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Planned Adaptation Combined Paper

**Net Energy Metering Policies and a Role for Planned Adaptation**

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**1. Introduction to Net Energy Metering**

Decreasing technological costs, increasing public attention to the issue of climate change, and the advent of innovative financing options have fueled significant growth in the renewable energy sector in recent years. Motivated to decrease carbon emissions, countries around the world are implementing increasingly ambitious renewable energy targets and policies. As of the beginning of this year, at least 164 countries had such targets and 145 had policies to support renewables (Lins, 2015). Despite the fact that increasing investment in clean and renewable energy technologies is widely regarded to be socially and economically beneficial in many places, there is much debate surrounding the different mechanisms that should be used to promote investment. These technologies are, by definition, different from conventional energy generating resources in that they yield no carbon emissions nor do they directly deplete limited natural resources in their use. Such characteristics produce positive externalities such as improved energy security and avoid negative global externalities associated with modes of climate change. Although renewables are generally thought to come at higher per-megawatt financial cost relative to conventional technologies in many regions, they are also seen to provide public goods on local and global scales. In the absence of a set price on carbon and legally binding agreement on climate among all of the world’s nations, governments resort to other next-best mechanisms to internalize the benefits of renewables (Schmalensee & Miller, 2015). Traditional policies that nations and states have used to promote renewables include tax incentives, grants, loans, and net energy metering (net metering, or NEM). While tax incentives, grants, and loans are temporary mechanisms for inducement, net metering provides small-scale renewable energy producers with a uniquely dynamic and continuous stream of financial payment. Under net metering, electricity customers with grid-connected renewable generation surpluses are allowed to sell their excess power back to the grid at the retail electricity rate in spite of the fact that larger grid-scale generators are only compensated at the wholesale rate.1 These customers receive credits on their utility bill, which offset their energy consumption during other times of the billing period. While the proliferation of net metering policies around the United States and the world has been a significant driver for the growth of distributed renewables and solar photovoltaics (PV) in particular, many deem these policies to unfairly subsidize such producers at the expense of regular utility customers (Stoutenborough & Beverlin, 2008). Others point to unexpected grid impacts and the long-term unsustainable nature of unabated net metering due to positive feedback mechanisms that could render distribution services unviable (Schmalensee & Miller, 2015).

The aim of this paper is to analyze the net metering debate from a political economy perspective, discuss features of net metering policies as planned adaptive mechanisms, explore areas where policymakers would do better to adopt frameworks for self-correction, discuss future regulatory models that may exemplify aspects of planned adaptation, and take a deeper dive into knowledge assessment issues on net metering successor tariff proposals in California. The arguments presented are intended to give a broad overview of this contemporary debate and focus in with an emphasis on concepts such as learning, self-correction, and feedback.

1.1 The Proliferation of Net Metering

The story of net metering traces back to serendipitous beginnings in 1979 when architect Steven Strong added solar panels to his two Massachusetts building projects and forgot to inform the local utility that he was feeding excess power back to the distribution network. He found that when he did so, his electricity meters ran in reverse and he was credited. His project’s success was retold in speeches by the director of the Solar Energy Research Institute and subsequently the state energy secretary, who praised utility executives for allowing interconnection. Although they were not familiar with the projects, the executives accepted the positive publicity and praised the projects in turn (Verzola, 2015).

Policies for net metering were first enacted in Massachusetts and Wisconsin in 1982 and have since spread to other states and countries around the world (Schmalensee & Miller, 2015). As of May 2014, 43 U.S. states and Washington, D.C. have adopted such policies, and as of early 2015, 48 countries have done so (Lins, 2015; Heeter, Gelman, & Bird, 2014). As shown in Figure 1, the number of electricity customers in the U.S. who use net metering has grown exponentially in recent years, from fewer than 7,000 in 2003 to over 450,000 in 2013. Despite their wide proliferation, net metering policies have significant diversity; state and district policies in the U.S. differ in the technologies and system sizes allowed. They also differ in their terms prescribed for excess generation credits and caps or trigger mechanisms to limit their use. (Heeter, Gelman, & Bird, 2014). Though net metering programs often apply to small wind, hydro and fuel cell technologies, among others, they are used predominantly by customers with distributed solar systems.



**Figure 1**. The number of net metered customers in the United States has grown exponentially over the past decade (Heeter, Gelman, & Bird, 2014)

The proliferation of net metering policies is widely thought to have helped the solar sector to grow by increasing returns to system owners (Heeter, Gelman, & Bird, 2014). Other studies show that as the solar industry has grown, the average cost per unit of energy has concurrently decreased, as shown in Figure 2 (Solar Energy Industries Association, 2015). Though efforts have not been found that quantify casual relationships between net metering policy proliferation, overall sector growth, and the decreasing unit cost of solar energy, their correlation is documented and it can be argued that mutual casual mechanisms have likely influenced this outcome in recent years.

While the proliferation of net metering policies is understood to have helped the solar industry, there are current debates about the future viability of this policy instrument. These debates focus around customers, utilities, regulatory agencies, and the solar industry.



**Figure 2**. The unit cost of energy from solar PV has decreased while the scale of solar installations has increased over time (Solar Energy Industries Association, 2015)

1.2 The Net Metering Debate

Though they employ a relatively simple crediting mechanism, net metering policies represent complicated sociotechnical issues and are the subjects of intense debate among stakeholders with multiple competing interests. The economics of net metering are also influenced by external factors and interacting policies such as the federal solar Investment Tax Credit (ITC).

Because net metering compensates customers with distributed energy systems at the retail electricity rate as opposed to the wholesale rate, net metering provides subsidies for distributed solar relative to other energy generators per unit of energy fed into the grid. This subsidy is equal to the difference between the retail and wholesale rates and would otherwise be kept by utilities as revenue for providing the service of maintaining transmission and distribution systems. While some would argue that these subsidies are necessary to internalize the positive externalities that solar confers, net metering mechanisms fail to ensure that these subsidies and benefits are kept equivalent to one another. The subsidy corresponds to the costs necessary to maintain electricity networks and these costs have no obvious correlation with the magnitude of benefit conferred by renewables; in fact, quantifying such benefit is a subject of significant debate in and of itself. Furthermore, as the technology mix for energy generation evolves, these economic incongruences do as well. At present, residential solar customers are effectively ‘free riding’ on the services provided by utilities and the associated costs are being passed down to customers without such generation capabilities (Darghouth, Wiser, Barbose, & Mills, 2015). In utility jurisdictions in California alone, Pacific Gas and Electric Company (PG&E) and Southern California Edison (SCE) estimate that net metered customers with rooftop solar will respectively push $24 billion and $16.7 billion of avoided network costs onto those without distributed generation systems within the next decade if net metering is allowed to continue (St. John, California Utilities Release New Plans to Replace Net Metering: Conflict to Come?, 2015). The magnitudes of subsidies become nontrivial in aggregate and with consideration of the predicted growth of distributed generation.

In the academic literature, there is further discussion about how, if left unabated, net metering is susceptible to positive feedback mechanisms. One such mechanism explains that as distributed generation penetration increases, utility customers consume less electricity from the grid while network costs remain constant or even increase. As a result, non-participant consumers absorb this extra cost, further incentivizing adoption of distributed generation and continuing the cycle. Taken to the extremes, this mechanism can potentially destroy the market for electricity distribution.

In addition to underperforming in its goal of appropriately subsidizing solar, net metering has redistributive implications for equity as well. Those who benefit from net metering are generally thought to be more affluent than those who lose out, as wealthier people are more likely to invest in distributed generation systems (Schmalensee & Miller, 2015). These redistributive effects have ugly implications in an analytic frame combined with positive feedback mechanisms as described above.

Finally, arguments have been made that net metering policies may be harmful to the stability of electricity grid infrastructure due to failure to limit interconnection density at the circuit-level. Representatives from the Hawaiian utility, Hawaiian Electric Company (HECO), have described technical issues resulting from too much rooftop solar. If there is more generation than consumption of electricity in a given area, circuits may experience overvoltage and unreliability. In addition, few circuits were originally designed to support bidirectional energy flow. When such issues emerge, as cases in Hawaii have shown, additional infrastructure investment and grid reinforcement measures are needed (Wesoff, 2014).

Though they have been in place for decades, arguments against net metering have only recently become relevant in the public eye. Before 2013, the volume of distributed generation on the grid and the negative effects of net metering either went unnoticed or were generally seen as too small to be worth fighting over. Today, it is a much more contentious issue (Verzola, 2015). As exemplified by the rapid proliferation of net metering policies and their exponential increase in use, these policies have a lot of supporters and have helped to significantly increase solar adoption. Consumers with distributed generation systems and the solar industry alike generally hold that net metering policies are essential to the industry’s continued growth. In most cases, they push to render net metering policies less restrictive and fight to keep them in place. State governments and policymakers have also historically favored net metering policies because they yield positive environmental impact and favorable public reception at no direct cost to the state itself (Stoutenborough & Beverlin, 2008).

Net metering opponents tend to include utilities, utility-scale solar companies, and academics seeking better long-term solutions. Utilities generally cite the problem of inequity among customer types while insisting that decreasing technological costs and other policies will preserve the market for solar even without net metering policies. They often fight for new fixed fees and for paying lower net-metered rates for solar energy. As shown in Figure 3, utilities in 27 states have filed proposals to reduce compensation rates for distributed solar between 2013 and September 2015 (Flores-Espino, 2015). Utility-scale solar companies have also called for the revision of net metering programs. In 2013, James Hughes, the CEO of First Solar, supported proposed restrictions to net metering made by Arizona Public Service, Arizona’s largest electricity provider. First Solar is a major player in the global utility-scale solar industry and has minimal participation in rooftop solar. Hughes argued that net metering policies prevent utilities from, “seek[ing] the highest volume of solar power at the lowest cost to rate-paying customers” and referenced the resulting, “burden on utilities and ratepayers” (Hughes, 2013). Hughes’ argument alludes to how inappropriate methods for subsidizing rooftop solar can hurt close-substitutes such as utility-scale solar, and how this can end up producing sub-optimal double bottom-lines. Finally, as will be elaborated on in the Planned Adaptation section of this paper, groups of academics oppose current manifestations of net metering due to the long-term undesirability of the policies. Prof. Ignacio Pérez-Arriaga from the MIT Center for Energy and Environmental Policy Research and MIT Energy Initiative explains how simple and conventional meters, combined with volumetric tariffs, exacerbate the inefficiencies associated with net metering polices. New types of tariffs with more frequent metering promise to significantly improve the economics behind such policies (Pérez-Arriaga & Bharatkumar, 2014).

**Figure 3**. States where utilities have filed proposals to reduce compensation for distributed solar (Flores-Espino, 2015)



Net metering is often also complicated by interacting policies and goals exogenous to those of policymaking jurisdictions. For example, solar penetrations in many states are nearing net metering program caps and these states are faced with the issue of how to best change their programs. In addition, the federal solar Investment Tax Credit (ITC), a federal policy that grants a 30 percent federal tax credit to residential and commercial solar systems, is currently set to expire at the end of 2016. Due in part to the expiring ITC, policymakers in Vermont have recently decided to raise the state’s net metering program caps to allow for as much federally subsidized solar development as possible (Heeter, Gelman, & Bird, 2014). Other examples of interacting policies include those affecting solar substitutes, such as subsidies on fossil fuels. The multifaceted political, economic, and technology landscape help to yield fertile grounds for controversy over net metering.

Net metering policies have been the subjects of active and intense debate in recent years. In the third quarter of 2015, regulators and legislators from 27 states where either conducting solar-valuation studies, net metering studies, or changing net metering policies. While some states are deciding on whether to raise net metering caps, others are investigating alternative mechanisms for promoting solar in their jurisdictions (Inskeep, et al., 2015). One of the undesirable byproducts of net metering policy disputes is uncertainty in the solar PV market. Because net metering policies have promised long-term benefit to solar and such technologies usually require long durations of use before customers realize positive returns, changes to these policies disrupts solar financing services and give existing and perspective residential solar users reason for concern about the viability of their current and future investments. In addition, current net metering policies are often ill-defined in technical terms. For instance, the state of Delaware has placed a cap on net metering at 5% of the utility’s “aggregated customer monthly demand;” however, it does not define what this term actually means and an exact interpretation of the metric is unclear even to experts. Uncertainty surrounding net metering policies results in problems where the continued adoption of solar decreases beyond what would be considered socially desirable and this can lead to unintended loss of jobs and business. Heeter et al. describe ways that states can mitigate the undesirable effects of uncertainty. Creating an equitable and fair queuing system for net metering that guarantees eligibility, provides adequate notification, and promotes data transparency on the status of net metering caps may help to preserve stability in the market for solar. Massachusetts’ System of Assurance provides exactly this kind of service through a web-based tool, and this helps to ensure perspective system owners that they can net meter before they begin development. The MassACA website is updated in near real-time with information about the state’s cap, pending allocations, and remaining capacity available. Services such as those provided in Massachusetts are important to mitigate uncertainty and promote successful transitions in policy (Heeter, Gelman, & Bird, 2014).

**2. Roles for Planned Adaptation**

Policies and decisions often yield consequences that are distinctly different from those originally intended. In the private sector, divergence from performance targets often results in the prompt revision of past policy; however, in the public sector, reaction times are considerably slower. With regards to policy, McCray and Oye explain that domestic and international regulatory regimes may be placing too much emphasis on “getting-it-right up front” and showing reluctance to reevaluate existing regulations without imminent need (McCray & Oye, Adaptation and Anticipation: Learning from Policy Experience, 2007). Such a stance leaves the public susceptible to ineffective policies for long durations of time, with decision-makers merely reacting when blatant and costly failures come to light. The concept of planned adaptation attempts to ameliorate this sub-optimal situation by encouraging policy and decision-makers to appropriately recognize uncertainties inherent at the time of enactment. McCray et al. describe a stance based on planned adaptation to reflect, “a commitment by the decision-maker to revisit the decision at a later time in order to make any needed modifications.” Planned adaptation has also been described to draw on the concept of feedback: the acts of both “sensing and controlling a process,” or having a “learning and a changing function” (McCray, Oye, & Petersen, 2010). Though the concept of planned adaptation may seem like an obvious, useful, and thus widespread approach to public policy, this fails to be the case. A 2007 working paper from McCray and Oye describes an analysis of 32 historical cases concerning the review of existing rules in U.S. regulation and found only eight that could be considered potential instances of planned adaptation. To explain its dearth in occurrence, the authors describe possible barriers to planned adaptation including regulatory opposition, the need to render regulations enforceable, the promotion of credibility and compliance, a high value on policy stability, the dominance of ‘notice-and-comment rulemaking,’ and the demanding condition of negotiation in the rulemaking process (McCray & Oye, Adaptation and Anticipation: Learning from Policy Experience, 2007).

2.1 Net Metering Caps

Net metering caps place limits on the amount of net metering that can be exercised in a given jurisdiction; arguments for and against increasing these caps mirror those proposed for net metering as a policy instrument in general. Increasing net metering caps have the effect of continuing net metering for longer durations, while failing to do so may hurt growth in residential solar but preserve ratepayer equity and grid reliability.

As of August 2014, 25 of the 44 U.S. states or districts with net metering policies employed peak or capacity caps (Flores-Espino, 2015). While these caps are relatively simple, they may be seen as mechanisms for planned adaptation which limit the potentially damaging effects of net metering.2 Though states may not be using ‘planned adaptation” in their regular lexicon, they are effectively demonstrating a commitment to revisit their net metering policies in the future, stimulate discussion, learn from their experiences, and adapt given social, economic, and technological change.2 Net metering caps exemplify the characteristic of feedback: sensing is demonstrated as caps near and policymakers open dialogue with stakeholders about the value of distributed generation and the design of associated policies. Control is demonstrated as policymakers draft new policies given the most up-to-date information and research. Taken together, sensing and controlling processes help states to ensure distributed solar will not reach levels that will disrupt the financial stability of utilities, cause system reliability issues, or considerably damage the rooftop solar industry.

Net metering program caps come in many varieties but the most common can be characterized as either being flat megawatt caps or caps based on a percentage of peak demand or capacity for states or individual utilities. California employs a unique metric: the “non-coincident peak demand” which is the sum of peak demands for individual loads. Some states, including California, also specify a date that will prevent additional net metering enrollment across the state if caps are not first reached; California mandates that utilities must offer net metering until either it reaches its 5% program cap, or July 1, 2017, whichever comes earlier (Heeter, Gelman, & Bird, 2014; Inskeep, et al., 2015). These mechanisms are interesting subjects for analysis because of their diversity and the varied sociotechnical circumstances in states. Net metering program caps are different from previously identified examples of planned adaptation in policy because they may be triggered on both time-based and event-based grounds. Having a flat megawatt cap may be advantageous because of the associated ease for which utilities can predict whether they are able to maintain financial and network stability at a given cap size. Other metrics may be advantageous for different reasons. Having percentage-based caps may be preferable because the financial and network stability of a power system employing net metering correlates with the size of the system; thus, if a utility’s load increases, the amount of net metering it can support may scale proportionally. Purely time-sensitive net metering policies are arguably less adequate than these measures because there may be significant uncertainties about the rate of residential solar adoption, the size power systems, and the financial health of utilities. For instance, if a breakthrough photovoltaic technology is developed that dramatically lowers the cost of solar, residential solar adoption rates will conceivably skyrocket, leaving a utility under strictly time-sensitive net metering policy restrictions vulnerable to bear the costs of unanticipated changes in systems dynamics.

Though considerations for net metering caps as planned adaptive mechanisms have clean explanations from a theoretical perspective, research into their historical use shows that they haven’t always been as quantitative and data-driven as may be preferred in policy decisions. A 2009 study by Doris et al. analyzes net metering cap size deliberations in other states in order to help inform such a policy decision in Minnesota. The authors describe a desire to quantitatively assess the impact of increasing net metering caps on various stakeholders but note significant limitations to doing so due to the lack of relevant data available. Furthermore, there were no generally accepted methodologies for calculating reasonable cap sizes at the time and most states did not undergo rigorous benefit-cost studies before increasing their caps. The authors ultimately make the recommendation for Minnesota to increase its cap size, citing other states who have done so and have not reported significant negative consequences on ratepayers. Though this study was done at a time when data was less available and solar penetrations were much lower than they are today, the case elucidates caution demonstrated by states in times of uncertainty and exemplifies a need for planned adaptive mechanisms. States such as Minnesota were uncertain regarding the ‘right’ policy decision and couldn’t even perform their own data-driven benefit-cost analyses; they instead had to rely on qualitative assessments and comparative analyses with other states and commit to revisiting their policy decisions in the future.

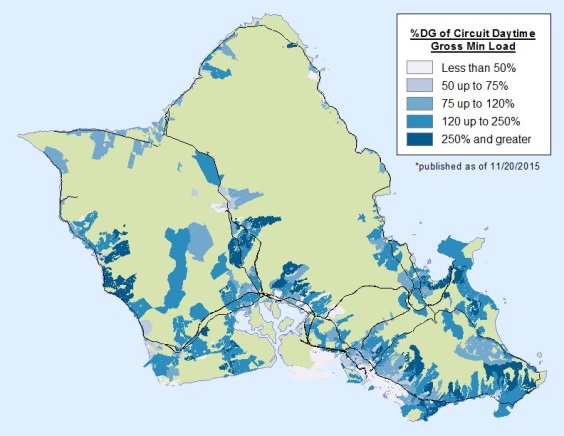
2.2 Net Metering Triggers

New Jersey, Maine, and Minnesota have ‘trigger’ or ‘notification’ measures in place instead of net metering caps in order to prompt a regulatory discussion about the status of net metering when predefined levels of solar penetration are reached. The difference between trigger mechanisms and caps is that these triggers do not require utilities to suspend net metering after the trigger level is reached (Heeter, Gelman, & Bird, 2014). In a framework focusing on planned adaptation, net metering triggers may be thought to be intermediaries between caps and a lack thereof. While triggers do not guarantee that utilities are completely safe from providing net metering services over a predefined level, they ensure that a formal discussion over the possible consequences of widespread net metering is held before conditions change too considerably. They are also beneficial because they prevent the rooftop solar industry from coming to a grinding halt as may happen in cases where net metering caps are met. With regards to feedback in net metering triggers, the sensing process concerns a measurement of the prevalence of net metering and a formal discussion about next-steps. The controlling process is optional: policymakers will only deviate from the status quo if deemed beneficial to do so.

2.3 Circuit-Specific Analysis in Hawaii

Solar has had remarkable success in Hawaii. Over 12% of electricity customers in the state generate power from solar PV and the state leads the nation in solar generation per capita. The solar industry in Hawaii owes part of its success to the state’s unique island energy ecosystem. The state has abundant solar irradiance and also has the nation’s highest electricity rates as it imports oil to power its grids as opposed to coal, due to coal being too difficult and expensive to ship (Trabish, 2015; Shimogawa, 2015; Bade, 2015). Furthermore, Hawaii has shown commitment to aggressive renewable portfolio standards; Hawaiian Governor David Ige recently signed a bill that directs the state’s utilities to generate 100% of their electricity from renewable sources by 2045, making it the first U.S. state to commit to complete decarbonization (Leong & McMillan, 2015).

Net metering policies in Hawaii are also unique. A cap of 0.5% of system-wide peak demand was initially established in 2006, and this number was subsequently increased to 1% and 3-4% in 2008. In 2011, this system-wide net metering cap was removed, and the state instead implemented a 15% cap of circuit peak demand by distribution company. Net metering above this cap was permitted provided utilities assess it as appropriate to do so by performing an Interconnection Requirements Study (IRS) and analyzing specific circuits. In 2013, HECO, discontinued requiring Interconnection Requirements Studies for circuits that have rooftop solar capacity below 100% of its daytime minimum circuit load (DML) (Heeter, Gelman, & Bird, 2014; Wesoff, 2014). For prospective solar customers, HECO provides an online address search tool called the Locational Value Map (LVM) that is updated every weeknight. Users can enter their address, see the penetration of distributed generation at their specific location, and evaluate how easy it would be for them to connect new rooftop solar to the grid and exercise net metering (Hawaiian Electric Company, 2015).



**Figure 4**. Location Value Map for Oahu depicting % Distributed Generation of Circuit Daytime Gross Minimum Load, November 20, 2015. (Hawaiian Electric Company, 2015)

HECO describes their problem with high penetrations of distributed generation to be one regarding the utility’s engineering model in addition to its business model. They cite potential overvoltage and reliability issues resulting from the possibility of more generation than consumption at any given time. They also note complications involving the conveyance of power in two directions. If users live in areas with solar generation capacity between 75% and 100% of DML, the utility will determine if circuit or protective equipment upgrades are needed through a “supplemental review” program at no cost. For customers connected to circuits with solar generation capacity greater than 100% DML, the utility will determine whether a full IRS is needed. If circuit upgrades are determined to be required by either of these studies, the utility will usually offer to install them at a prorated share of the cost (Wesoff, 2014).

Hawaii’s approach to allowing net metering caps employs a number of features worth considering as planned adaptive mechanisms. Because of the unique energy circumstances in the state, it has done away with the notion that simple net metering caps can provide the level of feedback necessary to promote supervised rooftop solar industry growth. Instead of relying exclusively on aggregate decisions made by state-level officials every time caps are met, the state also relies on data-driven circuit-specific analysis to provide information at the much more granular circuit-level. Hawaii’s HECO relies on its Locational Value Map online tool to provide a first-level filter for potential customers to gauge the likelihood they are eligible for net metering and interconnection. The data shown on the LVM reflects information portrayed by the utility’s sensing process, as they assess and communicate the loads on their circuits every weekday night. The controlling process is distributed among potential customers as HECO takes advantage of self-selection: potential customers are able to determine the difficulty of becoming eligible to net meter based on the solar generation capacity metrics at their specific locations. If a customer wants to connect despite unfavorable circuit conditions, he or she can take advantage of the utility’s supplemental review and IRS processes to make further determinations and potentially share the costs of circuit upgrades. The difficulties of undergoing such a process and the possibility of having to pay for infrastructure upgrades will discourage blatantly harmful rooftop solar interconnection requests, and the utilities themselves can block harmful interconnection without first securing the resources necessary to upgrade circuits and nullify interconnection problems.

2.4 Room for Improvement

Though net metering program caps, triggers, and circuit-specific analyses exemplify mechanisms for planned adaptation, other perspectives on net metering show that states do not always act in ways that demonstrate intentions for learning and self-correction. By pointing out past failures in this regard, recommendations for policy improvement can be made.

In the net metering literature reviewed, uncapped net metering policies themselves exemplify lack of foresight in policy design and implementation. As of August 2014, 16 of 44 jurisdictions with net metering programs placed no restriction on aggregate net metering capacity allowed (Heeter, Gelman, & Bird, 2014). Unlike many other incentives for the promotion of renewables, this implies that net metering in these states is currently never scheduled to end (Stoutenborough & Beverlin, 2008). This is especially problematic given the long-term negative implications of unabated net metering for customer equity and the economic and technological sustainability of electricity transmission and distribution, as discussed previously. As solar penetration in these states and jurisdictions grow, such uncapped net metering policies will need to be revisited in a reactionary manner, disrupting customer expectations and local markets for rooftop solar installers. Mechanisms like caps and triggers would help these groups to better calibrate their expectations and admit to future uncertainty. Ironically, the growth of PV generation, for which these cases of uncapped net metering are in part responsible, has jeopardized these policies’ own continued validity.

Studies of the dynamics of net metering policy diffusion among states give insight into the nature of state-level policy adoption. In the section of this paper that presents net metering program caps as examples of planned adaption, the argument was made that a lack of relevant data caused many states to concede uncertainty in policy, conduct comparative analyses, and adopt net metering caps based on the experiences of other states. This necessary admission of uncertainty led states to ultimately adopt cautionary program caps congruent with planned adaptation. Despite this, it can also be argued that such susceptibility for policy diffusion demonstrates an overreliance on following other states and a deficiency in sensing processes with regards to feedback. While the spread of net metering caps and triggers denotes the spread of caution and judiciousness, the original proliferation of net metering in general suggests the propagation of myopic policy. Stoutenborough and Beverlin conducted an event-history analysis of the diffusion of state net metering policies and found that states have been highly influenced by the policies of other states in their respective regions. They also found that influence from the Environmental Protection Agency’s (EPA) regional offices has helped to facilitate regional diffusion, and that some states have earned reputations for being the developers of innovative policies (Stoutenborough & Beverlin, 2008). It can be argued that many states placed a higher value on conforming to the seemingly innovative net metering policies of their neighbors than fully ‘sensing’ and evaluating net metering policies for themselves. Furthermore, the influence of the EPA’s regional offices exemplifies institutional promotion of such behavior. If net metering were scrutinized more carefully, its long-term unsustainability as a policy may have been discovered and communicated sooner. States can improve their policy compass for effective feedback if they focus more on the individual merits of proposed policy than on conforming to the practices of their regional peers.

**Figure 5**. States rapidly adopted net metering policies in the late 1990s and 2000 (Stoutenborough & Beverlin, 2008)



In response to deficiencies recognized in net metering policies, some states have tried to decrease the benefits conferred to net-metered customers by implementing fixed charges for all customers and decreasing retail rates for electricity. Their main purpose for doing so is to allow utilities to better recover the costs of operating and maintaining the grid from customers with rooftop solar. In 2014, the Wisconsin Public Service Commission carried out exactly such actions as they increased a fixed monthly fee for residential customers from $10.00 to $19.00 and decreased their rates from $0.111/kWh to $0.102/kWh (Flores-Espino, 2015). Though making such adjustments allowed the utilities to decrease compensation to customers with PV systems, it exemplifies the reactionary use of blunt instruments that distort the market for solar and increase the level of uncertainty for future payments. While fixed charges have the economic effect of decreasing the compensation for solar across-the-board, it does so in a way that hurts smaller producers to proportionally greater extents than larger producers. These fixed charges also lack the ability to self-correct and respond to changing market conditions. If the energy-mix on the grid changes drastically and the overall costs and benefits of solar change as a result, the effects of these distortions to the market will be amplified. Finally, such unannounced changes in net metering policy have the effect of increasing uncertainty in payments for rooftop solar, and this uncertainty can be potentially devastating to continued investment and solar financing schemes. Though changes in payments for technologies should be made to better reflect their economic and external benefits, it is important for those changes to be appropriately anticipated by those they affect. Failure to give adequate warning may further exacerbate prospects for future investment, and may also render investments made on past policy to result in monthly losses for system owners. It is recommended that the use of such fixed charges be critically evaluated before implementation, for more discriminatory market-sensitive mechanisms to be employed instead to increase feedback frequency, and for policies like grandfathering to be considered to decrease uncertainty and preserve the viability of past investments.

2.5 Developments Toward a More Adaptive Future

Energy systems are expected to change in the coming years with the continued integration of distributed energy resources including rooftop solar and distributed storage technologies, improved information and communication technologies, and loads with new characteristics such as electric vehicles. These changes, in addition to the political, economic, and social factors previously discussed, are predicted to yield problems under current regulatory frameworks but also enable technology and policy solutions to help solve them.

MIT Energy Initiative researchers Pérez-Arriaga and Bharatkumar explore anticipated problems brought about by an increasing share of distributed energy resources with current net metering policies, volumetric tariffs, and conventional metering practices. Volumetric tariffs charge network users average rates for broad classes of consumers: typically residential, commercial, and industrial customers. These rates bundle the utility’s total costs including the cost of generation, transmission, maintenance, customer services, and other charges such as those associated with energy efficiency, promotion of renewables, and industry restructuring. In addition, conventional metering technologies generally aggregate energy use in monthly or bimonthly billing cycles. The authors describe how it is actually the confluence of net metering policies, volumetric tariff designs, and conventional electricity metering technologies that produce the greatest threats to the viability of the distribution network as distributed energy resources become more prevalent (Pérez-Arriaga & Bharatkumar, 2014; Schmalensee & Miller, 2015). Volumetric tariffs combined with net metering lead to the undue subsidization of transmission and distribution charges from those without distributed generation systems to those with them, because net metered customers are unfairly refunded such implicit charges on top of the wholesale rate of electricity when they receive their generation credits. Conventional metering technologies exacerbate this effect because distributed generation and energy demand profiles have imperfect correlation. All else equal, if electricity is less expensive to generate in some parts of the day relative to others, for example when the sun is shining, energy generated at these times should be compensated less than when generation is more expensive. Despite the fact that generators should be credited according to the temporally differentiated value their services bring, conventional meters instead compensate distributed generation at a generally higher undifferentiated rate when combined with net metering. The result is overcompensating distributed generators in times of cheap generation and undercompensating generators otherwise.

Assuming that as the industry evolves and adopts “advanced metering infrastructure” that can deliver hourly or quarter-hourly network utilization information to utilities, Pérez-Arriaga and Bharatkumar propose a new type of tariff referred to as Distribution Network Use of System charges (DNUoS), which are calculated using powerful computational models. DNUoS will help lead to more sustainable economics for electricity distribution, improved network utilization, and a more equitable distribution of charges to customers. The team’s idea is that with advanced metering infrastructure that conveys network utilization profile information, utilities will be able to determine the contribution of each customer to each cost driver and their specific contributions to the total network cost. As opposed to volumetric tariffs, DNUoS charges will correspond to each user’s individual costs and create price signals to improve how their use of the distribution system affects the system as a whole. This will help to eliminate undue subsidies from one customer class to another, decrease inefficiencies, and incentivize behavior that optimizes network utilization. The authors propose the development and use of advanced computational tools called Reference Network Models, which model entire energy systems and allow contributions to network costs to be determined from network utilization profile information (Pérez-Arriaga & Bharatkumar, 2014). With data modeling, advanced metering infrastructure, and DNUoS charges as opposed to conventional metering and volumetric tariffs, the problems associated with net metering can be aptly internalized and price signals can be designed to encourage improved behavior for network use.

The future-state policy frameworks prescribed by academics including Pérez-Arriaga and Bharatkumar constitute elements of planned adaptation by way of greatly improved feedback. Enabled by new metering and data analysis technologies, DNUoS charges may provide tremendously more accurate price signals to customers than the current state. With net metering as presently implemented, generation credits conferred to distributed generation are generally rendered greater than the beneficial services actually provided. Planning for additional distributed generation happens when customers estimate that these amplified credits provide an acceptable return on investment, until perhaps a net metering cap is reached. In essence, the controlling process of investing in additional rooftop solar is influenced by a distorted sensing process and event-based triggers set in the distant past. On the other hand, the proposed policy framework based on computational modeling and revised DNUoS charges may potentially provide significantly more accurate price signals with near real-time frequency. Such a future-state leverages market mechanisms and technologies to provide greatly improved feedback, and exemplifies significant progress from a vista emphasizing planned adaptation.

**3. Knowledge Assessment: California’s Net Metering Successor Tariff Proposals and ‘Public Tool’**

In his recent email correspondence, McCray describes what he considers as a “strong form” of planned adaptation. He describes that this is when a decision maker (1) “commits to a de novo reconsideration of the assumptions and effects of a current policy, with an explicit time-trigger or event-trigger,” (2) “arranges for an independent assessment of such assumptions and effects” and (3) “specifies those assumptions and effects that it considers most germane, in order to encourage research on the right questions” (McCray L. , Comment on draft -- Net Energy Metering, 2015). A case study on California’s net metering successor tariff proposals arguably fits this definition of a “strong form” of planned adaptation and demonstrates an interesting technology-enabled example of knowledge assessment.

Californian utilities are mandated by California Assembly Bill 327 to offer net metering until either the state reaches its net metering cap of 5% “non-coincident peak demand” or the date passes July 1, 2017, whichever is earlier. When this happens, Californian utilities must offer a standard contract or tariff, which will be developed by the California Public Utilities Commission (CPUC) (Heeter, Gelman, & Bird, 2014). Though it may potentially include net metering, this standard contract is commonly referred to as a ‘successor tariff’ for net metering in the state. It will not have caps like the state’s current net metering regime and will not apply to customers who already entered into net metering agreements before being put into effect (Inskeep, et al., 2015).

In March 2014, CPUC opened bids for contractors to help develop its ‘Public Tool,’ a software program intended to analyze and compare the costs and benefits of possible successor tariffs and predicting customer adoption of distributed energy resources. CPUC granted the work the following month to Energy and Environmental Economics (E3), an energy consulting firm based in the area (St. John, California’s Software for Planning Net Metering 2.0 Is Broken, 2015). The public tool took the form of a complex excel-based program that models the impact of various rate designs and input assumptions over a 30-year timespan, runs custom scenarios, and performs sensitivity analyses, among other functions. Underlying goals behind the endeavor included the encouragement of sustainable growth in distributed generation, support for the adoption of a successor contract by December 31, 2015, and the development of alternative contracts for ‘disadvantaged communities’ (Price, Kahn-Lang, Chait, & Ming, 2014; St. John, California’s Software for Planning Net Metering 2.0 Is Broken, 2015). Perceived benefits of the tool is that it is allows for improved engagement of successor tariff stakeholders, it provides equal opportunity for these stakeholders to analyze and test their proposals, and it facilitates open communication among parties. Within the past year, stakeholders including utilities, solar advocacy groups, and CPUC’s consumer-advocacy arm, the Office of Ratepayer Advocates, reviewed draft versions of the public tool and used it to model their proposed tariff designs. They then worked with CPUC to address necessary changes for the final version of the public tool and subsequently used the tool as a platform to communicate the benefits of their proposed tariff designs, argue their assumptions, and respond to successor tariffs proposed by other stakeholders. Meanwhile, CPUC and E3 made changes to the preset processes and assumptions in their model based on stakeholder feedback, provided an exhaustive list of answers to questions, and held a series of discussions and workshops with stakeholders to instruct on the operation of the public tool and discuss policy objectives (Renewable Customer-Generation Successor Tariff or Contract, 2015; Price, Kahn-Lang, Chait, & Ming, 2014).

Though a final successor tariff has yet to be decided on, it is interesting to contrast positions taken in the associated public tool-facilitated debate. Like the net metering battles previously presented, the design of a net metering successor tariff has drawn a division between electric utilities and solar advocates. PG&E and SCE both filed proposals that have the effect of significantly reducing the returns to distributed generation systems relative to returns under net metering rules today. PG&E has proposed an additional charge based on residential solar customers’ highest energy demand over the month, which has the effect of incentivizing lower peak energy usage. SCE submitted a proposal for a $3 per kilowatt-month “grid access charge” based on the capacity of the distributed generation systems in question. On top of these charges, both utilities proposed crediting distributed generation customers at lower rates than the retail rate for electricity, constituting a further reduction in compensation (St. John, California Utilities Release New Plans to Replace Net Metering: Conflict to Come?, 2015). On the other hand, solar industry advocates such as The Alliance for Solar Choice, the Solar Energy Industries Association and Vote Solar have submitted proposals to continue net metering under existing policy. Though their stances are very different, both sides submitted their proposals using the CPUC public tool and claim their proposed policies promote balanced and sustainable markets for the continued growth of renewables (St. John, California's Solar Industry Fights Back on Net Metering 2.0, 2015). Somewhere in between these two groups lies the Office of Ratepayer Advocates, CPUC’s consumer-advocacy arm aimed to promote customer and environmental protections. The Office of Ratepayer Advocates proposes keeping net metering, but adding a $2 per kW capacity charge for the successor tariff. This charge would then increase to $5 and $10 per kW capacity as a utility’s aggregate customer peak demand reaches 6% and 7%, respectively (Inskeep, et al., 2015).

Though it is still too early to evaluate efficacy due to the fact that a decision has yet to be made, what is especially interesting about CPUC’s knowledge assessment efforts is its use of a software tool which aims to increase transparency, provide a common vocabulary, deliver a sophisticated model for all parties to leverage, avoid duplicate and incompatible work, encourage public discourse, compare stakeholder proposals, and improve auditability of underlying assumptions, inputs, and calculations. Such an approach can be seen to effectively moderate the adversarial political process by emphasizing a data-driven approach to decision making as opposed to one with an emphasis on rhetoric. As stated in the beginning of this section, this case may also be argued to exemplify the ‘strong form’ of planned adaptation. Impending time and event-triggers and using the public tool has motivated the original design of successor tariff policy by multiple stakeholders, arranged for independent assessments of proposals by CPUC and E3 while leveraging rebuttals from the stakeholders themselves, and facilitated the wide-ranging assessment of assumptions and effects.

**4. Recommendations**

I think that it’s important to recognize that net metering policies and debates stem from the inability of the international community to date on setting a price on carbon emissions. If we could tax emissions or set up cap and trade markets to internalize externalities associated with climate change, discussions about appropriately subsidizing solar would be irrelevant as markets adjust energy prices accordingly. It is important to also realize that individual nations or even groups of nations cannot act alone, since carbon emissions affect the global commons and energy prices are built into nearly all products and services. Differences in the treatment of emissions between countries thus yield penalties on stricter countries and are exacerbated by inequalities in trade. Setting an international price on carbon represents a serious collective action problem. Because of this, my first recommendation is for countries to work together and set a universal price on carbon.

Net metering is then one among a suite of practices and policies to incentivize clean and renewable energy technologies in the absence of a universal price on carbon. Though net metering has likely been beneficial on net regarding its necessary promotion of renewables in the past, I think net metering as it is enacted today underperforms as a long-term sustainable solution for incentivizing renewables. As mentioned in section 2, it suffers from myriad problems including inequity among customer classes, potential for positive feedback mechanisms, and grid destabilization. Though I am an advocate for the increased adoption of renewable energy technologies, I think improved mechanisms need to be set in place to appropriately match the magnitude of the social and environmental benefits from distributed generation with its subsequent compensation. I think that all of the steps that have been demonstrated toward improving frameworks for planned adaptation and feedback contribute positively in this regard. If I were a decision maker in this field, I would make a strong push for the development and enactment of DNUoS charges and systems as described in section 2.5. I would also encourage research institutions and the private sector to assist in piloting programs for their implementation. Information and communications technologies promise enormous benefit for the power and utilities sector and more aggressive efforts need to be made to capitalize on them.

My last recommendation is to crack down on unnecessary uncertainty in net metering policies. Uncertainty around the status of approaching net metering caps and changes to policies for existing customers will likely discourage investment past what is socially beneficial. If a prospective rooftop system owner is afraid that the returns on her investment may disappear overnight, she will be much less willing to make an initial investment. This concept extends towards solar financing organizations and those employed as local solar installers, and can lead to unnecessary loss of business and jobs. To alleviate problems associated with uncertainty, I would recommend for policies to embrace grandfathering rules that last as long as the average lifetime of the technologies in question. I would also recommend the implementation of transparent systems that inform stakeholders of progress toward net metering caps, provide fair queuing services for net metering eligibility, and notify the public about current discussions on successor policies.

**5. Conclusion**

Net metering policy debates reflect rich political economy issues including Olsonian collective action problems associated with carbon emissions, free-rider problems on electricity grids, Stiglerian influence regarding rooftop solar substitutes, uncertainty producing suboptimal investment, and problems with equity and fairness between subclasses of affected populations. It also presents unique cases for knowledge assessment encompassing adversarial political processes, third-party assessments, and in California’s case, a software tool to improve transparency, encourage constructive public discourse, democratize access to policy debates, and improve auditability of important assumptions in predictive modeling. Finally, net metering policies comprise diverse examples of planned adaptation. These policies have been shown to employ time-triggers, event-triggers, self-selection processes, near real-time sensing, and are poised to become increasingly market-based and technology-enabled. Though net metering policies are highly varied and their associated conflicts are far from sound resolutions, they represent interesting cases in policy that we should continue to study. In addition to enabling better energy policy, lessons learned may provide valuable insight that is transferrable to other industries and issues.

**6. Notes**

1 The retail rate is the volumetric price that consumers pay utilities per unit of electricity delivered to them via the distribution network. The wholesale rate is generally lower than the retail rate, and constitutes the rate that utilities pay grid-scale generators before distribution.

2Though net metering caps have been described, studied, and enacted, the author of this paper was unable to find any formal account which pronounced net metering as an example of planned adaptation in the literature. This section is a modest first attempt to do so.

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