IMPACTS OF SOLAR POLICIES ON LOW AND MODERATE INCOME PV ADOPTION

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Executive Summary

In the last decade, the solar industry has seen tremendous growth—the Solar Energy Industries Association estimates that the United States solar market has experienced a compound annual growth rate of fifty-nine percent since 2010 with over forty-two GW of total solar capacity installed as of the end of 2016.[1] Due to technological improvements and increased awareness, solar panel costs have also dropped during this time period (sixty-seven percent decline since 2011), and innovations in financing structures (e.g. third-party ownership, on-bill financing) have enabled more households to install solar panels than ever. Such market conditions have made solar installations, which typically require a high upfront capital expense, more accessible to low- and moderate-income (LMI) households who experience greater relative social and economic benefits from solar.

This study reviews over a decade of residential solar installation data spanning eleven states in the U.S. and assesses whether and how policies have facilitated solar adoption among LMI households. Our findings, which are based on in-depth analysis of five states' policies and market growth from 1999 to 2015, suggest that LMI solar adoption rates generally track overall market growth in these states. These states include California, Connecticut, Massachusetts, New Hampshire, and Nevada and featured very different rates of LMI solar adoption. Of the residential projects for which we had data in New Hampshire, nearly three-quarters of these were for LMI households, whereas only about one-third of residential projects in California belonged to LMI households. New Hampshire also has no LMI-specific solar policies, while California has almost a decade of solar policies targeting LMI.

We find that variations in adoption are difficult to attribute precisely to specific LMI policies, but that there is likely some influence from LMI-specific incentives in California and Massachusetts to adoption rates in those states. We also find that the Connecticut Green Bank has been active but that our data is not clear on how the solar market growth is tied to the Green Bank's activity. Plus, we find in New Hampshire that LMI solar installations grew without an LMI-specific policy.

[1] Solar Industry Data. 2017. http://www.seia.org/research-resources/solar-industry-data

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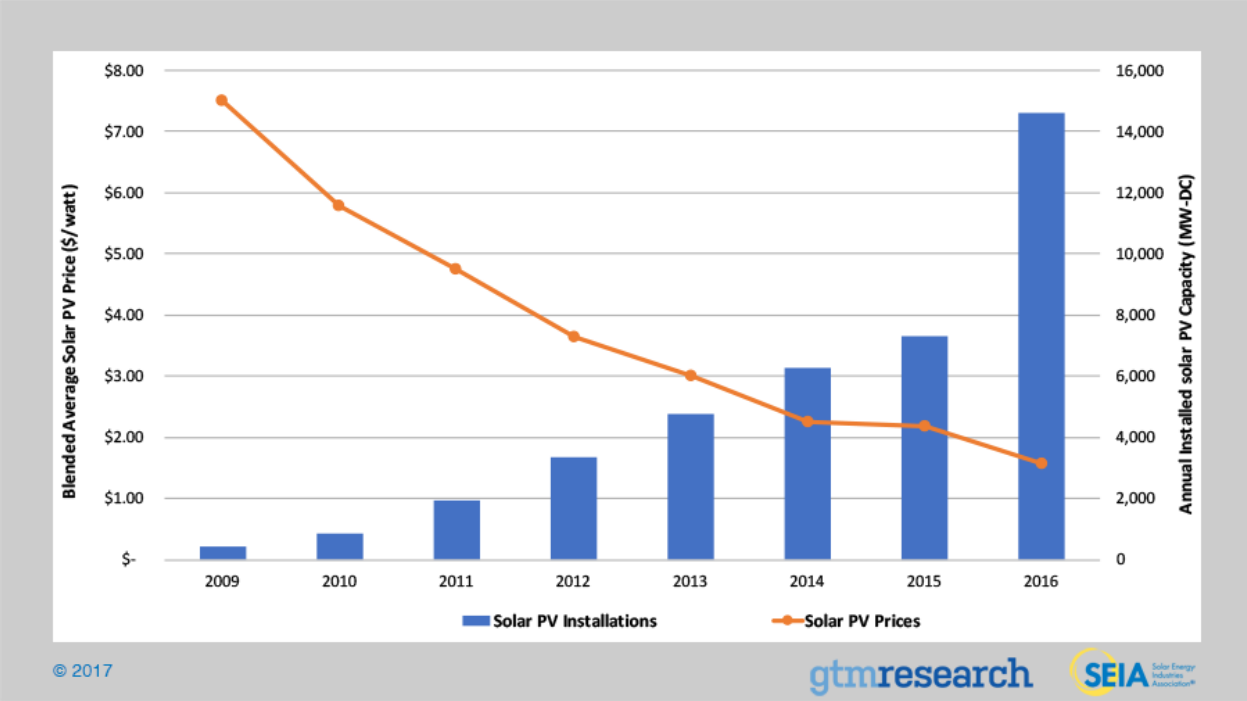
I. Introduction

Solar deployment in the United States has seen tremendous growth over the last twenty years. While declining costs have certainly played a large role in this trend, policies that make it easier for homeowners to finance solar panels, such as net metering policies, have helped as well.



As solar becomes more affordable, it can potentially benefit low- and moderate-income (LMI) residents who currently experience disproportionately high energy costs. The American Council for an Energy Efficient Economy estimates that LMI populations spend three times more of their income on energy[2], and a study conducted by Hernández and Bird found that upper-income households spend five percent or less of their income on energy expenses whereas low-income households spend ten percent or more. The very poor, whose homes are less energy efficient to begin with, may spend upwards of twenty percent of their income on energy.[3] The George Washington University Solar Institute's Bridging the Solar Income Gap report also indicated that households earning less than $40,000 per year make up forty percent of all U.S. households but only five percent of solar installations as of early 2015[4].

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[2] Drehobl & Ross. Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low-Income and Underserved Communities. 2016. http://aceee.org/research-report/u1602.
[3] Hernandez & Bird. Energy Burden and the Need for Integrated Low-Income Housing and Energy Policy. 2010. http://onlinelibrary.wiley.com/doi/10.2202/1944-2858.1095/epdf
[4] Mueller & Ronen. Bridging the Solar Income Gap. 2014. http://solar.gwu.edu/research/bridging-solar-income-gap

However, there are several barriers that prevent LMI residents from adopting solar. The "Low-Income Solar Policy Guide" from Vote Solar, the Center for Social Inclusion, and GRID Alternatives list out the barriers to LMI adoption of solar. For instance, the upfront cost of solar can be prohibitive, many roofs do not have enough sun resource available, and LMI residents are more likely to be renting, which makes it difficult to invest in home infrastructure. In addition, the guide notes that LMI residents are more likely to live in older homes with roof conditions that cannot support solar installations. Lastly, there are several education and outreach issues such as language barriers and distrust of solar salespersons[5], and further, solar is often perceived as a product for the wealthy.[6]

The policy guide then suggests several policy solutions that can help LMI populations acquire solar installations, including: net metering, community solar, tax credits, rebates, renewable energy credits, on-bill financing, property-assessed clean energy, community purchase programs, community development finance, green banks, grants, and place-based investments. Our state case studies touch on some of these policies and examine their effectiveness.

It is important for us to analyze the potential impacts of solar policies on LMI solar adoption, because LMI households stand to gain the most from clean energy resources. Given their proportionally high energy costs, LMI households benefit most from access to low-cost clean energy. In addition, when there are interruptions to electricity delivery, LMI households may be stranded for longer periods of time or lack the finances to acquire backup power, making them less resilient. At the end of the day, residential solar can level the playing field for LMI populations by helping them gain equitable access to the same energy services enjoyed by wealthier households.

Our study examines the growth in total number of projects and installed capacity of residential solar across eleven states in the U.S., identifies relevant state-level solar policies that specifically target LMI populations in five key states, and assesses whether there are trends in LMI adoption as a result of these policies. This study uses the Lawrence Berkeley National Laboratory's (LBNL) Tracking the Sun dataset, which is further described in the Methodology section below.

II. Methodology

Tracking the Sun (TTS), the primary dataset used for this report from Lawrence Berkeley National Lab (LBNL), contains over 800,000 data points across twenty-seven states with each data point representing one reported solar install. Altogether, this data represents over eighty percent of installs in the United States between 1999 and 2015. While the data covers a lot of

[5] "Low-Income Solar Policy Guide." Vote Solar, Center for Social Inclusion, GRID Alternatives. March 2017. Accessed May 5, 2017. http://www.lowincomesolar.org/wp-content/uploads/2017/03/Policy-Guide_3.7.17.pdf

[6] Hill J. How Wealthy are Solar Residential Customers? Greentech Media. 2017. https://www.greentechmedia.com/squared/read/how-wealthy-are-residential-solar-customers

ground and roof installations, the scope of our project only includes residential systems, which comprise around 550,000 of the total projects. Only a subset (337,742) of these include complete data for all the metrics we are interested in, namely:

1. Block group number;
2. Block group median income;
3. System capacity (kW);
4. Total installed cost; and
5. Rebate amount.

Data Completeness

Block group is a U.S. Census Bureau identifier that covers a smaller geographic area than zip code, improving the granularity of our data analysis. It was our intent to use block group data provided that a significant portion of a state's solar installs included block group information. We included system capacity, installed cost, and rebate data in order to evaluate market growth over time and rebate allocations for LMI and non-LMI households that added solar systems to their homes. These last three metrics were available for all projects reported to LBNL, so our primary goal when narrowing the data was to remove projects where block data was not collected or median income data showed "blanks".

Bearing our data requirements in mind, we performed an initial assessment to check for data completeness and narrowed the scope of this project to eleven states whose data included our five metrics and appeared representative of the state's overall residential solar adoption. Several active solar states such as Colorado were excluded from our analysis due to lack of block group data. A summary of this analysis, which includes the eleven states with the most complete data, appears below:

State	Number of Residential Projects	Number of Projects with All Criteria	Number of Projects without All Criteria	Percent of Projects without All Data
AR	87	72	15	17%
CA	443,729	238,777	204,952	46%
CT	13,186	12,756	430	3%
FL	1,547	1,423	124	8%
MA	39,397	33,076	6,321	16%
NH	2,561	1,570	991	39%

NV	13,783	12,878	905	7%
NY	40,395	27,503	12,892	32%
PA	6,325	6,007	318	5%
RI	321	184	137	43%
VT	3,628	3,496	132	4%
Total	**564,959**	**337,742**	**227,217**	**40.2%**

Table 1. Comparison of State Median Incomes

As noted above, sixty percent of the eleven states' Tracking the Sun data includes information on all of the criteria we sought to examine. California, Massachusetts, and New York had the highest number of installs. While California only had complete data for just over half of its residential installs listed in the full dataset, due to the large number of projects in California, California's solar data still represented seventy percent of the residential projects overall that addressed all of our criteria. From there, we determined block group data was sufficiently complete in these eleven states such that we could base our analysis on these 330,000+ data points. The next step was to define low- and moderate- income thresholds for each state.

Low- and Moderate-Income Definitions

The U.S. Department of Housing and Urban Development outlines the following definitions of low- and moderate-income thresholds:

Income Definitions	% of Median Income
Very Low Income	50%
Low Income	80%
Moderate Income	115%
High Income	Over 115%

Source: U.S. Department of Housing and Urban Development

Median income for each of the eleven states was incorporated into our analysis[7], and the income dollar value cutoffs were calculated accordingly per the table below.

		Federal Standard		
State	**Median Income (2015)**	**Very Low Income**	**Low Income**	**Moderate Income**
AR	$ 42,798	$ 21,399	$ 34,238	$ 49,218
CA	$ 63,636	$ 31,818	$ 50,909	$ 73,181
CT	$ 72,889	$ 36,445	$ 58,311	$ 83,822
FL	$ 48,825	$ 24,413	$ 39,060	$ 56,149
MA	$ 67,861	$ 33,931	$ 54,289	$ 78,040
NH	$ 75,675	$ 37,838	$ 60,540	$ 87,026
NV	$ 52,008	$ 26,004	$ 41,606	$ 59,809
NY	$ 58,005	$ 29,003	$ 46,404	$ 66,706
PA	$ 60,389	$ 30,195	$ 48,311	$ 69,447
RI	$ 55,701	$ 27,851	$ 44,561	$ 64,056
VT	$ 59,494	$ 29,747	$ 47,595	$ 68,418

Sources: Kaiser Foundation, HUD

[7] Henry J. Kaiser Family Foundation. Median Annual Household Income. 2015. Available at: http://kff.org/other/state-indicator/median-annual-income/?currentTimeframe=0&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D.

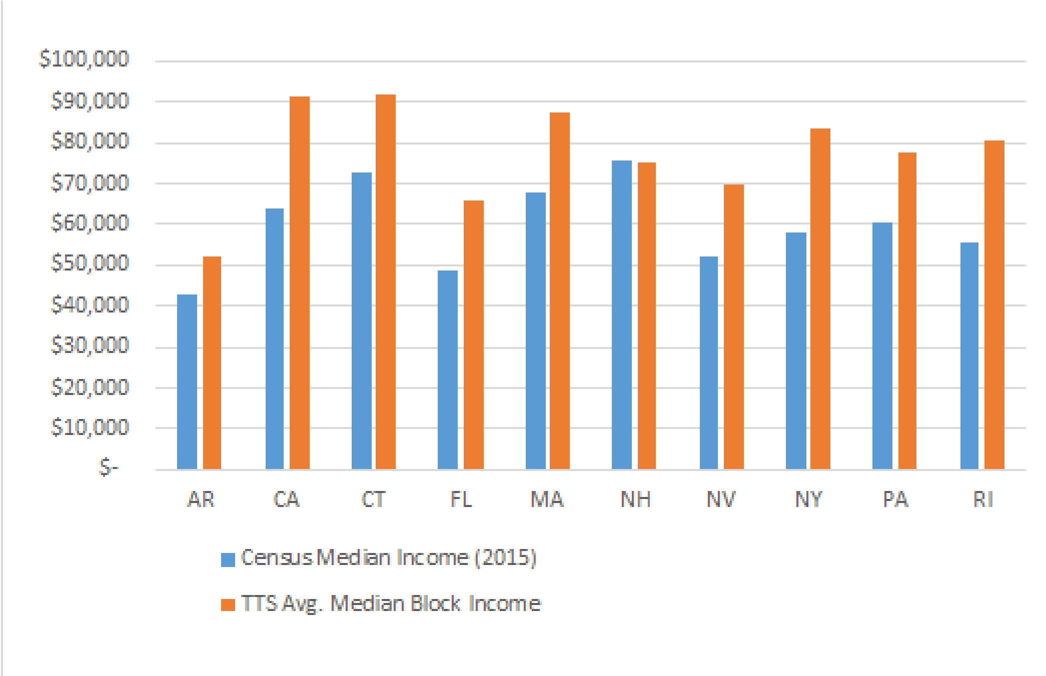

Figure 1. Comparison of State Median Incomes with Tracking the Sun's Block Group Median Incomes

A quick comparison of state median incomes to Tracking the Sun's block group median income showed, unsurprisingly, that the median income of households within each block group with solar PV installations in a state tended to be slightly higher than the median income for the state. This result is likely because solar systems were initially only available to wealthier households due to high upfront capital costs. The only state where we see that the overall median income is higher than the solar PV block group median income is in New Hampshire, which has the highest overall median income of the states we reviewed.

State-by-State LMI Solar Adoption Comparison

Using block group median income data, we were able to count the number of projects that fell into each income bracket as well as the capacity added per year and cumulative capacity in each year. This analysis enabled additional comparisons of the rate of change between LMI and overall project installs and capacity gains and also provided insight into the proportion of installs that belonged to LMI households. Based on the number of overall installs and the LMI solar adoption rate, we delved into five of the eleven states—California, Connecticut, Massachusetts, New Hampshire, and Nevada—to identify policy drivers (or lack thereof) that might have contributed to the residential PV penetration observed between 1999 and 2015.

III. Results and Analysis

A. Findings

1. General Findings

Though the eleven states that matched our criteria were located across the entire US, they were most heavily concentrated in the Northeast. The number of projects in each state was very disparate—ranging from more than 230,000 residential solar PV projects in California to 72 projects in Arkansas. However, despite the difference in the amount of solar installations, the patterns of growth and change were similar across all states.

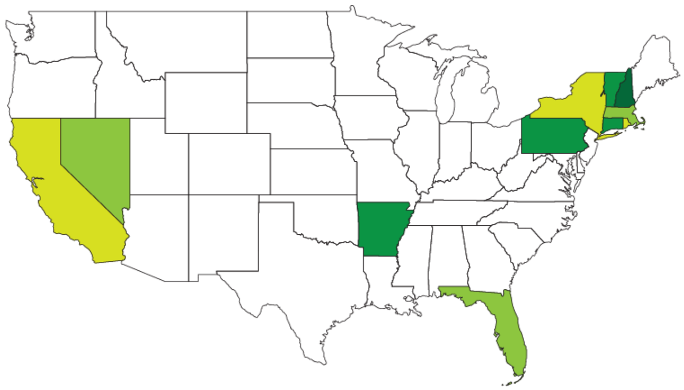

Figure 2. Map of Selected States

Legend:

(yellow)	12-23% LMI
(light green)	34-38% LMI
(green)	43-55% LMI
(dark green)	72% LMI

Overall, thirty-seven percent of the reported installed capacity and thirty-eight percent of the projects that included information covering all of our criteria belonged to LMI households. In some states, this ratio was even higher. For instance, around three quarters of New Hampshire's installed projects and capacity were associated with LMI households. Additionally, six of the eleven states are above the average, which is driven in large part by California's ratio. Generally, LMI projects are of slightly lower capacity than non-LMI projects. Overall, 39% of the population living in these eleven states fall within the low- and moderate-income brackets, and this ratio is reflected in the rate of LMI projects observed and the proportion of installed capacity that is LMI.

State	% of Population LMI	LMI Projects Installed	Total Number of Projects Observed	Percent of Projects that are LMI	LMI Capacity (kW)	Total Capacity (kW)	Percent of Capacity that is LMI
AR	**38%**	38	72	**53%**	169	413	**41%**
CA	**42%**	84,541	238,777	**35%**	487,043	1,366,313	**36%**
CT	**34%**	5,729	12,756	**45%**	39,843	93,479	**43%**
FL	**37%**	606	1,423	**43%**	3,420	8,044	**43%**
MA	**34%**	15,054	33,076	**46%**	105,126	34,902	**45%**
NH	**33%**	1,155	1,570	**74%**	5,526	7,680	**72%**
NV	**35%**	4,752	12,878	**37%**	30,143	86,757	**35%**
NY	**42%**	9,240	27,503	**34%**	66,571	206,321	**32%**
PA	**37%**	2,891	6,007	**48%**	21,706	46,253	**47%**
RI	**38%**	39	184	**21%**	196	1,089	**18%**
VT	**38%**	2,011	3,496	**58%**	11,445	21,270	**54%**
TOTAL	**39%**	**126,056**	**334,246**	**38%**	**771,188**	**2,072,523**	**37%**

Table 2. State Breakdowns of Total and LMI-specific Solar PV Installed Capacity

Though the Tracking the Sun database begins in 1999, there are very few projects prior to 2008.[8] Generally, each state followed one of two installation patterns over time. The first, as seen in California and the Northeast states can be referred to as the “hockey stick,” in which there has been an increase in the amount of projects, growing more steeply over time. In Arkansas, Florida, and Pennsylvania, the amount of solar grew very quickly, for 2-3 years, and then dropped off very sharply. When comparing these short “bursts” of solar installations to the longer-term trend of the hockey stick, it is most likely that local government policy has a significant impact on technology adoption.

[8] This increase post-2007 is likely due to the huge decrease in the cost of solar panels and the increase in federal and state incentives, which helped stimulate the market. SEIA. Solar Industry Growing at a Record Pace. Available at: http://www.seia.org/research-resources/solar-industry-data

Installed Projects (non-LMI + LMI)

State	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
AR	0	0	0	0	0	0	0	42	30	0	0	0	0	**72**
CA	1	0	22	40	3446	8029	13611	16772	22405	30249	36755	19572	87872	**238,777**
CT	0	0	31	81	146	256	452	452	366	574	1256	3069	6073	**12,756**
FL	0	0	0	13	37	29	592	504	64	39	28	42	75	**1,423**
MA	49	87	57	167	152	278	594	473	1044	2812	4610	8643	14108	**33,076**
NH	0	0	0	0	0	33	160	246	87	193	222	425	203	**1,570**
NV	0	5	54	62	92	77	160	275	121	44	195	1312	10481	**12,878**
NY	35	82	79	181	309	352	640	644	611	1400	2160	5640	15370	**27,503**
PA	0	0	0	0	0	0	332	2406	2130	687	436	16	0	**6,007**
RI	0	0	0	0	0	0	0	0	0	1	34	57	92	**184**
VT	1	64	36	62	57	82	142	175	361	451	800	926	339	**3,496**
Total	**86**	**238**	**279**	**606**	**4239**	**9136**	**16683**	**21989**	**27219**	**36450**	**46496**	**39702**	**134613**	**337,742**

 # Projects Installed at LMI Households

State	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
AR	-	-	-	-	-	-	-	21	17	-	-	-	-	38
CA	-	-	7	12	984	2,375	4,146	4,986	6,902	9,232	11,605	6,807	37,485	84,541
CT	-	-	10	29	47	104	195	178	154	209	489	1,331	2,983	5,729
FL	-	-	-	5	18	8	261	216	22	17	9	14	36	606
MA	22	43	36	89	89	147	289	246	446	1,167	1,922	3,940	6,617	15,054
NH	-	-	-	-	-	27	129	196	67	140	166	296	134	1,155
NV	-	1	18	14	29	32	43	74	31	11	59	472	3,968	4,752
NY	25	44	36	104	139	160	306	289	260	616	839	1,898	4,524	9,240
PA	-	-	-	-	-	-	146	1,107	1,084	337	211	6	-	2,891
RI	-	-	-	-	-	-	-	-	-	-	7	8	24	39
VT	-	52	24	40	36	44	85	97	182	227	470	545	209	2,011
Total	**47**	**140**	**131**	**293**	**1,342**	**2,897**	**5,600**	**7,410**	**9,165**	**11,956**	**15,777**	**15,317**	**55,980**	**126,056**

Table 3. Annual Solar Installs 1999-2015 by State

2. LMI vs. non-LMI

All eleven states included LMI installations (see Table 2). Overall, LMI installation trends closely followed those of non-LMI installations in the eleven states examined. Notably, while the cumulative capacity of all solar installations dipped between 2013 and 2014, this drop was much less pronounced in the LMI market.

From our analysis, we did not see a measureable impact of LMI policies on solar penetration. The chart below shows the cumulative number of projects in each state by LMI and non-LMI each year, as well as the cumulative installed capacity across the selected states for both LMI and non-LMI households. On a high level, this analysis shows that the rate of growth for LMI and non-LMI are very similar. There are no places on the curve where LMI appears much steeper than non-LMI, indicating that LMI solar uptake has outpaced non-LMI solar adoption to date. This may be due to the fact that the solar industry has only been growing significantly for the past ten years and LMI policy for ever fewer years, so the policies have not had enough time to make a large impact. It seems likely that these policies may have greater impact in the future. However, since each state in our analysis has different policies, the uptake of solar on LMI households has been different. In the section below we explore some of these states further.

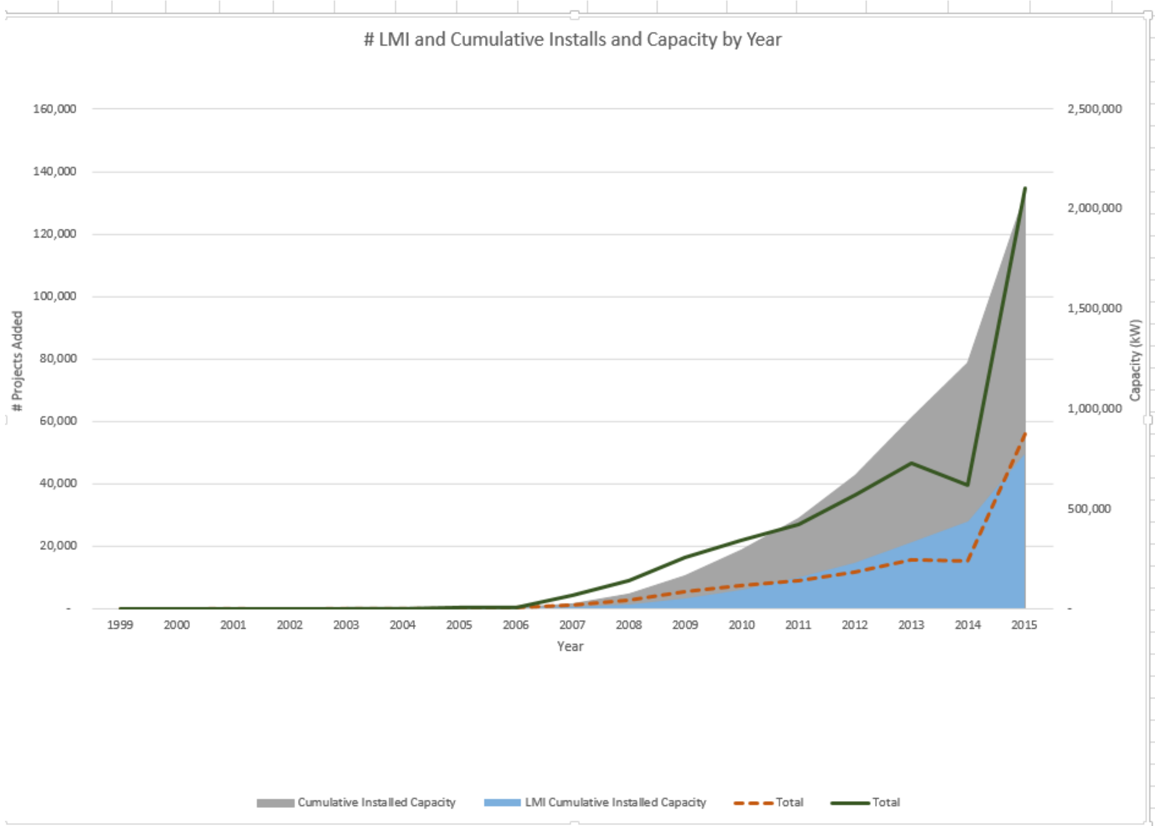

Figure 3. LMI and Cumulative Installations and Capacity by Year

When comparing project costs for our five in-depth states, we found that LMI projects typically had a lower project cost. California has a twenty-two percent price difference, which is significantly larger than all other states, which ranged between one and six percent. This may be due to the fact that California has many LMI-targeted policies, whereas New Hampshire, which has a price differential of one percent, has no targeted LMI policies. We will further explain the policy mechanisms for this reduction in costs later in the paper.

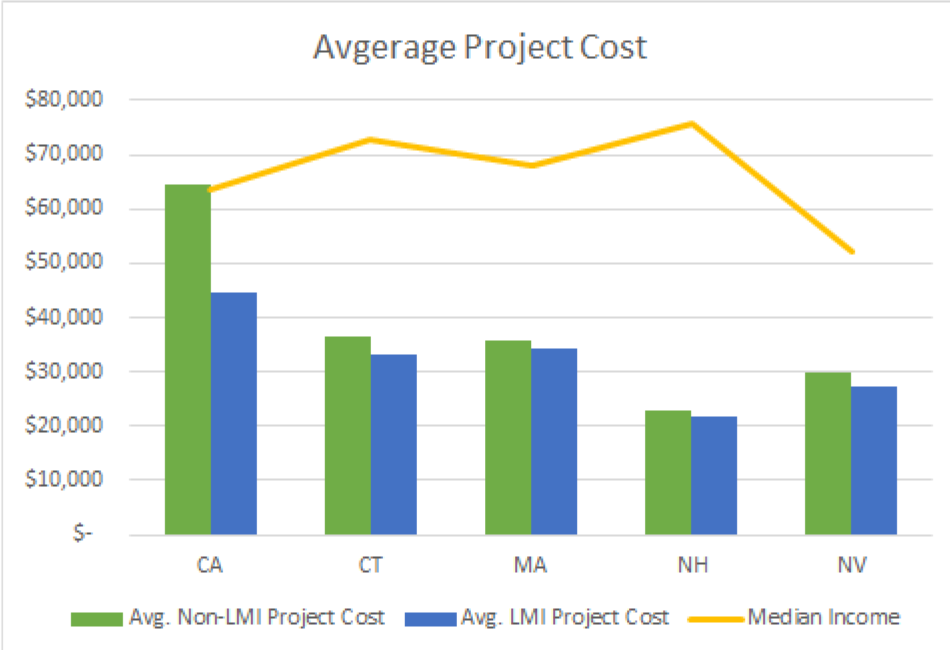

Figure 4. Average Project Cost

A different story is told when looking at rebates. In California and Connecticut, more non-LMI projects (see the bars on the chart below) are able to take advantage of rebates. However, on average, rebates cover a greater percentage of the project costs (see the lines in the chart below) in California, Massachusetts, and New Hampshire, as compared to Connecticut and Nevada. Though rebates are just one part of the solar financing toolkit, they can help move the market for LMI, as seen in New Hampshire and Massachusetts, which have above average numbers of LMI installations.

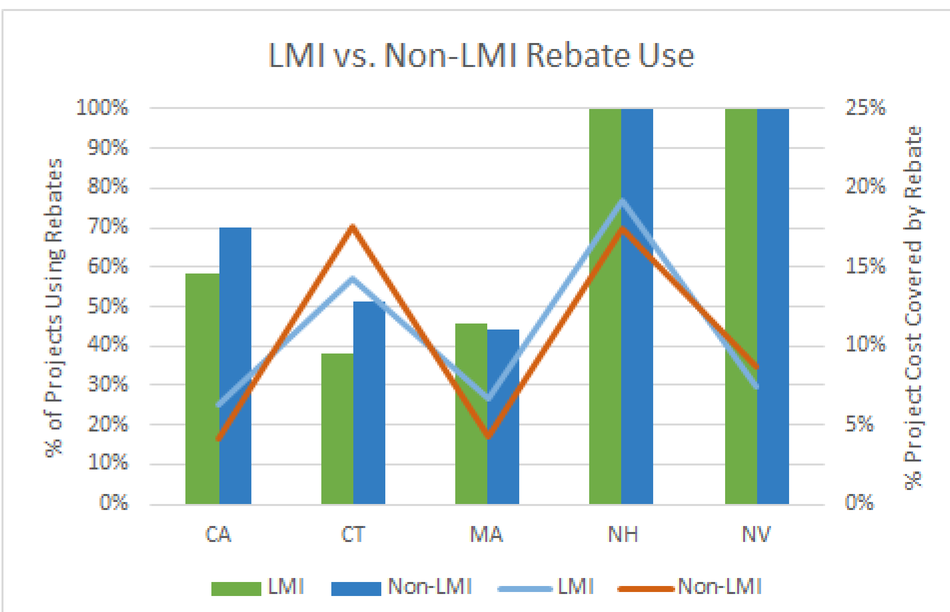

Figure 5. LMI vs non-LMI Rebate Use.

B. Case Studies

California: S(m)ASHing Solar Inequality

The state of California has a broad array of solar policies and incentives available at multiple levels of government. However, there have only been two low-income-focused statewide solar policies, and only one of them targets single-family residences. The Single-Family Affordable Solar Homes (SASH) policy began in 2009, providing a significant rebate for installations ranging from 1kW to 1MW in size.[9] At the start, the rebate was $4.75 to $7 per watt[10], depending on the applicant's income and enrollment in other low-income programs. The rebate has now dropped to a flat rate of $3 per watt. It is available to households who earn eighty percent of the area median income or less, which we assume to be approximately the same as the eighty percent block median income we use in our solar data. Therefore, SASH installations do not overlap with the higher end of our own LMI designation, but do match closely to the low-income (or "LI") section of our data. The total budget of the program began with $108 million, and was renewed with $54 million in 2013.[11]

Examining the trend of residential solar installations over time, the graph below shows that lower-income households increased their uptake of solar since 2008.[12]

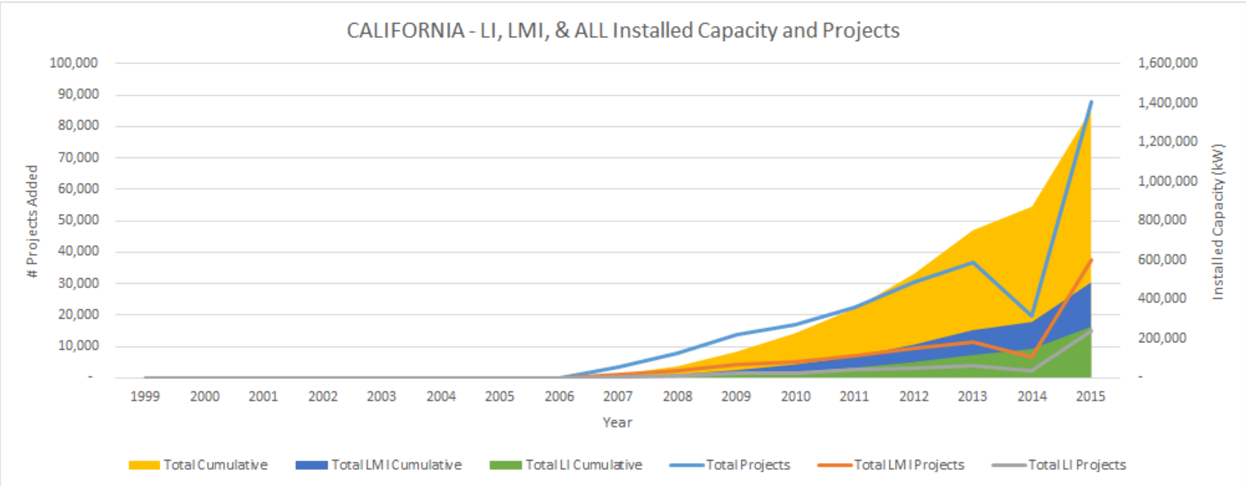

Figure 6. California Solar PV Installed Capacity and Total # of Projects for LMI and non-LMI

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[9] DSIRE "California Solar Initiative - Single-Family Affordable Solar Housing (SASH) Program." Update March 7, 2017. Accessed May 7, 2017. http://programs.dsireusa.org/system/program/detail/3673

[10] Constantine, Sachu et al. "California Solar Initiative Annual Program Assessment." California Public Utilities Commission. June 30, 2010. Accessed May 6, 2017 https://runonsun.com/~runons5/blogs/media/blogs/a/2010_CSI%20Annual%20Program%20Assessment.pdf

[11] "Appendix D: Single-Family Affordable Solar Homes (SASH) 2.0 Program Handbook" Accessed May 7, 2017. http://www.gosolarcalifornia.ca.gov/documents/SASH_Handbook.pdf

[12] We do not have a precise explanation for the dip across categories in 2014 and think it may be an anomaly due to the criteria we used to filter the data.

The following two graphs show that when LMI installations are compared to all installations, they both have grown at the same rates since 2007—before which there were so few installations such that the data is mostly noise. However, when we compare low-income installations only (those at households earning less than eighty percent of the area median income), suddenly we can see that the rate of installs for low-income homes has been faster than the cumulative rate for most years since 2007.[13]

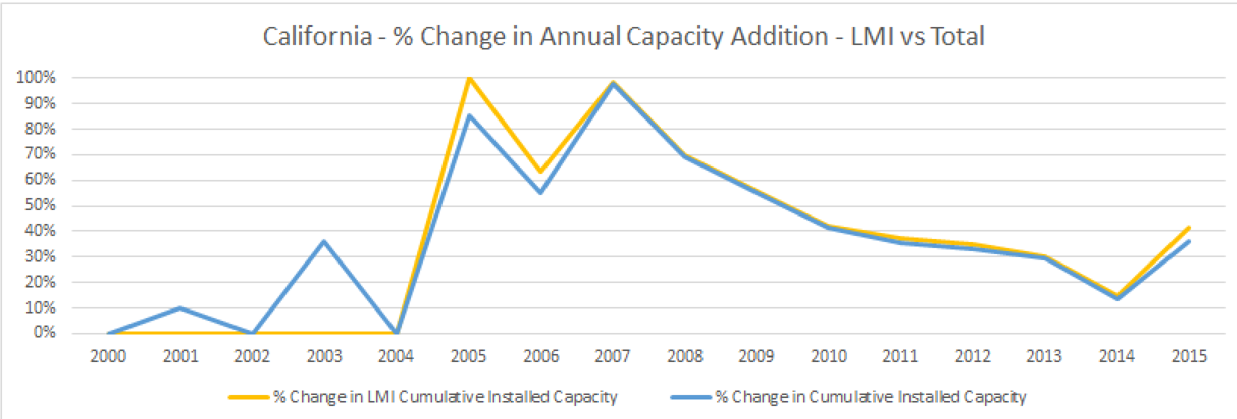

Figure 7. California Percent Change in Annual Solar PV Capacity Addition 2000-2015

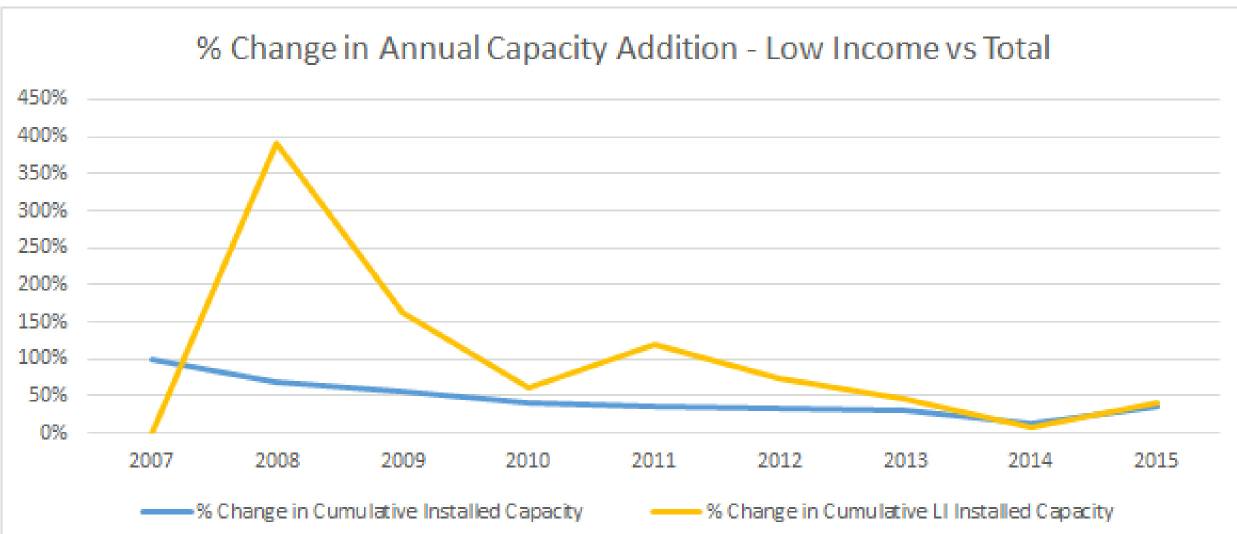

Figure 8. California Percent Change in Annual Solar PV Capacity Addition 2007-2015

GRID Alternatives, a nonprofit that does outreach to lower-income households and conducts panel installations, has implemented SASH. Therefore, data on SASH-specific installations is available. As can be seen in the following graphs, it has tracked fairly constantly in terms of number of projects per year.[14]

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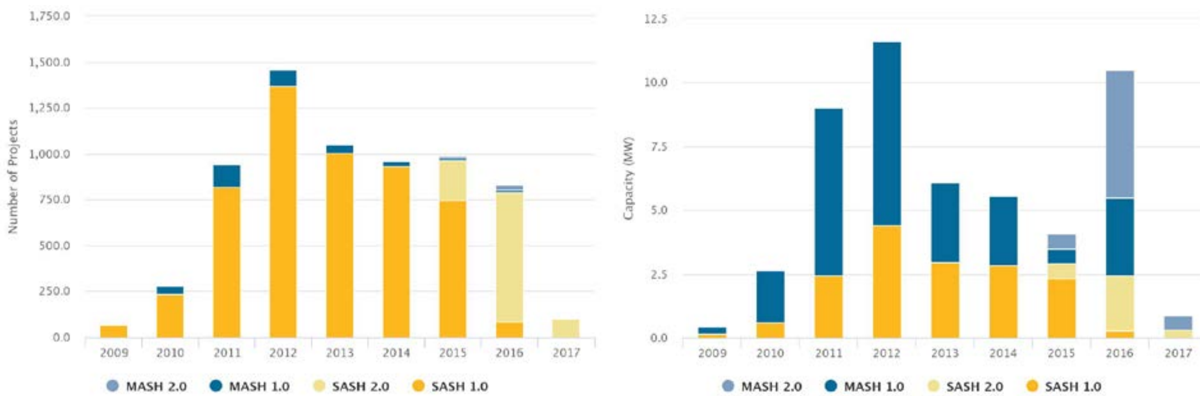
[13] The rate of low-income installs in the first two years is very high because there were so few installations.

[14] The other program in the graphs, MASH, is the multi-family equivalent program. “Statistics and Charts.” California Distributed Generation Statistics. Data current through 4/12/2017. Accessed April 18, 2017. http://www.californiadgstats.ca.gov/charts/li



Graphs from californiadgstats.ca.gov, data current through 4/12/17

Has SASH had an effect?

First, as the SASH capacity graph shows, the subsidy has been responsible for roughly 2.5 MW per year for most of the years it has been in effect. By comparison, our data shows that low-income solar capacity in all of California went from practically 0 MW to ~250 MW over eight years, or about 30 MW per year. SASH incentives therefore are directly tied to about seven percent of capacity installed on low-income homes per year.

This introduces a question: would those same LMI homes have installed solar anyway without the incentive, such that trend lines would have been identical without SASH? The likely answer is no. GRID Alternatives is the nonprofit that was chosen to administer SASH and deploy solar to LMI households.[15] If there had not been the government funding, GRID would likely not have had an alternative source of capital at the same scale. Plus with a heavy subsidy, it is unlikely that for-profit solar installers would have seen the same customers as economical.

The data supports this conclusion that SASH had an effect on low-income solar adoption at least initially. Even though SASH was introduced in 2009, the SASH graph shows that 2011 was the first year when capacity installed jumped markedly. This jump tracks with our trend graph, in which the rate of change of low-income capacity installed increases in 2011.

SASH then levels off by 2013 to a fairly constant capacity installed each year, but the rate of change of low-income installed capacity stays positive. This indicates that larger and larger amounts of solar were being installed on LMI roofs, with SASH subsidies being used for a smaller and smaller proportion of them. However, the rate of change for low-income capacity installations is higher than total installations up until 2014, which suggests that SASH had a continual positive effect. Overall, since a large proportion of low-income installations are not subsidized by SASH, much of the growth is likely due to the market forces at large, while SASH made the LMI market bigger than it would have been. (Meanwhile, our analysis did not examine whether SASH installations led to “peer effects” of neighboring LMI homes adopting solar.)

[15] GRID Alternatives. “SASH.” Accessed May 9, 2017. http://gridalternatives.org/what-we-do/solar-programs/single-family-solar/sash

Connecticut: The Green Bank State

Like many other states, Connecticut has seen a large uptick in solar installations at all levels of income in recent years. From a policy perspective, Connecticut has taken an aggressive stance to decarbonize its electricity sector. Its renewable portfolio standard calls for utility companies to acquire twenty-three percent of their distributed electricity from renewable sources by 2020.[16] For many of the state's electricity consumers, going solar makes a lot of sense when the proper incentives are in place. Connecticut has one of the highest electricity prices in the United States at nearly $0.18 per kilowatt-hour.[17] This price is well above the national average of $0.1042 per kilowatt-hour.[18]

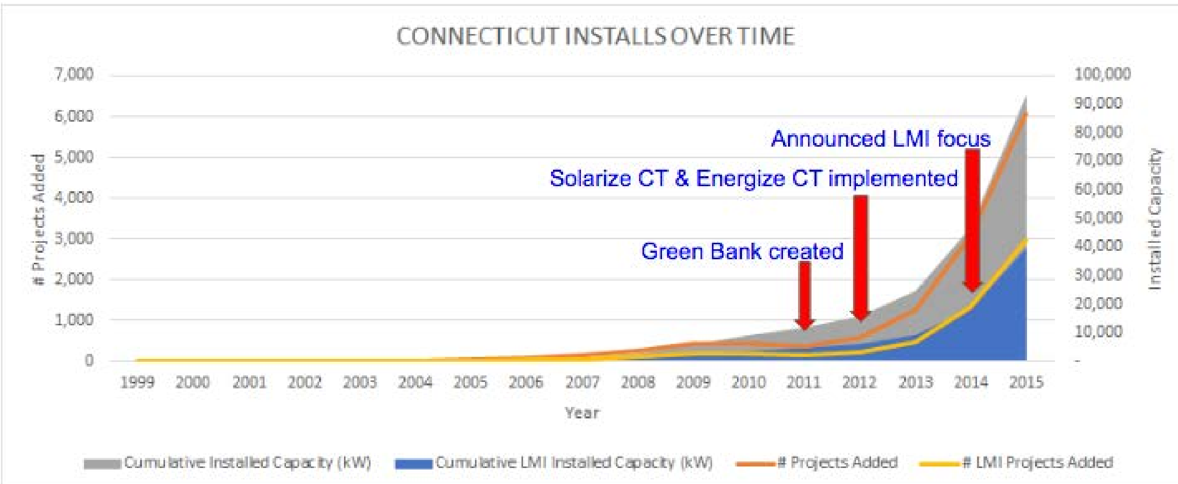


Figure 9. Solar PV Installations in Connecticut Over Time.

Connecticut's most intriguing policy innovation is its creation of a green bank to catalyze investments in clean energy sectors such as residential solar PV. Established by an act of the Connecticut General Assembly in 2011, the Connecticut Green Bank is a quasi-public agency tasked with increasing the state's adoption of clean energy and energy efficiency measures by stimulating demand for renewable energy and using innovative financing techniques to encourage the deployment of private capital towards non-traditional markets and projects.[19] The organization has $120 million in assets to deploy towards this goal and is supported by a $0.001 per kilowatt-hour surcharge on the electricity bills of ratepayers and proceeds from Connecticut's participation in the Regional Greenhouse Gas Initiative, which provide the agency

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[16] DSIRE. Renewables Portfolio Standard. July 17, 2015. Available at: http://programs.dsireusa.org/system/program/detail/195

[17] Nebraska Energy Office. June 18, 2016. Annual Average Electricity Price Comparison by State. Available at: http://www.neo.ne.gov/statshtml/204.htm.

[18] Ibid.

[19] Connecticut Green Bank. About the Connecticut Green Bank. Accessed: April, 29, 2016. Available at: http://www.ctcleanenergy.com/Default.aspx?tabid=62.

with a total of $30-$35 million per year for investment purposes.[20] In 2014, the Green Bank's Board of Directors instructed the organization to specifically dedicate resources to target LMI households for solar development.[21] So far, the Green Bank has created several programs that have succeeded, after much effort, in targeting LMI households. More than half of the state's LMI households live in single family owner-occupied homes or complexes with 2-4 rental units.[22] These market segments are the hardest to reach in any income group and are even more difficult to serve in the LMI context.

Established in 2012, Solarize Connecticut is one of the Green Bank's programs that has been successfully adapted to the LMI market. Broadly speaking, Solarize CT is a community-based program that lowers the overall costs associated with placing rooftop solar on a home. This program leverages the influence of social networks to encourage the adoption of residential solar.[23] Solarize campaigns put potential customers in contact with pre-approved solar installers, provide those customers with numerous financing plans including $0 down financing options that require no out-of-pocket expenses, and allow solar installation owners to keep both the thirty percent federal tax credit and the state rebate. Furthermore, each campaign includes a tiered financial incentive that encourages community mobilization around solar adoption. This incentive provides tiered group purchasing in a community that reduces solar system acquisition costs as more customers sign up, which encourages customers to spread the word about the rooftop solar and get as many of their neighbors to participate in the Solarize campaign as possible. The price reductions are only available for a limited time, which further incentivizes interested homeowners to go solar during the Solarize campaign.[24]

Solarize campaigns are conducted at the community level (town/city), which limits the impact of the program. However, in LMI communities such as Bridgeport, Enfield, Montville, Torrington, West Haven and Windham, the programs have been almost as successful as those conducted in middle-to-upper income communities. Compared to statewide averages of solar adoption, the Solarize campaigns in distressed communities reached ninety-five percent of the statewide penetrative rate for Solarize campaigns.[25] These campaigns also had penetration rates that were twenty-seven percent and twenty-one percent higher in less than sixty percent area-median-income and sixty to eighty percent area-median-income census tracts, respectively.[26]

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[20] Ibid.
[21] O'Neill, Kerry et. al. Role of a Green Bank - Low Income Solar Development. December 12, 2014. Available at: http://www.ctgreenbank.com/wp-content/uploads/2015/12/CGB-Low-Income-Solar-Strategy-BOD-Memo-v20141212.pdf.
[22] Ibid.
[23] Clean Energy States Alliance. Solarize Connecticut: Program Results and Secrets of Success. March, 28, 2014. http://www.cesa.org/assets/Uploads/Solarize-CT-Webinar-Slides-3.28.14.pdf (See slide 29).
[24] Solarize Connecticut. Home - Solarize Connecticut. Accessed: May 1, 2017. Available at: http://solarizect.com/.
[25] O'Neill, Kerry et. al. Role of a Green Bank - Low Income Solar Development. December 12, 2014. Available at: http://www.ctgreenbank.com/wp-content/uploads/2015/12/CGB-Low-Income-Solar-Strategy-BOD-Memo-v20141212.pdf.
[26] Ibid.

Energize Connecticut, also known as the Residential Solar Investment Program, is another program that the Connecticut Green Bank has utilized to encourage LMI residential solar PV adoption. Launched by the Green Bank's Connecticut Energy Efficiency Fund, Energize Connecticut provides information and financial resources to energy consumers to help them make energy efficiency and clean energy improvements.[27] The program has a number of features for consumers and property owners (both single-family and multi-family) and helps them with the entire process of getting their solar system installed, including (a)locating appropriate solutions for their energy needs depending on their individual situations (renewable energy systems, lighting, heating/cooling, energy efficiency, etc.); (b) locating a qualified contractor for solar PV installations from list of approved contractors; and (c) finding appropriate financing options and lenders depending on their needs.

An important component of the Energize Connecticut program is its incentive program for customers of the utilities Eversource and United Illuminating. Customers who choose to purchase and install a system on their homes are eligible for the Homeowner Performance-Based Incentive. This two-tiered incentive program provides customers with rebates of $0.540 per watt for systems up to 10kW and $0.40 per watt for systems between 10kW-20kW.[28] However, the incentives are based on the homeowners previous twelve months of energy consumption, so a consumer who installs a 5kW system but only used 3kW in the twelve months preceding installation would receive the full $0.540 per watt for three-fifths of the electricity produced by the solar PV system and $0.40 per watt for the remaining two-fifths. Homeowners who choose to lease a solar PV system are eligible for the Performance-Based Incentive, which provides rebates of $0.064 per kilowatt-hour and $0.060 per kilowatt-hour for the first six years' worth of electricity produced by systems up to 10kW and 10-20kW in size, respectively.[29] Overall, Energize Connecticut has been quite successful, meeting the residential solar PV installation target of 30 MW by 2022 in 2014–-eight years ahead of schedule.[30]

Energize Connecticut also manages two other financial programs that are important to the LMI residential solar market including Smart E-Loans. Smart E-loans is a loan program which offers long-term, low interest financing to individuals looking to make energy improvements to their homes, including installing solar PV. Loans are offered at no money down, for terms between 5-12 years with interest rates ranging from 4.49%-6.99%.[31] If customers choose the Solar PV bundle, which involves installing solar PV and making an energy efficiency improvement like

[27] Energize Connecticut. Residential Solar Investment Program. Accessed: May 2, 2017. Available at: https://www.energizect.com/your-home/solutions-list/residential-solar-investment-program
[28] DSIRE. Residential Solar Investment Program. June 28, 2016. Available at: http://programs.dsireusa.org/system/program/detail/5120
[29] ibid.
[30] Clean Energy Finance and Investment Authority. Solar Home Renewable Energy Credits (SHRECs): Growing Connecticut's Solar Market. February 10, 2015. Available at: http://www.governor.ct.gov/malloy/lib/malloy/2015.02.10_shrec.pdf
[31] Energize Connecticut. Smart-E Loans. Accessed: May 3, 2017. Avaialbe at: https://www.energizect.com/your-home/solutions-list/smarte

installing new wall or attic insulation, they can qualify for special loan interest rates of 2.99%.[32] Eligibility for this program is limited to owner-occupied buildings of no more than four units.

The Green Bank has demonstrated that it's Solarize and Energize Campaigns do have a positive impact on residential solar PV adoption. However, it is difficult to fully determine how much of Connecticut's adoption of solar PV generally, or in the LMI context, can be attributed to these programs and no other factors such as historic decrease in the solar PV module costs.

Massachusetts: The California of the Northeast?

Since 2010, residential solar PV installations in Massachusetts have taken off, increasing by nearly 200 MW from 2010 to 2015. A number of policies have likely contributed to this growth, including (1) a Renewable Energy Property Tax Exemption in place since 1975[33]; (2) a Residential Renewable Energy Income Tax Credit in place since 1979[34]; (3) a net metering program in place since 1982 with major amendments in 2008, 2010, 2014 and 2016[35]; (4) Solar Renewable Energy Certificates under Massachusetts' Renewable Portfolio Standard in place since 2010[36]; (5) the Commonwealth Solar Rebate Program in place from 2008 to 2015; and (6) the Mass Solar Loan Program in place since 2015.[37] As of 2015, close to forty-five percent of installed capacity and forty-six percent of installed projects in Massachusetts are located in LMI block groups, seven percent higher than the installed capacity and ten percent higher than the installed number of projects in LMI block groups in California. Two Massachusetts policies in particular have targeted LMI households: (1) the Commonwealth Solar Rebate Program; and (2) the Mass Solar Loan Program.

[32] Energize Connecticut. Smart-E Bundles. Accessed: May 3, 2017. Available at: https://www.energizect.com/your-home/solutions-list/smarte-bundles
[33] DSIRE. Renewable Energy Property Tax Exemption. May 24, 2016. Available at http://programs.dsireusa.org/system/program/detail/146.
[34] DSIRE. Residential Renewable Energy Income Tax Credit. Oct. 25, 2016. Available at http://programs.dsireusa.org/system/program/detail/144.
[35] DSIRE. Net Metering. Sept. 29, 2016. Available at http://programs.dsireusa.org/system/program/detail/281.
[36] DSIRE. Solar Renewable Energy Certificates (SREC-I). Feb. 16, 2015. Available at http://programs.dsireusa.org/system/program/detail/5678; DSIRE. Solar Renewable Energy Certificates (SREC-II). Feb. 16, 2015. Available at http://programs.dsireusa.org/system/program/detail/5679.
[37] DSIRE. Mass Solar Loan Program. May 24, 2016. Available at http://programs.dsireusa.org/system/program/detail/5850.

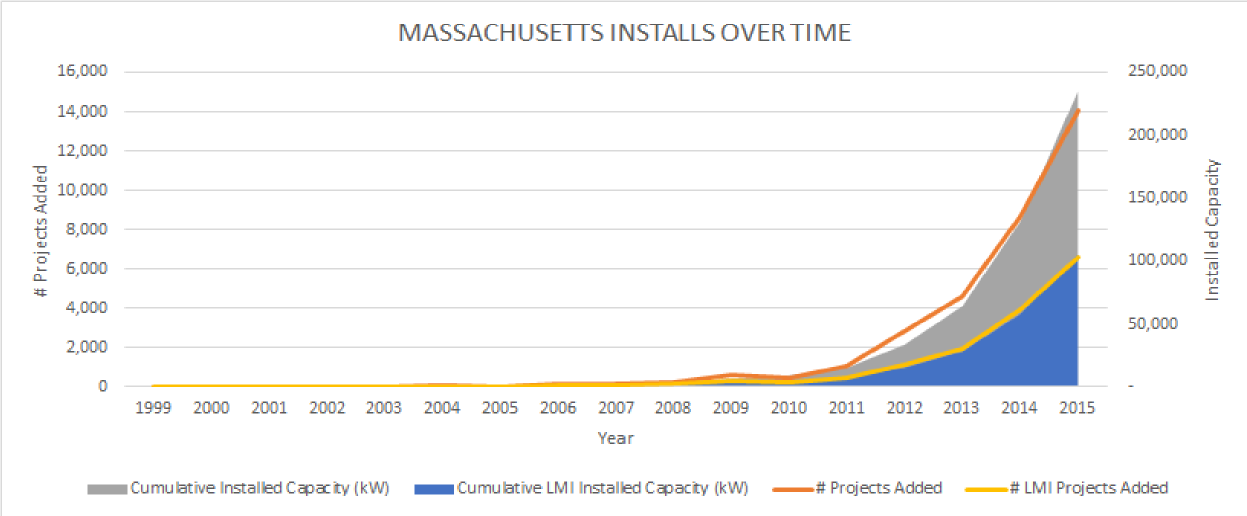

Figure 10. Solar PV Installations in Massachusetts Over Time.

Massachusetts enacted the Commonwealth Solar Rebate Program in 2008 (Commonwealth Solar I), and expanded the program to provide additional incentives for small-scale solar PV systems in 2010 (Commonwealth Solar II). The program, which ran through January 2015, provided a base incentive of $1 per watt up to 5000 watts ($5000) for residential PV systems. An "adder" provided an additional $1 per watt for households who qualified as having either (a) moderate household income (up to 120% of median) or (b) a moderate home value. This adder effectively doubled the rebate for LMI households. In addition, unlike similar programs in other states, residents of Massachusetts who applied for the rebate were also eligible to receive additional funding, including a tax credit worth fifteen percent of the system cost or $1000 through Massachusetts' Residential Renewable Energy Income Tax Credit program and Solar Renewable Energy Credits under Massachusetts' RPS Solar Carve-Out Program. This combination of incentives lowered the cost of solar for both LMI and non-LMI families.

The Commonwealth Solar Rebate Program met with great success. More than 12,500 solar electric systems were installed as part of the Commonwealth Solar II program, resulting in over 80 MW of installed capacity.[38] Comparing these numbers to LBNL's overall solar PV installation data from this time period indicates that close to half of all projects and capacity installed in Massachusetts from 2010-2015 received a rebate. Data from LBNL also indicates that during this same time period from 2010-2015, between 42 to 51 percent of projects in Massachusetts that received rebates each year were located in LMI block groups (see Table 4 below). Overall, LMI rebates accounted for 6.66 percent of total installed system costs compared to a 5.33 percent rebate rate overall. In sum, this data indicates that a large number of projects received substantial sums of money for solar PV installations in Massachusetts from 2010-2015, including many projects located in LMI blocks.

[38] Massachusetts Clean Energy Center. Commonwealth Solar II. 2016. Available at http://www.masscec.com/commonwealth-solar-ii.

	2010	2011	2012	2013	2014	2015
Percentage	51.6%	44.2%	42.4%	43.1%	47.7%	48.2%
Number	223	414	935	1,239	2,064	1,307

Table 4. Percentage and Number of Rebated Projects in Massachusetts Located in LMI Blocks

In 2015, Massachusetts switched from the Commonwealth Solar Rebate Program to the Mass Solar Loan Program. The Mass Solar Loan Program offers fixed, low-interest loans (maximum interest rate of 3.25 percent) to residents purchasing PV systems. Under the Program, low-income households (80 percent of median income) qualify for a thirty percent loan principal buy down and moderate-income households (80-120 percent of median income) qualify for a twenty percent loan principal buy down. Unfortunately, 2016 data is not yet available from LBNL to analyze the impact of this program. Future research is needed to examine the impact of Massachusetts' change from the rebate-style program to the loan-style program on LMI solar adoption.

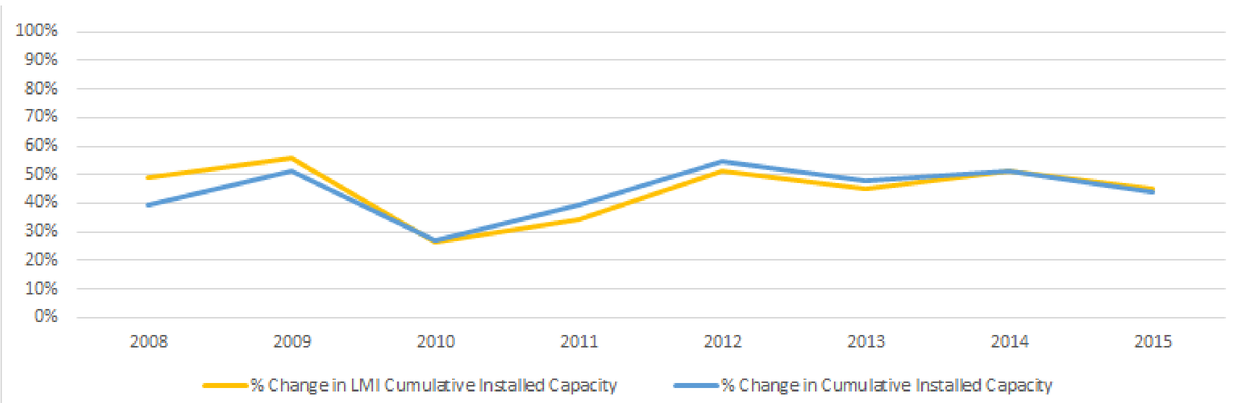

Figure 11. Massachusetts Rate of Change: LMI vs. Total.

Nevada: The Story of Net Metering

Nevada presents an interesting case study for residential solar PV because of the growth the industry has experienced in a relatively limited policy environment. Nevada only has fourteen active state policies that support solar PV development, only one of which directly targets the LMI market.[39] The success of Nevada's residential solar PV market has primarily been attributed to a singular policy: net metering.

Prior to 2016, net metering in Nevada was a keystone policy in the residential solar PV market. Customers were paid the retail price of electricity for the excess electricity they sent back to the

[39] DSIRE. Programs: Nevada. Accessed: May 5, 2017. Available at: http://programs.dsireusa.org/system/program?fromSir=0&state=NV.

grid. Net metering in Nevada was such an attractive incentive for residential solar PV that, between 2014 and 2015, it helped catalyze an increase of more than 400 percent in the number of rooftop solar PV installations in the state.[40] This drastic increase in residential PV installations was present in both LMI and non-LMI markets.

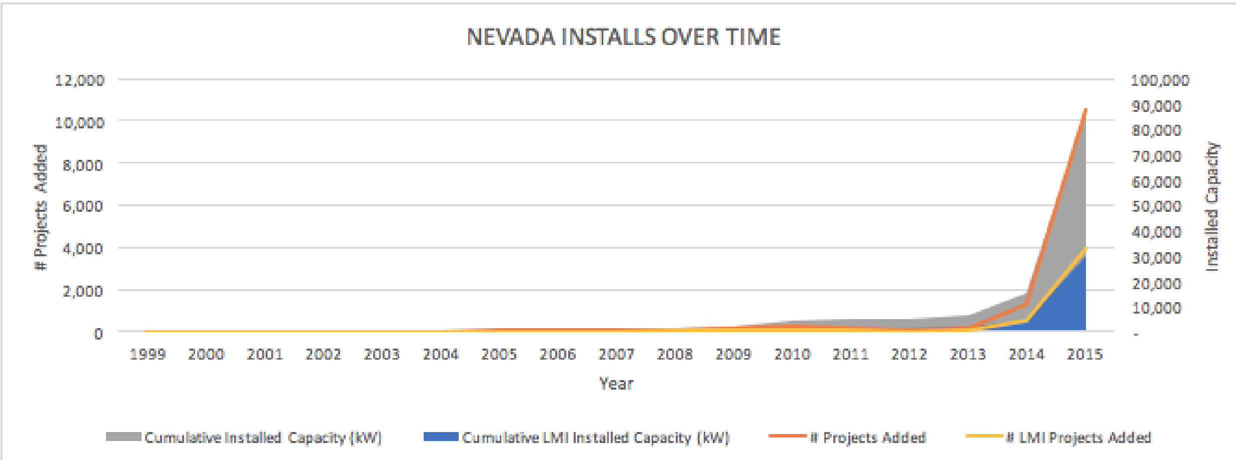

Figure 12. Solar PV Installations in Nevada Over Time.

In December 2015, the Nevada Public Utilities Commission (PUC) weakened Nevada's net metering policy, first by tripling the monthly service fee from about $12 to $38 and then by reducing the value of the electricity sold by rooftop solar homes to the grid from $0.11 per kilowatt-hour to $0.03 per kilowatt-hour.[41]

Considerable pushback from residential solar PV customers and companies led the PUC to revise its stance on net metering and grandfather in to the original net metering rules those who had active or pending applications for rooftop solar PV prior to Dec 31, 2015.[42] However, applications for residential solar PV installations under the new net metering rules have decreased significantly.

The Tracking the Sun dataset that was used for the basis of this project only provides data through the end of 2015. Thus, the impacts of the PUC's net metering decision are not captured in this paper's data or analysis and can only be discussed anecdotally. However, updating the dataset to include installations for 2016 and 2017 would add interesting context to this case study and could demonstrate the importance of policy continuity to the growth of the LMI residential solar PV market.

While net metering is the primary policy driver of residential solar adoption, it should be noted that the insolation rates witnessed in Nevada make the state an inherently attractive place to install solar projects. According to the National Renewable Energy Laboratory (NREL) PVWatts

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[40] PBS NewsHour (Producer). (2016, February 27). Debate over solar rates simmers in the Nevada desert. Available at: https://www.youtube.com/watch?v=awKfRBKzhgA.
[41] Ibid.
[42] Ibid.

calculator[43], 1 kW_{DC} capacity will produce 1,750 kWh per year if placed near Las Vegas, NV. Compare that to New Haven, CT where the same capacity can expect to put out 1,280 kWh per year. In the context of a 5 kW_{DC} system, the household in Nevada would produce 730 kWh per month. According to the EIA, the average household in Nevada consumes just over 900 kWh per month[44], which altogether makes up about 80% of the household's electricity consumption. In Connecticut, a 5 kW_{DC} system would serve about 73% of a household's annual demand.

Currently, NV Energy's RenewableGenerations Rebate Program is the only policy that directly targets the LMI solar PV market. Established in 2003, this policy provides rebates to customers who install solar PV systems to meet their electricity needs. The policy applies to solar installations in all sectors, with an adder for systems installed on low-income residential buildings.[45] The rebate is divided into two classes for system less than or equal to 25kW in capacity and those greater than 25kW up to 500kW. Systems up to 25kW in size receives Expected Performance Based Buydown rebate, which is a one-time payment, determined by the expected production of the solar system.[46] This rebate is currently 0.295 $/watt for low income housing.[47] Systems greater than 25kW receive a quarterly payment based on energy produced by the energy system over its lifetime. The rebate is currently set at 0.0317 $/kWh for low income housing.[48]

New Hampshire: No Grants in the Granite State

New Hampshire is an outlier. It has the greatest penetration (72%) of solar PV of our sample states in low- and moderate-income homes, without any LMI-specific policies.

New Hampshire has several features that make it stand out. First, its median income is $72,000, making it the highest in our sample data set. Second, similar to its neighboring states, New Hampshire has high residential electricity rates at $0.18 per kilowatt-hour, and a net-metering policy.[49] Third, 126 out of 235 counties in New Hampshire have a Renewable Energy Property Tax Exemption and all of the utilities in New Hampshire promote solar PV along with other renewable technologies and energy efficiency.[50]

Lastly, New Hampshire includes a generous Renewable Energy Generation Program. Through this program, residents who install solar PV systems up to 10kW, can receive additional

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[43] NREL PVWatts. Accessed June 28, 2017. Available at: http://pvwatts.nrel.gov/index.php.
[44] US EIA. Residential Electricity Consumption, Price, and Expenditures (2015). Table 5_a. Accessed June 28, 2017. Available at: https://www.eia.gov/tools/faqs/faq.php?id=97&t=3.
[45] http://programs.dsireusa.org/system/program/detail/124
[46] ibid.
[47] ibid.
[48] ibid.
[49] US EIA. Table 5.6.A. Average Price of Electricity to Ultimate Customers by End-Use Sector. Accessed April 30 2017. Available at: https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a.
[50] New Hampshire Office of Energy and Planning. Renewable Energy Incentives. Sanders, B. 2010. PSNH solar proposal sparks objections. New Hampshire Business Review. Available at: http://www.nhbr.com/Archive-2002/PSNH-solar-proposal-sparks-objections/.

incentives of $0.30 per watt or fifty percent of project cost up to $2,500. This program began in 2008, and the spike in installations is apparent (see figure 13 below). The amount of money in the fund, largely provided by utilities' alternative compliance payments was uncertain in 2012, leading to a drop in the number of installations, though it rebounded in 2013 and beyond.[51]However, since the compensation is very high, one hundred percent of all solar projects in New Hampshire, both LMI and non-LMI take advantage of the available rebates.

Looking at the charts below, LMI installs closely follow those of non-LMI installs, and the drop in installations relates to the uncertainties in the continuation of the incentives. Similarly, the change in installations over time are almost exactly the same trend. This finding is a clear example of how providing strong incentives can help stimulate markets and advance policy objectives. The New Hampshire example calls into question the cost-benefits of policy, when strong incentives appear to achieve policy goals as well. However, it remains to be seen if the incentives remain enough for market transformation. The rebates were reduced in 2015 (from $0.75/w or fifty percent of project cost up to $3,750), and Tracking the Sun does not yet have enough data to determine the impact of this reduction on PV adoption.

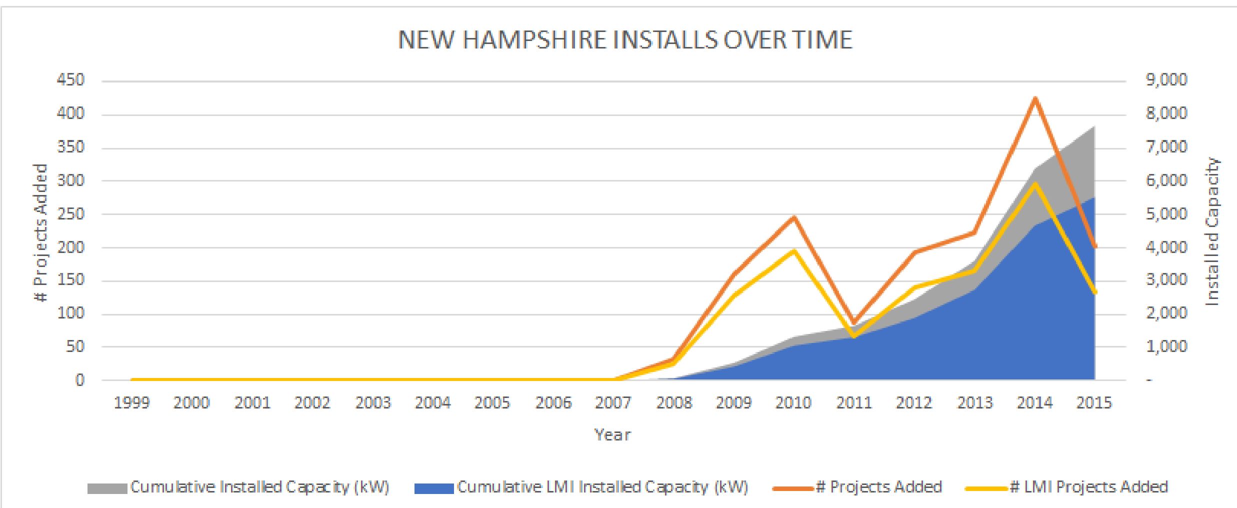

Figure 13. New Hampshire Installs and Capacity over Time

[51] Sanders, B. 2010. PSNH solar proposal sparks objections. New Hampshire Business Review. Available at: http://www.nhbr.com/Archive-2002/PSNH-solar-proposal-sparks-objections/.

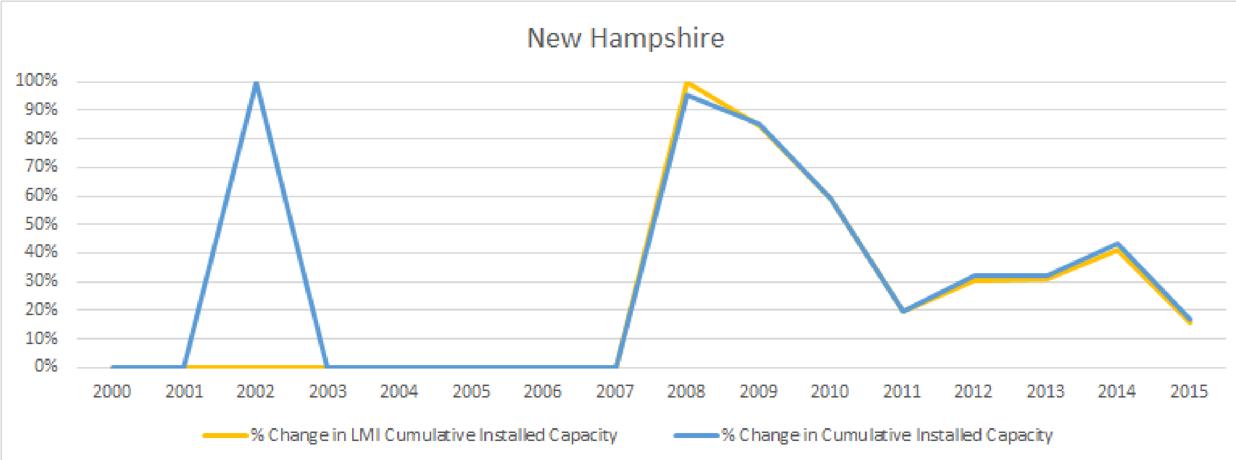

Figure 14. New Hampshire Rate of Change: LMI vs. Total.

IV. Conclusion

Residential solar PV has grown over the past decade with particularly explosive growth in recent years. As highlighted by this report, this growth has not been uniform across all states. While some states such as California and Massachusetts have experienced consistent growth across years, others such as Florida and Pennsylvania experienced spikes in certain years followed by a steady decline in solar PV installations.

Policies—in particular, monetary incentives—matter. States with strong policies, such as many of those in the Northeast, have seen consistent increases in solar PV adoption, while those without strong policies have not. Furthermore, years of policy uncertainty, such as in New Hampshire, lead to dips in solar adoption, further bolstering the case that policies matter.

In addition, these policies seem to matter for LMI adoption rates. We find steady and similar growth for both LMI and non-LMI households across states. Financial incentives such as SASH in California and the Commonwealth Solar Rebate Program in Massachusetts appear to complement the overall trend for LMI homes. The Green Bank in Connecticut has targeted LMI communities with some of its programs, but our data was not able to show a clear connection. New Hampshire meanwhile demonstrate that in certain cases LMI-targeted policies may not be necessary to encourage LMI solar adoption provided statewide financial incentives are strong enough.

However, our findings also indicate that LMI solar adoption still lags between non-LMI adoption in the eleven states examined with a disproportionate number of projects occurring in high-income block groups. Overall, only thirty-seven percent of reported installed capacity and projects belong to households in LMI block groups with a corresponding sixty-three percent of capacity and projects in high-income block groups. However, several states such as

Massachusetts, Connecticut, and New Hampshire include higher percentages of LMI adoption indicating that strong LMI adoption is possible given strong policies and campaigns.

Going forward, further research is needed to examine the impact of various policy changes. For example, Massachusetts recently switched from a rebate to a loan program with LMI targets, which may lead to even greater LMI adoption. In addition, Nevada's recent net metering changes may result in decreased LMI adoption going forward. Both of these states present interesting case studies going forward.

Block group-level data is also needed for more states. States such as Colorado, which include interesting policies and widespread solar adoption, are missing all address data, which makes LMI analysis difficult. Additional block group-level data would increase the robustness of this paper's state-level policy analysis.