Transitions in Energy Systems: The Mitigation-Adaptation Relationship

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Abstract

The study of large technological systems from a social science perspective assumes that it is possible build up a systematic knowledge of the transitions of those systems through comparative analysis. Although the assumption is fundamental to an STS perspective on energy transitions, there are also historical differences that are especially relevant for the case of the technological transition to low-carbon energy systems in the twenty-first century. Previous energy transitions, such as from horse-powered to machine-powered transportation or from gaslight systems to electric lighting, can provide valuable insights, but the limitations of such comparisons should also be recognized. This essay will discuss the value of an STS perspective rooted in the sociology of technology design, and it will focus on one significant difference between the current energy transition and those of previous eras: the intertwining of an energy transition based on sustainability and climate change mitigation with one based on resilience and climate adaptation.

Background

From previous research on energy-related transitions, we now understand several general features of technological transitions. Hughes (1983) demonstrated that energy transitions can go through phases from inventor-driven systems (niches) to large, corporate enterprises, and he also analyzed the interconnections among infrastructure, industry, and regulations. In a study of the shift from horse-drawn vehicles to automobiles, Geels (2005) drew attention to the growth of niches, the variegated pattern across transportation sectors, and "landscape" issues such as public acceptance. Energy transitions can also occur smoothly and within an existing industrial regime, such as when incumbent organizations develop electricity generation plants that can support both coal and biomass (Raven 2006). However, in other cases the new technologies and infrastructures are more disruptive, and consequently it is possible to develop a typology of transition pathways (Geels and Schot 2007). All studies point to the crucial role of government policy and dispel the myth that major, long-term transitions of energy systems are mostly or only market driven (Smith and Raven 2012).

In the early twenty-first century, one of the most important energy transitions involves the development of sustainable energy sources. Terms such as "green" or "sustainable" are highly contested and can be defined in various ways; for the present purposes, the focus will be on technologies and practices that reduce greenhouse-gas emissions. There are two major differences between the green-energy transition of the twenty-first century and previous energy-related transitions of large technological systems. The first differences is that political backlash is extensive: consumers and businesses resent increased costs and regulations associated with transition policies; politicians of a neoliberal persuasion reject strong government intervention in the economy on ideological grounds; utilities are concerned with intermittency, transmission congestion, and load management; many governments remain willing to meet electricity growth requirements with new fossil-fuel capacity; and in some places the fossil-fuel industry has mobilized politically to block further greening. In short, one of the central differences with previous energy transitions is that the guiding energy policies are often deeply interwoven in broad political conflicts (Grin et al. 2011, Hess 2012, Jørgensen 2012, Meadowcroft 2009).

Political conflict is not absent from energy transitions in previous time periods. For example, some farmers resented the use of machine-powered transportation on country roads, and anti-speed organizations emerged to protest some aspects of the automotive transition (Geels 2005). However, the history of the automotive transition does not exhibit a full-fledged social movement in support of the new technology that mobilized against the old transportation regime, and it does not have a widespread political mobilization by the declining industry to stop the growth of the rising industry. Although Hughes's (1983) account of the growth of the electricity system suggests some resistance from the gaslight industry, especially in the U.K., the scope of the mobilization was limited in comparison with that of the fossil-fuel industry in the U.S. today. The political mobilizations both in favor of and against the green-energy transition thus appear to be significantly different from those of previous energy transitions.

The second significant difference between the green-energy transition today and energy transitions of previous periods is that the pace of the technological transition is much more charged politically, because society-environment feedbacks were not as salient in previous energy transitions, and awareness of the effects of greenhouse gases was also lower. In previous transitions a slow pace could be beneficial because it provided time for regulatory policy, markets, and consumers to make adjustments. In the case of the green-energy transition, there are pressing environmental reasons for reducing greenhouse gases as quickly as possible, but the transition is occurring at a slow pace that is not keeping up with overall growth in consumption (Roberts 2011, York 2011).

The slow pace of the green-energy transition has led to a second, intertwined transition: adaptation. Governments and corporations throughout the world are now developing climate-change adaptation plans that are based on their perceptions of environmental change wrought by greenhouse gases, land-use decisions, and other environmental issues. Whereas sustainable technological systems and energy are central to the mitigation transition, the adaptation transition draws attention to the construction of resilient systems, and water infrastructures associated with droughts and flooding often assume a more central position. Thus, the water-energy interactions become the central focal point of the interwoven transitions. To explain how the two transitions are becoming intertwined, the next section will discuss some of the interactions.

Electricity and Adaptation

An adaptation perspective on a large technological system involves a very different set of challenges from a climate-change mitigation perspective. For example, in the case of a regional or national electricity system, the central policy research topics from a mitigation perspective include carbon taxes and markets, renewable energy portfolios, feed-in tariffs, energy-efficiency programs, financing incentives such as system benefits charges and property-assessed clean-energy bonds, transmission congestion, and load management for distributed energy. From the perspective of the need to develop adaptive infrastructure, governments and utilities face an additional set of challenges with respect to climate change. To provide a sense of what the adaptation transition looks like for an electricity generation and distribution system, the following section summarizes the prominent areas identified in the climate adaptation plans completed by state governments in the U.S. All state government plans were reviewed, and they were compared with adaptation plans in the E.U. The E.U. plans revealed similar concerns, although the focus on flooding was generally stronger.

The most salient aspect of the adaptation transition for electricity is the stability of future hydropower. In California and other states that rely on water from mountain ranges, snowfall will occur at higher elevations, snowpack will recede, and melting will occur earlier, thus reducing the stability of hydroelectric power sources (California Natural Resources Agency 2009). Furthermore, spring floods could overwhelm reservoirs, but summer droughts could make it impossible to operate hydroelectric facilities. Furthermore, low water flow will also have multiplier effects when hydroelectric power is located at more than one position along the same river, a problem that has been identified for the Colorado River. One solution to the threat of increased instability in water flow is to invest in water storage capacity, both for hydroelectric reservoirs and for consumers.

Heat waves and droughts can affect other forms of electricity production that also rely on water for cooling processes. Power plants are heavy users of water, and in the Western states their use contributes to aquifer depletion. Furthermore, as ambient air and water temperatures rise, cooling for electricity generation becomes less efficient. Power plants in the U.S. are not permitted to discharge warm water into rivers when the river temperature exceeds 86.9 degrees Fahrenheit. For example, in 2010 the Tennessee Valley Authority was forced to reduce the capacity of a nuclear energy facility because the heat wave had increased the temperature of the water of the Tennessee River to nearly 90 degrees (Karemer 2011). The change forced the authority to buy power on higher-priced spot markets and to invest in a new cooling tower at a cost of $80 million. More generally, the changes in the capacity to use water to cool electricity generation facilities are pushing utilities to consider new designs for water-based cooling technologies, such as closed loop and dry cooling of water and the energy-intensive alternative of air cooling.

Heat waves and droughts will also affect electricity demand. Most adaptation plans recognize the most straightforward pathway: warming temperatures increase peak demand for air conditioning, especially during summer heat waves, and at the same time heat waves lower transmission efficiency. Droughts will also increase demand for water, which requires energy to treat, pump, and store. In coastal regions, persistent droughts and seawater infiltration of freshwater systems may require the use of desalinization technologies, which are energy intensive. Flooding and droughts also lead to a decline in water quality, which increases the energy needs for water treatment (Averyt et al. 2011).

Another aspect of the adaptation transition for electricity involves the direct effects of flooding and storms on the stability of infrastructure. Several states have begun to map the exposure of electricity generation plants and transmission lines to freshwater flooding and sea-level rise. Rail lines, which transport coal, are also vulnerable to flooding, and some reports also mention increased risk to infrastructure from heavy winds, ice storms, and (in Alaska) permafrost thawing. The risks will require moving some infrastructure to less vulnerable locations and, where possible, placing transmission lines underground.

Dimensions of the Dual Transition

To some degree, the sustainability and adaptation transitions can be viewed as having a zero-sum or trade-off relationship: there are limited resources available to households, businesses, utilities, and governments, and those resources can be invested either in mitigation or in adaptation technologies. When adaptation challenges take the form of crises and disasters, investments in adaptation may become necessary and drain resources that could be used for other priorities. Although these trade-offs will emerge as adaptation crises become more acute, there is also some potential for positive-sum relationships.

Infrastructure. When both sustainability and resilience are included as system design criteria, decisions are more complex, but opportunities also open. For example, in the case of household energy, system design from a sustainability perspective would favor the most cost-effective means of reducing greenhouse gases, such as weatherization and building efficiency technologies. However, an energy-efficient building is not necessarily the most resilient during a power outage, and an adaptation perspective would favor system redundancy and storage, such as on-site storage and distributed electricity production. A combination of sustainability and adaptation perspectives draws attention to the need to combine the greening of buildings with multiple, redundant systems that can maintain functionality when one system is incapacitated. A similar approach applies to food, transportation, and other central topics of sustainability plans and polices (Hess 2013).

Knowledge practices. From a sustainability perspective, the central knowledge practices are research programs in climate science, climate mitigation technologies, new energy technologies, and implementation policies. In the United States, the standard advisory circuit from scientists to policymakers and back to scientists has been cut due to the influence of fossil-fuel funding on the political system and public opinion; policymakers are free to deny the climate science without suffering a collapse of credibility among voters. The research programs then operate in a polarized political environment that neutralizes their political effectiveness, encourages their political silence, and threatens budget cuts to ongoing funding (Hess 2014).

To some degree adaptation planning can avoid the political blockages associated with climate science denialism. Adaptation planning recognizes the uncertainties in downcasting climate models that are primarily global and long-term, and the science or art of developing adaptation scenarios recognizes multiple causes, including changes in agricultural and forestry practices, the location of urban and suburban development, the effects of water infrastructure decisions, and design decisions for buildings and infrastructure. Thus, to some degree the political disputes over climate science are side-stepped, because adaptation planning becomes folded into the broader problem of disaster preparedness. Yet, because of the potential points of convergence with mitigation technologies, such as distributed renewable energy, it is possible for the frame of disaster preparedness and adaptation planning to open opportunities for climate-change mitigation.

Energy Justice. The world of adaptation to climate change and other environmental stressors has highly uneven effects. People who live in regions prone to flooding and droughts are at the highest risk, and likewise people who have greater economic resources have more resilience. But there are also interconnections between the greening of systems, their resilience, and social disparities. For example, diesel buses have long been a target of environmental justice mobilizations, because the bus depots tend to be located in low-income neighborhoods, where the health effects of emissions are concentrated (Hess 2007). However, the calls of environmental justice organizations to replace dirty diesel buses with new buses powered by natural gas were complicated by the safety risks, maintenance problems, and higher costs of buses powered by natural gas. In response, fleet managers advocated “clean” diesel as a more resilient alternative to natural gas, and they argued that the lower cost of a transition to clean diesel could better enable transit systems to respond to calls from transit justice advocates, who supported more extensive public transportation. Thus, resilience and sustainability concerns played out in system design decisions.

Conclusion

STS perspectives on energy transitions offer several advantages to engineers, public advocates, and policy makers. Energy transitions involve the complex requirements of managing the relations among technical infrastructure, governing rules, and associated social practices, but they also involve relations among civil society, industrial, scientific, and political fields. The outcome of the political relations can be slow or blocked policies, which have resulted in ecological feedbacks that in turn triggered a dual transition. As awareness of the adaptation transition increases, trade-offs emerge with mitigation goals, and as the full costs of the adaptation transition become evident, resources for mitigation may be reduced. Thus, considerable pessimism is warranted for those who hope that a more rapid green-energy transition will take place. However, in addition to trade-offs between adaptation and mitigation, it is possible to look for positive-sum relationships between the two transitions. An STS perspective on design suggests that one can examine design from both technical criteria such as cost effectiveness and energy efficiency, but one can also include broader social goals such as resilience and social inequality. There is an opportunity to explore potential new synergies for dual-use approaches, such as distributed renewable energy with on-site storage or configurations of public transit that address sustainability, resilience, and transit justice goals. Integrating sustainability and resilience goals makes possible new ways of thinking about both public policies and technological designs for future energy systems.

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