Environmental Energy Technologies Division Lawrence Berkeley National Laboratory

How Much Do Local Regulations Matter?

Exploring the Impact of Permitting and Local Regulatory Processes on PV Prices in the United States

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Presentation Overview

- Questions and Objective
- Data Sources and Processing
- Variable Description and Summary Statistics
- Regression Analysis and Results
- Interpretation and Discussion
- Conclusions

Background

- PV cost reductions have been substantial in recent years, but have been largely driven by hardware price declines
  - "soft costs" are now a key target for cost reduction in the U.S.
- Streamlining local regulatory processes, including permitting, inspection, and interconnection, is a key target for reducing soft costs
  - 18,000 different jurisdictions exist in the U.S., many of which have unique (and sometimes onerous) requirements
- A variety of efforts are underway to document these local regulatory procedures, assess their impact on the PV market, and streamline them

Research Questions and Objectives

Research Questions:

1. To what degree do local regulatory processes impact residential PV system prices in the U.S.?

2. Do city-level "scoring" mechanisms capture the idiosyncrasies of these local processes?

Core Objective: Highlight the magnitude of cost reduction that might be expected from streamlining local regulatory regimes

Approach: Statistically analyse the impact of local, often city-level processes on the reported prices of residential PV systems, using two city-level "scores" of these processes: one created under the U.S. DOE's Rooftop Solar Challenge (RSC) and one by Vote Solar

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Work Leverages Unique PV Installation Data Source: Tracking the Sun VI Report

- Dataset developed for LBNL's Tracking the Sun (TTS) VI report
- Reported PV system prices for >200,000 PV installations
  - 47 PV incentive programs in 29 states
- Data also contain system information on:
  - date of installation; system size; geographical location; customer segment (residential, commercial, or other); technology type (module and inverter manufacturer and model, ground mounted vs. roof-mounted systems, new construction vs. retrofit systems)
  - can also infer BIPV vs. rack-mounted PV; thin film vs. crystalline modules; Chinese made vs. non-Chinese made modules; and micro-inverters vs. central or string
- Various screens applied to select data for use in this analysis:
  - isolate 1 kW - 10 kW residential systems coinciding geographically and temporally with jurisdictions scored by Vote Solar and DOE
  - remove outliers: consider cost per W, battery back-up, ground-mounted, self-installed
  - third-party owned systems installed by integrated companies also excluded, as prices reported in these cases are likely to represent appraised value (not installed price)

In Addition to PV System Information, Other Control Variables Were Constructed

- Using zip code and data from Census Bureau, demographic and socioeconomic characteristics were associated with each PV installation
  - household education level, average income, average housing prices, and average household density
- County-level composite labor-cost index derived from average administrative, electrician, and roofing wages
- Installer experience and competition variables:
  - county-level aggregate and installer experience, county-level installer market share, county-level Herfindahl–Hirschman Index (HHI) for installers
- Present value of customer economic benefits of each PV system
  - based on electricity rates and insolation levels (for net-metered systems), performance based incentives, federal and state incentives

Vote Solar (VS) “Project Permit” Description

- Set of best practices for municipal permitting used to score local jurisdictions by the Vote Solar “Project Permit” campaign
- Seven of these best practices were scored and weighted to determine jurisdictional performance in solar permitting
  - Best (7-10), Good (2.5-7), Worst (0-2.5)
- Data used by Vote Solar to determine scores was obtained from Clean Power Finance’s National Permitting Database
  - funded by the DOE and uses a crowdsourcing methodology to populate and verify information on municipal permitting practices
- Total of 915 jurisdictions in 39 states were scored

Vote Solar Scoring Questions and Methodology

#	SolarPermit.org Question	Scoring Metric	Score = Best Practice	Score = Not Best Practice	Weight	Final Score
1	Is there a solar permitting checklist	Posts requirements online?	yes	no	0.05	0.5
2	Online permit applications	Allows online processing?	available	no	0.05	0.5
3	Is there an over-the-counter permit option	Fast turn-around time?	yes	no	0.25	2.5
3	Average turn-around time for residential permit	Fast turn-around time?	< 3 days	> 3 days	0.15	1.5
4	Permit Fee = "Flat Rate" PLUS "$400 or less"	Reasonable permitting fees?	≤ $400	no	0.25	2.5
5	Licensing for solar contractors	No community specific licenses needed?	Additional licensing not required	Additional licensing required	0.05	0.5
6	Time window for a scheduled inspection	Offers a narrow inspection appointment window?	≤2 hours	>2 hours	0.1	1
7	Number of inspections required	Eliminates excessive inspections?	1 inspection	> 1 inspection	0.1	1
					Total Points:	10

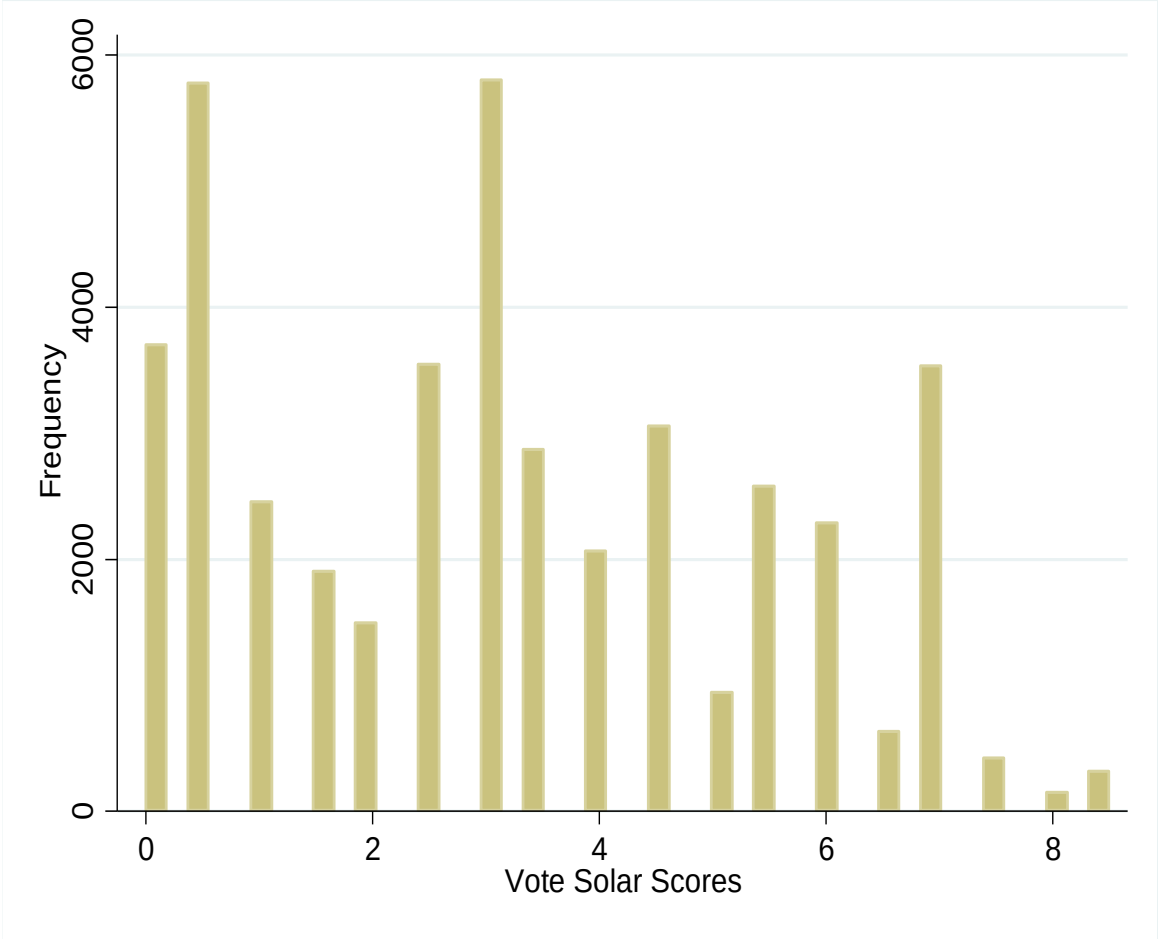
Vote Solar Matched Summary Statistics

- After matching the Vote Solar data to TTS data, 603 cities remain within 11 states
- 43,551 residential PV installations match to Vote Solar scoring data
  - >50% of total residential PV market in U.S. in 2012
- Assume PV installations in 2012 are reasonably reflective of permitting procedures in 2013

State	City Score (mean)	Average Price ($/watt)	Number of Matched VS Cities	Number of Installations
AR	0.0	7.07	1	3
AZ	3.2	5.24	40	5654
CA	3.4	6.32	318	32472
CT	2.9	6.53	8	52
MA	1.5	5.78	37	533
NJ	1.5	5.61	72	1662
NM	0.8	6.01	3	171
NY	2.5	6.33	54	542
OR	4.0	5.82	13	963
PA	1.5	5.89	45	550
TX	0.8	4.71	12	949
Total			**603**	**43551**

Distribution of Vote Solar Scores in Matched Dataset

- Vote Solar permitting scores range from 0 (onerous) to 8.5 (efficient), with an average of 3.1



U.S. Department of Energy "Rooftop Solar Challenge (RSC)" Description

- Competitively-awarded funding opportunity created by the U.S. DOE in 2011 with goal of eliminating market barriers and reducing soft costs via local and state-level initiatives
- 22 participating teams, representing 154 jurisdictions, provided responses to a questionnaire on the level of solar market maturity
  - responses converted to numerical scores, weighted within various categories
- Program participants were given one year to enact their strategies for enhancing local solar markets
  - once again scored to obtain a comparison against initial baseline scores
- Unlike Vote Solar scores, which focus exclusively on permitting, DOE RSC scores include larger array of indicators: permitting, interconnection, planning and zoning, net metering and financing

Rooftop Solar Challenge Scoring Methodology

ACTION AREA	POINTS
Permitting Process	**460**
Application	110
Information Access	60
Process Time	110
Fee	30
Model Process	30
Inspection	80
Communication w/ Utility	40
Interconnection Process	**110**
Application	40
Information Access	20
Process Time	20
Inspection	30

ACTION AREA	POINTS
Interconnection Standard	**100**
Net Metering Standard	**100**
Financing Options	**150**
Third Party Ownership (or equivalent)	90
Direct Finance Options	25
Community Solar	15
Other	20
Planning and Zoning	**80**
Solar Rights and Access	54
Zoning	20
New Construction	6
TOTAL POINTS POSSIBLE	**1000**

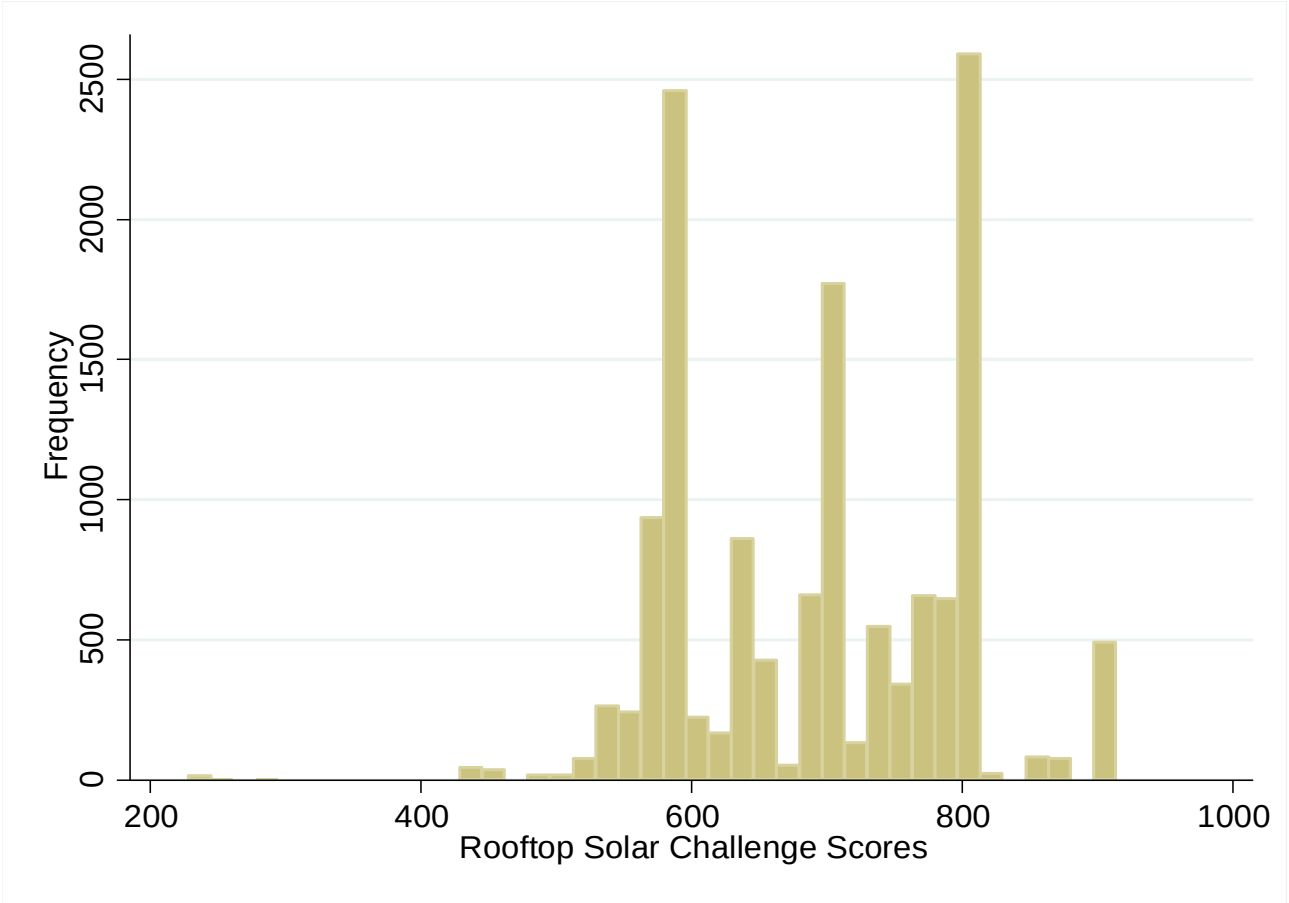
DOE RSC Matched Summary Statistics

- After matching the RSC data to the TTS data, 73 cities in 6 states remain
- Two scores available: baseline RSC scores (early 2011) and final RSC scores (late 2012)
  - Match 2011 PV installations with the 2011 baseline scores and PV installations from May through December 2012 with 2012 final scores
- 13,904 residential PV installations match to the RSC scoring data

State	Jurisdiction Score (mean)	Average Price ($/watt)	Number of Matched RSC Jurisdictions	Number of Installations
AZ	580	5.11	8	1543
CA	711	6.39	47	11487
MA	657	5.45	5	95
NY	557	9.07	1	5
PA	393	6.14	11	53
TX	669	4.28	1	721
Total			**73**	**13904**

Distribution of RSC Scores in Matched Dataset

- RSC scores range from 228 (more-onerous local procedures) to 914 (more-favorable local procedures), with an average of 615 in 2011 and 751 in 2012



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Control Variables

Variable	Definition	Expected Sign
system size	PV system size in watts	Negative
system size squared	Square term of system size	Positive
new construction	PV installed in new home construction (vs. retrofit on existing home)	Negative
BIPV	Building-integrated PV system (vs. not)	Positive
thin-film	Thin-film PV module (vs. crystalline silicon)	Either
China	China-made PV module (vs. not)	Negative
micro-inverter	PV system uses micro-inverter (vs. not)	Positive
TPO	Third-party owned PV system (vs. not)	Either
education level	Percent of individuals in zip code with bachelor's education or more	Negative
mean house value	Mean home value by zip code	Positive
mean income	Mean household income by zip code	Positive
household density	Total number of owner-occupied households per sq mile within county	Negative
labor cost index	Composite labor cost index in county	Positive
installer experience	County-level installation experience by installer, measured as the discounted cumulative number of PV systems installed	Negative
aggregate experience	County-level aggregate installation experience by all installers, measured as the discounted cumulative number of PV systems installed	Negative
installer density	Total number of installers within county in last six month per household	Negative
installer market share	Market share by installer at county-level within last year	Either
HHI	Herfindahl - Hirschman Index for county-level PV market (installer concentration indicator)	Positive
value of solar	Present value of customer-economic benefits of a PV system	Positive
time	Linear time trend (also tested other specifications)	Negative

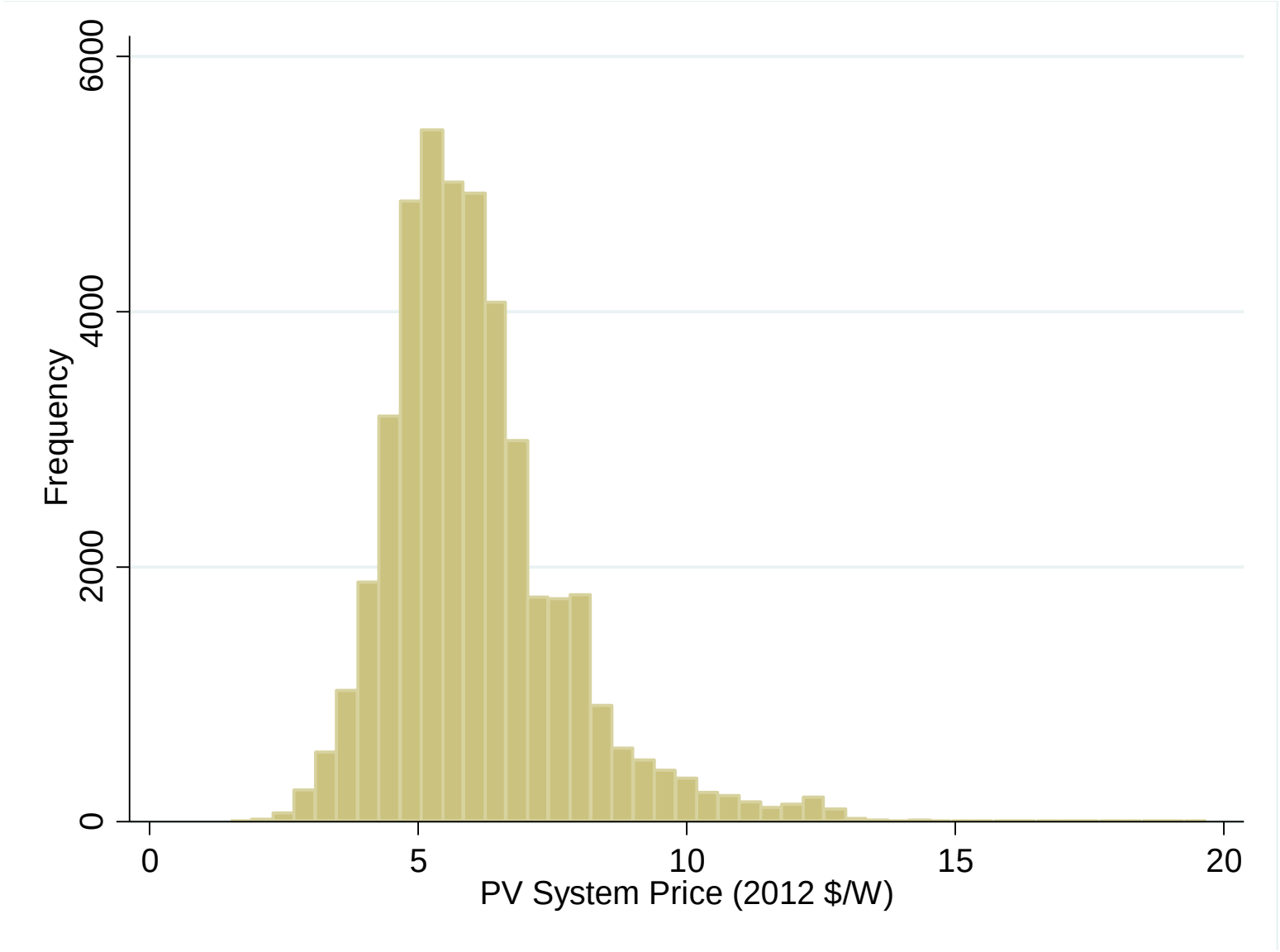
Summary Statistics: Vote Solar

	mean	s.d.	min	max	count
system price ($/W)	6.061	1.677	1.507	19.673	49864
Vote Solar score	3.104	2.229	0.000	8.500	49864
system size	5.060	2.135	1.000	10.000	49864
system size squared	30.163	23.764	1.000	100.000	49864
new construction	0.036	0.186	0.000	1.000	49864
BIPV	0.008	0.089	0.000	1.000	49864
thin film	0.004	0.062	0.000	1.000	49864
China	0.270	0.444	0.000	1.000	44295
micro-inverter	0.251	0.434	0.000	1.000	44713
TPO	0.405	0.491	0.000	1.000	49864
education level	0.360	0.177	0.000	0.928	49821
mean house value	462.215	219.946	61.647	1182.356	49635
mean income	94.026	34.643	28.300	394.381	49644
household density	0.098	0.163	0.000	2.837	49819
labor cost index	57.032	14.732	25.140	110.007	49679
installer experience	119.388	192.868	1.000	2142.346	49864
aggregate experience	0.003	0.001	0.000	0.009	49819
installer density	0.152	0.096	0.000	1.479	49822
installer market share	0.086	0.140	0.000	1.000	49469
HHI	0.101	0.114	0.024	1.000	49469
value of solar	6.278	1.609	1.844	14.632	49672
time	11.360	5.625	1.000	20.000	49864

Summary Statistics: RSC

	mean	s.d.	min	max	count
system price ($/W)	6.113	1.725	1.507	19.409	16427
RSC score	679.462	106.504	228.000	914.000	16427
system size	4.887	2.149	1.000	10.000	16427
system size squared	28.497	23.108	1.000	100.000	16427
new construction	0.040	0.195	0.000	1.000	16427
BIPV	0.005	0.071	0.000	1.000	16427
thin film	0.004	0.059	0.000	1.000	16427
China	0.261	0.439	0.000	1.000	14055
micro-inverter	0.257	0.437	0.000	1.000	14179
TPO	0.380	0.485	0.000	1.000	16427
education level	0.386	0.183	0.000	0.913	16407
mean house value	489.143	222.126	100.071	1160.356	16391
mean income	95.326	36.752	29.476	320.744	16399
household density	0.138	0.220	0.001	2.837	16422
labor cost index	57.562	12.300	28.130	102.270	16422
installer experience	163.685	270.184	1.000	2142.346	16427
aggregate experience	0.003	0.001	0.000	0.007	16422
installer density	0.140	0.088	0.000	0.717	16423
installer market share	0.059	0.073	0.000	0.895	16295
HHI	0.071	0.041	0.024	0.943	16295
Value of solar	6.254	1.663	3.285	14.141	16419
time	11.482	5.700	1.000	20.000	16427

Distribution of PV System Prices in Final Analysis Dataset



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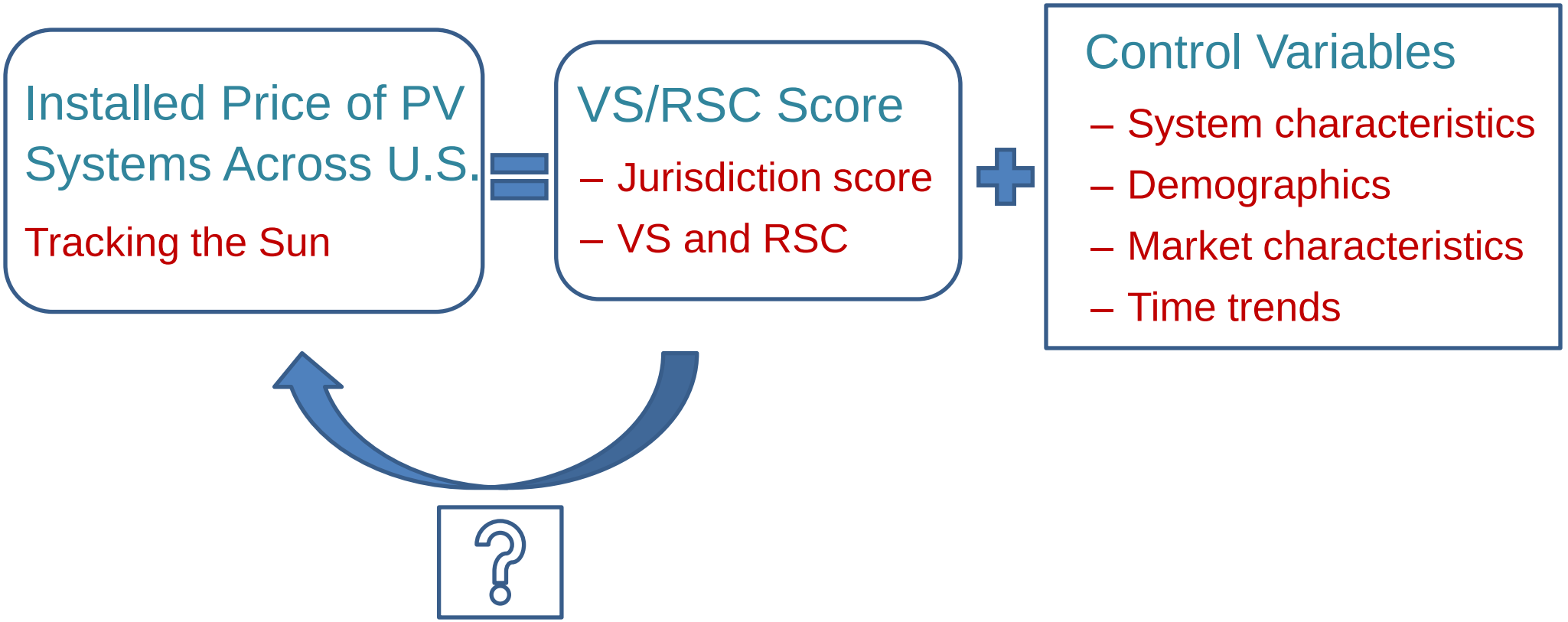
Regression Models: Overview



Preferred specification regresses installed price per watt on jurisdiction score, control variables, and jurisdiction- or state-level fixed effects to control for time invariant within-jurisdiction or within-state unobserved characteristics

Regression Models: Specifics

We present 3 primary model specifications for each scoring program

- **Baseline Regression:** Standard Ordinary Least Squares
- **Preferred Specification:** Jurisdiction or State Fixed Effects
  - Fixed effects control for time invariant unobserved characteristics specific to each jurisdiction or state: otherwise these unobserved, omitted characteristics can bias regression results
- **Robustness:** Sample Weighting
  - Observations are weighted by the inverse of the number of installations in each jurisdiction because some jurisdictions have a disproportionately large number of installations: weighting gives each jurisdiction equal traction in the results

Vote Solar Regression Results

(preferred specification in red – model 2)

Improved score has a reducing effect on prices

System characteristics

Demographics

Market characteristics

Value of solar and time trend

Indicator for weighting, fixed effects included, goodness of fit (R2), and number of observations (N)

	Price/W	Price/W	Price/W
VS score	**-0.0208*** (0.003)**	**-0.0209*** (0.003)**	**-0.0231** (0.008)**
system size	-0.560*** (0.016)	-0.564*** (0.016)	-0.606*** (0.053)
system size squared	0.0343*** (0.001)	0.0353*** (0.001)	0.0378*** (0.004)
new construction	-0.548*** (0.042)	-0.517*** (0.041)	-0.517*** (0.097)
BIPV	0.758*** (0.079)	0.840*** (0.077)	1.033*** (0.214)
thin film	0.340** (0.125)	0.397** (0.123)	0.275 (0.210)
China	-0.405*** (0.015)	-0.429*** (0.015)	-0.522*** (0.035)
micro-inverter	0.627*** (0.017)	0.597*** (0.016)	0.326*** (0.041)
TPO	0.330*** (0.020)	-0.0203 (0.022)	-0.189*** (0.053)
education level	-0.989*** (0.067)	-0.0879 (0.072)	-0.0461 (0.171)
mean house value	0.00109*** (0.000)	0.00000867 (0.000)	-0.000266 (0.000)
mean income	-0.000258 (0.000)	0.000669 (0.000)	0.00154 (0.001)
household density	1.148*** (0.052)	1.169*** (0.052)	1.317*** (0.173)
labor cost index	-0.0130*** (0.001)	-0.0125*** (0.001)	-0.00178 (0.002)
installer experience	-0.000212*** (0.000)	-0.000295*** (0.000)	-0.0000303 (0.000)
aggregate experience	-91.67*** (7.018)	-63.15*** (7.802)	-3.028 (15.274)
installer density	-1.034*** (0.104)	-1.494*** (0.106)	-0.609** (0.201)
installer market share	-0.0938 (0.085)	-0.129 (0.085)	-0.415* (0.190)
HHI	-1.001*** (0.099)	-0.292* (0.127)	-0.219 (0.281)
value of solar	0.204*** (0.008)	0.0421*** (0.009)	-0.0297 (0.022)
time	-0.0743*** (0.002)	-0.0882*** (0.002)	-0.102*** (0.004)
weight			yes
state fixed effect		**yes**	**yes**
R2	0.316	0.340	0.313
N	43551	43551	43551

RSC Regression Results

(preferred specifications in red – models 2 & 4)

Improved score has a reducing effect on prices

System characteristics

Demographics

Market characteristics

Value of solar and time trend

Indicator for weighting, fixed effects included, goodness of fit (R2), and number of observations (N)

	Price/W	Price/W	Price/W	Price/W	Price/W
RSC score	-0.000406**	-0.000930***	-0.000370	-0.00135***	0.000553
	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
system size	-0.682***	-0.717***	-0.545***	-0.676***	-0.274*
	(0.028)	(0.028)	(0.069)	(0.028)	(0.110)
system size squared	0.0451***	0.0476***	0.0364***	0.0449***	0.0119
	(0.003)	(0.002)	(0.006)	(0.003)	(0.010)
new construction	-1.081***	-1.171***	-0.458***	-0.979***	-0.190
	(0.068)	(0.070)	(0.137)	(0.068)	(0.148)
BIPV	1.253***	1.330***	0.771***	1.374***	0.917***
	(0.170)	(0.168)	(0.162)	(0.168)	(0.186)
thin film	0.529	0.562	-0.324	0.537	-0.537*
	(0.326)	(0.317)	(0.258)	(0.322)	(0.219)
China	-0.342***	-0.359***	-0.263***	-0.356***	-0.218*
	(0.027)	(0.027)	(0.065)	(0.027)	(0.086)
micro-inverter	0.496***	0.487***	0.298***	0.507***	0.405***
	(0.030)	(0.029)	(0.059)	(0.029)	(0.077)
TPO	0.328***	0.0518	0.304*	-0.0480	-0.0431
	(0.038)	(0.049)	(0.125)	(0.043)	(0.100)
education level	-1.905***	-0.422**	-0.666	-0.721***	0.358
	(0.121)	(0.157)	(0.440)	(0.135)	(0.389)
mean house value	0.00190***	0.000462**	0.000768	0.000474**	-0.000219
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
mean income	-0.000786	0.000314	0.00236	0.000533	-0.000957
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
household density	1.655***	11.25*	1.065	0.655***	1.244**
	(0.146)	(5.278)	(4.414)	(0.175)	(0.393)
labor cost index	-0.0254***	-0.0969***	-0.0465*	-0.00670*	-0.00555
	(0.003)	(0.010)	(0.020)	(0.003)	(0.006)
installer experience	-0.0000918	-0.000413***	-0.0000494	-0.000287***	-0.000358
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
aggregate experience	-221.6***	-181.0***	-165.3*	-154.6***	-39.56
	(14.780)	(40.696)	(69.419)	(17.107)	(35.726)
installer density	-0.486*	0.978	-0.729	-0.727**	-1.406**
	(0.232)	(0.587)	(0.902)	(0.236)	(0.515)
installer market share	-1.355***	-0.287	-2.748***	-0.635*	-0.121
	(0.233)	(0.258)	(0.662)	(0.252)	(0.960)
HHI	-5.982***	-0.769	-1.316	-1.713**	0.101
	(0.497)	(0.864)	(1.631)	(0.558)	(1.322)
value of solar	0.189***	0.108***	0.211***	0.0187	0.0743
	(0.016)	(0.024)	(0.059)	(0.019)	(0.046)
time	-0.0524***	-0.0469***	-0.0495***	-0.0684***	-0.0706***
	(0.003)	(0.004)	(0.010)	(0.003)	(0.008)
weight			yes		yes
state fixed effect				yes	yes
jurisdiction fixed effect		yes	yes		
R2	0.382	0.422	0.475	0.398	0.371
N	13904	13904	13904	13904	13904

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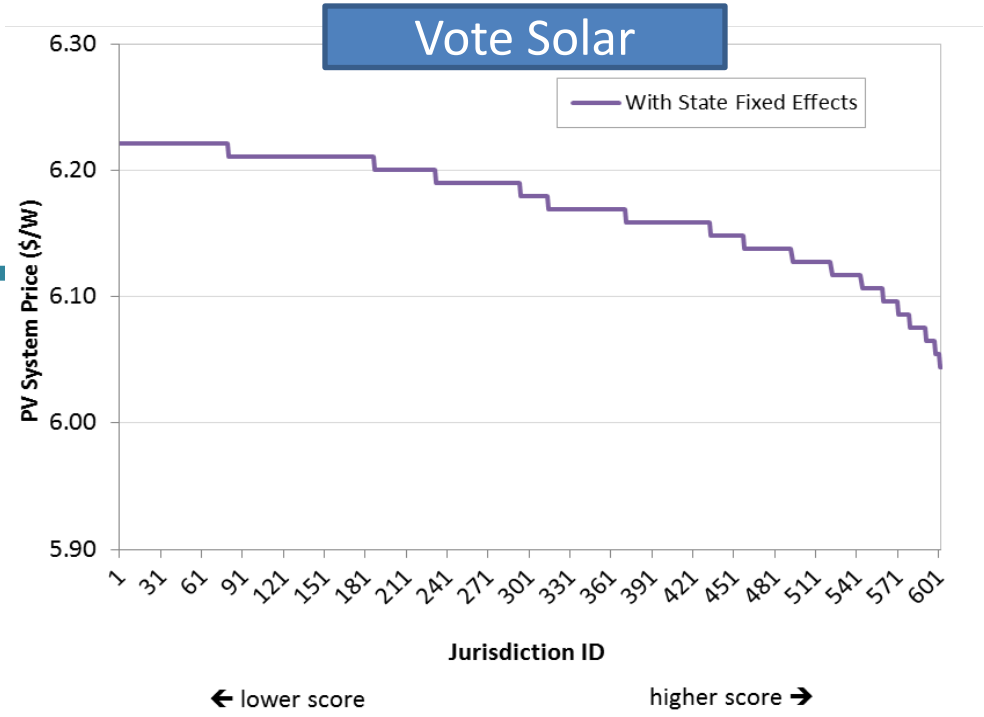
Interpretation of Results

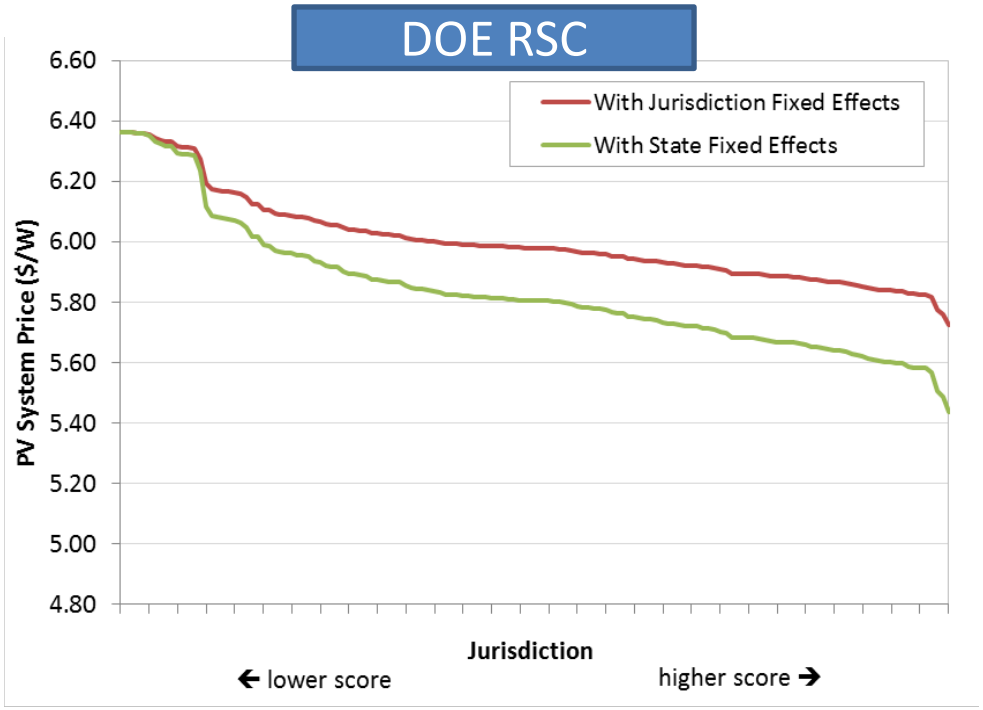
- Local regulatory processes can have a meaningful impact on residential PV prices
  - 1 point increase in Vote Solar score → $0.021/W reduction in PV prices (model 2)
  - 1 point increase in RSC score → $0.00093/W – $0.00135/W reduction in PV prices (models 2 & 4)
- Results for Vote Solar–using a larger dataset–are more robust
  - Use of sample weighting and exclusion of fixed effects do not affect Vote Solar results
  - In RSC analysis, sample weighting and exclusion of fixed effects do influence results: weighting results suggest that large jurisdictions are driving the RSC results in the preferred specifications

What Does this Mean?
Predicted Effects of Score Changes

- **Vote Solar:** Average price of PV in highest-scoring jurisdiction predicted to be $0.18/W (3%, $900 for typical 5-kW system) less than in lowest-scoring jurisdiction; when focusing on inner 90% of jurisdiction scores, this variation drops to $0.14/W (2.2%, $700)
- **DOE RSC:** Average price of PV in highest-scoring jurisdiction predicted to be $0.64-0.93/W (10-15%, $3200-4700) less than in lowest-scoring jurisdiction (depending on model); when focusing on inner 90% of jurisdiction scores, this variation drops to $0.50-0.73/W (8-12%, $2500-3700)

Figures summarize predicted effects of changes in Vote Solar and RSC scores on average PV prices, ignoring all other jurisdictional differences





What Does this Mean? DOE RSC Score Improvement Over Time

- Average RSC score increased by 163 points from the baseline to the final score
- Translates to a predicted decline in PV prices of $0.15-0.22/W (2.5-3.6%), or a total of $700–1100 for a typical 5-kW PV system
- Results suggest that 13-19% of the total PV price change from 2011 to 2012 might be attributed to improvements in permitting and other local regulatory processes

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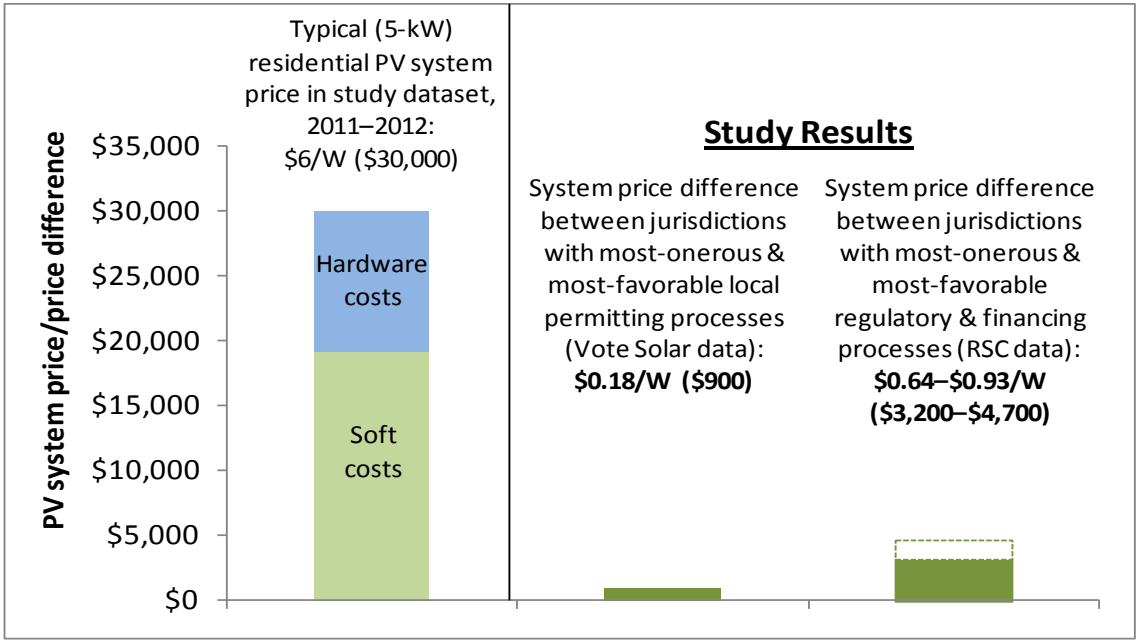
Conclusions

- Variations among and improvements to local regulatory and permitting processes can meaningfully impact residential PV prices

- RSC scores appear to drive larger local price variations than Vote Solar scores
  - RSC scores embed not only variations in permitting, but also variations in interconnection, planning and zoning, financing options, and net metering rules



- These cross-jurisdiction results add to previous literature that has evaluated the national average impacts of permitting and other local regulatory procedures

Possible Future Research

- Expand analysis to explore the impact of permitting and other local regulatory improvements on the participation of and competition among installers as well as on demand for PV systems
- Evaluate the impact of local regulatory procedures on larger-scale commercial installations
- As RSC program continues, directly evaluate the impact of the program by comparing price trends in participating jurisdictions relative to non-participating jurisdictions
- Conduct further research to understand heterogeneity in PV prices, beyond the impact of permitting and local regulatory procedures

For more information…

Download the full report, a 2-page fact-sheet, and this briefing:

http://emp.lbl.gov/publications/how-much-do-local-regulations-matter-exploring-impact-permitting-and-local-regulatory-p

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