THE EFFECT OF AUSTIN ENERGY'S VALUE-OF-SOLAR TARIFF ON SOLAR INSTALLATION RATES

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EXECUTIVE SUMMARY

Austin Energy, the municipal utility in Austin, Texas, introduced the first Value-of-Solar tariff (VOST) in the United States for its residential customers in 2012. The VOST replaced Austin Energy's net metering policy, which had allowed for solar customers to sell electricity generated in excess of their consumption back to the utility at the electric retail rate. Under the VOST, customers are charged for their electricity usage and receive a separate credit on each kilowatt-hour (kWh) their solar panels deliver to the grid. The VOST aimed to cover the infrastructure costs associated with distributed generation, while fairly compensating customers for the electricity they produced.

Using the difference-in-differences technique to assess the impact of the VOST on residential solar adoption rates, we analyzed solar installation rates before and after the tariff was implemented. The analysis controls for other variables to account for aggregate time trends, seasonality, population, average household income, political affiliation, solar rebates, installation cost, and retail electricity rate. We use two control groups to compare with Austin's solar installation data: 1) the rest of the state of Texas and 2) the cities of San Antonio and Dallas.

Our analysis suggests that the VOST increased solar installations rates in Austin when compared to the rest of Texas. However, this positive result was not statistically significant when compared to San Antonio and Dallas. This lack of significance may be due to the smaller sample size when using San Antonio and Dallas as a control group. However, it may suggest that there are unobserved factors or trends not relating to VOST that occurred in the more progressive cities and caused the increase in solar installations rates in Austin compared to the rest of Texas. While we cannot make any conclusive statements about the impact of the VOST on solar installations in Austin, we discuss lessons learned from the implementation of this new rate structure in Austin and how replicable they are to other locations in the United States.

INTRODUCTION

In October 2012, Austin Energy, the municipal electric utility in the city of Austin, Texas, became the first utility in the United States to implement a Value-of-Solar tariff (VOST) for residential electricity customers with solar photovoltaic (PV) systems on their homes. The tariff was implemented to supersede Austin's net metering policy, which had allowed for PV customers to effectively sell electricity generated in excess of their demand back to the utility at the electric retail rate.

Austin Energy officials determined that it was necessary to replace net metering with a tariff structure that imposed some grid costs on PV customers while also recognizing the value their PV systems provided to the grid.[1] In addition, the utility sought a structure that would enable them to properly charge PV customers for consumption with more dynamic rate structures, rather than crediting customers with a simple lump sum based on their excess production. The result was the development of the VOST, designed to fairly price electricity for residential PV customers without unduly burdening them or giving them a free pass to utilize the electric system without appropriately paying their fair share of costs.

As debate intensifies across the United States as to whether, when, and how net metering policies should be phased out and with what policies they should be replaced, Austin Energy's development of and experience with the VOST could help guide other utilities and regulatory commissions. However, while the concept of a VOST may be acceptable to utilities and solar advocates alike, the devil is in the details. A Value-of-Solar calculation that is favored by a utility may discourage solar adoption in practice, and a tariff structure that incentivizes adoption at a rate in line with a retail net metering program may place undue cost burdens on customers without PV and on utilities.

Because the VOST program was implemented by Austin Energy in part to ensure that solar customers would pay what the utility deemed to be an equitable proportion of fixed infrastructure costs, we expected that the new tariff structure would be less attractive to prospective solar customers, and would result in a decrease in solar installation rates in Austin. In the sections below, we first discuss the background of the net metering debate, Austin Energy's decision to adopt a VOST, and the structure of the new tariff. We then describe how we tested our hypothesis by analyzing solar installation rates in Austin before and after the tariff, controlling for other variables, in order to assess what kind of effect, if

[1] Harvey, Tim. Environmental Program Coordinator at Austin Energy. Telephone interview conducted by authors. April 11, 2017.

any, the VOST had on residential solar adoption. Finally, we discuss additional factors that may have influenced the solar installation rate in Austin, as well as the potential replicability of similar VOST programs at other utilities.

BACKGROUND

AUSTIN ENERGY

Austin Energy is the publicly owned electricity provider in Austin, Texas and surrounding areas. It is the eighth largest public utility in the United States, with more than 440,000 customers and a generation capacity of more than 3,400 megawatts (MW).[2] About 86% of its customers are located within Austin city limits.

Of the 12,574 gigawatt-hours (GWh) of electricity consumed by Austin Energy in 2015, coal generation accounted for 27%, natural gas and oil for 18%, nuclear for 29%, and renewables for 26% of total consumption. Austin Energy's 1.5 gigawatts (GW) of renewable capacity in 2015 was composed of 88% wind and less than 2% (or 27.5 MW) rooftop solar. As of October 2016, Austin Energy supported more than 5,600 residential solar PV systems.[3]

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[2] Austin Energy. *Company Profile*. http://austinenergy.com/wps/portal/ae/about/company-profile.
[3] Austin Energy. *Solar Solutions.* https://austinenergy.com/wps/portal/ae/green-power/solar-solutions/solar-solutions

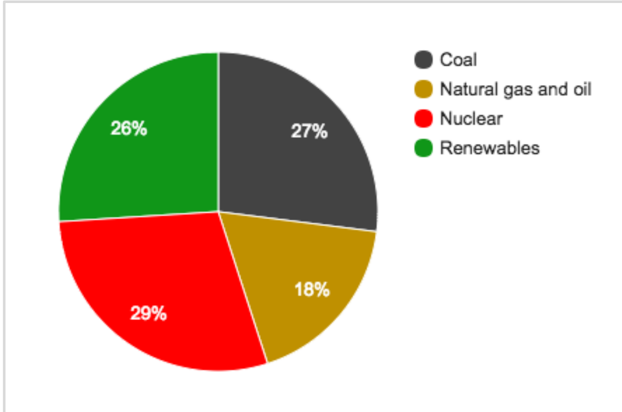

FIGURE 1. AUSTIN ENERGY'S ELECTRICITY GENERATION BY FUEL TYPE (MARCH 2017)[4]

Though the State of Texas has negligible renewable energy targets, the City of Austin has aggressive goals. The Austin City Council first adopted a renewable portfolio standard (RPS) in 1999, which was subsequently increased multiple times. The current RPS goal is 65% of electricity consumption from renewables by 2025, which is among the most ambitious targets in the country.[5] Within the RPS, the City Council approved a solar carve-out in 2014, which requires Austin Energy's generation mix to include 950 MW of solar capacity by 2025, including 200 MW of "local solar," of which at least 100 MW is required to be customer-controlled or "behind the meter" solar.[6] In addition, Austin Energy has a goal to reduce carbon dioxide emissions 20% below 2005 levels by 2020.[7] Both the RPS goal and the emission reduction goal are accelerating the installation of renewable energy in Austin, such as solar power.

As a method to provide community value, Austin Energy offers a number of energy efficiency, renewable energy, and rebates programs. These efforts aim to directly benefit customers and to help Austin Energy achieve efficiency and renewable energy goals set by Austin City Council. For example, in 2004, Austin Energy began the Solar Rebate Program, for residential customers, which is a capacity-based incentive for solar PV installations of up to 10 kilowatts (kW).

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[4] Open Data - City of Austin. *Generation by Fuel Type.* https://data.austintexas.gov/Utility/Generation-by-Fuel-Type/ss6t-rumq

[5] US Department of Energy. *City of Austin - Renewable Portfolio Standard*. https://www.energy.gov/savings/city-austin-renewables-portfolio-standard

[6] Austin Energy. *Austin Energy Resource, Generation and Climate Protection Plan to 2025: An Update of the 2020 Plan.* https://austinenergy.com/wps/wcm/connect/461827d4-e46e-4ba8-acf5-e8b0716261de/aeResourceGenerationClimateProtectionPlan2025.pdf?MOD=AJPERES

[7] Austin Energy. *Corporate Reports & Data Library.* https://austinenergy.com/wps/portal/ae/about/reports-and-data-library/data-library/power-supply

DECISION TO ADOPT A VALUE-OF-SOLAR TARIFF

As discussed, Austin Energy's decision to replace their net metering program was primarily a financial one. With an increasing block rate structure with two price tiers and a plan to expand to five tiers, many PV customers were being compensated for excess generation at rates higher than what similar non-PV customers would have been paying to consume a marginal kilowatt-hour (kWh) of electricity. Net metering could also be perceived as a disincentive for energy efficiency, as it kept rates low for customers who sold enough electricity back to the grid, regardless of their consumption level.[8] Additionally, PV customers were paying lower variable amounts under the net metering policy, and utility officials and net metering opponents were concerned that PV customers were being "cross-subsidized" by non-PV customers, as the former were paying less to cover fixed grid costs, despite using much of the same grid benefits as the latter.

Seeking to ensure adequate recovery of fixed grid costs, Austin Energy proposed in their 2011-2012 rate case to levy additional fixed fees on customers. This proposal would have led to fixed charges for residential customers increasing from $10 to $22 per bill period, despite the utility estimating that a fee of $34 per bill period was necessary to fully cover infrastructure costs.[9] This solution was not politically palatable as it had unfavorable distributional consequences, particularly for low-income customers and could have the effect of discouraging energy efficiency. Austin Energy looked for a more agreeable path forward that would still equitably recover fixed costs, while encouraging efficiency investments.

Ultimately, Austin Energy decided that the best solution was to decouple the consumption rate from the production credit. This way, they could fairly charge PV customers for the use of the grid, while also fairly crediting them for the value of the solar electricity they provided. While the consumption portion of the bill was straightforward, the credit portion was complex and required careful and meticulous calculations. Austin Energy had been working with a firm called Clean Power Research since 2006 on a Value-of-Solar calculation methodology that originally sought to establish the appropriate rate for power purchase agreements with utility-scale solar providers — in other words, the cost-neutral point at which the utility would have no preference between purchasing energy from a solar plant or producing it themselves. Recognizing that the rate at which to credit PV customers for their electricity production should

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[8] Rábago, Karl. *The 'Value Of Solar' Rate: Designing An Improved Residential Solar Tariff.* Solar Industry. February 2013. http://rabagoenergy.com/files/ra0301bago-value-of-solar-sim-feb-2013.pdf

[9] Austin Energy. *PUC Docket 40627. Response to PUC Texas Staff, 1-10. Attachment 2.* http://interchange.puc.state.tx.us/WebApp/Interchange/Documents/40627_59_743212.PDF

essentially answer the same question, the utility revisited these calculations and made tweaks to the methodology to apply it to small distributed generators. After countless conversations with stakeholders, public hearings, and approval from both the City Council and the Public Utilities Commission, the Vale-of-Solar credit was rolled out to Austin Energy's PV customers in the fall of 2012.

From an economic perspective, there are a number of advantages to the VOST. First, it addresses the distributional concerns associated with net metering, as PV customers pay fully for the generation, transmission, and distribution services embedded in the retail rate of the electricity they consume.[10] Second, it reduces the distortions caused by the block rate structure, removing disincentives for efficiency. Third, it provides fair value for production to PV customers by compensating them based on the benefits of their electricity production to the grid. Fourth, it keeps Austin Energy financially whole by ensuring that grid costs are fully recovered before credits for solar generation are distributed. Finally, it can help Austin Energy make smarter decisions about resource planning and load balancing in the future, since the VOS program required the installation of an additional electrical meter at households with PV in order to separate the measurement of electricity generated by PV from electricity consumed from the grid.

VALUE-OF-SOLAR CREDIT

Unlike with net metering, the VOST program decouples energy consumption from the Value-of-Solar credit rate; residential solar customers are billed for electricity consumed in a given bill period, then receive a separate credit on their bill for each kWh their solar panels generate and deliver to the grid. All fixed charges under the Residential Service rate schedule remain unaffected.

The credit is based on the average of the annual Value-of-Solar assessment of the next year and the previous four years' Value-of-Solar assessments, and the resultant VOS rate is effective as of January 1 the following year.[11] The amount of the VOST credit is calculated using algorithms developed by Austin Energy jointly with Clean Power Research. It is calculated based on the components listed below.

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[10] National Renewable Energy Laboratory. *Value-of-Solar Tariffs*. http://www.nrel.gov/tech_deployment/state_local_governments/basics_value-of-solar_tariffs.html

[11] Austin Energy. *City of Austin - Electric Tariff Value-of-Solar Rider.* http://austinenergy.com/wps/wcm/connect/c6c8ad20-ee8f-4d89-be36-2d6f7433edbd/ResidentialValueOfSolarRider.pdf?MOD=AJPERES

TABLE 1. AUSTIN ENERGY VOST VALUE COMPONENTS AND ASSOCIATED FORMULAS[12]

VOS Component	Formula
Energy Value	$\left[\frac{\sum(Implied\ heat\ rate * Gas\ price * PV\ production * Risk\ free\ discount\ factor}{\sum(PV\ production * Risk\ free\ discount\ factor)}\right] * (1 + Loss\ factor)$
Plant O&M Value	$\frac{[\sum(O\&M\ cost * (1 + inflation)^{year} * PV\ capacity * Risk\ free\ discount\ factor)] * (1 + Loss\ factor)}{\sum(PV\ production * Risk\ free\ discount\ factor)}$
Generation Capacity Value	$\frac{[\sum(Annual\ capital\ carrying\ cost * PV\ capacity * Risk\ free\ discount\ factor)] * Load\ match * (1 + Loss\ factor)}{\sum(PV\ production * Risk\ free\ discount\ factor)}$
Transmission and Distribution Value	$\frac{[\sum(Transmission\ cost * PV\ capacity * Risk\ free\ discount\ factor)] * Load\ match * (1 + Loss\ factor)}{\sum(PV\ production * Risk\ free\ discount\ factor)}$
Environmental Compliance Value	*Set at $0.02 per kWh, based on average premium paid in voluntary green power purchasing programs in Texas when VOS was implemented*

[12] *City of Austin - Electric Tariff Value-of-Solar Rider.*

ENERGY VALUE

The *energy value* is the estimated avoided cost of energy that would have been needed to meet electric demand, as well as transmission and distribution losses. The value is based on the solar production profile in Austin to account for the time of day when solar is offsetting those costs. It is inferred from wholesale market price data in the Electric Reliability Council of Texas (ERCOT) region, as well as from projected natural gas prices.

PLANT OPERATIONS AND MAINTENANCE VALUE

The *plant operations and maintenance value* is the estimated cost associated with natural gas plant operations and maintenance during times of peak demand that are offset by distributed energy resources (DER) supplying power during those times.

GENERATION CAPACITY VALUE

The *generation capacity value* is the estimated avoided cost of capital of generation that is offset by DER production during peak times. Like the energy value, the generation capacity value is inferred from ERCOT market price data.

TRANSMISSION AND DISTRIBUTION VALUE

The *transmission and distribution (T&D) value* is the estimated savings in transmission costs that results from the reduction in the peak load by DER, as well as the savings or costs related to capital investments to the distribution grid. The distribution value in Austin Energy's service territory is currently not calculated as part of the VOST but will continue to be reviewed as solar penetration increases to determine whether and when it merits being incorporated.

ENVIRONMENTAL COMPLIANCE VALUE

The *environmental compliance value* is the estimated avoided cost of complying with environmental regulations and local policy objectives. The environmental compliance value for Austin Energy's VOST is currently set at $0.02 per kWh based on the average premium that amount was being paid in voluntary green power purchasing programs in Texas when the VOST was first implemented.

The sum of the above factors is intended to reflect the value of distributed PV to Austin Energy — a value at which the utility would ostensibly be economically neutral to whether it supplies a kWh itself or a customer supplies it to the grid.[13] Although the VOST calculation accounts for environmental benefits of distributed PV, which some VOS stakeholders consider to be controversial, it does not include any value of economic benefits or variations in value due to the location of the system in the grid. These values have been considered in other VOS studies, and some argue that omitting them results in a more conservative calculation for the value of solar.

ADJUSTMENTS TO THE VALUE-OF-SOLAR TARIFF

Austin Energy's Value-of-Solar tariff does not institute a static credit amount; it is designed to change annually as part of the utility's budget approval process, based on updated inputs to the rate components described above. Since its initial implementation, the credit rate has been readjusted for each calendar year, with the new credit rate going into effect for the January billing cycle of each year. The original VOST credit rate was $0.128 per kWh, which was then reduced for the 2014 calendar year to $0.107 per kWh, and then increased in 2015 to $0.113 per kWh.

[13] Rábago, Karl. The 'Value Of Solar' Rate: Designing An Improved Residential Solar Tariff. Solar Industry. February 2013. http://rabagoenergy.com/files/ra0301bago-value-of-solar-sim-feb-2013.pdf

TABLE 2. AUSTIN VOS ASSESSMENT RATES AND EFFECTIVE VOS RATES,[14] 2012-2017[15]

Effective Date	VOS assessment ($/kWh)	VOS rate ($/kWh)
10/1/2012	$0.128	$0.128
1/1/2014	$0.107	$0.107
1/1/2015	$0.100	$0.113
1/1/2016	$0.097	$0.109
1/1/2017	$0.097	$0.106

In August 2014, to facilitate achieving the city's ambitious RPS goals, the Austin City Council directed the City Manager to carry out a number of policy changes, which included changes to the VOST.[16] These changes included 1) the ability for credits to carry over from year to year instead of resetting at the start of each year, 2) the removal of a 20 kW cap on residential solar capacity for systems eligible for the VOS credit, 3) the establishment of an annual price floor equal to the residential electricity rates of a "tier 3 customer," 4) the ability for leased system hosts to receive VOS credits, and 5) the adoption of a five-year rolling average in the annual calculation of the credit.

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[14] As previously described, the rate is based on the average of the annual Value-of-Solar assessment of the next year and the previous four years' Value-of-Solar assessments. The resultant VOS rate is effective as of January 1 the following year.

[15] *City of Austin - Electric Tariff Value-of-Solar Rider.*

[16] US Department of Energy. *City of Austin RPS*.

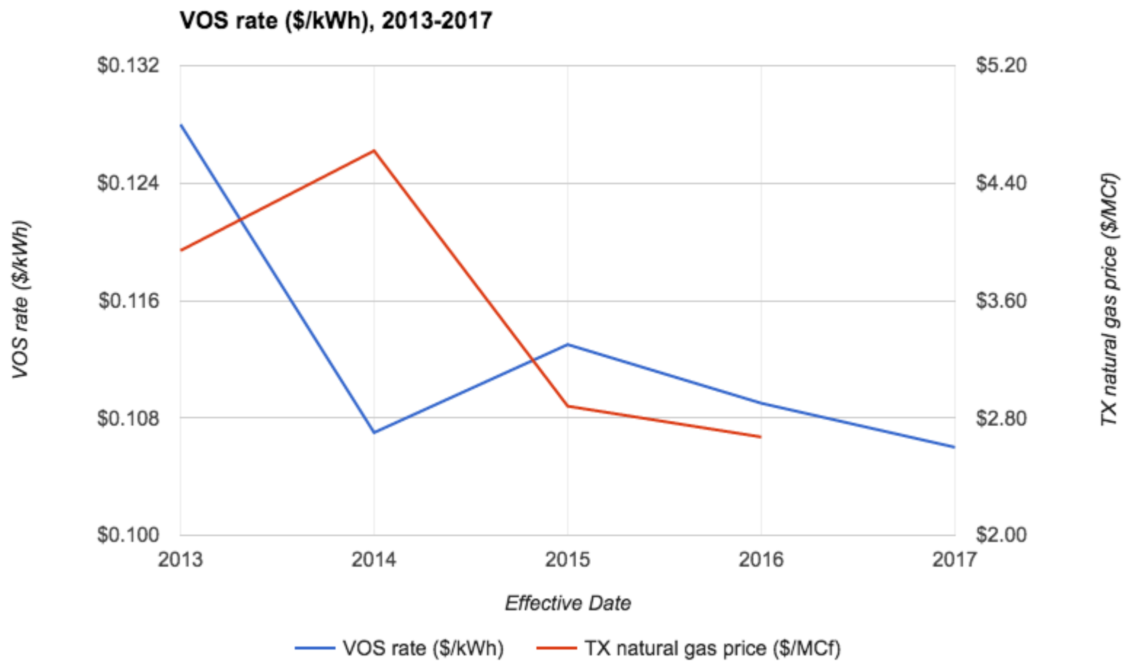

FIGURE 2. VOST RATE ($/KWH) AND PRICE OF NATURAL GAS ($/MCF)[17]

The adoption of a five-year rolling average was largely due to changes in generation costs for natural gas power plants. After a dramatic decline in natural gas prices and a corresponding decrease in the VOST credit rate, in the first few years of the program, Austin Energy modified the VOST rate to incorporate the rolling average in order to temper the impact that short-term gas price fluctuations can have on VOST rates. While the VOST rate changes annually, the rate customers receive is now an average of the current year and the four previous years. Despite falling gas prices, VOST rates in 2015 exceeded retail electricity rates by $0.036 per kWh.[18]

[17] *City of Austin - Electric Tariff Value-of-Solar Rider*; EIA. Natural Gas Prices. 2017. https://www.eia.gov/dnav/ng/ng_pri_sum_dcu_STX_a.htm

[18] Revesz, Richard and Burcin Unel. *Managing the Future of the Electricity Grid: Distributed Generation and Net Metering.* Institute for Policy Integrity, New York University Law School. February 2016. http://policyintegrity.org/files/publications/ManagingFutureElectricityGrid.pdf

ANALYSIS

DATA

Our main objective was to investigate the VOST's impact on the rate of residential solar installations in Austin. To conduct this analysis, we used residential solar installation data from the National Renewable Energy Laboratory's OpenPV Project. This dataset provides information for each installation, such as the date of installation, zip code, cost per watt, and utility, for the entire US. However, because this database consists of data that are contributed voluntarily from a variety of sources, the data are incomplete and could be inaccurate.

For our analysis, we used data for Texas installations from 2004 through 2015. Data for 2016 were available but appeared incomplete and were omitted from the analysis. The raw dataset for this time period contained 9,347 records of solar installations in Texas. Of these, 8,163 were residential, or about 87.3% of total solar installations in Texas. Cumulative installed capacity was 234,846 kW, of which residential installations accounted for 43,809 kW or about 18.7% of the total.

It appeared, however, that the residential installation data contained a number of duplicate records.[19] A total of 1,504 duplicate records were identified and removed, leaving 6,659 records for residential solar installations in Texas.

As discussed below, we controlled for other variables such as population, income, and political affiliation, rebates and retail rates. We used population and income data from the US Census Bureau's American Community Survey and county-level political affiliation data from the 2016 Presidential election. We used the rebate data for installations in Austin from the Open PV Project, and added rebate data from Database of State Incentives for Renewables and Efficiency (DSIRE) for San Antonio and Dallas (since it was largely missing from Open PV). We used the retail rate data listed for each utility on the PUC website.[20]

[19] There may be duplication in non-residential installations as well, but these were not the focus of our analysis.
[20] Public Utility Commission of Texas. *Residential and Commercial Bill Comparisons for Non-Competitive Markets.* https://www.puc.texas.gov/industry/electric/rates/NCrate/viewdownarc.aspx
Public Utility Commission of Texas. *Average Annual Rate Comparison Archive.* *https://www.puc.texas.gov/industry/electric/rates/RESrate/RESratearc.aspx*

The data show that Austin accounted for about 80% of all installations and installed capacity in Texas (Figure 3). There was a steady increase in the number of solar installations per month in both Austin and Texas, as seen in Figure 4. A sharp spike in monthly installations occurred in Austin in July 2012, immediately before the city's net metering policy was replaced by the VOST. It is possible that the announcement of VOST could have triggered the increase in 2012 before the introduction of VOST. However, the actual method and timing of the policy announcement remains unclear therefore no conclusion could be made.

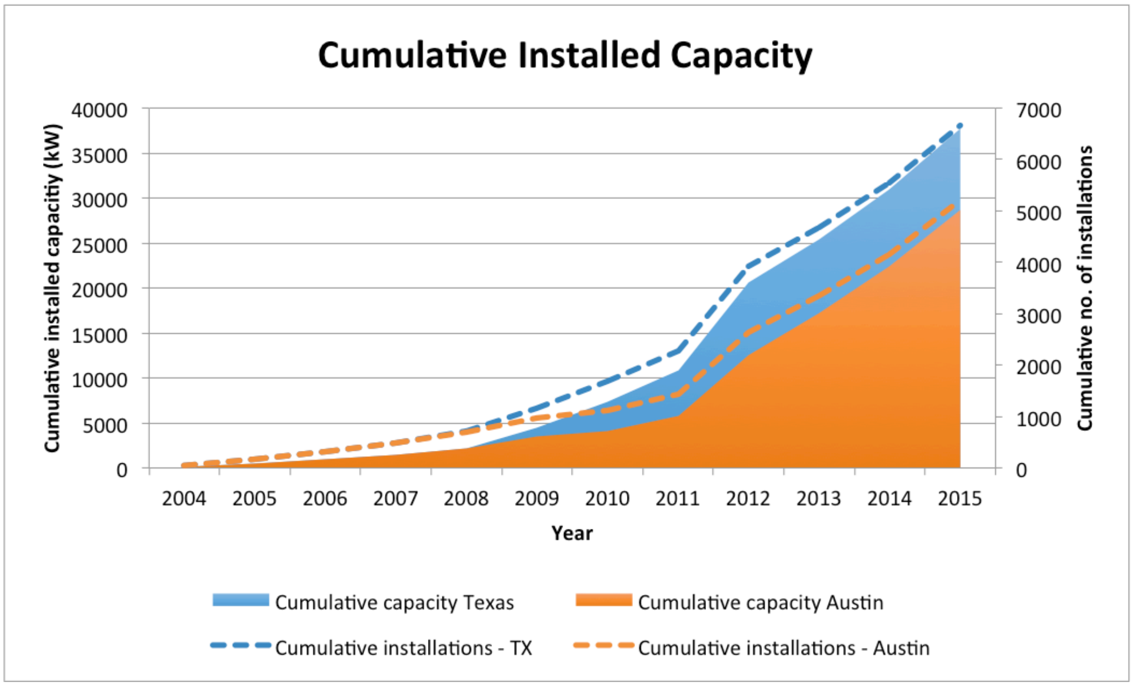

FIGURE 3. CUMULATIVE INSTALLED CAPACITY AND NUMBER OF INSTALLATIONS FOR AUSTIN AND TEXAS

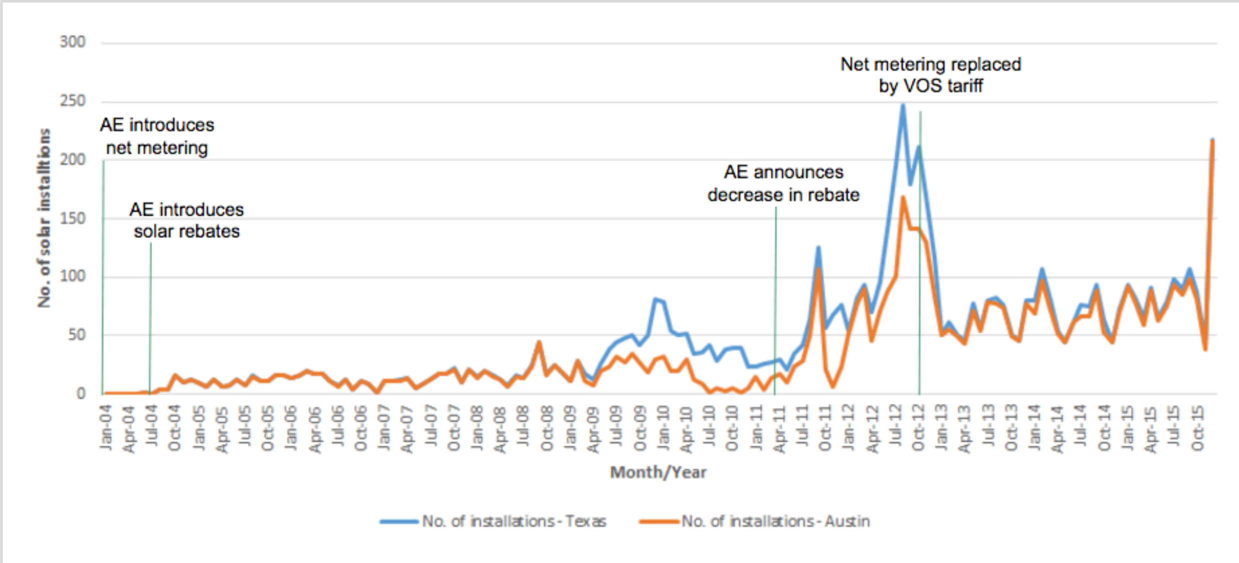

FIGURE 4. MONTHLY SOLAR INSTALLATIONS IN AUSTIN AND TEXAS (INCLUDING AUSTIN)

METHODOLOGY

DIFFERENCE-IN-DIFFERENCES TECHNIQUE

We used the difference-in-differences technique to evaluate the effect of the treatment, the implementation of the VOST program, on the dependent variable, solar installation rates in Austin, by comparing the average change over time in solar installations in Austin to two control groups — 1) the rest of Texas and 2) the cities of San Antonio and Dallas, aggregated. To effectively isolate the relationship between the introduction of VOST in Austin and a change in solar installation rates, we controlled for other variables and carefully selected control cities to conduct an appropriate comparison. Our methodology for choosing these cities and control variables is outlined below.

CONTROL CITIES

We chose the control cities of San Antonio and Dallas because they are similar to Austin in terms of solar radiation (Figure 5), income, political leaning and home ownership (Table 3). The other control group used was all of Texas excluding Austin. While this group was not as similar to Austin as San Antonio and Dallas were, it still shared the same state policies, which are important determinants in solar adoption.

TABLE 3. COMPARISON BETWEEN AUSTIN, DALLAS, AND SAN ANTONIO

City	Population[21]	Area (sq. mi)[22]	Median Household Income[23]	Party Affiliation[24]	Owner: Renter[25]
Austin	885,400	272	$57,960	65.8% D, 27.1% R	51:49
Dallas	1,258,000	386	$51,824	54.2% D, 40.8% R	51:49
San Antonio	1,409,000	465	$52,230	60.8% D, 34.6% R	57:43

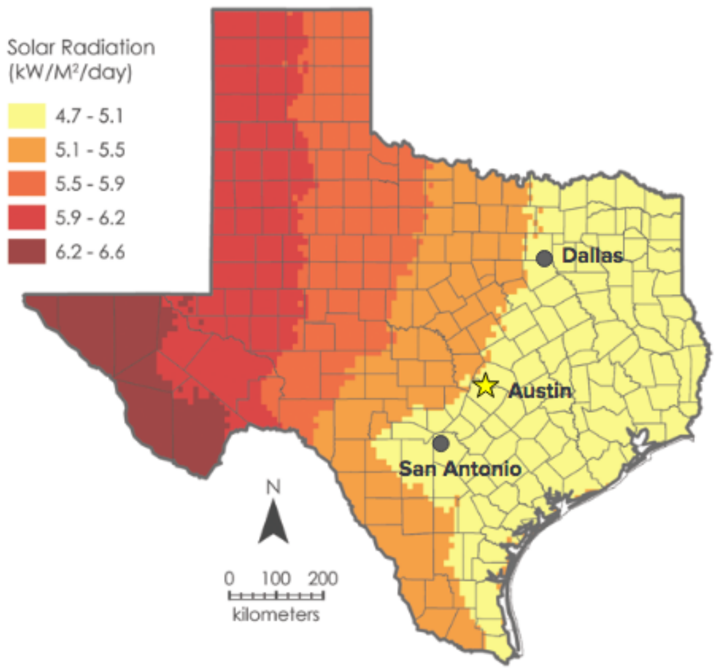

FIGURE 5. SOLAR RADIATION IN TEXAS[26]

[21] US Census Bureau. *American Community Survey 2011.* https://www.socialexplorer.com/explore/tables
[22] US Census Bureau. *Quick Facts: Places.* https://www.census.gov/quickfacts/table/PST045216/00
[23] US Census Bureau. *American Community Survey 2011*. https://www.socialexplorer.com/explore/tables
[24] Townhall. *County Level Election Results*. https://github.com/tonmcg/County_Level_Election_Results_12-16
[25] US Census Bureau. *American FactFinder: Community Facts.* https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_15_1YR_S2502&prodType=table

CONTROL VARIABLES

In addition to using control groups, our analysis controlled for a series of variables that likely influenced solar adoption, in order to further isolate the effect of VOST. This included month and year fixed effects (to control for aggregate time trends and seasonality), population, average household income, political affiliation, solar rebate amount, installation cost per watt, and retail electricity rate.

REBATE AMOUNTS

In designing our analysis, we determined that the dollar amount of residential solar rebates was one of the most important variables to control for, since financial incentives undoubtedly influence consumer decisions to adopt solar. As the solar market has grown and installation costs have declined, Austin's solar rebate amounts have decreased considerably from the original 2004 incentive of $5 per watt. In 2015, Austin Energy introduced a capacity-based incentive ramp-down schedule to provide greater certainty and transparency for customers and allow the utility to meet its solar goals on schedule and within budget.[27]

Although incentives for solar decreased by 88% between 2004 and 2016, solar installations in Austin increased dramatically over the same time period.[28] In some instances, the announcement of a rebate decrease appears to have led to a sharp increase in solar installations. For example, according to Austin Energy, a large uptick in installations around September 2011 (Figure 6) occurred in response to an announced rebate reduction from $2.50 to $2.25 per watt. This resulted in $4.5 million worth of incentive request submissions in March 2011, which triggered the spike the following September.[29]

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[26] Clayton, Mary E., Jill B. Kjellsson, and Michael E. Webber. Earth Magazine. *Can renewable energy and desalination tackle two problems at once?* October 2014. https://www.earthmagazine.org/article/can-renewable-energy-and-desalination-tackle-two-problems-once

[27] Austin Energy. 2017. *Solar Program: Residential Solar Photovoltaic Incentive Program Guidelines.* https://austinenergy.com/wps/wcm/connect/e4b07e7e-da58-42bc-8240-e2dfc8171de4/Residential+Solar+Program+Guidelines.pdf

[28] Harvey, Tim. Environmental Program Coordinator at Austin Energy. Email message to authors. April 24, 2017.

[29] Harvey, Tim. Environmental Program Coordinator at Austin Energy. Telephone interview by authors. April 11, 2017.

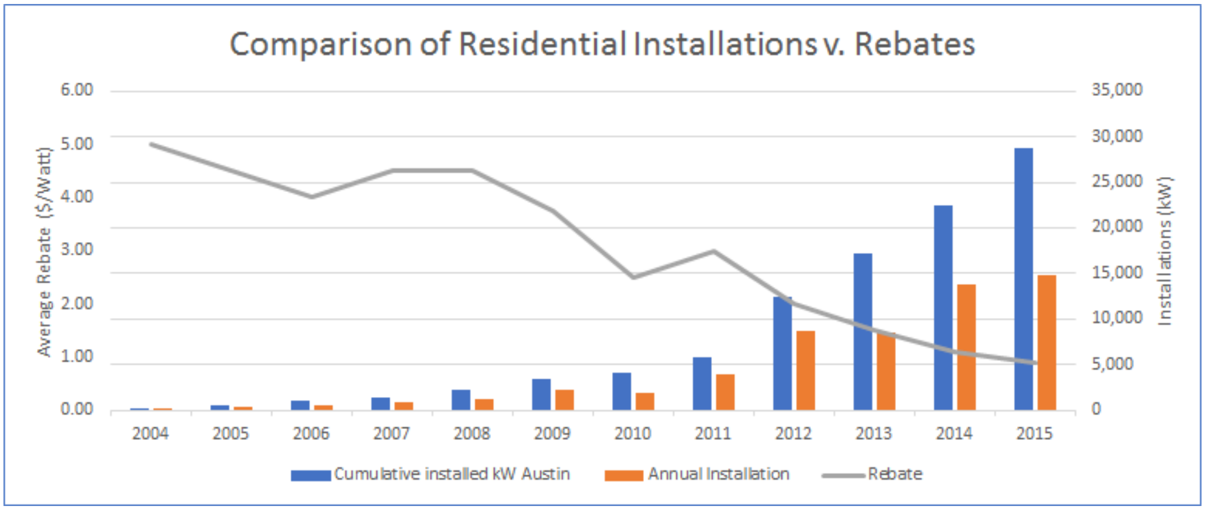

FIGURE 6. RESIDENTIAL SOLAR INSTALLATIONS AND SOLAR REBATES PROVIDED BY AUSTIN ENERGY

In contrast, San Antonio and Dallas offered solar PV rebates much later and in smaller amounts. For example, CPS Energy, the municipal utility in San Antonio, offered a rebate beginning in 2007 of $1.20 per watt that also followed a capacity-based ramp-down schedule.[30] Oncor Energy in Dallas began its rebate program in 2009, which offered one-time payments of $538.53 per kW and $0.2519 per kWh through 2012, and revived the program in 2016.[31]

[30] DSIRE. *CPS Energy - Solar PV Rebate Program.* http://programs.dsireusa.org/system/program/detail/2794
[31] DSIRE. *Oncor Electric Delivery - Solar Photovoltaic Standard Offer Program.* http://programs.dsireusa.org/system/program/detail/3168

REGRESSION MODEL

The regression model employed in our analysis used the following equation:

$$y_{mz} = \alpha + \beta.cityaustin + \boldsymbol{\gamma.cityaustin.postVOST} + \sum \delta.fixed\ effects + \sum \lambda.other\ control\ variables_{mz} + \varepsilon$$

where:

- y = number of monthly solar installations by zip code
- α = constant term
- β = treatment group specific effect (to account for average permanent differences between Austin and the control group)
- γ = true effect of treatment
- δ = time trend common to control and treatment groups
- λ = effect of other control variables

A key assumption of the difference-in-differences model is parallel trends between the treatment and control groups in the absence of the treatment. We compared trends in solar installations between the two groups before and after the VOST to test the validity of this assumption. As shown in Figures 7 and 8, there was somewhat of a parallel trend between Austin and rest of Texas before the VOST, whereas no discernible trend was observed between Austin and San Antonio and Dallas. This is mainly due to minimal solar installations in the latter cities (as illustrated in the LBNL Solar PV dataset), despite the introduction of solar rebates[32] and net metering policies (Figure 9). However, San Antonio and Dallas share similar characteristics with Austin and therefore provide a better counterfactual of solar outcomes in Austin absent VOST. As a result, we ran regressions for both control groups (Austin vs. the rest of Texas and Austin vs. San Antonio and Dallas).

[32] DSIRE. *CPS Energy - Solar PV Rebate Program.* http://programs.dsireusa.org/system/program/detail/2794; DSIRE. *Oncor Electric Delivery - Solar Photovoltaic Standard Offer Program.* http://programs.dsireusa.org/system/program/detail/3168

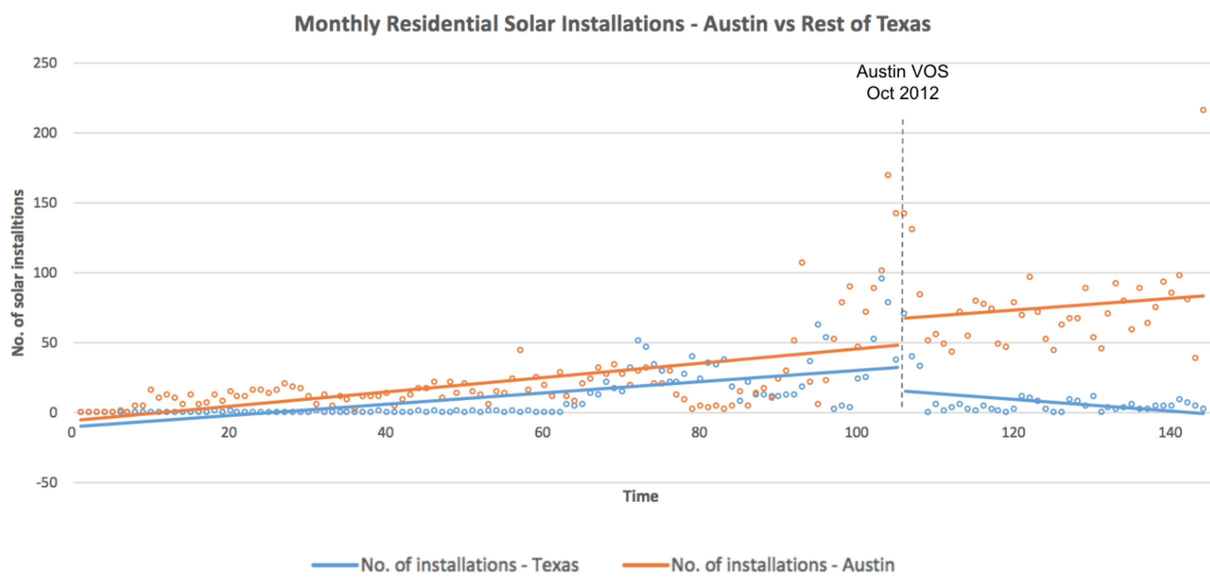

FIGURE 7. MONTHLY RESIDENTIAL SOLAR INSTALLATIONS IN AUSTIN VS. THE REST OF TEXAS

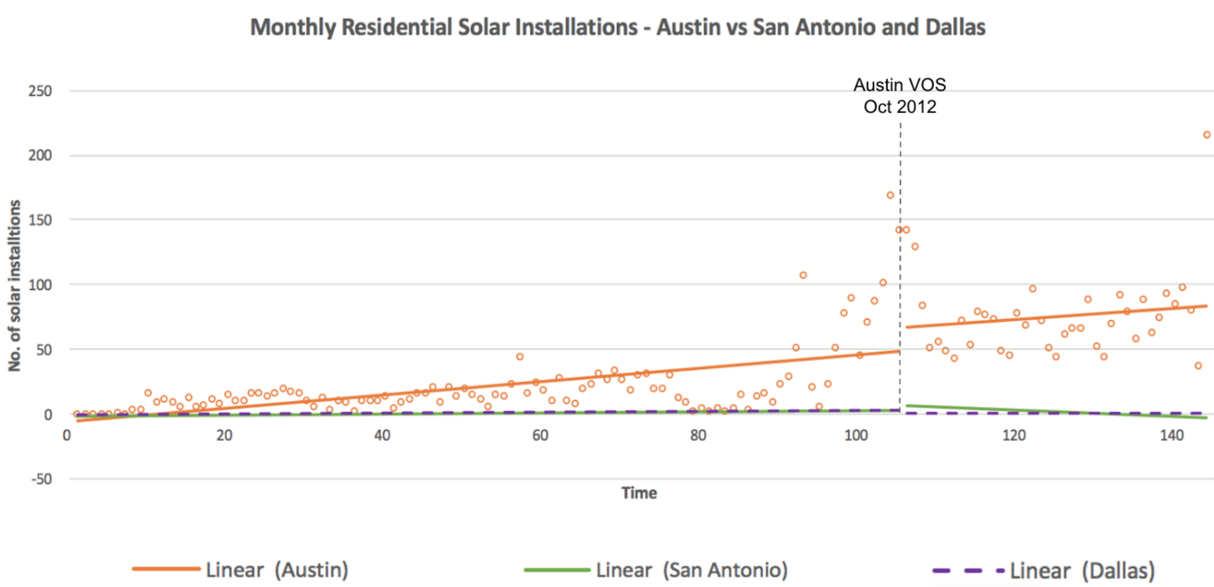

FIGURE 8. MONTHLY RESIDENTIAL SOLAR INSTALLATIONS IN AUSTIN VS. SAN ANTONIO AND DALLAS

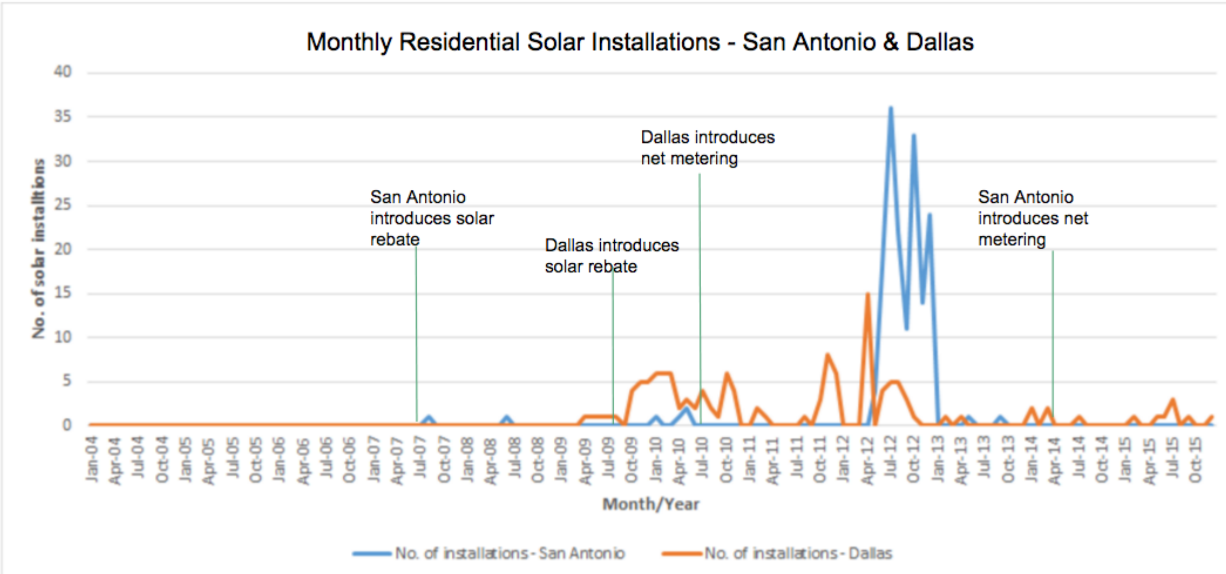

FIGURE 9. MONTHLY RESIDENTIAL SOLAR INSTALLATIONS IN SAN ANTONIO AND DALLAS

RESULTS

As shown in Table 4, the impact of VOST on solar installations in Austin is positive and statistically significant with a p-value of 0.038 (<0.05) when the control group is the rest of Texas. In this case, the results imply that VOST increased solar installations in Austin by 0.667 installations per zipcode per month.

However, when the control group is San Antonio and Dallas, the effect of the VOST is still positive, but not statistically significant, with a p-value of 0.154. When rebates and retail rates are included, the effect of the VOST on the rate of solar installations is reduced by half and also not statistically significant, with a p-value of 0.575. This change is mostly caused by rebates, whereas the inclusion of retail rates leads to minimal changes in the regression results. However, there are concerns with rebate data as discussed in the *Limitations* section below, so the results in the last case may be unreliable.

In addition, the results show that living in Austin clearly has a positive and statistically significant impact on solar installation rates. This is likely due to a combination of local policies — including financial incentives for solar — and the unique characteristics of Austin as described in the *Discussion* section below.

TABLE 4. REGRESSION RESULTS FOR MONTHLY TOTAL SOLAR INSTALLATIONS BY ZIP CODE

	Austin vs. Rest of TX	Austin vs. San Antonio & Dallas	Austin vs. San Antonio & Dallas (incl. rebates & retail rates)
City Austin	1.610***	1.650***	2.515***
	(0.232)	(0.403)	(0.492)
Post VOST	**0.667****	**0.748**	**0.312**
	(0.321)	**(0.524)**	**(0.557)**
Time Fixed Effects	Yes	Yes	Yes
Cost per Watt	-0.030	-0.064	-0.130
	(0.050)	(0.088)	(0.090)
Population	0.00001***	0.00003***	0.00003***
	(0.00000)	(0.00000)	(0.00000)
Average Income	0.00001***	0.00001***	0.00002***
	(0.00000)	(0.00000)	(0.00000)
Political affiliation	-0.334	4.232*	3.961
	(0.601)	(2.108)	(2.174)
Retail Rate			1.922**
			(5.213)
Rebates			-0.000
			(0.000)
Constant	-1.435	-5.208	-4.692

	(0.803)	(1.618)	(1.642)
R-squared	0.0912	0.0867	0.0976
Adj R-squared	0.0830	0.0750	0.0850
Number of Observations	3,149	2,216	2,175

Standard errors are reported in parentheses. *, **, *** indicates significance at the 90%, 95%, and 99% levels, respectively.

DISCUSSION

As discussed above, we expected a decrease in solar installations following the implementation of the VOST program, since we posited that the financial attractiveness of solar would decrease under VOST compared to net metering. Contrary to our expectation, we found that VOST has a positive and statistically significant effect on solar installations in Austin when the rest of Texas is used as a control group. However, the rest of Texas may not be a suitable control for Austin due to factors that we do not observe, therefore we considered another specification that uses Dallas and San Antonio as the control group. The results from this specification are again positive although the standard errors increase (the coefficient is now not statistically significant at a significance level of 0.1). The lack of significance could be due to decreased power to detect an effect from limiting the sample size. Alternatively, these results may lead us to interpret the first specification more cautiously if we suspect that there are unobserved factors or trends not relating to VOST that occurred in the more progressive cities (Austin, Dallas, and San Antonio). Regardless, we found that Austin residents are significantly more likely to install solar compared to the rest of Texas, including San Antonio and Dallas.

LIMITATIONS TO ANALYSIS

Our regression analysis had a number of limitations due to data availability and quality. Below, we outline the assumptions we made and how we addressed data discrepancies.

The OpenPV Project is a voluntary database, and therefore may include incomplete or inaccurate data. We identified and removed approximately 1,500 duplicate records, but there may have been additional duplicates that we were unable to identify. However, we believe that this is the most comprehensive dataset and thus we assume that any further inconsistencies are minor and do not significantly impact our analysis.

There was no single, comprehensive source of data for solar rebates in Austin, San Antonio, and Dallas. For Austin Energy's residential solar rebate, we used the data listed in the OpenPV Project, which was consistent with the data we received from Austin Energy. However, rebate data were missing for San Antonio and Dallas in the OpenPV dataset so we used the DSIRE database instead. It is important to note that there were inconsistencies in Austin's rebate data between the OpenPV dataset and DSIRE, which suggests that the DSIRE rebate data for San Antonio and Dallas may also contain inaccuracies.

The OpenPV Project provides data based on the US Census Bureau's Zip Code Tabulation Areas (ZCTA) rather than postal zip codes. However, we assume that the difference between these designations is negligible and does not impact our analysis.

Population and income data according to ZCTA were only available from the US Census Bureau's American Community Survey starting in 2011. Therefore, we applied the 2011 data to the preceding years. Lastly, for political affiliation, we used data exclusively from the 2016 Presidential election, rather than from each year for which we performed our analysis. We do not expect either of these adjustments to have a meaningful impact on our analysis.

OTHER KEY VARIABLES

There are a number of factors that can influence solar adoption. In our regression, we controlled for several factors, but there were a number of factors for which we were unable to control.

First, the way Austin Energy communicated the change to the VOST, and the way customers interpreted those changes, may have had a significant impact solar adoption. According to the Environmental Program Coordinator at Austin Energy, the utility held community meetings about the policy change, but it is not clear to what extent prospective solar customers were made aware of the change, and how these communications affected their propensity to invest in solar.[33] In the same vein, the way in which the change to VOST was portrayed by local players, such as city government, solar installers, and media organizations, could have affected solar adoption, but was not accounted for in our analysis.

Another factor that we could not control for was social contagion, whereby certain behaviors exhibited by one person are emulated by others. If there were a number of nearby installations, or a cluster of residential solar panels in certain densely populated neighborhoods, those proximal examples could have encouraged other residents to adopt solar, regardless of the change from net metering to VOST.[34]

Lastly, although our regression did control for political affiliation, which may be correlated with support for environmental causes, Austin residents may have a particular proclivity for solar energy, and may have been more inclined than customers in other regions to adopt solar PV, despite the change in policy.

POTENTIAL REPLICABILITY

As utilities across the country pursue alternatives to net metering, it is worth considering why Austin may have been uniquely positioned to pioneer a VOST methodology, and whether similar programs could be implemented elsewhere.

UNIQUE AUSTIN CIRCUMSTANCES

Because Austin Energy is a municipal utility, their financial decisions must be approved by the Austin City Council, in contrast to other US utilities, which are largely regulated by state public utility commissions (PUCs). PUCs tend to make decisions based on what will keep utility rates low for customers. While this is certainly a concern of the Austin City Council, the Council has a wider mission, making decisions based on a variety of objectives. The City Council is directly elected by Austin residents and as such, represents the city's relatively progressive-minded population. It is less likely that a state PUC would be as supportive of the type of pioneering VOST program that was implemented in Austin.

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[33] Harvey, Tim. Environmental Program Coordinator at Austin Energy. Telephone interview conducted by authors. April 11, 2017.
[34] Graziano, Marcello and Kenneth Gillingham. "Spatial patterns of solar photovoltaic system adoption: The influence of neighbors and the built environment." Journal of Economic Geography. (2015) 15 (4): 815-839. October 7, 2014. https://doi.org/10.1093/jeg/lbu036.

In addition to — and perhaps because of — the features unique to Austin Energy, some of the particulars of the VOST's component calculations may not be as palatable in other states and regulatory jurisdictions. For example, Austin Energy's *Value of Energy* calculation is based on highly transparent ERCOT power prices, but marginal energy costs are much more opaque in other parts of the country and thus difficult to identify. Austin Energy's $0.02 per kWh *Environmental Benefits* component is intended to capture the societal environmental benefits associated with incremental PV deployment. However, these benefits are not financially measurable from a utility's perspective, as few regulations currently exist to reduce the environmental externalities imposed by the electricity sector.

At present, the only other instance of a VOST in the US is in Minnesota, where legislation adopting a VOST was enacted in 2013. However, rather than comprehensively replacing net metering, the state legislature employed a more cautious strategy, making the VOST program optional to start. This way the efficacy of the program can be assessed before net metering is fully discontinued. To date, no utility has adopted the VOST, as the assessment currently values solar more highly than retail electricity rates.

Other states have taken a close look at the potential for VOST, such as Maine, where Clean Power Research has conducted a study similar to those in Austin and Minnesota.[35] In addition, numerous VOS studies have been released by a variety of stakeholders, most of whom have either touted the benefits of distributed solar or warned of the costs. Some utilities have commissioned VOS studies to quantify solar's costs to the grid. In Arizona, a recent VOS proceeding has resulted in the replacement of net metering with a VOS program that will reduce PV customer compensation.[36]

CONCLUSION

Because Austin Energy chose to replace net metering with the VOST primarily for financial reasons, we expected the change in tariff structure to lead to a decrease in the rate of solar installations in Austin. Instead, our analysis indicates that the VOST led to a statistically significant increase in solar installations in Austin when compared to the rest of Texas. However, this positive effect was not statistically significant when compared to San Antonio and Dallas. While San Antonio and Dallas provide better counterfactuals

[35] Clean Power Research. *Maine Distributed Solar Valuation Study.* 2015. http://www.maine.gov/mpuc/electricity/elect_generation/documents/MainePUCVOS-ExecutiveSummary.pdf

[36] Utility Dive. *Arizona regulators end retail net metering in value-of-solar proceeding*. December 21, 2016. http://www.utilitydive.com/news/updated-arizona-regulators-end-retail-net-metering-in-value-of-solar-proce/432838/

for solar installations in Austin absent the VOST, the limited sample size may have decreased the statistical significance of the results. We therefore cannot draw any definitive conclusions about the impact of the VOST on solar installations in Austin.

Moreover, the nascent nature of the VOST and the rapid changes in the solar industry make it difficult to isolate the most significant factors on the solar installation rate in Austin. Further study would likely be helpful in assessing the impact of a VOST policy compared to a net metering policy before it is possible to speculate on the potential success of a VOST in another jurisdiction. As discussed above, the circumstances in Austin may be unique and this type of program may not be easily replicated elsewhere.

As more utilities, regulators, and other stakeholders develop VOS tariffs and other innovative programs to replace net metering, other regions can adopt similar approaches that both preserve utility financials and allow for a vibrant market for residential solar. Despite the limitations of our analysis and the uncertainty of replicability, our results indicate that the VOST did not decrease the rate of solar installations, which may have promising implications for other well-executed VOST policies in the future.

APPENDIX

APPENDIX 1. AUSTIN ENERGY REBATE HISTORY: AMOUNT AND CAPACITY INSTALLED[37]

Date Rebate changed	Rebate changed to ($/W)	Capacity Installed at rebate level (kW-AC)
4/20/2004	$5.00	522
11/16/2005	$4.50	88
2/1/2006	$4.00	172
10/1/2006	$4.50	1,350
3/13/2009	$3.75	684
10/1/2009	$2.50	755
5/17/2011	$3.00	1,084
10/1/2011	$2.50	1,614
6/11/2012	$2.00	2,940
5/7/2013	$1.50	2,719
12/4/2013	$1.25	1,656
6/16/2014	$1.10	5,290
6/26/2015	$1.00	944
8/24/2015	$0.90	1,275
11/9/2015	$0.80	3,750
9/14/2016	$0.70	2,607
2/13/2017	$0.60	1,005

[37] Harvey, Tim. Environmental Program Coordinator, Austin Energy. Email to authors, April 11, 2017.

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