INCREASING SOLAR PENETRATION IN UNITED STATES BY REDUCING SOFT COST

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In the past decade, the price of solar panels has experienced a remarkable decline by over 80% and consequently, the solar industry in the United States has been growing more than 40% per year over the last decade.[1] From 2008 to the second quarter of 2016, residential PV electricity system prices fell by over 80 % in most competitive markets, and in an increasing number of markets, the cost of PV-generated electricity is already cheaper than residential electricity retail prices. The top ten states — California, North Carolina, Nevada, Massachusetts, New York, Arizona, Utah, Georgia, Texas and New Jersey — accounted for more than 86% of the US PV market, and California alone had a market share of 45%.[2] There are now more than 1 million operating solar PV installations, representing 27.5 GW_{dc} of operating solar PV capacity in the U.S and 90% of these projects came online during the current decade. In 2015, solar accounted for 64% of all new electric generating capacity installed in the U.S. exceeding natural gas capacity additions for the first time on an annual basis.

The soft costs of solar PV include the necessary aspects of getting a PV system up and running. The most obvious soft costs come from the other necessary hardware, such as rooftop mounting equipment and wiring, and having an electrician install the system. Other soft costs, which are perhaps less obvious, are the costs of permits, inspections, and interconnection with the power grid. While the cost of solar panels has fallen dramatically recently, soft costs have held steady. Thus, soft costs now account for the most of the price of solar power. Moreover, as the United States resolved a recent trade dispute with China, the price of solar panels may increase, which brings increasing importance to reduce solar soft costs. The current price trends for solar panels themselves are already falling, but the remaining costs of bringing solar power onboard are not.

The United States Department of Energy (DOE) has recently launched the SunShot Initiative, which aims to make solar power more economically competitive, in part by substantially reducing soft cost. The Initiative's main goal is to reduce the levelized cost of solar power to $0.06/kWh to make it economically competitive with other forms of energy. To that end, the Initiative aims to reduce solar soft costs. As part of the U.S. DOE's SunShot program, the Lawrence Berkeley National Laboratory (LBNL) reported that nationally, the median installed price for utility-scale PV has steadily fallen by nearly 60 percent since the 2007–2009 period. Until 2012, non-soft costs have been the main driver of reducing solar PV prices; however post-2012, soft cost reduction has been the main driver of reducing solar PV prices.

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[1] Lawton, N. (2014, April). Shrinking Solar Soft Costs: Policy Solutions to Make Solar Power Economically Competitive. Retrieved May 10, 2017, from https://law.lclark.edu/live/files/17499-shrinking-solar-soft-costs

[2] Barbose, G., & Darghouth, N. (2016). Tracking the Sun IX: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States.

The present edition of the Lawrence Berkeley National Laboratory Tracking the Sun report, the ninth in the series, describes installed price trends for projects installed from 1998 through 2015, with preliminary data for the first half of 2016. The report thus provides an overview of both long-term and more-recent trends, highlighting the key drivers for the installed price decline over different time horizons. The trends presented in this report are based primarily on project-level data provided by state agencies, utilities, and other entities that administer PV incentive programs, solar renewable energy credit (SREC) registration systems, or interconnection processes. The underlying dataset used for this year's report consists of more than 820,000 residential and non-residential PV systems representing roughly 85% of all residential and non-residential PV systems installed in the United States through 2015.[3]

The report also extensively characterizes the widespread variability in system pricing, comparing installed prices across states, market segments, installers, and various system and technology characteristics.
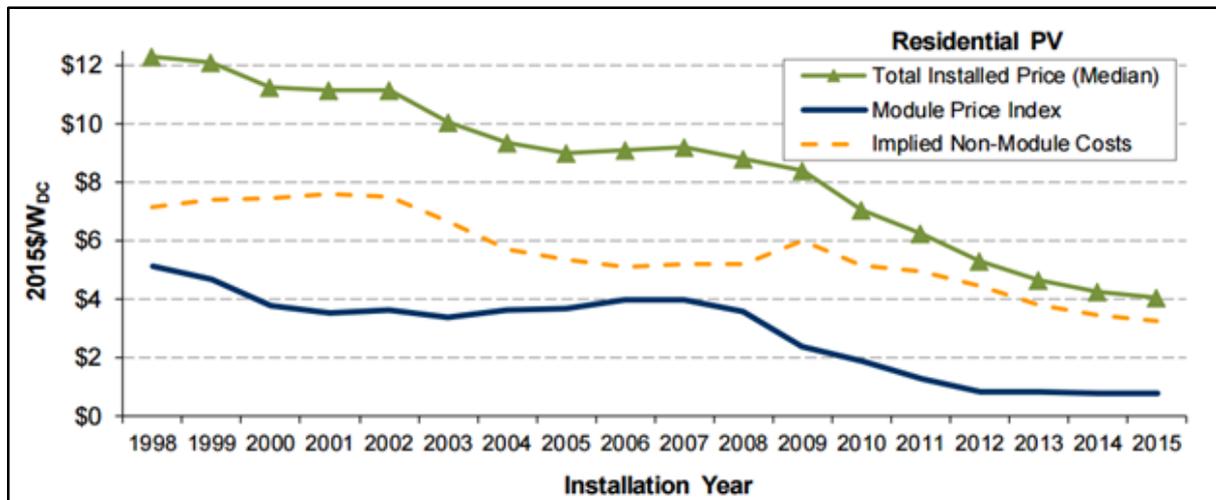

Figure 1. Installed Price, Module Price Index and Implied Non-Module Costs over Time for Residential PV Systems[4]

[3] Barbose, G., & Darghouth, N. (2016). Tracking the Sun IX: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States.

[4] Ibid

For the solar industry to attain competitive prices in the absence of government support, the non-hardware costs, or soft costs, of solar power must decline substantially. Hence our research is aimed at understanding the key drivers for the soft cost reduction of solar PV and the factors that can lead to sustained decline in soft cost for solar PV. We identified 3 main deliverables for our project:

1. Identify what leads to soft cost reduction

2. Determine ways to improve solar penetration to achieve the SunShot target of reducing the installed-system price contribution of total soft costs to approximately $0.65/W for residential systems and $0.44/W for commercial systems by 2020, with total installed system prices of $1.50/W and $1.25/W, respectively

3. Determine other policy (e.g. financial incentives) and industry efforts to further reduce soft costs.

Data Description

Data Source

Data from National Renewable Energy Laboratory (NREL) open data source was used in the analysis. It comprises of about 820,000 systems through 2015 representing 85% of US PV systems cumulatively installed through 2015 and 82% of annual 2015 installations. Derived primarily from state agencies and utilities that administer PV incentive programs, solar renewable energy credit registration systems, or interconnection processes. The installed prices are self-reported by PV installers and host customers, and the prices differ from the underlying cost borne by the developer and installer. The price data are historical, and therefore the price data may not be indicative of prices for systems installed more recently or prices currently being quoted for prospective projects. The data excludes third-party owned (TPO) systems for which reported installed prices represent appraised values, but the data include other TPO systems[5]. In this analysis, a total of 362,824 observations within 23 states were made.

Variables Considered

System size

System sizes of less than 100 kW were selected across the six customer segments: commercial, government, non-profit, non-residential, others, residential and school (-9999 means missing

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[5] Barbose, G., & Darghouth, N. (2016). Tracking the Sun IX: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States.

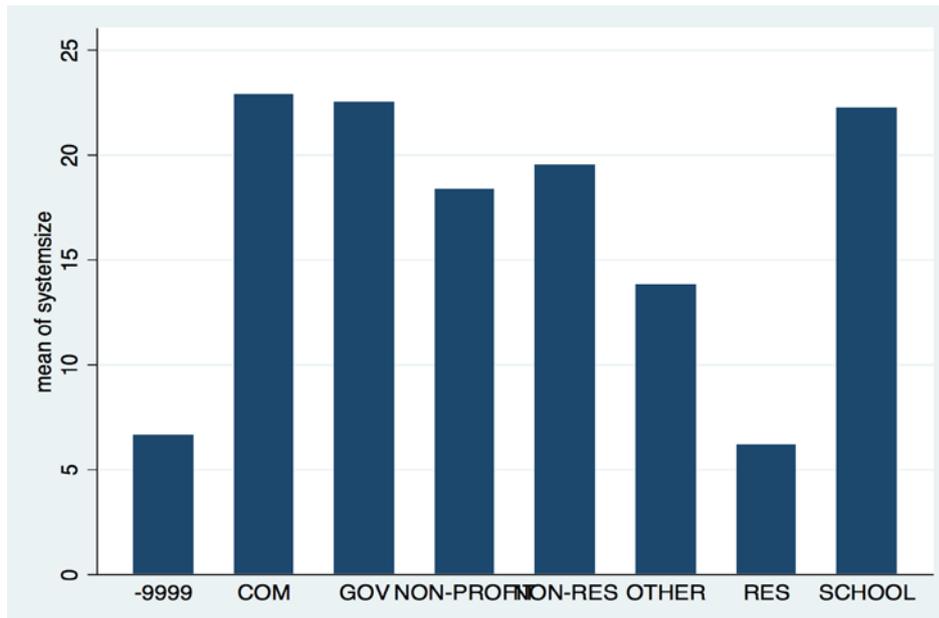data). The commercial sector has the highest mean of installed system size as illustrated by the graph below:

Figure 2 Mean Installed System Size by Customer Segment

Installation Labor Costs

Labor cost varies from state to state and in this data set, not all the states reported the actual labor costs. It is estimated that labor costs add on average $0.59/W-$0.33/W for roofer labor and $0.26/W for electrician labor to the overall cost of a solar PV system, accounting for roughly 15% of the total soft costs for residential solar. For commercial PV systems of 250 kW or smaller, labor costs add on average $0.42/W—$0.32/W for roofer labor and $0.10/W for electrician labor to the total soft costs[6]. Comparatively, labor costs in the United States are ten times higher than similar installation costs in Germany. This could stem from lack of standardization for systems and the rooftops are standardized. Sources of variability include different roof designs, electric systems, utility requirements, and customer preferences.

Permitting Cost

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[6] Ardani, K., Seif, D., Margolis, R., Morris, J., Davidson, C., Truitt, S., & Torbert, R. (2013, August). Non-Hardware ("Soft") Cost-Reduction Roadmap for Residential and Small Commercial Solar Photovoltaics, 2013–2020 - 59155.pdf. Retrieved May 10, 2017, from http://www.nrel.gov/docs/fy13osti/59155.pdf

The permitting cost contributes up to 0.20/W to installation costs and accounts for 2% of soft costs[7]. This value may however vary based on the area of jurisdiction and calculation by different organizations.

Incentives

For residential and non-residential PV, solar incentives have included combination of cash incentives provided through state and/or utility PV programs (rebates and performance-based incentives), the federal investment tax credit (ITC), state ITCs, revenues from the sale of solar renewable energy certificates (SRECs), accelerated depreciation, and retail rate net metering.

Taxes

This variable is estimated based on average sales tax rates for the given state and year, accounting for any sales tax exemptions that may exist for PV systems. Sales taxes, if applicable, are assumed to be levied only on hardware costs, which are calculated from U.S. module and inverter price indices. Sales taxes are considered to contribute about 5% of the total soft cost.

Ground Mounted

This indicates if the system is ground-mounted (which may include pole-mounted systems). PV systems consisting of a combination of rooftop and ground-mounted arrays were considered as ground-mounted. In terms of cost, ground mounted solar is considered to cost more than roof mounted systems, because they require additional materials, time, and labor. This, however, may not be the case where there is a need for retrofitting of the roofs before actual installation.

Building Integrated Photovoltaics (BIPV)

This indicates if the modules are building integrated photovoltaics (BIPV). The BIPV systems can be considered emerging technologies and are gaining much attention in the solar industry. It replaces parts of the conventional building materials and components in the climate envelope of buildings, such as the roofs and facades. It allows for double use by generating electricity while performing the necessary function of climate screening.

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[7] Ibid

Figure 3. BIPV as Roof Tiles[8]

Figure 4. BIPV Solar Cells as Glazing Facades[9]

According to Nano Markets, in New York, the global market for BIPV was expected to grow from $1.8 billion in 2009, to $8.7 billion in 2016. Further, copper indium gallium selenide (CIGS) solar cells was to account for 17% of the BIPV market by volume in 2016 and polysilicon-based BIPV volume to drop from 75% of the market to 33%[10].

BIPV technology is still a growing technology and it remains rather expensive[11]. It is still far from being a mature technology and is bombarded by greater uncertainties in factors such as installation, electrical aspects, safety issues, integration aspects, building physical aspects, protection versus climate exposure, durability, maintenance, architectural aspects among others. These factors may lead to an increase in the cost of these systems.

Year

We created a year dummy variable to identify installation before and after the year of 2011.

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[8] Jelle, B. (2015). Building Integrated Photovoltaics: A Concise Description of the Current State of the Art and Possible Research Pathways. Energies, 9(1), 21. https://doi.org/10.3390/en9010021

[9] Ibid

[10] Ibid

[11] Ibid

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State

We identified twenty-four states for this analysis based on the availability of data for the selected variables. These were Colorado (CO), Illinois (IL), California (CA), Connecticut (CT), DC, Delaware (DE), Florida (FL), Maine (ME), Minnesota (MN), New Hampshire (NH), New Mexico (NM), Nevada (NV), New York (NY), Rhode Island (RI), Texas (TX), Utah (UT), Vermont (VT), Maryland (MD), Ohio (OH), New Jersey (NJ), Pennsylvania (PA), Massachusetts (MA), Wisconsin (WI), and Oregon (OR).

Customer Segment

We considered five customer segments presented in the data from the National Renewable Energy Laboratory. These included: residential, non-residential, non-profit, commercial, school, others, and government.

Type	Name	Detail	Source
Continuous	System Size	Nameplate capacity in Watts	NREL
	Permitting Cost	Permitting Cost in $	NREL
	Installation Labor Cost	Installation Labor Cost in $	NREL
	Incentive	Calculated Total Incentive level includes several different incentives	Calculated
Dummy	Ground Mount	Equals 1 if system is ground mounted and 0 if it's rooftop	NREL
	BIPV	Building Integrated Photovoltaic. Equals 1 if system is BIPV	NREL
	Year	Before or after 2011	Created
Categorical	State	24 states considered CO, IL, CA, CT, DC, DE, FL, ME, MN, NH, NM, NV, NY, RI, TX, UT, VT, MD, OH, NJ, PA, MA and OR	NREL
	Customer Segment	5 Types: residential, non-residential, commercial, school and government	NREL

Table 1:Summary of Selected Variables

We used Multivariate Ordinary Least Squares Method in evaluating the key drivers in soft cost reduction. Soft cost was calculated based on the general formula below:

Soft Cost (pre-incentive) = installed price – partial incentive + tax – module cost – inverter cost

From this formula, we developed the base model for the multivariate linear regression with soft cost or soft cost per watt as the dependent variable and system size, grand mount, BIPV, state, customer segment, incentive, and year as the independent variables as below:

All States:

Pre-incentive cost/ Pre-incentive cost per watt = b0 + b1 System size + b2 Grand mount + b3 BIPV + b4 State + b5 Customer Segment + b6 Incentive/ Partial incentive + b7 Year dummy + e

Connecticut:

Pre-incentive cost/ Pre-incentive cost per watt = b0 + b1 Permitting cost + b2 Labor cost+ b3 System Size + b4 Grand mount + b5 BIPV + b6 Customer Segment + b7 Incentive/ Partial incentive + b8 Year dummy + e

For incentive, we used two approaches to determine the value. In the first case, it was considered as a total value while in the second case it was considered as the percentage of incentive on the soft cost (% soft cost * incentive).

Data Cleaning

We calculated the soft cost using the following formula: **soft cost = total installation cost – module cost – inverter cost.** Among 592,559 observations, 223,712 did not have total installation cost. For observations that have permitting cost, labor cost, and balance of system cost, we counted the sum of those cost as the soft cost. However, we had to drop the rest 10,564 observations that only contain total installation cost.

There were three sources of incentive: performance based incentive (PBI), rebate or grant, and Feed in Tariff (FIT). For performance based incentive, the data contained the amount and also the duration, thus we discounted the amount based on the duration with a discount rate of 6%. Similarly, we calculated the discounted feed in tariff value. Incentive is the sum of rebate or grant, discounted PBI and FIT. We also created a year dummy variable which indicates solar panel installed before and after the year of 2011. We classified missing data as zero in ground mounted and BIPV dummy variables.

The histograms of system size, incentive, and soft cost are extremely skewed. The range of system size is from 0 to 6000 kW, however, 99% of observations had system size below 100 kW. Thus, we exclusively looked at the observations with system size from 0 to 100 kW. Similarly, we cut off observations that have either incentive or soft cost value exceeds the 99% threshold. We narrowed down the data set to 362,824 observations within 23 states.

Regressions

The first two regressions have dependent variable as pre-incentive price and the last two regressions have dependent variable as pre-incentive price per watt. The difference between the first two regressions and the last two regressions is in the independent variable, we used either whole incentive or partial incentive regarding to the percentage of soft cost out of total installed price. If we look at the overall F statistic and all four models have a p-value of 0.000. The four regressions have R-squared value 70.1%, 69.9%, 3.7%, and 3.7% respectively. R-squared means how much percentage of the variability of the dependent variable is accounted for by the model. We observed more noise when we transformed the model to price/w, but these two models still presented us some valuable results.

In our models, we used three types of variables: continuous variables, categorical variables and dummy variables. Continuous variable such as system size and incentive. Their coefficients mean one unit change in the value of that variable, given that all other variables in the model are held constant. We observed from the Regression Table 1 from Appendix, one unit change in system size increases the pre-incentive cost, because pre-incentive cost is positively proportional to the system size. However, one unit change in system size decreases pre-incentive cost per watt, which implies that the larger scale of solar panel could bring down the soft cost per watt. Both incentive and partial incentive are negatively correlated with pre-

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incentive cost, which implies that higher incentive could bring down the soft cost. On the contrary, we observed a positive correlation between incentive and pre-inventive cost per watt. From Figure 4 System size vs. Incentive, we discovered that there are couple observations that did not receive any incentive even given their large system sizes and high incentives were given to difference system sizes due to different states' policies. The main trend still presents a positive relationship between system size and incentive.
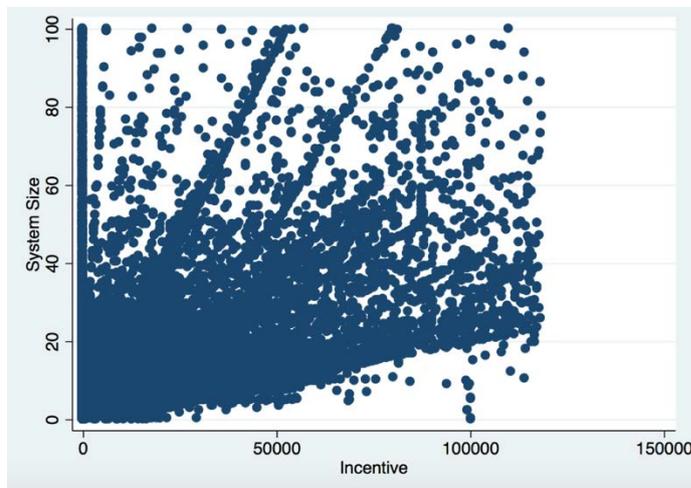

Figure 4 System Size vs. Incentive

We used categorical variables such as states and customer segments. We chose one category as the omitted category and we compared other categories with the one we chose. In our case, we set the most frequent category as the omitted category. The omitted state is CA and the omitted customer segment is residential. We were not surprised to observe that many states are dramatically different from CA. Given all the other conditions are the same, CO, IL, MD have higher pre-incentive price and pre-incentive price per watt. However, CT, DC, DE, FL, ME, MN, NH, NM, NV, NY, RI, TX, UT, VT present lower pre-incentive price and pre-incentive price per watt. The state of OR shows inconsistent result. Most states have lower pre-incentive price and pre-incentive price per watt, since labor cost is one important component of soft cost and CA is one of the states that have the highest labor cost. CO, IL, MD have higher soft cost given relatively cheaper labor cost [12] (Figure 5 2017 Minimum Wage by State). This observation suggests that policy incentive to bring down soft cost in those regions are very

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[12] Lerner, M. (2017, January 3). Find the Minimum Wage In Your State | Bankrate.com. Retrieved May 10, 2017, from http://www.bankrate.com/finance/jobs-careers/state-minimum-wage.aspx

much needed. For customer segment variable, comparing with residential customers, commercial and government have higher pre-incentive price and pre-incentive price per watt, given all the other conditions are the same. Despite the inconsistent correlations between system size and incentive or incentive per watt, in most cases, larger system size gives higher incentive. Most commercial and governmental buildings have larger system size and those projects could have more advantage on receiving funding. Other than this, we interpret the result as either commercial and government are granted higher incentive to convert or they are more aware of the available source to reduce their cost of installation.

Lastly, we included dummy variables such as ground mounted, BIPV, and year in our regressions. Those variables only have two outcomes: 1 or 0. The coefficient means the difference between the variable outcome. Both ground mounted and BIPV are significant in all four regressions, and they have positive coefficients as well. This indicates that if the solar panel were installed as ground mounted or applied BIPV technology, the soft cost would increase. This is consistent with our assumption, since ground mounted and BIPV methods need not only more hardware, but also more labor work. The year dummy is only significant for the first two regressions and negatively correlated with pre-incentive price. This indicates that solar panel installed after 2011 would have cheaper total soft cost. The significance disappeared as we changed the unit to dollar per watt, and this could result from the chaos created by changing units.

Figure 5 2017 Minimum Wage by State

We ran a group of separate regressions on the state of Connecticut, because permitting cost and installation labor cost data are available (see Regression table 2 in Appendix). The data set contains 13,273 observations. The four regressions have R-squared value 59.8%, 57.3%, 41.6%, and 34.1% respectively. Permitting cost and installation labor cost are both significant in all four models. Permitting cost is negatively correlated with dependent variables. Permitting cost is described as the cost of building and electrical permit fees. The result is the opposite of our assumption. Reasonable explanations could be that counties with additional permitting costs have more mature solar markets where costs are lower. Installation labor cost is positively

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correlated with dependent variables. The rest variables are very much consistent with the regressions on all states. System size is positively correlated with pre-incentive price but negatively correlated with pre-incentive price per watt. Incentive or partial incentive are negatively correlated with pre-incentive cost and pre-incentive cost per watt, which implies that higher incentive could bring down the soft cost. Commercial, non-profit, non-residential, and school are all positively significantly different from residential buildings. Customers used ground mounted installation spent more on soft cost. BIPV is not significant, since in our data set, there were only 15 observations with BIPV in the state of Connecticut. One interesting observation is that the year dummy is negatively significant, which implies that in CT, customers spent less money on soft cost after the year of 2011.

Several policy suggestions are provided here based on our regression results. These policies are put into two categories: demand-pull and technology-push. Demand-pull policies increased solar penetration by reducing the barriers consumers are facing and thus pulling up demand for solar, while technology-push policies push up supply by internalizing positive externalities of R&D which provides incentive for innovation.

Demand-pull Policies

Barriers solar consumers are facing include capital constraints, high soft cost and lack of information. These are all market failures which can be partially avoided by demand-pull type of policies.

Community-shared solar is a natural way to relieve capital constraints. Individual households are usually not able to afford the high initial cost of owning a solar system. However, community group purchasing can lower the average cost for each of the group members due to economy of scale, even if the total installed size is larger. This is consistent with our result that larger system size significantly lower the soft cost per watt. In addition, it is also suggested that onsite roof-top solar on multi-unit buildings should be utilized more, since roof-top solar is cheaper than ground-mounted according to our research. There are already several successful stories of community solar within the past decade, including Solarize Portland Project and Arizona Public Service Community Solar Project.

Figure 6 Different Types of Community-Shared Solar

Complementary policies should also be introduced to encourage more community-shared solar. Firstly, to further reduce capital constraints, extra funding which target specifically at community solar are needed. Those funding can take forms of direct funding or challenge and prize competitions. Prizing has an extra advantage than funding in the sense that it addresses

market failure from information asymmetry or learning-by-using by getting people informed and experienced. One example of extra funding is the national SunShot Prize (Solar in Your Community Challenge), which provides $5 million in cash prizes and technical assistance for teams to develop programs that expand solar access to underserved groups[13]. A second option is to introduce net metering (NM), especially virtual net metering (VNM) which allows individual households to receive bill credits from offsite community solar. This method lowers the everyday energy cost of consumers as well as providing a solution to the intermittency problem of having renewables on the grid. The third option is to keep current Investment Tax Credit (ITC) accessible to solar. Subsidy in other types, such as rebates and reducing permitting cost, should also be incorporated. Moreover, to avoid excessive administration cost, permitting process should be kept simplified. All these policies lower the cost for solar consumers and thus internalize the negative environmental externalities from fossil fuel combustion, such as greenhouse gas emission and air pollution.

Our results also show that there may be "rebound effect" here. We are not talking about the typical rebound effects in energy efficiency improvement, but the lay back of solar owner to purchase solar systems with the lowest hardware cost in reaction to cost-reducing incentive. More systematic research is needed to quantify this effect and figure out the effective way of modifying policies. However, using consumer behavior actions, such as consumption information and standardization, may be helpful by shifting consumption patterns[14].

All the complementary policies mentioned above should also be applied more general other than just on community solar. While doing so, policymakers should also take into consideration regional heterogeneity. Differences in energy resource, energy consumption structure, electricity price and renewable market structure all have influence on policy decision. Looking beyond solar penetration, the key reasons solar is preferred is that this energy source is both clean and renewable. Thus, in order to be sustainable, we want solar to substitute fossil fuels. Thinking at federal level, it is more reasonable to implement preferential policy for solar in states where energy portfolio is relatively dirty. Otherwise, those preferential policies may only lead to substitution of other more expensive renewables. Given the additional expense required in building up infrastructure such as High Voltage DC lines to carry electricity from regions of low demand to regions of high demand, we may also want to encourage solar adoption in states with sufficient sunshine to avoid the transmission costs. One more thing to consider is that different type of policies should be adopted between states with mature solar

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[13] SunShot Prize: Solar in Your Community Challenge | Department of Energy. (2016, December). Retrieved May 10, 2017, from https://energy.gov/eere/sunshot/sunshot-prize-solar-your-community-challenge

[14] Vivianco, D., Kemp, R., & Voet, E. (2016, July). How to deal with the rebound effect? A policy-oriented approach. Retrieved May 10, 2017, from http://www.sciencedirect.com/science/article/pii/S0301421516301586

market and states at earlier stages. Deeper study of heterogeneity among states is not within the scope of our research, but will be talked briefly in the future study part.

Technology-push Policies

One promising solar technology today is the BIPV. BIPV can be used on many parts of a building, and thus it extends the total capacity we can install on our limited roof and land. Our results suggest that BIPV is still expensive comparing to traditional solar panels. The share of BIPV in our dataset, and possibly in the whole US solar market is still small. For this kind of new technology, policies should be implemented to provide incentive for R&D and therefore alleviate the markets failures. Funding, subsidies and tax credits address the problem of positive externalities from the new technology. Additionally, gradually decreasing incentives also avoid learning-by-doing spillover by encouraging early adoption.[15]

Conclusion

As reduction of hardware cost of solar has leveled off in the past few years, soft cost becomes the key point for continued cost decrease in US. Soft cost includes several factors, such as permitting and interconnection fees, sales tax, labor costs, customer acquisition and finance. To test which factors contributed to the reduction, we did a regression using panel data from National Renewable Energy Laboratory. Results show that roof-top solar systems are significantly cheaper than ground-mounted ones. Correlation between incentive and cost is inconsistent among different models, which may due to lay back of solar owners to purchase

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[15] Gillingham, K., Newell, R., & Palmer, K. (2009, June 26). Energy Efficiency Economics and Policy - GillinghamNewellPalmerARRE Energy Effici.pdf. Retrieved May 10, 2017, from
https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/6993/GillinghamNewellPalmerARRE%20Energy%20Effici.pdf?sequence=1

solar systems with the lowest hardware cost in reaction to cost-reducing incentive. Based on the results, we provided several policy suggestions including both demand-pull and technology-push policies. Certain demand-pull policies, such as extra funding, VNM, ITC, rebates and simplifying permitting process, should be introduced to encourage more community-shared roof-top solar systems. Consumer behavior actions is also helpful to address to problem of owner's lay back. Technology-push policies, such as funding, subsidies and tax credits should be implemented to promote adoption of BIPV. To encourage early adoption, incentive should be gradually decreasing over the years. Beyond our research, we also recommend that policy maker seek deeper study into heterogeneity among states before making decision.

Further Study

Model Modification

There are several ways of improving the model used in this research. Firstly, real cost data should be collected instead of using installed price as estimation of installed cost. Price does not always equal to cost; the difference is largely dependent on market structure. Metrics to better approximate cost is needed to further improve credibility of future research using the same dataset. Second, inconsistent reporting practices should be eliminated. This problem exists in the dataset of this research since data are self-reported by competing PV installers. Third, it will be interesting to segregate the incentive variable into several different variables. Right now we only include one incentive variable calculated by adding up different types. While different types, such as ITC and rebates, may have different effect on soft cost, future studies may want to include this more detailed research. Moreover, more variables could be studied besides the ones we chose. Variables like permitting cost and labor cost are only included in regression of a few states due to limit of data. Finally, it is also important to avoid selection bias. There are mainly two selection bias in this model, including states dropped and third-party owned (TPO) type of solar systems excluded due to lack of data.

State-level Policy Analysis

Beyond this model, deeper research into differences between states is suggested to perform better policy analysis. Main differences affecting policymaking are listed and analyzed below.

Growth potential for solar exists, especially in the states with less solar incentives. At current, the top ten most successful states deploying solar power are CA, NC, NV, MA, AZ, NJ, NY, TX, HA, and NM[16]. For a more direct visual representation of the solar penetration, we introduced Figure 7 US Solar Installation Map[17]. A research done by NREL analyzed the technical potential of PV systems deployed on rooftops.

[16] Perea, A. (2017, March 9). U.S. Solar Market Insight 2016 Year in Review. Retrieved May 10, 2017, from http://www.seia.org/research-resources/us-solar-market-insight

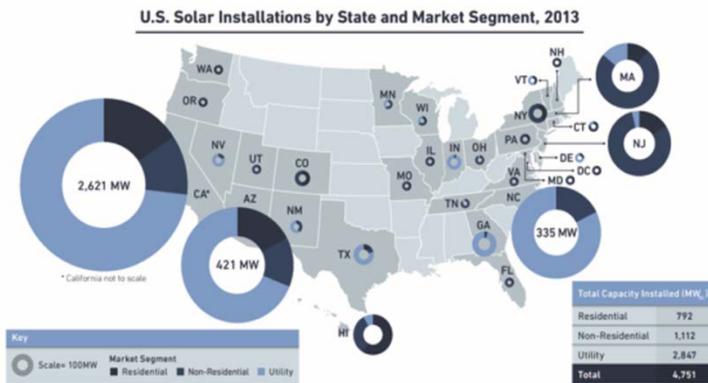[17] Ibid

FIGURE: US SOLAR INSTALLATION MAP

Figure 7 US Solar Installation Map

Figure 8 Small Building Suitability by Zip Code shows the percentage of small buildings suitable for PV in each ZIP code[18]. States such as CA, TX, MN, IA, SD, NE, KS, MO, LA have a large number of small buildings suitable for deploying rooftop PV systems. However, only CA and TX are currently in the top ten states of solar deployment. The rest states have a huge growth potential.
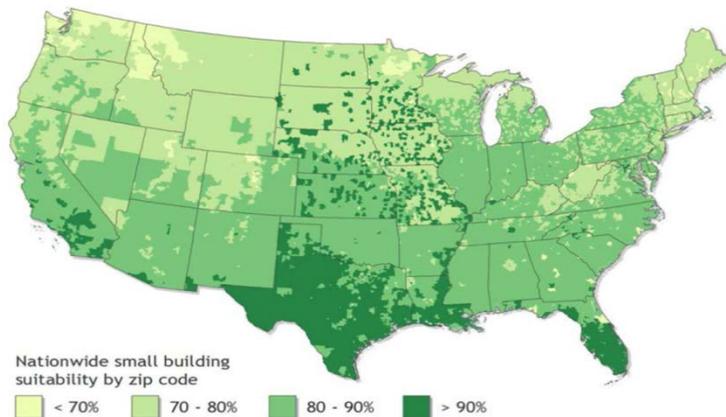

Figure 8 Small Building Suitability by Zip Code

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[18] Ardani, K., Seif, D., Margolis, R., Morris, J., Davidson, C., Truitt, S., & Torbert, R. (2013, August). Non-Hardware ("Soft") Cost-Reduction Roadmap for Residential and Small Commercial Solar Photovoltaics, 2013–2020 - 59155.pdf. Retrieved May 10, 2017, from http://www.nrel.gov/docs/fy13osti/59155.pdf

Even though solar hardware becomes cheaper, there is still need to bring down the soft cost and implement wise policies to minimize market failure, especially in the states with higher solar cost. Figure 9 U.S. Solar Energy Market and Policies shows the current solar policy by state. Only very few states have no statewide distributed generation compensation rules at all or have compensation rules other than net metering. However, the level of implementing net metering rules varies and many of the states are in the process of making changes to the current rules. The main opponent of giving solar generous incentives is that the industry no longer needs support given the largely reduced panel prices. However, this is not true. In Figure 10 Solar Cost by States, we can see that the price gaps among states are still big[19], and it is not a coincident that states without properly enforced compensation rules have higher solar costs. Lastly, grid parity will become true in more states in the coming future. Deutsche Bank produced a report predicting that solar electricity will become more and more competitive, despite the drop in oil price[20]. A main market failure for solar is that costumers are unaware of their potential savings in the future by implementing solar.
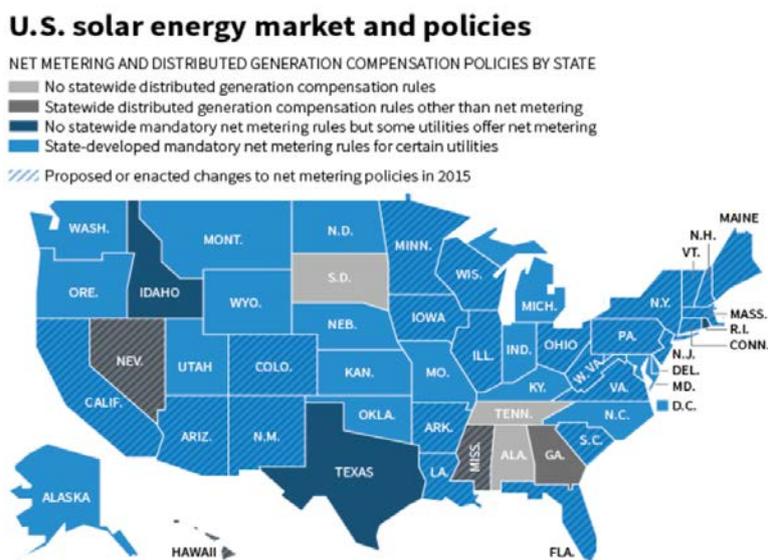

Figure 9 U.S. Solar Energy Market and Policies

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[19] Shahan, Z. (2014, February 1). Price Of Solar Much Lower Than Solar Savings [CleanTechnica]. Retrieved May 10, 2017, from https://cleantechnica.com/2014/02/01/real-cost-solar/

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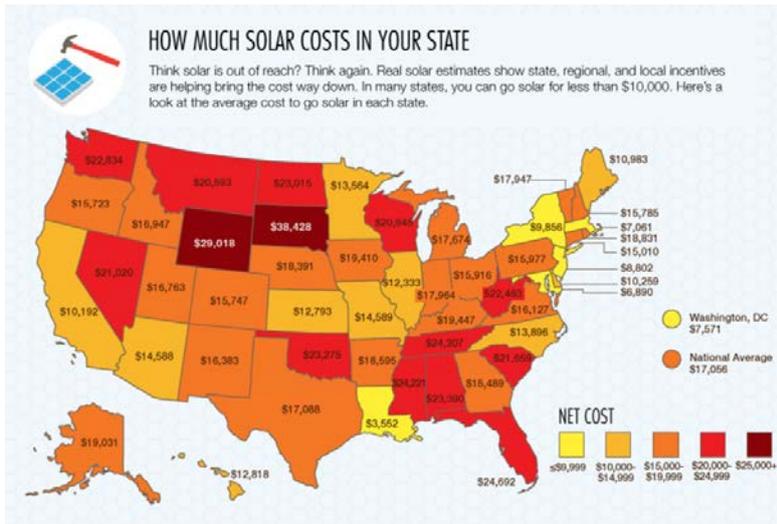
Figure 10 Solar Cost by States

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Appendix

VARIABLES	preincentive	preincentive	preincentivew	preincentivew
systemsize	3.68393**	3.62620**	-0.00010**	-0.00010**
	-0.02546	-0.02573	-0.00003	-0.00003
1.groundmounted	1,260.11444**	1,455.24067**	0.72679**	0.72850**
	-320.72778	-320.55068	-0.07781	-0.07784
1.bipvmodule1	7,758.12138**	7,792.36421**	0.66977**	0.68031**
	-998.77985	-979.38142	-0.18955	-0.18847
CO	1,037.42322*	1,753.65725**	0.94168**	1.03317**
	-417.03623	-409.18225	-0.28341	-0.29124
CT	-10909.62492**	-11342.38755**	-2.14257**	-1.98770**
	-112.62635	-111.49043	-0.09716	-0.07899
DC	-4,602.33235**	-4,888.74104**	-1.48961**	-1.52954**
	-600.35615	-600.75505	-0.29177	-0.29552
DE	-2,799.11047**	-3,163.16050**	-1.48357**	-1.51499**
	-302.28905	-302.41534	-0.16087	-0.16514
FL	-8,783.42980**	-10156.72194**	-6.44441**	-6.49189**
	-662.21923	-665.04711	-1.12698	-1.13153
IL	6,642.23852**	7,464.98340**	2.57583**	2.66732**
	-1,074.87	-1,079.86	-0.31829	-0.32645
MA	2,953.93912**	3,117.54823**	2.18029	2.14226
	-76.64695	-77.39323	-1.21804	-1.21804
MD	609.82360**	921.62918**	0.91839**	0.88070**
	-153.57561	-153.21731	-0.11049	-0.10747
ME	-6,310.08268**	-6,108.92487**	-1.77628**	-1.68475**
	-619.56435	-611.12358	-0.28228	-0.28053
MN	-14903.39283**	-15688.58721**	-4.03659**	-3.52398**
	-697.17697	-700.26306	-0.29097	-0.23435
NH	-14325.61940**	-14220.65886**	-1.36670**	-1.35958**
	-555.98879	-551.43079	-0.09653	-0.09685
NJ	1,241.89254**	58.04655	-2.28378**	-2.32688**
	-297.5609	-297.90648	-0.30186	-0.30748
NM	-15213.32339**	-15001.18894**	-1.70300**	-1.58138**
	-234.13485	-232.72726	-0.13782	-0.15335
NV	-9,453.23581**	-9,565.14215**	-1.49492**	-1.44321**
	-116.42601	-118.3438	-0.03866	-0.03689
NY	-1,878.11215**	-2,443.15705**	-0.69380**	-0.73370**
	-102.39211	-99.20813	-0.24429	-0.24676
OH	2,896.52	1,635.46	-1.65589**	-1.71482**
	-2,158.25	-2,120.78	-0.59349	-0.60103
OR	-4,467.80278**	-3,915.56580**	1.83942**	1.81873**
	-427.28925	-425.09231	-0.19628	-0.19334
PA	349.47731	319.85993	-0.15832	-0.19882
	-209.74616	-208.45253	-0.18794	-0.18772
RI	-7,850.31884**	-8,486.75708**	-2.15529**	-2.19530**
	-841.85145	-862.92856	-0.19812	-0.20385
TX	-11414.59746**	-12185.12193**	-3.45594**	-3.49780**
	-193.24844	-193.30337	-0.24268	-0.2493
UT	-5,722.51835**	-5,787.19022**	-1.46879**	-1.48983**
	-972.8393	-970.65291	-0.14151	-0.1434
VT	-1,992.38533**	-1,968.67224**	-0.21496**	-0.24761**
	-204.60066	-204.14478	-0.04417	-0.04538
WI	1,670.23090**	1,709.73739**	-0.04965	-0.09625
	-453.2524	-447.90839	-0.06302	-0.06652
MISSING	1,321.53740**	1,068.76796**	0.55743*	0.42878
	-402.83554	-394.33726	-0.27199	-0.27285
COM	3,662.85822**	2,812.81567**	1.32290**	1.36479**
	-470.82305	-470.66006	-0.4597	-0.45945
GOV	14,530.60159**	13,209.09334**	1.19472**	1.22554**
	-1,740.25	-1,754.24	-0.4449	-0.44394
NON-PROFIT	1,583.43	-73.38681	-0.64119	-0.59136
	-1,331.00	-1,345.22	-0.39865	-0.39499
NON-RES	-860.54132	-1,813.65965*	-0.22036	-0.20446
	-896.0621	-890.94688	-0.25669	-0.25601
OTHER	-19260.31564	-19835.46666	-0.7891	-0.78514
	-11,482.22	-11,525.32	-0.76341	-0.76343
SCHOOL	2,120.81	1,260.93	0.82000*	0.87146*
	-2,781.82	-2,820.77	-0.36269	-0.35686
incentive2	-0.26506**			
	-0.01358			
incentiveperc		-0.16336**		
		-0.01359		
incentivew			1.13220**	
			-0.1889	
incentivepercw				1.13254**
				-0.189
1.yeardum	-10101.69009**	-9,259.13570**	0.59884	0.59796
	-142.33799	-144.03894	-0.31729	-0.3172
Constant	14,089.34341**	13,436.26524**	4.22370**	4.26273**
	-135.93137	-132.01199	-0.34392	-0.3378
Observations	362,824	362,760	362,824	362,760
R-squared	0.701	0.699	0.037	0.037

Figure 1 Regressions on All States

VARIABLES	preincentive	preincentive	preincentivew	preincentivew
systemsize	2.94448**	2.78606**	-0.00008**	-0.00007**
	-0.08319	-0.08659	-0.00001	-0.00001
permittingcost	-9.96950**	-11.32520**	-0.00084**	-0.00109**
	-0.55912	-0.58008	-0.00006	-0.00007
installationlaborcost	0.25664**	0.28331**	0.00007**	0.00007**
	-0.06919	-0.0692	0	0
1.groundmounted	2,697.04475**	1,430.06	0.50170**	0.32264**
	-789.96544	-796.11151	-0.09071	-0.09483
1.bipvmodule1	4,260.85	5,324.65903*	1.22677	1.25906
	-2,685.12	-2,562.40	-0.69499	-0.70996
COM	27,407.54618**	20,482.95362**	1.14491**	1.00412**
	-3,538.46	-2,910.94	-0.16759	-0.15678
NON-PROFIT	17,819.25675**	11,631.48376*	0.87690**	0.70005*
	-6,065.89	-5,352.01	-0.29535	-0.30635
NON-RES	26,674.38	35,993.07024*	5.19057**	4.68831**
	-16,557.89	-16,493.13	-0.64393	-0.57889
SCHOOL	10,835.91146**	15,380.20214**	3.08671**	3.54421**
	-2,147.68	-2,279.02	-0.60323	-0.61767
1.yeardum	-17566.87852**	-12096.27646**	-4.19485**	-3.75131**
	-779.89822	-834.28352	-0.0987	-0.14801
incentive2	-0.47911**			
	-0.02854			
incentiveperc		-0.22237**		
		-0.03281		
incentivew			-0.83555**	
			-0.02169	
incentivepercw				-0.68861**
				-0.03608
Constant	18,363.37833**	13,478.16433**	7.68182**	7.06502**
	-751.64211	-759.13964	-0.10608	-0.15379
Observations	13,273	13,273	13,273	13,273
R-squared	0.598	0.573	0.416	0.341

Figure 2 Regressions on CT