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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 et al., 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

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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, 1987). 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% 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 et al., 2010; Smith et al., 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 1980s 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