Regulation, Innovation, and Experimentation: The Case of Residential Rooftop Solar

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I. Introduction

Over the past decade, the residential rooftop solar[3] market in the United States has grown exponentially, with installed capacity accelerating over the past three years. In 2014, a solar system was installed every 2.5 minutes, with the majority of the growth in residential sector with a total of 200,000 systems, up from 50,000 in 2011 (Lacey 2015). Not surprisingly, this growth has not occurred uniformly across the U.S., one reason being different state-level policies.

Reducing barriers to the research, development, and deployment of technologies such as rooftop solar is a generally agreed-upon economic and environmental policy objective. Status-quo regulation of electric utilities, entrenched by a history of inertia and technology lock-in, excludes market entrants who threaten the vertically integrated utility business model, and thus this regulatory and business environment acts as a considerable barrier to entry and innovation (Kiesling 2014). In this paper, we reexamine the growth of the U.S. residential solar market by surveying the intersection of various growth drivers and offering a framework to account for how, and to what extent, these factors fortify or reduce barriers to entry for solar firms and installers. We argue that the growth in the U.S. residen-

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3 The terms "rooftop solar" "photovoltaic" and "PV" will be used interchangeably throughout this text.

tial solar capacity is a consequence of intersecting layers of institutional experimentation, some of which facilitates market experimentation by both electricity suppliers and consumers.

Recent innovations in smart grid and distributed energy technologies, innovations in solar industry financial and business models, and utility concerns about their financial viability in the face of such innovations, motivate our analysis of the regulatory institutions and their features that may be conducive to lower barriers to innovation in electricity. Here we take residential rooftop solar as a case study that should, with subsequent research and analysis, continue to shed light on the burdens and opportunities facing technologists, entrepreneurs, policymakers, and regulators attempting to orchestrate more efficient, dynamic, resilient, and clean electricity markets.

Broadly, we identify four sets of experimentation factors that drive solar market growth, (though we acknowledge their applicability beyond the scope of this particular subsector). These factors include technological innovation, financial and business model innovation, regulatory change, and "exogenous factors." Table 1 summarizes these factors with examples from the solar sector.

Table 1: Residential Solar Market Growth Drivers

Factor category	**Example**
Technological innovation	Falling costs (in hardware manufacturing: PV modules, inverters, etc.; in soft costs: financing, installation, customer acquisition; a consequence of economies of scale, firm learning, and global competition), enabling technologies (digital smart grid technologies, energy storage)
Financial and business model innovation	Solar ownership models: power purchase agreements (PPAs),[4] leases,[5] and loans[6]
Policy/institutional framework	Solar policies: net metering,[7] interconnection agreements,[8] renewable portfolio standards (RPS),[9] tax credits, feed-in-tariffs[10]; regulatory context: market design (vertically-integrated electric utility, restructured market w/o retail competition, restructured market with retail competition. Each influences the legal and regulatory status of solar entrepreneurs and can act as an entry barrier.
Exogenous factors	Environmental policy, climate change, "energy independence," long-term energy supply and economic activity

4 A Power Purchase Agreement (PPA) is a financial agreement between a customer who wants an on-site solar electricity installation and a third-party developer who owns, operates, and maintains the solar system. The host customer-generator agrees to site the system on its roof and purchases the system's output for a period of 20 or so years. The customer procures stable, and sometimes lower cost, electricity from their solar system, while the third-party developer benefits from tax credits as well as income from the customer-generator's purchase of power.

5 With a solar lease, a homeowner leases solar panels at a flat monthly fee without upfront costs over a period of 15-25 years. At the end of the contract, the lessee may renew the contract, purchase the system, or have the panels removed.

6 Solar loans are a relatively new innovation in the solar financing. The terms of solar loans tend to mimic those of a power purchase agreement, as homeowners pay back the loan with per kWh generated payments. Solar loans allow customer-generators to claim the 30% federal tax credit, and, unlike a PPA, ultimately own their system.

7 Net metering: solar panels, for instance, are connected to a public-utility power grid and surplus power is transferred onto the grid, allowing customers to offset the cost of power drawn from the utility. The solar owner is generally compensated at the retail rate of electricity for surplus power.

8 The process of physically linking solar panels to the power grid.

9 Usually a state-level policy, a renewable portfolio standard (RPS)mandates that a certain percentage of electricity produced comes from renewable generation.

10 Solar power is sold to the grid at a pre-defined per-kWh rate of compensation, often exceeding the retail cost of electricity

In Section II, we describe and analyze the technological and financial innovations and the institutional framework driving residential solar market growth. In addition to the 30% federal tax credit for solar, many states simultaneously employ multiple renewables policies. California is the primary case study in our analysis, as in the past 15 years the State has exemplified the use of a renewable portfolio standard, net metering, feed-in tariffs, and some direct subsidy programs such as grants and rebates. Either individually or in combination, none of these policies is designed to or able to target some theoretical, optimal size of the residential solar market; they also do, to some extent, fall prey to the criticism that they are distortionary policies that subsidize particular technologies that may or may not be long-term technology "winners". Yet we can compare across these various policies and inquire into which are, by a relative measure, more likely to facilitate market experimentation by reducing barriers to innovation at the margin (and, conversely, erode the inertia and technology lock-in of incumbent utilities). Two policies that have shaped California's institutional context are net metering and the renewable portfolio standard (RPS). Compared to direct, targeted technology subsidies or mandates, net metering and the RPS are relatively more flexible and technology-agnostic, and allow for more market experimentation by both producers and consumers in the burgeoning residential distributed generation market.

In the 1990s, the generating capacity of solar remained negligible within the broader U.S. electricity mix. However, other technology and policy changes in the electricity industry were laying the groundwork for future solar growth and, indeed, set the course for many of the challenges and opportunities for distributed energy resources in U.S. retail electricity markets. Here we analyze the intersection of a number of structural, regulatory, technological, and financial changes to the electricity industry that influences the viability of distributed energy resources (DER), in particular residential rooftop photovoltaics. Our primary interest is in analyzing electricity regulation, state policies, solar business models, and solar financing as various *strata of experimentation*, and how these various strata or layers intersect to influence the success or failure of distributed energy resources, in particular residential rooftop solar in California. We then present a framework for analyzing how these factors relate to either reduce or strengthen barriers to entry into the renewable electricity industry to firms or potential solar customers. Policies that enable market experimentation are most conducive to the innovation process that can create electricity that is simultaneously economic and cleaner.

Such policies reduce barriers to market entry, enable retail competition, and are by definition technology-agnostic.

II. The U.S. Residential Rooftop Solar Market

A. The Current State of Residential Rooftop Solar PV in the United States: The California Case

The residential solar market has grown substantially over the past decade, through a combination of technology, market, and policy drivers. Three-quarters of U.S. utility, commercial, and residential-scale PV systems went online between 2011 and the first half of 2013 (GTM Research 2013). The installed cost of distributed photovoltaics fell 44% between 2009 and 2014, with distributed solar installations comprising 31% of all electric power installations completed in 2013; in that same year, overall residential solar PV capacity increased 68% across the nation. California led this growth with a 161% increase in 2013. However, excluding the growth in California, in the rest of the U.S., residential installations were in fact 18% lower in 2013 than in 2012 (Sherwood 2014).

Historically, strong state policies supporting solar PV in California have inspired investor confidence and provided financial support for the industry. As a result of the Public Utilities Regulatory Policies Act of 1978 (PURPA), the rise of generators using renewable energy sources showed that there were reliable sources of power other than large-scale centralized generation owned by a vertically-integrated firm. PURPA catalyzed early development of the solar industry in California more than in other states, and paved the way to make any future energy generation venture worthwhile, insofar as it could successfully bid into California's wholesale electricity market. The renewables policies currently in use in California include a renewable portfolio standard (RPS), California Solar Initiative subsidies, net metering, and feed-in tariffs. The organizational structure of regulated distribution utilities in California as monopolies without competition directly truncates the extent to which experimentation may occur on the network: while wholesale electricity generation is open to any supplier, parallel retail market processes are not available.

In 2002, California enacted its Renewable Portfolio Standard (RPS) targeting a 20% renewables mix by 2010. Legislation to reach 33% renewables failed in

2009, and in response later that year, Executive Order S-21-09 required the California Air Resources Board to develop a renewables program to reach a 33% RPS before 2020. In 2011, new legislation codified the 33% requirement with interim targets in 2013 and 2016 (DSIRE 2014). In the event of non-attainment, the California Air Resources Board is authorized to penalize non-compliant utilities.

In addition to the strong RPS mandate, in 2014 the California Solar Initiative (CSI) closed two years ahead of schedule. The California legislature created the program in 2006 with the aim of putting solar on 1 million roofs in California – 1,940 megawatts of residential and commercial projects by 2016 through $2.3 billion in taxpayer-funded cash-back incentives (DSIRE 2014). Even though the allocated funds were exhausted, total installs have exceeded the capacity targets by "hundreds of megawatts … 72 percent of all residential solar projects in the state were completed without any state incentives in the second quarter of 2014. California installers will deploy more than 1 gigawatt of residential and commercial projects this year, the majority completed without the help of the CSI incentives" (Lacey 2014). The program differs from other rebate programs, importantly, by reducing subsidies volumetrically as more solar capacity comes online, benefitting first movers while transitioning the industry slowly to a lower-subsidy marketplace The quiet success of the CSI demonstrates a way that states can ramp down subsidies as commercial activity grows around technology.

California also has one of the oldest and strongest net metering policies in the United States. A net metering policy requires the distribution utility to buy or credit owners of distributed generation for supplying their excess energy to other users on the distribution network, and stipulates the administrative price at which purchases will occur. First enacted in 1996, then reauthorized in 2008 and 2013, the current policy limits individual system capacities to 1 MW, though local governments and universities may apply to net meter systems up to 5 MW. In 2006, legislation increased the cap on net metering in a utility's service territory from 0.5% to 2.5%, and again in 2010 from 2.5% to 5%, of the utility's "aggregate customer peak demand." Calculations of "aggregate customer peak demand" differed among the three California utilities (SDG&E, SCE, PG&E[11]), and so in 2014 AB

11 San Diego Gas and Electric (SDG&E), Southern California Edison (SCE) and Pacific Gas and Electric (PGE). San Diego Gas and Electric (SDG&E), Southern California Edison (SCE) and Pacific Gas and Electric (PGE). PGE's service territory covers the majority of the northern part of the state, except for the Sacramento area (serviced by the Sacramento Municipal Utility District). SCE's territory extends throughout Southern California, except for, of course, San Diego, and some smaller electric co-ops.

327 codified a uniform methodology to calculate this number.[12]

Utilities must offer net metering to customers either until it reaches its cap, or until July 1, 2017, at which point utilities must offer a standard tariff for new customers selling power to the grid. In other words, once net metering is exhausted, the California Public Utilities Commission (CPUC)–the state's utility regulatory body–will require utilities to develop a standard contract for new and existing customers to sell power to the grid.

Net excess generation is carried forward to the customer's next bill. At the end of each 12-month period the utility is granted remaining credits. Importantly, the net metering legislation in California explicitly prohibits utilities from charging customer-generators any fees that other customer classes would not bear (such as demand, standby, minimum, or interconnection charges). However, this language suggests that charges such as a minimum bill are not prohibited if such charges were to be levied against all customers classes (not just those who net meter).

CPUC has also approved time-of-use rates with net metering ("co-metering"). However, each utility can decide whether or not to offer this pricing.

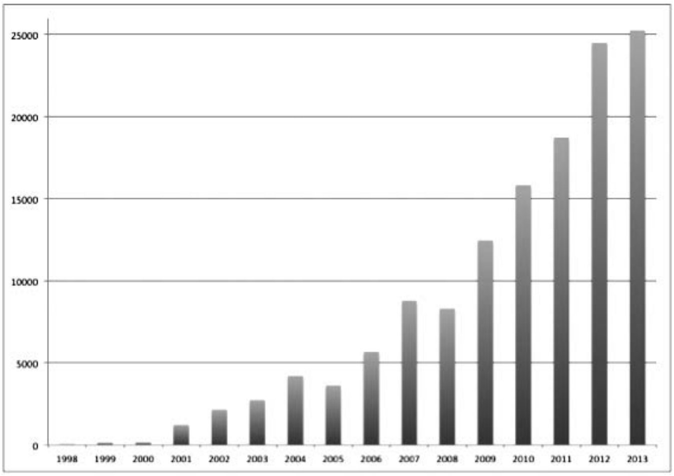
In July 2007, CPUC required PG&E and SCE to develop and offer feed-in-tariffs[13] for eligible renewables technologies. Over time, these tariffs were expanded to all investor-owned utilities, and multiple amendments increased the individual and aggregate capacities of the tariff program. All investor-owned utilities and public utilities with more than 75,000 customers were required to create a standardized feed-in tariff available to their customers as a mechanism for RPS compliance. The utilities offer customer-generators a per-MWh contract for 10-, 15- or 20- years for systems up to 3 MW. The tariff prices were based on previous auctions for renewables from November 2011, and then adjusted based on acceptance or decline of offers from utilities by customer-generators. These prices adjust every two months until 50% of the total targeted installed capacity is met, meaning there is a feedback loop in place to ensure that feed-in-tariffs are properly priced to meet renewable capacity goals.

Figures 1 and 2 indicate the growth and the cost reductions seen in the residential solar industry in California.

12 If not otherwise noted, data on California's renewables incentives are from the DSIRE database.

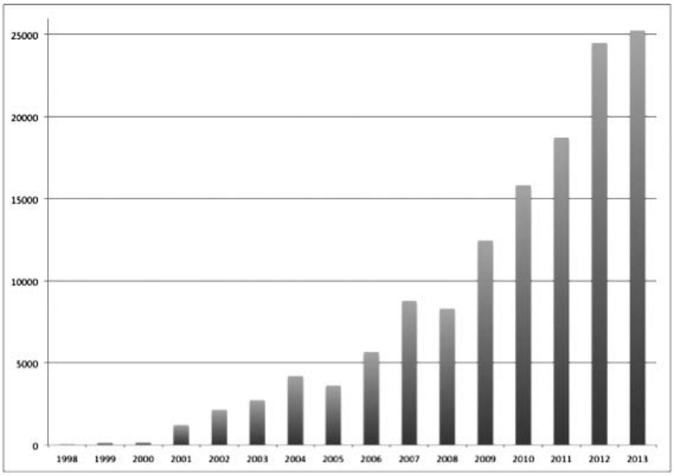
13 Feed-in-tariffs are a performance-based incentive for renewable energy production, where a customer-generator is compensated at a pre-determined rate for electricity sale. These contracts are long-term, allowing prospective customer-generators to accurately predict cost savings or revenues over the lifetime of renewable systems.

Figure 1: Number of new ≤ 10kW solar installations, annual, California



Source: Lawrence Berkeley National Laboratory (2014)

Figure 2: Median installed cost for <10kW projects ($/W), annual, California



Source: Lawrence Berkeley National Laboratory (2014)

California led the nation in installed PV capacity in 2013 with 2,478 MW[14], followed by Arizona, North Carolina, Massachusetts, New Jersey, Hawaii, Geor-

14 MWac, assuming 5% losses from DC to AC inversion.

gia, Texas, New York, and Maryland accounting for a total of 1,470 MW, or 33 percent of installed capacity. All other states combined for 437 MW in 2013, or 10% of installed capacity (Sherwood 2014). The overall residential solar PV market grew 38% between 2013 and 2014, with the top 10 installers growing 75% compared with 12% growth among all other installers. Not surprisingly, of the top ten residential solar PV installers in the United States (which combined account for more than 50% of the market), four of the top five have headquarters in California (SolarCity, Sungevity, Verengo, and Solar Universe). SolarCity led installations with 29% of the market share, followed by Utah-based Vivint Solar at 9% (Munsell 2014). Both companies are publicly traded as of 2012 and 2014 respectively (Wang 2014, Nasdaq n.d.).

California's regulation of the residential retail solar market maintains the distribution utility's monopoly over the provision of electricity service to residential customers. By removing a customer's opportunity to choose among retail service providers, such regulation undercuts the ability of consumers to experiment and learn about value propositions that might be welfare-enhancing other than the ones that the monopolist offers and the regulators approve. The lack of retail choice constitutes a legal entry barrier against competing retail service providers. Likewise, such regulation also stifles the development of differentiated products and services that consumers may find valuable. However, the CPUC does allow distribution utilities to offer a differentiated rate tariff, with time-differentiated rates and specific contracts for demand response and direct load control programs.

The retail regulatory feature that allows for consumer experimentation even in this monopoly context is the inability of the regulated monopolist to block "behind the meter" installations of consumers. The footprint of the regulated distribution utility stops at the meter, leaving the consumer free to choose what energy investments to make in the home. Combined with the solar-specific policies described above, this boundary of regulation created the opportunity for the residential solar market in California to develop out of its historical roots.

B. Technological Innovation, Financial Experimentation, and Solar Soft Costs

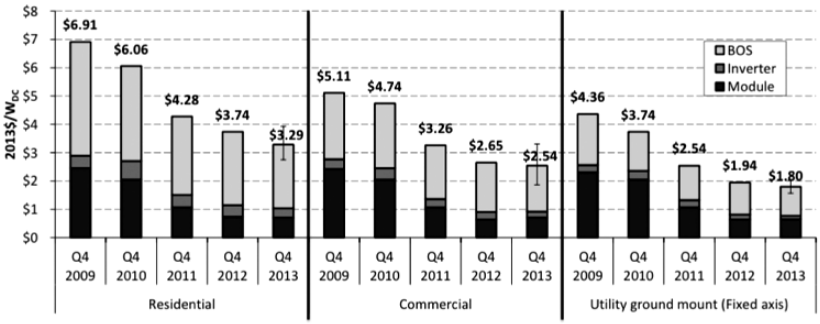
Whether they internalize an environmental cost or over-stimulate supply or demand, government policies do drive cost reductions for technologies, spur demand, increase supply, and decrease the cost of capital for entrepreneurs commercializing and marketing these technologies. This feedback loop between the public and private sectors, combined with research-driven energy efficiency improvements in PV technology, has contributed to cost reductions in technologies as a consequence of economies of scale and other efficiencies and innovations. The U.S. Department of Energy estimates that installed prices of solar decreased 6-7% per year from 1998-2012 and 12%-15% from 2012-2013. (Friedman, et al. 2013). The modeled system prices for installations in early 2014 was $3.29/W for residential (Feldman , et al. 2014).[15]

Analyst expectations suggest that by 2015 some residential systems will be installed at a price below $2/W, with the global module price index remaining stable, and major cost reductions coming from reduction in soft costs such as customer acquisition[16], as well as possibly lower cost of capital and streamlined regulatory procedures. Where precisely these “soft cost” savings will be is unclear, though undoubtedly with increased competition among residential solar providers, companies will be forced to find cost savings within their own business, rather than capitalizing on first-mover customers or regional familiarity. To illustrate this point, Figure 3 presents estimates of PV system prices for residential, commercial, and utility-scale installations. Note the sharp decline in module prices between 2009-2011, followed by flattening in 2012 and 2013. The yellow “balance of system” (BOS) or “soft costs” box has remained relatively static between 2009 and 2013, when compared with cost savings in modules and inverters. As the inverter market grows more mature and commoditized, costs will decrease as well. Firms are recognizing the value of reducing cost of customer acquisition, which is at present approximately $0.49/W; between 2014 and 2017, streamlining customer acquisition is likely to reduce those costs by roughly $.14/W (GTM Research 2013).

15 Module prices refer to the cost of photovoltaic panels alone, measured in capacity (i.e. the maximum amount of energy the module could produce), and traded as a commodity on global markets. Conversely, there are many ways to measure all-in system costs, which generally include the cost of modules, permitting, installation, labor, inverters, and other costs associated with setting up a solar PV system. Some analysis of system costs is reported by the solar industry itself, or costs can be estimated using a “bottom-up” approach, where various assumptions and costs are added to estimate a theoretical system cost.

16 Cost of customer acquisition refers to the expenses incurred by businesses to convince a customer to purchase a product, such as research and marketing.

Figure 3: *Bottom-up Modeled System Price of PV Systems by Sector, Q4 '09 - Q4 '13*



Source: (Feldman , et al. 2014)

C. Financial Innovation: Third Party Financing

The growth of rooftop residential solar markets is a consequence not only of flattening module prices and reduced soft costs, but also of financial innovation. Traditional ownership of solar PV entails significant financial and transaction expenses for a homeowner, including upfront cost of installation, equipment, operations, and maintenance. Third-party ownership allows developers to cover most of these expenses, and then be paid back over time through the sale of electricity directly to the customer-generator. These innovations have allowed customers to lock-in low-cost electricity with 20+ year contacts, which often include operations and maintenance. Customers no longer face the large upfront capital expenses for solar installations, and instead outsource much of the installation and operations process to third-party installers. Third-party ownership models such as leases and power purchase agreements (PPAs) dominated all subsectors of new solar capacity in 2013 (Sherwood 2014). The Solar Energy Industries Association finds that:

- More than 90 percent of New Jersey's residential solar market has consisted of third-party owned systems since Q2 2013.
- In Q1 2014, more than 50 percent of New York's distributed generation systems were third-party owned, and in California, Arizona and Colorado, 69 to 81 percent of installed distributed generation systems were third-party owned (SEIA n.d.).

According to a study of the Southern California solar market, third-party ownership is correlated with adoption by younger, less affluent, less educated populations than those customers purchasing systems outright (Drury, et al. 2011), implying that third-party ownership increases the total demand for photovoltaic systems rather than displacing demand from customers who would have otherwise purchased systems. The main causal mechanism is the extent to which third-party ownership decreases barriers to adoption, including upfront costs and technology risk and complexity. Around 20 states allow third party ownership.

These financial innovations in the solar sector present three types of challenges to the regulatory status quo in most of the United States (Kollins, Speer and Cory 2010). First, what is the definition of an electric utility? The states of Colorado, New Mexico, and California have each explicitly exempted third-party ownership structures from PUC regulation by declaring they are neither utilities nor electrical corporations. Second, is power generation equipment as such an electric utility? Nevada and Oregon explicitly exclude third-party owned renewable energy systems from utility regulation. Finally, what is the definition of an electric service provider? In regulated or hybrid-restructured states, utilities are often defined as organizations offering "electric services", so firms that do not provide electric services are not utilities. In Oregon, for example third-party owned systems are *not* considered competitive suppliers insofar as these systems do *not* provide ancillary services to the grid. (Kollins, Speer and Cory 2010)

In response to these and other regulatory issues, Kollins et. al. argue for a number of alternatives to third-party PPAs including solar leases. Leases allow customer-generators to lease solar equipment from companies and to then receive the power generated from that equipment. This model is a popular option in Florida, for example, where third-party power-purchase agreements (PPAs) are forbidden. Other institutional barriers remain as well, including Florida's lack of net metering and lack of solar contractors, and training, certification, inspection, permitting, and building code rules (Soskin and Squires 2013). Yet despite the lack of incentives and regulatory structure, Florida ranks among the lowest installed-cost of residential solar systems. These inconsistencies deserve further investigation. As Will Craven of SolarCity puts it, Florida remains the "sleeping giant" of the solar industry (Smith 2014). At a national level, solar leases are building momentum. As of Q1 2013, third-party financing for residential installations accounted for 50% of new capacity in California, Arizona, Colorado and Massachusetts, with the model gaining greater market share in other states such as Connecticut, Delaware, Maryland, New Jersey, New York, Oregon, Texas, Vermont, and Washington (Kann 2013).

A third financing innovation has been solar loans. SolarCity's new solar loans program is expected to serve approximately 50% of their clients in 2015 (Wesoff 2014). Solar loans resemble PPAs but allow homeowners to own the solar panels and take advantage of the 30% federal production tax credit. In theory, solar ownership should cost less than PPAs or leases by opening solar project financing to a larger pool of institutional investors such as banks, who offer homeowners better loan terms than a tax equity investor. In addition, new research out of Lawrence Berkeley National Lab concludes that owning solar systems increases the resale value of homes by $4 per watt on average (Hoen, et al. 2015). Offering loans allows solar companies to compete in states that forbid third party financing (Wang 2014). In April 2014, a survey of California homeowners found that 60% would prefer to own their rooftop solar systems, a finding compatible with solar loan financing (Wesoff 2014).

D. State Support for Residential Solar PV: Lessons Learned

In their SEC filings, SolarCity notes that treasury grants, federal and state tax credits, electricity rate design, customer fees and charges, limits on net metering, interconnection standards, the retail cost of electricity, and other government and utility policies greatly influence the residential solar industry's cost of capital, and therefore competitiveness with utility electricity (SolarCity Corporation 2013). For installers, in short, subsidies reduce the cost of capital by inspiring investor confidence that there is and will be demand for solar products. In turn, solar installers pass the savings from both government subsidies and more favorable financing terms from banks and investors on to solar customers. How a reduction or abandonment of the 30% federal tax credit would influence these installers remains unclear. Unlike the wind industry, which General Electric, Inc. has declared competitive without a federal tax credit, the solar industry remains fearful of regulatory, market, and government changes that influence the viability of solar PV (Pyper 2014). These battles have been particularly visible in markets like Arizona and Wisconsin, where utilities have proposed fixed fees and taxes that reduce the value of solar (Lacey 2014, Newman 2014).

The issue in these states is cross-subsidization. Under the traditional utility regulatory compact, all costs associated with the vertically integrated electric utility – generation, fuels, transmission, distribution, billing, etc., are bundled and then divided by kWh-sold to derive a volumetric price of electricity. Those advocating fixed charges for solar customers argue that solar customers, who are compensated via net metering for each kWh produced at that retail rate of electricity, are relying on the distribution network and other infrastructure for reliable delivery of power and a market to sell their net-generation, while not paying their share of costs associated with those services. Proposals to levy a fixed fee on customer bills to compensate for grid and other fixed costs attempt to quarantine variable from fixed costs. On the other hand, the business model for residential solar PV hinges on net metering, and any reduction in the per-kWh retail rate of electricity diminishes the profitability of solar products for customer-generators and the solar companies themselves. These differences are causing considerable tension as changes reveal the mismatch between traditional regulatory institutions and heterogeneous technologies.

In the United States, net metering remains the bedrock of solar PV incentives. In 2013, 95% of all distributed installed capacity of solar was located in states with net metering policies (Sherwood 2014). Krasko and Doris (2013) argue that net metering, along with transparent interconnection requirements and prices, form the first tier of a multi-tier solar penetration policy. Stoutenborough and Beverlin (2008) show that net metering, unlike direct incentives like grants, tax credits, and rebates, places the economic cost of distributed energy production on the utilities themselves (and thus in part on electricity ratepayers) rather than taxpayers at large.

E. Perverse Incentives, Impacts on the Utility Sector, and New Market Schemes

Many privately owned solar projects in the United States are exempt from federal regulations because installations are certified either as "Qualifying Small Power Production Facilities" under PURPA, or as "Exempt Wholesale Generators" under the Public Utility Holding Company Act of 2005 (SunEdison, Inc 2014). As a result, these facilities do not come under the Federal Energy Regulatory Commission's jurisdiction, and are exempted from federal and state laws that govern the regulation of electric utilities. Though insulated from direct regulation, the solar industry in the United States is still indirectly subject to various regulatory risks.

Investment risk and uncertainty for solar customers falls into at least three categories: 1) solar resource variability, 2) technical performance and maintenance, and 3) regulatory/market risks from future electricity rates and restructuring (Drury, Jenkin, et al. 2013). Solar customers, and installers as well, tend to think about returns of solar investments as fixed points such as payback time, savings on electricity bills, and others. Yet with a 20-30 year lifespan, solar projects remain vulnerable to changes in markets and solar performance throughout the project. For example, persistent weather events like La Niña can cause annual PV performance deviation up to 15% from the mean, although these events tend to even out over the lifetime of projects. Greater risk can be assigned to the degradation of PV systems, which tends to decrease performance by 0.5%-0.7% per year. Similarly, future operations and maintenance costs remain unknown in the future. At present, system maintenance costs owners around $5/kW per year, but unwarrantied products, particularly inverters, can raise costs up to $15/kWdc per year. However, most states and third-party installers tend to use warrantied products, decreasing the risks associated with equipment failure. In analyses of risks, both internal and external, regulators must be aware of the impacts their changes have on the economics of future as well as existing solar systems. Though most environmental policies around rooftop solar focus on a particular capacity target, future regulatory changes, perhaps outside the realm of environmental policies, may dramatically alter the success of previous efforts. Just as technology lock-in from the past 100 years has eroded opportunities for technological progress in the vertically integrated utility, we should be equally wary of present-day policies that codify advantages for particular distributed energy resources, rather than laying a groundwork for technology experimentation.

Changing market dynamics are a double-edged sword for PV projects, though. Residential solar PV helps hedge some market risk, such as electricity price volatility, environmental policies, or changing utility models. However, the assurance that PV can provide entirely depends on the stability of net metering policies. Some proposed rate structures significantly modify the value of PV by abandoning net metering at the retail rate. These restructurings revalue rooftop PV to around 7 cents per kWh, well below the U.S. average retail rate (Drury, Jenkin, et al. 2013). For example, California utilities have been proposing to merge various rate tiers that make solar PV less valuable to customers paying higher electricity rates.

As Darghouth et al. (2011) conclude, at least in California, bill savings per kWh of installed PV varies by a factor of four across customers as a consequence of the inclining block rate structure (under which customers pay higher unit prices the more they have consumed). This implies that, under current market dynamics, customers who consume more electricity are always rewarded more on a per kWh-generated basis than customers consuming less power. As a result, the policies put in place to protect low-consumption customers create a perverse incentive for this customer class *not* to reap the benefits of solar installations and vice versa (Darghouth, Barbose and Wiser 2011). In contrast with some other opinions, Cai et. al. (2013) argue that these restructurings imply the need to abandon net metering, and to replace it with a "value of solar tariff", as proposed for example by Austin Energy, Rocky Mountain Institute and others. Value of solar tariff proponents emphasize how generation and consumption of electricity ought to be metered separately, and customer-generators should be compensated not only for their energy value at the retail rate (per net metering), but also for other benefits including net avoided infrastructure costs and the environmental attributes of solar.

California's solar policies have set clear priorities for the state's procurement of renewable power. While setting market preparation policies, including interconnection and net metering standards, and preempting utility actions to devalue solar installations such as fixed fees, the state's increasingly stringent RPS, coupled with a strong regional solar industry and a variety of incentive programs, contribute to the state's robust market for residential solar power. It is also a state where the diversity of experimentation in technology, solar business models, and financing coincide with experimentation with policy drivers for renewables. These policies have also exposed internal shortcomings of the traditional electric regulatory scheme.

III. Regulation, Experimentation, and Innovation

The above analysis describes the recent growth in the residential solar market, especially in California, and the types of policies that have driven the growth in the California markets, as well as others across the United States. Table 1 identified policy change as one growth driver or inhibitor in the residential solar market. This table provides a conceptual schema for understanding the various overlapping realms of potential experimentation, but the details matter. Not all renewable portfolio standards are equal: their specific rules, implementation, and assumptions influence outcomes. For example, a renewable portfolio standard (RPS) that specifies the installation of a particular technology (e.g., utility-scale concentrated solar) by a specific type of market agent (e.g., the regulated distribution utility) would stifle the type of physical and financial innovation seen in the residential market.

Residential rooftop solar possesses several benefits, some of which satisfy policy mandates, and others that do not. For example, if state policies are aimed solely at meeting greenhouse gas mitigation targets, they ought to incentivize lowest-cost decarbonization (e.g., geothermal) rather than rooftop solar systems under 10kw capacity, which tend to be more expensive on a levelized cost of energy basis. However, the appeal of these policies often is not merely the environmental attributes: rooftop solar systems give homeowners greater independence, insulate them from future increases in the cost of electricity, and may provide aesthetic and social goods. The economic and environmental benefits and costs of any specific energy technology will change over time, as innovation and culture lead to changes in the (subjective) opportunity cost of each technology. Thus more technology-agnostic policies that do not reward or lock in specific existing technologies are more likely to be conducive to long-run sustainability in achieving policy objectives through experimentation-generated innovation. A more technology-agnostic and source-agnostic policy would create less of a barrier to innovation, and may reduce the taxpayer costs of these policies. Similarly, a residential retail market open to competition is likely to be more conducive to the type of product differentiation to attract diverse customers that would induce innovation, as well as trial-and-error experimentation by consumers.

Regulatory institutions can either enable or hinder innovation. The economic and policy environment in which the residential rooftop solar market is developing in the US is a complicated one, with both organic and artificial drivers (as seen in Table 1 and described above). Two dimensions of regulatory policy interact in the residential solar market – renewables policy and retail market regulation. Renewables policy refers to the source-specific policy context in which producers decide whether, what, and how much to bring to the solar market, and consumers decide whether, what, and how much to buy.

The policy environment in the electricity industry is complex and historically rooted. The industry faces regulation at both the federal and state levels, and an increasing synthesis of traditional economic regulation and environmental regulation at both levels. Government intervention has played a role in electricity for over a century, based both on social policy objectives of universal electrification and reliability, and national policy objectives of energy security. There currently is, and almost always has been, government intervention in the electricity industry, including policies over the past decades to subsidize the development and commercialization of every electricity generating technology.

Consequently, regulatory policy in electricity aims at multiple objectives using an accretion of multiple policy instruments: rate-of-return regulation of distribution wires utilities, the perpetuation of residential retail market monopoly in some states, and a panoply of renewables policies and programs ranging from the federal tax credit to state renewable portfolio standards to local tax exemptions for community solar. An idealized intervention-free electricity market simply does not exist.

Taking the multifaceted policy objectives and this complex environment as given, including the array of pre-existing solar subsidies, here we grapple with a more circumspect question: what is a useful conceptual framework for analyzing the variety of state-level solar-related policies in practice? In this framework we prioritize the policy objective of facilitating dynamic, forward-looking innovation in a cost-effective and resilient way, which means looking for dimensions of policy that reduce barriers to innovation but do not necessarily "pick winners" or subsidize specific technologies that may or may not be economically and environmentally sustainable.

Research, development, and commercialization of new technologies, products, and services necessarily involve duplication of efforts, false starts, and dead ends (Mokyr 2010). One of the greatest dynamic benefits generated through market processes is the trial-and-error learning that can lead to a new product's success or failure; market enterprise is a system of profit and loss, and failures and false starts in markets lead to error correction that makes the innovation process as cost-effective as is feasible. Progress toward cleaner and more energy efficient electricity is rarely predetermined or linear. Policy makers striving toward the objective of cleaner and economical electricity have to balance attempting to accelerate innovation while not wasting taxpayer resources, and they have to achieve that balance in the face of their epistemic and cognitive limits -- they cannot replicate the diffuse private knowledge that exists and is created in the interactions of distributed individual agents in the economy, both in the processes of exchange and the processes of research and development.

For those reasons, we take as our conceptual benchmark the extent to which a policy fosters *experimentation*. Experimentation means undertaking actions to discover something unknown, and is the hallmark of how market processes create value in a dynamic rather than a static sense (Kiesling 2014). When an entrepreneur develops a new product or service and brings it to market: that is an act of experimentation. When a consumer walks in to a store, explores what mobile communication devices are available, what features they have or lack, and their prices: that is an act of experimentation. When enough consumers choose a specific product and get consumer surplus from that choice, the producer profits; when consumers do not choose a product, or choose it and don't end up getting consumer surplus, the producer earns a loss, and error correction will involve either changing the production process and price, changing the product, or leaving the market. The interaction of producer and consumer experimentation through market processes over time yields commercial innovation, an example of which being the compound consequences of the Industrial Revolution (Mokyr 2010).

Policymakers interested in cleaner, economical electricity aim to influence this process to achieve their policy objectives. If the policy objective is to advance cleaner and more economic energy technologies, a problem of more prescriptive policies is that they limit experimentation. Policies that stipulate specific technologies that will be eligible for subsidies may induce growth in those technologies, but there is an unseen opportunity cost: the other technologies that could have been developed that may have been even cleaner, more economical, or more attractive to consumers. Policies imposing technology mandates stifle this dynamic experimentation process before it has even started, substituting policymaker judgment for the judgments of all of the producers and consumers subject to their control. Prescriptive technology policies narrow and focus the channel of innovation. That focus may yield some production economies of scale in the chosen technology, but at a cost of cutting off possibly beneficial exploration. Thus we can evaluate the terms of the multitude of state-level solar-related policies active in a state like California based on the extent to which they foster the kind of decentralized experimentation, of both producers and consumers, as in the idealized dynamic market process described above.

Policy goals such as capacity targets for renewables are an attempt to guide an already perverse and distorted regulatory electricity market. The extent to which electricity markets foster innovation and experimentation, we argue, should be a specific objective of future electricity market reform, and is not intended as a disparagement of existing policies. Policy makers are beginning to incorporate these values into future regulatory changes, most notably in New York.

One important caveat against such regulatory policy activity, though, is the "knowledge problem" critique typically associated with Austrian economics. In particular, regulation stifles the social learning that occurs through experimentation that happens in market processes. The learning aspect of market processes is crucial for enabling economic and social coordination, because knowledge is diffuse among the individual agents in society (Hayek 1945, 1974). With diffuse private knowledge, neither entrepreneurs nor policy makers can know what goods and services will succeed with consumers, and at what prices. Similarly, consumer preferences are not fixed and known *ex ante*, either to others or to themselves. Consumers only learn their own preferences through the process of evaluating available choices against each other, and the relative value of those tradeoffs changes over time and as the set of available choices changes due to entrepreneurial activity. Thus by extension, no policymaker or regulator can access such tacit knowledge created in the minds of individuals. Only in the process of evaluating the tradeoffs and opportunity costs in their electricity consumption decisions do individual consumers learn their own evaluation of those opportunity costs, and that knowledge is unavailable to bureaucrats or regulators except through transactive market activity.

The underlying theory and practice of regulation within the electric utility industry so far does not consider experimentation processes that convert creativity, innovation, and technological change into new value propositions for consumers, perhaps revising market boundaries and creating economic growth in the process. Experimentation is among the most substantial drivers of value creation in an entrepreneurial theory of competition that emphasizes competitive market processes—the ability of producers to bring new ideas to market, of producers to combine and bundle existing and new products and services in novel ways, and of consumers to discover these new value propositions and learn how much to value them. Yet despite the clear benefits, these concepts have not yet been integrated into the electricity sector. Rogers (1962) identifies experimentation as one of the primary factors influencing the diffusion of innovation. Greenstein (2008, 2012) argues that economic experiments played a significant role in creating value in the markets for Internet access; his analyses suggest that although economic experimentation is a driver of value creation, pre-1990s Federal spectrum policy erected a regulatory barrier to such experimentation. The technological, entrepreneurial, and regulatory parallels between the Internet and the electricity industry are stark.

Competition creates value through trial and error while exploring new technologies, innovations, business models, product differentiation, and commercial and profit opportunities. Both producers and consumers are entrepreneurs insofar as they discover new profit opportunities through their alertness. This experimentation-based theory of competition combines the Schumpeterian disruptive entrepreneur who generates creative destruction with the Kirznerian alert entrepreneur who interacts with those changes.

Schumpeter's (1934) pioneering work examines how disruptive innovation creates economic growth via individuals who create "new combinations" of materials and forces, leading to change away from economic equilibrium (1934, p. 65). Individuals come to discover these "combinations" by experimentation. Existing producers differ from these experimenters in their tendency to initiate dynamic, growth-generating change by participating in existing markets, producing existing goods and services, using existing techniques at lower prices. Schumpeter defines fives methods for creating dynamic change in markets: introducing a new good or service, or adding new features to an existing one, introducing new production technology or methods, opening new markets, and capturing new sources of raw materials or new methods of industrial organization (1934, p. 75). Competition in dynamic, free-enterprise societies is a process of change and creative destruction, with new combinations making previous ones obsolete (1942, 84). Dynamic competition often takes the form of product differentiation and bundling to compete *for* the market. Rivalry occurs among differentiated products; innovators and entrepreneurs change market definitions and boundaries by creating new products and services as well as new bundles of products and services. That dynamic discovery of new value propositions necessarily takes place in an experimentation process in which different producers interact, as do old and new combinations, to meet the market test of consumer value creation.

Schumpeter's disruptive innovator finds its complement in the activity of Kirzner's alert, aware, entrepreneur. The "entrepreneur-as-equilibrator" (2009, p. 147) uses *differential alertness* to profit, at least speculatively, from an existing opportunity to create net value. Differential alertness means awareness of and openness to a business opportunity that has not yet been widely noticed. This entrepreneur is not a Schumpeterian disruptive creator but engages in trial-and-error experimentation, playing a coordinating role by adapting to underlying changing conditions. Commercializing new products and service – as well as new bundles of products and services– is an example of "equilibrating entrepreneurship".

These ideas of entrepreneurship and experimentation are relevant to regulatory institutions and institutional change in electric power because decentralized coordination through market processes offers forward-looking coordination of future behavior that is not available to central authorities, including regulators. Markets offer agents of all types opportunities and incentives to make profitable discoveries through experimentation. Regulation as it is currently practiced does not. Regulatory institutions are based on equilibrium models grounded in static concepts of cost recovery that do not incorporate or allow for perceiving opportunities and making discoveries.

The technological and financial innovations described in Section II illustrate Schumpeterian and Kirznerian entrepreneurship through experimentation in the burgeoning residential solar market, and have created value for consumers and producers while meeting environmental policy objectives. The extent to which policies like net metering and a relatively technology-agnostic RPS enable decentralized market experimentation contributes to the innovation and growth in such a market.

IV. Conclusion

The case study presented above suggests that regulatory policies allowing for more producer and consumer experimentation enable social learning, and that market processes of trial and error give both buyers and sellers incentives to experiment, to create new and different value propositions, and to learn about how those different value propositions can be welfare enhancing. Given the array of federal and state policies, and that they are the combination of economic regulation and environmental regulation, in this complex policy context we are more likely at the margin to experience beneficial innovation where policies allow for experimentation on the part of both producers and consumers. In terms of economic regulation, this experimentation argument suggests that regulatory entry barriers in retail markets should be removed.

Renewable policies encompass the set of policies and programs enacted by state governments and often implemented through utility regulators to satisfy the state's environmental objectives. Examples of these policies include net metering, energy efficiency programs, and renewable portfolio standards. These policies are restrictive insofar as they impose particular service, investment, and/or pricing requirements on the regulated monopolist. Consider, however, an alternative approach to renewables and environmental regulations that is less restrictive in the sense that it does not rely on specific mandates or requirements. Instead, an unrestrictive policy might, for example, focus on removing existing entry barriers to all forms of renewables or energy efficiency technologies, and encourage market development for technologies that compete with traditional generation. The policy would, in other words, be technology agnostic, while relying on competition and changing technologies and business models to meet environmental demands.

Researchers, regulators, policymakers, and other stakeholders are in a unique position to contribute to future electricity market reforms by thinking not in terms of history or status quo, but by analyzing tabula rasa regulatory and policy arrangements critically. Like the Internet, the heart of a 21^{st}- century electricity system is experimentation and innovation.

References

Bass, Jonathan . "Monopoly Money." *SolarCity Blog* . January 23, 2015. http://blog.solarcity.com/monopoly-money (accessed January 29, 2015).

Burns, John Edward, and Jin-Su Kang. "Comparative economic analysis of supporting policies for residential solar PV in the United States: Solar Renewable Energy Credit (SREC) potential ." *Energy Policy*, 2012: 217-225.

Cai, Desmond W.H., Sachin Adlakha, Steven H. Low, Paul De Martini, and K. Mani Chandy. "Impact of residential PV adoption on Retail Electricity Rates." *Energy Policy* (Elsevier) 62 (2013): 830-843.

Canales, Molly. *SolarCity Launches First Public Offering of Solar Bonds.* October 15, 2014. http://www.solarcity.com/newsroom/press/solarcity-launches-first-public-offering-solar-bonds (accessed January 7, 2015).

Crago, Christine Lasco, and Ilya Chernyakhovskiy. "Solar PV Technology Adoption in the United States: An Empirical Investigation of State Policy Effectiveness ." Department of Resource Economics, University of Massachusetts Amherst, 2014.

Dargouth, Naïm, Galen Barbose, and Ryan Wiser. "The impact of rate design and net metering on the bill savings from distributed PV for residential customers in California ." *Energy Policy* (Elsevier) 39 (2011): 5243-5253.

Doris, E. "Policy Building Blocks: Helping Policymakers Determine Policy Staging for the Development of Distributed PV Markets." *National Renewable Energy Laboratory.* 2012. http://www.nrel.gov/docs/fy12osti/54801.pdf (accessed January 29, 2015).

Drury, Easan, et al. "The transformation of southern California's residential photovoltaics market through third-party ownership ." *Energy Policy* (Elsevier), December 2011: 681-690.

Drury, Easan, Thomas Jenkin, Dirk Jordan, and Robert Margolis. "Photovoltaic Investment Risk and Uncertainty for Residential Customers ." *IEEE Journal of Photovoltaics* 4, no. 1 (January 2013): 278-284.

DSIRE . *California Renewables Portfolio Standard.* June 25, 2014. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA25R (accessed January 7, 2015).

—. *California Solar Initiative, PV Incentives.* November 11, 2014. http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA134F&re=0&ee=0 (accessed January 1, 2015).

Feldman , David, et al. *Photovoltaic System Pricing Trends Historical, Recent, and Near-Term Projections 2014 Edition.* SunShot, U.S. Department of Energy, 2014.

Friedman, Barry, Kristen Ardani, David Feldman, Ryan Citron, Margolis Robert, and Jarett Zuboy. *Benchmarking Non-Hardware Balance-of-System (Soft) Costs for U.S. Photovoltaic Systems, Using a Bottom-Up Approach and Installer Survey – Second Edition.* National Renewable Energy Lab, 2013.

Greenstein, Shane. 2008. Economic Experiments and Industry Know-How in Internet Access Markets. In *Innovation, Policy, and the Economy,* vol. 8, edited by Adam Jaffe, Josh Lerner, and Scott Stern, 59-109. Chicago: University of Chicago Press.

—. 2012. Economic Experiments and the Development of Wi-Fi. *Advances in Strategic Management* 29: 3–33.

GTM Research. "US Solar Power Growth." *Cost of Solar.* 2013. http://costofsolar.com/management/uploads/2013/10/US-solar-power-growth.jpg (accessed January 1, 2015).

Hayek, Friedrich. (1945) "The Use of Knowledge in Society." *American Economic Review* 35(4): 519-530.

Hayek, Friedrich. (1974) "The Pretence of Knowledge." Nobel Memorial Prize lecture. Available at http://nobelprize.org/nobel_prizes/economics/laureates/1974/hayek-lecture.html. Accessed 5 February 2014.

Hernandez, Mari. *Solar Power to the People: The Rise of Rooftop Solar Among the Middle Class* . Energy team, Washington, DC: Center for American Progress, 2013, 10.

Hoen, Ben, et al. *Selling into the Sun: Price Premium Analysis of a Multi-State Dataset of Solar Homes.* Lawrence Berkeley National Lab, National Renewable Energy Lab, 2015.

Kann, Shayle. *U.S. Residential Solar PV Customer Acquisition: Strategies, Costs and Vendors* . September 29, 2013. http://www.greentechmedia.com/research/report/us-residential-solar-pv-customer-acquisition (accessed January 4, 2015).

—. *U.S. Residential Solar PV Financing: The Vendor, Installer and Financier Landscape, 2013-2016* . February 11, 2013. http://www.greentechmedia.com/research/report/u.s.-residential-solar-pv-financing (accessed January 7, 2015).

Kiesling, Lynne. 2014. "Incumbent Vertical Market Power, Experimentation, and Institutional Design in a Deregulating Electricity Industry." *Independent Review* 19(2): 239-264.

Kirzner, Israel. 2009. The Alert and Creative Entrepreneur: A Clarification. *Small Business Economics* 32, no. 2 (February): 145–52.

Kollins, Katharine, Bethany Speer, and Karlynn Cory. *Solar PV Project Financing:*

Regulatory and Legislative Challenges for Third-Party PPA System Owners . National Renewable Energy Lab, 2010.

Krasko, Vitaliy A., and Elizabeth Doris. "State distributed PV policies: Can low cost (to government) policies have a market impact?." *Energy Policy* (Elsevier), 2013: 172-181.

Kwan, Calvin Lee. "Influence of local environmental, social, economic and political variables on the spatial distribution of residential solar PV arrays across the United States." *Energy Policy* (Elsevier), 2012: 332-344.

Lacey, Stephen. *A Solar System Is Installed in America Every 2.5 Minutes* . January 12, 2015. http://www.greentechmedia.com/articles/read/a-solar-system-is-installed-in-america-every-2.5-minutes (accessed January 12, 2015).

—. *Arizona Public Service Enters the Rooftop Solar Business: Good for Installers or a Trojan Horse?* . July 30, 2014. https://www.greentechmedia.com/articles/read/arizona-public-service-enters-the-rooftop-solar-biz (accessed January 1, 2015).

—. *The End of a Solar Era: The Legacy of the California Solar Initiative* . November 4, 2014. http://www.greentechmedia.com/articles/read/the-legacy-of-the-california-solar-initiative (accessed January 7, 2015).

Lawrence Berkeley National Laboratory. *Tracking the Sun VII*. 2014.

Mokyr, Joel. *The Enlightened Economy: An Economic History of Britain 1700-1850*. New Haven: Yale University Press, 2010.

Munsell, Mike. *Top 10 Installers Eclipse 50% of US Residential PV Market in Q1 2014*. July 3, 2014. http://www.greentechmedia.com/articles/read/top-10-installers-eclipse-50-of-us-residential-pv-market-in-q1-2014 (accessed January 7, 2015).

Nasdaq. *Solarcity Corp (SCTY) IPO*. http://www.nasdaq.com/markets/ipos/company/solarcity-corp-752655-70925 (accessed January 7, 2015).

Newman, Judy. *Wisconsin utility companies take aim against solar power.* July 28, 2014. http://host.madison.com/business/wisconsin-utility-companies-take-aim-against-solar-power/article_cd1fb31a-c1ad-56a4-a71b-375830d5b6e1.html (accessed January 7, 2015).

Pyper, Julia. *GE Government Affairs Director: Midwest Wind Can Compete Without a Federal Tax Credit* . October 29, 2014. http://www.greentechmedia.com/articles/read/ge-govt-affairs-director-wind-ptc-can-expire-after-2015 (accessed January 5, 2015).

Rogers, Everett. 1962. *Diffusion of Innovations*. New York: Free Press.

Schumpeter, Joseph. 1934. *The Theory of Economic Development*. Cambridge, Mass.: Harvard University Press.

—. 1942. *Capitalism, Socialism, and Democracy*. New York: Harper Collins.

Sherwood, Larry. *U.S. Solar Market Trends 2013.* Interstate Renewable Energy Council, Inc. , 2014.

Smith, Heather. *No solar, please – we're Florida.* August 11, 2014. http://grist.org/climate-energy/no-solar-please-were-florida/ (accessed January 1, 2015).

Solar Energy Industries Association . *Solar Market Insight Report 2013 Year in Review* . March 4, 2014. http://www.seia.org/research-resources/solar-market-insight-report-2013-year-review (accessed January 7, 2015).

Solar Energy Industries Association. *Third-Party Solar Financing* . http://www.seia.org/policy/finance-tax/third-party-financing (accessed January 7, 2015).

SolarCity. 2014. http://www.solarcity.com (accessed January 5, 2015).

SolarCity Corporation. "2012 Annual Report Form 10-K." March 27, 2013. http://investors.solarcity.com/common/download/sec.cfm?companyid=AMDA-14LQRE&fid=1193125-13-129655&cik=1408356 (accessed January 5, 2015).

Soskin, Mark, and Heather Squires. "Homeowner willingness to pay for rooftop solar electricity generation." *Environmental Economics* 4, no. 1 (2013): 102-111.

Steward , D., E. Dorris, V. Krasko, and D. Hillman. *The Effectiveness of State- Level Policies on Solar Market Development in Different State Contexts* . National Renewable Energy Laboratory, 2014.

Steward, D., and E. Doris. *The Effect of State Policy Suites on the Development of Solar Markets.* National Renewable Energy Laboratory , 2014.

Stoutenborough, James W., and Matthew Beverlin. "Encouraging Pollution-Free Energy: The Diffusion of State Net Metering Policies." *Social Science Quarterly* (Southwestern Social Science Association) 89, no. 5 (2008): 1230-1251.

SunEdison, Inc. "SunEdison 2013 Annual Report 10k." April 16, 2014. http://secfilings.nyse.com/files.php?symbol=WFR&fg=24 (accessed February 3, 2015).

Wang, Ucilia. *SolarCity Offers Its First Home Solar Loan* . October 8, 2014. http://www.forbes.com/sites/uciliawang/2014/10/08/solarcity-offers-its-first-home-solar-loan/ (accessed January 8, 2015).

—. *Vivint Solar Prices Shares For IPO* . September 30, 2014. http://www.forbes.com/sites/uciliawang/2014/09/30/vivint-solar-prices-shares-for-ipo/ (accessed January 7, 2015).

Wesoff, Eric. *SolarCity CEO: Solar Loans Could Be Half of New Business by End of Next Year* . October 8, 2014. http://www.greentechmedia.com/articles/

read/SolarCity-CEO-Half-of-New-Business-by-End-of-Next-Year-Could-Be-Solar-Loan (accessed January 5, 2015).

Zhao, Tingting, Lindsey Bell, Mark W. Horner, John Sulik, and Jinfeng Zhang. "Consumer responses towards home energy financial incentives: A survey-based study." *Energy Policy* (Elsevier), 2012: 291-297.