Selling Into The Sun:
Price Premium Analysis of a Multi-State Dataset of Solar Homes

Report Summary

Ben Hoen

LBNL

Jan 22, 2014

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Questions

- Because of the large number of registrants for today's webinar, questions will be handled via the chat window after the presentation is complete.
- They will be answered in the order they are received.
- If there is not time to answer all of the questions during the 1-hour webinar, they will be answered via email.

Agenda

- Background
- Research Questions
- Methodology
- Data
- Results
- Conclusions, Next Steps & Outreach
- Other PV Real Estate News

Previous Literature

Author(s)	Year	Location	PV Sample Size	Sample Period	Method
Farhar & Coburn	2008	San Diego, CA	15	2001-2005	Comparison of Means
Watkins	2011	Multi-Cities, OR	23	2005-2010	Appraisals
Hoen, Wiser et al.	2011	Multi-Cities, CA	1,894	2000-2009	Hedonic Model
Dasturp et al.	2012	San Diego & Sacramento, CA	329	1997-2010	Hedonic Model
Desmarais	2013	Denver, CO	30	2011-2013	Appraisals

Previous literature is fairly thin, focused on California mostly, some small samples, and rarely includes the most recent period

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Literature Limitations

A number of areas have not been well covered in the nascent literature:

- Statistical measurement of premiums outside CA
- Premiums over time: e.g., pre & post-housing bubble
- New vs. existing home premiums
- PV system depreciation as they age
- Premiums vs. income and cost appraisal methods
- “Green cachet”: marginal effects for larger systems

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Research Questions That An Analysis Of Broader Dataset Of PV Homes Could Answer

1. Are PV home premiums evident for a broader group of PV homes than has been studied previously both inside and outside of California and through 2013?
2. Are PV home premiums outside of California similar to those within California?
3. How do PV home premiums compare to contributory values estimated using cost and income methods?
4. How did the size of the premium change over the study period, as gross PV system prices decreased and during housing market swings?
5. Are premiums for new PV homes similar to existing PV home premiums?
6. Is there evidence of a “green cachet” for PV homes above the amount paid for each additional watt added?
7. How does the age of the PV system influence the size of the PV premium?

Selling Into The Sun:

Price Premium Analysis of a Multi-State Dataset of Solar Homes

Purpose

Using actual sales prices, provide broadly applicable statistical evidence as to whether, and to what degree, **host-owned** PV systems increase the value of residential properties in multiple geographic markets in the U.S

Relevance

Provide solar stakeholders, especially those focused on valuation of PV containing properties, broad-based statistically defensible information about existence and magnitude of possible premiums for these properties.

Research Team

Led by LBNL, the team includes academic and appraising/valuation experts, including those professionally familiar with the valuation of PV properties.

Timeline

Started in FY2013 & Final Report completed in January 2015. Journal paper and outreach/dissemination activities continuing through FY2015.

Selling Into The Sun:
Price Premium Analysis of a Multi-State Dataset of Solar Homes

Research Team	Affiliation	Expertise
Ben Hoen	Lawrence Berkeley National Laboratory	Project Lead
Sandra Adomatis	Adomatis Appraisal Services	Appraising, Green Attribute Valuation
Tom Jackson	Texas A&M, Real Property Analytics	Appraising, Hedonic Models
Joshua Graff-Zivin	University of California at San Diego	Econometric Modelling, Stata
Mark Thayer	San Diego State University	Econometric Modelling
Geoffrey Klise	Sandia National Laboratory	PV Value Co-Creator, PV Property Valuation
Ryan Wiser	Lawrence Berkeley National Laboratory	Renewable Energy Policy, Modelling

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How Does One Accurately Measure The Treatment Effect Of Having PV On Homes?

Vs.

PV and Non-PV Homes can differ by:

Location, Size, Age, Condition, Parcel Size, Etc.

These Differences Can Be Estimated (i.e., Controlled For) Via A Hedonic Model

$$P = f\,(L, N, T, PV)$$

Where:

P = Sale Price

L = Home/Parcel Specific Variables

N = Neighborhood Variables

T = Time: Market Inflation and Deflation

PV = If the Home Has PV or Not

Hedonic Models Can Be Estimated To Test A Variety Of Research Questions

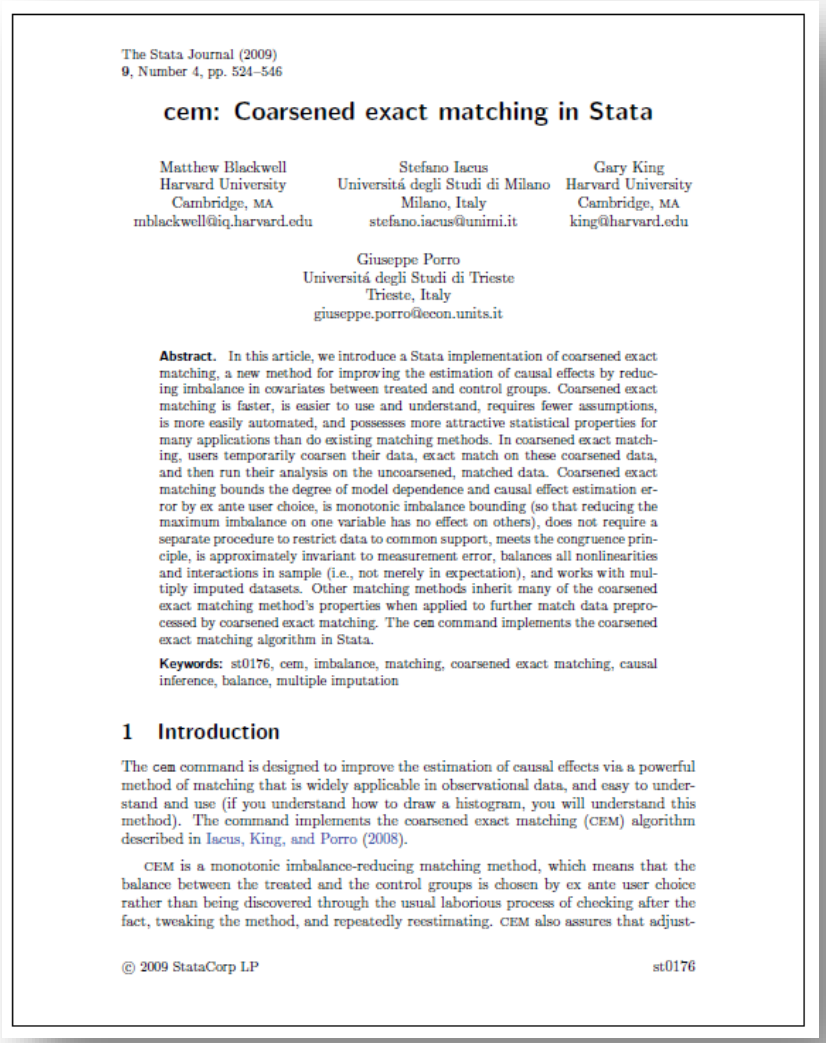
- Overall PV home premium (in $/watts)

- Premium * CA/Rest of US
- Premium * New/Existing
- Premium * Age of the PV System
- Premium * Year of the Sale

Data Subsets

- Premium in $/Watts and $/Watts^2

Data "Matching" Is Used To Ensure PV Homes Are Otherwise "Similar" To Non-PV Homes



The Stata Journal (2009)
9, Number 4, pp. 524–546

cem: Coarsened exact matching in Stata

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Abstract. In this article, we introduce a Stata implementation of coarsened exact matching, a new method for improving the estimation of causal effects by reducing imbalance in covariates between treated and control groups. Coarsened exact matching is faster, is easier to use and understand, requires fewer assumptions, is more easily automated, and possesses more attractive statistical properties for many applications than do existing matching methods. In coarsened exact matching, users temporarily coarsen their data, exact match on these coarsened data, and then run their analysis on the uncoarsened, matched data. Coarsened exact matching bounds the degree of model dependence and causal effect estimation error by ex ante user choice, is monotonic imbalance bounding (so that reducing the maximum imbalance on one variable has no effect on others), does not require a separate procedure to restrict data to common support, meets the congruence principle, is approximately invariant to measurement error, balances all nonlinearities and interactions in sample (i.e., not merely in expectation), and works with multiply imputed datasets. Other matching methods inherit many of the coarsened exact matching method's properties when applied to further match data preprocessed by coarsened exact matching. The cem command implements the coarsened exact matching algorithm in Stata.

Keywords: st0176, cem, imbalance, matching, coarsened exact matching, causal inference, balance, multiple imputation

1 Introduction

The cem command is designed to improve the estimation of causal effects via a powerful method of matching that is widely applicable in observational data, and easy to understand and use (if you understand how to draw a histogram, you will understand this method). The command implements the coarsened exact matching (CEM) algorithm described in Iacus, King, and Porro (2008).

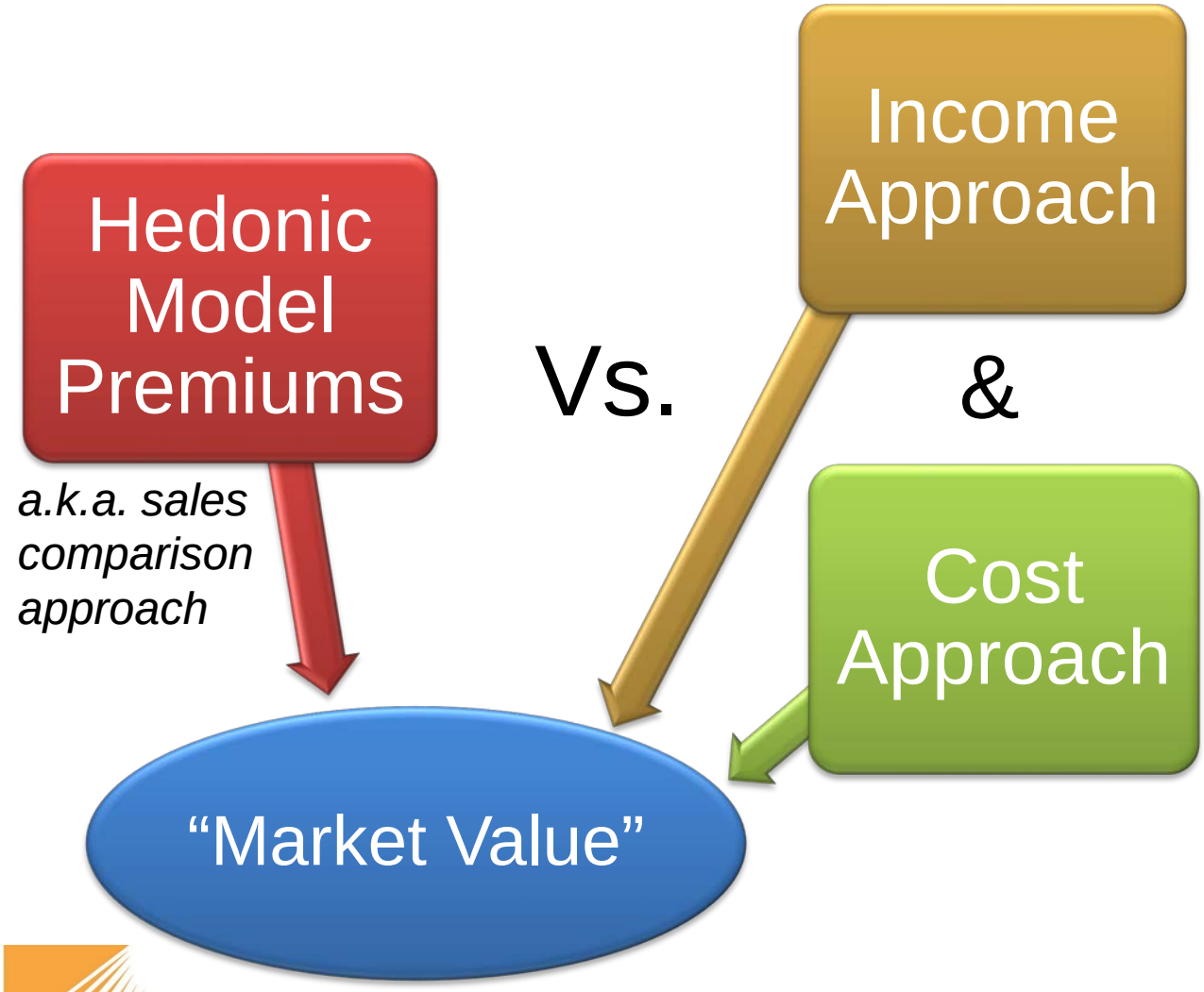
CEM is a monotonic imbalance-reducing matching method, which means that the balance between the treated and the control groups is chosen by ex ante user choice rather than being discovered through the usual laborious process of checking after the fact, tweaking the method, and repeatedly reestimating. CEM also assures that adjust-

Each PV home is "Matched" to non-PV homes via:

- Same block group ("location")
- Same sale year ("time")
- Similar Size, Age and Parcel Size ("type of home")
- Similar ratios of assessed value of land to total assessed value ("within neighborhood location")

This helps control for correlated omitted variables

We Compare Premiums To Income & Cost Estimates To Better Understand "Market Value"



Income Approach using PV Value®: Present value of stream of energy cost savings

Cost Approach: Installed costs of PV systems at time of sale: "Gross" or "Net" (less federal, state and utility incentives)

Robustness Models Can Be Used To Examine If Results Are Robust To Sample And/Or Model Specification

PV Only Model:
PV Homes are compared to other PV homes

Vs.

Repeat Model:
Selling prices of the same home are compared, once before and once after PV is installed.

Vs.

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Largest Dataset Assembled To Date - Spans 12 Years Through 2013 And Across 8 States

Sale Year	Non-PV Homes	PV Homes	Total
2002	107	18	125
2003	196	31	227
2004	238	53	291
2005	197	56	253
2006	348	64	412
2007	818	242	1,060
2008	1,251	453	1,704
2009	1,762	429	2,191
2010	2,751	504	3,255
2011	3,341	642	3,983
2012	3,928	694	4,622
2013	3,934	765	4,699
Total	18,871	3,951	22,822

Total 22,822 Homes

- 3,951 PV
- 18,871 Non-PV

Note: Each PV sale has at least one "matching" non-PV sale in the same census block group and year

State	Non-PV Homes	PV Homes	Total
CA	18,207	3,828	22,035
FL	317	25	342
Mid-Atlantic Region: MD, NC, PA	288	77	365
Northeast Region: CT, MA, NY	59	21	80
Total	18,871	3,951	22,822

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Selling Prices Range From $165K to Almost $900K With A Mean Of $460K

variable	description	N	mean	sd	min	median	max
sy	year of sale	22822	2010	2	2002	2011	2013
syq	year and quarter of sale (yyyyq)	22822	20103	23	20021	20112	20134
sp	price of sale (dollars)	22822	$ 459,319	$ 197,009	$ 165,500	$ 416,500	$ 899,500
lnsp	natural log of sale price	22822	12.94	0.44	12.02	12.94	13.71
sfla	living area (square feet)	22822	2,321	712	1,001	2,208	4,990
sfla1000	living area (in 1000s of square feet)	22822	2.3	0.7	1.0	2.2	5.0
acres	size of parcel (in acres)	22822	0.42	0.88	0.05	0.18	9.99
age	age of the home at time of sale (years)	22822	17	21	(2)	8	100
agesq1000	age of the home squared (in 1000s of years)	22822	0.7	1.3	0	0.1	10.0
pv	if the home has a PV system (1 if yes)	22822	0	0	-	-	1
size	size of the PV system (kilowatts)	3951	3.6	2.0	0.1	2.8	14.9
pvage	age of the PV system at time of sale (years)	3951	2.7	2.9	(0.5)	2.2	13.4
income	average PV Value estimate ($/watt)	3951	$ 2.93	$ 0.57	$ 1.18	$ 2.92	$ 4.98
netcost	net cost estimate ($/watt)	3951	$ 4.14	$ 0.93	$ 1.07	$ 4.04	$ 7.95
grosscost	gross cost estimate ($/watt)	3951	$ 6.90	$ 1.50	$ 3.15	$ 6.92	$ 11.83

And PV System Size and Age cover a wide range, as do the income, “gross” cost and “net” cost estimates

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Overall Models Performed Very Well

22,822 Cases:
18,871 Non-PV, 3,951 PV

Extremely High R^2 and Adjusted R^2

Number of obs	22822
F(53, 20938)	133.81
Prob > F	0.0000
R-squared	0.9306
Adj R-squared	0.9244
Root MSE	0.1211

lsp1	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
pv#c.pvsize						
non-pv	0	(omitted)				
pv	.009122	.0006954	13.12	0.000	.0077589	
sfla	.0002125	4.11e-06	51.70	0.000	.0002045	
lt1acre	.3857585	.028089	13.73	0.000	.3307019	
gt1acre	.029043	.0057194	5.08	0.000	.0178326	
bestages1	-.0065257	.0008302	-7.86	0.000	-.0081529	
bestages1sq	.0000564	8.50e-06	6.63	0.000	.0000397	
syq1						
20021	-.4409785	.0336729	-13.10	0.000	-.50698	-.374977
20022	-.3793516	.0377095	-10.06	0.000	-.4532652	-.305438
20023	-.3753209	.0358148	-10.48	0.000	-.4455207	-.3051211
20024	-.3059656	.0725669	-4.22	0.000	-.4482023	-.1637289
20031	-.0871893	.055746	-1.56	0.118	-.1964557	.0220772
20032	-.0769145	.037439	-2.05	0.040	-.1502979	-.0035311
20033	-.0253064	.0379518	-0.67	0.505	-.0996948	.049082
20034	-.0350796	.0370107	-0.95	0.343	-.1076234	.0374643
20041	.0010896	.0311238	0.04	0.972	-.0599155	.0620948
20042	.0952797	.0214987	4.43	0.000	.0531406	.1374187
20043	.1213304	.0237074	5.12	0.000	.074862	.1677987
20044	.1235824	.0284686	4.34	0.000	.0677817	.1793831
20051	.1374971	.0472251	2.91	0.004	.0449322	.2300619
20052	.2038294	.0394394	5.17	0.000	.126525	.2811337
20053	.1636163	.0620634	2.64	0.008	.0419673	.2852653
20054	.202122	.0378722	5.34	0.000	.1278895	.2763546
20061	.1590514	.0206409	7.71	0.000	.1185936	.1995093
20062	.1634347	.0206825	7.90	0.000	.1228953	.203974
20063	.1602919	.0219579	7.30	0.000	.1172527	.203331
20064	.0713501	.0219973	3.24	0.001	.0282336	.1144666
20071	.1619075	.0166881	9.70	0.000	.1291976	.1946174
20072	.1238737	.0200649	6.17	0.000	.084545	.1632024
20073	.0739541	.0161595	4.58	0.000	.0422802	.105628
20074	.001859	.0183644	0.10	0.919	-.0341366	.0378546
20081	.0220517	.0162681	1.36	0.175	-.009835	.0539384
20082	-.0049732	.0132325	-0.38	0.707	-.03091	.0209636
			-3.69	0.000	-.0767004	-.0234967
			-4.63	0.000	-.0938137	-.0380129
			-8.07	0.000	-.1408228	-.0858011
			-9.80	0.000	-.1385946	-.092413
			-10.61	0.000	-.1474333	-.1014695
			-9.70	0.000	-.1441907	-.0957092
			-9.03	0.000	-.1472306	-.0947305
			-10.75	0.000	-.1469764	-.1016294
			-11.66	0.000	-.1678397	-.1195194
			-14.07	0.000	-.1943154	-.1468001
			-15.17	0.000	-.1956327	-.1508603
20112	-.1894875	.0109182	-17.36	0.000	-.210888	-.168087
20113	-.1900824	.0111568	-17.04	0.000	-.2119506	-.1682142
20114	-.2051745	.0111736	-18.36	0.000	-.2270756	-.1832734
20121	-.2122221	.011171	-19.00	0.000	-.2341182	-.190326
20122	-.1759118	.0115874	-15.18	0.000	-.198624	-.1531996
20123	-.1538842	.0112622	-13.66	0.000	-.1759589	-.1318095
20124	-.1230809	.0120422	-10.22	0.000	-.1466846	-.0994773
20131	-.0902051	.009513	-9.48	0.000	-.1088513	-.071559
20132	-.0381185	.0091776	-4.15	0.000	-.0561072	-.0201298
20133	-.0091978	.0091848	-1.00	0.317	-.0272008	.0088052
_cons	12.49778	.0164878	758.00	0.000	12.46547	12.5301

(331 categories)

Highly Statistically Significant and Appropriately Leveled And Signed Controlling Home and Site Characteristics

Highly Statistically Significant and Appropriately Leveled And Signed Inflation/Deflation Variables

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Size Of PV System Is Strongly Related To Price of Home

Linear regression, absorbing indicators

Number of obs	= 22822
F(53, 20938)	= 133.81
Prob > F	= 0.0000
R-squared	= 0.9306
Adj R-squared	= 0.9244
Root MSE	= 0.1211

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bestages1	-.0065257	.0008302	-7.86	0.000	-.0081529	-.0048984
bestages1sq	.0000564	8.50e-06	6.63	0.000	.0000397	.000073
syq1						
20021	-.4409785	.0336729	-13.10	0.000	-.50698	-.374977

Highly Statistically Significant Effect

Effect Represents:

A 0.92% increase in value for each kW installed on a PV home, over the average price of a non-PV home

Equates To:

$4.18/watt increase over the average non-PV home value of $456,378

Equates To A Range Between: $3.56/watt and $4.80/watt

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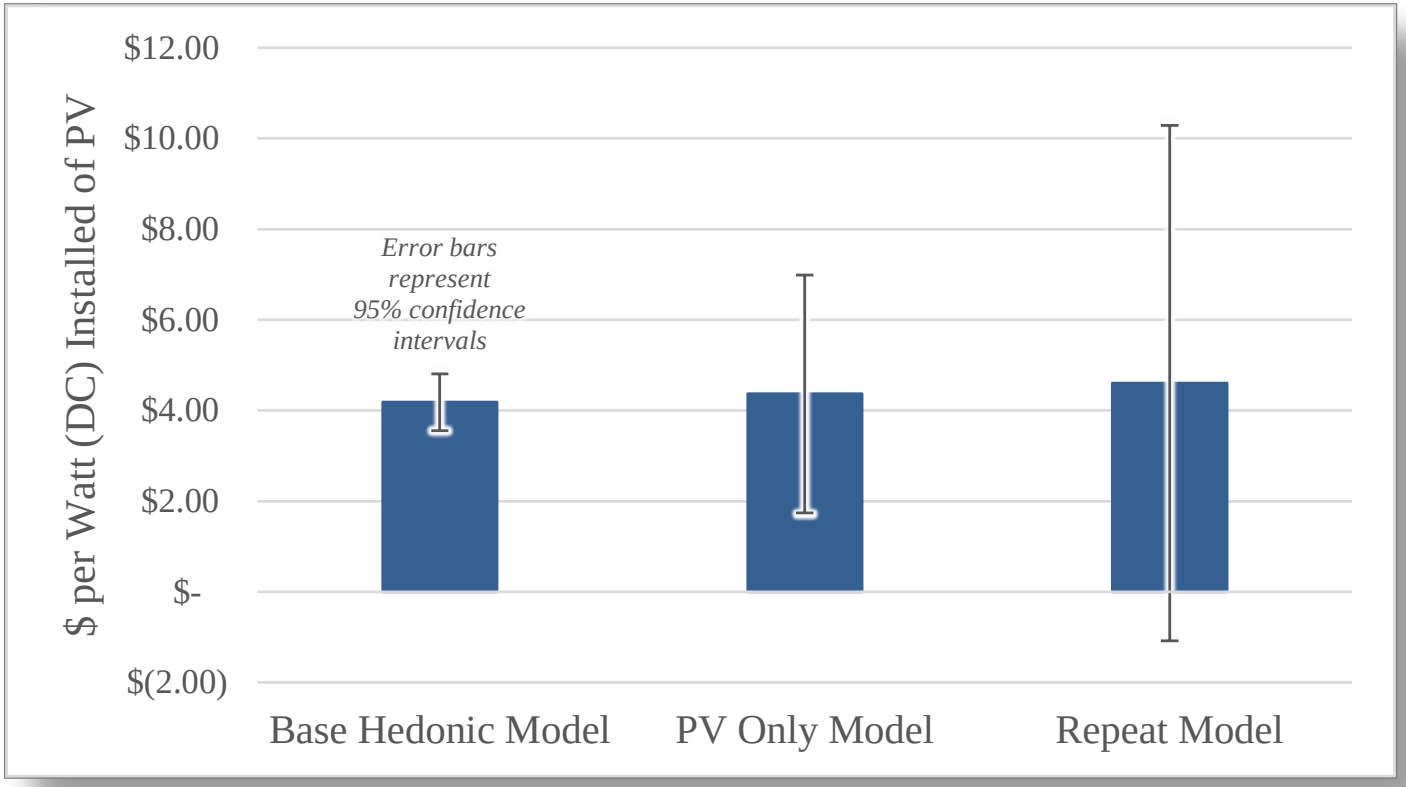
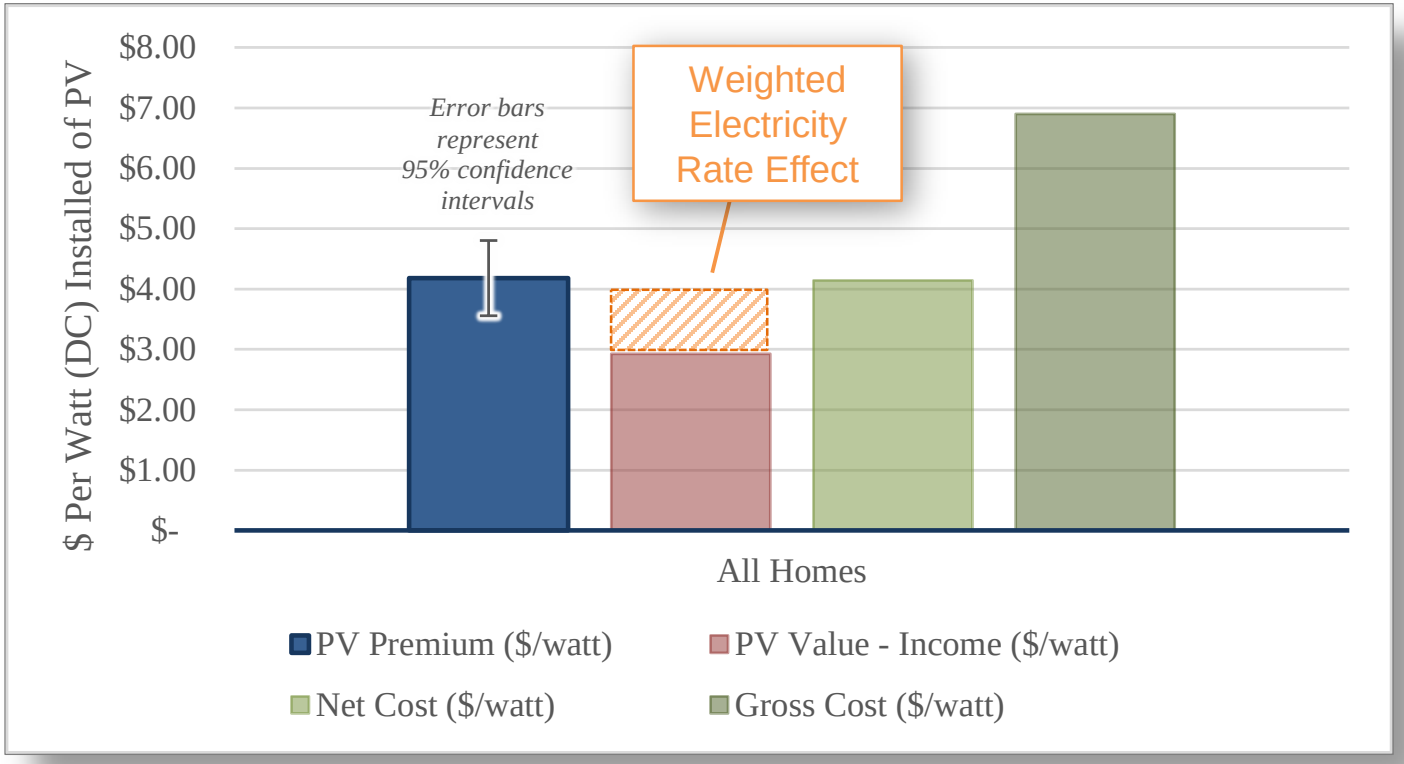
PV Only And Repeat Robustness Models Conform With Base Hedonic Results



Although Repeat Model results are not statistically significant, they equate to a similar $/watt premium

Premium Is Not Statistically Different From Net Cost Estimate

And is lower than the Gross Cost and higher than the Income estimates



If the Income estimate uses a weighted electricity rate, to account for California tiered rates, it falls in-line with the Premium

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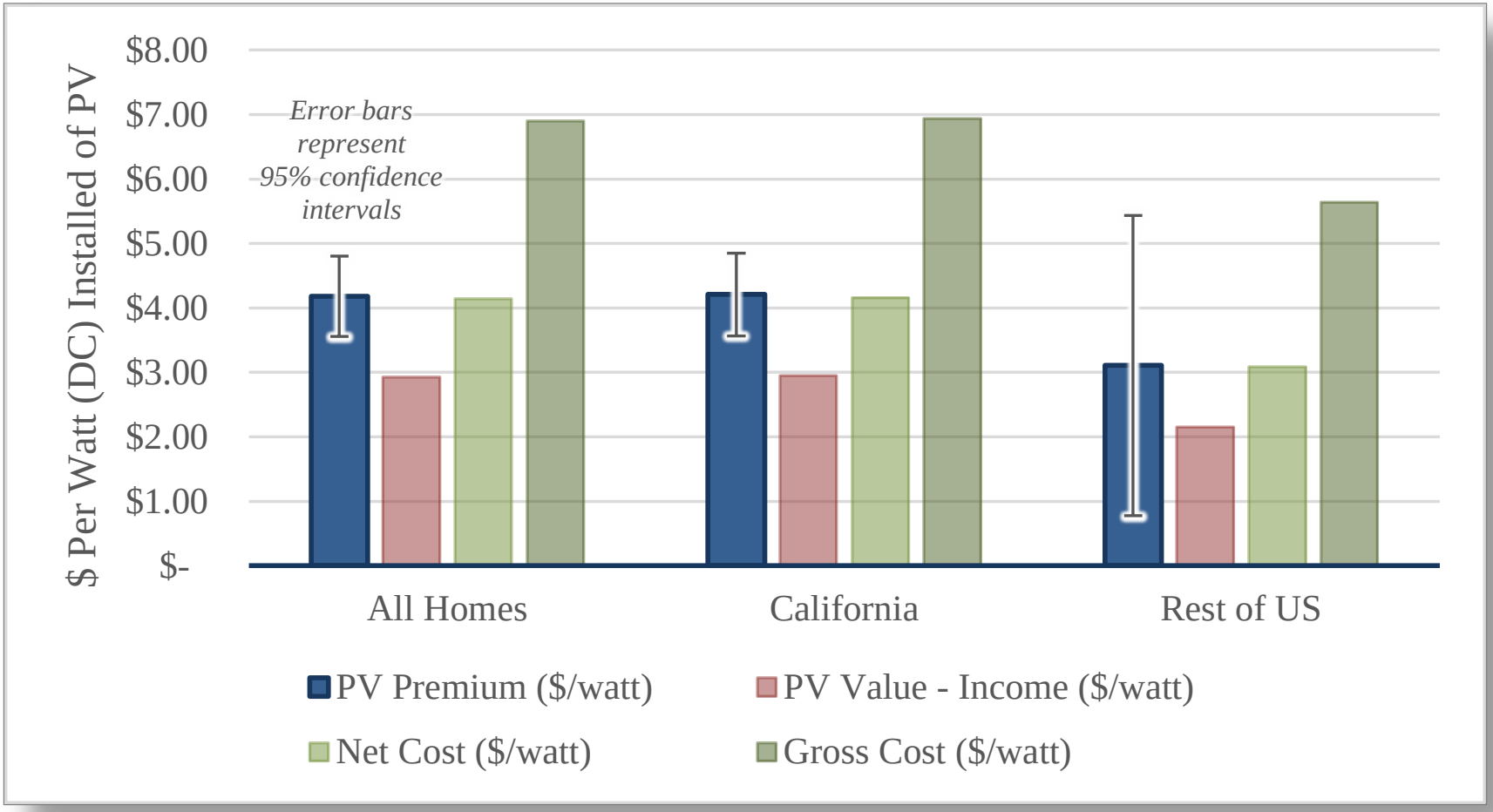
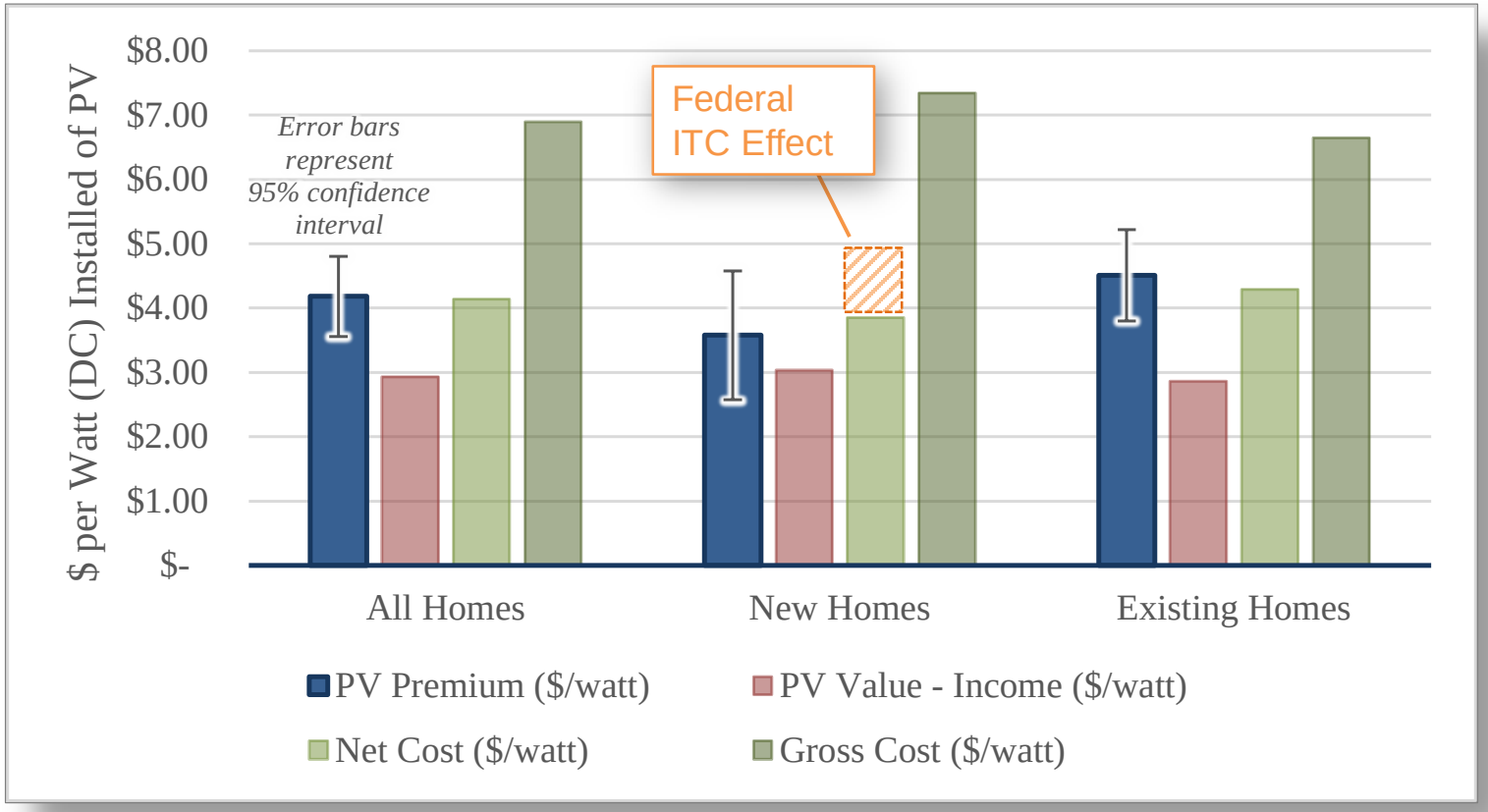
We Find Similar Relationships In California And In The Rest Of The US



New Home Premiums Are Lower But Not Statistically Different From Existing Homes



And because new home builders cannot claim the Federal ITC, the "builder's Net Cost" would be higher, implying, potentially, some discounting of PV systems by builders

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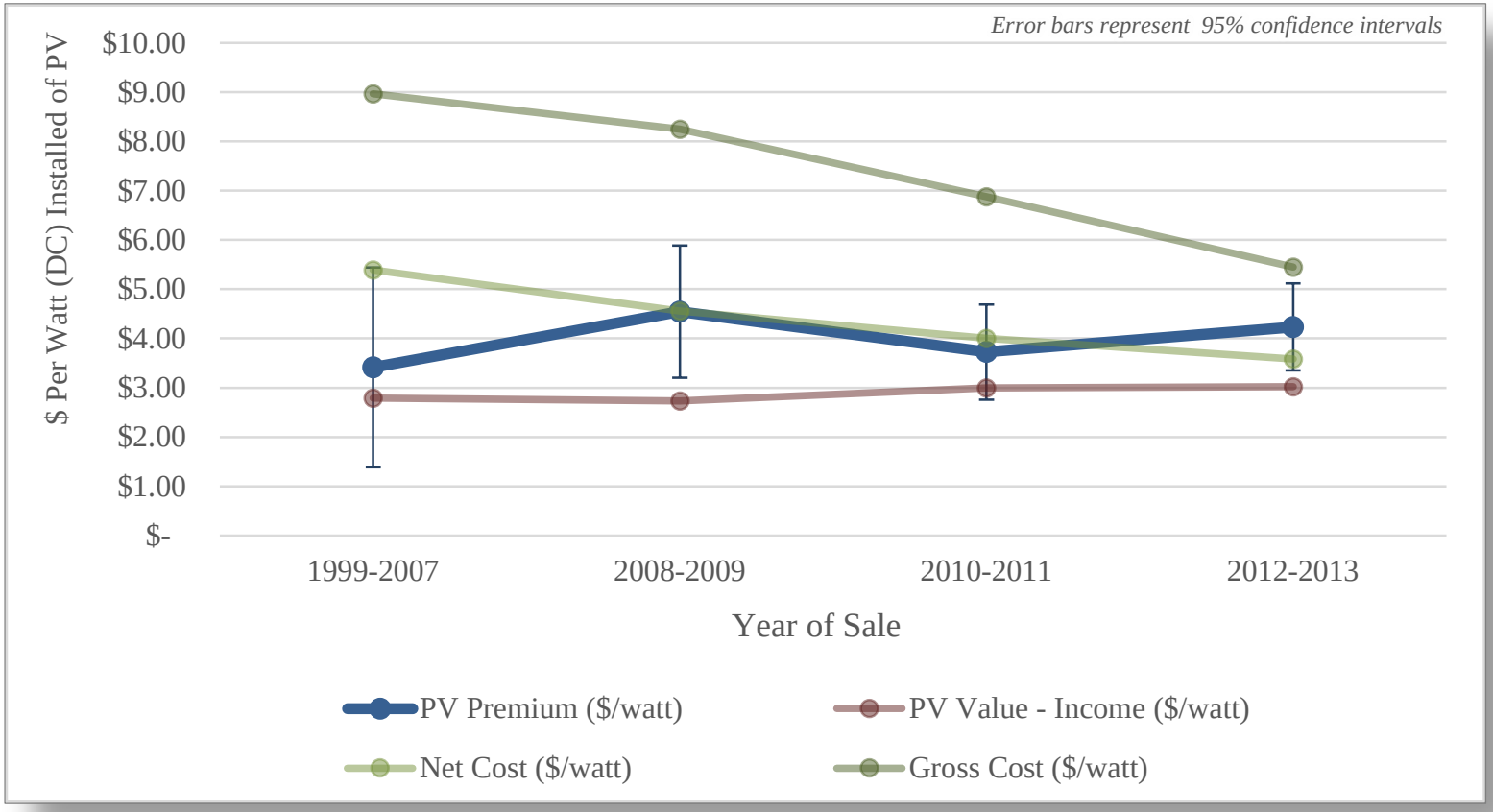
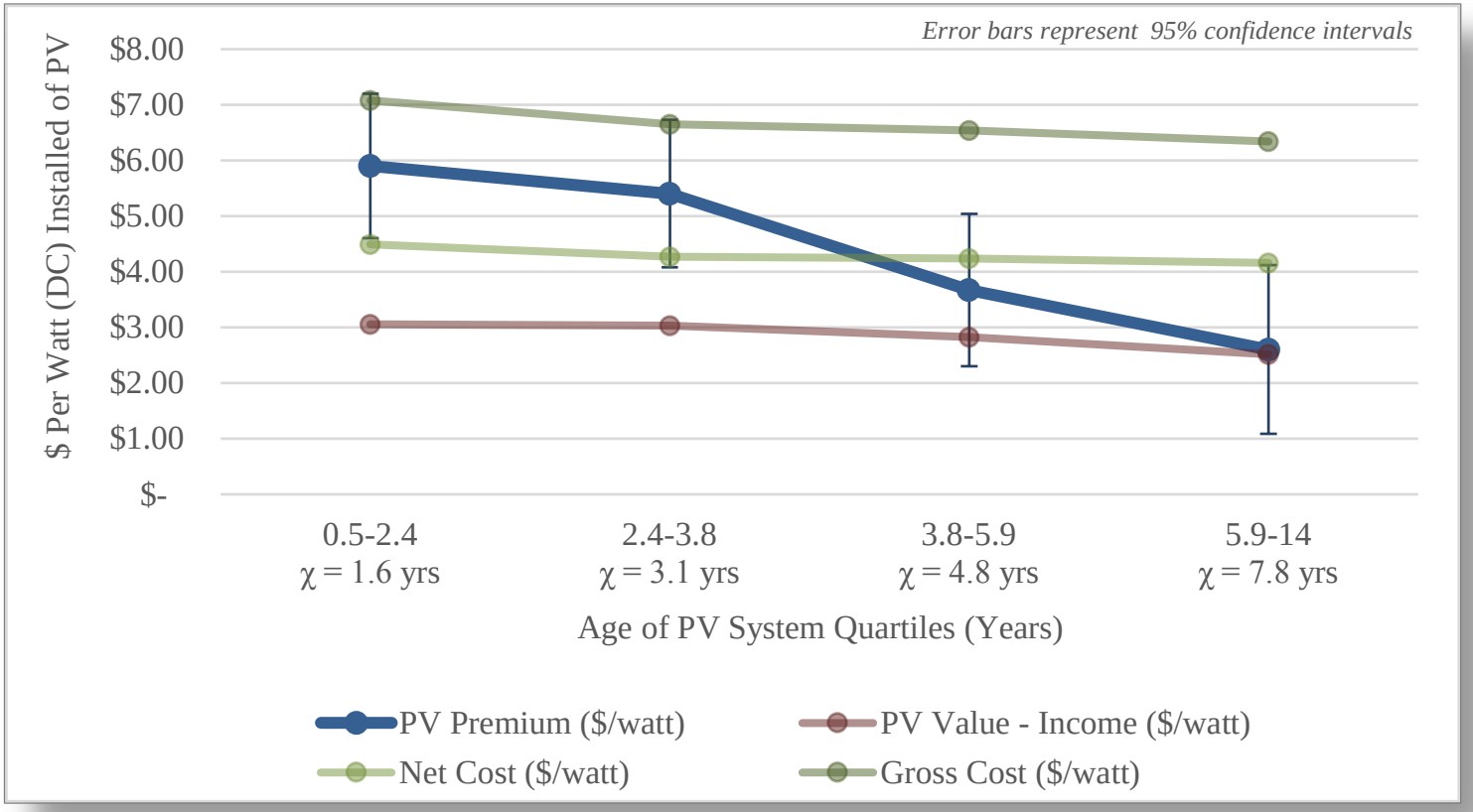
Over The Sample Period, Premiums Are Stable and Highly Correlated With Net Cost



Premiums seem to be independent of Gross Cost estimates

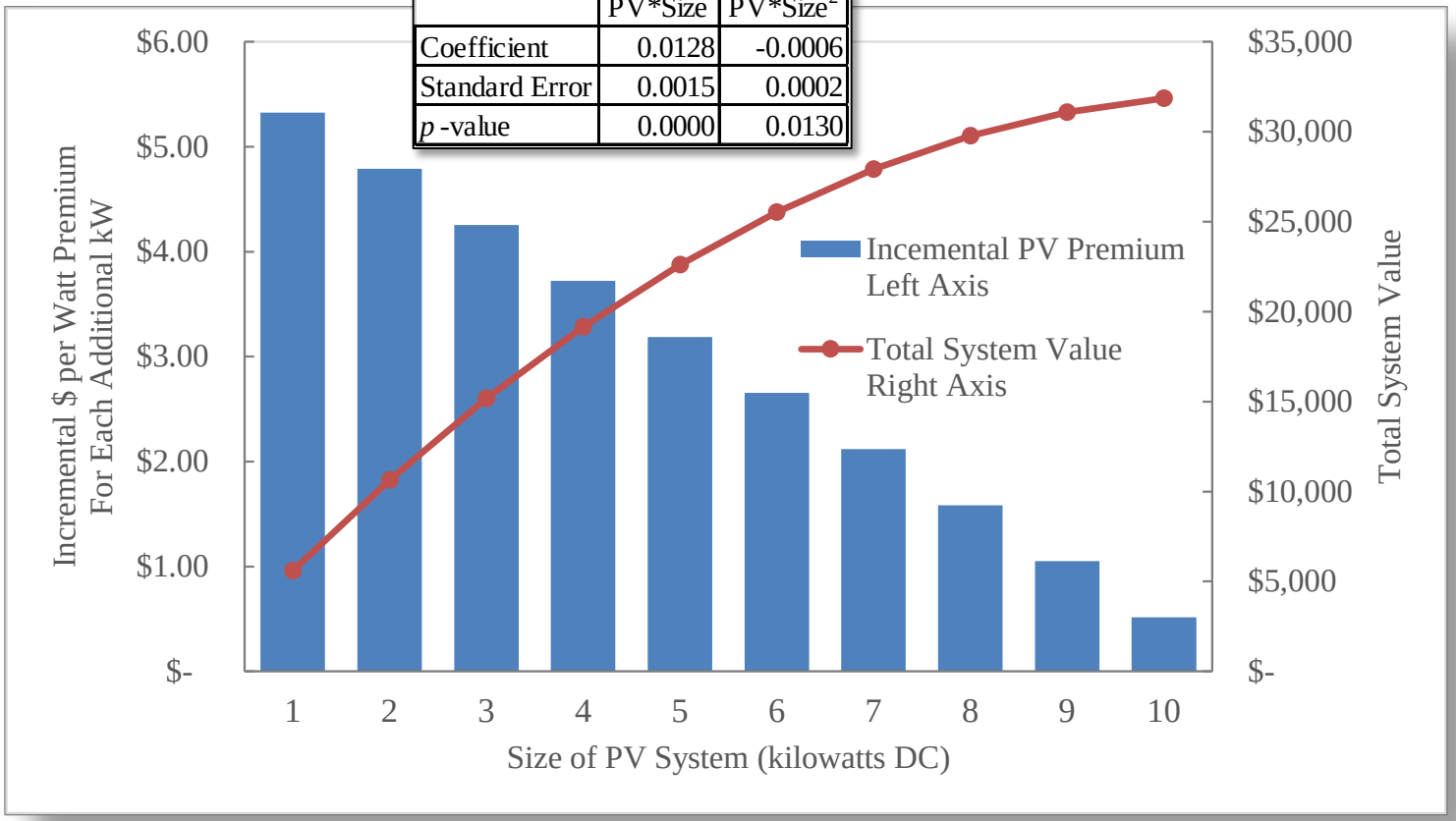
There Is A Clear Decrease In Price For Older Systems



There is less clarity as systems age into their second decade

Highest Marginal $/Watt Premiums Exist For Smallest Systems

	PV*Size	PV*Size^2
Coefficient	0.0128	-0.0006
Standard Error	0.0015	0.0002
p -value	0.0000	0.0130



This might indicate a "green cache" is present for all systems with an additional premiums for each kW added

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Conclusions

- PV consistently adds value ~ $4/watt in our sample
- Clear premiums both in/outside CA and thru 2013
- “Net” cost estimates are better proxy than “gross”
- Income estimates should account for tiered rates
- New and existing homes have similar premiums
- Some evidence of new-home builder discounting of PV systems
- PV systems significantly depreciate as they age
- Unclear how value holds up in second decade
- Larger PV systems receive incrementally less of a premium - “green cachet” might exist

Next Steps & Outreach

- Submit paper to journal in spring 2015 — Next Steps
- Conferences/Webinars: — Outreach
  - NAHB in January, 2015
  - PV America in March, 2014
  - Appraisal Institute Webinar: Late Spring 2015
  - SPI in June, 2015?
  - Greenbuild in November 2015?
- Other outreach ideas?

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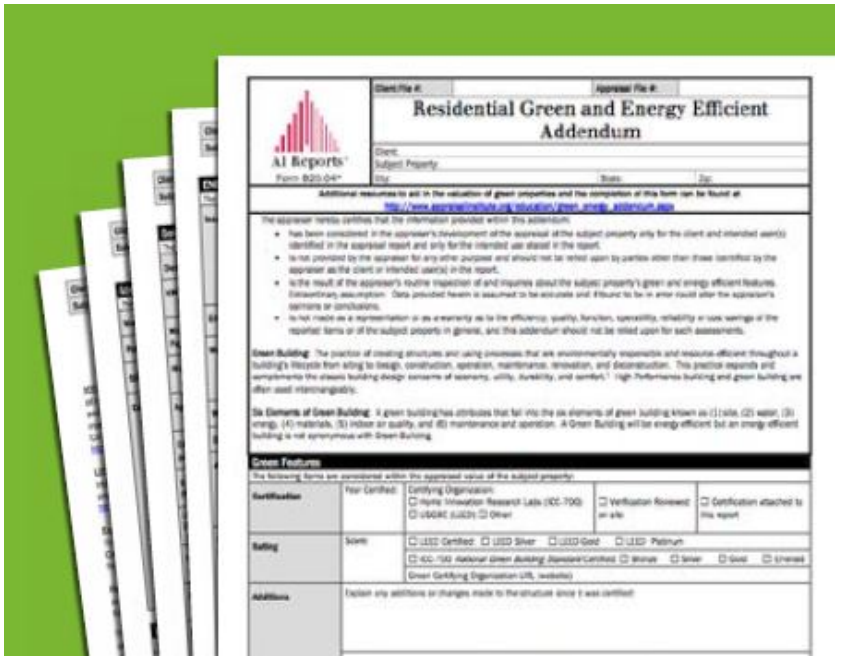
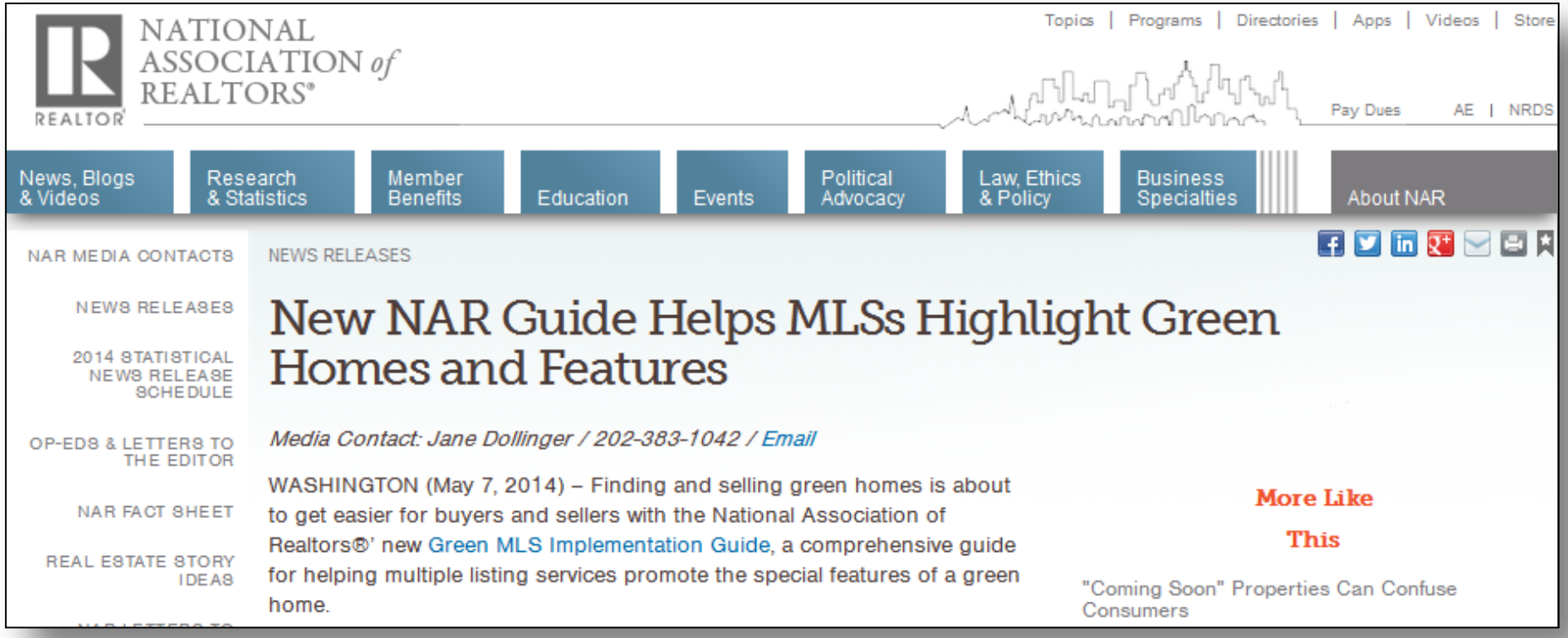
AI Residential Green & E.E. Addendum

- Appraisers
- Builders
- Real Estate Agents
- Energy Raters
- Sellers



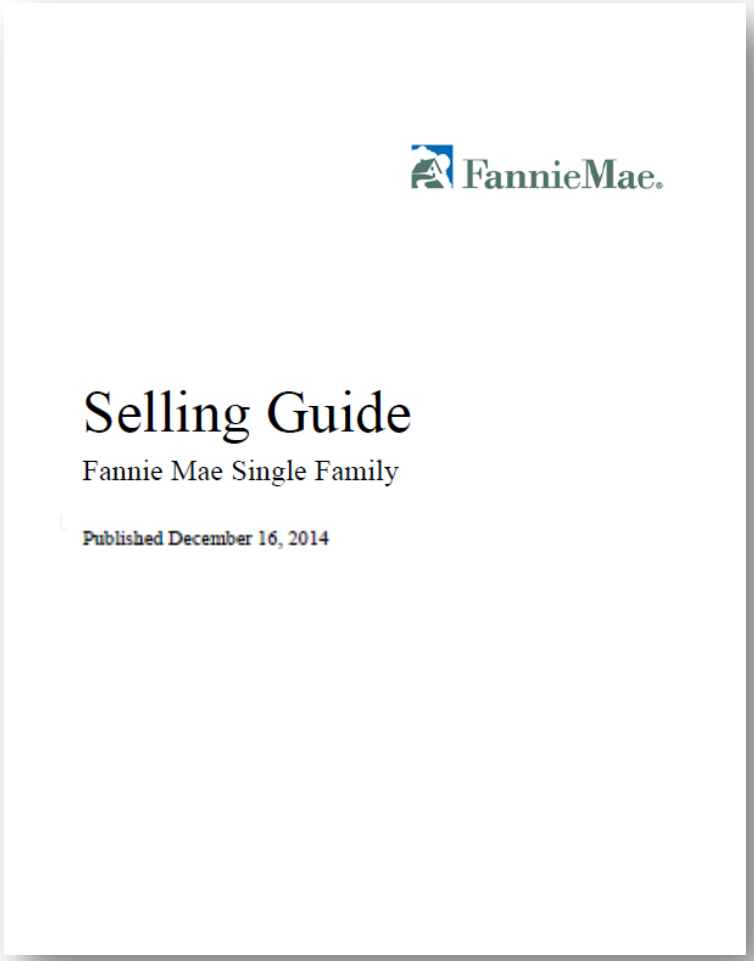
The direct link for the fillable PDF “AI Residential Green and Energy Efficient Addendum” is http://www.appraisalinstitute.org/assets/1/7/Interactive820.04-ResidentialGreenandEnergyEffecientAddendum.pdf

NAR Helped Develop And Promote MLS Fields To Capture Green Features



www.realtor.org

Fannie Mae Recognizes Solar's Value IF Property Owner Owns The System

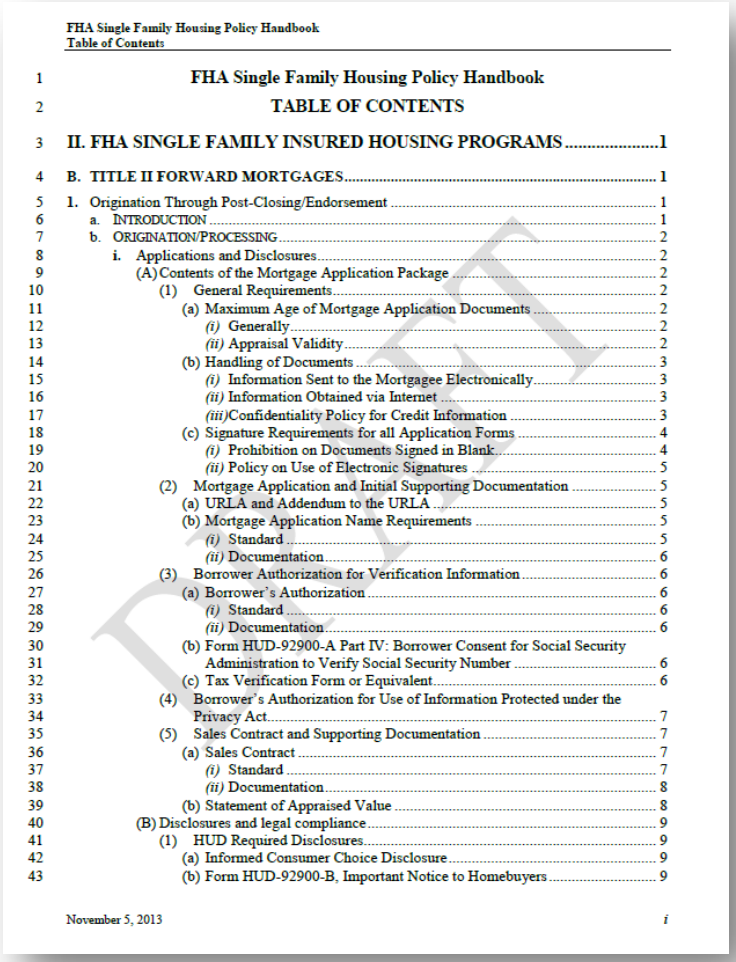


"Fannie Mae will purchase or securitize a mortgage loan on a property with solar panels."

"If the property owner is the owner of the solar panels, standard eligibility requirements apply (for example, appraisal, insurance, and title)."

"If the solar panels are leased…The solar panels may not be included in the appraised value of the property."

HUD's FHA Has Also Recognized Solar's Value
(In Their Draft Handbook – To Be Released In Early 2015)



FHA Single Family Housing Policy Handbook
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Solar Energy Systems

"A mortgagee may add the cost of a solar energy system to the mortgage up to 20 percent above than the maximum insurable mortgage limit."

"Costs for new solar systems may be added to an FHA-insured base mortgage, for the following Sections of the Act and transaction types:

- Section 203(b)
- Purchase Transaction
- Rate and Term Refinances and Simple Refinance"

Thank You

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