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Title: Institutional Transition in the Electric Power Grid: Solar PV in California

Net energy metering (NEM), the diffusion of residential photovoltaics (PV), and the smart grid transition are three accelerants of change that impact the rate of transitory change in the electric power grid system. Institutional relationships that underpin the old central station model now appear to be fracturing under the weight of that change. Like many states with NEM policy, California experiences heated disputes between investor owned utilities and the PV community over grid service valuation. The challenge for the California Public Utility Commission is to apply present NEM policy while revising it under legislative directive, all in the context of other state and federal policies that exacerbate elements of the conflict. This essay begins by qualitatively examining the present institutional setting in the state by using the Institutional Analysis and Development (IAD) framework. Quantitative exploratory spatial inquiry in the framework features location quotient data methodology of residential installation data, and finds statistically significant clusters of high and low values, as well as local cluster and hot spots of residential PV installations in the California study area.

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Institutional Transition in the Electric Power Grid: Solar PV in California

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TABLE OF CONTENTS

LIST OF FIGURES

List of Figures continued

LIST OF TABLES

CHAPTER 1. INTRODUCTION

Long taken for granted, the supply and delivery of electricity is a cornerstone of our modern way of life and economic vitality. The electric grid system, as presently constructed, is designed for a downstream flow of electricity from producer to consumer, but the accepted norm of supply and demand now shake from zones of weakness caused by an evolution in digital change. Producers of electricity are both aided and threatened by the change, and consumers now awaken to opportunities not previously available in the analog era. As end use consumers, utility ratepayers are constrained more by budgetary concerns than externalities (i.e. pollution and climate change), and live as a captive customer base in a defined territory served by a one specific utility. As evolution quickens in the grid, the path-dependent relationship between a utility, its ratepayers and a regulatory system entrusted with fairness, has begun to fracture under the weight of change.

The evolution of the electricity infrastructure is a function of three key accelerants. First, the residential solar photovoltaic (PV) technology is nearing maturity with market inertia, the diffusion of which is a function of technological advances, economies of scale, incentive programs and attractive procurement options (i.e. financing, leasing, and power purchasing agreements). Second, the implementation of the 2007 Smart Grid Investment Grant (SGIG) program, funded in large part by economic stimulus events in 2009, continues the trajectory of significant technical and operational technologies for digital conversion and distributive operation (U.S. DOE, 2013). Third, states' with Net Energy Metering (NEM) policy that directs utilities, particularly investor owned utilities (IOU's), to allow homeowners access to the grid with their supply of excess electricity while being compensated at the same retail rate charged by the utility. Combined, the three accelerants empower a class of ‘prosumer’ (producer/ consumer) ratepayers that have installed PV systems, initiated by the encouragement of NEM policy and tax credit incentives. With newfound economic power, prosumers backed by a robust PV industry and correlated energy policy directives, leverage smart grid advances and NEM benefits that significantly challenge the central station model of control long enjoyed by the utility sector.

Stunned by the escalating pace of PV diffusion and empowerment of prosumers, the utility sector now considers residential PV as a significant and escalating threat to their distribution system of operations. States’ NEM policy has become ground zero to staunch the threat of residential PV expansion. From the utility perspective, altering or eliminating NEM policy makes two corrections. First, the necessity to raise rates on non-PV customers (“cost-shift”) is avoided. Second, the utility sector seeks regulatory support to segregate PV owners, as a ratepayer class, to unique structures designed to offset costs of grid services, as viewed by the utility. Challenges to utility cost shift claims are contained in a growing cadre of recent reports and studies that highlight numerous benefits that PV provides to the grid and all ratepayers (Barnes & Varnado, 2010; Darghouth, Barbose, & Wiser, 2011; E3, 2010; IREC, 2013; RMI, 2012). The problem is that benefit and cost valuation, which is necessary to advise NEM policy revision, is difficult to achieve without available data, and the question of how to assess impacts of residential PV diffusion in states’ with NEM policy remains largely unanswered.

Unfortunately, a lack of transparent and reliable data in the public domain limits empirical work that could establish statistical relationship(s) between prosumer behavior and the perceived impacts to the grid. The limitation of available data creates research issues like small sample size and a necessity to piecewise information for inference. Methodology is not uniform and the results are mixed (Hansen, Lacy, & Glick, 2013). However, abundant and reliable data does exist. Utilities possess data amassed from millions of customer smart meters and digital hardware installed in their distribution networks, but utilities preclude data provision based on proprietary concerns. Privacy protection standards also restrict the release of personal information (Chang, Izant, Jamison, & Wong, 2013).

This essay examines the effect of residential PV diffusion on the geographic landscape, using California as a study area. To answer the question of whether the impact of residential PV diffusion is a random or constructed process, this essay employs Elinor Ostrom's Institutional Analysis and Development (IAD) framework as a method of qualitative examination of NEM and PV related issues to informs the process in the state. Inside the framework is an added quantitative method featuring exploratory spatial analysis, which addresses the effect of residential PV diffusion in the state. This spatial component examines whether residential PV is a random occurrence or if statistically significant patterns exist. The results indicate that residential PV installations exist as both clusters and hot spots.

The content of this paper identifies areas in regions of the state that have higher and lower levels of PV penetration than one might expect. This type of analysis is important for several reasons. First, the results of this paper can set forth methodology to uncover geographic heterogeneities. While there are suspicions that some areas (i.e. deep rural or inaccessible terrain) will remain disconnected from residential PV diffusion, the most salient issue is that increased levels of PV integration by all ratepayer types will impact the present grid system faster than interested parties anticipate (cascade effect). Though exploratory, this paper begins the process to highlight where infrastructure location of clusters may exist and deepens an understanding of where geographic advantages that some locations have in the grid infrastructure. Second, the empirical results provide a consideration to California NEM policy soon under review, and for other states considering NEM revision. As a result, subsequent research efforts can use the foundation set forth as a template for uncovering geographic markers for identifying growth opportunities, however that becomes defined over time.

This paper is structured as an exploratory research document. The following “Background” section provides an overview of the three accelerants, presented in this order: Net Energy Metering Policy, the Diffusion of Innovation: Residential PV, and the Smart Grid Transition. The “Methods” section introduces the IAD framework and describes the GIS tools used for spatial inquiry. The “Results” section populates the framework with qualitative content and presents quantitative data compilation and maps of the study area, all of which informs the subsequent “Analysis of Findings” section. The paper concludes with a brief discussion and recommendations.

CHAPTER 2. BACKGROUND

This chapter illuminates the dynamics of net energy metering (NEM), residential-level solar photovoltaic technology (PV), and the smart grid (SG) transition. These three dynamics are accelerants of change that push and pull the previous analog electric grid infrastructure into a new, digital based infrastructure. The transitory change of the grid system is having profound impacts on operation and control, both locally and regionally. Great pressures from many point sources are being placed on the utility sector and the regulatory framework by which it operates. Their challenge is to make adjustments necessary to accommodate the interests of the ratepayer sector while the transition occurs in real time.

The most profound transition requires the electric utility to fundamentally change its operations of business. For investor owned utilities, the prospect of change from control over investment of production resources and controlled supply of electricity, to harmonious management of distributed generation, is rife with difficulty and runs counter to its most basic assumption of market dominance. No better example of this stress fracture exists than in the state of California. The proliferation of distributed generation, promoted by state and federal policy instruments and the market diffusion technologies, challenges the existing utility business model for the three major state utilities like no other previous threat.

The inclining block structure of increasing rates, constructed over time by the utilities and its state regulator, net energy metering incentivizes the residential ratepayer class to include PV technology, the diffusion of low cost PV makes the consideration economically viable, and smart grid provides the operational means.

A. Net Energy Metering (NEM) Policy

NEM is a state-level policy first enacted by Minnesota in 1983 to provide state utility customers a credit for the electricity produced by using small renewable energy technologies (“home power”) championed previously by the so called ‘Appropriate Technology’ movement in the 1970’s (Rybczynski, 1980). Since then, NEM policies have been replicated in various forms by other states. States’ typically specify electric utility involvement in a state regulatory framework. Detailed conditions direct participatory actions of utilities toward its customers in allowing homeowner-generated electricity delivery into the grid, and the type and rate of utility compensation. Though NEM is linked with PV system technology, most any electricity-producing renewable technology could conceivably apply.

Presently, 40 states, the District of Colombia, and four U.S. territories have enacted NEM policies (DSIRE, 2014). States’ NEM policies specify compensation, whereas connectivity is proscribed at the federal level under the Public Utility Regulatory Policies Act (PURPA) (Keyes, Fox, & & Weidman, 2013). Figure 1 below shows states with NEM policy and their stated limits on the capacity of NEM policy coverage.

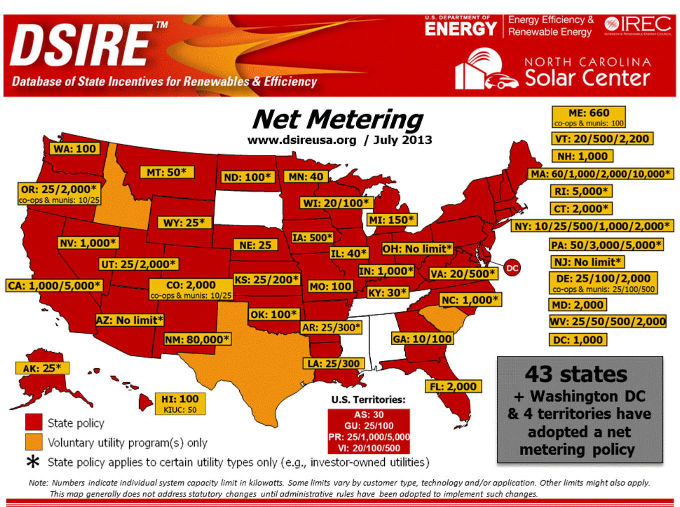


Figure 1. States with NEM policy
Source: DSIRE

NEM leverages digital ‘smart’ technology (e.g. smart meter) to record the flow of electricity. The difference between consumption and production is reconciled on the customer service account by kilowatts per hour (kwh), typically on a monthly basis. Surplus production is “netted” in favor the PV customer. In essence, the PV system becomes the primary source of electricity, and the grid is secondary for use as a “battery backup” and to “bank” kwh’s of electricity production for credit against future electricity demand (ALTA, 2013). Figure 2 below illustrates how excess electricity is redistributed to the grid.

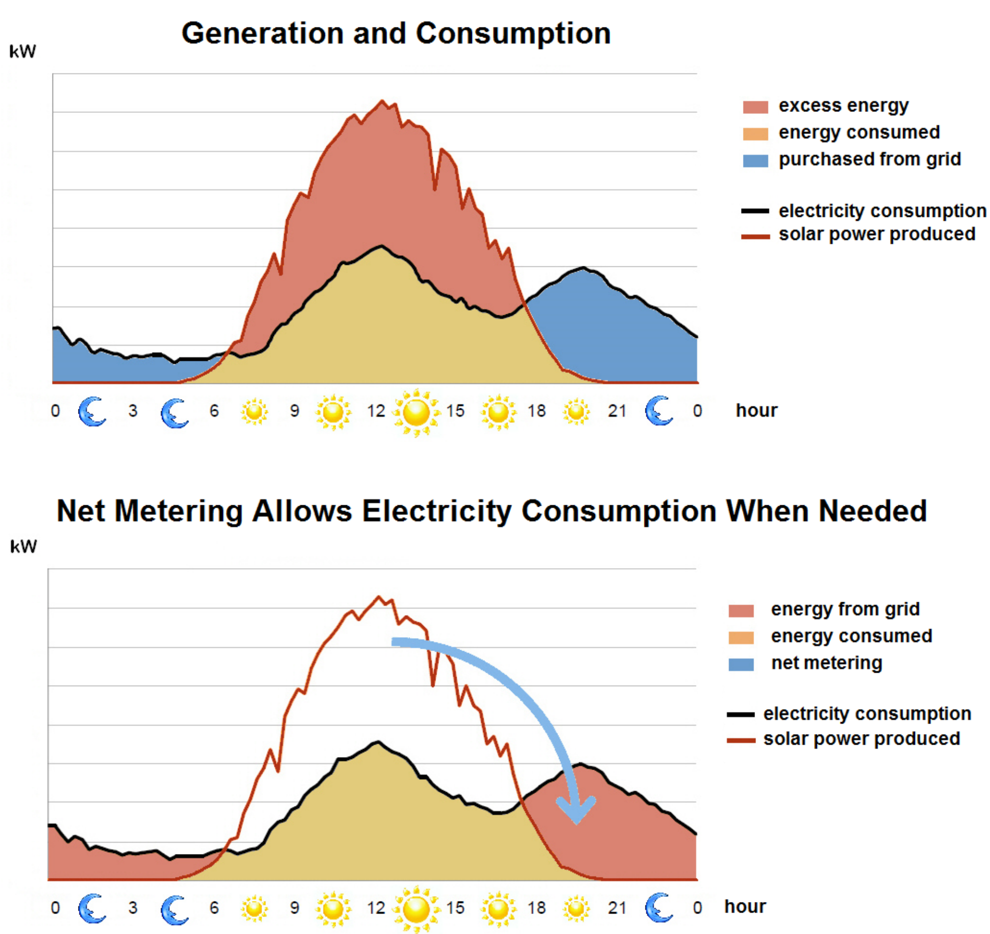


Figure 2. Redistribution of excess electricity to the grid by PV generation

Source: Heliopower

California for example, the utility calculates the net usage (consumption minus production) of every NEM customer on a monthly basis, and the net balance is reconciled at year-end resulting in a choice of a rollover credit or monetary compensation at the wholesale rate of electricity (Barnes & Varnado, 2010). At present, the state caps NEM at 5% for each participating utility, or 5573 MW, which is forecast to be reached by 2020 (Price et al., 2013).

Though procedures vary by state, a utility customer wishing to enroll in a NEM program and receive benefits must submit an application with their representative utility. This usually occurs in conjunction with the type of PV system chosen. System choice is usually the result of sales discussions with representatives of firms offering different system and/or financing options. Purchase and leasing are the two primary options available to homeowners.

The purchasing a system occurred early in PV growth, and was the most available option. Similar to other home improvements, price and budgetary considerations of high up front costs of PV require cash or home improvement financing. In 2010, the Orange County Business characterized solar growth in the southern California region as a "small, niche industry catering to businesses and well-to-do or environmentally conscious homeowners…fueled by rebates and incentives from governments and utilities" (Casacchia, 2010). Quoted sources in the article contend that getting a return on a purchased system takes five to seven years and that the high cost of the technology (~$20-40k) puts "solar out of reach for many homeowners and businesses."

A study in 2013 by the Center for American Progress (CAP) states that residential PV is occurs in neighorhoods where median income ranges from $40,000 to $90,000 (Hernandez, 2013). The report shows an average income level in California of under $60,000 and the income of customer installions at ~ $75,000 (Figure 3) using installation data from the California Solar Initiative.

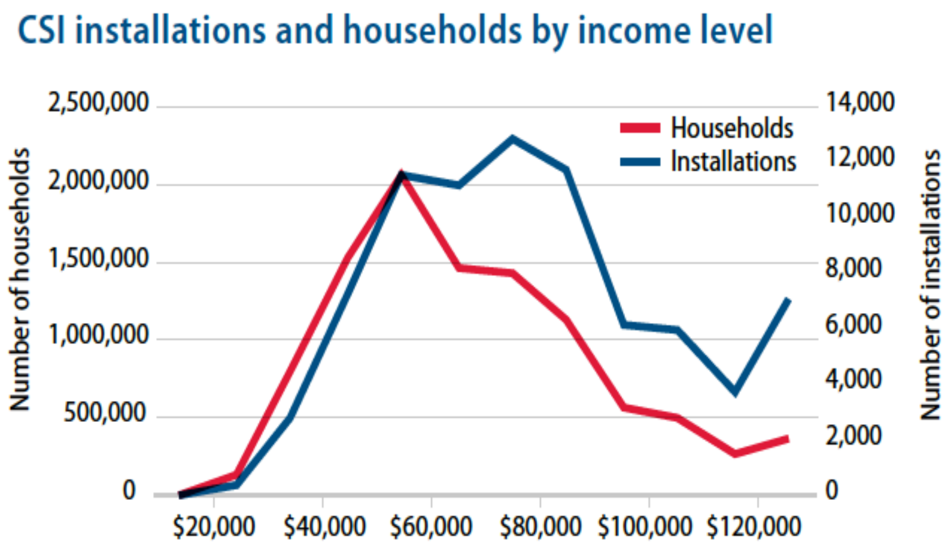


Figure 3. Graph of Households to Income in California
Source: Center for American Progress

Leasing a system avoids the steep upfront cost of purchasing a system. Structure as a power purchase agreement (PPA), a firm owns and installs the panels and the homeowner agrees to purchase the power in a fixed contract at a rate 15-30% less than utility rates. The contracts typically span 10 - 20 years (Gross, 2014). One firm, Sunrun Inc., operates in 10 U.S. states and specializes in residential installations (Gallagher, 2013). Another example, Sungevity, operates in nine states, Europe, and Australia and uses a social networking strategy to offer a $0 down option to attract customers (PR Newswire, 2011). Terms of a lease typically include design, installation, and maintenance of the system for the duration of the lease. By 2012, ~75% of new residential solar systems in California were leased as prices converged (Figure 4).

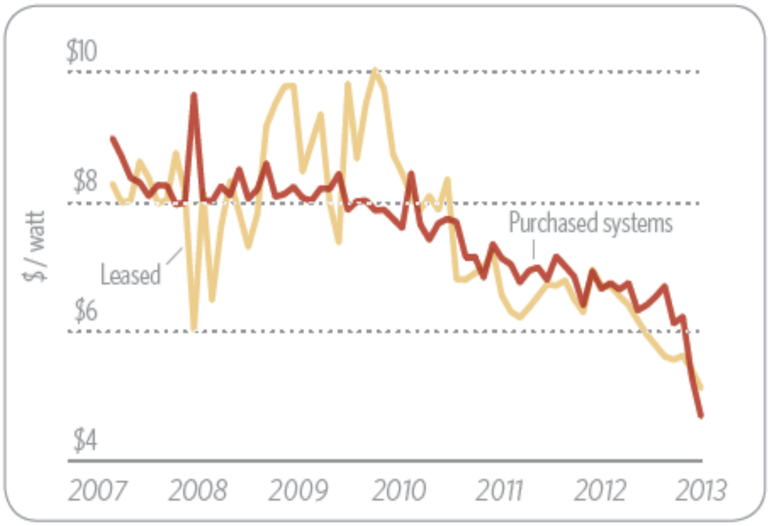


Figure 4. Lease versus purchase of solar rooftop systems.
Source: CPI

Leasing is an increasingly important driver for PV deployment because it contributes to growth even though the state CSI incentive program is concluding (Hobbs & Pierpont, 2013).

- Leasing transforms a complex investment into a money saving service
- Leased systems cost taxpayers less [incentive cost] than purchased systems
- Declining state incentives have partially driven the increase in leasing
- Solar leasing companies have a strong growth incentive
- Competition among solar leasing companies has lowered prices to consumers
- Wider economic classes of customers are being served

Regardless of the type of financing chosen, residential PV is an attractive hedge against household energy cost and future utility rate increases. The consumer enjoys use of the electricity produced by the system and production credit under state NEM policy, typically at the same retail rate charged by the utility.

It is worth noting two related NEM related programs – Virtual Net Energy Metering (VNM) and Community Solar (aka "garden solar") - are offered by some states' as NEM related benefits (Figure 5). VNM in California enables a property owner to allocate energy credits to benefit anyone that rents or leases in a multi-tenant building complex having a single point of access for electricity hookup. "The participating utility allocates the kilowatt-hours from the energy produced by the solar PV generating system to both the building owner and tenants' individual utility accounts, based on a pre-arranged allocation agreement" (CAPUC, 2014).

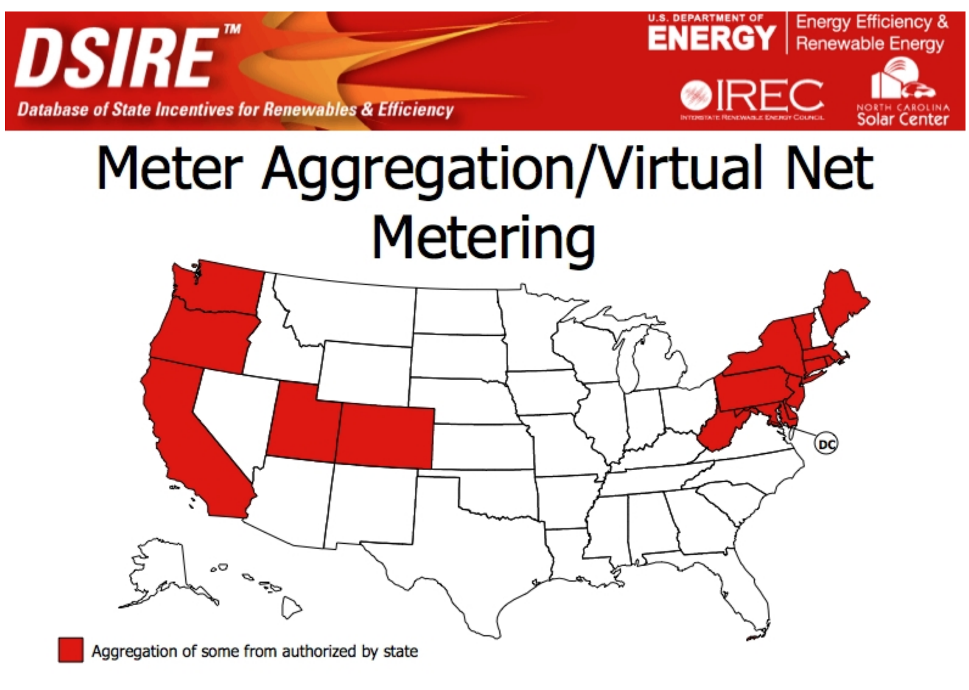


Figure 5. States with NEM-related programs
Source: DSIRE

The state allows occupants to receive a monthly energy credit for the PV system output, which is billed administratively by the utility. Recent modifications to VNM rules allow allocation to multiple buildings not contiguously connected so long as they operate under the same ownership. Business renters and lessees are also included. The intent is to make VNM more equitable since all ratepayers in the state, in effect, help fund solar incentive programs (SF Environment, 2013).

The *community solar* or *solar garden* is a related form of VNM whereby a cooperative network of people, acting under a common cause, host a PV installation to provide energy and/or NEM revenue for their collective need. An example is schools that install a PV system to provide ownership opportunities for parents' fundraising purposes (Holis, 2014). As long as a state has a VNM provision that includes an interface between system operator and its utility, community solar gardens can be constructed anywhere building codes allow. According to PV Magazine, the most difficult part of VNM is utility participation due to billing system challenges (Thurston, 2014).

The last option – the feed-in tariff (FIT) – is available in some states as well. The FIT (five states in the U.S.) is a negotiated production contract with the representing utility over an agreed timeframe, typically 15-20 years, similar to purchasing contracts utilities have with third party producers. Separate meters monitor consumption and production as two separate functions. Homeowners pay for consumption and are compensated for production at a negotiated rate with their utility, which is less than the retail rate under NEM.

The NEM Policy Debate

The NEM policy debate is increasingly fractious. Disputes over valuation between two opposing groups – utilities and solar – continues to grow in parallel with residential PV growth. Each group offers benefits and costs arguments in the regulatory sphere, the media, reports, issue briefs and the media. A limited number of research papers exist as well but data and methodology remain problematic, so empirical studies must rely on small samples or synthetic techniques for analysis.

A number of states (Figure 6) are currently experiencing the heat of the debate as their NEM policies either come under review and as utilities file review proposals to restructure rates or seek additional compensation from PV ratepayers specifically, or otherwise allude that increased rates will arrive at the doorstep of non-PV owners because those with PV systems are not paying their share.

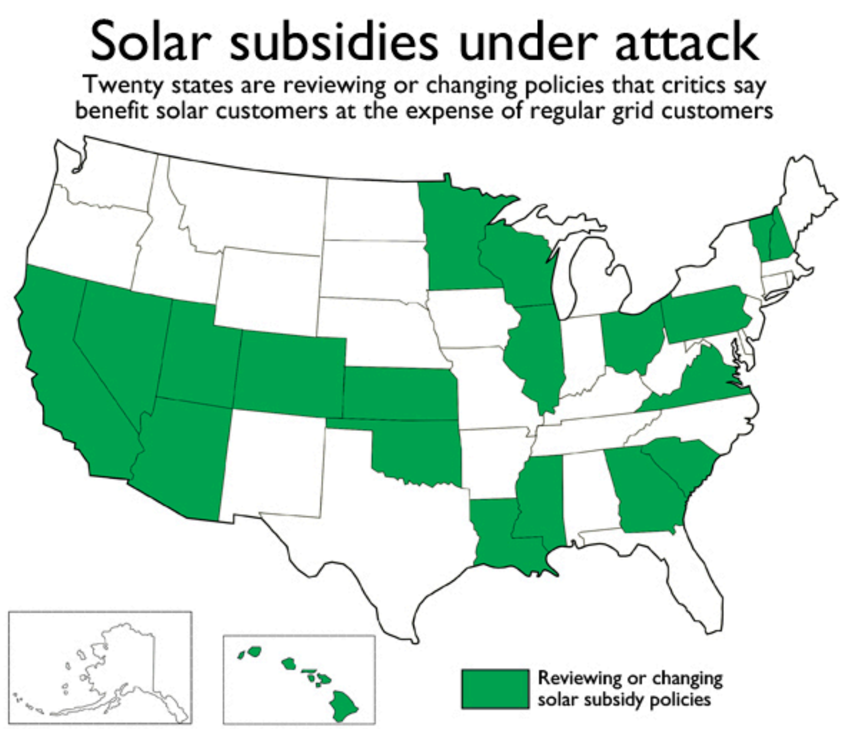


Figure 6. Current states where NEM policies are being challenged
Source: The Washington Examiner

The portrayal of the debate below follows the general trajectory of interaction between the two groups. That is, the ‘utility group’ position is presented first, followed by the solar position. This is because the utility group initiates calls for action, expressed as a cause for alarm requiring immediate rectification of cost-related problems they deem important. In response, the ‘solar group’ proffers a range of benefit valuations provided by residential PV. Benefit valuations remain mostly unrecognized, or are dismissed, by the utility group that portrays benefits in terms of what the grid provides PV owners, not visa versa. In fact, the utility group, represented by The Edison Foundation (IEI and IEE) explicitly avoids the solar group argument, and instead focuses on its core claim that NEM is an unfair subsidy, rather than a policy (Borlick & Wood, 2014; Wood & Borlick, 2013).

For utilities, the grid is a zero-sum game with predominantly fixed costs requiring recovery, and that the utility sector, with is expertise and scale, is most qualified to dictate its operation in the realm of regulated monopolistic control. The 2013 Edison Electric Institute (EEI) report (“Disruptive Challenges”) cites significant threats to investor owned utilities. The EEI, which represents utility industry interests, remains a clarion call for the utility industry to heed change necessary for continued operations, financial wellbeing, and survival (Kind, 2013). Kind contends that disruptive forces come from many directions. He cites emerging technologies (i.e. PV, electricity storage, fuel cells, electric vehicles, etc.) and their promotional incentives, renewable portfolio standards (RPS), and net metering as strong drivers that “…force[s] the cost of service to be spread over fewer units of sales [and] enhances the competitive threat of disruptive forces” (p.3). Another concern is that customers are "…not precluded from leaving the system entirely if a more cost-competitive alternative is available." Kind contends that the electric industry is highly vulnerable to market advances and ratepayer classes could easily defect as technology diffuses in the market. Content in the report cites a potential to lose preferred investment status, affecting future earnings and credit rating decline. For Kind, the electric industry must avoid failure that befell others (citing Kodak and USPS) and adapt like the telecommunications industry (see p. 6,14).

His prescription is to take immediate actions that effectively 1) creates a separate service charge be placed on all PV/NEM ratepayers to "recover fixed costs and eliminate cross-subsidies", 2) develop a separate [higher] rate structure for those ratepayers, and 3) treat PV as any other distributed generation (e.g. wind farms) and pay the lowest [wholesale] price available. For long-term actions, Kind recommends 1) recovery of a stranded cost of infrastructure investment caused by departing customers, 2) place a "customer advance in aid" [a fee]… to recover upfront the cost of adding new customers", 3) charge customers a [a fee] to recover investments subject to stranded cost and, 4) finds ways to compete against firms that currently erode utility supply of services (see p.18).

From the utility perspective, ratepayers have a commitment to their utility, and must pay the assigned rate according to the agreement between a utility and its regulatory authority. And a customer that installs a residential PV system should be required to pay any and all fees and surcharges necessary for "grid services" they are supplied, regardless of the time and amount of use (consumption). Residential PV (or any electricity not supplied by the utility) are "partial requirements customers" to be treated as separate rate-paying class (Gale, 2014).

Indeed, the argument by Kind and Gale presumes that all ratepayers are never able to fully leave their representing utility, and that all ratepayers have to support grid infrastructure investment and the central station model of operations. Hence, opponents of NEM regularly cite cost shift as being unfair ("unreasonably discriminatory") to non-NEM ratepayers, which unduly enriches NEM ratepayers. This creates a redistribution argument that divides ratepayers into an economic class structure: the 'affluent' can afford residential PV and receive NEM benefits without paying the cost. Meanwhile, those of lesser means (non-PV ratepayers) subsidize NEM payments indirectly through higher rates, fees, etc. as the utility requires (Anderson & Hunt, 2013; Borlick & Wood, 2014).

The affluent argument is disputed as a "red herring" for utilities, given that higher rate residential customers, having switched to PV, continually paid their "fair share" in order subsidize other rate payers since 2001 (a California rate adjustment), and that "rooftop solar merely reverses the subsidy" (Pentland, 2014). In Pentland's words: "Electric utilities are clinging to an industrial-age regulatory model that is ludicrously ill-equipped for calculating things like cost, return, and rates in an era of anemic demand growth, aging infrastructure and shifting policy goals."

The affluent characterization permeates the media as well. The Americans for Prosperity, for example, submit that NEM policies "hurt the poor" disproportionately because they spend a larger percentage of income on "basic energy costs" and are less likely to benefit from the subsidy (Americans for Prosperity Foundation, 2014). The economic fairness argument portrays PV homeowners as 'winners' and the ‘losers’ are non-solar customers that must pay “a perverse incentive” to solar companies in order to receive federal subsidies (Foster, 2014). The economic message is pervasive in the media as well. The American Legislative Exchange Council (ALEC), a lobby group representing utility sector interests, overtly characterize PV homeowners as “free riders” that do not contribute to an infrastructure they still use (Goldenberg, 2013).

The PV industry and other distributed energy interests strongly disagree with the fairness/ free-rider/ cost-shifting assertions. Submitted reports, briefs and opinions demonstrate an approach that arrives at benefit and cost calculation and consideration. Ultimately, the PV sector seeks retention, if not expansion, of NEM provisions.

One report delineates three ‘states’ of PV customer: the ‘Retail State’, the ‘Energy Efficient State’, and the ‘Power Export State’ (Beach & Mcguire, 2013). The three states correlate with the sun cycle and a typical period of customer energy demand. They conclude that the Power Export state provides a net benefit to the utility and other rate-payers due in part to the following avoided costs and reductions:

- Avoided energy costs
- Avoided capacity costs for generation
- Reduced costs for ancillary services
- Lower line losses on the transmission and distribution system (T&D)
- Reduced investments in T&D facilities
- Lower costs for the utility’s purchase of other renewable generation

A report by E3 in 2010 (for the California Public Utility Commission) quantifies program costs and the avoided cost of the three California utilities required to provide NEM benefits to PV customers. The results show the amount of program cost to utilities, bill savings of customers, and the avoided cost benefit for utilities' not having to purchase additional energy from other sources. Instead, the production difference is met by PV production (Figure 7).

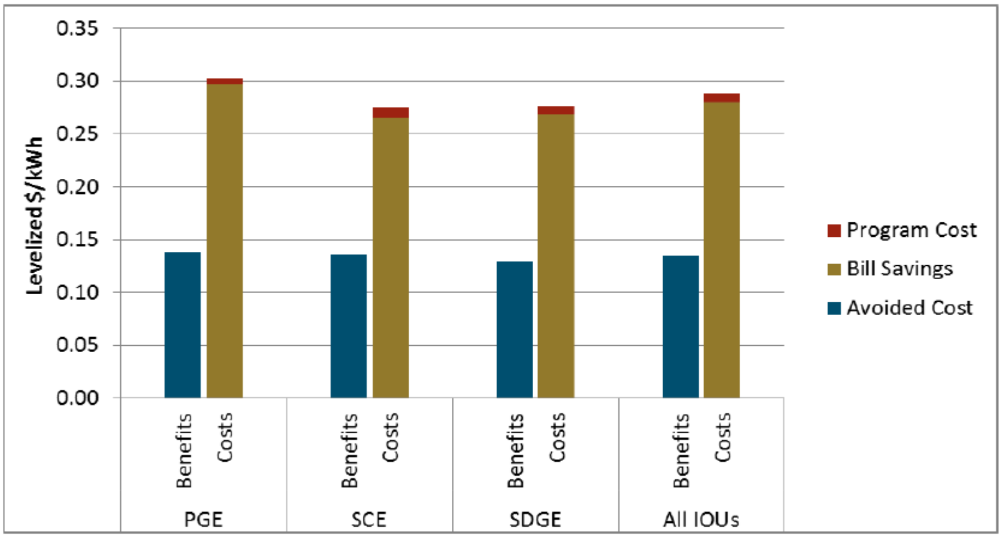


Figure 7. IOU levelized costs and benefits on a levelized $/kWh basis.

Source: E3

A second report by Energy Environmental Economics (E3) in 2011 quantifies benefits and cost impacts of solar PV in California during 2008 – 2009 of net meter customers. The report concludes that all residential ratepayers will "enjoy a more favorable benefit cost ratio without [state CSI and federal Investment tax credits]" starting in 2017 (E3, 2011). Similar results occur in a by the Lawrence Berkeley National Lab (LBNL) study that simulates PV adoption by 215 residential customers. The findings suggest that the value of NEM is tied to the design of customer retail rates and personal customer behavior. The LBNL concludes that NEM is only slightly beneficial to PV customers, and that the impact on other rate-payers amounts to about 38 cents per month (Mills & Wiser, 2012).

A common thread of energy value exists in most NEM reports, but the methodology used to attain results varies. To address the variance, the Rocky Mountain Institute (RMI) report aggregated key drivers and findings from 15 previous reports addressing distributed PV (Hansen et al., 2013). The RMI report illuminates notable variance in the review, noting non-uniformity in methodology and data limitations. However, many similarities exist as well, so RMI established an approach to value consideration beyond the argument of cost shifting. According to RMI, residential PV provides a *net value* of an expanded range of benefits (Figure 8).

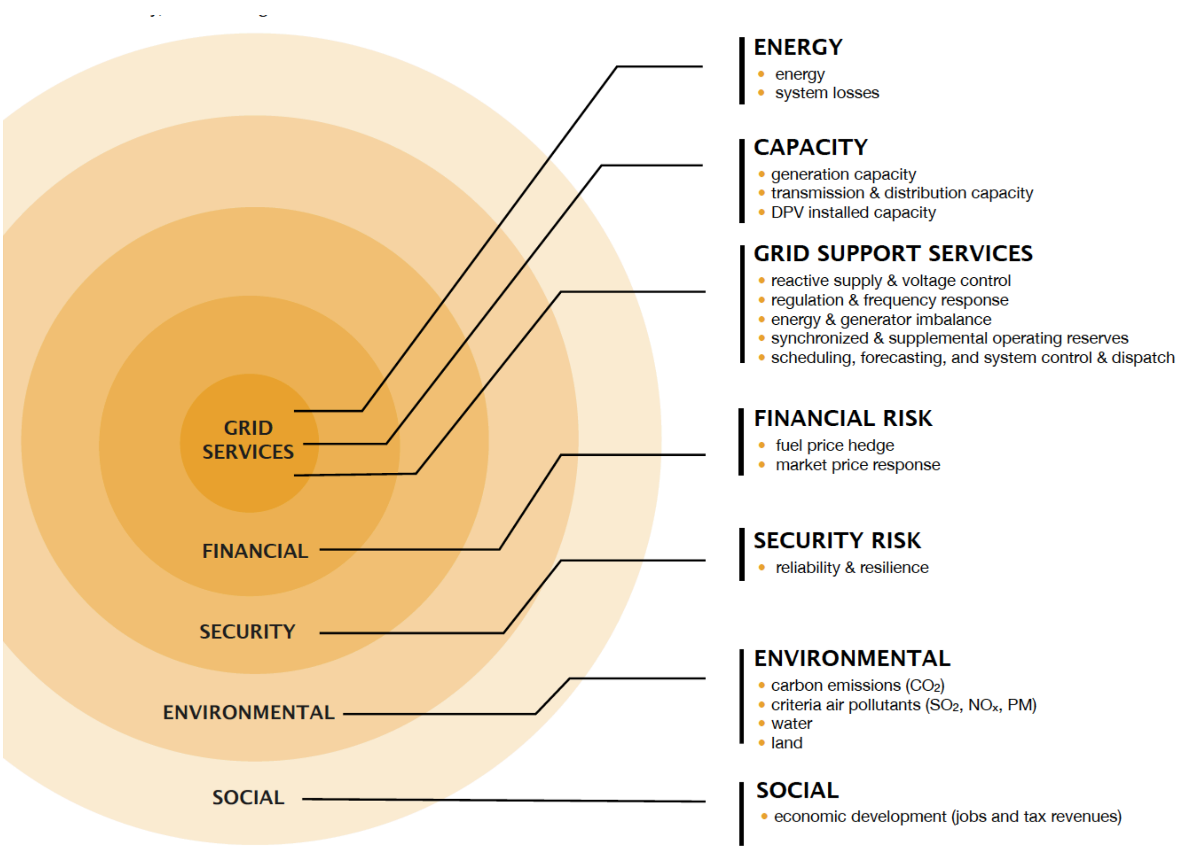


Figure 8. The net value of an expanded range of PV benefits.
Source: RMI

The Interstate Renewable Energy Council (IREC) review of cost and benefit echo the RMI report and evaluate impacts of lowered power line loss, avoided cost of natural gas, reduced capacity requirements, grid reliability, and avoided environmental compliance (Keyes & Rabago, 2013). The authors also notes the lack of usable data for empirical research analysis, and recommend that utilities provide data to better ascertain true cost and benefit, including:

- Hourly load shapes by rate class
- Hourly directional production profiles of PV owners
- Line losses based on hourly load data for marginal avoided cost calculation
- Both the initial capital cost and the fixed and variable O&M costs marginal generation

B. Diffusion of Innovation: Residential PV

Energy policies often incentivize behavior to influence technology innovation and, ultimately, diffusion in the market. Diffusion of innovation considers the trajectory of policy promotion over time. Diffusion of innovation is especially applicable to solar photovoltaic (PV) technology. Historically, the acceptance of PV has been problematic. Despite various state and federal incentive policies, PV remained marginalized because of practical, technical, and cost concerns. Yet, the price per watt declined expotential from the late 70's to the present (Figure 9).

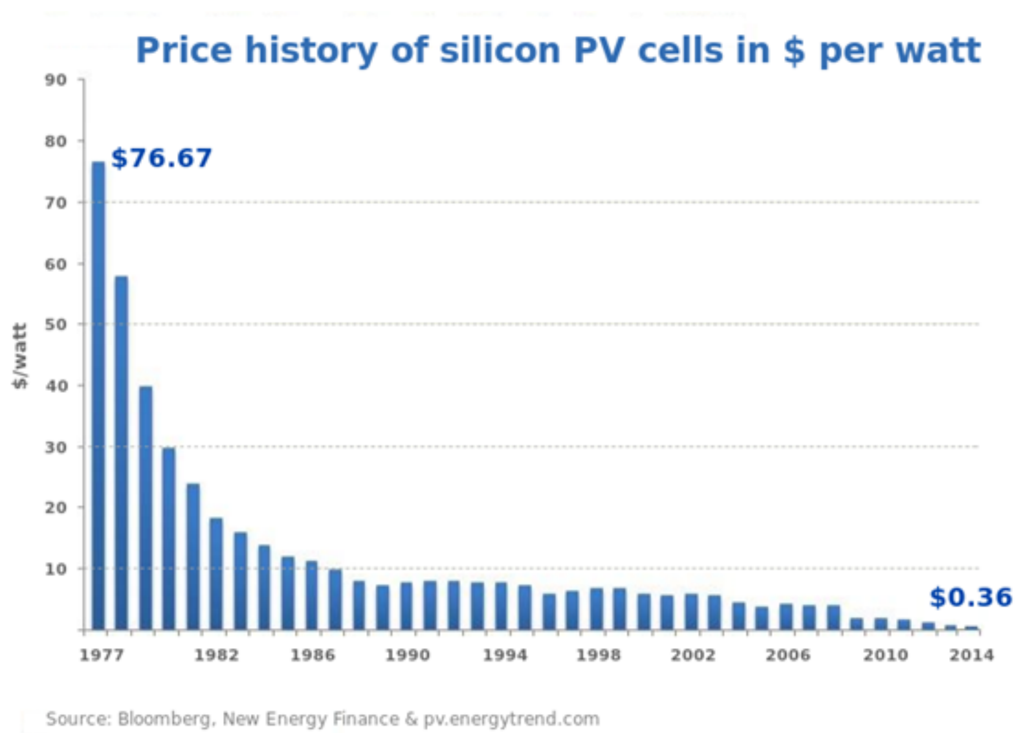
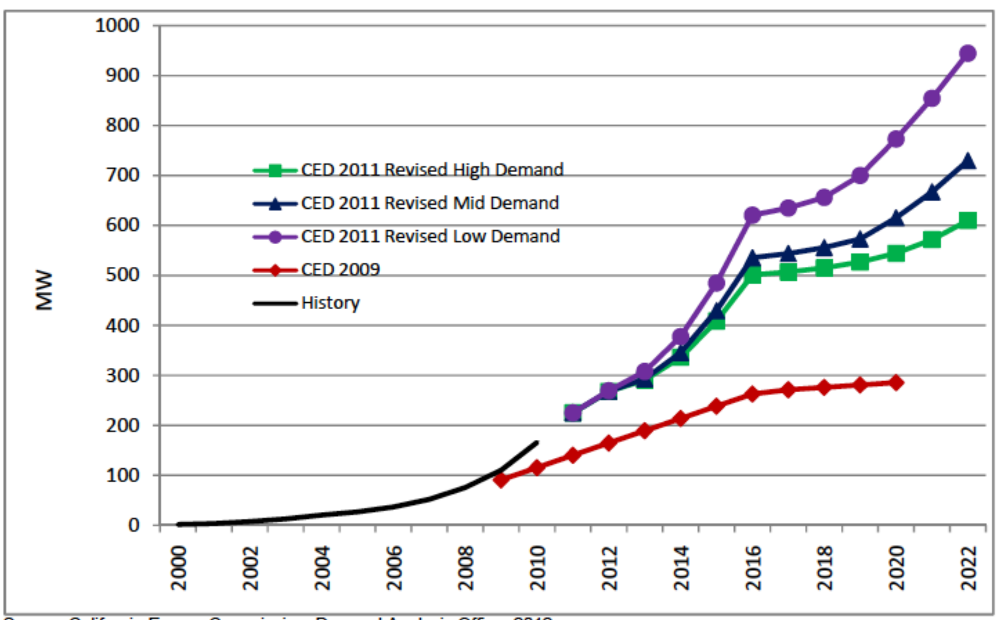


Figure 9. Historical price decline of PV price per watt

Source: Bloomberg

PV technology received notable support from the 2005 Energy Policy Act, which allows a 30% tax credit for all installed residential and commercial PV systems. (Note: the *Investment Tax Credit* (ITC) is available to businesses and the *Residential Energy Efficient Property Tax Credit* (REEPC) is available to individuals). The tax credit extends until 2016 and is “the most important federal policy mechanism to support the deployment of solar technology in the United States” (SEIA, nd).

In California for example, the 2011 California Energy Commission (CEC) demand projection (low, mid, and high demand) shows expotential demand for residential PV well past 2016 (Figure 10) for residential PV (Kavalec & Gorin, 2009; Kavalec et al., 2012), which is when the state and federal rebates conclude.



Source: California Energy Commission, Demand Analysis Office, 2012

Figure 10. Projected Demand for PV Through 2022.
Source: California Energy Commission

Meanwhile, growth of the industry expanded 15% from 2012 to 2013, and the national average price and installation of residential PV declined 11.5% and 5.4% respectively (PV Magazine, 2013).

As noted in the introduction, the diffusion of the technology is an important determinant, or cornerstone, when considering how change is occurring in grid. Many drivers underlie PV diffusion in the market. The following content encapsulates those drivers temporally, beginning with government policy.

Symbolic leadership ("policy by doing") often leads government policy intent as an example for others to follow (Koski & Lee, 2014). Koski & Lee contend that the public sector influences private sector if government is seen acting "in the public interest" rather than mandating by hierarchy [regulating power]. An example is the *Oregon 10-Year Energy Action Plan of 2012* that seeks greater energy efficiency of commercial buildings by establishing a "State Building Innovation Lab" that retrofits state-owned buildings in order to "establish baseline energy use…to create data and experience to help drive a larger [private] market" (State of Oregon, 2012).

Consumer resistance to adopt technology comes in many forms. For researchers Garrett and Koontz, finding linkages for "breaking the cycle of non-adoption" are economic considerations related to supply and demand, rather than consumer disinterest. Reliance on markets alone is not enough, so government must play the "role of change agent" as both innovator for demand-side interest and regulator for supply-side participation to stimulate adoption of government policies (Garrett & Koontz, 2008).

But if the diffusion of technology innovation is not sustained, the diffusion simply becomes a institutional fad – an ‘illusion of diffusion’ (Best, 2006). Best defines an institutional fad as “short enthusiasms that rise and fall within institutional settings” and considers the underlying dynamics of diffusion and the trajectory of fads as a roughly equivalent. Best draws a fad fades quickly and looks Gaussian, whereas diffusion continues an upward until it too eventually succumbs to exogenous circumstances.

> The hallmark of the institutional fad is the conviction that, far from being a fad, this innovation represents progress, that it is an improvement that will prove worthwhile and endure. Remember: the front half of the classic fad curve looks just like the beginning of the S-curve of diffusion. When an innovation is spreading, no one can be sure whether it will be an enduring instance of diffusion, or fade as a forgotten fad…It is only later, after the enthusiasm has died down, that people recognize that this was, after all, just a fad, and they experience the illusion of diffusion (Best, 2006).

For Best, the explanation is that enthusiasm for progress is based on a “culture that welcomes change, coupled with institutions organized to spread news about innovations [that] creates an environment that encourages individuals to adopt novelties” and institutional fads often follow the previous enthusiasm. At what point should society simply ‘give up’ on a technology as nothing more than a fad?

Solar technology began with promise of diffusion under President Carter in the 1970’s, but faded due to political and economic circumstances. Diffusion theory is a useful tool if innovation is not measured in the short term and single uniform patterns are not imposed upon value considerations. One renewable energy technology is not the same as another and each has its own diffusion trajectory.

Modeling the impact of government policy mechanisms is useful for assessing diffusion of innovation. For example, how the intent of policy and government promotion is affected by market pricing of a promoted technology (Rao & Kishore, 2010). In a review of reviewed 10 diffusion models (i.e. logistic approach, learning curve, influence, experience curves, and others), Rao & Kishore ascertain diffusion effectiveness under diverse market conditions and find that diffusion is a function of complex phenomenon requiring “significant financial and fiscal incentives” for adoption, and “thus reinforces the challenges of taking a new technology to the marketplace.” It is commonly understood that diffusion of innovation is often a function of incentive policy, but what is intriguing is how diffusion-by-incentive is aided by the alignment with other market drivers.

An amalgam of policy emulation, economic considerations, time, and a need for incentives helps explain a transformative process, but at what point does a technology become self-sustaining and integrated into an overall energy system? Jacobsson and Johnson (citing Calsson and Stankiewicz, 1991) consider diffusion of renewable energy part of a technological system, often requiring a ‘prime mover’ as a catalyst. Prime movers are actors with the competence, ability, influence etc. to elevate adoption of a technology directly or indirectly (Jacobsson & Johnson, 2000). The authors contend that the process of technology diffusion requires a long time period and is subject to price and performance pressures, and that the process may involve ‘inducement mechanisms’ as well as ‘blocking mechanisms.’ As an exogenous impediment to diffusion, a blocking mechanism like biased legislation favoring an incumbent technology or a media campaign serves to derail the intent of diffusion by others. In all, the authors associate the diffusion process with a high degree of uncertainty because incumbency dissuades new innovation incursion in the market. Thus, the forces brought by prime movers are required for diffusion, especially in the political arena. Jacobson and Johnson describe a situation about the late reaction of utilities to a new technology incursion, supported by institutional change.

When the EFL [a policy for renewable technology] was discussed and later passed by the Bundestag about 1990, no one (and in particular not the large utilities), could foresee the tremendous impact it would have on the rate of diffusion. Thus, the potential implications of the institutional change were not understood and there was little response from the actors in the incumbent technological system. However, with the rapid diffusion of wind power in the early 1990s, the larger utilities began to realise that the new technology constituted a threat and a struggle began to change the EFL.

In the meantime, however, the number of wind turbine owners had increased greatly in Germany and some local turbine manufacturers had emerged. These groups became well organised, and by teaming up with other associations in the renewable energy field they mobilized a large number of people to take part in the discussions over the future of the law. A very considerable effort was made by the German Wind Energy Association to seek out selected members of parliament and lay out arguments in favour of the law. In this process they were very much helped by the fact that wind energy had become the source of livelihood of a large number of people, in particular in the northwest of the country. Economic arguments could therefore be used…(Jacobsson & Johnson, 2000).

The present residential PV situation is drawn in parallel. The utility sector in California and around the nation appear stunned that customer-led PV, supported by NEM policy, is becoming mainstream in the energy domain. Prime movers, inducements, and blocking mechanisms are all present as decisions unfold about the future of NEM policy and PV diffuses into the market.

As just noted, incentives are required to continue the trajectory of innovation, but policy that subsidizes renewable technologies could help overcome some of the blocking mechanisms noted by Jacobsson and Johnson. But at what point should incentivizing terminate? When does government take off the training wheels, so to speak? An 11-year study of PV system diffusion in Japan indicates a positive effect of solar diffusion when regional government support includes housing, economic development, employment aid and other similar components compliment the PV market (Zhang, Song, & Hamori, 2011). A systems approach that considers other factors drives diffusion more so than simply subsidizing or incentivizing a specific technology. The authors suggest that regional differences plus environmental awareness are also factors for diffusion. If a systems approach supports PV diffusion, what barriers need to be identified? A systems approach for incentivizing renewable technologies and PV diffusion energy requires that policy recognize the interconnectedness of the technology and the economics of market forces.

Tsoutos and Stamboulis suggest “a techno-economic system that is radically different from conventional systems in terms of density, structure, regulatory and management practices.” As such, policies that focuses on “systemic innovation processes” of the industry (e.g. production and services) leads to technological deployment and a “technological regime shift” (Tsoutsos & Stamboulis, 2005). The authors consider two distinguishing aspects for the success of diffusing renewable technologies toward marketability:

1. Demand side where deployment depends on public motivation, concern of the environment, and daily convenience.
2. Supply side creation of skills and workplaces and economic activities that offer business opportunities.

Additionally, they contend that we are in a stage of technology emergence that is not yet established, but that “one may identify windows of opportunity for new players such as local authorities and cooperative schemes within new institutional and regulatory arrangements…" where, "the role of networking between economic, technological, and regulating agencies and the interaction between users and producers is critical for RETS [renewable energy technologies] to achieve sustainable integration into the system." The authors identify the following 8 barriers to address:

1. Technological immaturity concerns over large-scale deployment, embedded system complexity, and managerial relearning.

2. Government policy and regulatory frameworks that provide unclear messages and are risk averse because of political cost or the influence of vested interests.

3. Cultural and psychological factors of society that finds comfort in existing system and is reticent to change because of fears of uncertainty, unfamiliarity, and reliability.

4. Risk aversion that affects consumer willingness to pay when specific expectations are not met or evident, which affects any necessary adjustment process.

5. Production factors that devalue present technologies forced to succumb to change, resulting in obsolescence and workforce changes.

6. Infrastructure and maintenance required two systems incompatible with one another and the high sunk costs of an existing infrastructure.

7. Undesirable societal and environmental effects that create aesthetic or production concerns over deployment of new installations.

8. Economic factors related to financing, economies of scale, and price.

For new policy direction, Tsoutsos & Stamboulis recommend that renewable technology be deployed as "solutions to concrete systems problems, rather than as a form of technology in search of application." Their recommendation is to 1) develop learning mechanisms 2) encourage new types of players, and 3) provide flexible financing mechanisms adapted to the level of individual applications. They conclude with a "strategy for use-oriented innovation" having deployment dynamics constituted by a flow of structural, organizational, economic and social elements that together provide competitive advantage and lift barriers for renewable energy diffusion into the market. The concept is important because the elements are applicable to the diffusion of solar PV in California, as well as other states' promotion efforts of the technology. A careful viewing of the Tsoutsos & Stamboulis flow diagram (Figure 11) describe a diffusion process that originates at the 'Changes in Regulatory Arrangements & Institutional Strategies'. As an origin, the pairing of regulatory and institutional strategies impact development and accelerate diffusion through a feedback process. The 'dynamics of a niche formation strategy' is an interconnected system, rather than a unitary diffusion promotion.

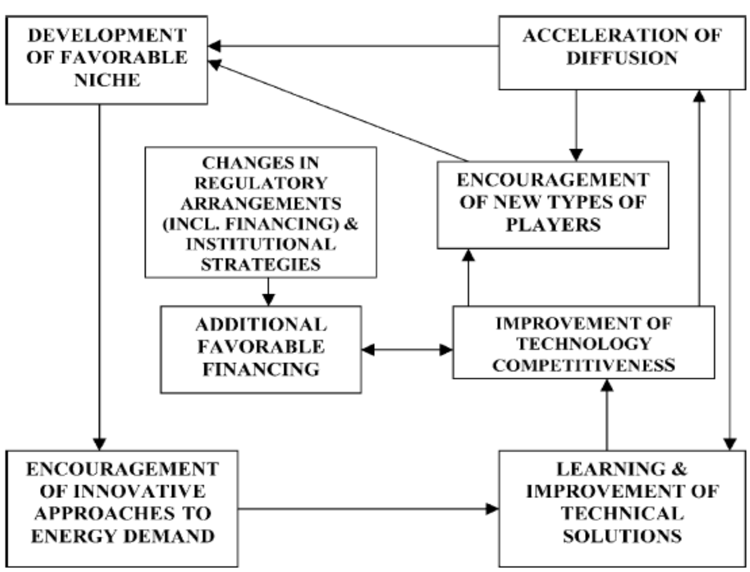


Figure 11. The dynamics of a niche formation strategy

Source: Tsoutos and Stamboulis

Consumer intent is another important consideration for diffusion of innovation. The diffusion of innovation theory contends a process of communication takes place over time as consumers perceive information and base their decisions accordingly. The theory “sets out a practical innovation-adoption process and presents a categorization of consumers that defines the relative speed at which they adopt” (Faiers, Neame, & Cook, 2007). For most products, consumers’ consider the relative advantage when making a choice to purchase or consume. Faiers et al considers whether differences exist between so called “innovative” and “pragmatic” homeowners as they consider solar power attributes. Assuming the two groups would make choices differently, the authors’ survey results suggest that economic situation may play a greater role than their perception of the technology innovation, which is not surprising if cost is determining factor. But the findings also indicate that innovators’ interest in the technology provides a core of adopters that (presumably) would initiate greater market acceptance.

Building on the focus of adopters, other research finds that adoption probability is associated with a need for effective education, and adoption campaigns should highlight investment criteria, government subsidy offers, and the environmental attributes as “seeding strategies” to accelerate adoption using “word-of-mouth” transfer of information (Islam, 2014). Islam also notes an important demographic consideration: younger households that have higher awareness are more apt to choose adoption and have higher adoption rates. Higher awareness indicates social communication, which in turn creates peer effects and community organizations of like-minded citizens. An example are the Solar Community

Organizations (SCOs) that act as social networks and provide the ‘peer effect’ of local PV adoption.

SCOs are positively charged citizen groups intent on reducing barriers to PV by providing access information while encouraging adoption. Research indicates that the peer effect of social interaction between SCOs and potential adopters is an effective leverage mechanism to advance social learning in a community (Noll, Dawes, & Rai, 2014). The authors’ note that two ends of the extreme – strong context (high-favorability) versus weak context (low-favorability) – is marginal; therefore, the most opportunity for diffusion is in the middle where influence is most favorable. Their case study findings indicate that SCOs operations are diverse, ranging from neighborhood activity to statewide organizations. Additionally, the SCOs often partner with other like-minded organizations and state agencies that operate in the energy realm to promote policy and funding opportunities. Common shocks like energy shortages or other geopolitical events are used readily as evidence to convince citizens of the importance of adoption (Noll et al., 2014).

When Diffusion Becomes a Contagion

Thus far the focus has been on diffusion, which been implied as a necessity to encourage consumer adoption of a renewable technology. But when has consumer acceptance occurred to the point where diffusion becomes standard behavior? In a diffusion-to-standardization continuum, some force or forces must be exerted to overcome institutional barriers. The term *social contagion* has similar context and is defined as “the process by which consumers influence one another to adopt and use a product in a specific way” (Langley, Bijmolt, Ortt, & Pals, 2012). In other words, consumers drive one another rather than be specifically driven by policy or exogenous concerns.

Consumer influenced behavior to actively purchase PV systems defines the technology as a *social contagion*; however, conditions in California and other high profile, PV adoption-led states may exceed the social contagion definition. The acting forces of price combinations, state and federal energy policies, environmental concerns, production shifts, a growing labor market, and socio-economic conditions appears to have created conditions that potentially alters the institutional framework of electricity supply and demand. Indeed, the structure of the electric grid and producer/consumer/regulator relationships is undergoing change. The magnitude of change in this present-day scenario is best described simply as a *contagion* because, as an interim force and depending on one’s point of view, the concept of a contagion includes both positive and negative consequences. As PV adoption increases, the electric utility needs to raise rates and fees on ratepayers to maintain its profit margin and cover costs. In turn ratepayers are incentivized to adopt PV, and so on, creating a '*feedback cycle'* having significant consequences for the state.

Due to falling PV prices and rising electricity rates, it is becoming increasingly attractive for residential consumers to install rooftop PV systems and reduce their electricity purchases from the grid. On the other hand, capital investments in transmission and distribution infrastructure are unlikely to fall in proportion with grid consumption. In order for utility companies to recover their infrastructure costs from a smaller consumption base, they will have to increase electricity rates. However, higher electricity rates make it more attractive for consumers to adopt PV and cause utility companies to lose more sales. Concerns have been raised regarding the impact of this feedback cycle on non-solar customers" (Cai, Adlakha, Low, De Martini, & Mani Chandy, 2013).

In 2012, Cai et al modeled a feedback cycle condition facing Southern California Electric (SCE). As one of the three largest investor owned utilities in California, SCE operates in the state as a regulated monopoly having a defined region of service and whose set rates are based on a rate of return mechanism. The mechanism is based on generation of energy delivered to the customer and recovery of delivery cost (i.e. transmission and distribution costs) that includes and an allowed return on investment. Customer energy use determines the rates, effectively penalizing a customer for excess use by charging higher rates above a set baseline allocation in a tiered rate structure (Cai et al., 2013).

The Cai model specifies revenue as the dependent variable to calculate revenue loss from PV adoption. The model accounts for the type of customer most likely to install and benefit from PV adoption. Their data was not current; instead, they sampled data from previous rate cases. The federal income tax credit is the only government incentive considered. Net-metering costs (utility purchase of excess power generated by the customer) are modeled against increasing PV adoption. Using the highest tiered rate, their findings indicate that, "in order for utility companies to recover their infrastructure costs from a smaller consumption base, they will have to increase electricity rates. However, higher electricity rates make it more attractive for consumers to adopt PV and cause utility companies to lose more sales."

Additionally, the authors find that net metering increases costs to SCE because of increased PV adoption. Further, the utility could lose a significant fraction of its high-income customers (e.g. early adopters in the diffusion process), while its customer base shifts toward lower income customers more sensitive to price increases. Hence, the feedback cycle appears to be a threat to present and future SCE operations.

The Prosumer

In the U.S., it took over four decades for PV technology to become economically viable and attract mainstream consumers. Behavioral scientists note that as people become comfortable with new technology, they become more autonomous and independent as their participation with new technology becomes normalized (Ritzer, Dean, & Jurgenson, 2012). A homeowner with a PV system is no different. No longer passive participants, they gain a sense of independence and empowerment, causing a reconsideration of their consumption and potential trade of any excess energy production. Additional energy considerations, like banking energy (e.g. storage) for gain also enters the mental calculus. As noted earlier, once the concept of production and consumption are considered jointly, and the homeowner realizes a degree of market power not previously available, he or she becomes a *prosumer* (Schleicher-Tappeser, 2012).

Prosumers are economically motivated to find the optimal compromise between outlays and consumption and maximize their gain. Over a million households in the U.S. now include PV ownership and continued double-digit growth appears to be a reasonable assumption. The pattern is occurring worldwide and business models that accommodate distributed generation will require the existing energy grid to evolve toward the use of more, supporting digital technologies such as energy storage and microgrid infrastructures (Szablya & Beck, 2010).

Utilities realize that taking empowerment away from the prosumer is a very difficult proposition, especially if the regulatory regime favors a new, smart grid infrastructure that ultimately benefits the prosumer. If the institution of full distribution system control is not feasible, utilities must adapt to market change and prosumer impacts. Before the advent of the grid, the nascent electric industry did not sell electricity to consumers; it sold convenience in the form of lighting and comfort (Szablya & Beck, 2010).

C. THE SMART GRID TRANSITION

In this essay, the smart grid transition is the third determinant of change, for it underlies the transformative change from analog structure to a digitally integrative system comprised of digital communication and smart control hardware.

Constructed in large part during the last century, the analog structure is characterized by a top-down approach of service under control of utilities that procure and deliver the electricity via transmission and distribution systems to classes of customers (residential, commercial, etc.) that reside in its service district (Figure 12).

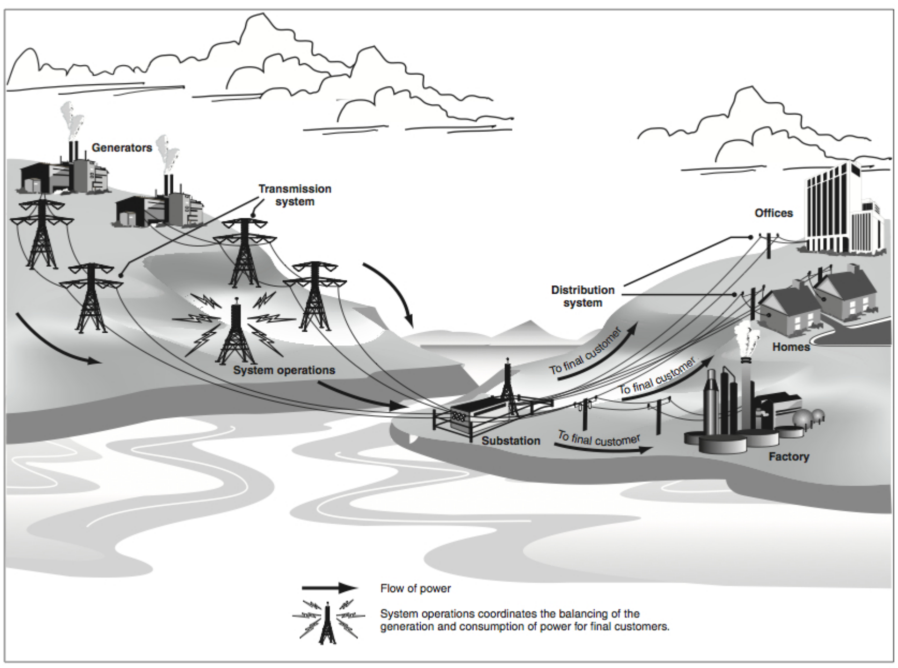


Figure 12. Stylized depiction of the analog grid and central station model

Source: WIKI Online (Original source is the GAO)

Advances in digital technology began to permeate the utility sector during the early 1990's (Litos Strategic Communication, n.d.), but a large-scale transformation occurred under the American Recovery and Reinvestment Act (ARRA) of 2009 (aka the "stimulus") as a result of the Great Recession in 2008 (U.S. DOE, 2012). As a significant part of ARRA, the Smart Grid Investment Grant Program (SGIG) program incentivized selected utilities to digitize key areas their infrastructure, thus promoting technological advancement in hardware, software, and communication while also funding education, training, and exploratory research programs. As the primary recipient of the incent (typically 50% of the cost), the utility sector purchased millions of smart meters for homeowners, voltage control technology for distribution systems, and operational software for system monitor and control. The Department of Energy (DOE), as the program administrator for SGIG grant funding, selected proposals from utilities that demonstrated smart grid advancement capability and advance the goal of greater distributed generation in the U.S. grid (U.S. DOE, 2013).

Today, smart meters (digital meter) are nearly ubiquitous on the consumer side, and serve as the first step to the high-availability of information (data). Nearly half of the U.S. now have smart meters (IEE, 2013). As the integral component of the Advanced Metering Infrastructure (AMI), smart meters provide abilities for the utility to gather consumer use data, refine billing techniques, monitor peak demand, pinpoint outage (loss of service), and serve as a voltage control device in the distribution system. Smart meters effectively eliminated the need for utilities to manually read customer meters manually, resulting in a significant reduction in labor cost (a somewhat perverse result given ARRA stimulus intent). For consumers, the smart meter is equally advantageous, for it is the gateway to integrate devices on their side of the meter (i.e. home network, smart appliances, smart applications, etc.). For prosumers, smart meters are integral for compensation. The smart meter “turns backward” and records production from PV output or other future technology (i.e. fuel cell, battery storage, etc.) (RMI, 2012).

Another smart grid advancement is the contribution of digital voltage control hardware and devices that provides system efficiency and optimization. Voltage control continually monitors operations for necessary adjustment, minimizes system failure (e.g. fault location), and provides contingencies for outage to restore electricity supply. A smart grid also includes a conversion of supervisory control toward digital management system (DMS) software having complete system-wide application. Though presently complex and unique to individual utility system of operations, DMS algorithms are ultimately necessary to balance a growing diversity of loads and production (i.e. PV, wind, natural gas) of an advanced smart grid-enabled distributed generation system (Figure 13).

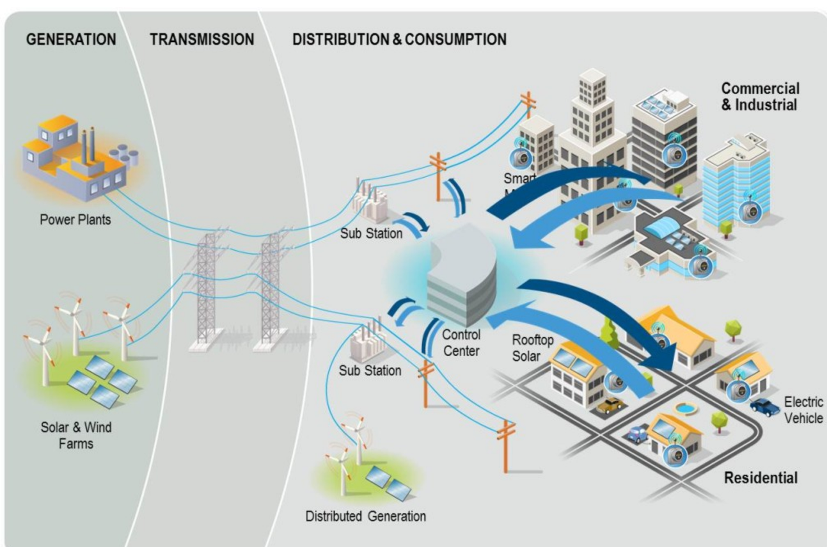


Figure 13. Stylized smart grid operation
Source: Trilliant

CHAPTER 3. RESEARCH METHOD

The State of California is the area of study for this essay. The state leads the nation in residential PV installation, supported in large part by a robust NEM policy, and the California Solar Initiative (CSI) rebate program. Together, the NEM and CSI require the three investor owned utilities – PG&E, SCE, and SDG&E – serving over 38 million residents (U.S. Department of Commerce, 2014) to advance state energy to promote the diffusion of solar PV. Other state energy strategies, such as energy efficiency, distributed generation, demand response, and economic investment in energy research and development occur as well. The state leads the nation with its renewable portfolio standard, requiring that renewable resources provide 33 percent of retail electricity sales with by 2020, and is the first state to require all utilities to include electricity storage technology by the same date. Finally, the state has comparatively strict regulatory oversight over emissions, energy consumption, supply and standards, enforced in large part by the California Public Utilities Commission (CPUC) (IER, n.d.).

To address the impact residential PV diffusion has on the state, this essay utilizes the Institutional Analysis and Development (IAD) framework developed by Elinor Ostrom (see Sabatier, 2007). As an iterative framework, the IAD is well suited as a methodological approach because it provides mechanisms to disaggregate the complexity of activity in the state. By applying framework components accurately to a study area, the role of state institutions, social interactions, and the decision-making process come into focus for outcome analysis (Ostrom, 2009).

The design of this research follows Ostrom's seven steps for analysis:

1) Analyze physical and material conditions
2) Define the policy analysis objective and specify the analytic approach
3) Determine community attributes
4) Apply rules-in-use
5) Integrate the analysis
6) Observe patterns of interaction
7) Analyze outcomes

The visual schematic of the operational framework (Figure 14) shows how the *Rules-in-Use*, *Physical Material*, and *Attributes of the Community* impact the situational problem for analytic study – called an *Action Arena*. The Action Arena comprises an *Action Situation* (the topic of this research) and is populated by *Actors* that are functionally relevant to the situation. Actions in the arena produce *Patterns of Interaction.* Together, the defined exogenous variables and patterns of interaction activity provides for policy evaluation in *Outcomes*. Hence, the process of an IAD becomes an iterative exercise designed to be an interactive tool, rather than a static depiction of an event.

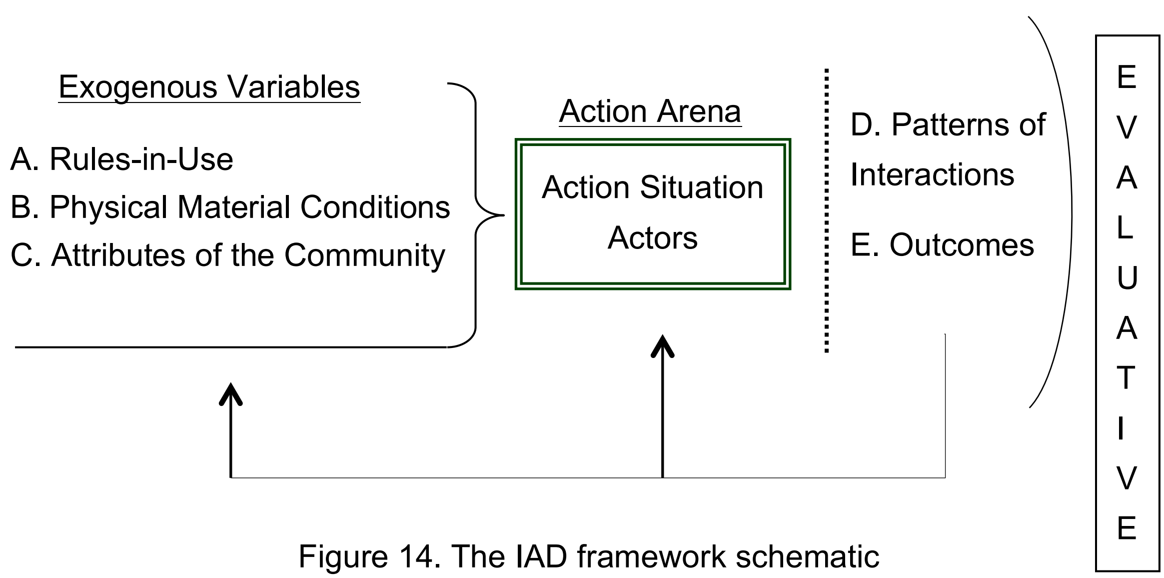


Figure 14. The IAD framework schematic
Source: D. McGie (modified from Ostrom)

Actors utilize rules at different levels is a fundamental component of the framework, and there are indeed specific, multi-level, and formulated combinations to consider. Within agencies are rules for operation, and within the operations are yet other rule-ordered-actions. Combine all the relevant rules and it becomes apparent that some form of order is required. For this reason, Ostrom proposes a "Multiple Levels of Analysis" method to distinguish the hierarchy of rules based on cumulative effect. This analytical method shows situational linkages of rules designed to demonstrate the power of rule hierarchy.

IAD Definition of Terms

An **Institution** is the point of origin for analysis that refers to "fundamentally invisible, shared concepts that exist in the minds and routines of participants in policy situations." Ostrom contends that institutions delimit the capacity for social change and structure information and create incentives to act (or not) in a particular situation, thus imposing constraints on the range behavior (Polski & Ostrom, 1999).

The **Action Arena** is the starting point of discovery from which research actions emanate. It is the focal unit for analysis. Here, the analytical study of the situation begins in order to describe the structure of the situation. In effect, an action arena is like a dependent variable affected by other interests. Defining the scope is up to the research effort. Described a fluid rather than static, inter-connectivity with other action arenas are probable (Ostrom 2007).

An **Action Situation** refers to "the social space where participants with diverse preferences interact, exchange goods and services, solve problems, dominate one another, or fight (Ostrom, 2005)." The action situation has seven key components:

1) Participants in the situation
2) Participants' positions
3) Outcomes of participants' decisions
4) Payoffs or costs and benefits associated with outcomes
5) Linkages between actions and outcomes
6) Participants' control in the situation
7) Information

The **Actors** can be thought of as a group of stakeholders that may or may not be specifically aware of one another, or have distinct relationships. Their inclusion in a study is based on shared impacts in the action arena framework.

Exogenous Variables

A. The **Rules-in-Use** attempt to understand how and why individuals make decisions and justify actions based on the forces of external rules. External rules take may forms, but the idea is that rules influence or shape the Action Situation and impact Actors in some way. The rules-in-use may evolve over time as in one action situation interact with others. The framework contemplates "rule-ordered actions" consisting of rules having a specific degree of impact upon the action arena. Ostrom advises that analysis is based on an understanding of "rules nested in another set of rules that define how the first set of rules can be changed" (Ostrom 2007).

B. The **Physical Material** comprises the 'flow of services' infrastructure' having varying degrees of resource renewability and consumptive subtractability and participant excludability, hence the need for policy controls.

C. The **Attributes of the Community** captures something significantly relevant about the community. The meaning of the term includes both features and needs, which can be weighted and construed as positive or negative depending on the analytic point of view. Attributes provide tangible examples that directly affect actions in the arena.

Evaluative

The **Patterns of Interactions** are the resulting forces that occur by Actor activity in the Action Arena. Interaction activity and observed results can be overt or subjective.

The **Outcomes** are the results of the activities by the Actors, after the interactive patterns are analytically described. Outcomes can be both qualitative and quantitative, but have some inherent benefit for future study or policy analysis. Evaluating outcomes based on the following six economic values is what Ostrom proposes.

1. Economic efficiency
2. Fiscal Equivalence
3. Redistributional Equity
4. Accountability
5. Conformance to Morality
6. Adaptability

Subsequent research introduces other outcomes measures as well. One example is the inclusion of equity, legitimacy, and participation metrics thought to augment economic valuation (McGinnis, 2011). In fact, a cursory online review of other research reveal a wide range of Outcomes portrayal, including “inintended”, “perverse”, “global”, “processes”, “hypothetical”, “undesirable”, “strategic”, and so on. These examples may be evaluative or presciptive, since both options underlie framework possibility. Open application of Outcomes is a function of the interative property of an IAD framework, and that is its true charm – flexibilty extends to the purpose of research, not visa versa.

This essay builds upon the expansive quality of framework Outcomes by including spatial outcomes, in conjunction with economic valuation. The difference is that economic valuation is reflective of qualitative information gathered under IAD research process, and spatial valuation adopted in this essay is a quantitative process designed to give spatial texture to study area. Both economic and spatial outcomes perform the same function of the framework – to be iterative. The basis for spatial consideration arise from access restrictions to data, and literature suggest finding new methods for analysis (RMI, 2012). Another report considers new pricing mechanisms, a point of contention between the utility and solar sector, that include locational hot spot pricing in electricity distribution systems (Glick, Lehrman, & Smith, 2014). The ultimate goal of economic and spatial outcomes is to provide pathways toward grid valuation for actors in the study area.

Spatial outcomes are results derived using data and tools of GIS to detect spatial patterns of location, meaning that we may want to know if and where conditions of residential PV diffusion exist in the study area. The reason we may to want know this information is because NEM policy consideration is important relative to the interests of all utility ratepayers, the CPUC, IOU's, solar firms, and other interested parties in the state and around the nation. Stated differently, spatial outcomes evaluation provides information that may assist groups advance their 'grid services' and 'value to the grid' debate over NEM policy, as highlighted in the previous Background chapter.

The method of spatial evaluation is exploratory, though its results are based on statistical significance. Exploratory inquiry is a necessary first step to more advanced spatial inquiry (e.g. spatial regression). Where conventional statistical analyses impose condition and assumption of randomness on data to achieve statistical significance, exploratory spatial analysis tests against the assumption of non-randomness in the data used. In geographic space, features having close proximity are more likely to be considered similar to one another rather, rather than with those further away. This similarity of features is referred to as *spatial autocorrelation* (SA), which can be thought of as the lack of randomness an attribute has with itself in geographic space. In spatial analysis, randomness is the null hypothesis, and tests having statistical significance are conducted to reject the null.

This essay follows a popular method to detect SA, beginning with global scale examination of the spatial data, followed by local scale methods. As the name implies, a global measure provides a 'big picture' of the data, and provides a metric for SA detection considering the entire study area at once. Local measures consider variety in the data at a granular scale, which emphasize difference rather than similarity. In a sense, spatial data are simply a collection of statistics that are different by location, tested locally and globally. By simplifying assumptions of SA, local statistics become simple random samples from the total population in the study area. The expectation is that local statistics will be normally distributed about the statistical mean, and unusual cases (those we are interested in) occur in the statistically significant tails of a normally distributed curve. Used together as exploratory tools, both local and global measures assist in finding statistical meaning for patterns of location in the California area under study.

The two global measure tools are the *Global Moran's I* and the *General G* by Getis-Ord. The Global Moran's I tool is a inferential spatial pattern statistic that simultaneously measures location and value a feature in geographic space that, for the unit of analysis in this essay, are polygon areas of California ZIP codes. The General G tool is an inferential spatial pattern statistic as well, measuring the data for spikes, or high/low clusters. Global detection tools are important first step to determine SA, whereas local tools provide an important secondary level of detection, refined to illuminate *where* in the study area patterns of location exist.

The two tools used for detection of local spatial phenomena are the *Anselin Local Moran's I* and the *Getis-Ord Gi**. The Anselin Local Moran's I *Index* identifies statistically significant areas (0.05 level of significance) areas in the output map that appear as clusters of interest using the following metrics:

HH = cluster of high values
HL = outlier of a high values surrounded by low values
LH = outlier of a low values surrounded by high values
LL = cluster of low values

The Getis-Ord Gi* tool outputs a *GiZscore*, which is three statistically significant measures (0.10, 0.05, and 0.01) of where features may cluster spatially. The measured gradient of *GiZscore* intensity indicates high-value clustering by location, referred to as *hot spots (*O'Sullivan and Unwin, 2010).

Both global and local measures are based on adjacency to one another, also referred to as contiguity. Contiguity is a method to weight features, which is necessary for SA calculation. This essay measures weight based on one edge of contiguity ("rook") and the single point of contiguity ("queen") contact a feature has to its surroundings, among all others in the geographic space of the study area. Comparatively, the rook option is statistically more rigorous.

Data used for spatial tools is publicly available and provided by the California Solar Initiative (CSI) as designed. The CSI updates the data weekly and is available for download in spreadsheet format from its Go Solar California database website (State of California, 2014). The data was selected in semi-annual timeframes in years 2011, 2012, and 2013, using the last week of January and June data for each year. This resulted in six epochs for analysis. The dataset for each epoch was trimmed for occasional omission errors and standardized to include only observations having the following variables:

- ZIP codes
- Residential, commercial, government, and non-profit incentive recipients
- The status of each observation (installed-only)
- The three participating service utilities:
    1) Pacific Gas and Electric (PG&E)
    2) Southern California Electric (SCE)
    3) San Diego Gas and Electric (SDG&E)

       Note: the CSI data identifies the California Center for Sustainable Energy (CCSE) as the representative for SDG&E

The data were processed using the following methods. First, it was collapsed in

STATA software to aggregate the number of installations for each zip code, service utility, and incentive recipient. The aggregated and collapsed data into a single numeric value were applied by unit of analysis, ZIP codes (n=1648), and organized by epoch. The resulting data were converted into location quotient (LQ) values using Excel tools. The resulting tables of LQ values for each epoch were joined in a shapefile of California ZIP codes in ESRI ArcGIS 10.1. Tools of the software provide spatial statistics and mapping capability for quantitative analysis.

A location quotient is a basic model to ascertain impacts having practical application in policy and decision making (Crawley, Beynon, & Munday, 2012). Historically, the LQ has been used in different types of analysis to accomplish numerous tasks for industry analysis requiring minimal computation, which aids in the policy decision process (Carroll, Reid, & Smith, 2007; Crawley et al., 2012; Cromley & Hanink, 2012). A LQ is a ratio of ratios that compares the proportion of a local activity to that same activity in a larger reference area. The result of a standard reference value measurement that is based on an assignment of comparative value of 1 in location *i,* typically

$LQ_i < 1$ indicates a 'low' level of local activity relative to the comparative region
$LQ_i = 1$ indicates local and global activity is the same
$LQ_i > 1$ indicates a 'high' level of local activity relative to the comparative region

However, the assignment of value is arbitrary; that is, any value could be used depending on a researcher. Thus, additional methods are necessary to attain statistical significance of results. The method to accomplish significance, at a geographic level, is described below.

As a descriptive statistic, this essay retains the above standard reference value of $LQ_i = 1$. The LQ data are used with spatial toolsets, as previously described, as well as mapping of LQ values and baseline growth, which is the percent growth of residential PV installations, by ZIP code, divided by the sum of all PV installations by all sectors in the state. This essay calculates the LQ as the metric of residential PV in a given ZIP code location, to the greater contiguous study area. As a ratio of ratios, the LQ metric for this essay is:

$$\frac{\dfrac{\text{The sum of all residential-only PV installations (per ZIP code)}}{\text{The sum of all (residential, commercial, government, and non-profit) PV installations (per ZIP code)}}}{\dfrac{\text{The total of all residential PV installations in each utility service area}}{\text{The number of PV installations in the state}}}$$

Where the numerator ratio represents PV installations by ZIP code and the denominator ratio represents total installations. The ‘utility service area’ is the defined distribution system domain of each of the three IOU’s, respectively, who actualize the CSI program for the state. Also note that the “GRID ALTERNATIVE” installation values in the CSI data set are included in this essay’s data compilation for each IOU domain.

CHAPTER 4. RESULTS

The IAD framework on the following page (Figure 15) represents key components of the study area, relative to California NEM policy and the impact of PV diffusion in the state. Each of the components (A-E) is summarized on the following pages. The Action Arena is implicit in this essay, so its components are not specifically revisited. For example, the Action Situation is the thrust of this essay, and the Actors are identified in the content, particularly in the Rules-in-Use. One issue to note is that CAISO, the state grid balancing authority, is in both the Rules and Actor because it performs both functions at a significant level.

ACTION ARENA

A. RULES-IN-USE

Meta-Constitutional

- FPA (1920,1935)
- BPA (1937)
- PURPA (1978)
- Energy Policy Act (2005)
- EISA 2007
- ARRA (2009)

Constitutional

- CAISO (regulatory)
- NEM (SB 6656)
- CSI
- RPS
- AB 327

B. PHYSICAL MATERIAL CONDITIONS

Characteristics of Goods (Private, public, toll) and Services (common pool resources)

- Subtractability
- Excludability

C. ATTRIBUTES OF THE COMMUNITY

- Trust
- Reciprocity
- Common Understanding
- Social Capital
- Cultural Repertoire

Action Situation

The evolving events impacting Actors relative to:

- PV Diffusion
- NEM
- The Grid
  - Costs
  - Benefits
  - Services
  - Equity

Actors

- FERC
- CAISO (members)
- CPUC
- CEC
- IOUs
  - PG&E
  - SCE
  - SDG&E
- Ratepayers
  - Prosumers
- PV technology providers
  - Sellers
  - Lessors
  - Venture Capital
- Smart grid technology providers
  - Inverters
  - Home smart devices

D. PATTERNS OF INTERACTION

- CPUC NEM workshop
- IOU participatory strategy
- IOU operational strategy
  - CPUC response
  - Prosumer response
- CAISO "Duck Curve"

E. OUTCOMES

Economic

- Economic Efficiency
- Fiscal/ Equivalence
- Redistribution equity
- Accountability
- Conformance to morality
- Adaptability

Spatial

- *Location Quotient*
- *Baseline*
- *Global Moran's I*
- *Getis-Ord General G*
- *Anselin's Local Moran's I*
- *Getis-Ord Hotspot*

Figure 15. A Schematic of an Essay applied IAD Framework

Source: D. McGie

A. RULES-IN-USE

The *Rules-in-Use* concept assembles “rule-ordered actions”, often consisting of “rules nested in another set of rules that define how the first set of rules can be changed” (Sabatier, 2007). A fundamental component of NEM policy is the identification of rules at different levels. The rules are both specific and multi-level formulated combinations. Within the agencies are rules for operation, and within the operations are yet other rule-ordered-actions. For this reason, Ostrom proposes to distinguish the hierarchy of rules to demonstrate situational linkages Action Arena (see Table 1). This essay identifies ‘Metaconstitutional’ and ‘Constitutional” levels, in that order, to illuminate the major rules processes.

Table 1: Situational Levels of Rules-in-Use

Situations Levels	Meaning of Rule Effect	Examples
Operational	Directly affect day-to-day decisions made by participants	Stakeholder strategies and operations
Collective Choice	Eligible individuals that (together) can change Operational Rules	Public Utility Commission regulation, orders, and decisions
Constitutional	Determining individual eligibility and rules to craft Collective-Choice Rules	State legislation
Metaconstitutional	The over-arching premise of actions for which all other actions are based	Federal Acts

META-CONSTITUTIONAL RULES (Federal-level)

Federal Power Act (FPA)

The FPA in 1935 (enacted originally as the Federal Water and Power Act in 1920) coordinated the development of large hydroelectric projects in the U.S., most notably those on the Columbia River system. Secondarily, the Act created the Federal Power Commission (FPC) as the licensing authority for the hydroelectric generation plants. Iconic examples of dams include Hoover Dam and the Grand Coulee Dam on the Columbia River. The 1935 version of the Act, as amended, expanded regulatory jurisdiction to include interstate electricity transmission and sales (U.S. BR, 2009).

The FPC became the Federal Energy Regulatory Commission (FERC) in 1978 when energy related agencies became consolidated under the new Department of Energy. FERC is an independent federal agency within the department that regulates the interstate transmission of electricity, along with natural gas and oil (FERC, 2014). FERC also requires utilities to open their transmission lines to competitors (Order 888), which has led to some forms of deregulation (OpenSecrets, nd).

The Bonneville Project Act (BPA)

The BPA was as a regional development strategy to provide electricity to large areas in the Northwest devoid of electricity (Harrison, 2008). The BPA created the Bonneville Power Administration, which continues to administer electricity production from dams and the transmission network to deliver power regionally. The projects generate a significant supply of hydroelectric power for the northwest region as a regional, multi-state transmission network (Figure 16).

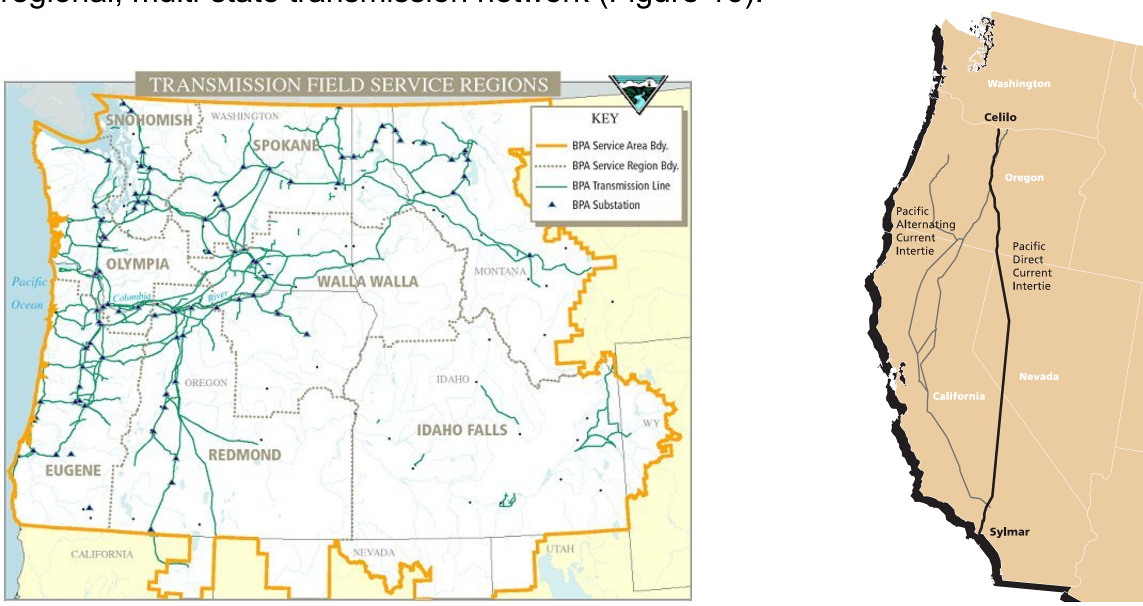


Figure 16. The BPA network and intertie
Source: BPA

The BPA network accommodates electricity production by numerous wind farms along the Columbia River Gorge and inland in Washington and Oregon, and also includes two contracted high voltage transmission lines to transmit electricity as demanded between the states. The implication is that PV diffusion may alter California’s need for the intertie (Profita, 2013).

Public Utilities Regulatory Policies Act (PURPA) of 1978

PURPA was enacted in political response to second energy crisis of the decade – the common shock of increased oil prices and uncertainty over its supply. As an attempt to reduce the perceived problem of foreign oil dependence, PURPA introduced a new policy solution by increasing opportunity for integration of diversified, renewable energy resources. PURPA allowed greater energy provision, pricing, social values and economic equity (Simon, 2007).

PURPA is the most effective single measure in promoting renewable energy. One of the most important effects of the law was to create a market for power from non-utility power producers, to promote alternative energy sources and energy efficiency, and to diversify the electric power industry. PURPA is the only existing federal law that requires competition in the utility industry and the only law that encourages renewables. Technically, PURPA only calls for renewable energy if it is cost competitive with conventional polluting resources. Many of the benefits of renewables are not included in the price, such as clean air, but PURPA makes no provision for including these (Union of Concerned Scientists, nd).

The Act opened state regulatory processes to include greater public participation in energy policy. Prior to PURPA, state commissions, charged with states' energy policies, operated as iron triangles. A tight relationship existed among state commissioners, business executives, transmission operators and utilities. The utility sector controlled the entire electricity delivery system with no ability for a non-utility generator to enter an electricity market because utilities had no interest in facilities other than their own (Komar, 2004).

The effect of PURPA altered the central station model and utility control and procurement of energy resources. PURPA required utilities' that sell over 500,000 MWh per year to forego sole ownership and operation of their electric generation and include electricity purchase from independent companies, referred to as "qualifying facilities” (QF). As a regulatory requirement, utilities purchase electricity from a QF at the utility’s ‘avoided cost’ of producing electricity based on marginal, next unit of cost, pricing (Keyes et al., 2013). As such, PURPA was the first statutory mechanism allowing an external ‘feed in’ to the grid from renewable sources (ALTA, 2013).

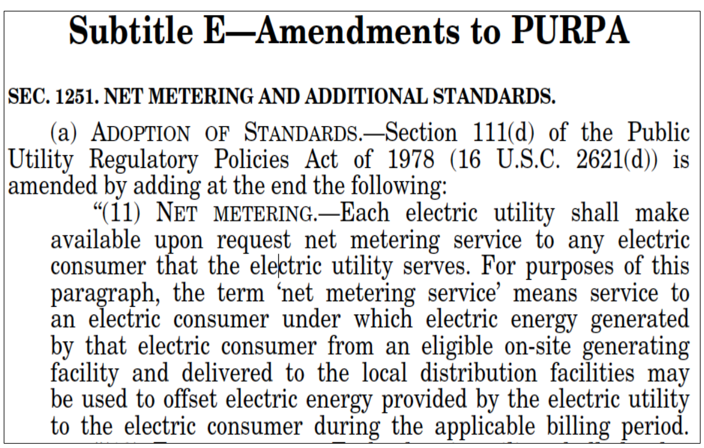
The imprecise language of PURPA created problems with implementation and interpretation for FERC. Examples include states’ 1) electric rates being set above avoided cost; 2) errors in avoided cost methodology; 3) requiring uniform QF rates despite differences in generation; 4) not providing a limit on the amount of QF capacity. Another the problem is that favorable consideration for project financing is often needed for a QF to become viable in the energy market. In response to these and other objections of PURPA provisions, FERC proposed bidding mechanisms and regulations as a condition to price QF power (Graves, Hanser, & Basheda, 2006).

The prominence of PURPA is currently being resurrected after decades of interpretation, and to some degree, decline. Most notable is a consideration that the avoided cost provision in PURPA is applicable to distributed generation valuation. In particular, the avoid cost should apply “to more accurately value the energy contribution of distributed facilities that serve local load”, but necessarily onsite load (Keyes et al., 2013). For Keyes, the avoided cost basis of PURPA could include reduced cost considerations (i.e. reduced line losses, small-scale deployment savings, avoidance of transmission and distribution costs). Though intriguing, PURPA-based approach by Keyes has only begun the discussion extending PURPA policy provision and interpretation.

Energy Policy Act of 2005 (EPA05)

The EPA05 legislation covers a multitude of topics, including electricity, fuel standards, tax incentives and standards for production and efficiency, resource extraction (i.e. oil and natural gas), as well as horizon technologies like hydrogen and fuel cells (Holt & Glover, 2006). The Act is a cornucopia of energy opportunities, funding, and blunt policy measures that have reshaped energy in the U.S. An emblematic example is how the EPA05 suspends oversight of the Safe Drinking Water Act (SDWA) in favor of hydraulic fracturing techniques ('fracking') to gain access to subsurface oil and methane (natural gas) deposits in the contiguous U.S.

The net metering amendment requires each electric utility to "make available" net metering as service for all their customers who elect to self-generate electric energy (Figure 17). The act adds five new standards to PURPA listed below (Section 111(d)) that states must consider U.S. DOE, nd), though no monetary penalties exist for failure to comply (Kenneth Rose & Karl, 2005).



Subtitle E—Amendments to PURPA

SEC. 1251. NET METERING AND ADDITIONAL STANDARDS.

(a) ADOPTION OF STANDARDS.—Section 111(d) of the Public Utility Regulatory Policies Act of 1978 (16 U.S.C. 2621(d)) is amended by adding at the end the following:

"(11) NET METERING.—Each electric utility shall make available upon request net metering service to any electric consumer that the electric utility serves. For purposes of this paragraph, the term 'net metering service' means service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period.

Figure 17. The 2005 Energy Policy Act Amending PURPA to include NEM

Source: U.S. Government Printing Office

<u>Five New Standards for PURPA</u>

1. Net metering
2. Fuel sources
3. Fossil fuel generation efficiency
4. Time-based metering and communications
5. Interconnection

The Energy Independence and Security Act of 2007 (EISA07)

The EISA07 legislation adds four additional “states must consider” standards to PURPA, augmenting the EPA05 provision. The four additional standards include:

1. Integrated resource planning
2. Rate design modifications to promote energy efficiency investments
3. Consideration of smart grid investments
4. Smart grid information

As amended, PURPA preserves legal authority with the states, but requires their regulatory and/or governing boards to adopt the ‘must consider’ requirements for all utilities (not just IOU’s). The two smart grid standards are most germane to this paper. First, the ‘Consideration’ standard requires states’ utilities to consider smart grid improvements, and when “undertaking investments” that include six “appropriate factors” of smart grid options (Rose & Murphy, 2007):

1. Total costs
2. Cost effectiveness
3. Improved reliability
4. Security
5. System performance
6. Societal benefit

Second, the smart gird information standard requires that all purchasers of electricity be provided smart grid information about:

- PRICES (time-based wholesale and retail pricing in their market)
- USAGE (units in kwh)
- INTERVALS AND PROJECTIONS (daily updates in information)
- SOURCES (annual written information on sources of power)

2009 American Recovery and Reinvestment Act (ARRA)

ARRA provided funding for the Smart Grid Investment Grant (SGIG). The SGIG, administered by the Department of Energy, incentivized numerous utilities to upgrade their distribution systems with digital technology. The most prolific upgrade is the replacement (in the millions) of residential analog service meters with *smart meters* as part of an advanced meter infrastructure (AMI). Smart meters and the infrastructure they help create provide three distinct benefits and capabilities for utilities.

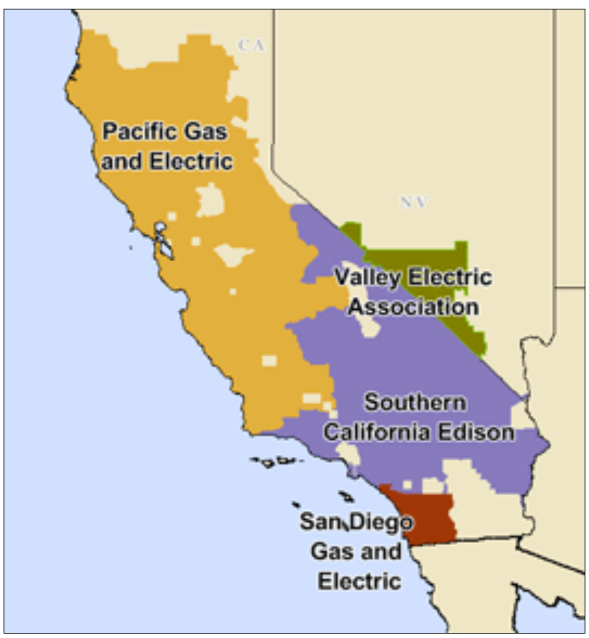
1. Reduced labor and operational costs
2. Circuit sensing
3. Data (customer and operational)

Other SGIG provisions for utilities include voltage control devices and operational software. In short, the SGIG under ARRA gave the utility sector a strong incentive to transition from the analog grid to a more digitally, oriented system. The system is being populated by smart meters in all customer locations, as well as voltage monitoring technologies in transmission and distribution systems. Finally, the SGIG program implicitly promotes distributed generation throughout the grid, but is most applicable to large distribution systems operated by IOUs in the state. The implication is that utilities are gathering real-time data, derived continuously in increments of minutes, from the both systems for efficiency.

CONSTITUTIONAL RULES (State-level)

California Independent System Operator (CAISO)

CAISO is the independent transmission operator in the California. Regulated by FERC, CAISO ensures the “reliable performance of the high-voltage electricity grid, open access to participants, and a transparent, competitive market for energy” by regulating the wholesale power market in the state electric grid system (CAISO, 2014). The power market is comprised of energy market settlement (purchasing of power (day, hour, and real time), ancillary services, and transmission rights (FERC, 2013). Three of CAISO owners are also the same three largest IOU’s serving the distribution systems (Figure 18) in the state (see panel below right).



CAISO Ownership

Citizens of Sunrise Transmission LLC
Cities of: Anaheim, Azusa, Banning, Colton, Pasadena, Riverside, and Vernon

DATC Path 15, LLC
PG&E
SDG&E
SCE
Startrans IO, LLC
Trans Bay Cable, LLC
Valley Electric Association, Inc.
Western Area Power Administration, Sierra Nevada Region

Figure 18. Geographic map of CAISO territory
Source: CAISO

SB 656 (Sec. 2827)

Net metering was established in California in 1995 under Senate Bill 656, Section 2927. The legislation specifies that “every electric utility in the state” participate, and identifies their net metering capacity relative to peak system demand (in MW). Section 2827 (a) declares the state’s intent (Rahus Institute, 2005; Ca.gov. nd).

Net-metering for eligible customer-generators is one way to encourage private investment in renewable energy resources, stimulate in-state economic growth, enhance the continued diversification of California’s energy resource mix, and reduce utility interconnection and administration costs.

Through as series of revisions to NEM, the state regulations require utilities to provide NEM value to its customers with the following benefits:

California does not allow any new or additional demand charges, standby charges, customer charges, minimum monthly charges, interconnection charges, or other charges that would increase an eligible customer-generator's costs beyond those of other customers in the rate class to which the eligible customer-generator would otherwise be assigned. Technologies eligible for net metering (up to 1 MW) are exempt from interconnection application fees, as well as from initial and supplemental interconnection review fees (Desire 2014).

SB 656 provided the impetus for anther iconic solar program. The 2006 SB1 Million Solar Roofs was designed to put the state on track to build a million solar roofs in tens years. The bill increased the cap on NEM, mandated solar panels be offered in all new construction, required state utilities to create their own solar rebate program and sought a review of licensing requirements for solar installers for training and installation of solar systems (Ca.gov. nd). The solar rebate program required of utilities became the California Solar Initiative (CSI), under direction of the California Public Utilities Commission.

California Solar Initiative (CSI)

The CSI program emanates from Governor Schwarzenegger's Million Solar Roofs plan in 2006. The California Public Utility Commission and California Energy Commission jointly oversee the program and require the three largest IOUs in the state – PG&E, SCE, and, SDG&E – to administer the program in their respective territories. The CSI intent is to create a self-sustaining solar market in the state from inception through the sunset date of 2016. The expectation was/is to provide incentives for residential, commercial, government, and non-profit ratepayers to invest in solar systems designed to meet some or all electricity consumption. To do so, the CSI is structured to reduce incentives over time as solar installs increase, thereby achieving the policy goal of diffusion at lowest cost to taxpayers. The program budget of $2.167 billion over 10 years (2007-2016) seeks to reach 1,940 MW of installed solar capacity by the end of 2016 (E3, 2011). Funding for the program comes from electric ratepayers (Go Solar California, 2013).

The CSI is the country's largest solar program, helping make the state the leader in solar technology. By 2013, over 140,000 residential PV systems were installed, producing over 1500 MW of electricity. The program is also a major driver in economic growth, helping to infuse the state economy with over $10 billion in private investment (PR Newswire, 2014). In the same year, 1889 solar companies employing over 47,000 people continue to grow the market (SEIA, 2014).

Renewable Portfolio Standard (RPS)

A RPS is a state-level, mandated requirement of utilities to procure energy from known renewable resources. The current California RPS requires all electric service providers to increase procurement from eligible renewable energy resources from 20% presently, to 33% by the end of 2020 (CPUC 2013). Figure 19 below shows the compliance period of the RPS.

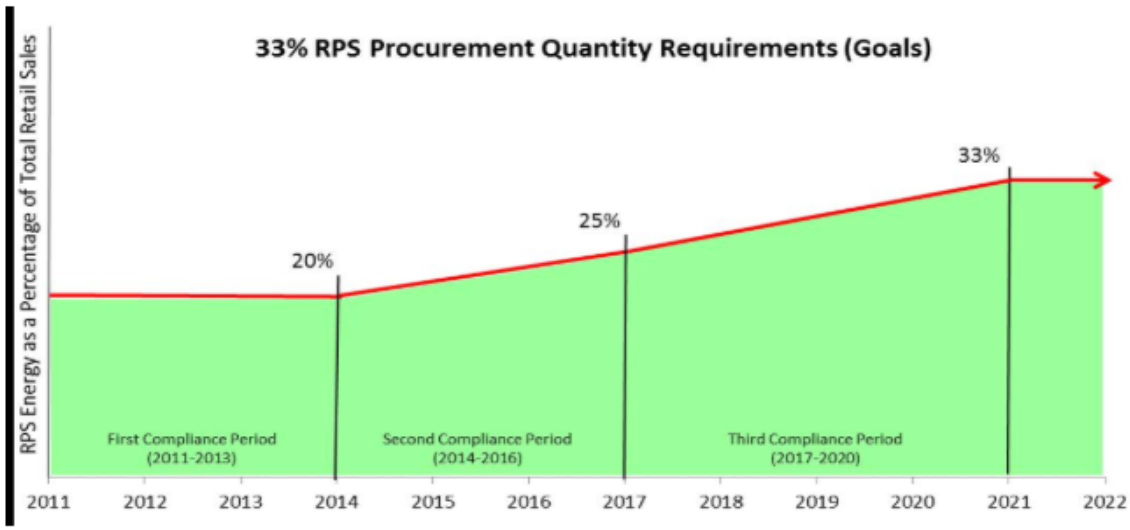


Figure 19. The California RPS inclining standard to reach 33%
Source: CPUC

The mandate requires 75% of renewable energy from facilities directly interconnected to the grid. This ‘local footprint’ augments the political desire to retain economic productivity within the state, rather than import new transmission and energy from out of state (Donnelly-Shores, 2013). As part of the existing grid system, the California/ Oregon intertie system offers capacity value for the 33% RPS mandate. As such, a ripple effect of concern about the impacts on RPS mandates in Oregon, Washington, and Montana are being considered (PNUCC, 2010).

B. PHYSICAL MATERIAL CONDITION

Physical material condition is germane to the California study area due the high penetration of PV technology in the state that captures an abundant supply of sunlight. The physical material condition of goods (or services) is generally defined by two characteristics–*subtractability* and *excludability* (Ostrom, 2005). Subtractability is the consumption of a unit of a resource that lowers potential enjoyment by others, while excludability is how costly it would be to prevent consumption by others having no control rights. In traditional economic theory, appropriated products diminish (subtract) resource availability and are controlled (excluded) by the appropriator for advantage (i.e. consumption or trade) in some production function.

Sunlight violates both of these conditions, as it is neither a subtractable nor excludable resource. Hence, a dilemma occurs: the economic value of the resource is not subject to the three types of 'goods' found in economic theory.

Type 1: Private Goods (Subtractability and low costs of exclusion)

> Private goods and services can be produced efficiently through processes of market exchange. To operate efficiently, markets must be located within the supporting framework of such public goods as rule of law, secure property rights, and a medium of exchange

Type 2. Public Goods (Non-subtractability and high costs of exclusion)

> Free rider problem leads to sub-optimal production of public goods and services.

Type 3. Toll Goods (Non-subtractability and low costs of exclusion)

> When consumption can be restricted to members of a defined club.

Further, sunlight is an obvious, and ubiquitous, Common Pool Resource (CPR). As such, it has no property right consideration, except in the case of access, and no 'free-rider' condition exists. Therefore, an appropriation externality cannot occur and rent cannot be a factor of benefit or cost. However, productive yield can be affected depending on an incident condition of solar irradiance (i.e. location to an adequate amount of productive sunlight). As such, a technological externality may occur as a consequence of unequal access of differing levels of effectiveness. An example may include an inequitable infrastructure provision, such as differences in access. An example is a structural orientation of a building that blocks effective sunlight (shadow effect). Another example is the perception of inequality whereby some homeowners have location, ownership, or economic advantage over others to secure a PV system. In any event, only the technology of capturing sunlight, like a PV system, is subject to market forces of supply and demand.

As a CPR, sunlight demanded for PV is escalating. Intermediary rents cannot occur, so market forces apply only tangentially, not directly. Further, government intervention, such as taxation or regulation, cannot be imposed in the resource except, again, tangentially on technologies and their construction and application. As a ‘fuel’ resource for solar PV technology, sunlight is: ubiquitous, neither subtractable nor excludable, not subject to rent profit, and cannot be taxed. This creates an interesting conundrum for market consideration, especially when technologies for its capture and conversion into electricity become comparatively cost effective without subsidy against traditional energy resources (Randall, 2014).

C. ATTRIBUTES OF THE COMMUNITY

According to Ostrom, important Attributes of the Community include,

> The values of behavior generally accepted in the community; the level of common understanding that potential participants share (or do not share) about the structure of particular types of action arenas; the extent of homogeneity in the preferences of those living in a community; the size and composition of the relevant community; and the extent of inequality of basic assets among those affected (Ostrom, 2005).
>
> Five Important attributes to consider are:
>
> - *Trust* against vulnerability and agreements being honored
> - *Reciprocity* of cooperation
> - *Shared Understanding* of core values or goals
> - *Social Capital* of mutual reliance generated by stable networks
> - *Cultural Repertoire* of strategies (i.e. norms, rules, practices) for processes of deliberation and implementation

For this California case study, the values and consideration of attributes (listed above) of Actors in the action arena(s) are synthesized into four considerations.

> *Consideration 1. The knowledge and information Actors' have about their relationship in the context of state policy strategies, actions, and outcomes appear well understood.*
>
> *Consideration 2. The Actors' values and preferences, with respect to policy strategies for achieving outcomes, are defined but polarized.*
>
> *Consideration 3. The Actors' appear less aware of the implication of global relationships impacted policy-oriented strategies, actions, and outcomes.*
>
> *Consideration 4. The Actors' are cognizant about other participants' strategy preferences and outcomes; however, the positions appear intractable.*

Note: This essay considers Attributes of the Community in the context of future research, which is advised by the content of this essay research.

D. PATTERNS OF INTERACTION

The Patterns of Interaction refer to the interactive characteristics of conduct and behavior by Actors' (in an action arena) that flow as strategies from a range of available possibilities. In the resulting structure, inferences are made about the conduct of Actors' interactions within the context of community norms, and how situations may impact potential change in the institution. Over time, Actors seek strategic change, as results become known. In the process, innovation and new organizational structures may occur (Polski & Ostrom, 1999).

For this essay, the patterns of interaction results are constrained to include recent participatory actions (and their responses) to the problems. At the primary level, NEM-related workshops at the ground level are being conducted by the CPUC around the state ahead of the December 15, 2015 revision mandate, as required by the legislature in Assembly Bill 327 (CPUC, 2014). The workshops seek input for the CPUC to consider structuring the state NEM program to determine how PV will be considered economically beneficial in the future (Akins & Nelson, 2014).

- Ensure that customer-sited renewable distributed generation continues to grow
- Include alternatives among residential customers in disadvantaged communities
- Ensure that the successor tariff is based on the costs and benefits
- Ensure that the total benefits of the tariff equal the total costs
- Allow projects greater than 1MW to interconnect under reasonable charge
- Establish terms of service and billing rules for eligible customer generator

Communication methods comprise a secondary level of interaction. The pattern of interaction includes four notable communication methods occurring in the study area. The first method is the numerous and timely reports that serve to define, clarify, and propose considerations that residential PV, NEM, and distributed generation impact. The second method involve interactions the three IOU's have with the CPUC and PV community, which is contrast to their projected persona in the public sphere. The third method is use of third party participation in a collaborative workshop environment. The fourth method is the predictive "duck curve" presented by CAISO, which set in motion significant discussion about how distributed solar PV, residential in particular, could have on the California grid in years to come. Each of these three communication methods is summarized below.

As a communication method, submitted reports serve many purposes, including reference for this essay. Some reports attempt discussion guidance with pointed a perspective that attempt to clarify issues like valuation of grid services to solar ratepayers, or valuation solar PV provides the grid. Here we find content that attempts to elevate the debate discussion outward, which oftentimes media sources relay to the public. Other reports are research tools, designed to quantify a range of valuation metrics largely based on cost benefit criteria. Research reports often contain projections that itself becomes fertile ground for additional debate. At the macro scale, reports collectively inform one another temporally, but in circular fashion.

The second communication method involves IOU actions specifically. Publicly, the IOU's portray residential PV and NEM in positive light. Each utility has dedicated much website space and content intended to cast their involvement, generally, as dedicated community partners. Advertising is another venue for this portrayal. For example, a San Francisco Giants fan will see PG&E emphasize a human relationship, featuring its workers as dedicated members of the community. However, those same viewers will see greater ad spots by solar companies who emphasize reduction in electricity bills when switching to solar. As distribution level service providers, IOU's continue to fulfill their participation requirements of state and federal legislation, regulated under authority of the CPUC. But underneath the media representations are IOU's that actively challenge NEM policy and seek recourse to offset stated losses by targeting residential PV customers.

Southern California Edison (SCE)

SCE denies NEM applications of residential PV installations that include a battery backup in the final installed system. Denial of NEM benefits by the IOU often comes after the system is installed. Any battery technology requires the homeowner, and their contractor, to submit a different, non-NEM generation application similar to those required of large generation facilities. In any case, the homeowner must resubmit the application with revision for review, which restarts the application process.

SCE contends that battery systems could be used to store electricity from the grid, which is supplied by the utility, and could potentially be resold back to the utility at a higher rate than purchased. Further, SCE says that no distinction can be made between grid and PV-generated electricity. Finally, SCE defines a battery in a system, not as storage technology, but as a generation device. SCE is reviewing all its previous NEM installations for battery backup technology. Discovery merits removal from the NEM program and negates kWh credits received by the prosumer.

Prosumer Interactive Response

SCE cannot unilaterally change the CSI rules. A battery stores electricity. A battery cannot generate electricity. Purchasing an added battery backup to the system, while cost effective for the homeowner during times of power outages makes no logical, economic sense if trying arbitrage upon the utility.

CPUC Interactive Response

While the inclusion of battery backup technology in PV system may comply with CSI requirements, SCE requirements are different; as such, potential prosumers' must comply with requirements of their SCE service utility. Meanwhile, the CPUC continues its process in formulating new rules for interconnectivity.

San Diego Gas & Electric (SDG&E)

SDG&E sought a revision of its rates structure in 2012 to create a Network Usage Charge (NUC). A NUC is a demand charge applied specifically to NEM customers. As intended by the utility, the charge would have created a fee for exchange of electricity to and from the grid, based on the average hourly amount of power exchanged.

Prosumer Interactive Response

The fee makes new PV systems economically unaffordable

CPUC Interactive Response

The fee creates a “new charge” that is inconsistent with the state Public Utilities Code; therefore the NUC is illegal and denied.

Pacific Gas & Electric (PG&E)

1. PG&E appears to seek change at the political level rather than directly confront the CPUC or its ratepayers, even though the IOU consistently contends that NEM is an unfair cross-subsidy. Two political actions are noteworthy. The first a ballot measure promoted by PG&E in 2010. The Proposition 16 sought to restrict local governments to expand or create a local utility. The defeated measure would have made it difficult for local governments to challenge the dominant monopoly position enjoyed by PG&E. The utility reportedly spent $46 million in support of the measure. Two publicly operated community choice aggregates were created since the defeat of Proposition 16, with 15 more in the planning stage (Hales, 2014).

The second political event is the current federal and state investigation concerning the brewing scandal between three top-level PG&E representatives and the CPUC that sought political contribution from PG&E to oppose specific legislation. PG&E sought a favorable political appointment to administer hearings concerning a recent natural gas explosion in southern California. PG&E fired the three executives and has acknowledged responsibility and expects to face penalties. The CPUC is involvement is more onerous, as the President, a Commissioner, and advisor to the Governor have been directly implicated. While the actions do not involve NEM specifically, the results impact CPUC impartiality to represent the public interest.

Prosumer Interactive Response

None specific to prosumer. However, consumer advocates are demanding a refund from PG&E

CPUC Interactive Response

The President has tendered his resignation. Investigation is ongoing. The

CPUC has fined PG&E $1.05 million (with other restrictions) for its improper communication participation with the CPUC. *That is correct, the CPUC fines the utility for having improper actions the CPUC improperly participated in!*

2. On 11/2013 PG&E filed an application with the CPUC for a 2013 Rate Design Window Proceeding. The motion seeks to make the CPUC "take official notice of the CPUC's report" submitted by E3 Consultants, Inc. that contains a conclusion favorable to the utility contention of cost-shift fairness, based on earlier data. The study by E3 is referred to in the motion as "The CPUC Study". By filing the motion, PG&E appears to be attempting a strategic action ahead of the NEM rate revision in 2015.

Prosumer Interactive Response

Attorneys for the Solar Industries Association filed a response requesting the CPUC to deny the PG&E Motion. The counterclaim contends the PG&E action is procedurally invalid, and that the CPUC must hold hearings on the E3 report to interpret and test the validity of the results before taking official notice.

CPUC Response
Pending

As a third method of communication, utilities may seek third party participation as strategy to project and justify their position, while also garnering outside viewpoints in a collaborative venue. Two IOU's – PG&E and SDG&E – have a record of outside participation with other groups, but similar involvement by SCE has not been forthcoming. For its part, SDG&E convened a collaborative stakeholder group comprised of utilities, government representatives, solar developers and advocates, environmental groups, and others to "determine the net cost of having distributed PV [residential PV] connected to the electric system [SDG&E distribution system]" (Black and Veatch and Clean Power Research, 2014). The provision of non-publicly available data by SDG&E is an important component of the research and its results. Other data is derived from CAISO, CPUC, FERC filings, data requests, testimony, etc. The extent of the collaborative effort is well beyond the scope of this essay, but some important points are notable.

1. SDG&E provided information upon request. The study group processed all the information and data. Comments on the results were made by the utility and outside interests, which the Study Team provided comment and correction prior to publication.

2. “Services” of both the utility and PV customer were considered.
3. “Costs” were comprehensively addressed.
4. Impacts to the SDG&E distribution were quantified.

On behalf of PG&E, the Rocky Mountain Institute (RMI) convened a workshop with external participants (principals) to address concerns expressed by the utility in the context of market valuation concerns caused in large part by solar PV diffusion. The workshop addressed these four these questions:

1. How will increased penetration of distributed resources and ZNE [zero net energy] buildings affect cost and value for the utility and its customers?

2. How could rate structures be modified to enable sustainable, fair, and efficient development of these resources?

3. How might utility business models change?

4. What innovative energy services could be provided by the utility in conjunction with distributed resources and ZNE customers? What is the value of these services to all customers?

The report does not directly answer the questions above. Instead, the participants’ views are summarized and presented as competing rationale depicting answers. In other words there is no agreement, just dialogue. However, the report implicitly presents overarching problems and “approach to solutions” in descriptive content and graphics (RMI, 2012).

The fourth and final method of communication is the now famous CAISO “duck curve” portraying potential impacts on the grid over time. In a workshop with CPUC and CEC, CAISO conducted panel discussions with industry representatives and interested observers concerning the projected impacts that residential PV and other distributed generation resources may have at the regional-level of resource planning and load balancing (Gerber, 2013). The duck curve is a strong method of communication because of its focal representation of grid function, or dysfunction depending on perspective. In other words, it's a big deal to many of the actors, and is cited in many discussions over PV impact and valuation. Not surprisingly, it serves as a lighting rod as well. The curve is described in terms of load (consumption) and PV production on a seasonally typical day. The content below outlines the discussion.

Historically, the projection would be indicate a sharp demand ramp for electricity from about 4:30 am to 7:30 am, increase steadily until late morning, and then drop slightly until 4:30 pm when people begin to return home from work. Once home, demand rises sharply in the early evening and them tapers sharply overnight. The blue line on Figure 20, resembling the shape of an elephant, represents this.

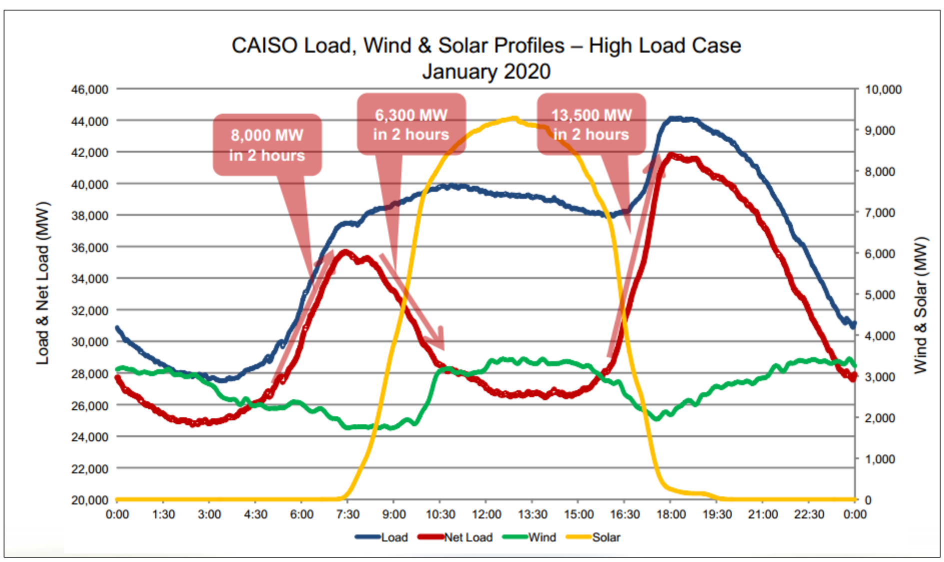


Figure 20. CAISO wind and solar profiles
Source: Wartsila

The net load (red line) accounts for wind (green line) and solar (yellow line) inputs. Again, this is a generalized projection by CAISO designed to illustrate the impact of solar and wind distributed generation. That is, the diurnal peaks and the steep trough (ok, the camel) during the day is an evolution (from an elephant) as wind and solar supply the grid (Figure 21).

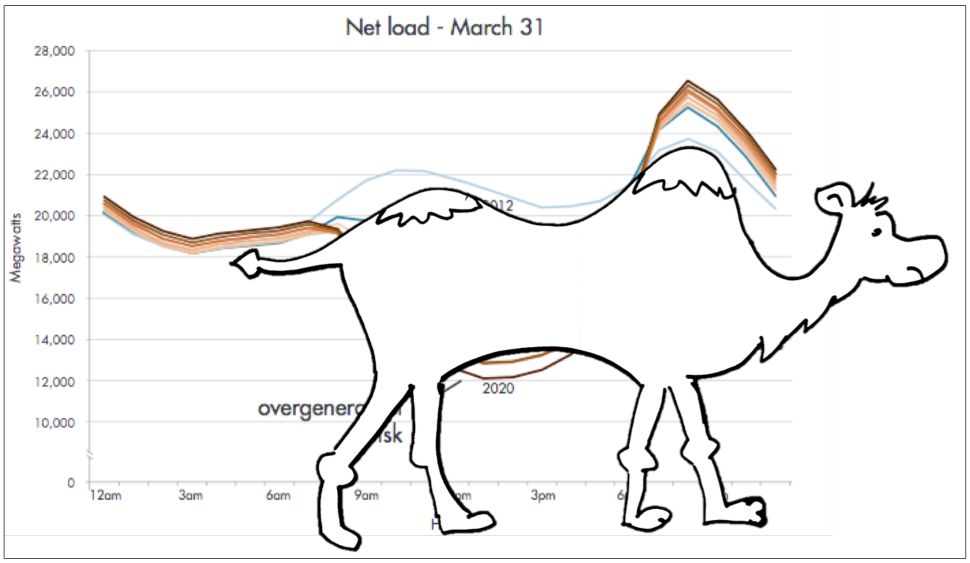


Figure 21. Present net load curve
Source: Insideenergy.org

As a pattern of interaction, the CAISO intention is to highlight the projected growth impact PV (and the 33% RPS) would have on the California grid. To get to that point, the evolution of animals continues, and a duck emerges. The "duck curve" on the following page (Figure 22) illustrates an important point CAISO intended to make in the panel discussion and, subsequently, in the public domain. The point is that over-generation from distributed resources – residential PV in particular – could cause a significant increase in excess generation, which threatens grid stability. As the belly of the duck continues to drop over time, the difference between supply and demand increases, causing greater grid dysfunction. The neck and head of the duck represent a late-day, steep demand ramp requiring quick substitution of energy resources as sunlight and PV output diminishes (Tweed, (2014).

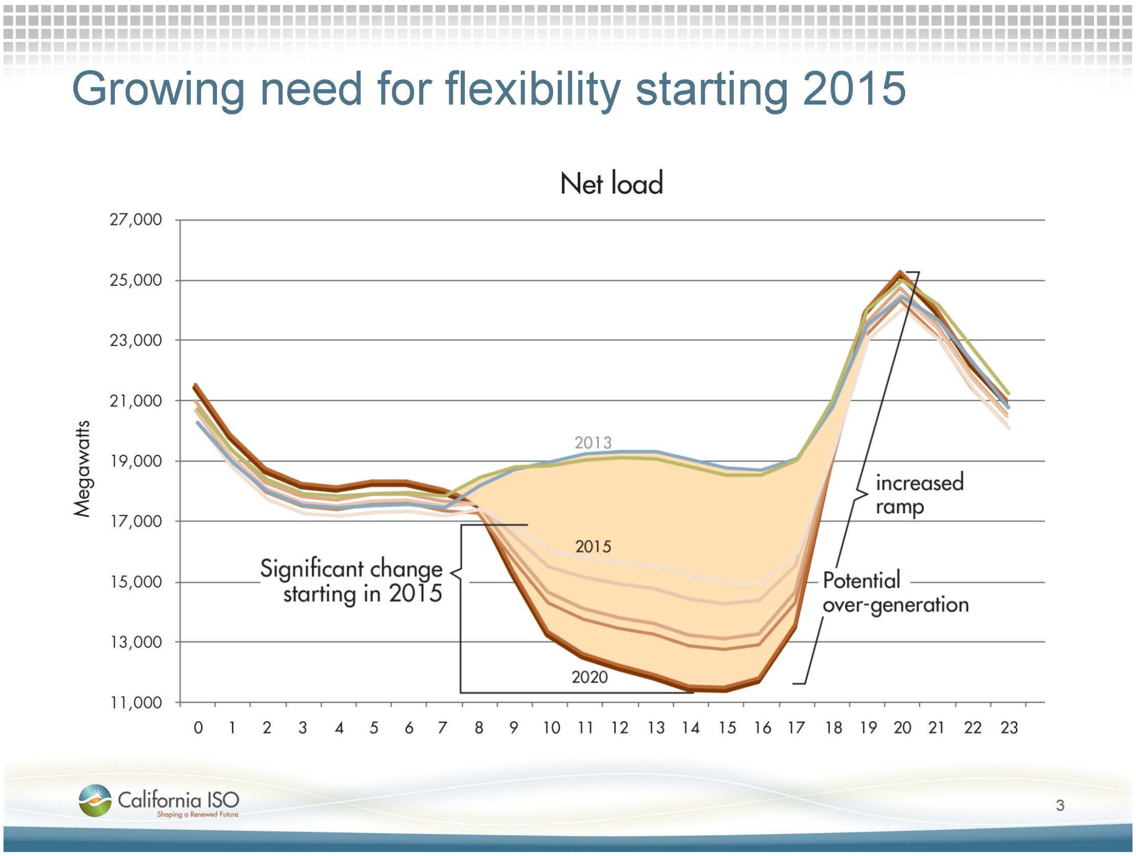


Figure 22. The CAISO "Duck Curve"
Source: CAISO (modified image is from Cal Watchdog)

In the realm of pattern interaction, the utility group finds the duck a problem whereas the PV group finds it "a good problem to have" and is "solvable" (Clean Coalition, 2013). Indeed, potential options exist if the problem were ever to occur (understanding that the CAISO duck curve is merely a theoretical construct). Clean Coalition cites import/export opportunities, energy efficiency and demand response, storage technology, and lastly, natural gas generation. Taking the solutions baton one lap further, author Jim Lazar offers 10 strategies (listed below) that “Teach the Duck to Fly” (Lazar et al., 2014).

Strategy 1: Target energy efficiency measures to match load ramps
Strategy 2: Orient solar panels west to maximize late afternoon sunlight
Strategy 3: Substitute some PV to heat water for energy storage technology
Strategy 4: Implement service standards for grid operators to actuate #3
Strategy 5: Require large air conditioners to include two hours of storage
Strategy 6: Retire inflexible generation plants
Strategy 7: Concentrate rates toward price induced ramping hours
Strategy 8: Deploy strategic storage technology in targeted locations
Strategy 9: Implement aggressive demand response programs
Strategy 10: Use inter-regional power transactions

Utility representative, Brent E. Gale, contends that, “it is not possible to teach the duck to fly if it refuses to leave the nest of the residential full requirements rate” and that “these parties [PV group] can’t have it both ways and cry “fowl” about being placed on an appropriate rate” (Gale, 2014).

E. OUTCOMES

Elinor Ostrom defines institutions as “fundamentally invisible, shared concepts that exist in the minds and routines of participants in policy situations” (Ostrom, 2005). Under this definition, institutions are relationships reinforced over time by shared concepts. The California electric grid system is similar to other states in that relational path dependencies exist between a regulatory authority and investor owned utilities (IOU’s).

However, California is different from other states in regard to its numerous policies and benchmarks, having cross current effects that target the three IOU’s for compliance. Another challenge for the state regulator (CPUC), for it must regulate utility actions toward the California Solar Initiative (CSI) policy, which the CPUC inherently co-promotes along side the California Energy Commission. To complicate matters even more, the legislature directed the CPUC to amend the state NEM policy by a 2015 end date and reduce the number of rate options, virtually guaranteeing a reorder of winners and losers among ratepayers.

As a result of state policies and the uncertainty of an impending NEM revision, the weight of self-interest permeates the state grid system, which is fracturing. The fundamentally invisible shared concept is challenging the CPUC is to manage the transitory process of residential PV diffusion in the state, created in large part by the state NEM policy and the CSI. Its institutional relationship is triangular, involving each of the three IOU’s and all state citizens. Similar to other states, the CPUC considers IOU requests in the context of existing NEM policy. It also must consider the intent of other state policies, political pressure from the legislative branch, as well as the goals set by the governor. Finally, the CPUC must also be mindful of federal policy, regulation, and oversight as it applies metrics of valuation to possible NEM revision that affects the stability of state electric grid.

An evaluation of outcomes having high complexity is a task requiring specialized tools. The outcomes in an IAD flow logically from Actors' patterns of interactions, once attributes of the community and rules are identified in the action arena. Ostrom evaluates outcomes on the basis of six economic metrics, used as analytic tools for policy performance (Sabatier, 2007).

However, problems arise when comparing economic criteria to the complexity of human behavior. For example, tension between the goals of efficiency and re-distributional equity makes the choice of valuation difficult, especially when a cost-benefit structure is relied upon. Further, policy formulation based on economic valuation can result in peculiar outcomes. When the equitable division of a resource is an important consideration, the normative assumption is that it is divisible, subtractable, and excludable. But when we apply economic valuation to solar resources, we get a marginal cost of zero when another user utilizes the resource, and thus the efficient price becomes zero. If marginal cost and efficient price is zero, effort to arrive at equitable redistribution based on benefit /cost valuation becomes problematic. Nevertheless, this essay retains the six economic valuations as a coarse metric for outcome evaluation. A caveat is that each of the economic valuations is highly subjective and subject to bias. Each of the economic valuations is applied below in Table 2.

Table 2. Outcomes summary of economic value

Economic Value	Ostrom's Definition	Outcome
Economic Efficiency	Benefit and cost consideration; rates of return on investment; magnitude of change associated with allocation or reallocation	Unsettled because benefit and cost values remain undefined. All rate payers will be affected by NEM policy revision; reorder of winners and losers may cause behavioral change. Investment is made on temporal and geographic variations based on the value of electricity.
Fiscal Equivalence	Willingness to contribute based two principals 1) equity of contributions to benefits derived 2) differential abilities to pay	Imbalance between residential and utility contribution toward residential PV. Benefits remain undefined and unquantified. The differential over abilty to pay is relative to ratepayers unable to include PV as an investment hedge against rate hike and monthly electricity cost.
Redistributional Equity	Policy provisions that redistribute resources to "poorer" individuals; an equity goal that tempers resource use to "the greatest net benefit"	The balance of equity is in two forms. First, service rates are the proxy for valuation arguments by utilties who vow rate increases on non-PV ratepayers. Until valuation is defined in the market, this remains a wedge argument. Second, the provision of NEM resources includes those without the present possibility of including PV technology. Here, community solar provision under NEM attempts to ameleiorate inequity. Consideration of the greatest net benefit goes well beyond disagreement over NEM. Instead, the consideration includes a wider universe of values relating to growth, employment, and environmental concerns. While these considerations have introduced and quanitfying

		attempts have been made, little sustantive agreement yet exists on how such valuations should be represented in econometric models.
Accountability	Officials accountable to needs of citizens preferences; efficiency realized when information available to achieve redistribution objectives	Policy objective to 'fairly' distribute future NEM benefits met when information reflects citizen preferences primarily and utility preferences secondarily, which is the present situation. Revision to NEM may reverse the order of utility arguments prevail, which redefines efficiency as equitable division of costs to save non-PV ratepayers.
Conformance to Morality	Evaluate institutional arrangements for kept promises that results in rewards realized over time and cheaters who unfairly realize gain	NEM policy promises to 'grandfather' benefits for present residential PV owners. However, rates may certainly change for all rate payers, especially for PV owners. Change in NEM after 2015 revision bay be different for new PV adoptees. "Cheaters" exist in the minds of the utility sector and its adherents as they portray PV owners as "free riders" who "do not pay their fair share" of grid costs.
Adaptability	Institutional arrangements must be able respond to policy change; inflexibility results in failure of investment	The institutional arrangement is relational, and any policy change to NEM will assuradly be met with heated scrutiny. The challenge for the CPUC is to make NEM adaptable to change and agreeable for all parites, a tall order given the level of complexity of competitng and cross current considerations of the debate over cost and benefit valuation.

While economic outcomes are reflective of conditions, the spatial outcomes introduced in this essay begin a prescriptive process to address impacts. The spatial outcomes methods are exploratory, but they return statistically significant results and are therefore relevant for discussion about present and future residential PV diffusion and NEM impact.

The spatial methodology is based on location quotient (LQ) data, which is derived from known PV installations in the state California Solar Initiative (CSI) database. The data were selected on approximately six-month intervals, referred to as epochs, from 2011 through 2013. The CSI data were converted to LQ data (see Methods section for more complete descriptions) and input into ArcGIS software by combining tabular LQ data with a California shapefile containing state ZIP codes (the unit of analysis). The outputs of LQ data are expressed in both tabular and map format. Tabular values (Table 3) are mostly consistent over all epochs.

Table 3: Location Quotient Summary

		Epoch					
Value	LQ Score	11-Jun	11-Dec	12-Jun	12-Dec	13-Jun	13-Dec
A	High	1.05318080	1.04886150	1.04996526	1.04684925	1.04375613	1.04201124
B	Low (exc. zero)	0.15045440	0.17481025	0.17499421	0.17447488	0.13046952	0.13025141
C	Mean	0.93008524	0.92963278	0.92247390	0.92757460	0.92887314	0.92848212
D	Total Res	48777	60211	71970	89820	108122	122372
E	Total Obs	51371	63153	75566	94028	112853	127513
F	Global Ratio (D/E)	0.94950458	0.95341472	0.95241246	0.95524737	0.95807821	0.95968254

The total number of residential installs (D) increases by 73,595, or about 39.9%. In comparison, the number of all installations (E) (residential, commercial, non-profit, government) increases 76,142, which is just over 40%. Also, the spread increases in total observations versus residential only observations increase (2594 in year 1 to

5141 in year 3).

The high LQ (1.05+) occurs in the initial epoch and fluctuate slightly (1.04+). The low LQ score occurs in the final epoch with a higher fluctuation in 2-4 epochs. The mean is steady at just under one (~0.93). The global ratio of total residential installs to total observations (all installs), or the ratio of D/E, also remains numerically consistent at ~0.95.

Below is the initial 06/2011 Location Quotient map (Figure 23). Using the legend of color and value, the focus should be on the green areas (greater than one), representing locations having a greater ratio of residential PV installations relative to all residential PV installations in the state.

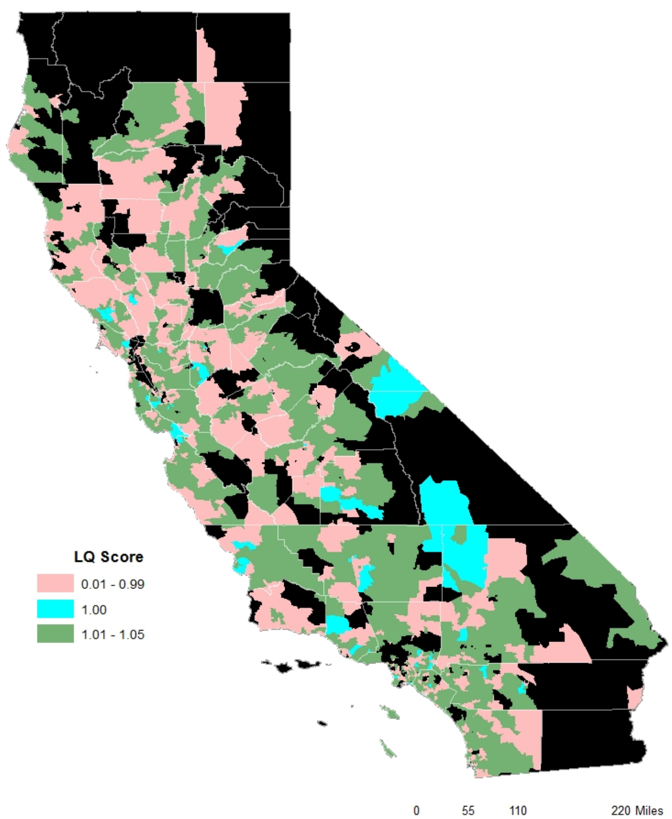


Figure 23. Initial epoch location quotient map
Source: D. McGie

We compare the initial map above to the final 12/2013 maps below (Figure 24), and discover some subtle differences. For example, the two large areas having unitary value (1.0) change color to green (>1.0) and some areas below 1.0 become unitary. Overall, the trend toward higher LQ score location increases, indicating growth in residential PV installations. However, the LQ maps only represent change in the data over time. Subsequent spatial tests refine the indication of growth.

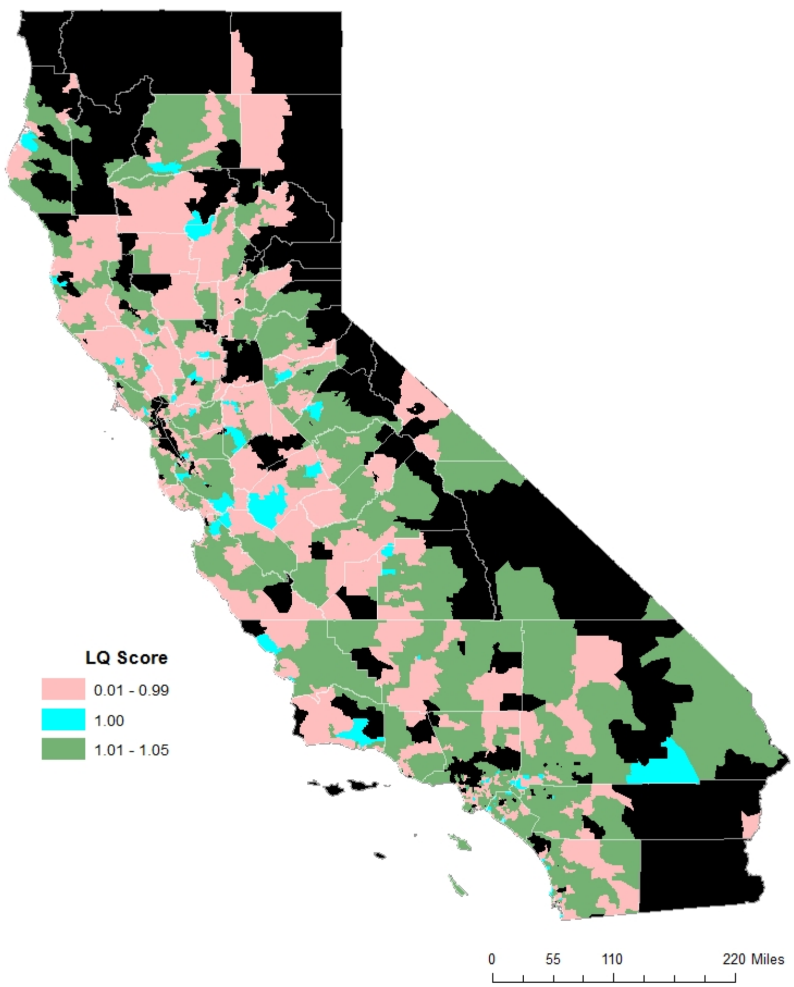


Figure 24. Final epoch location quotient map
Source: D. McGie

Tabular and mapping of baseline values is another exploratory second step for spatial outcomes. Baseline is the percentage of residential installs in each ZIP relative to total installs in the state. Table 4 summarizes the calculated values. The actual percentage numbers are very small. The percent min declines steadily and while the percent max fluctuates. The mean declines steadily, with the greatest drop in the last two epochs. The minimum frequency does not deviate from one because residential PV systems are not removed once installed. The maximum frequency follows the expectation of increase, though a near doubling of the value is notable.

Table 4: Baseline Summary

	Epoch					
LQ Score	11-Jun	11-Dec	12-Jun	12-Dec	13-Jun	13-Dec
% Min (All Zip Codes)	0.00194662	0.00158346	0.00132335	0.00106351	0.00088611	0.00078423
% Max (All Zip Codes)	0.72609060	0.68880338	0.66299659	0.67001319	0.67875909	0.62581854
Mean (All Zip Codes)	0.03895598	0.03694126	0.03494060	0.03007519	0.02888504	0.02805049
Min Freq / ZIP code	1	1	1	1	1	1
Max Freq / ZIP code	373	435	501	630	766	798

The initial Baseline map (06/2011) output has six values in the legend. The map is visualized mainly by color temperature, as the values are arbitrarily assigned to maximize spread in the data (Figure 25). The blue colors represent cool and the highest value red represents the areas of highest residential PV installations, relative to all PV installations (residential, commercial, non-profit, government) in the CSI database.

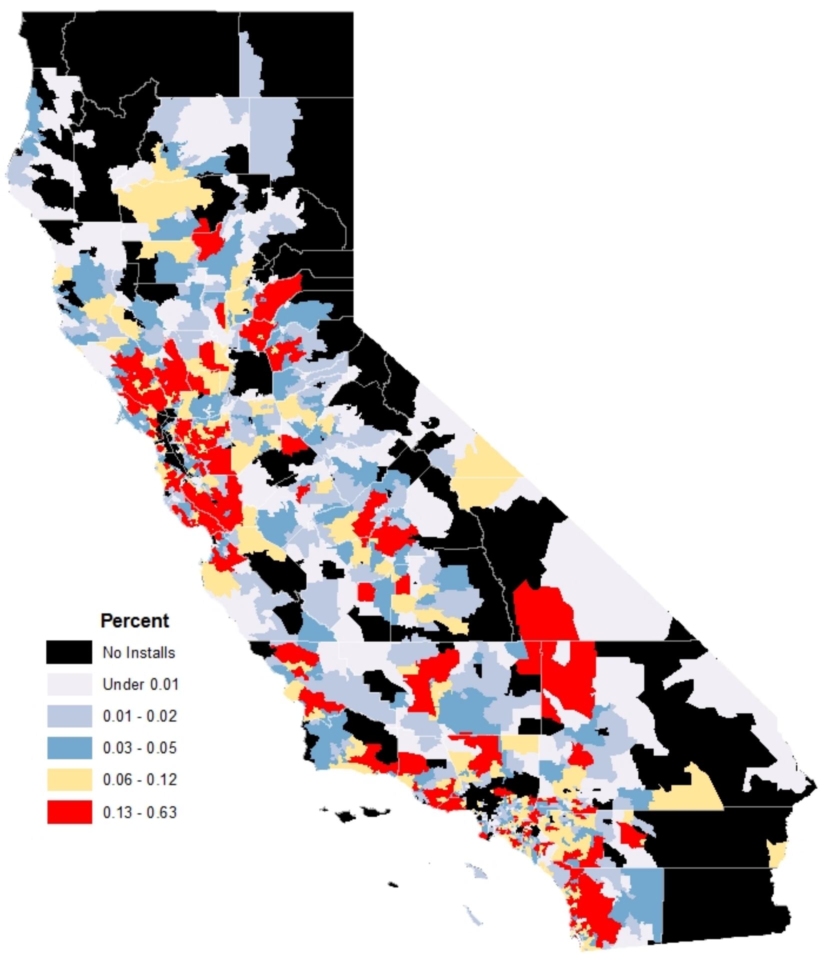


Figure 25. Initial epoch Baseline map
Source: D. McGie

Turning to the final epoch Baseline map (12/2013), the red values remain somewhat consistent, but more notably, previous areas with zero installations (black) emerge with installation values (Figure 26). The visual representation shows change in the data only. Subsequent tests validate indicative change.

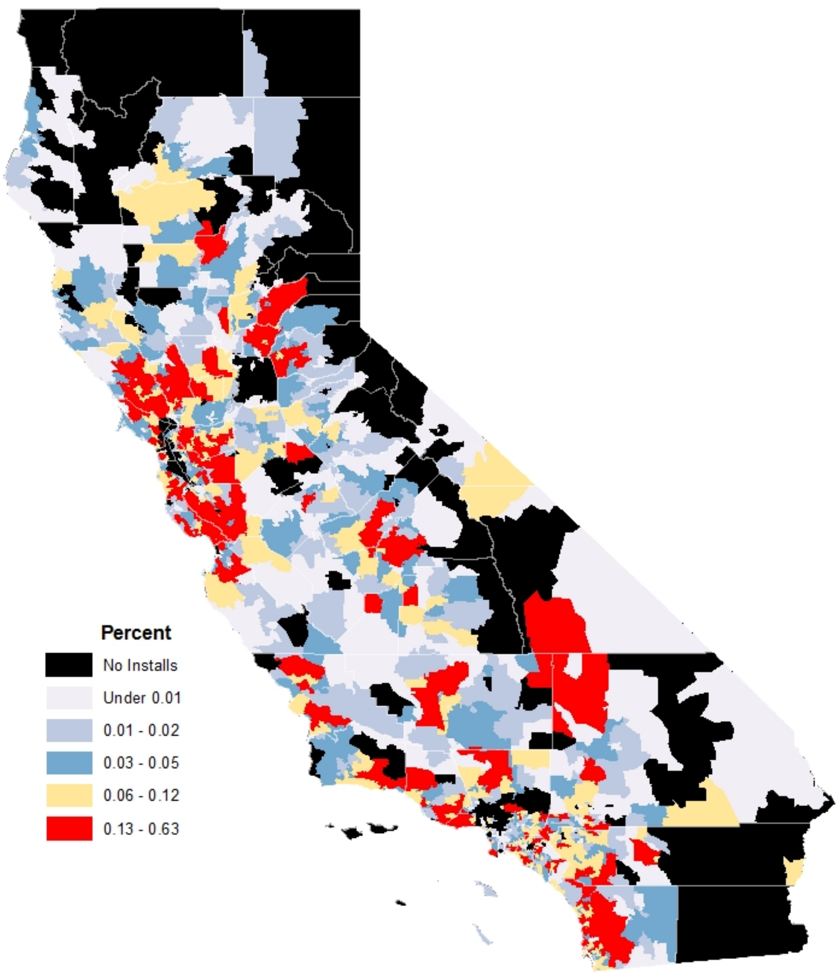


Figure 26. Final epoch Baseline map
Source: D. McGie

The first statistical test the LQ data measures whether the data exhibits cluster values or is spatially random. Areas that cluster are unique and of interest. The *Global Moran's I* tests for clusters based on statistically significant results. As Table 5 shows, the Z-scores and P-values are statistically significant for both Queen and Rook contiguities across all epochs. The Moran's Index is positive and increases slightly over time. The positive value of the Index indicates that the data set tend to cluster spatially.

Table 5: Global Moran's I (Spatial Autocorrelation)

		Epoch					
Contiguity	Moran's I	11-Jun	11-Dec	12-Jun	12-Dec	13-Jun	13-Dec
Rook	Moran's Index	0.480982	0.483815	0.49097	0.50208	0.504377	0.511906
	Exp. Index	-0.000589	-0.000589	-0.000589	-0.000589	-0.000589	-0.000589
	Variance	0.000242	0.000242	0.000242	0.000242	0.000242	0.000242
	Z-score	30.954986	31.13798	31.598072	32.313411	32.461514	32.945901
	P-value	0.0	0.0	0.0	0.0	0.0	0.0
Queen	Moran's Index	0.48106	0.484028	0.490618	0.501459	0.504409	0.511397
	Exp. Index	-0.000589	-0.000589	-0.000589	-0.000589	-0.000589	-0.000589
	Variance	0.000238	0.000238	0.000238	0.000238	0.000212	0.000238
	Z-score	31.247185	31.440638	31.868365	32.572868	34.709967	33.218498
	P-value	0.00	0.00	0.00	0.00	0.00	0.00

The second statistical test is the *General G*, which is a test of whether high or low clustering exists in the LQ data. The weighted Queen and Rook contiguity values (Table 6) are similar across all epochs. The Z-scores and P-values are statistically significant for the Observed G metric, which is positive across all epochs, indicating high, positive clusters in the data.

Table 6: General G (High-Low Clusters)

		Epoch					
Contiguity	Moran's I	11-Jun	11-Dec	12-Jun	12-Dec	13-Jun	13-Dec
Rook	Observed G	0.000730	0.000723	0.000723	0.000718	0.000716	0.000779
	Exp. G	0.000587	0.000587	0.000587	0.000587	0.000587	0.000768
	Variance	0.00	0.00	0.00	0.00	0.00	0.00
	Z-score	22.559081	22.226611	22.483083	22.595156	22.396687	24.309469
	P-value	0.00	0.00	0.00	0.00	0.00	0.000016
Queen	Observed G	0.000729	0.000722	0.000723	0.000718	0.000715	0.000714
	Exp. G	0.000587	0.000587	0.000587	0.000587	0.000587	0.000587
	Variance	0.00	0.00	0.00	0.00	0.00	0.00
	Z-score	22.649450	22.316974	22.545922	22.641303	22.448385	22.488503
	P-value	0.00	0.00	0.00	0.00	0.00	0.00

With the Global Moran's I and General G results, the understanding is that LQ data of residential PV installations is clustered with high/low values in the California study area, based on the statistical significance of the results. This discovery of spatial outcomes validates further exploratory analysis of the LQ data. Two spatial tools are used to measure local spatial patterns of location. These tools output statistically significant locations of the study region in map format.

The *Anselin's Local Moran's I* index indicates local location of clusters in the data, based on a 0.05 test of significance. The single red (HH) value indicates high cluster ZIP codes surrounded by like high values. The orange (HL) is high cluster ZIP codes surrounded by low values. The light blue (LH) represents low cluster ZIPS surrounded by high values, and the dark blue (LL) is extremely low ZIP clusters in similar low areas, or voids in data coverage. Change in values is discernible in some areas between the initial 06/2011map on the left and the final 06/2013 maps on the right (Figure 27). Discussion of change occurs in the next Analysis section.

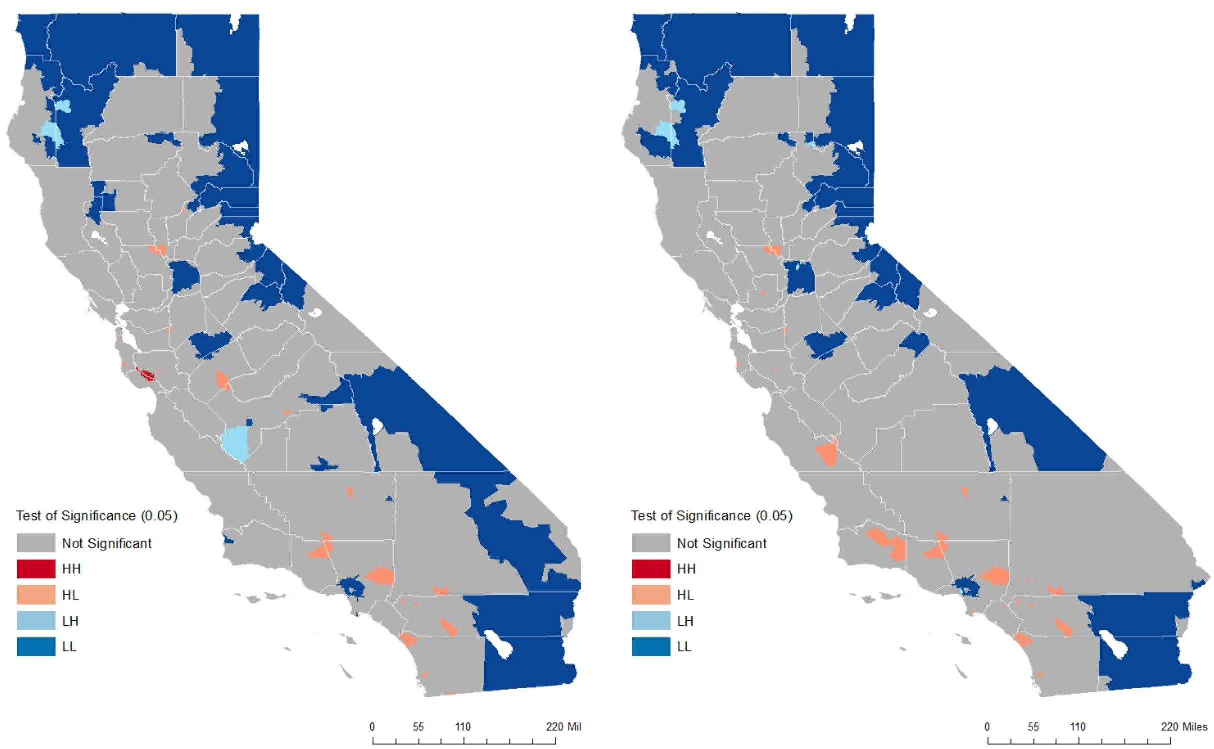


Figure 27. Change maps of Anselin's Local Moran's I
Source: D. McGie

The *Getis-Ord Gi** outputs a “GiZscore” that are “hot spot” clusters in the LQ data. The GiZscore are three confidence intervals based on statistical significance. The low interval (1.65-1.96) is 90% confidence, the 1.96 to 2.58 is 95%, and the 2.58 and greater is 99%. Similarities exist in both maps, but the final map on the right indicates greater hot spot activity (Figure 28). Discussion of change occurs in the next Analysis section.

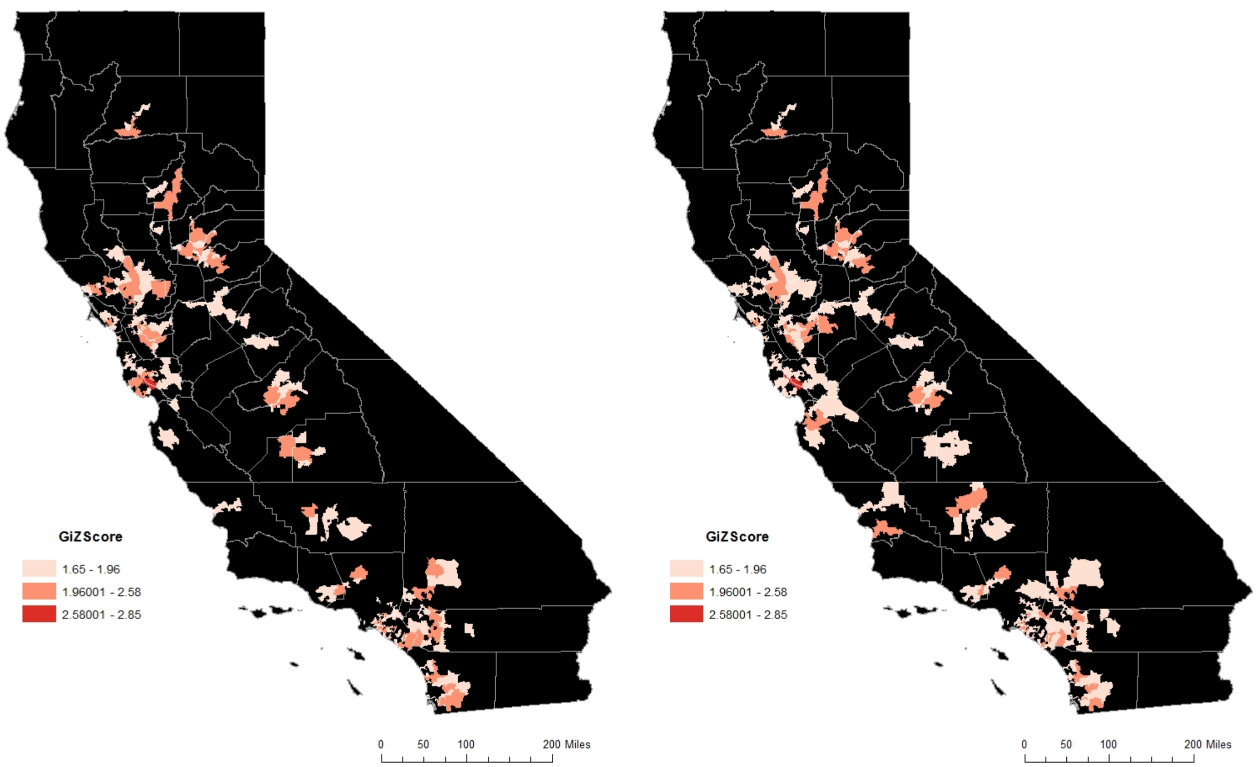


Figure 28. Comparison of hotspot changes using Getis-Ord Gi*
Source: D. McGie

CHAPTER 5. ANALYSIS OF FINDINGS

The first and foremost consideration of the grid system is to keep operational stability at the forefront. Utilities have a proven track record of stability and conservative growth of operations, which kept costs at a minimum for ratepayer classes and provided IOU's with a protected rate of return for its investors. Over time, the CPUC and the three state IOU's have crafted rates and other actions with the intent to keep this trajectory intact. Nothing about the provision of energy is static, however, and the three determinants of change (PV diffusion, smart grid, and NEM) have created conditions that appear to upset the institution of electricity delivery and consumption in the California study area, and around other NEM hot spots in the U.S.

Content of the IAD framework, as applied by this essay to the study area of California, establishes five major considerations about NEM policy and residential PV diffusion in the state. First, a significant threat to the existing utility model exists. Second, the institution is fracturing into self-interest, unbounded by market constraints that would otherwise contain actors' actions in the past. Third, the universe of policy instruments appears to either be incongruent with the market trajectory of PV diffusion, or necessarily reapplied in haste to meet new conditions and considerations as they arise. Fourth, resolution in debates over benefit and cost valuations are collectively open-ended, meritorious, divisive, and woefully unsettled. Fifth, the provision of transparent data is minimal, which affects methodological uniformity, and requires alternative research structures like spatial inquiry to be introduced and relied upon as important considerations. Implications are analyzed below.

A significant threat to the existing utility model exists because competitive firms openly compete against IOU's. The firms win market share of electricity provision as ratepayers opt for services the utility is either unwilling or unable to provide. The firms are brazen and unapologetic in their attempts to take ratepayer consumption away from utilities. Though not a complete defection, the financial impact upon utilities could become enormous as increased numbers of ratepayers include PV as an investment, and as a hedge against monthly electricity cost and future rate hikes, which utilities contend must happen to recover costs. Relatedly, PV diffusion is not limited to the residential sector. Small and large commercial firms seek similar cost reduction advantage, further exacerbating the financial condition for utilities.

An ancillary effect of PV diffusion is the operational challenge of incorporating PV in its energy mix. As a distributed energy resource (DER), PV forces utilities to reset operations away from their historic provision of electricity to a new "orchestrator" model of operations (RMI, 2012). The change will not be inexpensive or easy, and sources of revenue for this function are not presently defined. In the scenario of orchestrator, a utility must commit a much greater share of investment in smart grid hardware and software. Smart grid hardware is technical engineering and is mostly understood to provide operational efficiency. Thus, smart grid hardware is well within a utility's domain of knowledge and understanding, plus a pool of vendors now exists in the market from the Smart Grid Investment Grant promotion under ARRA. Operational software, on the other hand, is complicated and problematic because each utility needs algorithms written specific to the distribution system. No 'one-size-fits-all' economies of scale exist.

Technology advancements that aid ratepayers look to be threats to utilities. For instance, advanced battery and inverter technologies make PV operationally more efficient, which further reduces the necessity of electricity purchase. Such technologies do, however, nudge homeowners toward self-reliance. In Hawaii, for example, ratepayers leave the utility's grid entirely. For this state and others, defecting from the grid, also referred to as "grid parity", is imminent consideration for certain utility customers, especially as new technologies enter the market (RMI, HOMER ENERGY, & COHNREZNICK THINK ENERGY, 2014).

Differences in scale aside, California and Hawaii share similar concerns over high residential PV diffusion, technology advancement, and high electric rate structures. As well, both states have generous NEM policy to attract homeowners toward residential PV. Ultimately, the most significant technological threat to utilities are solar panels, which continue to decline in price while, at the same time, become more efficient in their operation. Combined, technology threatens the utility model mostly because consumers may choose to invest in PV and related technologies regardless of policy incentives.

The utilities exhibit their discomfort with residential PV diffusion by seeking rate restructure and cost recovery in the regulatory sphere. This strategy may prevail in the short term. If other states' NEM revisions are indicative of change, California may include special fees and costs for PV owners exclusively. In the long term, this strategy only masks the ultimate threat to utilities: their monopoly structure that is captive to strict regulatory oversight. Simply put, they struggle to compete in an increasingly competitive market. To further the hurt, the legislative directives, executive goals, and regulatory control by California continually erodes utility domination. The relationships in the institution that built yesterday's monopoly structure now appear to be in flux as the rate of change escalates. In this regard, both the utility and its CPUC regulator face the challenge of evolution in both the market and in policy. Given this change, is it soon time to examine the utility/regulator model for inefficiency, and rebuild the institution to satisfy a larger need for distributed energy resource (DER) generation and a growing prosumer participation of production?

The segment of the electricity grid, commonly referred to as distribution infrastructure, is the geographic area granted by the state that, under a regulatory framework, grants protected status of operation to a specific utility. As previously noted, California has established three specific geographic areas to be served by the IOU's. The operational area, or domain, contains the physical infrastructure of the IOU constructed by IOU investment, much of which comes from its ratepayers. The institutional infrastructure, as the IAD in this essay describes, is the relational government and utility institution that intends to serve the residents within the domain. Even though each utility operates independently within its domain, it abides by global state directives, yet receives personal consideration by the CPUC concerning matters specific to its needs, such as the rates paid by its customers. The institutional and distribution infrastructure was taken for granted in the former analog grid, and it worked well accordingly for that time, but a burgeoning digital smart grid and cross cutting policy pierce the veil of the natural monopoly status, whereby the IOU and CPUC operate independently of one another, and for the benefit of citizens residing in the IOU's distribution domain. The institutional relationship between the CPUC and IOU's is troubling, however. As information in the IAD discloses, the CPUC and PG&E engaged in quid pro quo actions concerning the IOU's natural gas calamity and CPUC favored legislation. Regarding the SCE, a CPUC rules in favor of SCE operations over the concerns of citizens who have installed PV systems with battery backup capability, even though the installations were made according to the California Solar Initiative (CSI) guidelines that the CPUC itself helps administer. Perhaps a question for the CPUC to answer is why these actions do not breach its duty of care to state citizens.

An even more important question to ask is whether the electricity market is failing because of the monopoly centric institution that IOU's and the CPUC co-operate. In other words, is the electricity market becoming economically inefficient because of institutional monopoly protection? If we define market failure as an occurrence when a market is economically inefficient despite proper institutional support (the breach of duty question aside), then we should look for root causes for failure. The monopoly structure in the institution is under competitive duress. Citing NEM, SDG&E sought recourse of lost revenue by targeting residential PV owners specifically for access fees to the grid. The CPUC denied the request, but cost recovery is at the forefront of NEM revision considerations in 2015. In a natural monopoly model, rates are supposed to offset all its operational costs plus a fair rate of return (profit). A utility's average cost pricing attempts to capture all costs, which is the issue at bar between IOU's that want rates increased and PV groups that don't. Resolution in debates over benefit and cost valuations are collectively open-ended, meritorious, divisive, and woefully unsettled. While each side attempts to define benefit and cost, little if any agreement exists. IOU's emphasize grid services to residential PV, whereas the PV sector emphasizes their services to the grid. Meanwhile, continuation with the 'fair rate of return' metric when considering IOU request is increasingly difficult when competitive firms increasingly enter the market, encouraged by state policies like the California Solar Initiative that promote competition. One must wonder why the CPUC must continue to administer its regulatory authority under an assumption that IOU monopoly structure sound. By doing so, the definition of economic inefficiency is not only fulfilled by the evidence, it is confounded by cross cutting policy. This brings to fore an issue that the universe of policy instruments appears to either be incongruent with the market trajectory of PV diffusion, or necessarily reapplied to meet new conditions and considerations as they arise.

PURPA is a prime example of a policy being reapplied in order to meet new conditions. As the IAD shows, PURPA is a meta-constitutional rule-in use. Originally enacted 1978 during the second energy crisis of the decade, the Act was designed to steer utilities away from burning oil to generate electricity. The Act "was the legislative hammer that at least partially cracked the nut of utility monopoly" to include renewable energy from third parties at the utility's "avoided cost" (Carus, 2013). The Energy Policy Act of 2005 (EPA05) resurrected the importance of PURPA by including NEM for states to consider. Thus the avoided cost principle is now center to the debate over valuation of grid services relative to NEM. The term is especially important to PV and renewable energy groups that see IOU's avoided cost in terms of needing less power generation from traditional sources and increased efficiency in a distribution system needing less capital investment and shorter distance of consumption from prosumer production. The utility sector flips the term to "cost avoided", defined as a utility "not having to deliver the electricity displaced by the energy produced onsite" (Borlick & Wood, 2014). More than just a play of words, the "onsite" consideration is really where the debate seems to be moving. In lieu of NEM, the utility sector wants PV owners to pay at the rate of consumption negotiated by the IOU and CPUC, and then get paid for their prosumer production at the wholesale rate that an IOU pays, under contract, to large electricity producers that PURPA identifies as a Qualified Facility (QF). Conversely, PV adherents view the QF provision in PURPA as having compensatory attributes beyond raw electricity production (e.g. environmental considerations). There expanded view PURPA includes protection from discriminatory fees and charges and release from the onsite load restriction that current NEM policy requires (Keyes et al., 2013). In sum, utilities want PURPA for its reduced payout structure and, ultimately, to eliminate NEM. The PV sector wants PURPA for its undefined, but possibly applicable, provisions to continue diffusion. For PURPA, what was old is new again. Now embossed with an EPA05 logo, PURPA is the *futbol* in the scrum of rugby-like competition between opposing groups, each attempting to kick the opponents ball out of bounds or run with it to gain yardage. How good the CPUC and other state regulators are at being referee is a very open question indeed.

The final point of this analysis concerns the use of economic valuation and exploratory spatial tools to evaluate the outcomes of NEM policy activity described the IAD. Economic valuation is useful in the narrow realm of the six economic valuation considerations, which Ostrom suggests are important. The intent is to apply the valuations retroactively in an iterative process, which assumes collaborative learning will aid with institutional relationships growth (or repair) without the need for strong government intervention. As an economist by trade, we can assume that Ostrom considers economic valuation to be the most important metric, and that economic theory trumps other behavioral theories because people are predisposed to be rational, negotiating maximizers. This line of reasoning has a degree of utility for this essay and is considered in the IAD Outcomes results. Just as an IAD disentangles institutional relationships, Outcomes address the economic efficiency of NEM policy. Unfortunately, economic efficiency is a narrow light for examination. Perhaps market failure is an efficient economic consideration, but is fails to capture the impacts of social cost and benefits unless specifically directed. Even then, social consideration becomes economically defined. A more complete analysis includes many of the tools that sociology provides.

A different consideration is one that begins a process toward determining future actions. Being reflective has its merit, but we may want to know how to advise potential impacts NEM policy geographically, given the rate of residential PV diffusion in the study area. Spatial inquiry fills the need for alternative research methods cited in reports by providing geographic texture to actual residential PV location in the study area. It is quite fortunate, and rare, to have access to the level of data the CSI provides. The limitation of the data is that it is granular only to the level of city, county and ZIP code, so research effort using the weekly updated data is largely limited to a temporal count process from the selection of variables in the data set. In this essay, the known residential installation data were synthesized into location quotient (LQ) values.

This essay respects the critique of LQ methodology not having any suitable statistical tests to determine whether evidence of concentration exists in a study area (Guimarães, Figueiredo, & Woodward, 2009). For Guimarães et al, LQ's "purport to reveal distinct specializations" that include the positive agglomoration of clusters in areas that could be otherwise simply random occurances. As such, they are simply "dart board tests" having no statistical support, and without statistical significance, inference of location importance is simply based on false discovery. One method attempts to include statistical significance test to LQ data by developing methods to include confidence intervals that reflect variability and correlations in samples, and then test whether the data equal one (review Methods section for more detailed explanation of LQ measurement). Using geographically based point data, Djira et al conduct a simulation studies that test LQ results based on 'multiplicity adjustment' methods that "account for variability and correlations in the joint distribution of the statistics used to construct confidence intervals" (Djira, Schaarschmidt, & Fayissa, 2010), finding results that indicate statistical significance is attainable with the method under study. Closer to this essay is the test of LQ data against (in comparison with) the Gi* test of spatial autocorrelation (Carroll et al., 2007). Carroll et al find the Gi* test “resonate better than location quotient” and recommend the use of both for intial screening of areas.

This essay advances the Carroll recommendation one step further. Instead of comparing the results of two methods, this essay combines them. LQ serves the purpose of scale sensitivity while spatial tools provide statistical significance to patterns of location. In spatial outcomes, consideration of LQ data at a global scale indicates statistically significant clustering (Global Morans I) and high/low clustering (General G) of residential PV installations in the study area. Local scale areas is shown to cluster (Local Moran’s I) and have hotspots (Getis-Ord Gi*).

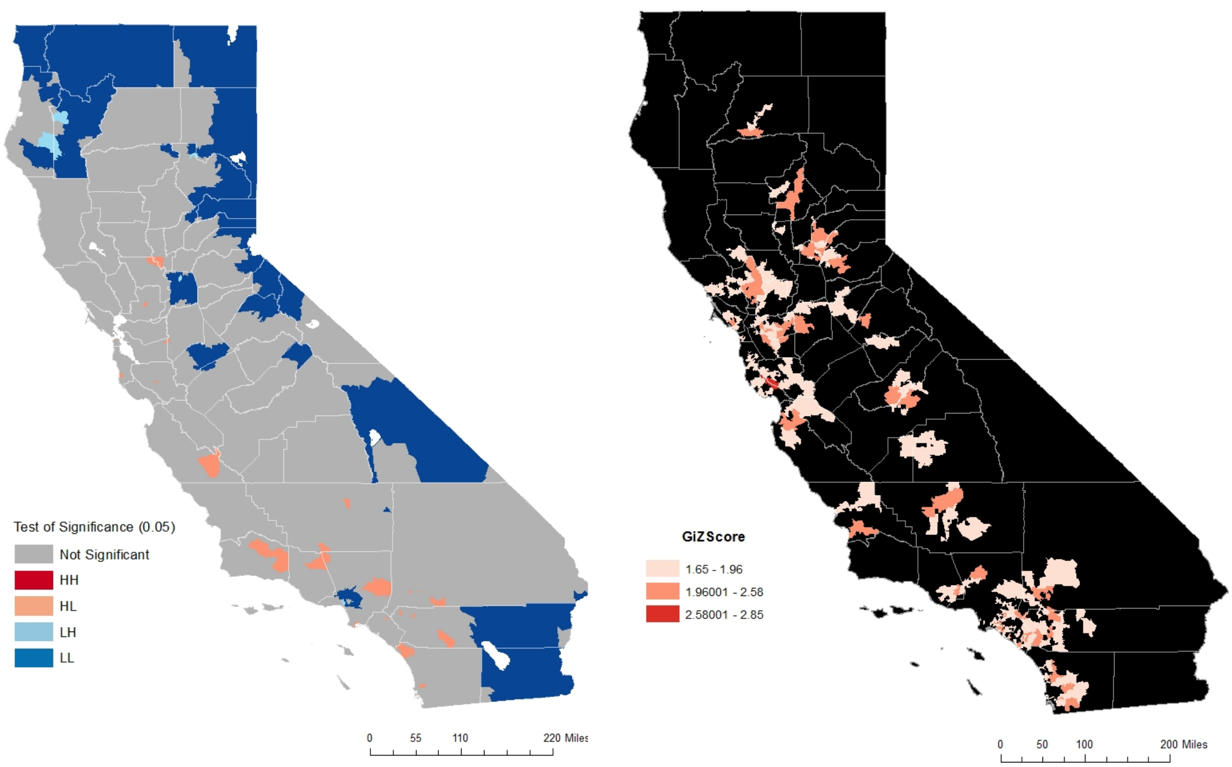


Figure 29. Comparison between Local Moran’s I and Getis-Ord Gi*
Source: D. McGie

When comparing each local measure using a final epoch map of each, we see distinct differences between the two. The Gi* indicates hotspot areas based on Z-score, confidence intervals of 90%, 95%, and 99%, in comparison to the Moran's Index 90% test of significance. Thus, we can loosely compare the Moran's Index to the 90% (1.65-1.96) Gi* hotspot areas. Interestingly, we find little visual congruence and a high degree of departure between the two results. In other words, cluster areas are not necessarily similar to hot spot areas. Intuitively, we might expect some degree of similarity, but the results do not follow intuition. Here is why: Local Moran's I analyzes only neighboring values, excluding the value of the feature being analyzed. Comparatively, the Getis-Ord Gi* includes each feature, including the one in question. With Getis-Ord Gi*, a feature with a very high value shows up as a hot spot when surrounded by low values because the high value of the feature brings the local mean up. When using Local Moran's I, the same feature is a High value surrounded by Low values (HL). Neither analyzes are wrong or inconsistent, just different.

Taken a step further, the Local Moran's I and Getis-Ord Gi* map outputs are combined into one map (Figure 30) to illustrate a locational example involving the state "Community Choice Aggregation" event. This event is notable because it is the product of a contentious political action, funded in large part by PG&E under Proposition 16 (2010) to limit the ability of local governments to compete with the utility (Baker, 2010). The Figure 30 map (next page) draws a relationship between clusters, hotspots, and specific counties. Both Sonoma and Marin counties now compete with PG&E to provide service, though the utility provides the electricity.

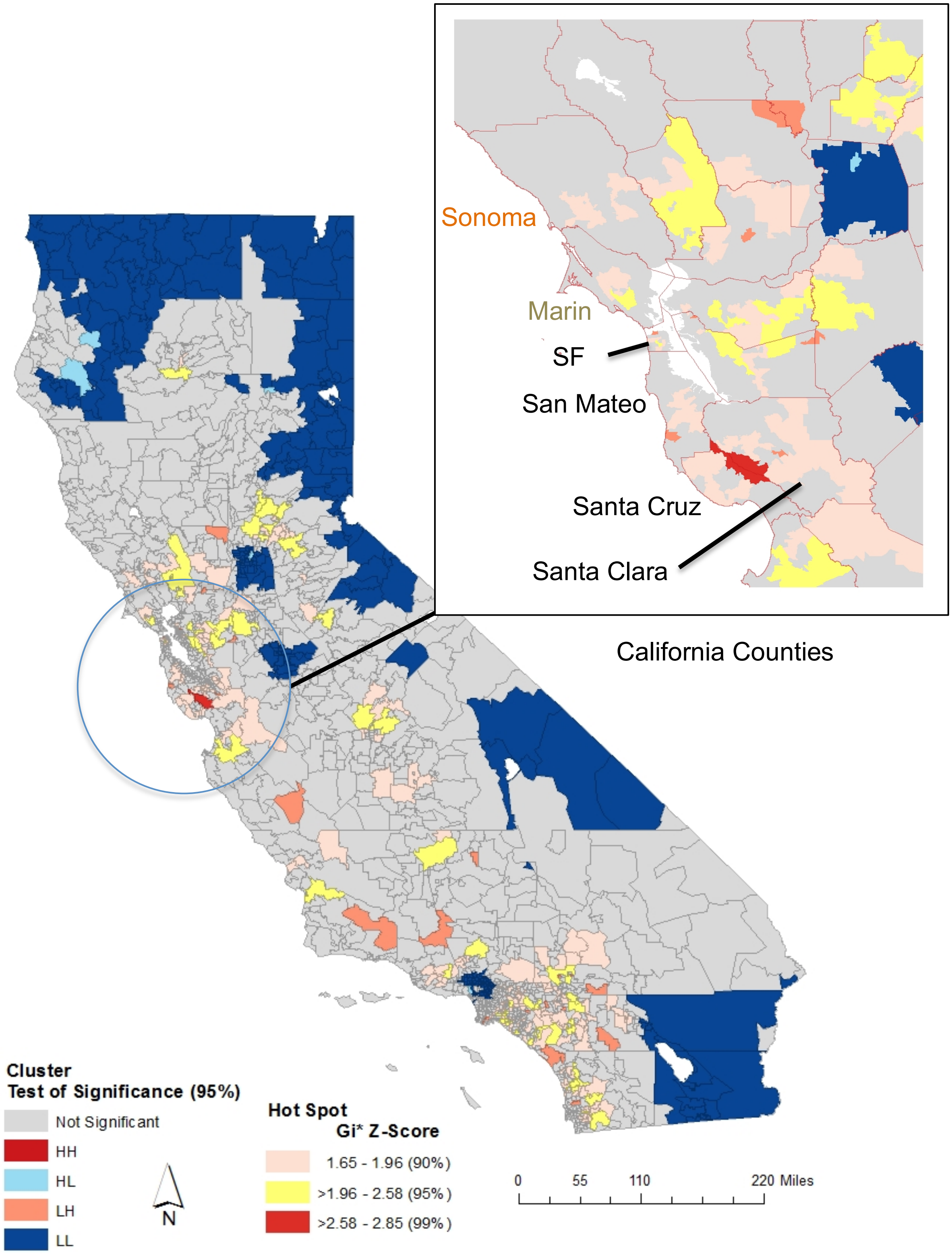


Figure 30. Final epoch, both Cluster and Hotspot together, with focus on "Community Choice Aggregation" county areas

Source: D. McGie

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

The predicate of this essay is that three accelerants set forth a trajectory that fundamentally changes the structure and operation of the electric grid, from analog to digital operations, and from central station to distributed generation production. The diffusion of solar PV technology is the determinant that gives rise to a prosumer class of ratepayers apart from all others. Prosumers utilize their PV systems for greater economic efficiency by reducing their cost of consumption, which is achieved by banking consumption credit when their excess production is sold back to their utility. Prosumers also enjoy a hedge against future rate hikes with this production, but also because the PV system itself is convertible to subsequent technologies, such as smart inverters and storage capability, which continues the prosumer advantage.

The trajectory of the smart grid began in the early 1990’s with utilities seeking operational efficiency, but the serendipity of the Great Recession accelerated smart grid advancements by funding, typically at the half cost, numerous technical, operational, and educational programs for selected utilities across the nation. As a whole, the utility sector benefits by having a range of advanced smart grid products from a growing pool of competitive vendors. The smart meter is the most utilized technology tool for the utilities, for it reduced labor cost and now provides access to ratepayer activity like no other technology. But the smart meter is a bidirectional device, so the advantage cuts both ways for prosumers who export their excess electricity for compensation, paid by their utility, and that compensation is guaranteed by net energy metering policy.

As the third accelerants, net energy metering requires a utility to compensate prosumers at the retail rate utilities charge its ratepayers. The utility sector contends the policy is unfair because it potentially burdens non-prosumer ratepayers with increased rates, due to free riding prosumers who avoid their fair share of distribution system costs. Residential PV owners and their agents contend that PV production provides a range of benefits to the utility's distribution grid, and that the policy should remain or be expanded. Disagreement over system benefit and cost valuation is the crux of acrimonious arguments about retention or revision of net energy metering, which has now become a proxy of institutional struggles over how the new digital grid is to operate.

This exploratory essay examines the impact residential PV and net energy metering has upon the study area of California. The tool of choice is the Institutional Analysis and Development framework that offers an important schematic structure to disentangle the myriad of actions and relationships that comprise the institution of electricity delivery in the state. This essay closely follows the schematic, paying specific attention to the major rules impacting Actors' actions in the Action Arena. The Patterns of Interaction is also given the weight attention because the content is especially important for analysis. In this section of discovery, we observe numerous examples of why the institution is suffering from the weight of change, if not failing outright. Relationships built upon the central station model appear ill equipped to continue into the new era of distributed generation that increasingly includes the bidirectional electricity delivery to and from the grid. The strain is most evident on the social and structural relationships between the state investor owned utilities, the regulatory body of the California Public Utilities Commission, and the general public.

Net energy metering policy presently binds the groups under an old paradigm of production, consumption, and oversight, but it could very well be the lynch pin that sets in motion an entirely new relational order in the state electricity system. The probability of this occurrence is based on the positive impacts of known variables, including the continued expotential growth of residential (and commercial) PV, the ancillary technologies of smart inverters and electricity storage, and specific state policies that continue to challenge utility operations in favor of advancing social and environmental goals. Residential PV is one of the few levers available to engage citizens to an effort to staunch negative climate change impacts, and net energy metering is the policy mechanism that grows that effort through mass participation rather than goals or directives.

The Outcomes is the final component of the framework. This essay retains the suggestion by Elinor Ostrom, originator of the framework, to use six economic metrics to reflect upon policy efficiency. The metrics are applied, but not relied upon, because benefit and cost valuation remains woefully unsettled, as disagreement between the two groups suggest. To complicate matters further, reliable data necessary to address the disagreement is presently difficult to attain, though it exists in abundance.

Though the present situation is confounding, spatial tools for inquiry may present a prescriptive path forward. As such, this essay presents the results of four spatial tools used to establish a ground floor for future research that may seek to address the impacts that expotential growth residential PV has in the state and beyond. The results of two global tools indicate that residential PV growth is clustered with high and low values. The two local tools, each with different but complimentary outcomes, indicate location and temporal change of areal clusters and hotspots occurring in the study area. The statistical significance of the results is based on rejection of the null, which states that the data occurs randomly. The results of spatial tools occur only after installation data is converted into location quotients, a novel yet effective procedure that dovetails nicely with GIS-based spatial tools of location. The implication here is twofold. First, spatial inquiry presents geographic evidence of change that is highly applicable to questions impact, and many spatial tools exist to carry forward this method of inquiry. Second, raw installation data publicly obtainable from the state California Solar Initiative database is ideal for conversion into location quotient data, which is then counted as temporal growth. State data continues to accumulate until the end of the program in 2017. As such, subsequent research using location quotient conversion could continue as well. The only caveat of the state data is that ZIP codes are the greatest degree of granularity.

Though this essay sets a new course with its data and inquiry of spatial of location, certain limitations of their use must be addressed. Primarily, the context is strictly exploratory, no specific questions were asked of the data beyond locational spatial clustering and hotspot. New models, such as Geographic Weighted Regression, could greatly advance the inquiry of locational impact, especially in specific utility distribution systems, which could then be compared regionally. Here, scale would be an important consideration. Other spatial tools, such as remote sensing, offer expanded examination capability as well. Finally, social data could offer highly relevant variables for econometric modeling that is mapped spatially.

Conceivably, spatial tools and creative application of data could supplant the reticence of utilities to supply their smart grid-derived data, and the state's privacy concerns over personal data disclosure.

Another limitation is that the framework, while complimentary, needs to be much more expansive in order to capture information this essay missed. One example is to address, in greater detail, Attributes of the Community. Another example is to include Collective Choice and Operational Rules-in Use levels for analysis. By doing so, greater connectivity among Actors and actions could be achieved. These concluding remarks make some inherent recommendations, but for clarity, the list below is directional for future research.

1. Legislate requirements upon public utility commissions, such as the CPUC, to require utilities to produce system and consumer data, scrubbed of identity as necessary, for use in benefit cost valuation.

2. Increase spatial test methodologies, especially in cluster and hot spots locations identified by this essay.

3. Examine specific utility distribution systems for residential and commercial PV load impact.

4. Expand the use of an IAD framework by taking advantage of its iterative property.

5. Disclose the internal relationships between CAISO and its members, especially three IOU's, for collusion in the name of grid stability.

6. Identify microgrids relative to cities and counties as they move toward defection from IOU service areas, specifically PG&E.

7. Theoretically consider new public administration processes that address institutional relationship change.

8. Include tools of sociology in the framework for analysis. Social, economic, and spatial analysis provides the trifecta of research discovery.

REFERENCES

ALTA. (2013). *Placing a Value on Distributed Solar Generation*.

Americans for Prosperity Foundation. (2014). *State Net-Metering Policies*.

Anderson, M., & Hunt, S. E. (2013). *Bright Consumers : Cost Inequity in Solar Power Generation* (Vol. 22201).

Barnes, J., & Varnado, L. (2010). *The Intersection of Net Metering & Retail Choice. An Overivew of Policy, Practice, and Issues*.

Beach, R. T., & Mcguire, P. G. (2013). *Evaluating the Benefits and Costs of Net Energy Metering in California*.

Best, J. (2006). The illusion of diffusion. *Society*, *43*(3), 50–55. doi:10.1007/BF02687596

Black and Veatch and Clean Power Research. (2014). *SAN DIEGO DISTRIBUTED SOLAR PHOTOVOLTAICS IMPACT STUDY*.

Borlick, R., & Wood, L. (2014). *NET ENERGY METERING: SUBSIDY ISSUES AND REGULATORY SOLUTIONS*.

Cai, D. W. H., Adlakha, S., Low, S. H., De Martini, P., & Mani Chandy, K. (2013). Impact of residential PV adoption on Retail Electricity Rates. *Energy Policy*, *62*, 830–843. doi:10.1016/j.enpol.2013.07.009

Carroll, M. C., Reid, N., & Smith, B. W. (2007). Location quotients versus spatial autocorrelation in identifying potential cluster regions. *The Annals of Regional Science*, *42*(2), 449–463. doi:10.1007/s00168-007-0163-1

Casacchia, C. (2010). Solar Power Shines; Extended Forcast? *Orange County Business Journal*, pp. 2–4.

Chang, A., Izant, M., Jamison, T., & Wong, D. (2013). *Exploring the Feasibility and Implementation of a California Energy Data Center* (pp. 1–26).

Clean Coalition. (2013). *Flattening the Duck*.

Crawley, a., Beynon, M., & Munday, M. (2012). Making Location Quotients More Relevant as a Policy Aid in Regional Spatial Analysis. *Urban Studies*, *50*(9), 1854–1869. doi:10.1177/0042098012466601

Cromley, R. G., & Hanink, D. M. (2012). Focal Location Quotients: Specification and Applications. *Geographical Analysis*, *44*(4), 398–410. doi:10.1111/j.1538-4632.2012.00852.x

Darghouth, N. R., Barbose, G., & Wiser, R. (2011). The impact of rate design and net metering on the bill savings from distributed PV for residential customers in California. *Energy Policy*, *39*(9), 5243–5253. doi:10.1016/j.enpol.2011.05.040

Djira, G. D., Schaarschmidt, F., & Fayissa, B. (2010). Inferences for Selected Location Quotients with Applications to Health Outcomes. *Geographical Analysis*, *42*(3), 288–300. doi:10.1111/j.1538-4632.2010.00794.x

E3. (2010). *Introduction to the Net Energy Metering Cost Effectiveness Evaluation*.

E3. (2011). *California Solar Initiative Cost-Effectiveness Evaluation*.

Faiers, A., Neame, C., & Cook, M. (2007). The adoption of domestic solar-power systems: Do consumers assess product attributes in a stepwise process? *Energy Policy*, *35*(6), 3418–3423. doi:10.1016/j.enpol.2006.10.029

Gale, B. E. (2014). Energy in the Southwest. In B. Gale (Ed.), *Law Seminars International Energy in the S.W.* MidAmerican Energy Holdings Company.

Gallagher, P. (2013). Solar ieasing firm expands to Conn. *Fairfield County Business Journal*.

Garrett, V., & Koontz, T. M. (2008). Breaking the cycle: Producer and consumer perspectives on the non-adoption of passive solar housing in the US. *Energy Policy*, *36*(4), 1551–1566. doi:10.1016/j.enpol.2008.01.002

Glick, D., Lehrman, M., & Smith, O. (2014). *RATE DESIGN FOR THE DISTRIBUTION EDGE Authors*.

Graves, F., Hanser, P., & Basheda, G. (2006). *PURPA : Making the Sequel Better than the Original*.

Guimarães, P., Figueiredo, O., & Woodward, D. (2009). Dartboard tests for the location quotient. *Regional Science and Urban Economics*, *39*(3), 360–364. doi:10.1016/j.regsciurbeco.2008.12.003

Hansen, L., Lacy, V., & Glick, D. (2013). *A REVIEW OF SOLAR PV BENEFIT & COST STUDIES*.

Hernandez, M. (2013). *Solar Power to the People : The Rise of Rooftop Solar Among the Middle Class*.

Hobbs, A., & Pierpont, B. (2013). *Improving Solar Policy : Lessons from the solar leasing boom in California Climate Policy Initiative*.

Holt, M., & Glover, C. (2006). *CRS Report for Congress Energy Policy Act of 2005 : Summary and Analysis*.

IEE. (2013). *UTILITY-SCALE SMART METER DEPLOYMENTS: A Foundation for Expanded Grid Developments*.

IER. (n.d.). *California Energy Facts*.

IREC. (2013). *A REGULATOR ' S GUIDEBOOK: Calculating the Benefits and Costs of Distributed Solar Generation*.

Islam, T. (2014). Household level innovation diffusion model of photo-voltaic (PV) solar cells from stated preference data. *Energy Policy*, *65*, 340–350. doi:10.1016/j.enpol.2013.10.004

Jacobsson, S., & Johnson, A. (2000). The diffusion of renewable energy technology : an analytical framework and key issues for research. *Energy Policy*, *28*.

Kavalec, C., Fugate, N., Gorin, T., Alcorn, B., Ciminelli, M., Gautam, A., … Sullivan, K. (2012). *California Energy Demand Forecast 2012-2022 Volume 1: Statewide Electricity Demand and Methods, End-User Natural Gas Demand, and Energy Efficiency*.

Kavalec, C., & Gorin, T. (2009). *CALIFORNIA ENERGY DEMAND 2010-2020*.

Kenneth Rose, & Karl, M. (2005). *Reference Manual and Procedures for Implementation Of the " PURPA Standards " in the Energy Policy Act of 2005*.

Keyes, Fox, & & Weidman. (2013). *Unlocking DG Value: A PURPA-based approach to promoting DG growth*.

Keyes, J. B., & Rabago, K. R. (2013). *A REGULATOR ' S GUIDEBOOK : Calculating the Benefits and Costs of Distributed Solar Generation*.

Kind, P. (2013). *Disruptive Challenges : Financial Implications and Strategic Responses to a Changing Retail Electric Business*.

Koski, C., & Lee, T. (2014). Policy by Doing: Formulation and Adoption of Policy through Government Leadership. *Policy Studies Journal*, *42*(1), 30–54. doi:10.1111/psj.12041

Langley, D. J., Bijmolt, T. H. a., Ortt, J. R., & Pals, N. (2012). Determinants of Social Contagion during New Product Adoption. *Journal of Product Innovation Management*, *29*(4), 623–638. doi:10.1111/j.1540-5885.2012.00929.x

Lazar, J., Migden-ostrander, J., James, C., Farnsworth, D., Sedano, R., Allen, R., … Wigg, B. (2014). *Teaching the " Duck " to Fly Author*.

Litos Strategic Communication. (n.d.). *THE SMART GRID : An Introduction*.

Mcginnis, M. D. (2011). An Introduction to IAD and the Language of the Ostrom Workshop: A Simple Guide to a Complex Framework for the Analysis of Institutions and Their Development. *Policy Studies Journal*, *39*(1), 169–183.

Mills, A., & Wiser, R. (2012). *An Evaluation of Solar Valuation Methods Used in Utility Planning and Procurement Processes*.

Noll, D., Dawes, C., & Rai, V. (2014). Solar Community Organizations and active peer effects in the adoption of residential PV. *Energy Policy*, *67*, 330–343. doi:10.1016/j.enpol.2013.12.050

Ostrom, E. (2005). *Understanding Institutional Diversity*. Princeton University Press.

Ostrom, E. (2009). Beyond Markets and States : Polycentric Governance of Complex Economic Systems Brief Overview of the Journey.

PNUCC. (2010). *Exploring the Impacts of California ' s Renewable Portfolio Standard*.

Polski, M. M., & Ostrom, E. (1999). An Institutional Framework for Policy Analysis and Design.

Price, S., Horii, B., King, M., DeBenedictis, A., Kahn_Lang, J., Pickerell, K., … Bowers, J. (2013). *California Net Energy Metering Ratepayer Impacts Evaluation*.

Rao, K. U., & Kishore, V. V. N. (2010). A review of technology diffusion models with special reference to renewable energy technologies. *Renewable and Sustainable Energy Reviews*, *14*(3), 1070–1078. doi:10.1016/j.rser.2009.11.007

Ritzer, G., Dean, P., & Jurgenson, N. (2012). The Coming of Age of the Prosumer. *American Behavioral Scientist*, *56*(4), 379–398. doi:10.1177/0002764211429368

RMI. (2012). *Net energy metering, zero net energy and the distributed energy resource future*.

RMI, HOMER ENERGY, & COHNREZNICK THINK ENERGY. (2014). *THE ECONOMICS OF GRID DEFECTION: When AND WHERE DISTRIBUTED SOLAR GENERATION PLUS STORAGE COMPETES WITH TRADITIONAL UTILITY SERVICE*.

Rose, K., & Murphy, M. (2007). *Reference Manual and Procedures for Implementation o f the " PURPA Standards " in the Energy Independence and Security Act of 2007*.

Schleicher-Tappeser, R. (2012). How renewables will change electricity markets in the next five years. *Energy Policy*, *48*, 64–75. doi:10.1016/j.enpol.2012.04.042

Baker, D. (2010). SFGate. PG&E's Prop. 16 lost big in its service area. Online at http://www.sfgate.com/business/article/PG-E-s-Prop-16-lost-big-in-its-service-area-3185513.php

SF Environment. (2013). *Virtual Net Energy Metering at Multitenant Buildings*.

State of Oregon. (2012). *10-Year Energy Action Plan*.

Szablya, B. L., & Beck, R. W. (2010). Distributed Generation— When Customers are Generators. *Electric Light & Power*.

Tsoutsos, T. D., & Stamboulis, Y. a. (2005). The sustainable diffusion of renewable energy technologies as an example of an innovation-focused policy. *Technovation*, *25*(7), 753–761. doi:10.1016/j.technovation.2003.12.003

U.S. DOE. (2012). *2010 Smart Grid System Report*.

U.S. DOE. (2013). *American Recovery and Reinvestment Act of 2009 Smart Grid Investment Grant Program Progress Report II* (Vol. 18).

Wood, L., & Borlick, R. (2013). *VALUE OF THE GRID TO DG CUSTOMERS*.

Zhang, Y., Song, J., & Hamori, S. (2011). Impact of subsidy policies on diffusion of photovoltaic power generation. *Energy Policy*, *39*(4), 1958–1964. doi:10.1016/j.enpol.2011.01.021