Industrial Fields and Countervailing Power: The Transformation of Distributed Solar Energy in the United States

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Abstract
The case of distributed solar energy (e.g., rooftop photovoltaics) and the electricity system in the U.S. is used to develop the theory of long-term transitions in large sociotechnical systems. The study shows the advantages of analyzing sociotechnical transitions as taking place in technological fields in which advocates of different design approaches struggle for position. Over time, grassroots innovations that are connected with aspirations of local ownership tend to be displaced by better-funded models of financing supported by corporations in the financial and technology industries. The processes of blockage by the incumbents, countervailing industrial power, and incorporation and transformation (by incumbents) are developed in a field theory framework to advance the study of large technological systems in general and sustainability transitions in particular.

1. Introduction

The multiple environmental challenges facing the world today—climate instability, shortages of food and water, irreversible ecosystem damage, and persistent chemical pollutants—require fundamental changes in technological systems. The changes are shaped not only by technological innovation and competition in the marketplace but also by political processes that involve conflicts among social movements, corporations, and governments. One example for which such political processes are especially important is the role of grassroots innovations (GIs) in sustainability transitions. This study will contribute to research on GIs and technological change by developing a political process perspective that focuses on the role of the industrial power of large corporations in shaping contention over sustainable technology.

The term "grassroots innovation" is defined here as experimentation with technological change that involves a social movement component, that is, mobilization in support of a broad social change agenda (Hess, 2007; Seyfang and Smith, 2007). Organizationally, a GI can have diverse social addresses: a community-based organization, a local government initiative, or even a new business enterprise that has sympathies with broad social movement goals. Research on the long-term history of GIs from the 1970s to the present suggests that large corporations sometimes accept the GIs, but the GIs often undergo significant organizational and technical design changes in the process (Hess 2007). In other words, success in the sense of widespread diffusion often comes at the cost of cooptation.

The study that follows contributes to understanding the role of GIs in long-term changes in large technological systems (LTSs) that are undergoing a sustainability transition. LTSs are understood here as "sociotechnical" systems that have a large scale (such as a city level or higher); substantial material infrastructure that is difficult and expensive to change; and associated regimes of regulation, industrial organization, and consumer practices (Bijker, Hughes, and Pinch, 1987). For example, for electricity generation the LTS includes both the generation and transmission infrastructure and the legal, organizational, and cultural practices associated with electricity production and consumption. This study will focus broadly on electricity generation in the U.S. and specifically on distributed solar energy (DSE). Because some of the models of GIs for DSE are found in other countries, the broad outlines of the analysis are likely to be generalizable, and likewise the general theoretical framework is likely to be valuable in the broader study of sustainability transitions. The study contributes to the analysis of change in LTSs by drawing attention to three important political processes: incumbent blockage of GIs, the incorporation and transformation process of GIs into the mainstream of industrial fields, and the role of countervailing corporate power in enabling changes in industrial fields.

2. Background, Problem, and Methods

2.1 Definitions and Background

Sustainability is defined as a condition in which a society consumes resources and deposits waste at a rate that is within the referent ecosystem's capacity to replenish resources (or to supply substitutions) and to process the pollution and waste (Daly 1990, 1996). Because a national society or region can export its sustainability problems, the ultimate level of analysis for societies today must be global (York and Rosa 2003). From a normative perspective, a sustainability transition also requires consideration of equity issues, such as intergenerational and within-generation equity (e.g., World Commission on Environment and Development, 1989). With respect to electricity generation, sustainability in the U.S. is understood as the change or "transition" in the LTS to low-carbon alternatives, that is, away from the current electricity generation mix, which is about 70% fossil fuels.

Because solar energy currently accounts for less than 1 percent of electricity generation but continues to undergo reductions in costs, the potential for it to play a significant role in the long-term change in the electricity system is increasing. DSE is defined here to include photovoltaics at the scale of a rooftop on a building, in contrast with utility-scale solar farms. The division in scale is analytical rather than technological; because of the modular design of solar photovoltaics, the technology is often similar at both levels, although concentrating solar is generally only a utility-scale technology. DSE technology is small-scale but scalable: if every building in a country were to have photovoltaics on its roof or nearby grounds, we could say that the LTS of electricity generation had undergone a transition.

In the U.S., electricity distribution occurs through three main types of organizations: public "utilities," which are often part of a city government but can include some federal government entities (such as the Tennessee Valley Authority); distribution cooperatives, generally organizations that deliver electricity to rural cities and farms; and investor-owned utilities (IOUs), which are publicly regulated, for-profit companies. Although the number of public utilities and cooperatives is higher than that of the IOUs, most of the former do not engage in electricity generation, and they serve a smaller total percentage of customers than do the IOUs. Since the restructuring of electricity markets that took place during the 1990s, IOUs have tended to shed some of their generation capacity, but many still have both distribution and generation operations.

From the perspective of organizations that manage electricity generation and distribution, such as the IOUs, there is a preference for "baseload" generation, that is, stable generation from nuclear energy, hydropower, or fossil fuels. Although DSE offers benefits such as avoiding new transmission lines and providing resilience in the event of power outages, the problems of intermittency and load management have caused IOUs to discourage the rapid scale-up of the technology. Furthermore, government rebate programs have not been enough to motivate more than a small percentage of households and businesses to undergo solarization (Drury et al., 2012). Thus, a historical opportunity has opened up for new and creative ways to finance the growth of DSE, and some of the proposed solutions could be classified as GI. In summary, the position of DSE in the LTS of electricity generation is growing, but DSE is itself a field with very different models of financing and ownership at stake.

2.2 Conceptual Framework and Theoretical Contribution

Theories of sociotechnical transitions of LTSs have frequently used a “multilevel perspective” that focuses on how new niches can scale up and affect or even replace existing technological regimes, including those associated with LTSs (e.g., Geels, 2005). A largely exogenous category of “landscape”—which includes long-term societal changes, cultural practices, and public policy—is used as a residual explanatory resource. Some work in this field also recognizes that new niches cannot prosper without protection from governments until they have reached critical scale, in effect a requirement that the scaling up of niches must be managed by governments (Smith and Raven, 2012). Transitions in LTSs can also occur through pathways other than the scaling up of a niche; for example, they may occur as a result of changes in the landscape or of the hybridization of regimes (Geels and Schot 2007).

The multilevel models of LTSs and their processes of change have advantages and disadvantages. In contrast with constructivist accounts of technological change, multilevel models have the advantage of drawing attention to long-term processes and scalar dynamics. Although an evolutionary and managerial perspective in some work on transitions can underplay power relations, work in the multilevel perspective tradition has increasingly acknowledged the importance of social movements and political conflict as important factors in explaining the outcomes of niche-regime dynamics (e.g., Elzen et al. 2011; Grin’s chapters in Grin, Rotmans, and Schott, 2011; Smith and Grin, 2010). For example, Avelino (2011) has examined the issue of power and transitions extensively, and Jørgensen (2012) also highlights the role of conflict among actors in shaping the outcome of transitions.

GIs are of particular interest to the study of transitions in general, because they often envision an extensive change in the LTS and are likely to be rebuffed by incumbents who are invested in stasis. As a result, issues of power and political process are likely to be especially salient. For example, cooperatives of locally owned and controlled renewable energy could replace a utility-based system of centralized electricity based on fossil fuels and nuclear energy. A sociotechnical transition of that magnitude would involve differences in both technological infrastructure and in ownership and organizational structures. In a complete transition as originally envisioned by the solar energy movement of the 1970s, the LTS could become a system with few transmission lines, little centralized electricity production, and high levels of local public and private ownership (Reece, 1979). Even though social movements and some solar entrepreneurs favored that alternative vision of the LTS, by the 1970s the utility industry had worked to ensure that long-term changes in the electricity system did not result in such a threatening outcome, and it has continued to try to keep the genie of decentralized solar energy in the bottle of a niche position.

More generally, GIs oriented toward sustainability and LTSs tend to involve two important features: a radically different vision of the desirable future for the LTS or existing regime, and a corresponding incumbent industry that does not agree with the different vision. Not all GIs wish to replace the incumbent industry and LTS; in some cases of GIs associated with solar energy, the goal is local self-sufficiency rather than a more pervasive transition in the mix of electricity generation or the overall ownership patterns of the field. However, when agents do wish to bring about a broader change or scale up their niche experiments to bring about fundamental changes in the LTS, there is a conflict between incumbents and challengers. The outcome of the conflict, including the capacity for challengers to displace incumbents, cannot be explained completely in terms of instrumentalism (one approach to the electricity mix solves technical problems better than others) or marketplace competition (one approach is cheaper than another). Although those factors can be recognized as contributing, often conflict in the political field over governing policy has an equal or greater effect. As a result, the issue of a sociotechnical transition is simultaneously a political conflict between a challenger and an incumbent industry. This political conflict plays itself out in various battles over regulatory and industrial policy, usually in the form of the incumbent industry in opposition to an alliance in support of an alternative pathway for the LTS.

To understand clearly the political dimensions of the conflict, field sociology provides a helpful conceptual framework. Field sociology is well understood in the social sciences and has diverse approaches, including Bourdieusian field theory and strategic action fields (Bourdieu, 2005; Fligstein and McAdam, 2012). Fields are relations of conflict and cooperation among agents (individuals, organizations, or informal networks) who have a shared stake in a particular outcome (such as the mix of electricity generation) but differential capacity to influence the outcome. Agents in the field possess different types and levels of capital (e.g., financial, environmental credibility, political), and in most fields they can be categorized as occupying dominant or subordinate positions, such as the fossil-fuel and nuclear-energy generation companies and the much smaller and less powerful renewable energy companies and GI projects.

From a field sociological perspective, the changes in the structure of the LTS (both technological and organizational structure) are viewed as outcomes of relations of conflict and cooperation in interconnected fields. In the study of LTSs, two societal fields are of great significance: the political field, in which contention occurs over the regulatory regime that affects the LTS, and the industrial field, in which contention involves the position of different firms and associated technologies. As transition studies have documented, industrial and regulatory policy links the political and industrial fields by providing policy support to new firms and industries to enable them to scale up. However, less attention is given to the situation in which incumbents in the industrial field view policy support as a threat, and they mobilize to block the policy or to absorb and control the challenging firms and their associated technologies and products. To resist attempts by the threatened industry to block the transition of an industrial field, government authorities must have adequate autonomy from the industrial field, but government autonomy can be compromised due to the political influence of the incumbent industrial agents. For example, in the U.S. the fossil-fuel industry has a significant effect on variation in state-government voting patterns on green-energy policies, and the industry's effect on the political process makes it difficult for political leaders to have an independent role in steering a transition to a low-carbon electricity system (Coley and Hess, 2012).

Drawing on field theory, this study advances the theory on transitions in LTSs by delineating three political processes. First, the study draws attention to the processes of marginalization and blockage. The incumbent organizations will mobilize political resources to block an effort to change the regulatory and industrial policy environment to scale up the challenger, in this case DSE. Blockage strategies may be quite successful at keeping niches from scaling up, but two other processes reduce the possibility that a blockage strategy will always be successful.

The challenger may respond to blockage by developing coalitions with countervailing power. Galbraith (1952) introduced the concept of countervailing power to describe how unions, consumer associations, farmers, and even the government could provide a balance to the economic and political power of large corporations, but the concept also described how one network of corporations (such as retail chains) could offset the economic power of another (such as suppliers of goods). In the case of conflicts over DSE in the U.S., the concept of countervailing power will be used to show how a government entity (such as a city or state government) and a related industry (large financial and technology corporations) have formed alliances with DSE advocates that have provided them with the capacity to transform their field position.

Often when the support of a countervailing power is mobilized, the incumbent industry will shift strategy from marginalization and blockage to incorporation and transformation. Because the GIs themselves constitute a diverse field, some within the field shift toward more accommodationist strategies by embracing incorporation and transformation processes. Although the pattern is not universal, it is empirically supported by the general historical pattern of changes in LTSs with respect to sustainability challenges in the waste, housing, transportation, food, health, software, and finance industries (Hess, 2007). The view is at odds with the more optimistic prognosis of grassroots activists and advocates who hope to see their GIs scale up and replace existing regimes. The incorporation process can involve literally the absorption of small organizations by larger ones, or it can involve transformations of the challengers into larger organizations. However, incorporation rarely leaves the challenger unchanged, and the design of challenging technologies is often transformed over time. For example, organic food and sustainable agriculture began as a challenge to the dominant, industrial food system, but over time portions of the movement were transformed into a supermarket-oriented, industrialized form of organic food with long commodity chains. In the process, the agricultural techniques and definitions of the category “organic” underwent changes; that is, in additional to organizational incorporation into the existing regime, there were transformations of technical design and products (Hess, 2007). The dominant organizations in an industrial field tend to absorb the challenging technological models, but in the process they also transform the designs to make them more compatible with the existing technologies and products favored by the incumbents.

This conceptual framework—industrial and political fields that involve processes of marginalization-blockage, countervailing power, and incorporation and transformation—can be used along with the conceptual tool-kits of both microsocial studies of technology (e.g., interpretive flexibility, enrollment, social negotiation, closure) and the multilevel approach to STs (e.g., technological niches and regimes). However, a political process approach provides a valuable complement to those approaches by highlighting the often glossed-over political processes in which conflicts over GIs and changes in LTSs can be studied.

2.3 Research Questions and Methods

DSE in the U.S. is understood here as a field within the broader industrial field of electricity generation and distribution. Some models for DSE can be classified as GIs because they are associated with social movement goals of broad societal change, especially a combination of local ownership (sometimes call “localism”) and environmental sustainability (Hess, 2009). Organizationally, the GIs involve experimentation with local public ownership, cooperatives, and policy support for residential ownership of DSE. In contrast, a growing sector of the DSE field involves “third-party,” for-profit companies that are not concerned with broad social goals such as increased local ownership of energy production. In between, there are models in which for-profit businesses and public-private partnerships facilitate local ownership. The central problem of the analysis that follows is the explanation of the conditions under which the grassroots models for financing DSE in the United States are remaining in a relatively marginalized position, whereas other models are undergoing growth.

The following research questions are addressed:

1. What models of rooftop solarization have shown a trend to rapid growth (or stasis), and what political and industrial factors explain their growth (or stasis)?
2. As some models of DSE and actors achieve dominance in the DSE field, what are the implications for decentralized versus corporate forms of ownership?

To answer the questions, the analysis that follows is based on a comparative case study method, using as a data set the range of models for financing DSE in the United States. Research is based on bibliographic sources, but it draws on a broader project of U.S. green-energy transition policies that involved eight graduate research assistants who conducted field site visits and interviews (Hess 2012).

4 Results

The analysis that follows examines four positions in the field of DSE: public ownership, PACE financing, share-based models, and third-party financing. These four models overcome some of the hurdles of traditional models of financing, such as home-equity loans or up-front expenditures from savings, which face problems of capitalization, transaction costs, and liquidity. Each of the approaches to DSE discussed here is potentially scalable to widespread electricity production and could result in a sociotechnical transition. However, only some of the approaches are undergoing rapid growth.

4.1 Public Ownership and Solarization

In general, IOUs have resisted solarization partly because of their investments in fossil fuels and nuclear energy and partly because of the problems of load management posed by the intermittency and transmission congestion associated with solar and wind energy (e.g., Wang, 2010). In contrast, some of the publicly owned utilities have been leaders in the green energy transition, and they have supported DSE. Because public utilities retain profits that otherwise would go to investors for IOUs, it is possible for the city government or other governing unit to mandate that the public utility direct some of the profits into support for DSE. For example, the Sacramento Municipal Utility District and city of Ellensburg, Washington, offer a solar-share program, which is described in more detail below; the public utilities for Los Angeles and Long Island offer feed-in tariffs for DSE; Seattle City Light offers community solar projects; and Austin Energy offers residential rebates, commercial incentives, and loans for solar photovoltaics. By undertaking municipalization (government ownership) of electricity services, a city government can recapture profits and exert greater control over electricity generation. A city could then follow the model of other public utilities and offer rebates, feed-in tariffs, and other programs to support increased DSE. If all cities were to do so, there would be a fundamental transition in the LTS toward local public ownership. Municipalization is arguably the most radical and most highly contested model of GI in the U.S.

Although there is municipal ownership of electricity distribution (and in some cases generation) in several large cities in the U.S., municipalization is a challenging road to a sustainability transition. The transaction costs are high, because cities must borrow to pay the IOUs for the power lines, they must develop the expertise and ability to manage a LTS, and they often face years of battles in courts and in elections due to challenges from the IOU. In recent decades, few cities have undergone municipalization in the United States. San Francisco tried, and its story has become a warning to other cities.

Angered by power outages and rate hikes that had accompanied the liberalization of retail energy services during the 1990s, San Franciscans engaged in various attempts to municipalize their electricity. Advocates of municipalization believed that local control would make it easier for the city to pursue its own green energy transition and by-pass opposition from the IOU, Pacific Gas and Electric Company (PG&E). In 2001 two ballot propositions would have enabled the city to municipalize its electricity, but they faced strong opposition from the IOU. Both ballot propositions were defeated, one by a narrow margin of 500 votes. Advocates tried again in 2002, but their campaign expenditures of $50,000 did not match that of the IOU, which spent over $2 million. In general, IOUs have intensely resisted municipalization efforts, just as cable companies have resisted efforts to undertake public ownership of broadband Internet (Greeley and Fitzgerald, 2011).

Because of the resistance from the IOU, advocates of community energy pursued other strategies, which were more successful. Propositions B and H of 2001 enabled the city to finance renewable energy generation through revenue bonds. Although electricity distribution would take place through the IOU, the local ownership of generation would benefit the city by providing rate stability from the long-term investment. The city also began to explore community choice aggregation (CCA), which collects all customers within a geographical region into a large contract with the electricity service provider (in this case the IOU) based on a negotiated price and energy mix.

The change from the municipalization strategy to CCA is an example of the beginning of the incorporation and transformation process. Although many electricity advocates and activists in San Francisco favored municipalization, community choice was a fall-back position. Local power advocate Paul Fenn led the effort; he and other advocates of community-controlled electricity succeeded in convincing the California state legislature in 2002 to pass the enabling law, AB 117. CCA solves one central problem for municipalization: the high cost of transferring ownership of distribution to a city government or other local public entity. Potentially, under a CCA agreement a community can achieve greener electricity, less expensive electricity, or a mixture of the two. For example, the Cincinnati region negotiated for a 100 percent renewable energy mix (Simes, 2012.) In the case of San Francisco, Fenn's plan was to use the city's "solar bond" authority to finance a build requirement for renewable energy, including rooftop solar, as part of the CCA contract. In this configuration, CCA would have achieved one potential benefit of municipalization (local ownership of generation), but it did not threaten the IOU as directly as did municipalization, because it left distribution in the hands of the IOU.

In 2004 the California Public Utilities Commission adopted a plan to allow cities and counties across the state to adopt CCA, and by 2007 dozens of cities were pursuing plans for CCA. In 2004 San Francisco's Board of Supervisors directed the city's Public Utilities Commission to move forward with a plan for CCA. The plan originally included a goal of 360MW (about half the city's load) in wind generation, distributed generation (e.g., DSE), and efficiency measures. The city government announced a CCA program, CleanPowerSF, but it was unable to resolve negotiations with a service provider firm. Meanwhile, in May 2010, the state's first CCA, Marin Energy Authority, began operation. It offered customers electricity that was 25 percent from renewable sources, in contrast with 12 percent from PG&E at that time, and it also offered 100 percent renewable energy at a five-percent price premium (Braley, 2011). Renewable electricity was purchased from Shell Energy North America, which owns wind farms.

In 2011 the San Francisco Public Utilities Commission followed the Marin County model by announcing an arrangement with Shell to service 75,000 of the city's customers in a pilot program. The estimate of 75,000 was based on an expected opt-out rate from an initial offering to 280,000 customers. Shell would purchase 100 percent renewable electricity power on the grid at a small price premium. The city abandoned the goal of purchasing electricity at a price reduction but found that there was a segment of the customer base that would purchase all-green electricity at a premium of about $10 per month for the average residential customer. City officials stated that they expected opposition from the IOU, which they believed might employ rate spikes to frighten customers (Bowe, 2011). The program also faced some opposition from green jobs advocates until the city representatives agreed to include green energy construction as part of the program.

In response to the successful development of CCA in California, the IOU sponsored a ballot proposition in 2010 at the state government level that would have required a two-thirds vote in a district in support of a CCA agreement, instead of a simple majority. The utility spent over $46 million dollars on the initiative, in contrast with about $100,000 from the supporters of CCA (Baker, 2010). The defeat of the initiative even in the face of the heavy spending by the IOU suggests the level of knowledge among customers in the state. In 2011, a state senate bill (SB 790) was introduced to allow the state to direct some of its public benefits fund to CCA entities. The law would also prohibit the state's IOUs from marketing campaigns directed at CCAs.

From a field theory perspective, the incumbent IOU attempted to block the challenges of the city government and the coalition of energy reformers. However, there was a countervailing power, the state government, which enabled cities in California to attain the regulatory approval needed for CCA, and the IOU was not successful at blocking the countervailing power even with a well-funded ballot proposition campaign. Finally, there was an incorporation and transformation process, in which the original grassroots aspirations of municipalization, which included locally owned DSE, gave way to the public-private partnerships of CCA with the IOU as intermediary and a large energy corporation as the energy generating company. In effect, the

CCA program became a voluntary green pricing program based on an opt-out rather than opt-in rule. One can see clearly from this case that although marketplace dynamics such as pricing issues were important, the transition was a fundamentally political process.

4.2 PACE Financing and Related Models

Another example of GI in the DSE field occurred in 2008. Francisco DeVries, chief of staff for the mayor of Berkeley, California, wanted to put solar panels on his own home, but the up-front cost of the project ($30,000) and the threat of losing the investment if he had to move made it unattractive, even if the long-term return on investment was solid. To solve the problem, he developed the idea of a Sustainable Energy Financing District, which would issue municipal bonds to fund the up-front costs of solarization, then recuperate the expenditure as an item on taxpayers' property tax bills that was calculated to be roughly equivalent to the energy saved from the installation. Together with Stephen Portis, he founded Renewable Funding, a company that purchases bonds from cities and then aggregates and sells them on financial markets (Jenkins, 2009). Unlike third-party financing (discussed below), under this model the ownership of the DSE rests with the building owner.

The result of DeVries's efforts was the country's first property-assessed clean energy (PACE) program—the Berkeley Financing Initiative for Renewable and Solar Technology (FIRST)—and the beginning of the PACE reform movement. The California state government soon approved legislation to facilitate similar programs statewide, and other states soon followed with PACE-enabling laws, especially during 2009, when federal funding from the American Recovery and Reinvestment Act became available (Van Nostrand 2011). As PACE programs took off, they also included energy efficiency projects. Over 100 cities in California launched PACE plans, enabling legislation was passed in twenty states, and the federal government made plans to award hundreds of millions of dollars in federal assistance to support them. Political support tended to be bipartisan, and PACE-backed legislation was passed in both Republican-dominated and Democrat-dominated state legislatures (Coley and Hess, 2012). However, in 2010 the Federal Housing Finance Agency declared that PACE loans to homeowners were unacceptable, because the local government claimed to have a senior lien status on mortgages that had been resold to the federal agency. As a result, a rapidly growing financing mechanism for locally owned rooftop solar and energy-efficiency improvements came to a halt.

Although there are potential alternatives to residential PACE programs (repayment via utility bills rather than property taxes, and PACE financing with a second-lien status), after 2010 the primary development has been for commercial and other nonresidential property such as apartment buildings. By 2011 there were 17 nonresidential programs either in operation or in start-up phases throughout the country, and the programs were supported with revenue bonds, local treasury funds, or federal funds (Lawrence Berkeley National Laboratory et al., 2011). In 2012 in California, 140 counties and cities in partnership with a state agency launched the CaliforniaFIRST program, which finances water and energy improvements of a minimum level of $50,000 for nonresidential buildings (CaliforniaFIRST 2012). Supported by tax-free municipal bonds, the initial program had $250 million in support from private capital. A similar PACE program that involved a partnership with Barclays Capital and Ygrene Energy Fund involved over $500 million for the Miami, Florida, area (Gerdes 2012a, 2012b). Those involved in financing the programs predicted a growth to billions of dollars per year (Carbon War Room 2011, Gerdes 2012b).

In summary, in the PACE case there was no direct assault on the profits of the IOUs, as occurred in the case of municipalization and CCA, and there was no corresponding resistance from the IOUs. However, PACE financing also reveals the potential that IOUs had to finance DSE and their passive blocking through lack of programs. It was necessary for the countervailing state and local governments in partnership with the financial industry to enter the field to enable PACE models to scale up from their humble origins in one California city. However, because PACE models involved a mortgage lien, they challenged the incumbent in the regime of residential property financing, and the response was blockage in another policy field. The only countervailing power that could have overturned the decision would have been Congress, and the proposed federal PACE-enabling law did not garner enough votes for passage.

Although the history is too recent to see an incorporation and transformation process into an established industry, there is a crucial role again for countervailing power, and there is a transformation process. A model that was originally oriented primarily toward homeowners and solarization has been transformed into a model that is primarily available for nonresidential building owners, open to a variety of renewable and energy efficiency improvements, and supported by increasing funding from large financial organizations. Because of the transaction costs and financing thresholds (such as the $50,000 minimum in California), it is likely that medium-sized and larger businesses will be the primary beneficiaries. Although some of the businesses will be locally owned with owner-controlled rooftop solar, nonresidential PACE in California is now open to third-party financing arrangements, and there is a slow separation from the original aspirations of solving the problems of homeowners for rooftop solarization.

4.3 Share-Based Models

Another family of models for scaling up DSE involves purchasing shares in an organization. There are two main types of share-based models: shares that purchase advice that reduces transaction costs, and shares that enable quasi-ownership rights in solar energy generation.

In Washington, D.C., Anya Schoolman, an environmental policy analyst, and her sons recruited members from the neighborhood and lobbied to get approval for a solar carve-out in the District's renewable electricity portfolio standard. Once rebates were approved, the Mt. Pleasant Solar Co-op started facilitating the solarization of the neighborhood's rooftops. For example, the cooperative negotiated with the IOU, Pepco, to have two-way meters installed and to ensure support for DSE. The cooperative does not own solar generation but benefits members by reducing the transaction costs. Schoolman went on to found other solar cooperatives in the city (Solar Today 2011). Technically, they might be characterized as transition-assistance cooperatives in order to distinguish them from solar-energy generation cooperatives or rural electricity distribution cooperatives.

Although Schoolman's cooperative model was successful at reducing transaction costs, it did not diffuse rapidly across the country and scale up. However, the private sector has developed a similar service of aggregating customers at a neighborhood level and providing assistance with the transaction costs of solarization. One Block Off the Grid (1BOG), founded in 2008, identifies solar contractors who are willing to install multiple systems in a neighborhood for a discount, then it recruits homeowners to join the group purchase. The deal "tips" when enough homeowners have agreed to join, and homeowners usually receive a 15 percent discount on solarization projects (Hargreaves, 2011). Although it is too early to tell how successful the model will be, the 1BOG model has the capacity to attract financing more easily than the neighborhood cooperative model.

The second way to reduce transaction costs is for individuals to purchase solar shares in an entity that produces solar energy. In several states, enabling legislation for community solar gardens is now in effect, and the laws are especially attractive to renters and people whose rooftops and grounds do not have access to adequate solar energy. Chris Herman and other board members of Sustainable Edmonds, a nonprofit organization in the state of Washington, decided to launch the Edmonds Community Solar Cooperative in partnership with Tangerine Power, a private company that assists in the arrangements. Enabled by state government legislation, the cooperative sold forty-two shares in its initial offering. The solar garden was installed on the rooftop of a building that houses the city's Parks and Recreation Department, and the city purchases the solar energy from the cooperative at a reduced rate. Memberships in the cooperative cost $25, and a SunSlice Share is $1000. Repayment is estimated at $100 per year over the ten-year membership period, after costs to the cooperative are subtracted (Tangerine Power, 2011).

As in the case of 1BOG, there is a similar growth of for-profit approaches to the solar garden idea. In 2011 in Colorado Springs, David Amster-Olszewski launched the start-up company SunShares, which aimed to build solar gardens in the state (Winecke 2011). The business was made possible by legislation that the state government passed in 2010 in support of community solar gardens, which are defined as solar generation facilities of 2 MWh or less that sell energy to a utility and are owned by 10 or more subscribers. Residents of Colorado Springs may purchase shares in the city's solar garden and then receive a credit on their municipal utility bills based on the energy generated. When shareholders move, they can sell their shares to other residents in the city (SunShare 2011). The first community solar garden sold out quickly, and a new one was launched in 2012.

It is also possible for individuals to purchase solar shares directly from electricity service providers. In some cases, the electricity service provider owns the solar generation facility, and in other cases it contracts out the purchase. For example, the public utility of Ellensburg, Washington, paid for the initial construction of the photovoltaic panels at a site in the town. Customers then pay for a share and receive a rebate based on the solar energy generated, and they may then sell or give away shares to other customers or nonprofit organizations. The public utility Sacramento Municipal Utility District (SMUD) has a similar program, but the ownership of the solar energy generation rests with a private company. As of 2011, SMUD had sold about 1,000 shares to local residents, who paid a rate premium for a solar share in return for a rate rebate. (In some months their rebate from the solar energy generation was greater than the premium.) SMUD then contracted with enXco, a private generation company that owns the photovoltaic system and leases it for twenty years to SMUD (Northwest Community Energy, 2011). Customers and SMUD do not actually own the solar generation; in effect, they are paying for a lease on the energy produced from the private company's solar farm.

In summary, these programs can help to spur the development of DSE, but in some cases, such as the Sacramento program, a person is basically purchasing a share in a utility-scale solar farm owned by a for-profit partner of the utility. These programs are similar to green-pricing programs, but instead of charging customers a monthly premium to switch to renewable energy, they require an up-front purchase of a share and then pay a dividend or rebate on the share. A summary of the models is presented in Table 1.

Organization Name	**Description**	**Consumer Ownership**	**Community Ownership**	**Company Ownership**
Mt. Pleasant Solar Cooperative	Solarization assistance cooperative	Rooftop ownership	No	No
1BOG	Solarization assistance business	Rooftop ownership	No	No, but company grows by fees
Edmonds Community Solar Coop	Solar garden cooperative	Shares	No	No, just contract with developer
SunShares	Solar garden business	Shares	No	Yes, SunShares
Ellensburg	Municipal service provider	Shares	Yes (via public power)	No

Sacramento	Municipal service provider	Shares	No	Yes, enXco

Table 1. Ownership Patterns among Share and Share-like Arrangements

These models show little evidence of blockage but some evidence of countervailing power and the incorporation and transformation process. In the case of 1BOG, the company received $5 million in venture capital financing, and venture capital usually requires a financial model that leads to growth and a liquidity event. Indeed, the liquidity event occurred in 2012, when 1BOG was acquired by the Canadian solar project developer Pure Energy Group (St. John, 2012). Because part of 1BOG's offerings includes help in locating third-party financing, the model could evolve into a service wing of third-party financing, thereby reducing the connections between DSE and local ownership. There is also the beginning of the incorporation and transformation process, because it is likely that the for-profit model of 1BOG will grow and crowd out the cooperative model of Schoolman. Likewise, SunShares represents a for-profit model for solar gardens, and it is growing. It is possible that the small-scale aspect of solar gardens will make the business unattractive to large capital, but it is also possible that at some point the for-profit solar gardens industry will grow and undergo consolidation.

4.4 Third Party Financing

The final case is third-party financing, which includes both the power purchase agreement (PPA) and the lease. In both cases, DSE is installed on a homeowner's roof or yard, but the homeowner does not own the installed system. In the PPA, the homeowner purchases DSE at an established rate from the company that owns and manages the photovoltaic system, and in the lease the owner pays a negotiated amount to the leasing company and receives payment from the electricity service provider for the DSE generated. Third-party financing models can also be classified based on the relations between the third-party company and installers and capital sources (Linder and Capua, 2012). As a family of DSE models, third-party financing solves general hurdles such as up-front financing and transaction costs, and in some cases the work of maintaining systems is also transferred from the building owner. However, the models overcome the hurdles at the cost of energy generation ownership. At the end of the PPA or lease period the building owner does not own a long-term capital investment that continues to pay dividends. Because the contracts generally include a purchase option for the remaining value of the photovoltaic system, it is possible that most of the third-party models will flip into long-term local ownership. However, contracts may also allow owners to renew the agreement or have the system removed.

Third-party financing has grown rapidly, and it has become the dominant form of financing for commercial rooftop solar (Wesoff, 2011). In some markets it is also growing rapidly for residential photovoltaics. For example, in a southern California sample, third-party financing grew from 16 percent of residential installations in 2009 to 48 percent in 2011, thus achieving rough parity with customer-owned DSE. Wealthier households tend to select customer-owned financing, whereas lower-income households prefer third-party financing (Drury et al., 2012).

Third-party financing has also attracted large pools of capital from the technology and finance industries. For example, in 2011 Google created a $280 million fund with Solar City for PPA and lease financing (Bass, 2011). The tech company sees potential synergies with its software capabilities as DSE and the smart grid develop. In another example, in 2011 the company Clean Power Finance was financing $1 million per day of power purchase agreements and leases. The company also partnered with Vivint, a former home security firm that entered the residential solar market, has a base of 600,000 customers, and has set a goal of 150,000 annual PPA or lease agreements (Trabish, 2012a). In 2012 the financial group Blackstone acquired Vivint, which announced that it would increase its power purchase agreements to 10,000 systems in 2013, and in 2012 Clean Power Finance also entered into a $300-million agreement with Morgan Stanley. By the beginning of 2012, the five largest solar installation companies—SolarCity, SunRun, Recurrent Energy, SunEdison, and Solar Power Partners—had attracted over $1 billion in financing (Feinstein, 2011; Trabish, 2012b). The rapid growth and high levels of corporate financing suggest that third-party agreements were quickly coming to dominate the DSE field.

5. Discussion and Conclusion

DSE is in a subordinate position in the field of electricity generation in the U.S., which is dominated by centralized, baseload generation of electricity from coal, natural gas, nuclear energy, and in some areas hydropower; however, DSE is itself also a field in the sense that multiple agents engage in relations of conflict and cooperation over contrasting visions of how to achieve the solarization of homes and commercial buildings. The DSE field is undergoing rapid change, and the positions of agents within the field are also rapidly changing. Models of public ownership (such as the San Francisco solar bonds or the Ellensburg photovoltaic panels) play a minor role, and increasingly the models in support of residential ownership of DSE are also becoming marginalized. Instead, nonresidential PACE and third-party financing are growing. As those programs grow, the position of DSE within the broader electricity generation field is also undergoing a scale shift.

As the industrial field of DSE undergoes a transition, the GI models are increasingly marginalized. Grassroots innovators such as Paul Fenn, Francisco DeVries, Anya Schoolman, and Chris Herman attempted to link DSE with an alternative energy generation regime based on local ownership in one form or another (city government,cooperative, local businesses, or homeowner). Yet, in each case there has been an erosion of local ownership. In the case of municipal or public power, there was a gradual change from local government ownership to the CCA model. Although the CCA model can be combined with government-issued solar bonds and local public DSE generation, the trend has been toward aggregated purchase agreements from large, renewable energy providers such as Shell. Likewise, PACE financing has shifted increasingly from a local government program oriented toward homeowners to programs with heavy participation from large financial corporations that are oriented largely toward commercial building owners, and the emergent models of nonresidential PACE include third-party financing. The cooperative models in support of either local homeowner-based DSE (Schoolman) or community solar gardens (Freeman) have remained experimental niches, whereas private-sector companies have entered this space and are growing more rapidly. All of these models are being outpaced by the rapid growth of third-party financing.

The processes of marginalization-blockage, countervailing power, and incorporation and transformation are evident in the history of the DSE field. Blockage was especially evident in the case of attempted municipalization, and the state and local governments provided countervailing power when the IOU was not supportive of proposals to increase the scale for DSE through municipalization. More generally, the financial services and to some degree technology companies such as Google and Vivint have come to see DSE as a new investment opportunity, and the growing volume and significance of the investments provide an important countervailing power to the passive blockage from the IOUs. However, the support from the countervailing power is accompanied by the incorporation and transformation of the original DSE models into a corporate-oriented financial services regime. GIs with diverse forms of local ownership are being crowded out by models in which an energy generation company owns access to the sun on the property of homeowners and businesses.

In this history of the development of the DSE field in the U.S., change does occur, but the dominant models in the DSE field are aligned with a countervailing industrial power (e.g., Google or Morgan Stanley) that favors third-party financing. As the third-party financing industry grows, it will likely have increasing political influence in state legislatures and public utility commissions, therefore providing a countervailing power to the resistance to solarization that sometimes comes from the IOUs. But local and residential ownership are not central to the business models of countervailing power. Thus, a sustainability transition gradually unfolds, but the models that are linked to local ownership by city governments, cooperatives, and homeowners tend to become marginal players in the field. Although solar energy technology was originally believed to favor decentralized ownership because of its modular design, the growth of utility-owned solar farms and third-party financing has demonstrated the resilience of centralized ownership.

In summary, the IOUs could have provided more financing for DSE, but they have been reluctant partners, and the role of extrafield finance has been crucial for the scaling up of DSE. However, the "success" of DSE models that rely on extrafield finance, in terms of number of buildings that have been solarized, has come at a substantial sacrifice from the perspective of GI visions of locally owned and/or community-based solarization, because building owners who accept third-party finance no longer own the means of solar energy production.

It is possible that a backlash against third-party financing will erupt when homeowners face the removal of rooftop photovoltaic systems at the end of the lease period, and disputes may emerge over roof damage or the cost to purchase a system that is 15 to 20 years old. It is also possible that a form of third-party financing will emerge that flips into a loan with local ownership after a multi-year term, much like a mortgage or automobile loan. Furthermore, a second generation of DSE technology with micro-inverters and on-site storage might reopen political-economic opportunities to decentralized ownership. If all-in-one systems of solar generation, electricity conversion to AC power, and energy storage could be made simple and portable, then transaction costs and liquidity barriers would be reduced. Low-cost, off-the-shelf, off-grid systems would likely create yet a new set of relations in the DSE field, but they could also be offered on a lease basis similar to that of the current third-party arrangements. Thus, the field is in a constant state of change, and the changes describe here are neither inevitable nor irreversible.

More generally, this study has argued for the value of a field theory approach to the study of changes in LTSs. The perspective suggests that countervailing corporate power rather than mobilizations by communities and grassroots innovators is likely to play an important role when the incumbents in the industrial field, such as IOUs, do not welcome the changes proposed by the GIs. In short, a field theory perspective suggests that GIs can play a role in STs, but their role is not likely to be as influential as originally envisioned. The grassroots innovators can make history, but it is not exactly as they please.

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