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EC 538

Term Paper

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**The Solar Cost-Shift:**

**A Review of Solar Cost/Benefit Studies in the United States (2010 – 2016)**

The quickening pace of market penetration of distributed solar photovoltaic (PV) systems across the United States over the past decade has triggered a growing interest, concern, and even resistance among retail electric utilities.[[1]](#footnote-1) Net energy metering (NEM), a common enabling policy that establishes compensation rules and standards for end-user-generated electricity, has been at the ground zero of conflict. Utilities decry the requirement that they compensate end-users for generated electricity at retail prices, and they have increased their attention to the revision and/or removal of net metering policies, the reduction of NEM compensation to wholesale levels, and the increase of fixed charges. From the retail utility perspective, customers who go solar end up shifting grid operation and maintenance costs onto non-solar customers. Solar industry advocates, however, argue that the overall net benefit of end-use customer investments into solar ultimately saves all ratepayers money.

This policy conflict has been playing out in state after state, generating a number of cost/benefit studies that, at least in part, have endeavored to answer the question of whether solar net metering causes a cost shift from NEM participants to non-NEM participant rate payers. Some of those studies have indicated that non-participants enjoy net benefits, while others have identified net costs accruing to non-participants. The intent of the meta analysis that follows is to explore and evaluate the studies generated for consideration by policy makers. Our exploration of these cost/benefit studies had two goals:

1. Gain a better understanding of the most significant sensitivities driving the study conclusions; and
2. Come to some conclusions of our own in regard to the primary question being posed by the studies: Do solar net metering policies cause a shifting of costs from NEM participants to non-NEM participants?

**BACKGROUND**

Net metering policies have been a part of the American energy landscape for decades, developing in parallel with the introduction of solar PV products into the market place. NEM policy was first applied in Arizona (1981), with its adoption spreading to ten states by 1988. Ten years later, NEM was utilized in twenty-two states, with that number doubling again by 2005.[[2]](#footnote-2) During that time, there has always been a degree of concern, held by electric utilities, in regard to potentially negative revenue impacts. This concern, without data from actual solar PV penetration, led states to regularly impose certain proscribed constraints, such as system size limitations and NEM penetration caps (typically expressed as a percent of total load) on programs at their onset. For example, when the California legislature created NEM policy for the golden state (in 1995), it imposed a 10 kW maximum size limit and a program penetration cap at 1 percent of total load.[[3]](#footnote-3)

Prices for solar PV systems dropped considerably between the 1970s and 2008, owing primarily to conversion efficiency advancements in crystalline silicon PV technologies, manufacturing advancements, and some limited manufacturing scale-up (initially driven by the German market). In the United States, regional markets with high energy prices (e.g. California, Hawaii, and New York) and constituent concerns over greenhouse gas (GHG) emissions took advantage of the increasingly competitive prices for solar PV by incentivizing its market penetration even further. Since 2009, the price for solar power has continued to fall, opening up more state markets for distributed solar PV, and fueling consternation among retail electric utilities that their revenues—and potentially their companies—are at risk of experiencing a “death spiral.”

The vast majority of American electric utilities have business models that are built on a foundation of revenue generated from the volumetric sale of electricity. The proliferation of solar PV is a direct threat to this traditional business model if the lost power sales (revenues) to one set of customers triggers the utility to raise prices for electricity sold to a shrinking pool of customers in order to sufficiently recoup the costs of providing service to all customers. Utilities fear that as they increase their costs, more of their customers will find solar PV cost-effective, diminishing utility loads further and increasing costs for remaining customers—which then triggers a new round of load defection, revenue loss, and price increases. At a certain point, if the utility does not change its business model, the company is forced into bankruptcy. This scenario, especially when viewed in parallel with steadily falling solar system costs, has been a significant catalyst for the evaluation of the costs and benefits of solar NEM programs.

**TYPES OF COST/BENEFIT EVALUATIONS**

There are several commonly used approaches for evaluating the costs and benefits of investments made by electric utilities. Many of these evaluations are commonly used to assess energy efficiency and other demand-side management investments, in particular. Listed below are descriptions of each type of evaluation, along with short definitions (from the Midwest Energy Efficiency Alliance).[[4]](#footnote-4)

* **Total Resource Cost (TRC)**: The TRC measures whether the total costs of energy in the utility service territory decreases or increases.
* **Program Administrator Cost Test (PACT), Utility Cost Test (UCT), Utility Resource Cost Test (URCT)**: These tests evaluate whether or not the cost to the utility/program administrator will likely increase.
* **Participant Cost Test (PCT)**: The PCT examines whether or not the participants benefit over the measure life and they examine benefits and costs from the perspective of the customer installing the measure.
* **Societal Cost Test (SCT)**: The SCT examines the total impact on society (rather than focusing on end-users/participants, programs, or utilities).
* **Rate Impact Measure(RIM)**: The RIM examines whether or not utility rates will increase based on the effects from a specific action, policy, program, or investment.

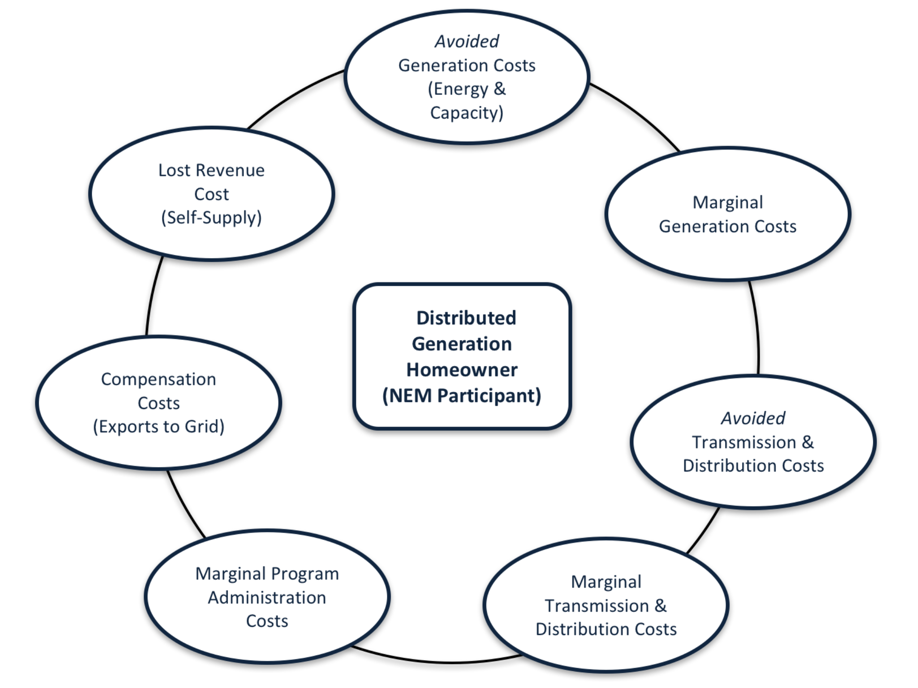


Figure 1: Typical costs and benefits included in a RIM test.

In our efforts to pursue findings that could inform the debate over the potential cross-subsidization of NEM participants by non-NEM participants, we purposefully focused our efforts on the exploration of analyses that focused directly on the determination of net rate impacts. While this proved to be a helpful screening practice, especially in the face of a large list of reports to review in a bit of a mad-dash fashion, it also proved to be limiting (see recommendations for further study, below).

**COST/BENEFIT REPORTS USED FOR THIS META ANALYSIS**

There have been many studies published in the United States over the past decade that have attempted to calculate and communicate the costs and benefits of solar PV systems that are enrolled in NEM programs. Because our investigation is focused on more fully understanding the potential *cost-shifts* from NEM program participants to non-NEM program participants, many of the existing studies fell outside the scope of this study. Many studies, for example, were focused on articulating the value of solar, but had little if any focus on costs. Other studies were focused on total resource costs and impacts to utilities, placing them similarly out of scope for any focused examination on cost-shifts associated solar PV NEM programs. Subsequently, our evaluation utilized the following studies, articulated below by state, year, and authoring institution, which incorporate RIM tests as part of their investigations:

1. Arizona, 2013 (Crossborder)
2. Arizona, 2016 (Crossborder)
3. California, 2010 (E3)
4. California, 2013 (Crossborder)
5. California, 2013 (E3)
6. Colorado, 2013 (Xcel)
7. Colorado, 2013 (Crossborder)
8. Louisiana, 2015 (Acadian)
9. Massachusetts, 2013 (LaCapra, Meister, & Cadmus)
10. Mississippi, 2015 (Synapse)
11. North Carolina, 2013 (Crossborder)
12. Nevada, 2014 (E3)
13. Nevada, 2016 (E3)
14. New York, 2012 (NYSERDA)
15. Vermont, 2014 (Vermont Dept. of Public Service)

**FINDINGS**

Below is a capturing of data from thirteen reports produced to inform NEM policy revision efforts in nine U.S. states, between 2010 and 2016. We have also attached the raw meta analysis as Appendix A, below.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Total Cost or Benefit ($/Year)** | **Total Cost or Benefit ($/kWh)** | **Total MW** |  | **Included in RPS?** | **Societal Benefits Included** | **Time Horizon of Value Est.?** | **Export +Self Supply or export only** | **Avoided T & D costs?** |
| **AZ 2013 (Crossborder)** | $34M | $0.08 | 431 |  | Yes | Yes | 20 | Export only + Self Supply | Yes |
| **AZ 2016 (Crossborder)** | N/A | $0.119 | N/A |  | Yes | Yes | 20 | Export only + Self Supply | Yes |
| **CA 2010 (E3)** | -$20M | $-0.12 | 386 |  | No | No | 20 | Export only | Yes |
| **CA 2010 (Crossboarder)** | $92.2M | N/A | 5,262 |  | No | Minimal | 20 | Export only | Yes |
| **CA 2013 (E3)** | -370M (E) -1.18B (all) | -$0.12 -$0.15 | 1,300 |  | No | No | 20 | Export +  Self-Supply | Yes |
| **NV 2014 (E3)** | $64M | $0.01 | 50 (existing) 234 (future) = 284 |  | Yes | No | 25 | Export +  Self-Supply | No |
| **NV 2016 (E3)** | -$36M (existing) -$15M (future) | -$0.08 -$0.04 | 265 (existing) 265 (future) = 530 |  | Yes | No | 25 | Export +  Self-Supply | Yes |
| **LA 2015 (Acadian) - 1 Existing** | N/A  -$89M (lifetime) | N/A | 42 |  | No | No | 35 | Export +  Self-Supply | Yes |
| **LA 2015 (Acadian) - 2 @ Cap** | N/a -$125.54M (Lifetime) | N/A | 78 |  | No | No | 35 | Export +  Self-Supply | Yes |
| **LA 2015 (Acadian ) - 3 No Cap** | N/a -$488.26M (lifetime) | N/A | 494 |  | No | No | 35 | Export +  Self-Supply | Yes |
| **MS 2014 (Synapse)** | $27M/mWh | N/A | N/A |  | No | No | 25 | Export +  Self-Supply | Yes |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Total Cost or Benefit ($/Year)** | **Total Cost or Benefit ($/kWh)** | **Total MW** |  | **Included in RPS?** | **Societal Benefits Included** | **Time Horizon of Value Est.?** | **Export +Self Supply or export only** | **Avoided T & D costs?** |
| **NC 2013 (Crossborder) - 1 DEC** | N/A | $0.034 | N/A |  | No | No | 15 | Export +  Self-Supply | Yes |
| **NC 2013 (Crossborder) - 2 DEP** | N/A | $0.018 | N/A |  | No | No | 15 | Export +  Self-Supply | Yes |
| **NC 2013 (Crossborder) - 3 DNCP** | N/A | $0.034 | N/A |  | No | No | 15 | Export +  Self-Supply | Yes |
| **VT 2013 (PSD)** | N/A | $0.009 | N/A |  | N/A | No | 20 | Export +  Self-Supply | Yes |
| **MA 2013 (La Capr, Meiste, & Cadmus)** | N/A -$500-933M Lifetime | N/A | 1600 by 2020 |  | Yes | Yes | 25 | Export +  Self-Supply | No |
| **NY 2012 (NYSERDA)** | N/A -$3.48B Lifetime | N/A | 5000 by 2025 |  | Yes | Yes | 25 | Export +  Self-Supply | Yes |

Figure 2: Data summary of cost-benefit analyses undertaken between 2010 – 2016

Unfortunately, variations in problem statements, methodology, and reported data in the studies, above, created significant challenges in conducting a meaningful meta analysis. Most importantly, only 12 of 19 studies reported net impacts as $/kWh; others reported total net impact over the lifetime of specific installation vintage groups (sometimes categorized according to historical and future; other times organized according to changes in NEM policy, and still other times according to existing NEM cap targets). And, of those 12 studies that did report results using $/kWh, 11 were conducted by either E3 or Crossborder. Subsequently, the most “significant” finding, according to our data analysis, was that Crossborder Energy typically determined benefits that were $0.015 higher than the E3 studies.

The data also indicates that states that counterfeit distributed generation output toward the achievement of renewable portfolio standards (RPSs) showed an increase in net benefits of $0.086/kWh. Here, most studies showed in increase in benefits due to the effect of diminishing the total cost of renewable resource acquisition. Interestingly, the Nevada reports stood out by interpreting this typically acknowledged benefit as a marginal cost. From their perspective, if resource acquisition decisions were made centrally, by the utility, the acquisition would have been much cheaper. As utility-scale solar costs fell, the marginal costs of adding distributed solar grew, eventually turning Nevada’s total NEM impact from a net benefit (2014) to a net cost (2015).[[5]](#footnote-5) According to NV Energy, the shift from net benefit to net cost occurred when solar acquisition costs fell to $80/mWh. NV Energy projected net costs (under the original NEM policy) to exceed $500 million when utility-scale solar costs reach $50/MWh.[[6]](#footnote-6)

In addition to the findings, above, what else can we report in regard to our original queries? Obviously, our first pass at an analytical interpretation of the data above didn’t bear much fruit. That said, we did learn a few things from reviewing the larger contextual corpus of materials included in the bibliography—some of which can help us prime our future research to enable more meaningful observations and conclusions.

One of our stated goals was to gain a better understanding of the most significant sensitivities driving the study conclusions. Beyond Crossborder typically finding more benefits than E3 (something that we didn’t necessarily need data crunching to tell us), did we accomplish this goal? The answer is clear to us that, likely due to the way in which we framed our research, is no. While it is true that we learned about many different kinds of sensitivities that *could* impact the net totals in the reports, above, we do not feel that we achieved clarity in regard to the “most significant” of those sensitivities that *do* impact the net totals.

The second stated goal of our research was to come to some conclusion of our own in regard to the primary question being posed by the studies: Do solar net metering policies cause a shifting of costs from NEM participants to non-NEM participants? Here, it certainly *seems* as though the cost-shift hypothesis has some validity to it—especially for those NEM programs that offer compensation levels that are greater than the total avoided costs stemming from any NEM program. That said, cross-subsidies are not new and aren’t always a bad thing, when viewed from a societal perspective. The best example is, of course, the long-fought but eventually accepted urban rate payers’ cross-subsidization of rural rate payer services. Yes, there was certainly a total net cost associated with rural electrification; however, society has clearly been the better for it and has accepted it as a worthwhile investment for a long time.

A more poignant takeaway, from a larger contextual evaluation, reveals something potentially more important. The bigger picture that a review of all of these NEM valuation studies conveys is an oft-repeated one: these forecasts are problematic. All of the valuation studies suffer from some of the same assumptions:

* the distributed PV systems will continue to perform as they have historically been configured to;
* new technologies will not be integrated into NEM solar PV systems; and
* system peaks will largely remain the same.

This is very likely not to be the case, making every one of the studies seem a bit detached from reality. For example, it is getting increasingly difficult to imagine the trend of falling prices for distributed battery storage (along with their increasing power density) stopping or reversing any time soon—especially considering the ongoing transition of the transportation sector move toward electric vehicle production.

The blind eye that every one of the studies gave toward the integration of battery storage is interesting to consider. To be fair, from 2010 through 2013, it wasn’t quite as apparent that battery storage technologies would gain as much market attention as they would come to. Of course, one of the biggest drivers pushing the battery market forward was the NEM policy debates themselves. The more that the nation’s retail utilities pushed to reform NEM compensation, the more solar companies were incentivized to pair up with battery storage companies. After all, if the primary business proposition solar companies had to offer end-users (that they could use the local NEM policy to pay off their systems and then enjoy the benefits of reduced bills for decades) was threatened, a secondary business proposition needed to be secured as a backup plan. The solar-plus-storage combo can offer customers the optional value of self-supply if NEM compensation policies are drastically changed. And, ultimately, widespread movement toward self-supply threatens utility revenues potentially even more than NEM policies—since the load defection-driven revenue impacts are likely to be higher.

Additionally, the proliferation of both stationary and mobile storage across distribution systems is likely to make retail loads less peaky—especially if policies are responsive to their market penetration. Subsequently, peak forecasts developed by utilities like NV Energy, who ramped up their fixed charges in part to account for their long-term obligations to provide peak capacity support (at existing levels), are likely overestimated.[[7]](#footnote-7) And, not only are retail utilities’ marginal capacity estimates probably set too high in their long-term forecast, their avoided transmission and deferral (T&D) costs are all probably low. Utility culture is very slow to accept new technology and new business practices—especially when it comes to replacing or deferring large capital T&D investments that they can earn a guaranteed rate of return on with NEM-based investments that they either can’t or are much more modest.

Even more ironic is the realization that the more that utilities succeed at driving down NEM compensation levels for power exported from distributed generation systems (from retail toward wholesale), the more the those same utilities are helping to create the conditions for a peer-to-peer energy trading market to develop. While much of the intent is framed with the rhetoric of concern over cost shifts, the real threat is lost revenue from decreased volumetric sales. The same companies trying to maintain their status quo business models are likely the ones speeding up the conditions for their own demise—unless they successfully pivot their business model to include the provisioning of services (like selling solar PV, batteries, energy management, etc.). Ultimately, it seems like we’re observing a situation where even when utilities might appear to succeed in their efforts to reduce NEM compensation, they are likely undercutting their business over the long haul.

**LESSONS LEARNED (RECOMMENDATIONS FOR FUTURE RESEARCH)**

Recommendations

1. Expand the scope of the meta analysis to include more than RIM tests.
2. When available, enhance contextual understanding by including data/source material regarding final NEM policy decisions made at the PUC level. (What data was used for the final determination of policy?)

Perhaps the most significant lesson learned from this short sprint of research is that a comprehensive meta analysis of the costs and benefits of solar PV-based NEM systems (in regard to rate impact) would be strengthened by the inclusion of more studies—even if they were limited to focusing on just one element of costs and/or benefits. Our somewhat myopic focus on RIM studies had the effect of removing much of the context of the larger debates occurring within each state as NEM policies came under review—and parties from all sides submitted studies to inform costs or benefits calculations (or both). Not all parties to these state-level debates over NEM policy had the budgets, time, or resources to invest into the development of a massive study (similar to California’s investment into the quite extensively scoped E3 studies). Instead, many parties focused on the provision of data for a smaller subset of costs and/or benefits—sometimes as a rebuttal of the findings contained in another report submitted to the same policy venue.

Even though they don’t directly address cross-subsidization between rate payers, these smaller studies offer an opportunity to better evaluate the findings of each study by comparing the individual components/sub-elements against other relevant studies. Focusing a portion of future research on the comparison of data at the component level could provide additional opportunities to make observations on whether a particular study’s findings are within the “normal” boundaries of estimation or not. Regardless of whether one is investigating estimates of avoided generation costs, avoided T&D costs, or other sub-elements contributing to rate impacts, having access to a larger data set can make for a much more informative comparative analysis.

In some states, like Nevada and California, decisions have already been made to reform NEM policy. For these states, it could prove fruitful to collect any evidence that shows what the final (PUC-level) evaluations considered when framing decisions or recommendations to a state legislature. If there is evidence available, how do *those* findings compare against the larger whole, against the state-level reports submitted in the state under consideration, or even against other formal PUC decisions? Do decision-makers favor certain approaches and assumptions over others? Comparing policy input studies against each other is one thing; comparing the actual numbers used to set policy is another altogether—especially considering the high-stakes for retail utilities, third-party solar installers, and the associated trade allies for both groups.

It is a bit disheartening to have to put this research on the shelf at this point, particularly since our experience to date has primarily been limited to familiarizing ourselves with the range of studies undertaken across the United States and the context surrounding (at least some of) them. The underwhelming nature of our first round of observations is matched only be the reality that our time is up…just at the point when we are finally starting to get a better idea on how to approach this work on the next pass. Consider this draft an early down payment on a larger purchase.

**APPENDIX A: Meta Analysis**

Formula:

**Benefit/Cost $PkWh = Beta0 + Beta1 (InRPS) + Beta2 (Export) +Beta3 (Author) + E**

The meta analysis shown in figure 1 focuses on the per kWh cost or benefit of each individual study as our dependent variable while using InRPS, Export and Author as our independent variables. The variable $PkWh was used rather then the total cost/benefit dollar value or total mega watts because it is less likely to be skewed based on the sizes of the area each study gathers data. Our three independent variables were plucked out based on a complete comprehensive understanding of the entire body of studies that we felt could have the most significant sensitivities on the final outcome of the studies in total.

Out of 19 studies chosen for inclusion of the meta analysis, only 12 had $/kWh broken out. This is a significant decrease from the total studies we evaluated but only slightly less then the number of studies that included total benefit/cost dollar value, which were 14. Of the 12 studies only two types of authors had a significant amount of data to be included (E3, Crossborder). In total there were 6 E3 studies and 5 Crossborder studies included in our data set. Both InRPS and Export had all of the data points for 11 studies included in this analysis.

At first glance, our three variables do a pretty good job explaining the variations in $PkWh based on 93 % R-Squared. Looking further at our data, on average, the E3 studies cost to ratepayers comes in at $-0.12 kWh. Next, we focused on RPS; if the studies including DPV as part of the utilities renewable portfolio standard (RPS) see an increase in the previous E3 averaged benefits by $0.086 per kWh. This is a good example of a sensitivity we were looking for as it has a pretty significant effect on the data. In comparison, Export or Export plus self-Supply is a sensitivity the data seems to indicate that we can skip over as it has little to no significant effect on our data. This, however, is likely only because the majority of the studies counted both exports and self-supply. With self-supply accounting for such significant revenue loss, its inclusion has a significant impact on individual studies—just not with our initial data set.

Finally, we come to the differences between the E3 studies and the Crossborder studies. The Crossborder studies come in at a $0.15/kWh benefit increase over the average of the E3 reports. This is a very significant margin and the largest sensitivity we see in the data. Shown more clearly in figure 2 we see the points of the E3 studies listed in row one, Crossborder in row 2 and the one study from Vermont in row 3. The E3 studies plots fall more on the left side of the graph that represent a $PkWh cost to ratepayers where as the Crossborder studies fall on the right side representing a $PkWh benefit to ratepayers.

Residuals:  
## Min 1Q Median 3Q Max   
## -0.038333 -0.012083 0.001667 0.008333 0.051667   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -0.12000 0.02868 -4.184 0.00412 \*\*   
## InRPSTRUE 0.08583 0.01851 4.636 0.00238 \*\*   
## ExportExportSelf -0.00750 0.03333 -0.225 0.82836   
## AuthorCrossboarder 0.14917 0.01851 8.057 8.71e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.02868 on 7 degrees of freedom  
## (8 observations deleted due to missingness)  
## Multiple R-squared: 0.9262, Adjusted R-squared: 0.8945   
## F-statistic: 29.27 on 3 and 7 DF, p-value: 0.0002471

Figure 1: Summary of Meta Analysis

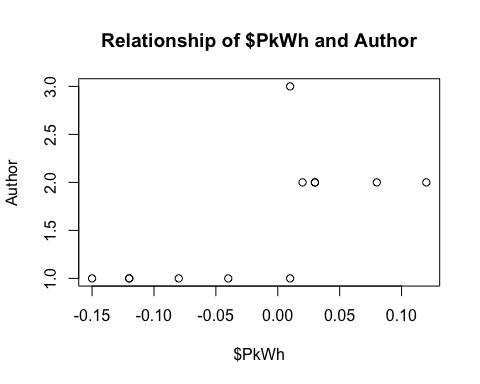


Figure 2: The relationship of $/kWh and Authors

**Residuals vs Fitted**

The Residuals versus Fitted plots diagram is a good way for us to tell if our data is linear and check for outliers of the data set. Looking at our plots in figure 3 we can see that they bounce rather randomly around zero. The line looks relatively flat and holds around zero as well. This is a pretty good indicator that we have a linear relationship between our variables. It also seems that we 3 outliers in the data labeled by plots 1, 7 and 8. The three outliers are a bit concerning as they make up almost one forth of the data however it is nice to see that they are evenly spaced across the whole graph.

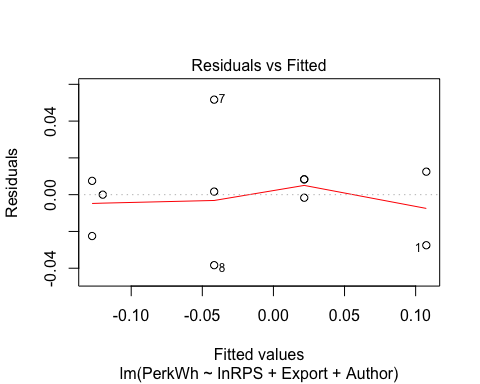


Figure 3: Residuals vs Fitted Plot

**APPENDIX B: ANNOTATED BIBLIOGRAPHY**

Edison Electric Institute, *Solar Energy and Net Metering*, Oct. 24 2016, <http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf>

The Edison Electric Institute is an organization that represents American electric utilities. This position paper provides a formal representation of the utility perspective in regard to net energy metering policies. It is useful in regard to the positions and rhetoric of electric utilities but it does not have usefully data for use in our study. It’s value is limited to context.

Gideon Weissman and Brett Fanshaw, for Environmental America Research and Policy Center, *Shining Rewards: The Value of Rooftop Solar Power for Consumers & Society, 2016 Ed.,* Oct. 2016,<http://environmentamerica.org/sites/environment/files/reports/AME%20ShiningRewards%20Rpt%20Oct16%201.1.pdf>

This review of solar valuation studies is unabashedly pro-solar and is aimed at U.S. state policy makers (and those that lobby them). After reviewing 16 studies, the authors report that 12 studies made determinations of net benefits, while also pointing out that 3 of the remaining 4 that found net costs were funded by electric utilities. It is probably telling that the study scope did not include many of the state reports that we have found in our preliminary research, including the majority of those conducted in WECC states. Problems aside, it does offer some interesting information and ideas on how to categorize and visualize the findings associated with costs and benefit studies, along with a high level summary of the takeaways from the reports that they analyzed.

North Carolina Clean Energy Technology Center, *The 50 States of Solar: Q1 2016 Quarterly Report*, April 2016, <https://nccleantech.ncsu.edu/wp-content/uploads/50-SoS-Q1-2016_Final.pdf>

The purpose of the report is to provide an up to date, unbiased reference for all interested parties of how states are choosing to handle policies associated with solar DG. It is updated on a quarterly basis by the North Carolina Clean Energy Technology Center a public service center administrated by the college of engineering ay North Carolina Sate University. The report focuses on several key questions that are facing the solar landscape to date. First, what changes to the traditional rate design futures and net metering police are being implemented? Second, what potential affects of policy or regulatory decisions have on solar DG?

Rocky Mountain Institute, *A Review of Solar PV Benefit and Cost Studies*, 2013, <http://www.michigan.gov/documents/mpsc/solar_pv_benefit_and_cost_studies_448376_7.pdf>

This review of solar valuation studies conducted in the United States explores a range of issues associated with categories, methodologies, and gaps associated with the costs and benefits of rooftop solar PV in order to “create a clear foundation from which additional work on benefit/cost assessment and pricing structure can be built.” The study warns about the high degree of variation (in existing solar valuation studies) in regard to local context, input assumptions, and methodologies—making any meta-analysis difficult without first normalizing the data. The most significant methodological gaps identified by the study include: value to distribution grids, grid support services, and financial, security, environmental, and social values.

**Arizona**

Black and Veatch, *Solar Photovoltaic (PV) Integration Cost Study*, Nov. 2012.

Black and Veatch prepared this study for the Arizona Public Service Company (APS) in order to help the utility prepare for the integration of solar PV projected through the 2020s. In particular, the study focuses on projected reserve requirements (timing, volume, and cost) needed to maintain reliability. This study envisions a future with no measurable storage technology uptake (that would otherwise help balance the variable output of solar PV systems).

Crossborder Energy, *The Benefits and Costs of Solar Distributed Generation for Arizona Public Service*, May 2013, <http://www.seia.org/sites/default/files/resources/AZ-Distributed-Generation.pdf>

Crossborder Energy prepared this study for the Solar Energy Industry Association in May 2013. The study took data from two previous studies prepared for a local utility called Arizona Public Service. One study was done in 2009 by R.W Beck and the other in 2013 by SAIC. The Crossboarder study used different methodology when coming to their conclusion. One of the main differences was the use of a 20 year snapshot of the benefits of DG rather than the 1 year used by the Beck and SAIC Studies. The study concludes that DG and net metering will provide the Arizona Public Service customers with $34 million in benefits per year.

SAIC [prepared for Arizona Public Service], *2013 Updated Solar PV Value Report,* May 2013, <https://www.azenergyfuture.com/getmedia/77708c68-7ca6-45c1-a46f-84382531bae3/2013_updated_solar_pv_value_report.pdf/?ext=.pdf>

SAIC prepared this study for a local utility called Arizona Public Service in May 2013. The SAIC report is an updated version of a study done by R.W. Beck, Inc. in 2009 that was also commissioned by Arizona Public Service. For the most part, the same methodology for valuing future solar projects in that report was also used in this study with one major difference being the new data that had been collected over the last several years was used. Compared to its predecessor, this study finds the value of Solar DG to be less then half of the 2009 study. Reasons for this include a reduction in the cost of power generation due to the decease in natural gas prices and the lower excepted cost of CO2 emissions due to a decrease in federal legislation.

Navigant Consulting, Inc., *Solar Project Return Analysis for Third Party Owned Solar Systems*, 2015, <https://www.azenergyfuture.com/getmedia/7bae619f-cc06-4724-9d6d-de6c862aa901/Navigant-TPO-Study.pdf/?ext=.pdf>

The Arizona Public Service commissioned their third solar valuation study in 2015. Navigant consulting out of San Francisco prepared it. This study differed from the previous ones by the fact it focused on the benefits of solar DG and net metering on the third party owned leasing solar businesses rather then the individual ratepayers. Focusing on the business models of the leasing companies, the research indicated that the companies choose to operate in areas where they can maximize their returns by undercutting utility offset rates. The overall concussion of the study is that the solar third parties owned lease companies have some room to adjust to changes in the rate structure at the same time sustaining returns.

Crossborder Energy, *The Benefits and Costs of Solar Distributed Generation for Arizona Public Service (2016 Update)*, Feb 2015.

This analysis was submitted as formal testimony filed in response to the Arizona Corporation Commission’s request for “proposals on how to value distributed generation resources in Arizona.” The filing argues that determining what is in the “public interest” requires cost-benefit analyses for all key stakeholders, including net metering/distributed generation participants (generators), non-net metered rate payers, and the utility system/society as a whole. Crossborder (that is, B. Thomas Beach) typically sees little difference between rate-payers and society as they are often practically indistinguishable under the current regulated monopoly paradigm.

**California**

Naim Dartmouth, Galen Barbose, and Ryan Wiser, Ernest Orlando Lawrence Berkeley National Laboratory, Environmental Energy Technology Division, *The Impact of Rate Design and Net Metering on the Bill Savings from Distributed PV Residential Customers in California*, April 2010.

LBNL produced this research in an effort to contribute to the continued evolution of policies aiming to compensate distributed generation producers for the electricity they export to the grid. The study is primarily focused on the costs and benefits associated with residential owners of solar PV in the PG&E and SCE service territories. The authors do not pursue any examination of costs and benefits for other rate payers, utilities, or society. They do, however, examine alternative approaches to net metering.

California Public Utility Commission, Energy Division and Energy and Environmental Economics, Inc., *Introduction* and *Net Energy Metering Cost-Effectiveness Evaluation*, March 2010, <http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=4290>

The CPUC commissioned this study by E3, limiting the scope to focus on costs and benefits of “grid exports” from homeowners to the grid; however, it does not explore the extent to which NEM program participants pay any share of utility costs. The report explains the lack of attention to non-exported (self-consumed) solar generation by rationalizing that those benefits would exist with or without the NEM program (which raises the question of just how much solar we would have witnessed in CA by 2010 *without* NEM—likely a sizable difference).

Crossborder Energy, *Evaluating the Benefits and Costs of Net Metering in California,* Jan. 2013.

This study, funded by Vote Solar, was offered as a rebuttal to E3’s 2010 analysis. The authors point out some significant differences that have developed between assumptions and reality. In particular: tiered rates were collapsed from five to four (a $10/kWh difference), retail utility rates failed to increase as drastically as expected, renewable costs fell, and called out need for high NEM program administration costs to be addressed. Found 80+ percent of cost shift was driven but PG&E residential customers, with 70+ percent of the costs attributed to the highest tier.

Energy and Environmental Economics, Inc., *California Net Energy Metering Impacts Evaluation*, Oct. 2013, <http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=4292>

The California Public Utility Commission (CPUC) funded and oversaw E3’s execution of this cost-benefit study of net energy metering (NEM) in the state, evaluating the program at the capacity levels that were established in order to achieve the goals of the CA Solar Initiative and the 5 percent NEM program cap. Conducted as a formal update to the CPUC’s 2010 report, but with an expanded scope of query, the study’s driving pursuit is clear: “Who benefits from, and who bears the economic burden, if any, of the NEM program?” As with the CPUC’s 2010 study, it does not attempt to evaluate societal benefits from clean energy sources, instead referring readers to the CA Energy Action Plan for the results of earlier analytic endeavors.

**Colorado**

Xcel Energy Services, *Costs and Benefits of Distributed Solar Generation on the Public Service Company of Colorado System*, May 23, 2013.

This study, prepared in response to ongoing policy development by the Colorado Public Utilities Commission, examined the costs/benefits of 140 MWs of solar PV on the Public Service Company of Colorado’s power supply system (by the end of 2014). The analysis does not treat the impacts to distributed generation owners, non-distributed generation owners, the state, program, or society at large.

Crossborder Energy, *Benefits and Costs of Solar Distributed Generation for the Public Service Company of Colorado: A Critique of PSCo’s Distributed Solar Generation Stud*y, Dec. 2, 2013.

In this report, released as a rebuttal to the 2013 Xcel report, above, Crossborder attempts to articulate the costs and benefits stemming from distributed solar PV to PSCo’s power system. It does not evaluate the impacts to owners of those solar PV systems or non-solar PV owners. Interestingly, the report points out that the avoided costs identified in 2013 were essentially the best that would ever be observed, since the value of additional solar, over time, will be (incrementally) worth less. This is likely only to come to pass if storage technologies fail to penetrate the market in any substantial form. Solar, combined with other energy technologies/solutions such as batteries, energy management, electric vehicles, and smart appliances, could substantially change the existing load shapes that in turn shape market conditions.

**Louisiana**

Acadian Consulting Group, *Estimating the Impact of Net Metering on LPSC Jurisdictional Ratepayers*, Feb. 27, 2015.

Prepared for the Louisiana Public Services Commission, this study provides a basic overview of distributed generation interconnection and net metering policy in the United States. It also provides a high-level overview of several solar cost-benefit studies, though it doesn”t analyze them in any kind of meta analysis. The study, itself, is broken into three buckets of analysis: total systems installed to date, total systems installed at the present NEM cap, and total installations by 2020 with no cap.

**Massachusetts**

La Capra Associates, Sustainable Energy Advantage, Meister Consultants Group, and Cadmus, *Task 3b Report: Analysis of the Economic Costs and Benefits of Solar Program,* September 30, 2013.

This study was prepared for the Massachusetts Department of Energy Resources to evaluate the costs and benefits associated with a projected installation target of 1,600 MWs by 2020. The study is focused primarily on impacts to rate payers and the statewide economy (although analysis on jobs impact is not undertaken).

**Mississippi**

Synapse Energy Economics, *Net Metering in Mississippi: Costs, Benefits, and Policy Considerations,* Sept. 19, 2014.

This report, prepared for the Public Services Commission of Mississippi, examined the potential impact of a net metering policy in Mississippi—which currently does not have net metering.l. Interestingly, the report argues strongly against the counting of lost revenue as a cost created by NEM installations. “Sunk costs should not be used to assess future resource investments because they are incurred regardless of whether the future project is undertaken. Consequently, the application of the RIM test is not valid for analyzing the efficacy of net metered or distributed resources as it is a violation of this important economic principle.” (pp. 33-34.). The study found that avoided energy costs held the largest share of benefits, followed by avoided T&D.

**Missouri**

Missouri Energy Initiative, *Net Metering in Missouri: The Benefits and Costs*, Winter 2015.

The MEI’s effort is an example of what a university project with green researchers and limited ties to the utility industry (and their data) can produce. The content is very light, and at one point they actually claim “there are only a few studies [of the solar cost-benefit variety] that exist so far”—written in 2015. They also point out that “the results are not meant to be representative of the actual costs the utilities or ratepayers may incur…MEI is simply working to expand the understanding of this complicated topic [to some university students, primarily, I think].

**Nevada**

Energy and Environmental Economics, Inc. *Nevada Net Energy Metering Impacts Evaluation*, July 2014, <http://puc.nv.gov/uploadedFiles/pucnvgov/Content/About/Media_Outreach/Announcements/Announcements/E3%20PUCN%20NEM%20Report%202014.pdf>

This E3 study was commissioned by the Nevada Public Utilities Commission with the goal of examining the impact of NEM participating solar systems put in place through 2016. The study is broken into three parts: cost-benefit analysis, macroeconomic impacts, and demographic comparison of NEM and non-NEM participants. For our work, two portions of the cost-benefit analysis are particularly helpful: the measure of ratepayer impacts and the societal cost test. Interestingly, the societal value is found to be nil, due to the explanation that utility-scale solar is cheaper. Every kWh produced from rooftops diminishes the utility’s need (under Nevada’s renewable portfolio standard) to produce a kWh from a utility-scale renewable resource, which is less expensive, so the net costs to the utility are higher and the societal good is deemed nullified because an equivalent, cheaper, substitution is available.

NV Energy, *Application of Nevada Power Company d/b/a NV Energy for Approval of a Cost of Service Study and Net Metering Tariffs, Vol. 2 of 2*, Electronic Filing to the Public Utilities Commission of Nevada, submitted July 31, 2015.

NV Energy submitted this rate filing in 2015, with as much bravado as you might ever see in one of these filings—announcing the creation of a new partial customer class for NEM participants and their response to the solar industry’s calls for more certainty for solar. The changes amounted to the addition of an escalating monthly fixed fee, the reduction of NEM payments from retail to wholesale, and the retroactive application of the new rates to existing NEM participants. “To be clear, however, customers who choose to install renewable distributed generation can reduce their Nevada Power bill under the NEM2 rules and rates, even though a customer who installs renewable distributed generation might end up paying more for energy when the cost of buying or leasing the system, or purchasing the output of the system is taken into consideration.” (p.6). Yep. No participant cost test needed, here, thanks.

Energy and Environmental Economics, Inc., *Nevada Net Metering Impacts Evaluation 2016 Update,* Aug. 2016, <http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2016-8/14264.pdf>

In Nov. 2015, the NV Energy (and the Nevada PUC) caused a shitstorm of protest across the state when they modified the state’s NEM rules by ramping down payments to participants for their grid exports (moving payments from retail to wholesale levels), instituted a significant monthly charge to solar customers (moving from ~$7 to ~37 per month over a series of five or so years), and then made the policy retroactive for all existing NEM participants. A class action suit was immediately filed by those who felt betrayed by the state so soon after investing into solar systems that the state had incentivized. The primary purpose of this particular study was to explore the cost of grandfathering in existing NEM participants. The secondary purpose was to demonstrate evidence of a cost-shift from solar to non-solar utility customers. The study excludes the counting of any distribution benefits from solar PV, and like the 2014 study, this report also nullifies any emissions benefits as being easily replaceable by utility-scale solar.

Solar City and NRDC, *Distributed Energy Resources in Nevada: Quantifying the Net Benefits of Distributed Energy Resources*, May 2016.

This report, by two obvious proponents of solar power, was developed as part of the response to Nevada’s (widely acknowledged) drastic changes to the state’s net metering program in Nov. 2015. By the time this report was released, SolarCity (along with two other major solar installers) had packed up their operations and abandoned the Nevada marketplace. Not surprisingly, this study found net benefits accruing to Nevadans (as opposed to net costs reported by E3 and NV Energy), and the recommendations call for the treatment of utility bias toward utility-scale installations and the modernization of distribution planning processes (that currently do not acknowledge any grid-tied benefits accruing to distribution systems).

**New York**

New York State Energy Research and Development Authority (NYSERDA), New York Solar Study: An Analysis of the Benefits and Costs of Increasing Generation from Photovoltaic Devices in New York, January 2012.

NYSERDA developed this analysis in response to legislative direction (the Power New York Act of 2011) to “evaluate the costs and benefits of increasing the use of solar PV in New York state to 5,000 MW by 2025.” The results showed net benefits if solar PV costs were to fall per the DOE Sunshot goals. However, the mid-cost (their base case) and high-cost scenarios resulted in net costs.

**North Carolina**

Crossborder Energy, *The Benefits and Costs of Solar Generation for Electric Ratepayers in North Carolina*, Oct. 18, 2013.

Prepared for the North Carolina Sustainable Energy Association, this Crossborder analysis looks at the solar NEM impacts on then rate payers of three investor owned utilities. Uses the PJM;’s methodology of estimating capacity factor seasonally, rather than annually. The authors point out one of the key advantages to solar DG: it can be installed fairly quickly and steadily build in impact, incrementally, as opposed to the “lumpiness” of central plant investment and implementation. The authors also point out that at some point, utilities will adjust to the new technology and integrate it into their planning processes—similarly to how energy efficiency and demand response were eventually adopted by many utilities.

**Vermont**

Vermont Department of Public Service, *Evaluation of Net Metering in Vermont (revised)*, 2014.

The 2014 Vermont Legislature directed the development of this research report, specifically requesting the evaluation of any cross-subsidy between NEM participants and non-NEM participants. The report does find small net benefits to both ratepayers as a whole and to society (with larger benefits accruing to society). Unlike many other NEM cost/benefit studies, the Vermont report addresses multiple types of distributed generation (not just solar) and also includes an evaluation of community-scale installations for both wind and solar.

1. Edison Electric Institute (2016); see Appendix B: Annotated Bibiliography for more details on shortened citations. [↑](#footnote-ref-1)
2. [Cite Louisiana, [↑](#footnote-ref-2)
3. Robert Verzola, “Net Metering History and Logic [part 2 of 3],” republished on *CleanTechnica,* Sept. 2015, from *Crossing Over: The Energy Transition to Renewable Electricity* (2015); <https://cleantechnica.com/2015/09/08/net-metering-progress-in-japan-california-hawaii-net-metering-history-logic-part-2/> (last accessed on Nov. 15, 2016). [↑](#footnote-ref-3)
4. Midwest Energy Efficiency Alliance, Definitions and Discussion of Benefit-Cost Tests, <http://www.mwalliance.org/node/3032> (last accessed on Nov. 15, 2016). [↑](#footnote-ref-4)
5. NV Energy’s 2015 cost of service study, that stood as the rational for its revised NEM policy, did not organize its data in a way that we could use for our meta analysis; however, it directly informed the state’s reformed NEM policy that was formalized in Nov. 2015—with disastrous results that continue to play out. [↑](#footnote-ref-5)
6. NV Energy, Nevada (2015), p. 10. [↑](#footnote-ref-6)
7. NV Energy, 2015 [↑](#footnote-ref-7)