

Net Metering in the States

A primer on reforms to avoid regressive effects and encourage competition



The Center for
Growth and Opportunity
at Utah State University

Net Metering in the States: A primer on reforms to avoid regressive effects and encourage competition

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Executive Summary

Net metering allows an owner of rooftop solar panels to participate in the electric grid as a distributed energy producer.¹ Solar panels first supply power to the home, and at times when the solar panel produces more power than the home is using the power is sent back onto the grid to be used by other customers. The meter “spins” backwards, subtracting the power sent onto the grid from the total power used by the consumer. That is how net metering gets its name—it means that at the end of the month the consumer is charged only for net electricity used.²

Policymakers enact net metering policies to encourage consumers to install rooftop solar by increasing the return on investment from solar panels. The justification for this is based on the potential benefits of having solar power as part of the grid.

A wealth of academic research on net metering, however, suggests that net metering is ineffective as an environmental policy and creates serious regressive effects. For example, compared to utility scale solar, distributed solar is an expensive means of lowering carbon emissions and can discourage other environmentally conscious choices.

Net metering also imposes a regressive cost-shift from solar adopters onto non-solar adopters. Although part of net metering’s appeal is its simplicity, when rooftop solar owners net to zero, that is, when they do not pay a bill because their production equals their consumption, they do not cover the costs of maintaining the wires and transmission lines. This cost-shift is estimated to be between \$45 and \$70 per month per rooftop solar owner that nets to zero. Wealthy households therefore benefit disproportionately from this hidden subsidy because they tend to be the ones who are able to pay the high upfront cost of installing solar panels.

We examine several reforms that reduce or eliminate the cost-shift without restricting an interested individual from installing solar panels. These include:

- Compensating homeowners who export electricity to the grid at the rate that producers receive (wholesale) rather than what consumers pay (retail)
- Reforming rate design to more closely reflect the types of costs that consumers impose on the grid
- Removing barriers to solar adoption, such as tariffs and burdensome regulations, that artificially increase the price of rooftop solar
- Restructuring electricity markets to allow more competition between electricity providers and provide retail choice to consumers

Electricity’s value is dependent on the time and place it is generated. The simple one-to-one retail rate that net metering relies on is an inefficient, regressive, and expensive way to advance environmental policy goals. Policymakers should consider these, and other reforms, to more accurately compensate the full costs and benefits of rooftop solar.

This paper first explains how electricity markets work, how net metering works, and then offers multiple suggestions for reform.

¹ Energy produced by many small-scale producers is termed “distributed energy” to distinguish it from energy produced by large-scale producers (sometimes called utility-scale producers).

² Rules differ from state to state on when and how rooftop solar owners and other distributed generation owners are paid. Some are done monthly while others are done annually.

How Electricity Markets Work

Most consumers get their electricity from a utility, which is a regulated public or private entity that sells electricity to energy consumers. Historically, a utility owned, operated, and maintained electricity generation, transmission, and distribution systems, the physical infrastructure of which generally consists of generating stations, wires, poles, transformers, meters, and control centers.

At the retail level, utilities are frequently granted exclusive monopolies by state and local governments to serve defined geographical territories. The justification for exclusivity is that it might be inefficient to reproduce the vast infrastructure required to generate and deliver power to consumers. Why build multiple power lines to the same destination when one will do?³ Such monopoly power is often created with the caveat that the utility is not allowed to behave like a monopolist by setting artificially high prices. Regulated monopolies generally must receive permission from state public utility commissions to raise prices and must show that current rates are not sufficient to cover the utility's costs in order to do so. Public utility commissions also scrutinize utility investments to ensure that new investments are prudent and previous investments remain used and useful.

The utility may operate its own generating facilities, including power sources like nuclear, coal, natural gas, hydro, solar, or wind. Utilities that own their power-generating inputs are referred to as vertically integrated utilities. In states with vertically integrated utilities, much of the power generation and distribution is performed by a single firm. The utility will provide generation services and then carry that power to its retail customers over wires that it maintains. Until a series of market restructurings across some states in recent decades, most US utilities were vertically integrated.⁴

Like any business, utilities try to sell power at prices above what they either produce or buy it for. This lower price is referred to as the wholesale rate, and the higher price at which the utility sells power to consumers is called the retail rate. The difference between the wholesale and retail rates allows the utility to cover the cost of managing and maintaining the grid and of ensuring an adequate supply of electricity at peak hours, as well as making a return on investment.⁵ The rate charged by regulated, vertically integrated utility companies is approved at public rate hearings by state public utility commissions.⁶

In states and regions with restructured wholesale markets, utilities are not vertically integrated. Instead, they serve only as distributors and resellers of electricity procured from other suppliers, not as producers. In restructured states, power producers must compete with each other to sell power at the lowest wholesale price to the utility (or utilities). The utility purchases the power, sends it through the distribution network, and then sells it to consumers and businesses at the other end of the line. The distribution network is composed of the local distribution lines, which are state regulated and owned, and transmission lines, which are federally regulated and owned by ISOs (Independent System Operators) over a specific region of the U.S.⁷ In some states, like Texas, utilities are granted a geographical monopoly only over the wires,

3 Regulatory Assistance Project, "Electricity in the US: A Guide," (March 2011):3-4, 8, accessed December, 4, 2017. <https://www.raponline.org/wp-content/uploads/2016/05/rap-lazar-electricityregulationintheus-guide-2011-03.pdf>

4 Regulatory Assistance Project, "Electricity in the US: A Guide," (March 2011):3-4, 8, accessed December, 4, 2017. <https://www.raponline.org/wp-content/uploads/2016/05/rap-lazar-electricityregulationintheus-guide-2011-03.pdf>

5 ISO New England, "Wholesale vs. Retail Electricity Costs," Wholesale vs. Retail Electricity Costs, <https://www.iso-ne.com/about/what-we-do/in-depth/wholesale-vs-retail-electricity-costs>. Edison Electric Institute, "Solar Energy and Net Metering," (January 2016), <http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf>. Steven Braithwait, Dan Hansen, Michael O'Sheasy, "Retail electricity pricing and rate design in evolving markets," *Edison Electric Institute*, (July 2007): 31, http://eei.org/issuesandpolicy/stateregulation/Documents/Retail_Electricity_Pricing.pdf.

6 ISO New England, "Wholesale vs. Retail Electricity Costs," Wholesale vs. Retail Electricity Costs, <https://www.iso-ne.com/about/what-we-do/in-depth/wholesale-vs-retail-electricity-costs>.

7 "Role of ISOs and RTOs." About the IRC, accessed February 01, 2018. <http://www.isorto.org/about/role>.

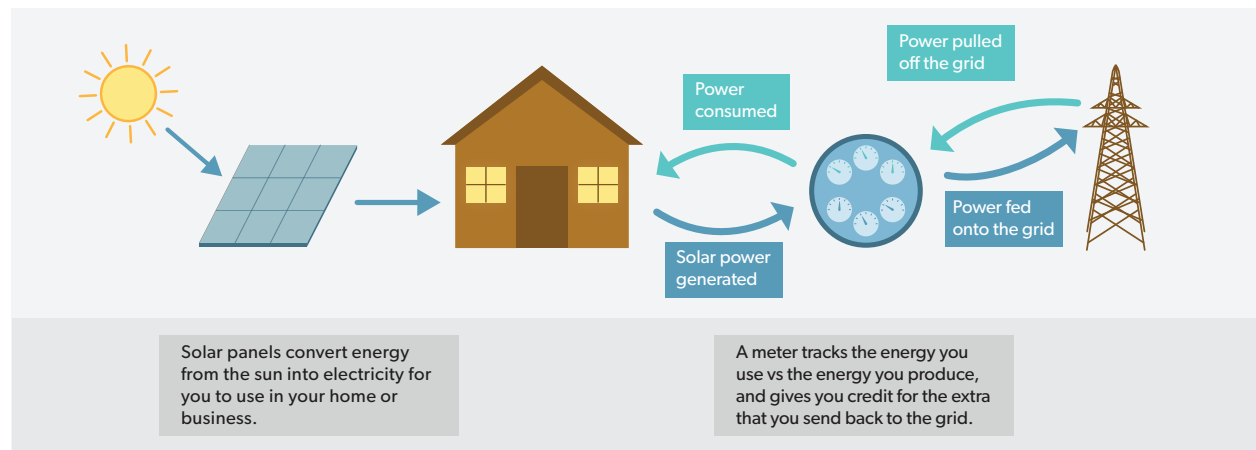
while customers can choose among competing electricity suppliers for the provision of the electricity that is delivered to them.⁸

How Net Metering Works

Net metering allows the owner of rooftop solar panels to participate in the electric grid as a distributed energy producer. A homeowner installs a solar panel on their roof and connects it to the grid through an electric meter and existing distribution lines.⁹ The solar panel first supplies power to the home. When the homeowner uses more electricity than their solar panel generates, at night, for example, the home draws power from the grid to make up the difference. The electricity meter records how much energy the home draws from the grid.

When the solar panels produce more power than the home is using, the power is sent back onto the grid to be used by other customers. The meter “spins” backwards, subtracting the power sent onto the grid from the total power used by the consumer. At the end of the billing cycle, often a month, the number of kilowatt hours recorded and subsequently charged to the homeowner is equal to the number of kilowatt hours drawn from the grid minus the number of kilowatt hours fed onto the grid. That is how net metering gets its name—it means that at the end of the billing cycle the consumer is charged only for net electricity used.¹⁰ This process is depicted in Figure 1 below.

Figure 1: How Net Metering Works



Net metering credits rooftop solar customers at the full retail rate for the electricity that their solar panels produce.¹¹ This effectively forces utilities to buy back the rooftop solar power produced at the retail rate rather than the much lower wholesale rate paid to mass electricity producers.¹² The wholesale rate reflects the generation cost typically paid to third-party generators, or the production cost paid by a vertically in-

8 Public Utility Commission of Texas, “FAQs,” <http://www.powertochoose.org/en-us/Content/Resource/FAQ>, (December 15, 2010). Note that not all of Texas’s electricity markets are restructured like this. Some areas function like the vertically integrated model.

9 Net metering can apply to other forms of distributed generation, like wind. Because, however, almost all net metering is done through solar, this paper will focus on solar.

10 Rules differ from state to state on when and how rooftop solar owners and other distributed generation owners are paid. Some are done monthly while others are done annually.

11 Edison Electric Institute, “Solar Energy and Net Metering,” (January 2016):6, <http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf>

12 Edison Electric Institute, “Solar Energy and Net Metering,” (January 2016), <http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf>. Steven Braithwait, Dan Hansen, Michael O’Sheasy, “Retail electricity pricing and rate design in evolving markets,” *Edison Electric Institute*, (July 2007): 31, http://eei.org/issuesandpolicy/stateregulation/Documents/Retail_Electricity_Pricing.pdf.

tegrated utility. Notably, net metering policy requires the utility to buy excess solar power at above-market rates.

State Policies to Compensate Rooftop Solar

Net metering is a common state-level policy. Currently, 37 states and Washington D.C. offer net metering while 11 states use a variety of other compensation methods. Idaho and Texas have voluntary policies adopted by individual utilities, but the policies differ between the two. Texas is a restructured electricity market while Idaho's net metering policies must be approved by its public utilities commission.¹³

Although important differences exist, state net metering policies can be broadly categorized in three ways based on how they compensate rooftop solar owners: at the retail rate, less than the retail rate, or more than the retail rate. Most states compensate rooftop solar producers at the retail rate, some do so at less than the retail rate, and others are considering paying more than the retail rate.

For example, Colorado currently pays rooftop solar owners the retail rate for each kilowatt-hour their panels feed onto the grid.¹⁴ On the other hand, Utah recently lowered its payments to nine cents per kilowatt hour—slightly less than the retail rate of about 10 cents per kilowatt hour that had previously been paid.¹⁵ Paying rooftop solar owners more than the retail rate has gained popularity and has recently been considered in at least three states.¹⁶ Minnesota authorized compensating rooftop solar owners at rates higher than the retail rate in lieu of net metering. As of March of 2018, however, no utilities in Minnesota had adopted the policy.¹⁷ We review how such policies work and point to unintended problems they create in the next section.

Some states, such as Arizona and Hawaii, have taken steps to mitigate the cost shifts incurred by using the retail rate to compensate solar panel owners.¹⁸ For example, the Arizona Corporation Commission, which manages the state's utilities, eliminated net metering in December of 2016 and now credits solar panel owners at the lower avoided cost rate instead.¹⁹ The avoided cost rate is the cost at which a utility would have to otherwise purchase or generate electricity itself.

The Regressive Effects of Retail Net Metering

A chief concern with net metering is that these state-level policies are *regressive*, a term that refers to policies that disproportionately help the wealthy, disproportionately harm the poor, or both. Net metering may be regressive in both of these ways.

Wealthier individuals are more likely to invest in rooftop solar. While the difference in adoption rates between upper and lower income groups is declining as solar panels become more affordable, the me-

13 "Idaho Power - Net Metering." Database of State Incentives for Renewables and Efficiency. (2016, October 27). <http://programs.dsireusa.org/system/program/detail/279>.

14 Database of State Incentives for Renewable and Efficiency, "Net Metering," (August 27, 2015), <http://programs.dsireusa.org/system/program/detail/271>

15 U.S. Energy Information Administration, "Table 5.6.A. Average Price of Electricity to Ultimate Customers by End-Use Sector," (December 1, 2017),

https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a; Emma Penrod, "Utah regulators approve end of net metering, beginning of new deal for Rocky Mountain Power solar customers," *Salt Lake Tribune*. September 29, 2017, <http://www.sltrib.com/news/2017/09/29/utah-regulators-approve-end-of-net-metering-beginning-of-new-deal-for-rocky-mountain-power-solar-customers/>.

16 Grow Solar. "Value of Solar Methodology", (2017) <http://www.growsolar.org/technical-assistance/value-solar-methodology/>. Hoff, Tom. "Is it rational for the value of solar to exceed existing average retail electricity rates?" (2014, June 19). <https://www.cleanpower.com/2014/can-value-of-solar-exceed-retail-rates/>.

17 Database of State Incentives for Renewables and Efficiency. "Value of Solar Tariff". March 19, 2018. <http://programs.dsireusa.org/system/program/detail/5666>; Taylor, Mike, "The Minnesota Solar Experiment — Value of Solar: Part III," *Renewable Energy World*, accessed December 26, 2016. <http://www.renewableenergyworld.com/articles/2016/12/the-minnesota-solar-experiment-value-of-solar-part-iii.html>.

18 Edison Electric Institute, "Solar Energy and Net Metering", (Jan. 2016). <http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf>.

19 Database of State Incentives for Renewables and Efficiency (DSIRE), "Net Billing", *U.S. Department of Energy*, May 30, 2017, accessed December 1, 2017. <http://programs.dsireusa.org/system/program/detail/3093>.

dian income of a solar adopter, according to an April 2018 report by the Berkeley National Laboratory, was still 54 percent higher than the median income of non-solar adopters, a difference of about \$32 thousand per year.²⁰ Other researchers have also found that subsidies for solar adoption disproportionately go to wealthier areas.²¹

Net metering may disproportionately benefit the wealthy. Investments in rooftop solar have not always financially benefited the solar adopters, but recent research on California's residential solar policies shows that investments in rooftop solar became a net benefit to the owners of the panels only in the last five years, depending on the billing methods used.²² Other investigations found rooftop solar provides net financial benefits to rooftop solar owners in only seven of the 19 studied states. Those states tend to have more abundant solar resources or higher electricity prices and largely depend on net metering being practiced in the state.²³ In other words, owners of rooftop solar panels, who tend to be wealthier than average, can financially benefit if their panels can generate large amounts of electricity, offset high electricity prices, or both.

Net metering can also disproportionately harm the poor. When utilities cannot recover the costs of grid maintenance that a customer with rooftop solar imposes on them, other users of the grid are forced to cover those costs.²⁴ These are cross-subsidies, which are subsidies from one type of user to another. In the case of net metering, cross-subsidies force non-solar customers to cover the portion of the grid maintenance costs not covered by rooftop solar owners. This is sometimes called a "reverse Robin Hood" effect because those households who cannot afford solar panels subsidize those who can afford them.²⁵ Additionally, because low-income individuals spend a greater proportion of their earnings on energy needs, they are disproportionately impacted by the costs of net metering's cross subsidy.²⁶

When a utility is forced to buy power from a solar customer at the retail rate, the utility is often unable to recover the costs of grid maintenance and management imposed by the residential solar customer. When few solar panel owners are connected to the grid, that might not present much of a problem. As the number of solar panel owners grows, however, revenue losses can become significant. This may force the utility to ask regulators for approval of higher electricity rates.²⁷

The fundamental source of the net metering subsidy is in retail rates consisting of only volumetric or variable charges. Many of the costs associated with serving electricity customers are fixed. In the case of a net zero bill, the net metered customer avoids paying all the fixed costs that they impose on the utility and those costs are then shifted onto non-solar customers. Consider an example of the cost-shifting effect of retail net metering. Net metered customers who produce the same amount of excess electricity as the amount they draw from the grid (a net zero bill) use the grid infrastructure at all hours but contribute nothing to the owner of the infrastructure (the utility) for its use. Customers who lack onsite energy storage, as most do, use the grid as kind of "storage" that provides them energy when their solar panels do not.

20 Barbose, Galen L, Naïm R Darghouth, Ben Hoen, and Ryan H Wisler. Income Trends of Residential PV Adopters: An analysis of household-level income estimates. 2018. Lawrence Berkeley National Laboratory. LBNL-2001146. Retrieved from http://eta-publications.lbl.gov/sites/default/files/income_trends_of_residential_pv_adopters_final_0.pdf

21 Vaishnav, P; Horner, N.; Azevedo, I. L. Was it worthwhile? Where have the benefits of rooftop solar photovoltaic generation exceeded the cost? *Environ. Res. Lett.* 2017, 12 (0) 1– 46 DOI: 10.1088/1748-9326/aa815e

22 Severin Borenstein, "Private Net Benefits of Residential Solar PV: The Role of Electricity Tariffs, Tax Incentives, and Rebates," *Journal of the Association of Environmental and Resource Economists* 4, no. S1 (September 2017, Part 2): S85–S122. <https://doi.org/10.1086/691978>

23 Vaishnav, P; Horner, N.; Azevedo, I. L. Was it worthwhile? Where have the benefits of rooftop solar photovoltaic generation exceeded the cost? *Environ. Res. Lett.* 2017, 12 (0) 1– 46 DOI: 10.1088/1748-9326/aa815e

24 Lisa Wood "Why Net Energy Metering Results in a Subsidy: The Elephant in the Room." *The Edison Foundation Institute for Electric Innovation*, (June 13, 2016), http://www.edisonfoundation.net/iei/publications/Documents/IEL_Net_Energy_Metering_June2016.pdf.

25 Ashley Brown and Jillian Bunyan. "Valuation of Distributed Solar: A Qualitative View." *The Electricity Journal* 27, no. 10 (Dec. 2014): 45-46. doi:10.1016/j.tej.2014.11.005

26 Dustin Chambers, Courtney A. Collins, and Alan Krause. "How Do Federal Regulations Affect Consumer Prices? An Analysis of the Regressive Effects of Regulation." *Public Choice*, (February 2016). doi:10.1007/s11127-017-0479-z.

27 Nevada already has seen a debate between NV Energy, a utility, and the Nevada Public Utility Commission over proposed rate increases. Riley Snyder, "NV Energy backs off proposed residential rate hike," *The Nevada Independent*, (November 28, 2017), <https://thenevadaindependent.com/article/nv-energy-backs-off-proposed-residential-rate-hike-designed-to-pay-for-rooftop-solar-program>.

The cross-subsidy for rooftop solar customers and other distributed generation technologies under retail net metering is substantial. A 2016 study estimated that when rooftop solar owners consume zero net energy from the grid, the cross-subsidy they receive to cover grid services can range from \$45 to \$70 per month, on average.²⁸ Other studies have estimated the costs of the cross-subsidy as well. In a 2013 analysis for the California Public Utilities Commission, the energy consulting firm Energy+Environmental Economics estimated that retail net metering in California could shift \$1.1 billion in costs annually by 2020 onto Californians not participating in net metering.²⁹

Net metering appears to be regressive both because its benefits fall disproportionately on the wealthy and because the poor bear the brunt of the cost. Fundamentally, this stems from how rooftop solar owners are paid for the electricity they feed onto the grid. Paying the retail rate for the electricity that rooftop solar panels feed onto the grid shifts costs from solar adopters to non solar adopters. Since the wealthy are much more likely to adopt solar than the poor, net metering often has a reverse Robin Hood effect.

Policy Alternatives to Net Metering

Given the problem of cost-shifting, the core policy question of net metering is this: How should owners of solar panels be compensated for the power they generate and send to the grid? Similarly, how should rooftop solar owners compensate the utility company, or other consumers, for their use of the grid?

Improved rate design is one way to avoid the cross-subsidies imposed by net metering. A 2015 quantification of cross-subsidies used a “reference network model” to design electrical grids and simulate 12 networks across the US under 8 scenarios of increasing solar use. In all networks and scenarios cross-subsidies existed.³⁰ Importantly, the cross-subsidy results when a single volumetric rate prevents a utility from making any distinctions between different consumers that impose different costs on the grid. Net metering allows the rooftop solar owner to pay only for the power they draw from the grid without paying for the cost of their grid connections, the cost of ensuring reliable service at peak hours, or the utilities’ administrative costs.³¹ These grid management costs are shifted to other customers. Improved rate designs that require customers to pay for their own costs would help mitigate regressive cross-subsidies.³²

Policymakers in different states have attempted to compensate rooftop solar and other distributed generation technologies by adopting a variety of policies that depart from traditional retail net metering. In some states, rooftop solar owners are compensated at the wholesale rate instead of the higher retail rate. Other states have proposed paying rooftop solar owners more than the retail rate because of its environmental benefits. Changing the rate structure by separating out different types of charges or varying the cost of electricity according to the time of use have also been proposed and experimented with on a small scale.

While there is likely no single rate structure that can perfectly capture all relevant costs and benefits, today’s net metering policies fail to appropriately account for even the well-established costs and bene-

28 Lisa Wood “Why Net Energy Metering Results in a Subsidy: The Elephant in the Room.” *The Edison Foundation Institute for Electric Innovation*, (June 13, 2016), http://www.edisonfoundation.net/iei/publications/Documents/IEI_Net_Energy_Metering_June2016.pdf.

29 Energy+Environmental Economics, Inc., “California Net Energy Metering Ratepayer Impacts Evaluation”, (28 October 2013): 6, http://www.cpuc.ca.gov/uploadedFiles/CPUC_Website/Content/Utilities_and_Industries/Energy/Reports_and_White_Papers/NEMReportwithAppendices.pdf.

30 Picciariello, A., Vergara, C., Reneses, J., Frías, P., & Söder, L. (2015). Electricity distribution tariffs and distributed generation: Quantifying cross-subsidies from consumer to prosumers. *Utilities Policy*, 37, 23-33

31 Edison Electric Institute, “Solar Energy and Net Metering,” (January 2016), <http://www.eei.org/issuesandpolicy/generation/NetMetering/Documents/Straight%20Talk%20About%20Net%20Metering.pdf>.

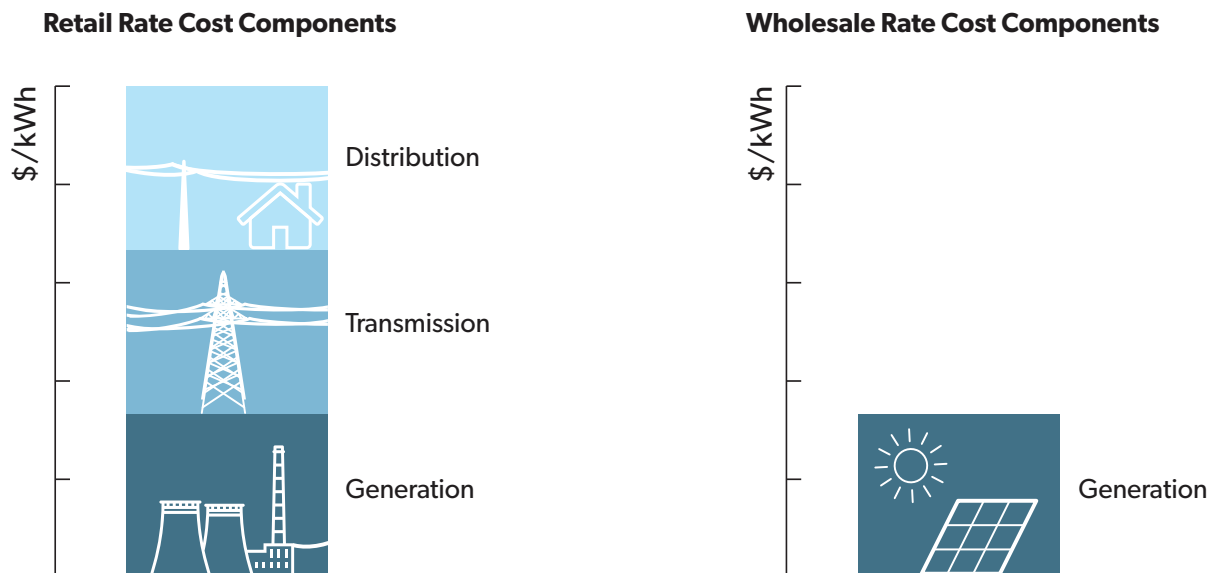
32 Energy Initiative Massachusetts Institute of Technology. (2015). “The Future of Solar Energy: An Interdisciplinary MIT Study”. P. 219-220. Retrieved from: <http://energy.mit.edu/wp-content/uploads/2015/05/MITEI-The-Future-of-Solar-Energy.pdf>

fits of solar power.³³ Reforms from rate design changes to electricity market restructuring are better able to account for the dynamic nature of the economy and the energy industry as well as the environmental benefits of distributed solar generation. Net metering unintentionally discourages investments in energy efficiency, is much less cost effective than utility scale solar, and can also discourage generation at times when the demand for electricity is highest.

Compensating at the Wholesale Rate

One of the simplest reforms for current net metering policies is to compensate solar power owners at the wholesale rate rather than the retail rate. One way to approximate a wholesale rate is to use an existing framework that was built 40 years ago to accommodate cogeneration facilities. The Public Utility Regulatory Policies Act of 1978 (PURPA) required states to establish an “avoided cost” rate that utilities would use to compensate facilities that provide power to the grid. The avoided cost rate, which is meant to reflect the cost that the utilities would have to bear to generate an additional kilowatt-hour of electricity, is part of each state’s implementation of PURPA and therefore a practical and administratively simple alternative to retail rate net metering.³⁴ Figure 2 shows a high-level breakdown of the costs included in each rate.

Figure 2: Retail Rate Components Compared to Wholesale Rate Components



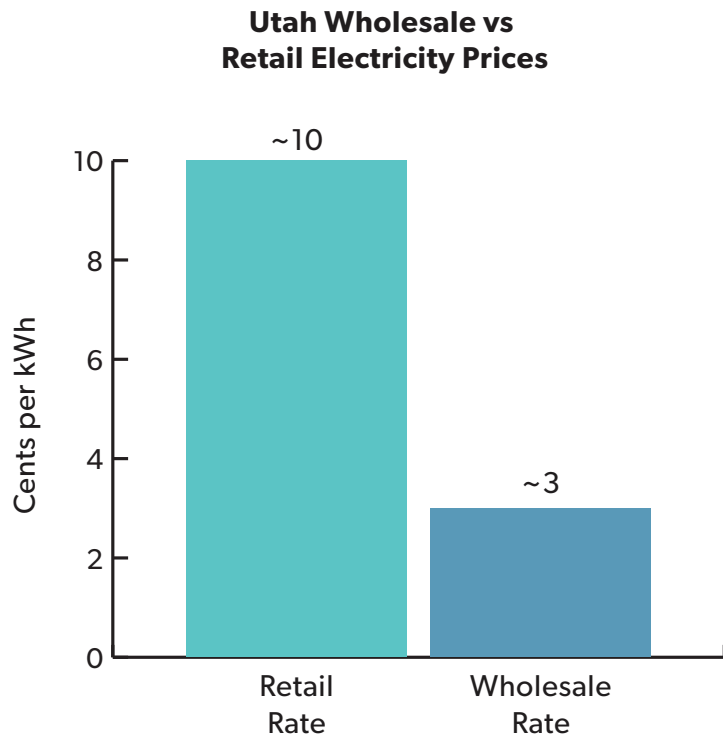
Because rooftop solar owners only contribute generation and do not provide or pay to support distribution or transmission services, compensating rooftop solar at the wholesale rate may be a simple alternative to retail rate net metering. For example, policies could tether compensation to actual market prices in organized wholesale markets. As electricity meters become smarter, customers have increased access to real-time prices in wholesale electricity markets. These prices more accurately reflect changing supply and demand conditions than a flat retail rate. In each case, the wholesale rate (on average) is significantly lower than the retail rate.

33 Brown, D. P., Sappington, D. E. M., (2017). Designing Compensation for Distributed Solar Generation: Is Net Metering Ever Optimal? *The Energy Journal*, 38, 3; L. Lynne Kiesling, “Alternatives to Net Metering: A Pathway to Decentralized Electricity Markets.” *R Street*. R Street Policy Study No. 52. (February 2016):17. <http://www.rstreet.org/policy-study/alternatives-to-net-metering-a-pathway-to-decentralized-electricity-markets/>; Faruqi, Ahmad. Davis, Wade, Duh, Josephine, and Cody Warner. “Curating the Future of Rate Design for Residential Customers.” *The Brattle Group* and *Electricity Policy*. (July 2016).; Brown, D. P., Sappington, D. E. M. (2017). Optimal policies to promote efficient distributed generation of electricity. *Journal of Regulatory Economics*

34 “What are the Benefits of QF Status?” *Federal Energy Regulatory Commission (FERC)* November 18, 2016. <https://www.ferc.gov/industries/electric/gen-info/qual-fac/benefits.asp>.

In Utah, for example, the retail rate was between 10 and 11 cents and the wholesale rate was about three cents in 2016.³⁵ A recent change to net metering rates in Utah lowered the payment for net metering to about 9 cents, around three times the rate that utility-scale solar generators would receive for their power in the wholesale market.³⁶ Figure 3 compares Utah’s retail and wholesale rates.

Figure 3: Utah’s Wholesale Rate Compared to Utah’s Retail Rate Comparison



Since wholesale rates reflect the cost of electricity generation, crediting or paying rooftop solar customers at the same rate other generators receive is a simple alternative to retail net metering rates.

Compensating Using the Value of Solar Methodology

Another way of compensating rooftop solar energy fed onto the grid is through the value of solar (VOS) methodology. Like the other compensation schemes for rooftop solar, VOS includes the avoided costs, but also includes the environmental benefits of using a non-fossil fuel generating source.³⁷ While it is reasonable to argue that solar generators should be compensated for the power they supply to the grid, using the VOS methodology likely double-counts the benefits of solar power while ignoring the costs of existing subsidies and the engineering challenges of integrating large amounts of solar into the electrical grid.

VOS offers a rate even higher than the retail rate offered by net metering. This makes it an attractive valuation method for solar companies and rooftop solar owners, but it is an expensive public policy. To justify

35 “Electric Power Annual: Table 2.10. Average Price of Electricity to Ultimate Customers by End-Use Sector, by state, 2016.” *U.S. Energy Information Administration* (December 7, 2017). https://www.eia.gov/electricity/annual/html/epa_02_10.html; Emma Penrod, “Settlement would let Rocky Mountain Power charge nonsolar customers to pay for rooftop solar power.” *The Salt Lake Tribune*. (September 11, 2017). <https://www.sltrib.com/news/2017/09/11/settlement-would-let-rocky-mountain-power-charge-nonsolar-customers-to-pay-for-rooftop-solar-power/>

36 Emma Penrod, “Settlement would let Rocky Mountain Power charge nonsolar customers to pay for rooftop solar power.” *The Salt Lake Tribune*. (September 11, 2017). <https://www.sltrib.com/news/2017/09/11/settlement-would-let-rocky-mountain-power-charge-nonsolar-customers-to-pay-for-rooftop-solar-power/>

37 “Value of Solar Methodology,” *Grow Solar*, (2017). <http://www.growsolar.org/technical-assistance/value-solar-methodology/>; The environmental benefits are often referred to as the avoided environmental costs of using fossil fuels.

the higher rate, VOS methodologies rely on many factors, but we focus on two common justifications.³⁸ First, VOS supporters argue that the economic benefits of using rooftop solar flow from the avoidance of environmental costs and the unexpected fluctuations in prices that occur in other fuel sources like natural gas. Proponents of the VOS methodology argue that because solar energy has no fuel costs, it is preferable to sources subject to fluctuating prices.³⁹ Second, VOS advocates argue that rooftop solar avoids the costs associated with building additional grid infrastructure or expanding power plant capacity.⁴⁰

The VOS method, however, overlooks the possibility that other government policies already take the benefits of solar into account. Many state and federal tax credits and other subsidies support solar as well as other renewable energy sources. Between 1950 and 2016, renewables received \$158 billion from the federal government through various incentive programs.⁴¹ According to the Government Accountability Office, 345 federal initiatives for solar energy were in place in 2012, second only to bioenergy's 398 initiatives.⁴² Each of those programs is meant to compensate for solar energy's social and environmental benefits. Thus, the VOS compensates solar panel owners for social and environmental benefits that they are already compensated for through other policies.

Some analyses have attempted to account for the costs of these other solar subsidies.⁴³ A prominent example is the 2015 study written by Dr. David Dismukes, the executive director of the Center for Energy Studies at Louisiana State University.⁴⁴ Dismukes found that, even after accounting for a \$40 per ton cost of carbon, the costs of net metering were 1.5 times as large as the benefits. The study concluded that the likely net loss to Louisiana ratepayers due to net metering was \$89 million in present value terms but could be as high as \$488 million.⁴⁵

Additionally, a comparison between distributed solar and combined-cycle gas-fired generation found that the social cost of carbon would need to be greater than \$316 per ton in order to make replacing natural gas with solar socially cost-effective.⁴⁶ By comparison, the upper bound of the EPA's 2016 estimate of a high impact social cost of carbon in 2050 is \$212 per ton, and all estimates in the average range are below \$100 per ton.⁴⁷ This implies that distributed solar may not be a cost-effective way to address climate change, even if climate change is far more expensive than anticipated. Utility scale solar is much more cost

38 Jason B. Keyes, and Karl R. Rabago. "A Regulator's Guidebook: Calculating the Benefits and Costs of Distributed Solar Generation." *Interstate Renewable Energy Council, Inc.* (October 2013). http://www.irecusa.org/wp-content/uploads/2013/10/IREC_Rabago_Regulators-Guidebook-to-Assessing-Benefits-and-Costs-of-DSG.pdf. Norris, Ben. "PV Valuation Methodology: Recommendations for Regulated Utilities in Iowa". *Clean Power Research*. (February 2016): 5-6, 17. <https://www.growsolar.org/wp-content/uploads/2016/03/PV-Valuation-in-Iowa.pdf>

39 Norris, Ben. "PV Valuation Methodology: Recommendations for Regulated Utilities in Iowa". *Clean Power Research*. (February 2016): 5-6, 17. <https://www.growsolar.org/wp-content/uploads/2016/03/PV-Valuation-in-Iowa.pdf>

40 Jason B. Keyes, and Karl R. Rabago. "A Regulator's Guidebook: Calculating the Benefits and Costs of Distributed Solar Generation." *Interstate Renewable Energy Council, Inc.* (October 2013). http://www.irecusa.org/wp-content/uploads/2013/10/IREC_Rabago_Regulators-Guidebook-to-Assessing-Benefits-and-Costs-of-DSG.pdf.

41 "Two Thirds of a Century and \$1 Trillion+: U.S. Energy Incentives Analysis of Federal Expenditures for Energy Development, 1950-2016," *Management Information Services, Inc.*, (May 2017). <https://www.nei.org/CorporateSite/media/filefolder/Backgrounders/White-Papers/EnergyIncentives-MISI-0517.pdf?ext=.pdf>

42 This number includes programs that are not only for rooftop solar. "Renewable Energy: Federal Agencies Implement Hundreds of Initiatives," *Government Accountability Office*, GAO-12-260. (February 2012). <http://www.gao.gov/assets/590/588876.pdf>.

43 Fossil fuels also receive substantial subsidies that have negative environmental effects. See: David Coady, Ian Parry, Louis Sears, and Baoping Shang. "How Large Are Global Fossil Fuel Subsidies?" *World Development*, 91 (March 2017): 11-27. doi:10.1016/j.worlddev.2016.10.004.

44 There was immense pressure by solar lobbying groups to exclude Dismukes's work from consideration by the Louisiana Public Utilities Commission because his consulting company had previously done work for members of the oil and gas industry. See: Gulf States Renewable Energy Industries Association. "Re: Docket No. X-33192 Acadian Consulting Group Complaint and Request for Disqualification," accessed December 1, 2017. <http://www.gsreia.org/site/wp-content/uploads/Re-X-33192-LPSC-GSREIA-Complaint-Filing-070114.pdf>; Roberts, Casey and Joshua Smith. "Sierra Club Exposes Flaws in Louisiana Net Metering Report." *Sierra Club*, April 8, 2015. <https://www.sierraclub.org/planet/2015/04/sierra-club-exposes-flaws-louisiana-net-metering-report>.

45 Dismukes, David E. "Estimating the Impact of Net Metering on LPSC Jurisdictional Ratepayers." *Acadian Consulting Group*, February 27, 2015. <http://lpscstar.louisiana.gov/star/ViewFile.aspx?Id=f2b9ba59-eaca-4d6f-ac0b-a22b4b0600d5>; Edward Klump. "Controversial La. report sees high costs from net metering." *Energywire*, March 5, 2015. <https://www.eenews.net/energywire/stories/1060014495>. Numbers are present value for 2015.

46 Borenstein, S. (2012). The Private and Public Economics of Renewable Energy Generation. *Journal of Economic Perspectives*, 26.1, 67-92

47 Environmental Protection Agency. (2016). EPA Fact Sheet: Social Cost of Carbon. Retrieved from: https://www.epa.gov/sites/production/files/2016-12/documents/social_cost_of_carbon_fact_sheet.pdf

effective, though the social cost of carbon would still need to be at least \$100 per ton to make utility scale solar cost competitive.⁴⁸

Solar power also imposes costs on the electrical grid for which the VOS methodology does not account. Power produced must be balanced with power used at all times. When more power is demanded than supplied, dispatchable generators must produce more power to keep supply and demand in balance. If more power is produced than the grid currently is using, power supply must be reduced.⁴⁹ A photovoltaic solar power facility, whether installed on rooftops or at a utility-scale plant, cannot be ramped up or down to reflect changes in daily or seasonal demand. Solar energy is not dispatchable because those running the grid cannot control how much electricity solar generators produce.

The non-dispatchable nature of solar make the VOS arguments about avoiding fuel price variations and environmental costs unrealistic. It is true that solar “fuel” is freely available, but it is not always available when it is needed, as evidenced by its failure to increase outputs at times of peak demand. As long as solar is neither dispatchable nor reliable, it will impose some environmental costs because of the baseload cycling it requires.⁵⁰ Baseload cycling is when a large electricity generator must rapidly ramp up and down its production to ensure the grid maintains a balance between demand and supply of electricity.⁵¹

Since rooftop solar’s production cannot be controlled by utilities, its value is dependent on when it is produced and when people need power. More specifically, the value of electricity is dependent on both the time and location that it is produced.⁵² Electricity demand fluctuates during the day, though exactly how it fluctuates depends on the local climate and season. Throughout the year electricity demand rises in the morning as people get ready to leave their homes. In colder months and climates, demand falls in the middle of the day and then rises again for a second peak in the evening when people return home. By contrast, in warmer months and climates electricity demand peaks in the middle of the day and early afternoon when air conditioning is most heavily used, and then gradually falls through the evening. Figure 4 displays changing seasonal energy demands for PJM, an organization that coordinates electricity transmission over 13 states.

48 Borenstein, S. (2012). The Private and Public Economics of Renewable Energy Generation. *Journal of Economic Perspectives*, 26.1, 67-92

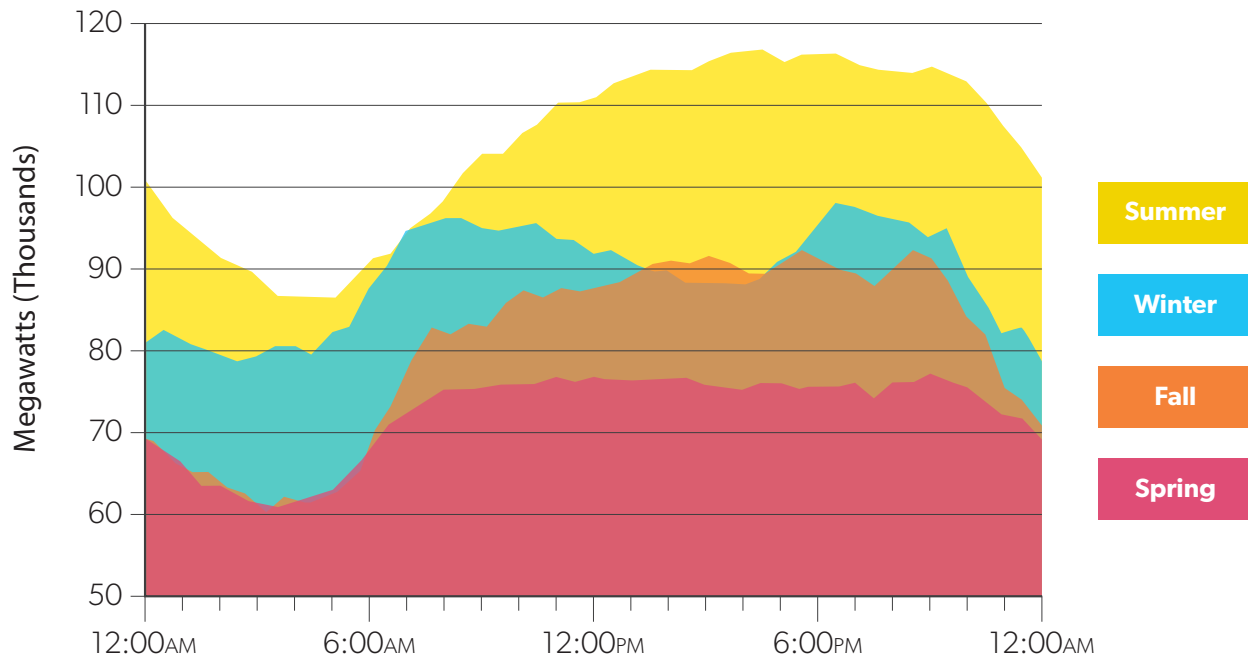
49 Quadrennial Energy Review (QER) Task Force. “Ensuring Electricity System Reliability, Security, and Resilience.” In *Transforming the Nation’s Electricity Sector: The Second Installment of the QER*, January 6, 2017. <https://energy.gov/sites/prod/files/2017/01/f34/Chapter%20IV%20Ensuring%20Electricity%20System%20Reliability%2C%20Security%2C%20and%20Resilience.pdf>.

50 Some energy commentators have noted this problem and suggested implementing an energy capacity market as a solution. Questions about capacity markets are beyond the scope of this project, however. The Energy Collective has a useful introduction to capacity markets for interested readers: Adam James, “How A Capacity Market Works,” *The Energy Collective*, June 14, 2013, <http://www.theenergycollective.com/adamjames/237496/energy-nerd-lunch-break-how-capacity-market-works-and-why-it-matters>; Texas, however, has seen success without such capacity markets: Devin Hartman, “Testing Texas Power.” *R Street*, January 5, 2018, <http://www.rstreet.org/2018/01/05/testing-texas-power/>.

51 Katzenstein, Warren, and Jay Apt. “Air Emissions Due To Wind And Solar Power.” *Environmental Science & Technology* 43, no. 2 (Jan. 2009): 253-58. doi:10.1021/es801437t; Hansen, M. E., Simmons, R. T., Yonk, R. M. “The Unseen Costs of Solar-Generated Electricity.” *Institute of Political Economy*. (April 2016):24. https://www.strata.org/pdf/unseencosts/unseen_solar_full.pdf.

52 Cohen, M. A., & Callaway, D. S. (2016). Effects of distributed PV generation on California’s distribution system, Part 1: Engineering simulations. *Solar Energy*, 128, 126-138; Cohen, M. A., Kauzmann, P. A., & Callaway, D. S. (2016). Effects of distributed PV generation on California’s distribution system, part 2: Economic analysis. *Solar Energy*, 128, 139-152.

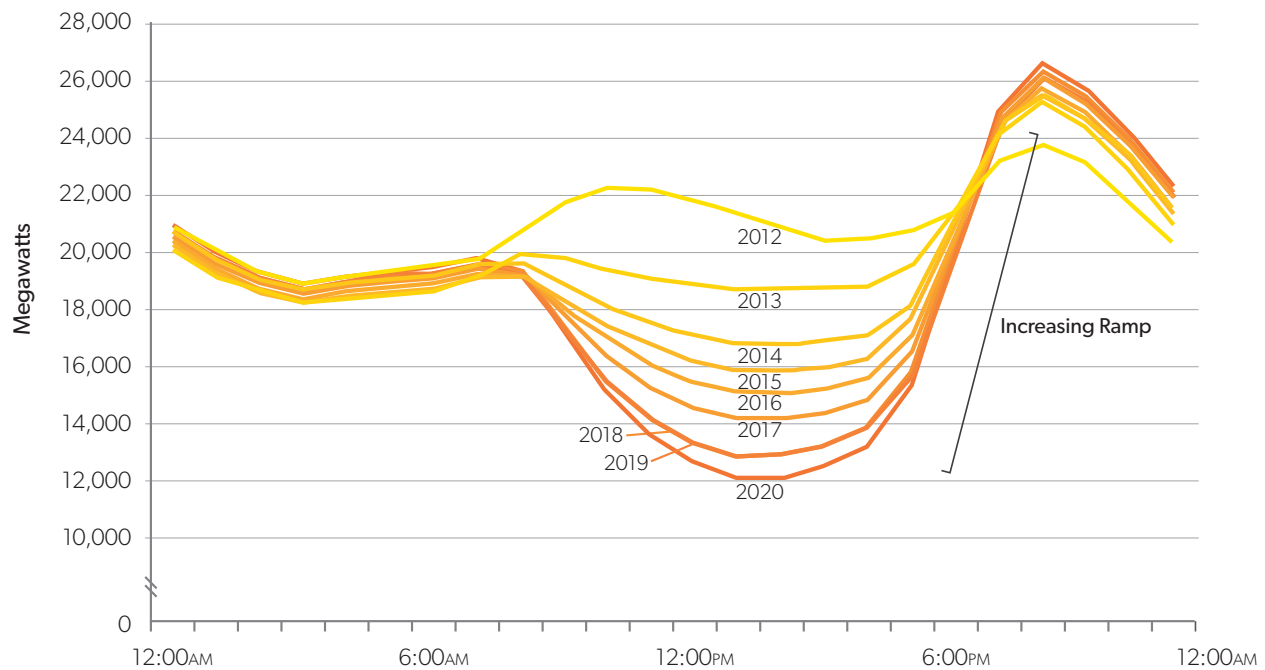
Figure 4: PJM Electricity Demand By Season



Solar energy production peaks close to peak electricity demand in warmer months. Because of this, advocates for VOS pricing have argued that solar provides power at peak demand when prices are highest and additional production is most valuable. While this is true for a small amount of solar use, the peak power production value created by solar does not persist as solar use increases, and the costs of excess ramping that solar can impose can eat away the gains from solar at high levels of solar use. This is illustrated by what the California Independent Service Operator termed the “duck curve”, shown in Figure 5 below. Substantial solar production in the middle of the day causes dispatchable and baseload producers to reduce their output. Towards the late afternoon and evening, solar production falls faster than electricity demand, forcing other sources to make up the difference. As more solar is added to the grid this evening ramping up gets steeper, and this can reduce the environmental benefits solar is estimated to provide. Much like initially starting your car’s engine emits more pollutants than simply driving down the highway, power plants generally produce more emissions as they are started up and wound down than once they are running at capacity.⁵³

53 Ashley Brown and Jillian Bunyan. “Valuation of Distributed Solar: A Qualitative View.” *The Electricity Journal* 27, no. 10 (Dec. 2014): 45-46. doi:10.1016/j.tej.2014.11.005; U.S. Department of Energy. “Staff Report to the Secretary on Electricity Markets and Reliability.” (August 2017). Pg. 154-155. https://www.energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf; Katzenstein, Warren, and Jay Apt. “Air Emissions Due To Wind And Solar Power.” *Environmental Science & Technology* 43, no. 2 (Jan. 2009): 253-58. doi:10.1021/es801437t; Hansen, M. E., Simmons, R. T., Yonk, R. M. “The Unseen Costs of Solar-Generated Electricity.” *Institute of Political Economy*. (April 2016):24. https://www.strata.org/pdf/unseencosts/unseen_solar_full.pdf.

Figure 5: The “Duck Curve”: Ramping Requirements Grow as More Solar is Added to the Grid⁵⁴



A theoretical analysis of net metering examined the conditions under which the value of solar is either greater or lower than the retail rate. When additional distributed solar lowers the costs of generation, transmission, distribution, and network management costs to the utility, and when additional solar successfully reduces externalities from other forms of electricity generation, the social value of solar is likely to be greater than the retail rate. If the opposite of these conditions hold, then the value of solar is likely to be below the retail rate.⁵⁵

Empirically, the value of solar has been found to be positive in low levels, but decreases quickly as additional solar connects to the grid. An analysis of European distributed solar found that at low levels of solar penetration (around two to five percent), the value of solar was actually higher than the wholesale rate. This is mainly because solar produces best at the middle of the day when prices, especially in the summer, are higher. But additional solar connecting to the grid eventually lowers the price of electricity in the middle of the day, and consequently lowers the value of solar. The analysis also finds that this is true even when the price of carbon is high (through a high carbon tax or restrictive cap-and-trade, for example) because at high carbon prices expensive technologies like nuclear or carbon capture become more valuable. The researchers note that, “counterintuitively, ambitious climate policy canacerbate, rather than alleviate, the loss of solar’s market value.”⁵⁶

Researchers at the Lawrence Berkeley National Laboratory have made similar findings about solar energy in America. They examined how much solar power generation offsets electricity demand at peak periods on the grid. Pointing to data on electricity demand from major cities, the researchers note that peak

54 This graphic uses the original projections from 2014 onward. California Independent System Operator. (2016). What the duck curve tells us about managing a green grid. *CASIO*. https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf.

55 Brown, D. P., Sappington, D. E. M., (2017). Designing Compensation for Distributed Solar Generation: Is Net Metering Ever Optimal? *The Energy Journal*, 38, 3; Brown, D. P., Sappington, D. E. M. (2017). Optimal policies to promote efficient distributed generation of electricity. *Journal of Regulatory Economics*.

56 Hirth, L. (2015). Market value of solar power: Is photovoltaics cost-competitive? *IET Renewable Power Generation*, 9, p 37-45

demand for electricity is often outside of the window of when solar panels generate the most electricity.⁵⁷ They conclude that each additional unit of solar contributes less to reducing peak demand, although this is also specific to location, season, and time of day.⁵⁸ Further, the capacity value of solar PV—in other words, its reliable contribution to peak demand—approaches zero at solar penetration levels as low as 6 percent according to data from Texas’s market.⁵⁹ Solar investments can avoid capacity costs only for low levels of solar penetration.

One environmental implication of when there is a mismatch between solar energy production and energy demand is that solar may displace the cleanest fossil fuel generators, not the dirtiest. This is because the generators producing more carbon for each unit of energy are usually operated only when the demand for energy is at its peak. Since solar energy normally is being fed onto the grid at times when electricity demand is low and dirty plants are not online, solar generally does not displace the dirtiest generators. Instead, solar production competes with the more efficient and, hence, cleaner burning fossil fuel plants.⁶⁰ For example, a 2013 report by the Interstate Renewable Energy Council, Inc. listed the fact that distributed solar mainly offsets natural gas generation as one of its major conclusions.⁶¹ In states with relatively large amounts of solar energy, such as California, there are concerns that baseload energy producers may be pushed out, creating additional costs and challenges for those managing the grid.⁶²

Taken together, these studies show that although solar production can reduce peak demand, it can also create periods of surplus energy production that create operational problems like the duck curve and fail to align with actual energy needs on the grid. This makes requiring a higher compensation rate for solar through a VOS methodology unlikely to be efficient or effective at meeting energy needs.

As Ashley Brown, Executive Director of the Harvard Electricity Policy Group, concludes in his analysis of VOS methodologies, “[V]alue analysis” replaces competition and cost-based regulation with theoretical, highly subjective notions of ‘value,’ derived from highly speculative, largely undisciplined assertions which, used as a standard for pricing, would impose maximum costs on consumers.”⁶³ Ultimately, the VOS methodology is too optimistic an estimation of solar’s value that overlooks important factors about the operation of the grid and the nature of solar energy. Unless these problems are accounted for, it cannot serve as a credible tool for policymakers in estimating the value of distributed solar’s electricity production.

Compensating by Changing the Rate Structure Used

Another alternative to net metering is changing the rate structures used by utilities to more closely reflect the types of costs that consumers impose on the grid. As Dr. Lynne Kiesling notes in her own analysis

57 Darghouth, Naïm, Galen Barbose, Andrew Mills, Ryan Wisser, Pieter Gagnon, and Lori Bird. “Exploring Demand Charge Savings from Residential Solar.” (2017). *Lawrence Berkeley National Laboratory*. p. 45. <https://www.osti.gov/servlets/purl/1373280>

58 Darghouth, Naïm, Galen Barbose, Andrew Mills, Ryan Wisser, Pieter Gagnon, and Lori Bird. “Executive Summary: Exploring Demand Charge Savings from Residential Solar.” (2017). *Lawrence Berkeley National Laboratory*. http://eta-publications.lbl.gov/sites/default/files/resdemandcharge-execsummary_final.pdf

59 Abdel-Karim, Noha, David Calderon, Mark Lauby, Thomas Coleman, and John Moura. “Impact of Wind and Solar Variability on the Resource Adequacy for North American Bulk Power System.” 2016 *International Conference on Probabilistic Methods Applied to Power Systems (PMAPS)*, December 5, 2016. doi:10.1109/pmaps.2016.7764176; U.S. Department of Energy. “Staff Report to the Secretary on Electricity Markets and Reliability.” (August 2017). Pg. 154-155. https://www.energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf.

60 Brown, Ashley, and Jillian Bunyan. “Valuation of Distributed Solar: A Qualitative View.” *The Electricity Journal* 27, no. 10 (Dec. 2014): 45-46. doi:10.1016/j.tej.2014.11.005; U.S. Department of Energy. “Staff Report to the Secretary on Electricity Markets and Reliability.” (August 2017). Pg. 154-155. https://www.energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf

61 Jason B. Keyes, and Karl R. Rabago. “A Regulator’s Guidebook: Calculating the Benefits and Costs of Distributed Solar Generation.” *Interstate Renewable Energy Council, Inc.* (October 2013). http://www.irecusa.org/wp-content/uploads/2013/10/IREC_Rabago_Regulators-Guidebook-to-Assessing-Benefits-and-Costs-of-DSG.pdf.

62 Jordan Wirfs-Brock, “IE Questions: Why is California Trying to Behead the Duck,” *Inside Energy*, October 2014, <http://insideenergy.org/2014/10/02/ie-questions-why-is-california-trying-to-behead-the-duck/>.

63 Ashley Brown “The Value of Solar Writ Large: A Modest Proposal for Applying “Value of Solar” Analysis and Principles to the Entire Electricity Market.” *Harvard Electricity Policy Group*, (November 2016) https://sites.hks.harvard.edu/hepg/brown_papers/Brown%20Value%20of%20Solar%20Writ%20Large.pdf.

of net metering, “The problems of net metering regulation are problems of rate design.”⁶⁴ Retail rate net metering is a particular type of rate structure, but utilities can and do use many alternative structures that differ in complexity. Many changes to rate structures have been proposed as solutions to the problems created by net metering.

The simplest rate structure charges the same rate for each kilowatt hour of electricity consumed. It is a basic volumetric or variable charge which goes up and down completely dependent upon the amount of electricity consumed. Alternative rate structures quickly become more complicated in an attempt to capture the different forms of costs utilities and electricity providers face. For example, fixed delivery charges are sometimes applied to account for the costs of upkeep of the grid and billing fees are also included as a way to recoup the costs associated with billing ratepayers. In general, the motivation behind using increasingly complex rate structures (variable plus fixed rates, time-of-use, demand charges, etc.) is to accurately reflect the dynamic economic conditions on the grid.

Rate design systems that are more flexible than a simple volumetric charge use price signals to encourage the level of electricity production and consumption that maximizes social welfare. These rate structures closely match costs and benefits to the overall electrical system with costs and benefits of the individuals using the grid. Two important forms of rate design, three-part rates and time-of-use rates, are likely more efficient and may avoid cost-shifting.

Three-Part Rates

Utilities and grid managers face three broad kinds of costs when providing electricity to customers: costs from buying electricity from generators, the costs of maintaining and building wires and poles to transmit power, and costs from maintaining the capacity to satisfy peak demand periods. Yet many utilities only recover costs through two types of charges: a single volumetric charge for electricity consumption and a fixed grid maintenance fee. This creates a mismatch between the costs a consumer creates for a utility and the charges that a utility assesses on that customer.⁶⁵

Importantly, the mismatch also means that customers consume too much electricity when it is expensive to generate and too little when it is inexpensive.⁶⁶ This creates costs for the utility that it cannot effectively relay to customers through price signals.

In light of this failure to match costs and revenues, several utilities are reforming their electricity rates to use a three-part rate.⁶⁷ The rate consists of: (1) a monthly service charge, (2) a demand charge, and (3) a volumetric charge. Each of these charges relates to a type of cost that a consumer imposes on a utility. The monthly service charge is a flat rate that covers the fixed costs utilities incur, like billing, metering, and other customer services. The demand charge is meant to cover peak-demand-driven costs, including the transmission, distribution, and generation infrastructure. These are assessed according to the customer’s use at peak demand so that customers who use more electricity when there is greater stress on the grid pay more than those who use electricity at times with less total demand. The third part of this rate design is the volumetric charge, which is tied to how much electricity the consumer

64 L. Lynne Kiesling, “Alternatives to Net Metering: A Pathway to Decentralized Electricity Markets.” *R Street*. R Street Policy Study No. 52. (February 2016):17. <http://www.rstreet.org/policy-study/alternatives-to-net-metering-a-pathway-to-decentralized-electricity-markets/>.

65 Faruqui, Ahmad, Davis, Wade, Duh, Josephine, and Cody Warner. “Curating the Future of Rate Design for Residential Customers.” *The Brattle Group and Electricity Policy*. (July 2016). http://files.brattle.com/files/7137_curating_the_future_of_rate_design_for_residential_customers.pdf.

66 Faruqui, Ahmad, Davis, Wade, Duh, Josephine, and Cody Warner. “Curating the Future of Rate Design for Residential Customers.” *The Brattle Group and Electricity Policy*. (July 2016). http://files.brattle.com/files/7137_curating_the_future_of_rate_design_for_residential_customers.pdf.

67 Faruqui, Ahmad and Ryan Hledik. “An Evaluation of SRP’s Electric Rate Proposal for Residential Customers with Distributed Generation.” *The Brattle Group*. Prepared for the Salt River Project, January 5, 2015. <https://www.srpnet.com/prices/priceprocess/pdfx/DGRateReview.pdf>.

uses and mirrors variable generation costs. Consumers who use more—particularly at times of peak demand—pay more under this rate design.⁶⁸

Three-part rates offer promising opportunities to improve efficiency and avoid cost-shifting by charging customers according to both the fixed and variable costs they impose on the grid, rather than by capturing both fixed and variable costs through a single rate per kilowatt hour.⁶⁹ Three-part rates take into account the customer's contribution to peak demand, which incentivizes customers to lower their use during peak demand conditions.

Time-of-Use Rates and Real-Time Pricing

Another possibility for adjusting electric rate structures to accommodate increases in distributed generation technologies is time-of-use rates or real-time pricing. The value of electricity varies throughout the day as reflected in fluctuations in wholesale prices, but many retail rates do not change. This means that consumers over-consume when electricity generation is expensive and under-consume when it is cheaper. Time-of-use rates vary according to the time of day while real-time pricing is set based on the costs of generating electricity in real time. Time-of-use rates often vary in a simple two-tier fashion, higher prices are charged when demand is at its peak, and lower prices are charged when it is not. Real-time pricing can vary over intervals as short as five-minutes.

Time-of-use rates and real-time pricing allow electricity providers to charge individuals for the electricity they use at rates closer to the actual cost of the electricity at the time it is used. Generating electricity off-peak is less expensive than at peak demand and time-varying rates capture this fact. For example, a report by the Environmental Defense Fund and the Citizens Utility Board of Illinois estimated that time-varying prices could save 97 percent of Commonwealth Edison customers almost \$30 million in 2016.⁷⁰

California is already experimenting with compensating rooftop solar according to time-varying rates. Although it maintains the retail rate of compensation, the state's program is a step towards accounting for the demand-driven differences of electricity generation costs across time. It works by crediting rooftop solar at lower rates during off-peak times when generation is less valuable and higher rates at peak times when electricity is more valuable.⁷¹

Time-of-use rates can be combined with three-part rates, although the demand charge in a three-part rate is already related to the time of day when electricity is most expensive. Both of these options, however, incentivize the production and use of electricity in socially beneficial ways. If the compensation for rooftop solar's production is directly tied to the time of the day when electricity is most valuable, like peak demand periods, and fixed charges are assessed separately so that rooftop solar owners pay for their share of the fixed costs of grid maintenance, then there would likely be less cost-shifting between customer classes and operational problems like the duck curve would be lessened. This is because price signals coordinate the actions of consumers and producers.⁷² When prices are high, consumers will use less electricity and producers will supply more, smoothing out electricity demand over time, which will reduce ramping problems and make solar more valuable to the grid.

68 Faruqui, Ahmad, Davis, Wade, Duh, Josephine, and Cody Warner. "Curating the Future of Rate Design for Residential Customers." *The Brattle Group and Electricity Policy*. (July 2016). http://files.brattle.com/files/7137_curating_the_future_of_rate_design_for_residential_customers.pdf.

69 L. Lynne Kiesling, "Alternatives to Net Metering: A Pathway to Decentralized Electricity Markets." R Street. R Street Policy Study No. 52. (February 2016):17. <http://www.rstreet.org/policy-study/alternatives-to-net-metering-a-pathway-to-decentralized-electricity-markets/>.

70 Zethmayr, Jeff, David Kolata. "The Costs and Benefits of Real-Time Pricing: An Empirical Investigation into Consumer Bills Using Hourly Energy Data and Prices." *The Citizens Utility Board and The Environmental Defense Fund*, November, 14, 2017. <https://citizensutilityboard.org/wp-content/uploads/2017/11/FinalRealTimePricingWhitepaper.pdf>. Citizens Utility Board. "New Smart Meter Data Shows Potential of Real-Time Pricing to Lower Electric Bills," November 14, 2017. <https://citizensutilityboard.org/realtimepricingnewsrelease-2/>.

71 Matasci, Sara. "Solar and time-of-use electricity rates: what you need to know." *EnergySage*, July 27, 2017. <https://news.energysage.com/solar-time-use-electricity-rates-need-know/>.

72 Friedrich A Hayek, "The Use of Knowledge in Society," *The American Economic Review* (1945): 519-530; L. Lynne Kiesling, "Alternatives to Net Metering: A Pathway to Decentralized Electricity Markets," *R Street*, R Street Policy Study No. 52 (February 2016):9. <http://www.rstreet.org/policy-study/alternatives-to-net-metering-a-pathway-to-decentralized-electricity-markets/>.

Removing Barriers to Solar Adoption

Solar industry advocates may be concerned that without retail net metering, demand for rooftop solar will decrease. There are, however, opportunities to encourage rooftop solar that would likely benefit both ratepayers and the solar industry. Policymakers should consider removing excessive regulations and trade barriers that slow solar adoption or make the panels more expensive.

In January of 2018, President Trump's administration imposed a 30 percent tariff on solar panel imports.⁷³ Before the tariff was enacted, a group of 10 public policy research groups sent an open letter to President Trump urging him to reject such limits on trade and pointing out that similar policies have had severe negative consequences for the economy.⁷⁴ Greentech Media, a market research and analysis company specializing in renewable energy issues, estimates that over the next five years this tariff will lower new solar construction within the United States by 7.6 gigawatts relative to projected solar development without tariffs.⁷⁵

In addition to trade policies, recent reports from members of the solar industry have also pointed out that arduous regulations hamper the development of residential solar. Andrew Birch, a former CEO for Sungevity, a company that installed solar panels and provided maintenance for them, points out that the cost of installing rooftop solar in the U.S. is about \$10,000 more than in Australia. Birch says that "American consumers are being charged over two times more for solar than is the average consumer overseas." He blames this discrepancy on the permitting process and other red tape. For example, Birch states that the U.S. National Electrical Code, on average, adds 49 cents per watt to the cost of a solar installation and doubles the installation time compared to Australia. In addition, he notes that there appears to be little additional safety gained from the United States' red tape. Australia's installed panels appear no more likely to fail or to pose a danger to the homes they are installed on than those installed under the review process the U.S. requires.⁷⁶

Additionally, policymakers should keep in mind the ultimate purpose behind encouraging more rooftop solar. If the goal of net metering policy is to efficiently advance low-carbon energy, then net metering may not be the most effective way. Net metering does not encourage owners of rooftop solar to invest in energy storage technology, for example, because it allows the owner to use the grid as storage.⁷⁷ It may also discourage investments in energy efficiency if it forces utilities to increase the portion of the volumetric rate that covers fixed costs. As Ashley Brown argues, this would have an ironic "anti-green result that the rewards for energy efficiency, energy conservation, and distributed generation itself become smaller and smaller as more and more costs are shifted to the one part of the bill that everybody has to pay without regard to the level of consumption".⁷⁸

Rooftop solar may not even be the most effective recipient of solar energy subsidies. Utility-scale solar farms are better able to capitalize on economies of scale.⁷⁹ Yet net metering policies pay a less efficient form of solar energy production, rooftop solar, a much higher rate than the more efficient utility-scale farms. Lazard's levelized cost of energy comparison, which compares the costs of certain types

73 Krysti Shallenberger, "Trump issues 30% tariff on solar panel imports," *Utility Dive*. January 22, 2018, <https://www.utilitydive.com/news/trump-issues-30-tariff-on-solar-panel-imports/515265/>.

74 Clark Packard, et al., "Open Letter to President Trump: Avoid Trade Restrictions on Solar Panels." *R Street Institute*, (October 26, 2017). <http://www.rstreet.org/outreach/open-letter-to-president-trump-avoid-trade-restrictions-on-solar-panels/>.

75 Lacey Johnson, "Forecast Shows How Trump Tariffs Will Hurt Solar Growth, State by State," *Greentech Media*. February 1, 2018, <https://www.greentechmedia.com/articles/read/forecast-shows-how-tariffs-will-hurt-solar-growth-state-by-state#gs.XzPX1MU>; Julia Pyper, "New Tariffs to Curb US Solar Installations by 11% Through 2022," *Greentech Media*. January 23, 2018, <https://www.greentechmedia.com/articles/read/tariffs-to-curb-solar-installations-by-11-through-2022#gs.rtzChJk>

76 Andrew Birch, "How to Halve the Cost of Residential Solar in the US." *Greentech Media*, January 5, 2018. <https://www.greentechmedia.com/amp/article/how-to-halve-the-cost-of-residential-solar-in-the-us>.

77 Gautier, A., Jacqmin, J., Poudou, J. C., (2018), The prosumers and the grid. *Journal of Regulatory Economics*. 53, 1.

78 Brown, A., Lund, L., (2013). Distributed Generation: How Green? How Efficient? How Well-Priced? *The Electricity Journal*.

79 Brown, Ashley, Bunyan, Jillian. "Valuation of Distributed Solar: A Qualitative View." *The Electricity Journal* 27, no. 10 (Dec. 2014): 27-48. doi:10.1016/j.tej.2014.11.005.

of energy generation technologies, shows that residential solar is among the most expensive version of solar.⁸⁰ Larger and more cost-effective carbon emission reductions would likely come from utility-scale solar farms rather than small rooftop solar installations. In fact, a cost-benefit analysis of the subsidies provided to distributed solar concluded that, “[T]he public has not got its money’s worth in pollution reduction from the subsidies offered to distributed solar PV: rebates and credits vastly exceed health and environmental benefits.”⁸¹

Restructuring Electricity Markets

Restructuring of electricity markets to provide retail choice could protect non-solar customers from increased costs due to the cost-shifting created by net metering.⁸² Retail choice allows electricity providers to sell electricity to consumers who select among the electricity providers to find a plan that suits their needs. Texas is the leading model for retail choice, with over six million residential customers. Depending on the location in the state, retail electricity market customers can choose between 14 and 55 different retail electricity providers.⁸³ Instead of managing both the distribution and supply of electricity, states should consider moving towards a platform model where a single regulated organization maintains the electrical grid, and competing electricity providers supply electricity through the grid.⁸⁴

Texas is one successful example of a state that has experimented with restructuring its retail electricity market by separating the management of the grid from the reselling of electricity. While vertically integrated states have utilities that both manage the grid and sell electricity to consumers, in Texas those tasks are managed by separate companies. This allows for competition between resellers of electricity, known in Texas as retail electricity providers.⁸⁵

Although Texas does not have a statewide mandated net metering policy, the solar industry in Texas continues to grow, and some retail electricity providers offer net metering rates to customers with solar panels.⁸⁶ Instead of mandated rates, in areas with retail choice, rooftop solar owners must work with their retail electricity provider to create an interconnection agreement.⁸⁷ This may provide some evidence that

80 Lazard. “Lazard’s Levelized Cost of Energy Analysis.” (November 2, 2017). <https://www.lazard.com/perspective/levelized-cost-of-energy-2017/>.

81 Vaishnav, P.; Horner, N.; Azevedo, I. L. Was it worthwhile? Where have the benefits of rooftop solar photovoltaic generation exceeded the cost? *Environ. Res. Lett.* 2017, 12 (0) 1–46 DOI: 10.1088/1748-9326/aa815e

82 Restructuring of retail electric power to provide customer choice raises many issues well beyond net metering policy, and well beyond the scope of this paper. The effects of restructuring on the net metering debate, however, are one indication of how enabling consumer choice limits the ability of policy to impose cross-subsidies on consumers and as a result depoliticizes the individual choice to install solar systems. Much of the academic debate on the outcomes and value of restructuring concerns California’s experience after it restructured the supply side of its electricity market in 1996. Interested readers should consult: Borenstein, S. (2002). The trouble with electricity markets: understanding California’s restructuring disaster. *Journal of Economic Perspectives*, 16(1), 191-211; Borenstein, S., & Bushnell, J. (2015). The US electricity industry after 20 years of restructuring. *Annu. Rev. Econ.*, 7(1), 437-463; Wolak, F. A. (2014). Regulating competition in wholesale electricity supply. In *Economic Regulation and Its Reform: What Have We Learned?* (pp. 195-289). University of Chicago Press.

83 Abbott, Kristin. (2017). Scope of Competition in Electric Markets in Texas. *Public Utility Commission of Texas*. http://www.puc.texas.gov/industry/electric/reports/scope/2017/2017scope_elec.pdf; Morey, M. J., & Kirsch, L. D. (2016). Retail choice in electricity: What have we learned in 20 years. *Washington, DC: Christensen Associates Energy Consulting LLC for Electric Markets Research Foundation*. <https://sites.hks.harvard.edu/hepg/Papers/2016/Retail%20Choice%20in%20Electricity%20for%20EMRF%20Final.pdf>.

84 L. Lynne Kiesling “Alternatives to Net Metering: A Pathway to Decentralized Electricity Markets,” *R Street*, R Street Policy Study No. 52, (February 2016): 13-14. <http://www.rstreet.org/policy-study/alternatives-to-net-metering-a-pathway-to-decentralized-electricity-markets/>

85 “Who are the Players in the Texas Electricity Market?” Bounce Energy, accessed January 3, 2018, <https://www.bounceenergy.com/articles/texas-electricity/players-in-texas-electricity-market>,

86 L. Lynne Kiesling “Alternatives to Net Metering: A Pathway to Decentralized Electricity Markets,” *R Street*, R Street Policy Study No. 52, (February 2016): 13-14. <http://www.rstreet.org/policy-study/alternatives-to-net-metering-a-pathway-to-decentralized-electricity-markets/>; Robert Walton, “Sunrun enters Texas solar market with virtual net metering offer,” *Utility Dive*, June 2, 2017. <https://www.utilitydive.com/news/sunrun-enters-texas-solar-market-with-virtual-net-metering-offer/444076>; Jeff Mosier, “Texas installs enough solar panels in last three months to power 44,000 homes,” *The Dallas Morning News*, December 14, 2017, <https://www.dallasnews.com/business/energy/2017/12/14/texas-still-one-fastest-growing-solar-states>; Robert Walton, “In Texas, 1 company is making rooftop solar work without net metering.” *Utility Dive*, July 25, 2016, <https://www.utilitydive.com/news/in-texas-1-company-is-making-rooftop-solar-work-without-net-metering/423192/>;

87 Power to Choose. (2018). Buying Renewable Power. *Public Utilities Commission of Texas*. <http://www.powertochoose.org/en-us/Content/Resource/Selling-Renewable-Power>.

solar has value to resellers of electricity, and that mandating net metering might be unnecessary once a state has an adequate level of competition.

Restructured markets and retail choice provide options to both rooftop solar and non-solar customers. By shopping between competing electricity providers, rooftop solar owners can find best rate for the electricity they feed onto the grid. Similarly, non-solar consumers can find the lowest rates that they will have to pay for the electricity they consume. This may mean that non-solar customers will shift away from electricity providers paying the retail rate for electricity generated by rooftop solar owners.

Restructured markets allow electricity providers who can profit from retail rate net metering to continue using it. For example, two companies in Texas, SolarCity and MP2 Energy, are offering retail rates for the extra energy that rooftop solar panels produce.⁸⁸ It can also avoid cost-shifting by creating competition between alternative electricity providers for customers to switch to if they believe their rates are too high.

Although they are often described as preventing the development of distributed generation by rooftop solar panels, Texas's net metering policies simply do not provide an additional subsidy alongside the existing federal and other state programs. Instead of mandating specific rates for the electricity produced by rooftop solar, Texas's voluntary system allows the owner of the solar panels and the electricity providers to come to a mutually beneficial agreement. Restructuring can be an especially powerful tool for encouraging more efficient electricity consumption, especially if combined with competitively set time-varying rates and changes in the structure of the electricity rates offered to ratepayers.

Conclusion

The current norm of retail net metering rewards those with solar panels, but penalizes those without. Since it is largely wealthier individuals who can afford to invest in rooftop solar, retail rate net metering results in a regressive subsidy of the rich by the poor. Policymakers can stem the substantial cost-shift created by retail net metering through rate structure reforms, paying the wholesale rate for rooftop solar generation, and restructuring retail electricity markets.

The most ambitious reform is to restructure electricity markets and end mandated electricity rates. Policymakers should allow distributed generation resource owners and utilities to negotiate the price of rooftop solar production. When paired with time-varying rates, this reform has the potential to provide lower electricity prices while preventing the cost-shifting common under current policies.

Restructuring a state's electricity market is a daunting task. An easier starting point for policymakers who want to avoid the regressive effects of retail rate net metering is altering rate structures to more accurately reflect the cost of electricity. Policymakers should also consider removing artificial barriers to solar adoption. Tariffs and burdensome regulations make solar solar more expensive than it otherwise would be.

Replacing retail rate net metering with wholesale rates, or implementing time-of-use rates to compensate solar's generation would likely incentivize solar adoption without burdening non-solar ratepayers. Not only are there many other existing incentives for solar use at both the federal and state level, but there are still significant, private benefits that will draw individuals towards installing solar panels. For states where restructuring is unlikely, moving away from mandated retail rate net metering and towards other types of rate structures may be a more appropriate reform.

Currently, both solar companies and owners of solar panels benefit from retail rate net metering at the expense of potential competitors in the electricity generation sector as well as non-solar customers. In

⁸⁸ Robert Walton, "In Texas, 1 company is making rooftop solar work without net metering," *Utility Dive*, July 25, 2016, <https://www.utilitydive.com/news/in-texas-1-company-is-making-rooftop-solar-work-without-net-metering/423192/>; "Value of Solar (VoS) Rate," Austin Energy, accessed January 15, 2018, <https://austinenenergy.com/ac/green-power/solar-solutions/value-of-solar-rate>.

place of this special treatment, regulators should foster competition and allow for market-driven pricing wherever possible. Restructuring retail markets akin to Texas's model and implementing better rate design are both reforms that are likely to avoid the regressive effects of retail rate net metering policies while maintaining the incentive for investment in distributed generation technologies like rooftop solar.