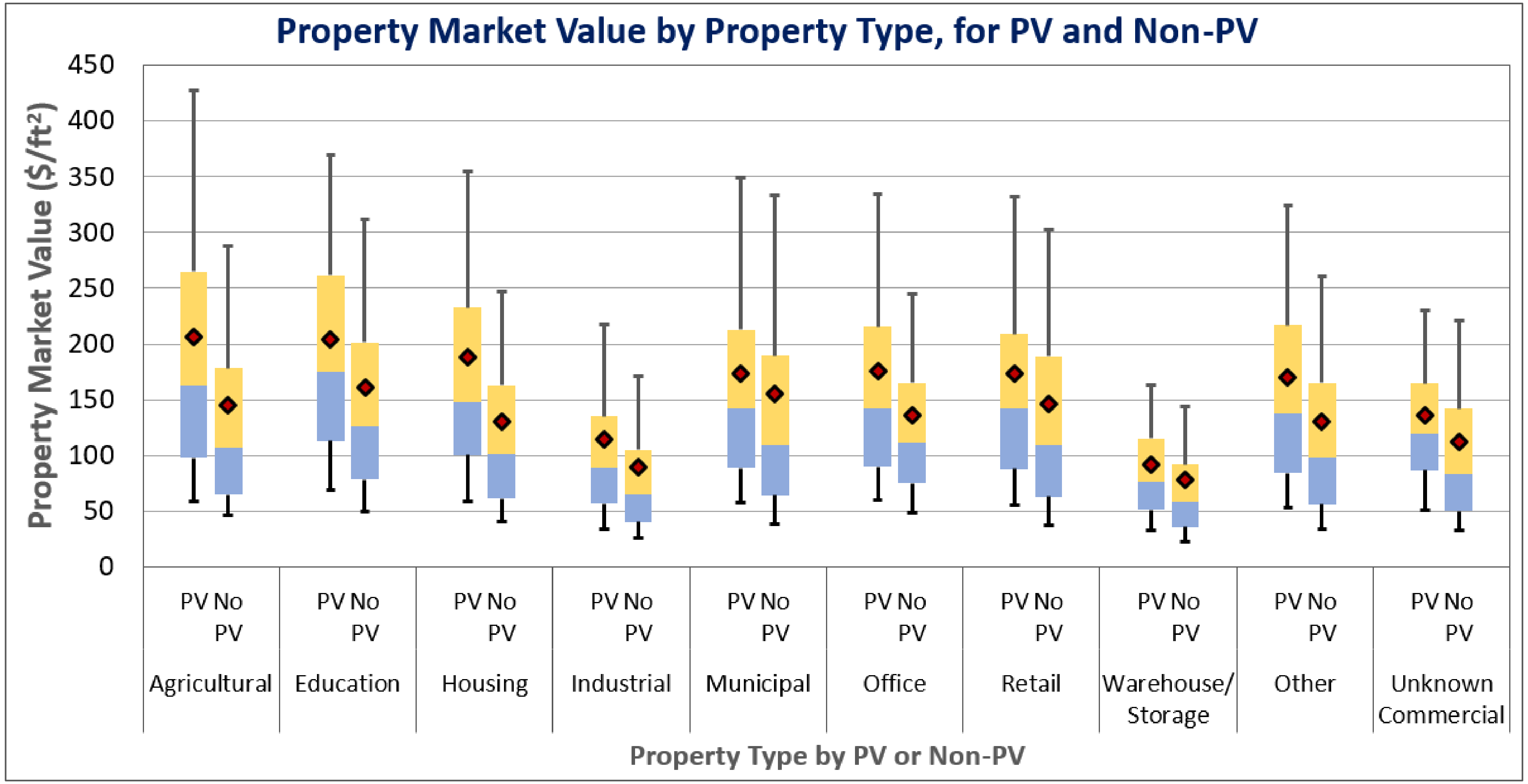
There is unmistakable trend of higher penetrations among properties that have a higher market value per square foot



Notes: *Approximately 60% of the full dataset had information on market value per square foot. PV buildings* (mean = \$168/ft²) *are significantly higher valued than non-PV buildings (mean = 129; p*-value <0.00)

- Penetrations for buildings with values below \$30/ft² are just over 0.5% while buildings over \$225/ft² see penetrations over 2%
  - PV system installed prices are correlated with increasing building market value but the effect is small (\$0.002/watt; p <0.00), so there is no pricing advantage for these buildings (in fact there is a small disadvantage)
  - On average, system sizes decrease slightly as the buildings increase in value (*p* <0.00)
  - CA, which has a higher % of high-value buildings than other states, influences but does not dominate this trend. I.e., it is also evident outside of CA
  - Therefore, increasing penetration seems driven by forces unrelated to installation prices, and instead, other drivers
    - Those drivers might include higher electricity rates coincident with higher value buildings, and installing solar for it's "green cache" value, which might meet sustainability goals and, potentially, might be passed on to occupants in the form of higher rents

PV property market values consistently exceed the values on non-PV properties, regardless of property type

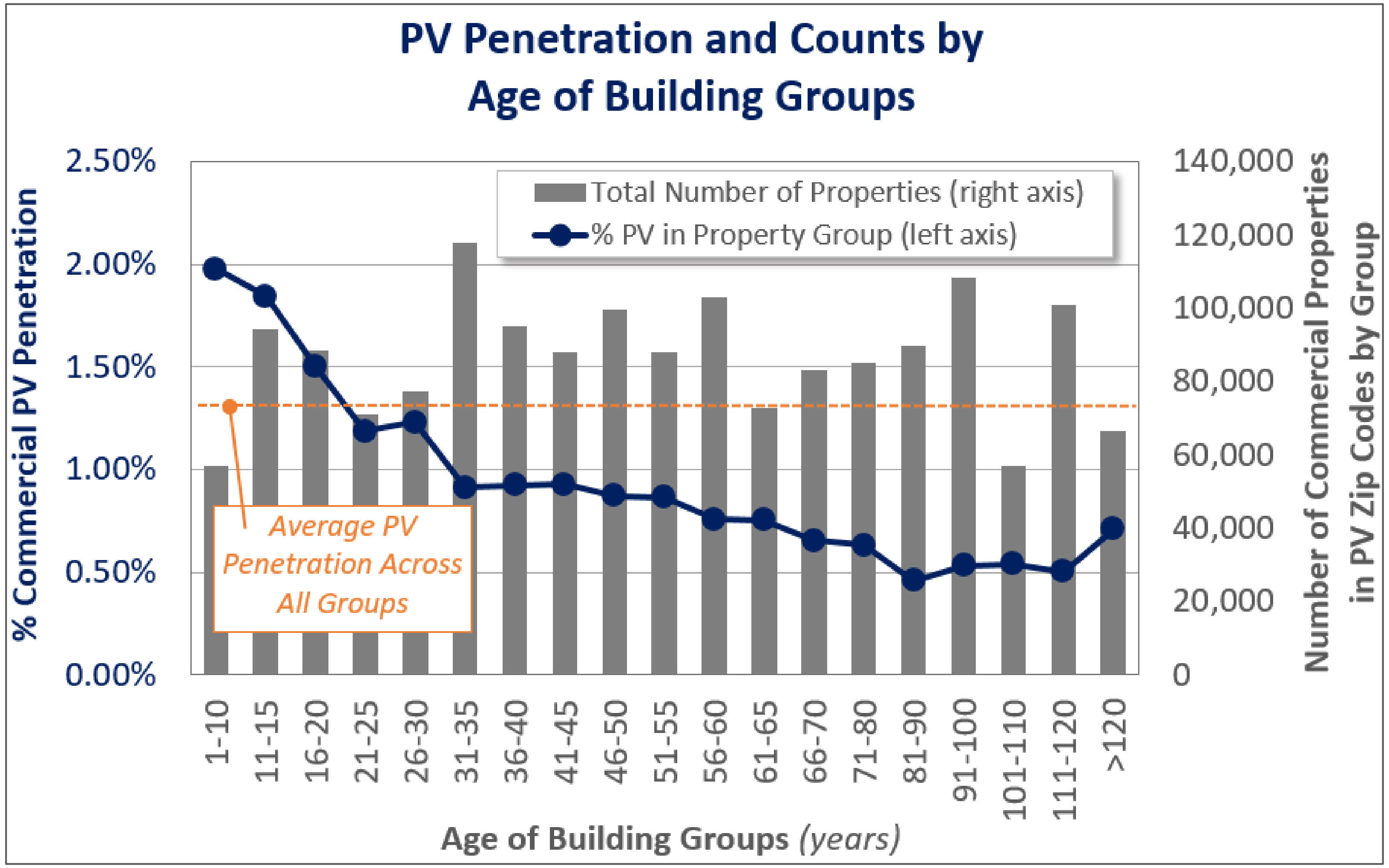


Notes: *100% of the full dataset had information on building size. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. The large disparity in the mean and median, indicates that in all years, many very large PV buildings were developed, but they represent a small portion of the total.*

- Market value across all PV buildings types exceeds that for non-PV buildings
  - PV properties are ~$40/sf^2 higher in value than non-PV properties (*p* <0.000)
- This is an indication that PV is being marketed to higher valued buildings
  - Note: PV system value is assumed to not be included in the property market value as assessors normally are prohibited from adding to properties when solar is installed[1]
  - Even when the value of he installed PV system is removed from the property market value, a significant difference still exists ($6.40/ft^2; *p* <0.000)

[1] **see Marsh (2017)**

There is unmistakable trend of lower penetrations as buildings increase in age, up to roughly 90 years



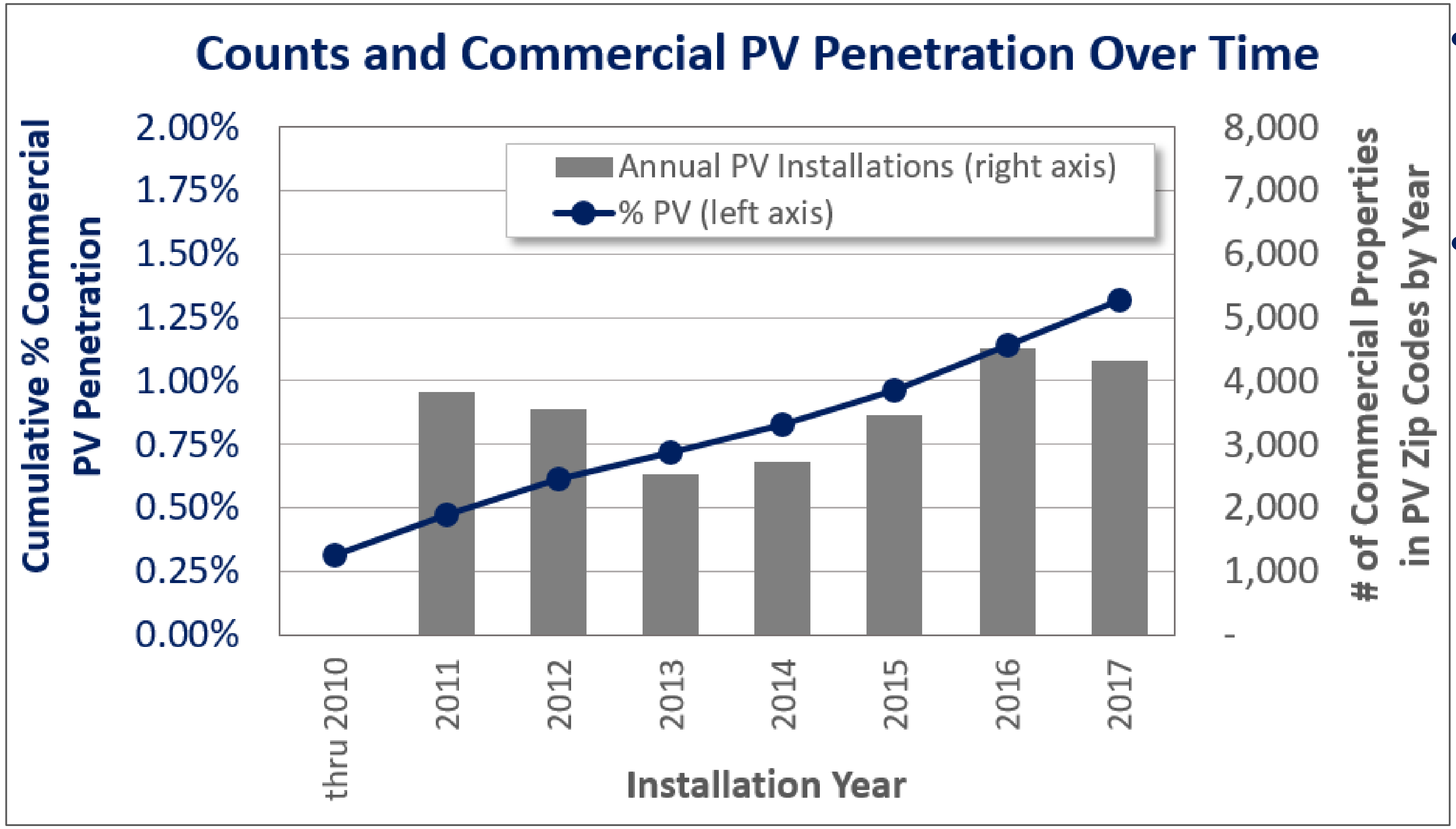
Notes: *Approximately 67% of the full dataset had information on the age of the building. PV buildings* (mean = 46 years) *are significantly younger than non-PV buildings (mean = 58; p*-value <0.00)

- Penetrations for buildings less than 10 years old are over 2%, while buildings between 80 and 120 years see penetrations near 0.5%
  - The PV system installed prices per watt are positively correlated with increasing building age (in years) but effect sizes are small ($0.004/watt for each year; *p* <0.00) across all systems; the effect is much larger for buildings less than 45 years old ($0.02/watt; *p* <0.00)
  - Therefore, increased penetrations for younger buildings might be driven by lower prices
  - Further, potentially the very young buildings were constructed with solar in mind, therefore decreasing installation costs
  - Finally, older buildings might have related structural or roofing changes required as part of installations that are outside the price of the installed system but decrease the overall ROI

Outline

- Overview and Background
- Data
- **Results**
  - PV Penetration Overall, State and Property Type
  - What Property & Building Characteristics Are Correlated With Higher Penetrations?
  - **How Have PV Property & Building Characteristics Changed Over Time?**
  - How Have PV System Characteristics Changed Over Time, And By State and Property Type?
- Conclusions & Next Steps
- Appendix

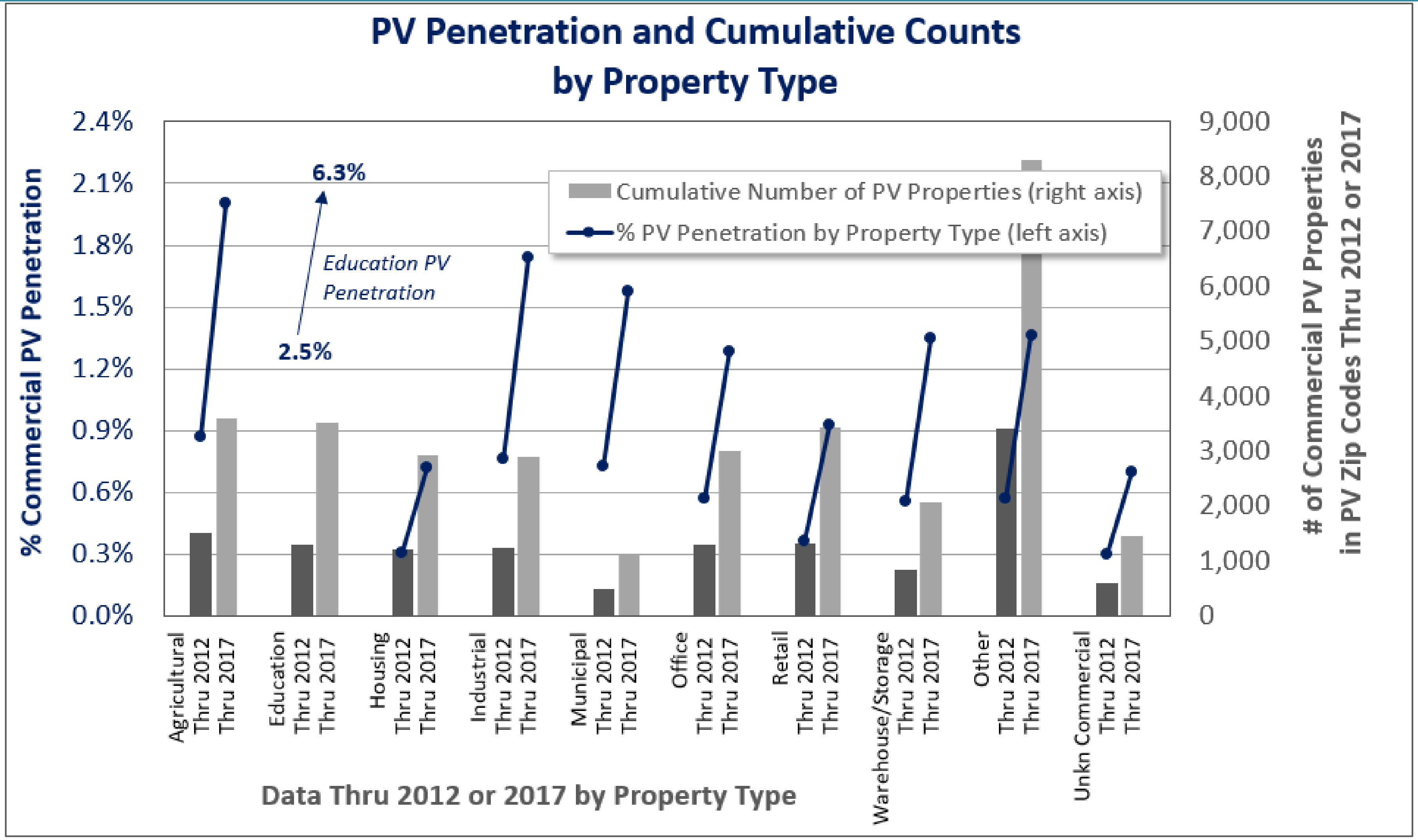
Commercial PV penetration has been steadily increasing over the last 8 years through 2017, though not accelerating, yet



- Through 2010, penetrations were just above 0.25, but have climbed linearly to 1.3% through 2017
- Though 2016 and 2017, at roughly 4,660 installations each, was a 50% increase over the average of the previous five years (3,082), therefore potentially indicating an acceleration is occurring
  - But, this might be related to the impending ITC phase-out. Future years data will need to be examined to disentangle

Notes: *Although the numbers of PV buildings have increased since 2013, so too have the numbers of available buildings that have been newly built. Hence, despite the increasing number of installations deployment is linearly increasing.*

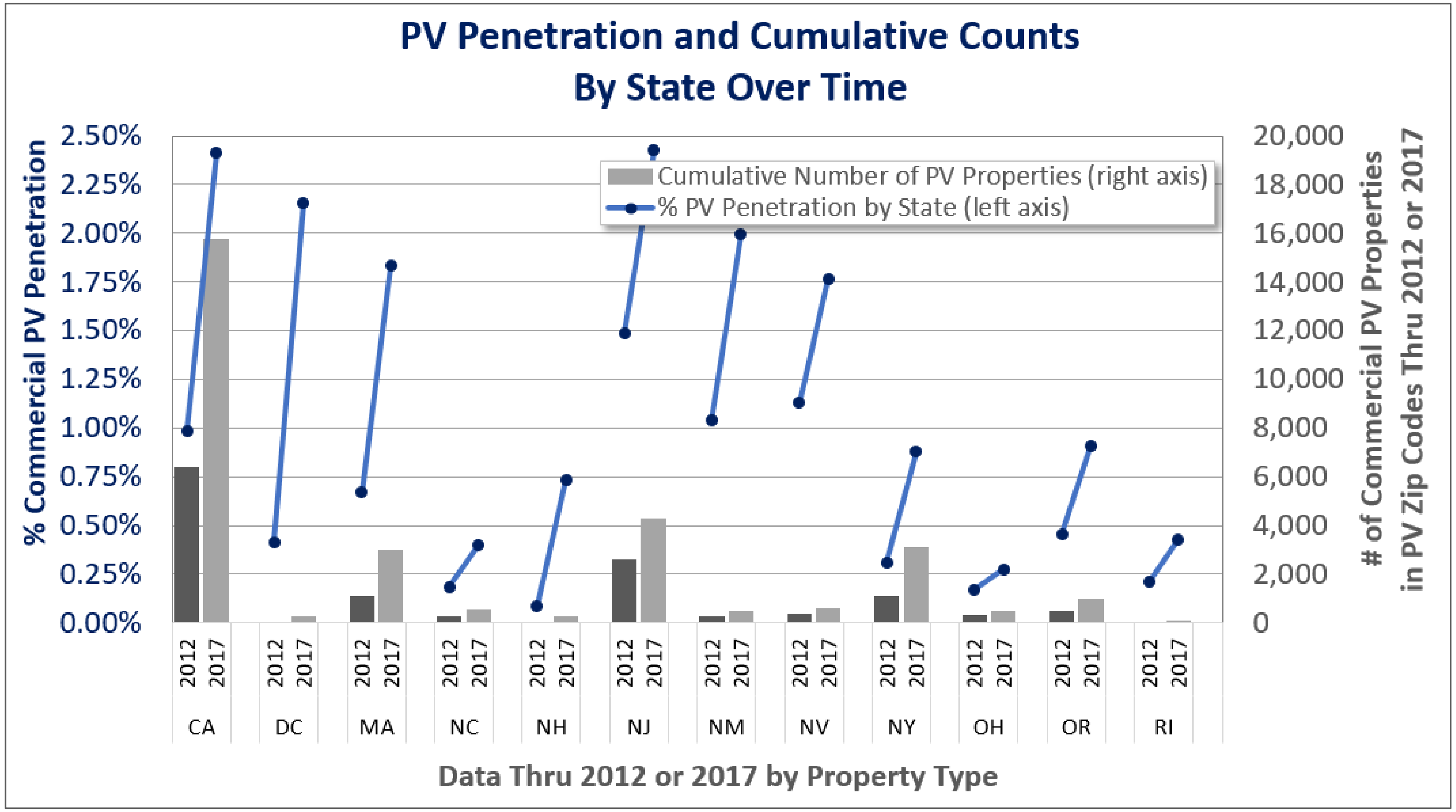
Each of the main property types have seen similar increases in penetrations from 2012 to 2017



- All property types saw a doubling in penetration from 2012 to 2017
- Similarly the numbers of PV properties (as indicated by the darker and lighter bars) roughly doubled in size
  - Although the numbers of non-PV buildings also increased over this period, they did so at a much smaller % than the numbers of PV buildings
- This implies that no particular segment experienced a breakthrough in deployment over this period

Notes: *Although the numbers of PV buildings have increased since 2013, so too have the numbers of available buildings that have been newly built. Therefore % increases in penetration might not equate to % increases in numbers of PV properties. “Unkn Commercial” properties are properties that are commercial but have not been further categorized.*

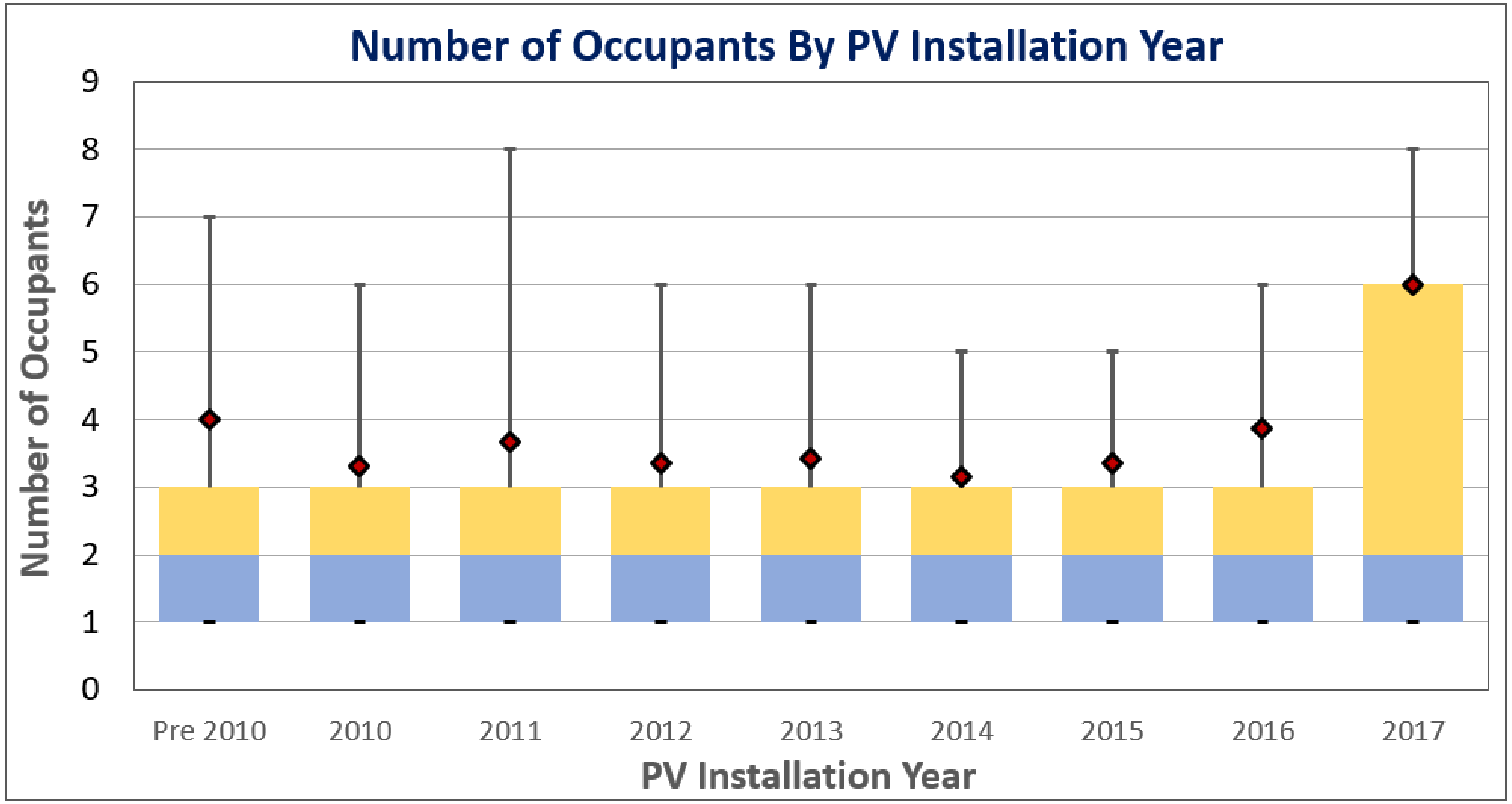
Virtually every state saw a significant increase in commercial PV penetration from 2012 to 2017 in our sample



Notes: *The figure contains only states with >60% coverage. All states are shown in a similar figure in the Appendix*

- DC enjoyed a 5x increase and NH a 8x increase
- All other states saw at least a doubling in penetration from 2012 to 2017, except NJ, which climbed from 1.4% to 2.3%
- This implies states/districts are continuing to find deployment opportunities, yet few are experiencing a breakthrough
  - This is true at least in terms of building installed commercial PV. Offsite virtual PPAs are not considered in this analysis

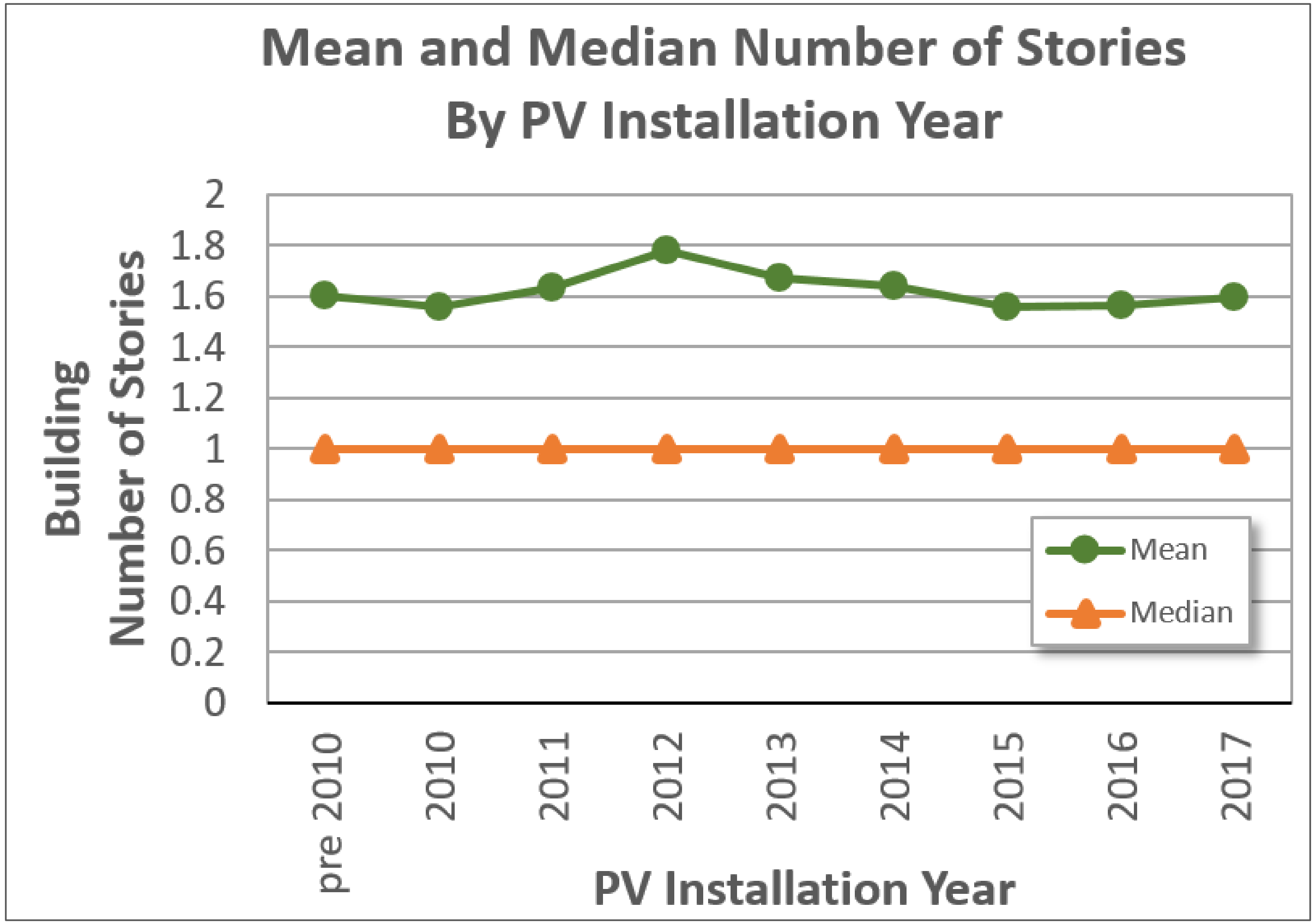
The mean and median number of occupants for PV buildings held flat through 2015, after which the mean climbed rapidly



- The mean and median number of occupants in PV buildings held constant through 2016 at roughly 3.5 and 2, respectively
- 2017 saw an increase in the mean number of occupants to almost 6
  - Additional analysis is required to understand this recent trend

Notes: *Approximately 40% of the full dataset had information on the number of occupants. The above figure excludes residential multi-family properties. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. The disparity in the mean and median, indicates that in all years, some PV buildings were developed with a large number of occupants, but they represent a small portion of the total.*

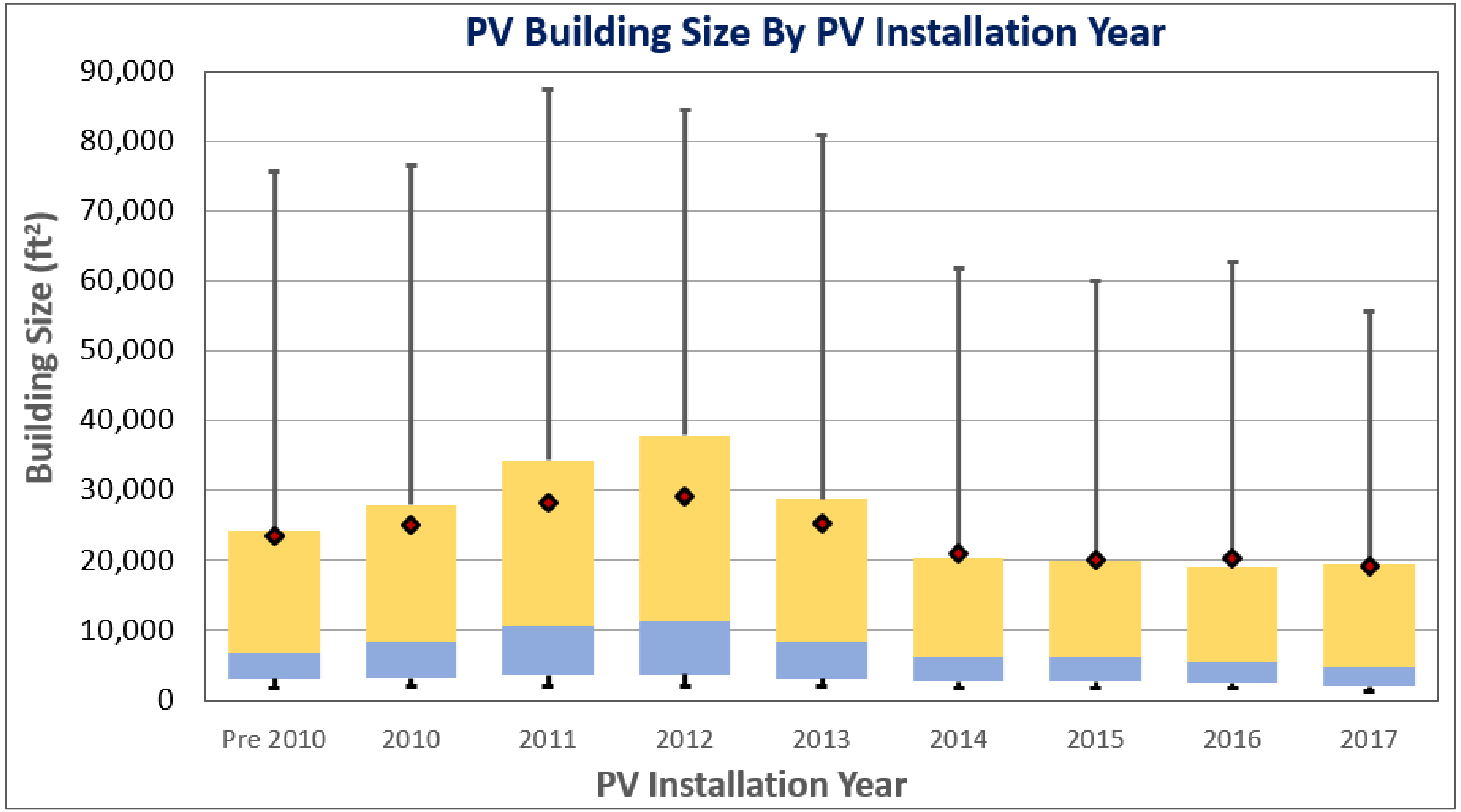
The mean and median numbers of stories for PV buildings has remained fairly constant over time



- The mean and median number of stories in PV buildings holds constant at 1.6 and 1

Notes: *Approximately 56% of the full dataset had information on the numbers of stories. The disparity in the mean and median, indicates that in all years, many multi-story PV buildings were developed, but they represent a small portion of the total.*

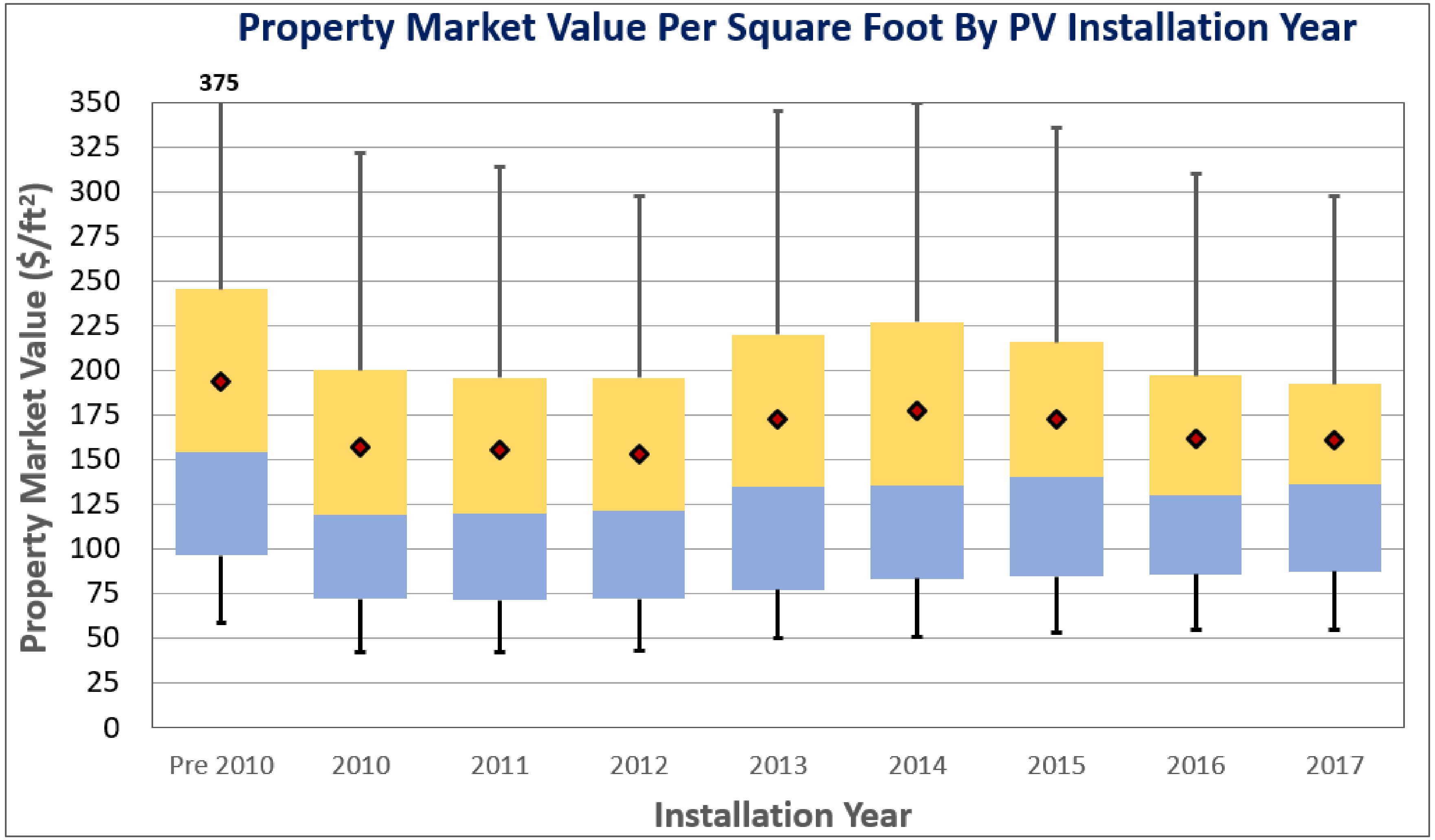
After steadily increasing through 2012, the size of PV buildings dropped through 2015 and has since remained steady



- Prior to 2010, the mean PV building size was 23,665 ft^2 while the median was 6,733
- Sizes peaked in 2012 and and returned to lower overall levels by 2017
  - This could be an indication of greater success in marketing to smaller customers
  - Roof size, which is only available for a portion of the data, exhibited the same pattern over time

Notes: *100% of the full dataset had information on building size. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. The large disparity in the mean and median, indicates that in all years, many very large PV buildings were developed, but they represent a small portion of the total.*

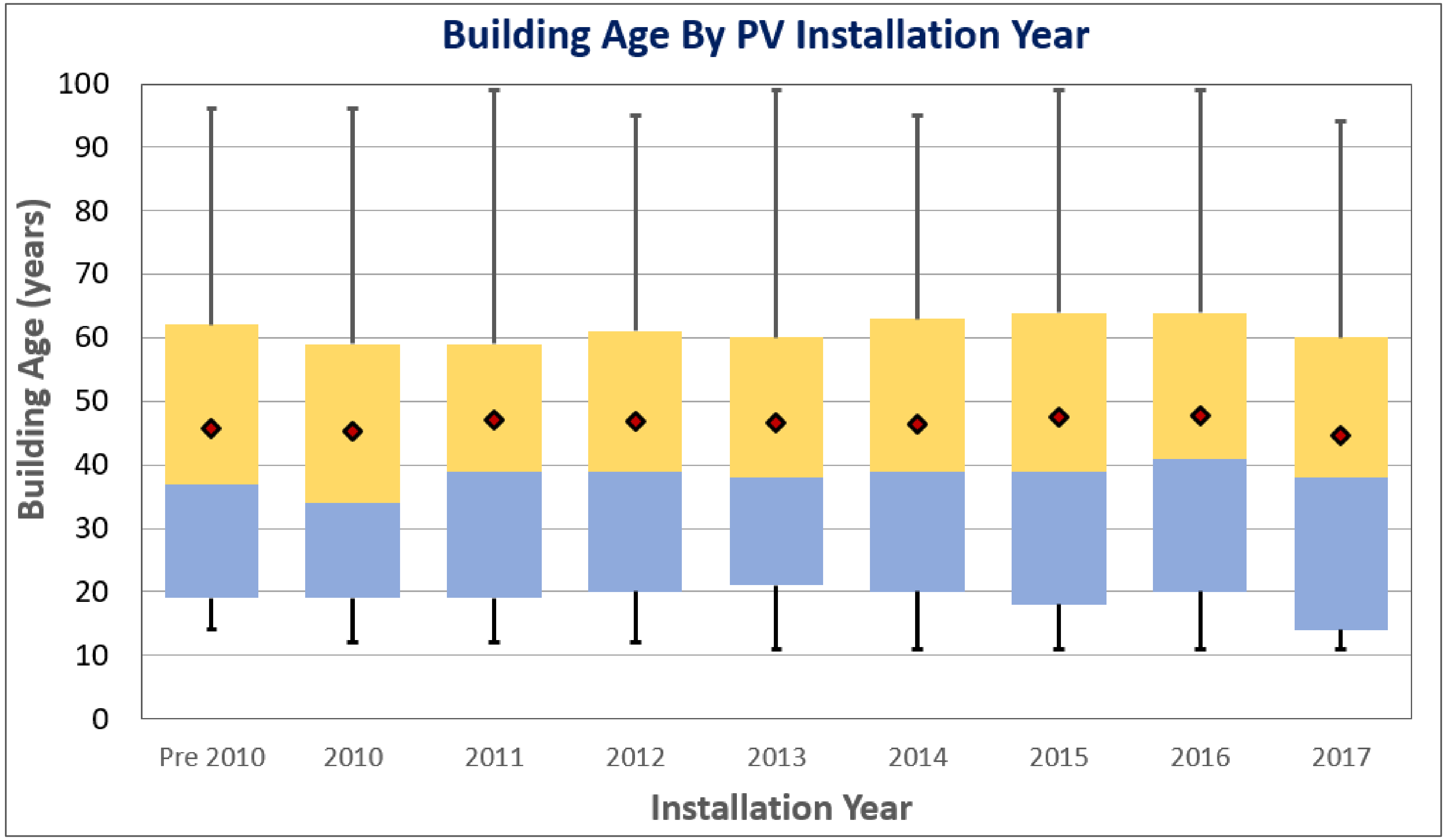
The mean and median market value per square foot for PV buildings has remained fairly constant over time



- The mean and median PV building market value for square foot has held roughly constant at $170/sf² and $132/sf², respectively
- Prior to 2010 the mean market value approached $200/sf²
  - Of course, prices for PV systems at this time were also relatively expensive

Notes: *Approximately 60% of the full dataset had information on the market value per ft². Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. The disparity in the mean and median, indicates that in all years, some high valued PV buildings were developed, but they represent a small portion of the total.*

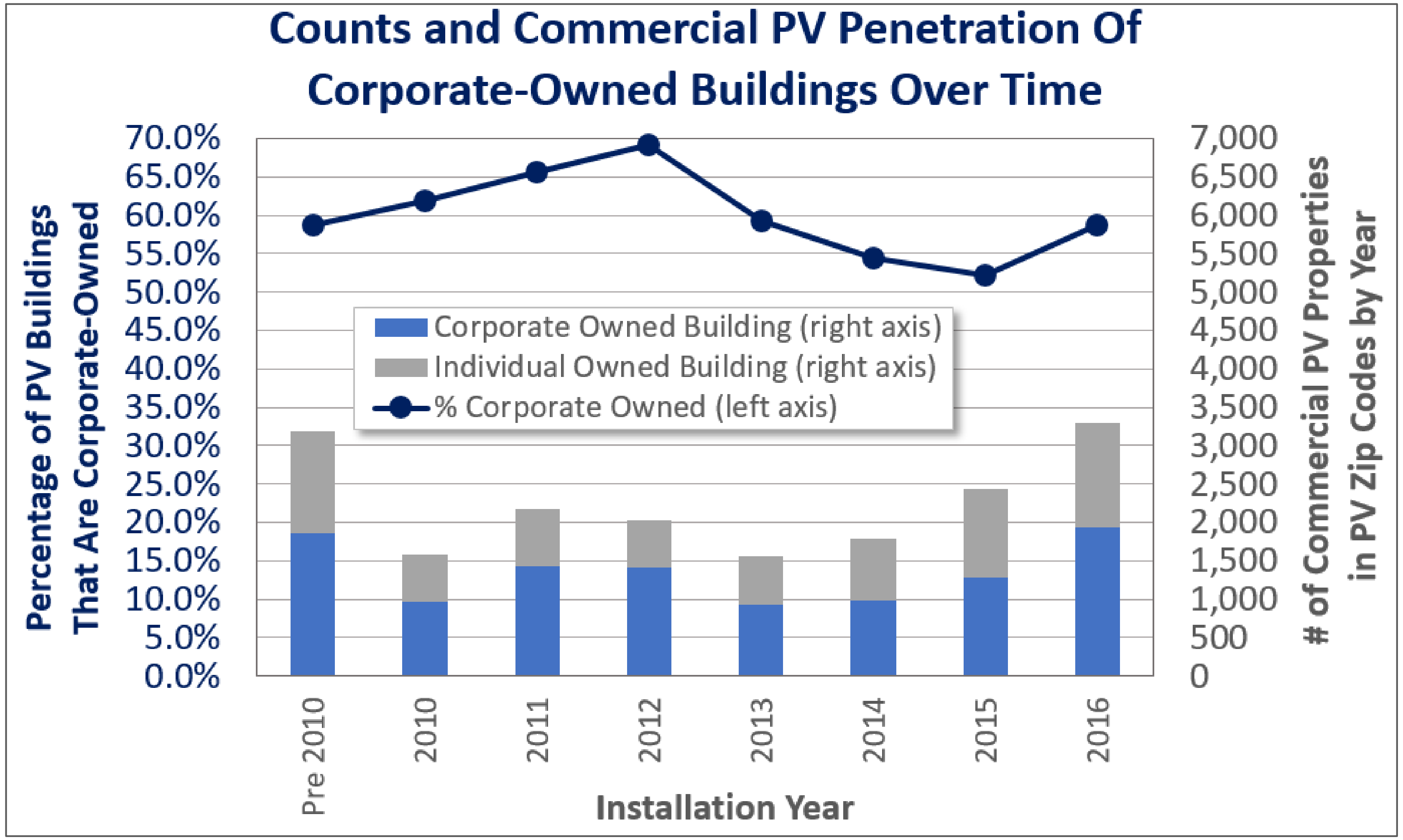
The mean and median age of buildings with commercial PV installations has remained fairly constant over time



- The mean and median PV building age has held constant at roughly 46 and 38, respectively

Notes: *Approximately 67% of the full dataset had information on building age. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. The disparity in the mean and median, indicates that in all years, some very old PV buildings were developed, but they represent a small portion of the total.*

After peaking in 2012 the penetration into corporate-owned (vs. individually-owned) PV properties has fallen thru 2017

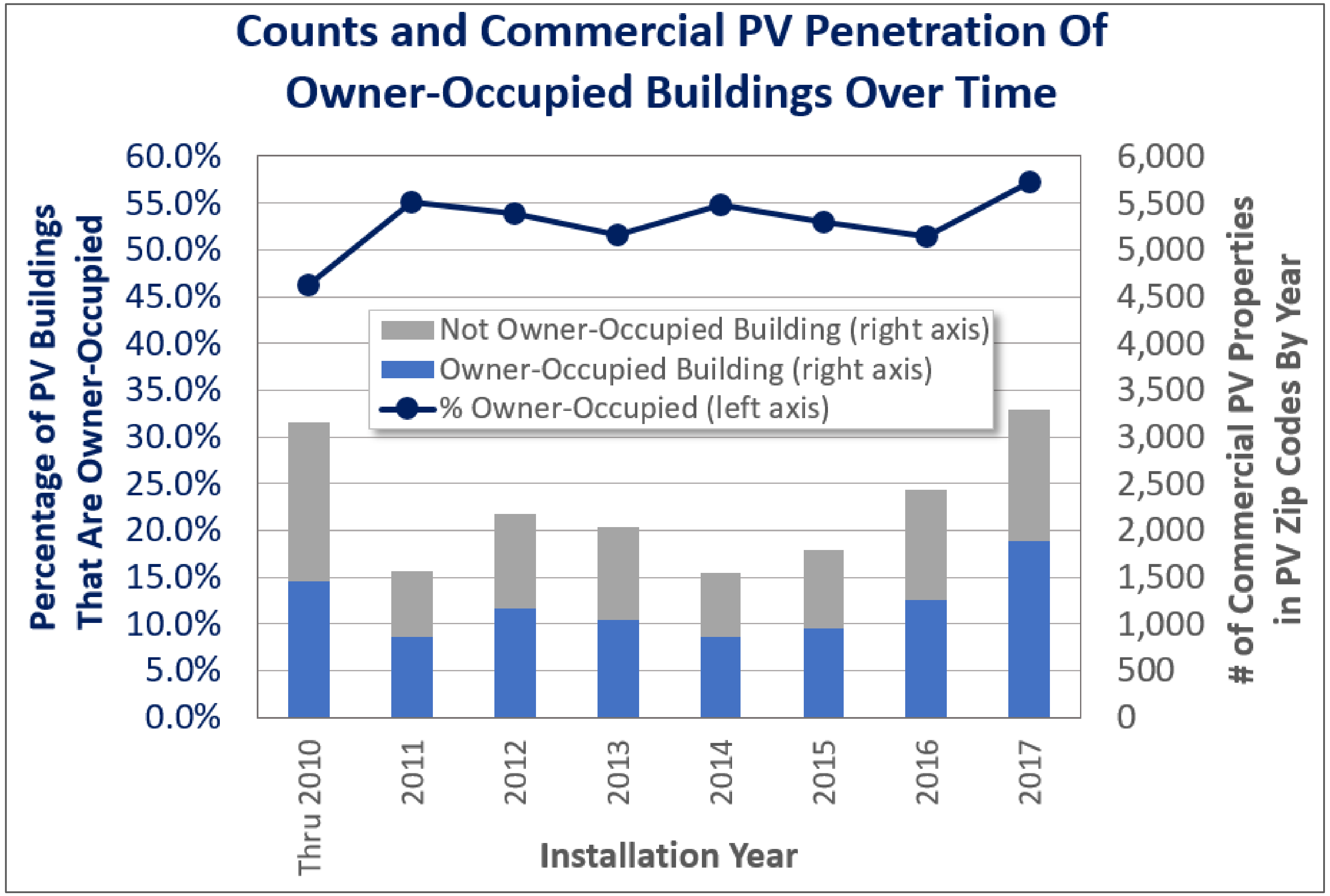


- As noted previously, SMR flags any property as "corporate" when it finds "corporation", "corp", "llc", "ltd", etc. in its name.
  - Therefore, even when this flag = 0, it might still have a corporate owner
- With that caveat in mind, the percent of corporate-owned properties, peaked in 2012 at 70% but has since returned to levels closer to 55%

Notes: *100% of the full dataset had information on whether the building was owned by a corporation or an individual*

BERKELEY LAB

Penetrations into owner-occupied buildings has remained steady over the study period



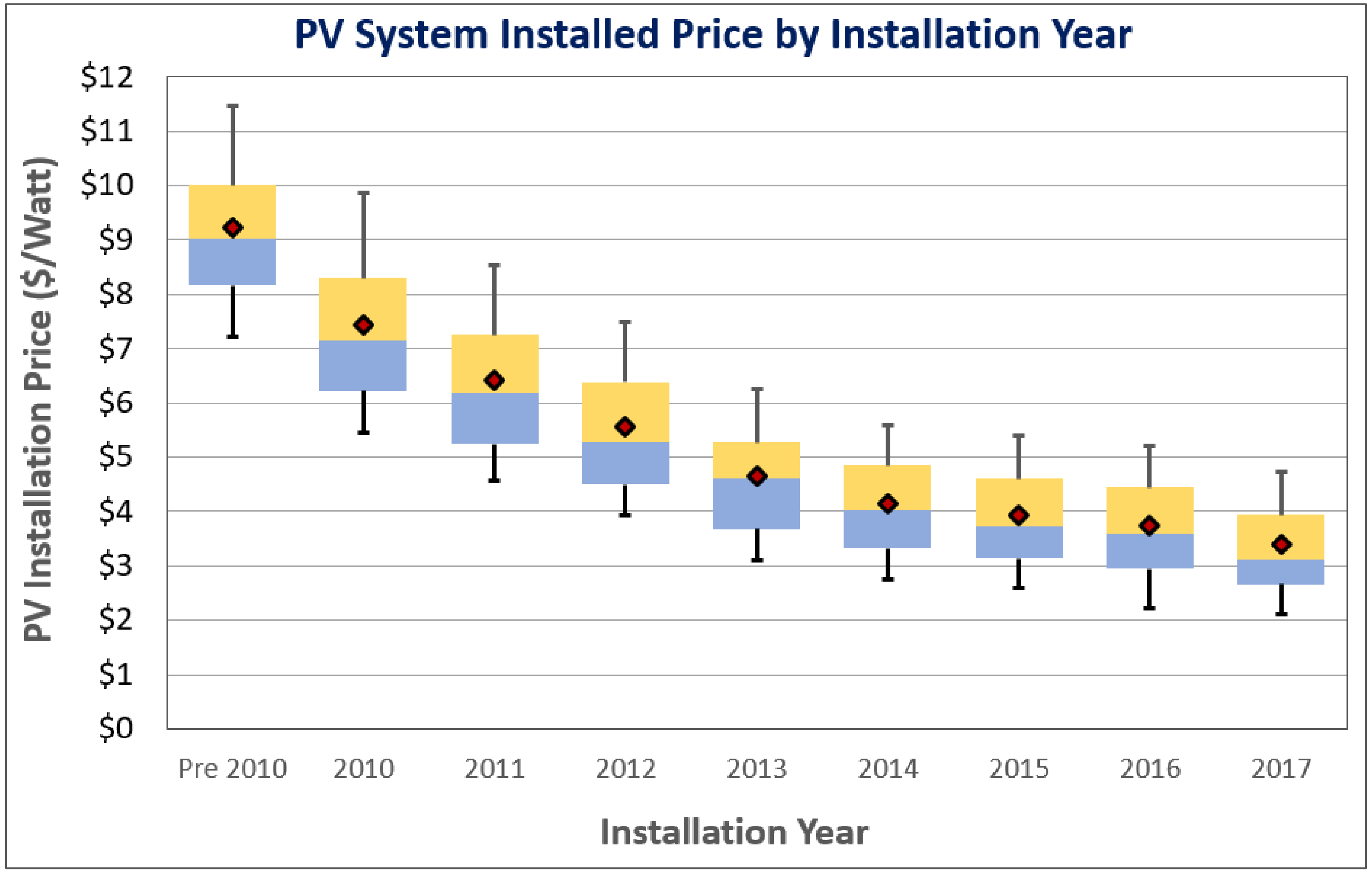
Notes: *Approximately 96% of the full dataset had information on whether a building was owner-occupied or not. The "Thru 2010" column is cumulative, while the other years shown on the x-axis are annual*

- The percent of commercial PV properties that are owner-occupied has remained steady between 50 and 55% throughout the study period
- Therefore, the cumulative numbers of owner-occupied buildings are steadily increasing
- And, as noted previously, PV penetration rates among owner occupied buildings are much higher (1.5%) than non-owner-occupied buildings (0.7%)

Outline

- Overview and Background
- Data
- **Results**
  - PV Penetration Overall, State and Property Type
  - What Property & Building Characteristics Are Correlated With Higher Penetrations?
  - How Have PV Property & Building Characteristics Changed Over Time?
  - **How Have PV System Characteristics Changed Over Time, & By State and Property Type?**
- Conclusions & Next Steps
- Appendix

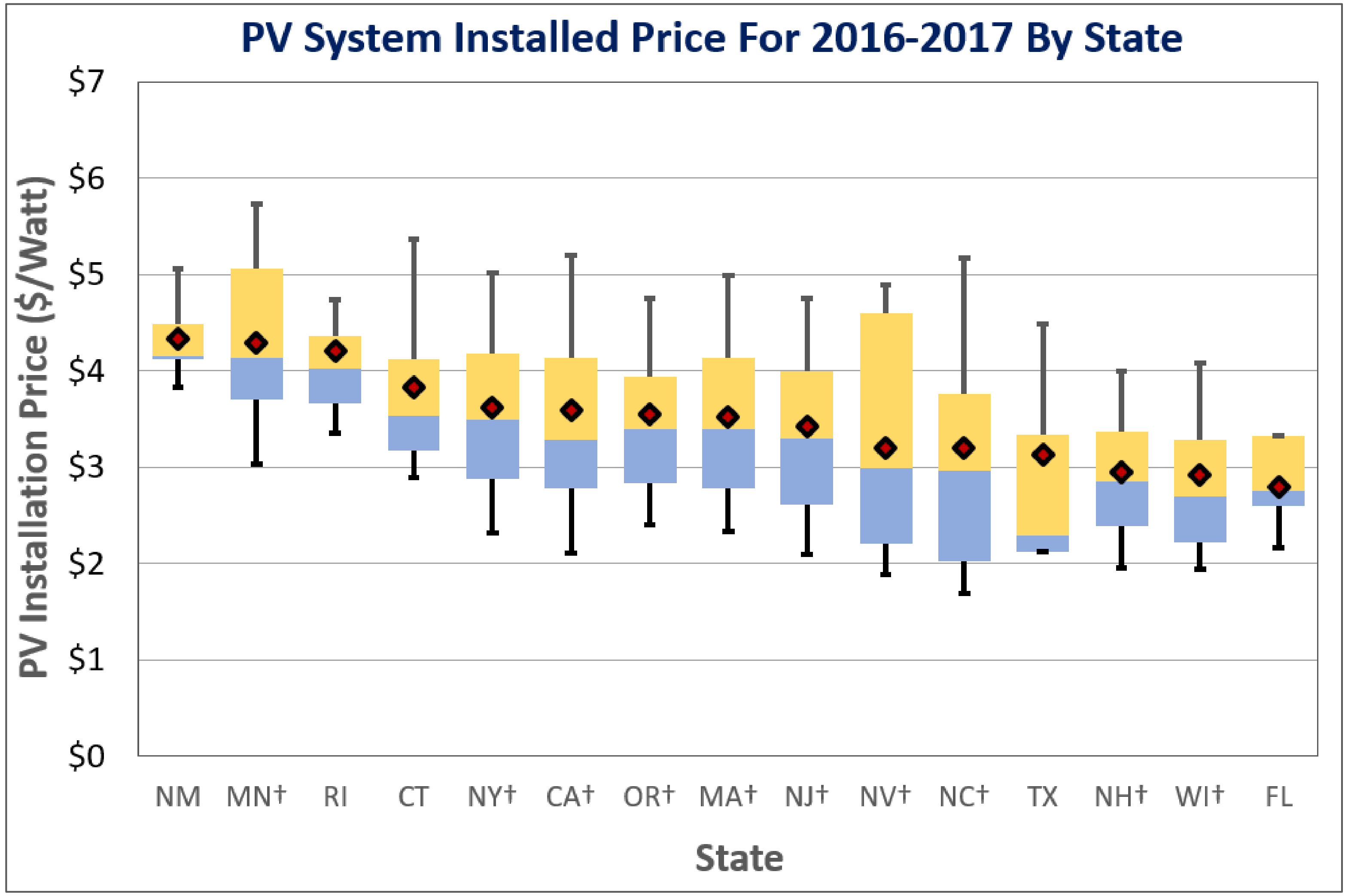
The installed PV system price for commercial PV has steadily declined from its pre-2010 levels to just below $3.40/watt



Notes: *85% of the PV dataset had information on the PV system installation price. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. Prices reflect full installation costs prior to any incentives in real 2017 dollars.*

- Using data collected as part of the Tracking The Sun Series, we find the mean price for PV installed on commercial properties prior to 2010 was greater than $9/watt, but has continued to fall since then reaching just below $3.40/watt in 2017
  - Some TTS data have a "commercial" designation. Although, that designation was not used for this analysis (because the USPS and SMR commercial property matches were more comprehensive), the price trends for TTS "commercial" systems (e.g., Figure 30; Barbose et al, 2019) are very similar to the figure to the left
- The distribution of prices have also remained fairly stable over time, with a slight narrowing in more recent years
- All else being equal this should be a driver for greater numbers of installations in the future

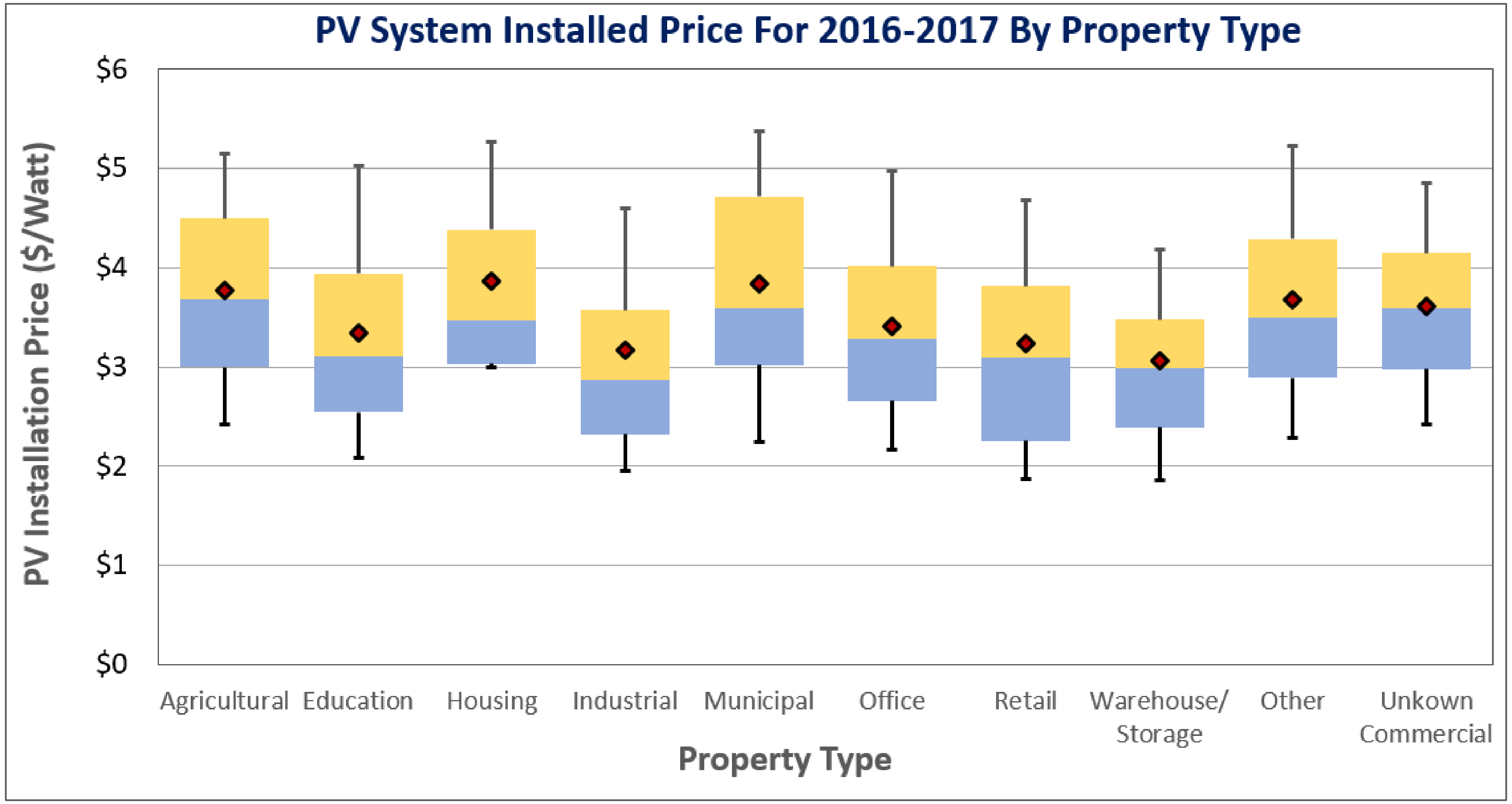
Mean installed PV system prices across all states (for 2016 and 2017) have ranged from above $4.33 to $2.79



Notes: *85% of the PV dataset had information on the PV system installation price. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. † indicates data coverage in the state of less than 30 cases*

- Mean installed PV systems prices across all states have ranged within a fairly wide band of approximately $4.30 to $2.80/Watt
  - These estimates are derived from just 2016 & 2017, and therefore might be higher than would be found in 2018
- Some states have incomplete data coverage (see † for those with >30 cases), while other have no data and are omitted (IL, PA, AR)
- Of those with complete coverage, MN and NY have the highest prices at $3.70 and $2.88/watt

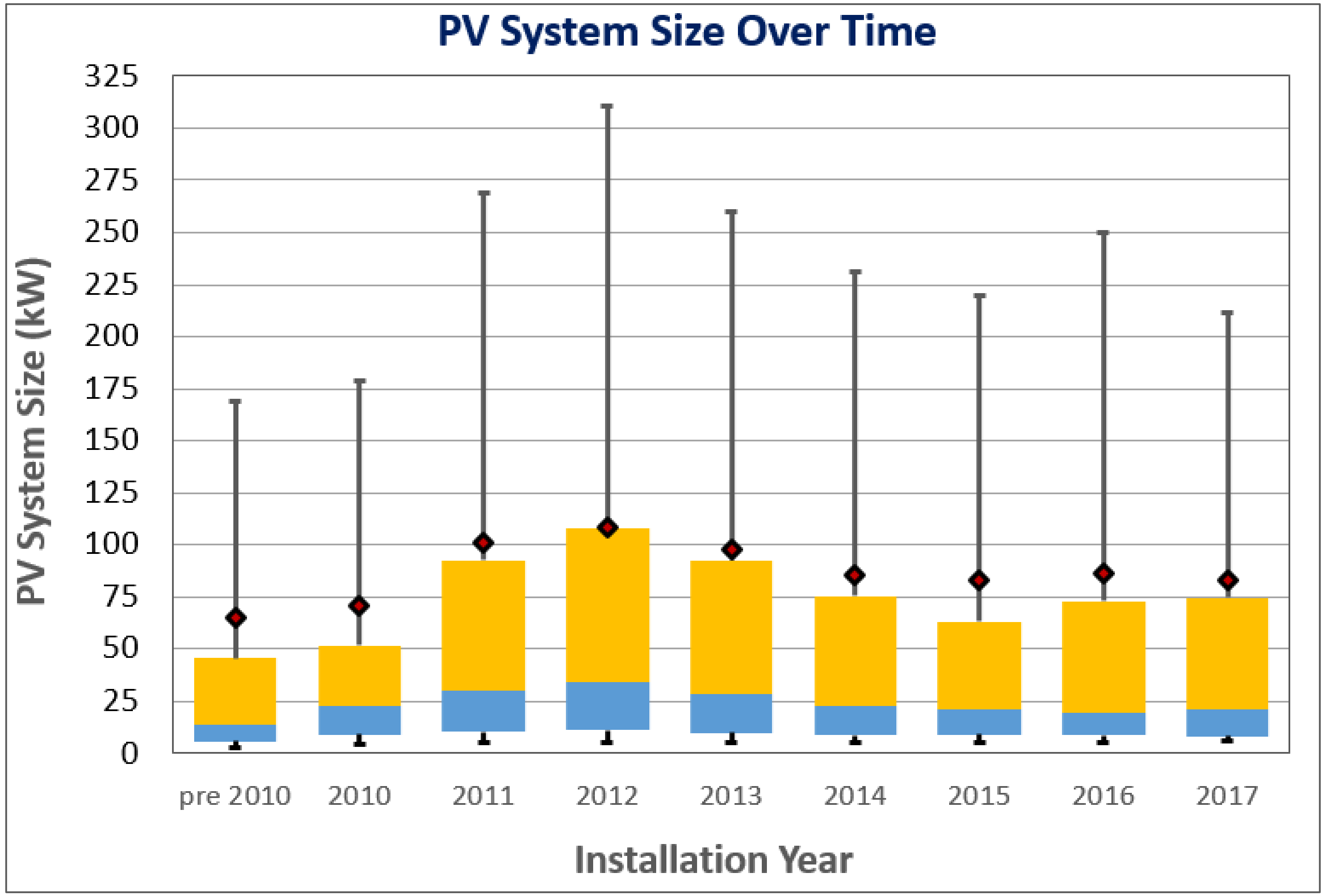
PV system prices by property type for 2016 and 2017 range between roughly $3.85 and $3.05



Notes: *85% of the PV dataset had information on the PV system installation price. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. "Unknown Commercial" properties are properties that are commercial but have not been further categorized.*

- Mean installed PV systems prices across all property types for 2016 and 2017 installations have ranged between approximately $3.85 to $3.05/Watt
  - These estimates are derived from 2016 and 2017 years, and therefore are potentially higher than would be found in 2018
- Agricultural, large multi-family housing and municipal installations have some of the highest prices across all years, while industrial and warehouses have some of the lowest
- These trends are correlated with system sizes with larger systems enjoying lower prices (see slide 48)

The mean and median PV system size for PV properties after peaking in 2012 has returned to more constant levels

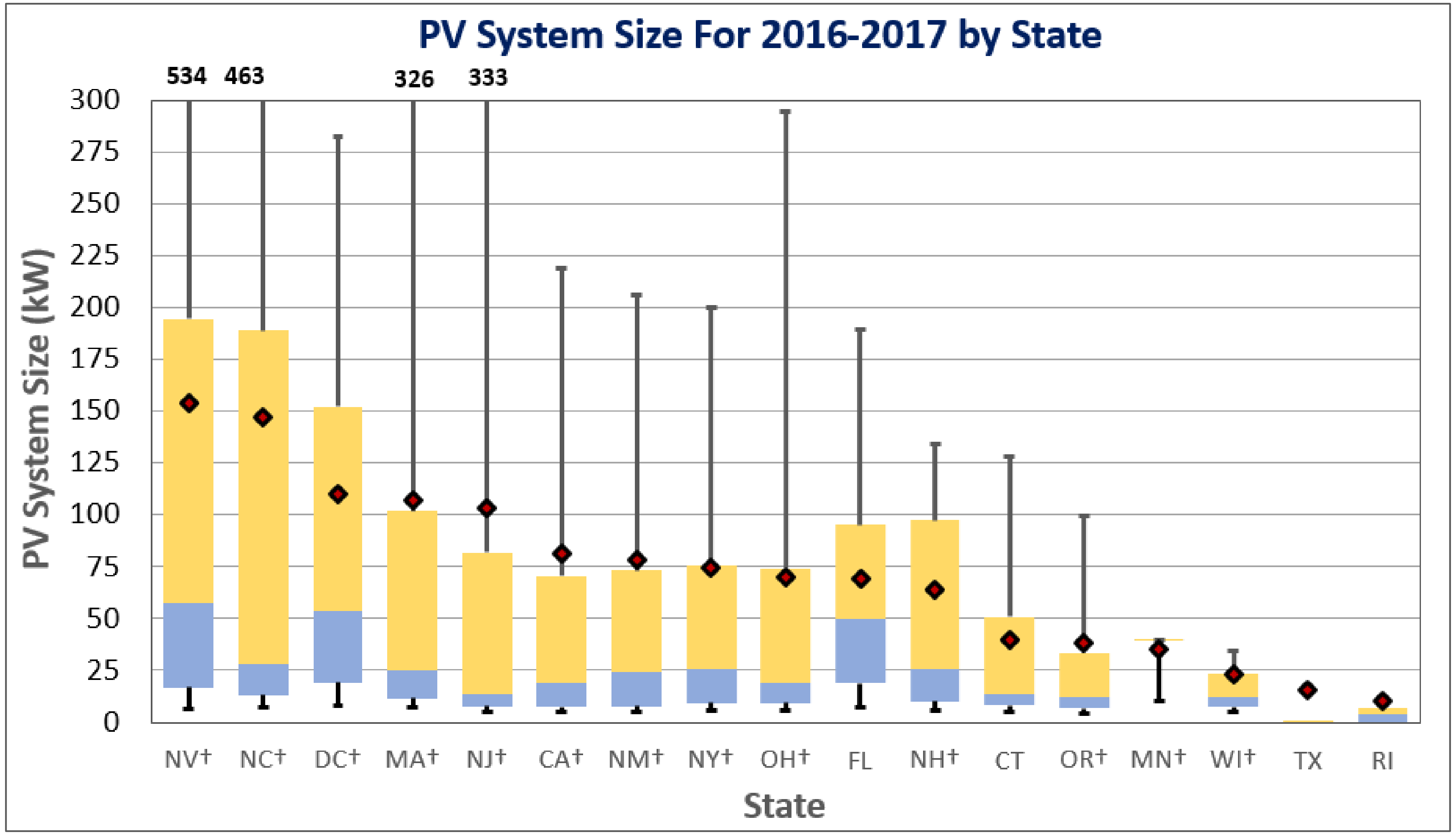


Notes: *100% of the PV dataset had information on the PV system size*

- Although mean and median PV system sizes peaked in 2012 at 100 kW and 30 kW, respectively, they have settled at 74 and 16 kW, respectively, from 2014 through 2017
- Given increases in panel efficiency, this might be an indication of smaller roof spaces being developed, though slide 36 shows that not to be dramatic
- The disparity in the mean and median, indicates that in all years, some large systems were developed, as evidenced by the upper 90^{th}% error bars, but they represent a small portion of the total

BERKELEY LAB

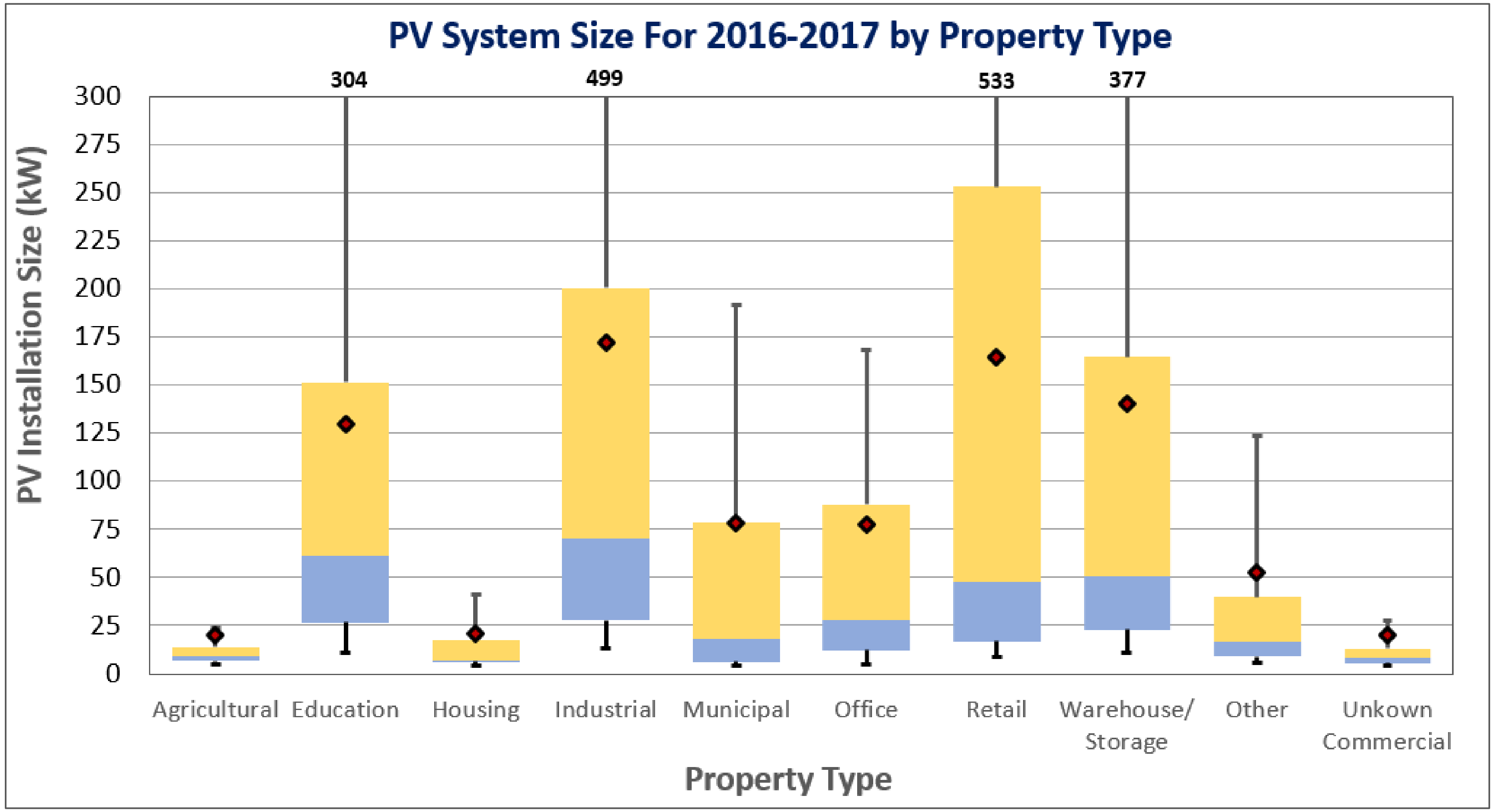
Mean PV system size across states for 2016 and 2017 ranged widely from greater than 150 kW to less than 10 kW



Notes: *85% of the PV dataset had information on the PV system installation price. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means. † indicates data coverage in the state of less 30 cases*

- Mean PV system sizes differed greatly between states (as did medians) with many being larger than 75 kW and another set smaller than 25 kW
  - Some of the variation might be driven by states policies encouraging either larger or smaller systems See Barbose (2018) for more information on these policies

The type of property strongly impacts the the PV system size. Industrial properties' are the largest; agricultural or housing are smallest

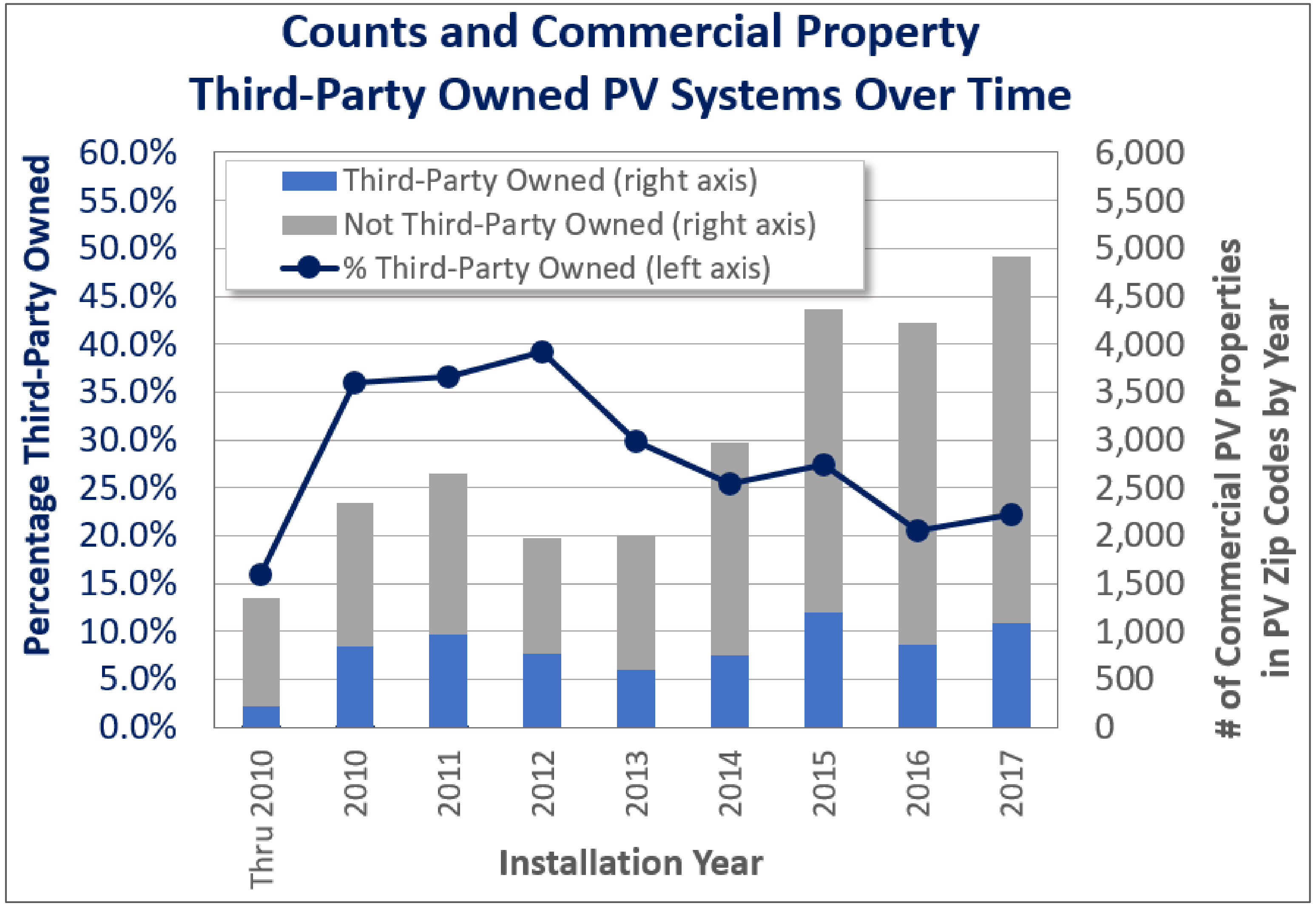


- Four property types have distinctly larger mean (and median) system sizes
  - They include industrial (171 kW), retail (164 kW), warehouse & storage (140 kW), and education (129 kW)
  - While agricultural and housing & lodging (both ~20 kW) and unspecified (i.e., "unknown") commercial properties (20 kW) have consistently smaller systems

Notes: *85% of the PV dataset had information on the PV system installation price. Boxes represent quartiles. Whiskers are p10 and p90. Red diamonds are means.*

BERKELEY LAB

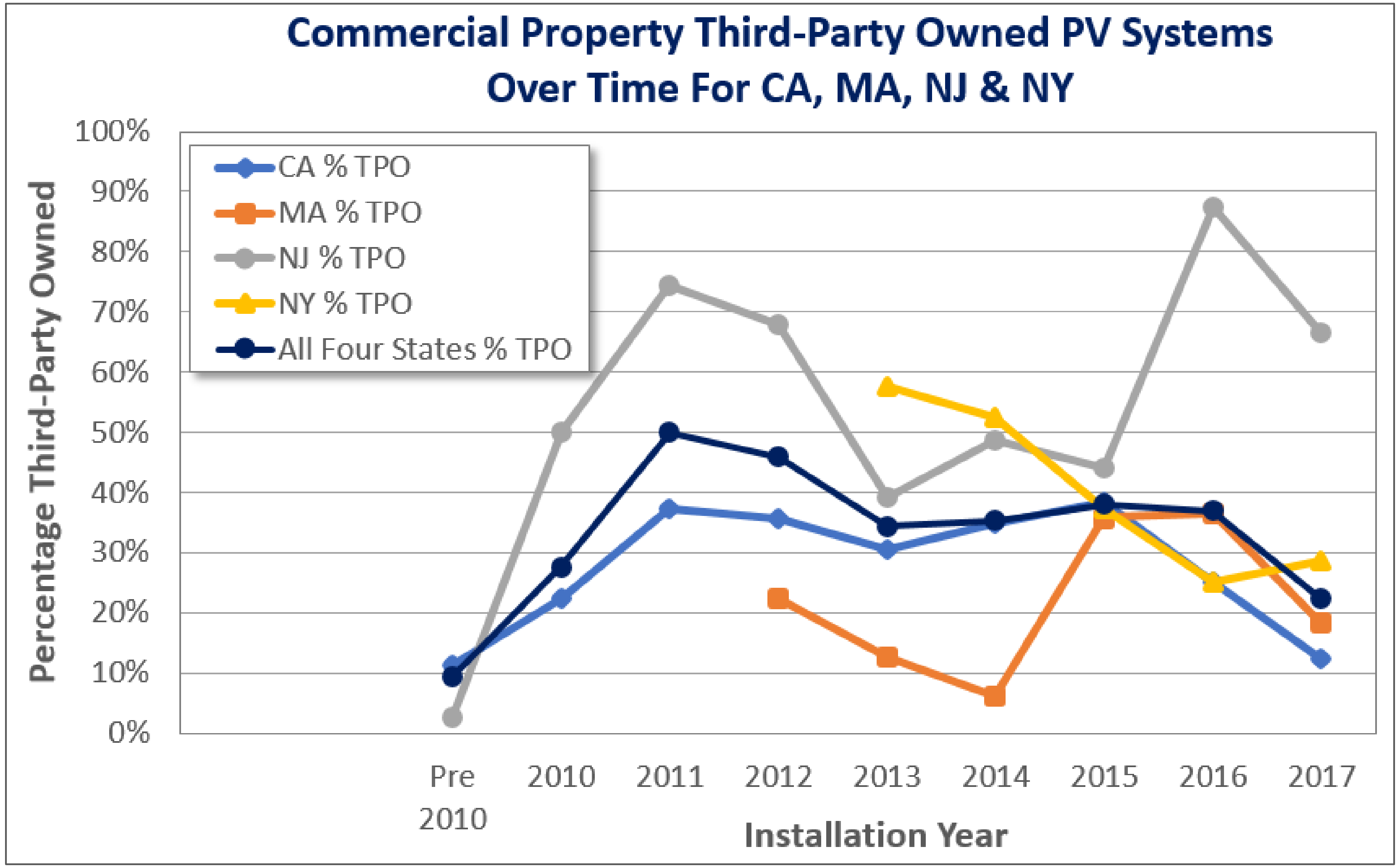
The percentage of third-party owned PV systems peaked in 2010 to 2013 period and has steadily fallen since



- Third-party ownership among commercial properties was at 40% in 2013, its peak, but has steadily fallen to 22% in 2017
  - Davis (2018b), of WoodMackenzie, concludes that TPO is on the rise among “commercial systems”, but that rise is almost entirely attributed to community solar. When they are excluded a drop, similar to the one found here, is evidenced in their data
- This drop is likely in part due to alternative financing options available for commercial PV customers as well as opening of new markets in states where TPO systems are not encouraged
  - Just noting here that our analysis excludes virtual PPA systems, which, by definition, are TPO
- As will be shown on following slides, large TPO % disparities exist among different states and building types

Notes: *Approximately 81% of the PV dataset had information on whether the PV system was owned by a third-party or not*

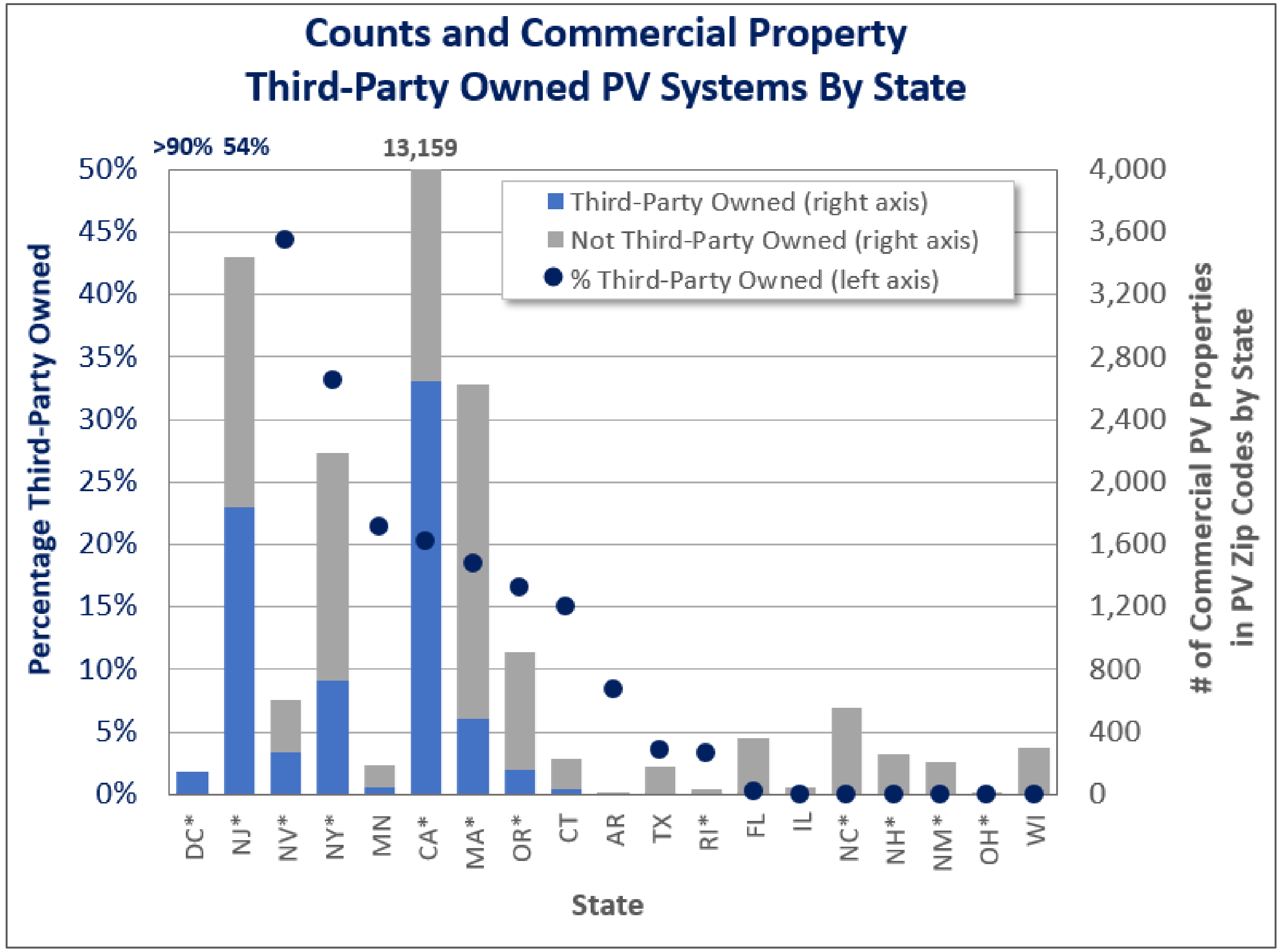
The four states with nearly complete TPO data coverage over time tell a similar story as all 20 states: TPO peaked in 2013 and has fallen since



Notes: *Approximately 81% of the PV dataset had information on whether the PV system was owned by a third-party or not. Gaps in figure are for cells that contain less than 100 cases*

- Focusing on CA, MA, NJ and NY, which together total more than 18,000 installations, and are missing only <15% of their data, a similar story unfolds as was shown when all states are aggregated (slide 48): TPO peaked in 2011 and has fallen since
- The anomaly among them is NJ, which has fluctuated between 40 and 90% since 2010
- Clearly customers in these high-PV-deployment states are finding ways to finance without relying on third-party ownership

The percentage of third-party owned PV systems across states differs dramatically (and might be a reflection of data availability)

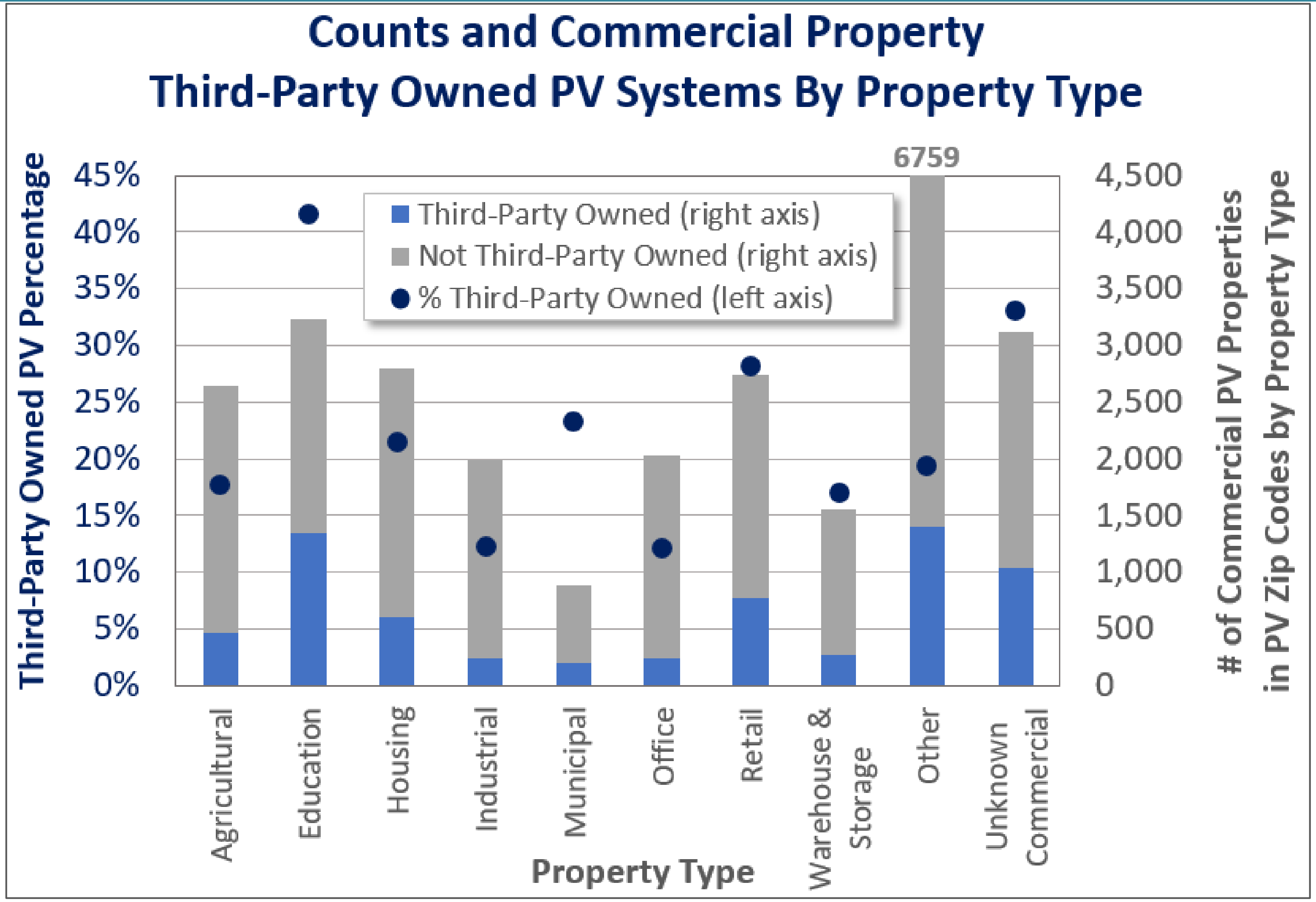


Notes: *Approximately 81% of the PV dataset had information on whether the PV system was owned by a third-party or not. * indicates data coverage in the state of less than 60%*

- Third-party PV system ownership among states ranges from >90% in DC to ~ 0% in many states (e.g., IL, NC and OH)
- In CA, with more than 13,000 commercial PV properties, TPO penetration is at 20% indicating the availability of alternative means of financing available to these customers
- In other states, where we see 0% TPO penetrations, states do not allow TPO installations (FL & NC)[1], others remain unclear (WI), and finally others are missing a TPO/non-TPO declaration for a high % of their data (OH & NM)
- Although not shown many of the patterns shown to the left (for all years) are similar for data from only 2016-2017

[1] See NC Clean Energy Tech Center (2018)

TPO percentages are highest among educational installations, likely due to the inability to absorb tax incentives



- Education properties are among the highest in terms of TPO penetrations
  - Federal tax incentives, which can constitute a major portion of PV investment, would not be available to tax exempt education institutions
  - Interestingly, municipal properties do not exhibit a particularly high TPO%, despite a similar tax exempt status
- Alternatively, industrial and office properties see significantly lower TPO penetrations
- Although not shown, the patterns for 2016-2017 installations are similar

Notes: *Approximately 81% of the PV dataset had information on whether the PV system was owned by a third-party or not. "Unkn Commercial" properties are properties that are commercial but have not been further categorized.*

Outline

- Overview and Background
- Data
- Results
  - PV Penetration Overall, State and Property Type
  - What Property & Building Characteristics Are Correlated With Higher Penetrations?
  - How Have PV Property & Building Characteristics Changed Over Time?
  - How Have PV System Characteristics Changed Over Time, And By State and Property Type?
- **Conclusions & Next Steps**
- Appendix

Conclusions (1 of 2)

- This constitutes the most comprehensive comparative analysis of commercial PV and non-PV real estate to-date focusing on property and building characteristics. Over 30,000 PV properties were investigated
- The commercial market is important because of its enormous potential. So far, though, development has lagged that of residential and utility scale in terms of building installed solar. *(Though, virtual PPAs might be a less costly substitutions for entities looking to increase solar, which are not part of this analysis.)*
- Five "states" (CA, MA, NM, NJ, NV) plus DC have commercial PV penetrations over 1.5%, while the majority (14) have penetrations lower than 1%
  - And most of the low penetration states are at or below 0.5%. Yet, penetrations have doubled over the last 6 years in nearly all states, with some "states" (e.g., DC and NH) seeing dramatic increases
- PV penetration varies significantly by property type
  - Education buildings have highest PV penetration (6.9%), yet industrial and warehouse (1.6%), (1.5%), and agricultural (1.5%) properties are also above average. Housing (0.9%) and retail (0.9%) are both lagging
  - There are multiple possible explanations for the disparities in PV penetrations across property types, including: tax credit eligibility, roof space, concentrated/private ownership, sustainability goals, etc.
  - These disparities are examined using bi-variate analysis, with some accompanying side-bar analysis

Conclusions (2 of 2)

- Commercial PV system prices have declined significantly over the past decade, from roughly $9/W in 2010 to $3.38/W in 2017
  - Yet there is still considerable price variation between states and property types. Municipal installations have some of the highest prices, while warehouses, industrial and retail are lowest
- Several other key drivers correlate to higher PV penetrations:
  - The property being owner-occupied appears to increase penetrations, as does having fewer occupants, and and having fewer stories
  - Larger properties, e.g., >9,000 ft^2, are also correlated with higher penetrations as are more valuable and newer properties
- Despite what one would assume to be a heterogeneous market, many aspects have remained constant over time implying limited deployment innovation
  - The numbers of occupants and stories have remained flat since 2010, on average, as have building market value and age, and the percent which are owner-occupied
  - Alternatively, the percent of buildings that are corporate (vs. individually) owned and the size of buildings has dropped, which might be a signal of some deployment innovation
- Percentages of third-party owned PV systems over all states peaked in ~2012 and has dropped since
  - Four states with near complete data coverage show a similar pattern. Tax exempt entities see higher percentages

For Further Information

Contact the authors

Ben Hoen, bhoen@lbl.gov, 845-758-1896

Joe Rand, jrand@lbl.gov, 707-633-8505

Salma Elmallah, salmae@lbl.gov, 510-486-6032

Download other Berkeley Lab renewable energy publications

https://emp.lbl.gov/publications

Sign up for our email list

https://emp.lbl.gov/join-our-mailing-list

Follow us on Twitter

@BerkeleyLabEMP

Appendix
Supplemental Materials

Analysis Sample: Annual Commercial PV Adopters by State

State	<=2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
AR	0	0	0	0	0	0	0	0	0	2	10	0	0	0	0	0	0	**11**
CA	42	99	148	275	298	339	516	675	569	737	1,323	1,395	1,216	1,574	2,035	2,297	2,254	**15,792**
CT	0	0	0	1	0	10	16	50	44	50	29	13	8	9	16	23	7	**273**
DC	0	0	0	0	1	1	1	0	8	9	26	10	15	21	25	93	81	**288**
FL	0	1	0	0	0	0	5	7	98	107	43	43	25	10	8	6	14	**365**
IL	5	3	15	2	5	9	10	6	10	28	9	36	0	0	0	0	0	**136**
MA	0	3	15	28	25	56	28	59	129	204	243	290	263	245	383	557	455	**2,982**
MN	0	0	0	0	0	0	0	0	0	0	0	0	0	25	46	58	62	**191**
NC	0	0	0	0	0	1	4	11	20	65	62	83	43	62	93	80	26	**550**
NH	0	0	0	0	0	0	0	0	0	6	10	16	26	22	48	81	54	**263**
NJ	0	7	11	20	43	78	65	121	232	443	839	741	296	142	104	580	546	**4,269**
NM	3	1	1	2	4	9	8	8	22	46	69	78	52	63	40	49	30	**483**
NV	0	0	0	0	8	6	7	11	22	72	210	62	56	82	35	36	23	**629**
NY	0	0	5	14	7	16	26	41	104	205	246	434	335	340	444	418	499	**3,133**
OH	0	1	0	0	1	1	3	12	20	46	142	87	65	37	32	51	15	**511**
OR	3	3	7	17	17	14	26	55	91	90	93	74	48	56	109	109	168	**978**
PA	0	0	0	0	0	0	0	0	44	312	353	128	50	3	0	0	0	**889**
RI	0	1	0	1	5	1	6	4	2	0	5	12	2	1	9	18	10	**75**
TX	0	0	0	0	0	0	0	0	3	65	45	24	17	14	6	6	16	**196**
WI	0	0	0	0	0	0	0	0	0	24	78	34	18	29	31	40	49	**303**
Total	**52**	**118**	**202**	**360**	**412**	**539**	**720**	**1,061**	**1,414**	**2,508**	**3,834**	**3,559**	**2,535**	**2,733**	**3,462**	**4,501**	**4,308**	**32,317**

BERKELEY LAB

Analysis Sample: Annual Commercial PV Capacity (kW) by State

State	<=2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
AR	-	-	-	-	-	-	-	-	-	0.0	0.2	-	-	-	-	-	-	**0.2**
CA	0.4	1.3	6.7	12.1	16.9	19.3	34.8	74.4	44.7	58.6	147.4	142.9	112.7	130.0	172.3	214.0	154.2	**1,342.7**
CT	-	-	-	0.0	-	0.3	1.5	5.4	6.2	1.9	2.2	0.5	0.0	0.1	0.3	0.9	0.2	**19.6**
DC	-	-	-	-	0.0	0.0	0.0	-	0.3	0.1	1.3	0.4	0.9	0.7	0.9	11.2	7.8	**23.7**
FL	-	-	-	-	-	-	0.1	0.2	1.8	4.0	3.0	3.9	1.9	0.5	0.3	0.8	0.6	**17.0**
IL	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.5	0.1	0.9	-	-	-	-	-	**1.9**
MA	-	0.1	0.1	0.4	0.5	2.1	0.7	2.2	5.2	12.6	18.6	39.2	28.8	28.7	42.8	45.7	62.0	**289.6**
MN	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	1.3	2.0	2.2	**6.4**
NC	-	-	-	-	-	-	0.1	0.3	1.3	8.3	8.1	9.6	3.7	4.4	13.6	14.0	1.4	**64.9**
NH	-	-	-	-	-	-	-	-	-	0.0	0.1	0.2	0.5	0.6	1.5	5.3	3.4	**11.6**
NJ	-	0.4	0.6	0.3	2.2	10.1	7.4	11.4	31.4	55.1	145.0	138.0	61.6	30.8	15.8	47.6	66.3	**624.0**
NM	0.0	-	0.0	-	-	0.1	0.1	0.0	0.5	2.7	3.6	3.2	7.4	4.3	1.5	3.2	3.1	**29.6**
NV	-	-	-	-	0.1	0.1	0.2	0.2	0.7	3.5	14.7	6.2	4.3	10.7	7.0	6.4	2.7	**56.9**
NY	-	-	0.0	0.1	0.1	0.2	0.3	0.7	2.3	6.0	6.9	13.0	14.0	14.0	21.8	24.7	43.2	**147.2**
OH	-	-	-	-	0.0	0.0	0.0	0.4	0.4	2.6	9.7	16.6	5.2	2.5	1.1	4.0	0.6	**43.0**
OR	-	-	0.0	0.1	0.1	0.1	0.3	1.6	3.1	3.0	2.6	2.9	1.3	1.8	4.5	5.5	5.0	**31.9**
PA	-	-	-	-	-	-	-	-	0.8	14.9	18.2	4.7	1.9	0.0	-	-	-	**40.5**
RI	-	-	-	0.0	0.1	-	0.0	0.0	0.0	-	0.1	0.1	0.0	0.0	0.1	0.2	0.1	**0.8**
TX	-	-	-	-	-	-	-	-	0.1	2.1	1.7	0.8	0.3	1.3	0.1	0.1	0.3	**6.6**
WI	-	-	-	-	-	-	-	-	-	0.5	1.2	0.6	0.3	0.2	0.4	0.7	1.3	**5.3**
Total	**0.5**	**1.9**	**7.8**	**13.0**	**19.9**	**32.2**	**45.5**	**96.9**	**98.8**	**176.4**	**384.7**	**383.7**	**244.8**	**231.5**	**285.1**	**386.4**	**354.3**	**2,763.2**

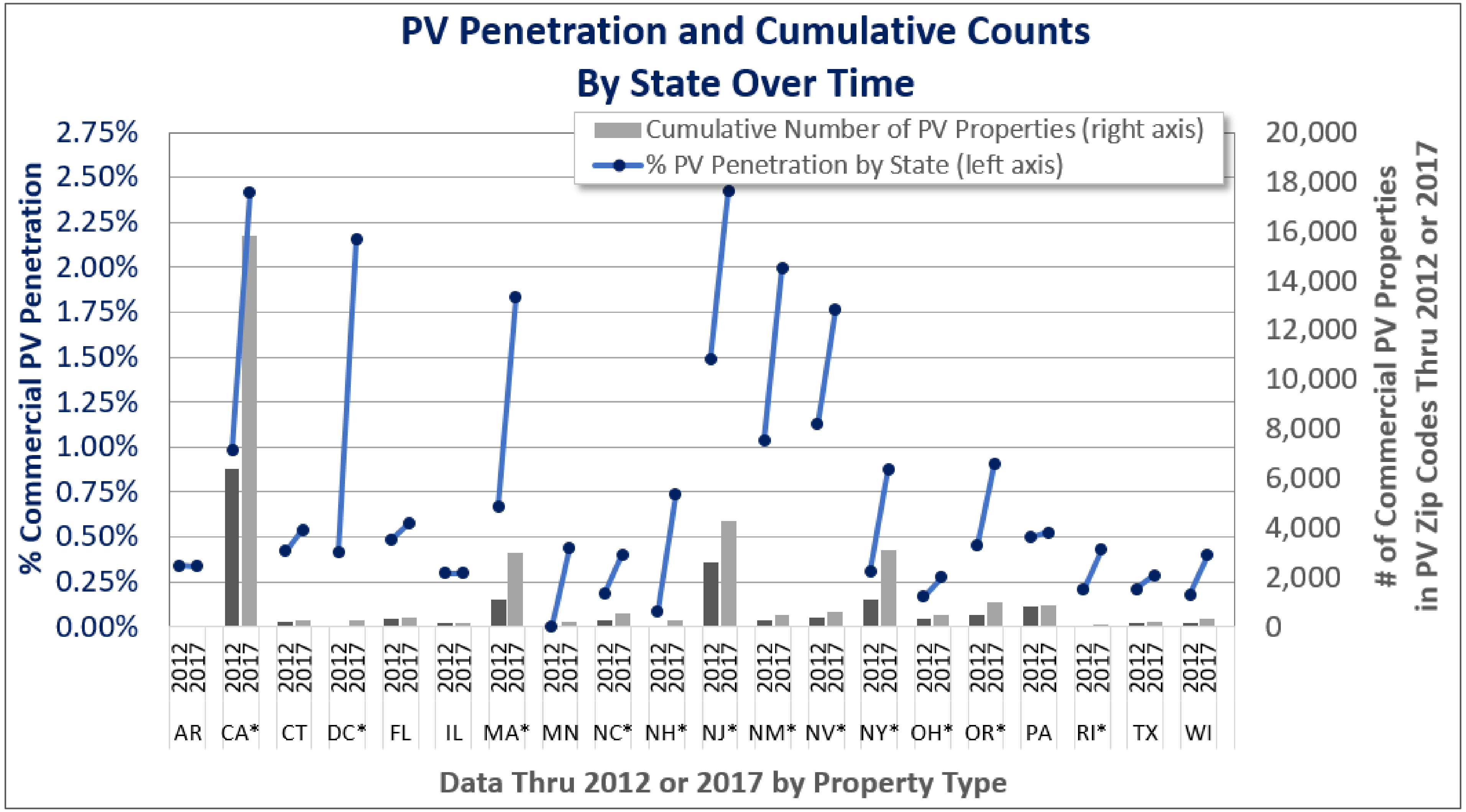
BERKELEY LAB

Property Type Category Detail

Overall Category	Detailed Category	Simplified Category For Figures
Agriculture	Farms & Ranches	Agricultural
	Grain Elevator	
	Orchards & Vineyards	
Banks & Professional	Financial Bldg (Bank; S&L; Mtge; Loan; Credit)	Other (Banks/Professional)
	Professional Bldg/Offices	
	Professional Bldg-Eng/Arch./Legal/Accntng	
	Professional Bldg-Real Est/Insurance	
Cemetery	Cemetery	Other (Assorted)
Clubs, Lodges, Charities	Clubs/Lodges/Associations/Non-Profits	Other (Clubs/Lodges/Charities)
Education	College, University, Vocational School	Education
	Day Care, Pre-school & Nurseries	
	Schools, Public & Private	
General Commercial	Commercial (General)	Unkn (i.e., "Unknown") Commercial
	Commercial/Industrial Condominium (Not Offices)	
	Other Tax Exempt Properties	
	Wholesale Trade	
Government-Owned	City, Municipal, Town, Village Owned	Municipal
	County Owned	
	Emergency (Police/Fire/Rescue/Shelters)	
	Federal Property	
	Governmental (General)	
	Military (Office/Base/Post/etc.)	
	Miscellaneous	
	State Owned	
Housing & Lodging	Apartment Building	Housing
	Apartment Building, Large	
	Boarding/Rooming House	
	Hotel/Motel Chain	
	Institutional Quarters	
	Lodging	
	Welfare, Social Service, Low Income Housing	
Industrial	Commercial/Industrial Condominium (Not Offices)	Industrial
	Distillery, Brewery, Winery, Bottling	
	Entertainment Industry	
	Food Packing/Processing/Manufacturing	
	Industrial-General	
	Industrial-Heavy	
	Industrial-Light	
Information	Information Industry	Other (Assorted)
Laboratory	R&D Facility, Laboratory Or Research	Other (Assorted)
Marine	Shipyards & Marine Facilities	Other (Marine)
Medical	Hospital	Other (Medical)
	Medical Bldg/Offices (Excluding Hospitals)	
	Veterinary, Animal Hospital	
Mining	Mining & Refining	Other (Assorted)
	Quarries, Mineral Processing	
Miscellaneous Services	Airport & Related (incl. Air Transit)	Other (Misc. Services)
	Auto Repair (& Related), Garage	
	Business Services	
	Construction/Contracting Services	
	Funeral Home, Mortuary	
	Non-Auto Service/Repair Shops	
	Personal Services (Barbers, Salons, Spas, Gyms)	
Mixed Use	Comm/Ofc/Res Mixed Use	Other (Mixed Use)
	Stores/Mixed Use	
Museums/Libraries	Museums, Library, Gallery/Historical Site	Other (Assorted)
Office Buildings	Condominium Offices	Office
	Multi-Tenant Offices	
	Multi-Tenant Offices/Stores	
	Office Building	
Parking Garage, Deck, Or Lot	Parking Garage, Deck, Or Lot	Other (Parking)
Postal	Post Office	Other (Assorted)
Recreation	Golf Courses & Country Clubs	Other (Recreation)
	Indoor Recreational Facility	
	Outdoor Recreational Facility	
Religious	Religious, Church, Worship	Other (Religious)
Retail	Appliance Store	Retail
	Auto Parts & Related	
	Bakeries (Wholesale & Retail)	
	Bar, Tavern	
	Car Wash	
	Chain Drug Store	
	Chain Restaurant	
	Convenience Store	
	Department Store/Wholesale Outlet	
	Drug Store / Pharmacy	
	Dry Cleaner, Laundry	
	Florist, Nursery, Greenhouse (Retail/Wholesale)	
	Garden Center, Home Improvement	
	Gas Stations & Fuel Dealers	
	Grocery Store	
	Lumberyard, Building Materials	
	Multi-Tenant Retail	
	Pet Stores & Services	
	Restaurants	
	Retail Stores NEC	
	Shopping Center Or Mall	
	Supermarket	
	Vehicle Sales, Rentals	
	Wine & Liquor Stores & Imports	
Rv, Mobile Home, Trailer Park	RV, Mobile Home Park, Trailer Park	Other (Assorted)
Transportation	Transportation	Other (Assorted)
Utilities	Utilities	Other (Utilities)
Warehousing & Storage	Mini-Warehouse, Self Storage	Warehouse/Storage
	Storage yard, Open Storage	
	Warehouse/Storage	
Waste	Miscellaneous	Other (Assorted)
	Waste Disposal, Sewage Treatment	

BERKELEY LAB

Virtually every state saw a significant increase in PV penetration from 2012 to 2017 (figure showing all states)



- Most states saw at least a doubling in penetration from 2012 to 2017
- This implies states/districts are continuing to find deployment opportunities, yet few are experiencing a breakthrough

Notes: *States with >60% estimated data coverage are marked with an *.*

References

Barbose (2018) U.S. Renewables Portfolio Standards: 2018 Annual Status Report. Lawrence Berkeley National Laboratory. November 2018. 38 pages. https://emp.lbl.gov/publications/us-renewables-portfolio-standards-1

Barbose, Darghouth, LaCommare, Millstein & Rand (2018) Tracking the Sun: Installed Price Trends for Distributed Photovoltaic Systems in the United States - 2018 Edition. Lawrence Berkeley National Laboratory. September 2018. 52 pages. https://emp.lbl.gov/publications/tracking-sun-installed-price-trends

Bird, Gagnon, & Heeter (2016) Expanding Midscale Solar: Examining the Economic Potential, Barriers, and Opportunities at Offices, Hotels, Warehouses, and Universities. National Renewable Energy Laboratory. Golden, CO. NREL/TP-6A20-65938, September 2016. 57 pages.

Gagnon, Margolis, Melius, Phillips & Elmore (2016) Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment. National Renewable Energy Laboratory. Golden, CO. NREL/TP-6A20-65298, January 2016. 82 pages.

Davis, Michelle (2017) Executive Summary: Commercial Solar Asset Ownership: Landscape and Strategies. GTMResearch. November 2017. 12 pages. https://www.woodmac.com/our-expertise/focus/Power--Renewables/Commercial-Solar-Asset-Ownership

Davis, Michelle (2018a) Wunder Capital Closes $112 Million Fundraise for Commercial Solar. GTM news. April 18, 2018. https://www.greentechmedia.com/articles/read/wunder-capital-closes-112-million-fundraise#gs.4aq6it

Davis, Michelle (2018b) Commercial Solar May Be 78% Third-Party Owned by 2021. GTM news. April 26, 2018. https://www.greentechmedia.com/articles/read/commercial-solar-expected-to-be-78-third-party-owned-by-2021#gs.490y8f

Davis, Michelle (2018c) Commercial Solar Markets: Scalable or Snowflakes? GTM news. July 26, 2018. https://www.greentechmedia.com/articles/read/commercial-solar-markets-scalable-or-snowflakes#gs.48vcii

Davis, Michelle & Smith, Colin (2018) US Corporate Solar Procurement Surges in 2017. GTM news. April 12, 2018. https://www.greentechmedia.com/articles/read/us-corporate-solar-procurement-surges-2017#gs.4ar84a

Marsh (2017) Solar property tax exemptions: are they available where you live? Energy Sage. August 22, 2017. https://news.energysage.com/solar-property-tax-exemptions-abatements/

Merchant, Emma (2018) A Growing Roster of Startups and Developers Looks to De-Risk Commercial Solar. GTM news. January 18, 2018. https://www.greentechmedia.com/articles/read/a-roster-of-startups-and-developers-look-to-derisk-commercial-solar#gs.4aqch8

NC Clean Energy Technology Center (2018) 3rd Party Solar Power Purchase Agreement (PPA). DSIRE. March 2018. 3 pages. http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2018/03/DSIRE_3rd-Party-PPA_March_2018.pdf